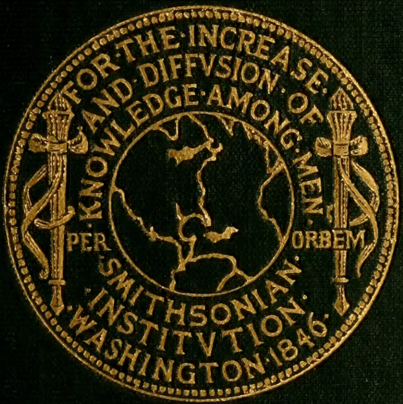
FOR THE INCREASE AND DIFFVSION OF KNOWLEDGE AMONG MEN
PER ORBEM
SMITHSONIAN INSTITVTION
WASHINGTON 1846

SMITHSONIAN
MISCELLANEOUS COLLECTIONS

VOL. 72

"EVERY MAN IS A VALUABLE MEMBER OF SOCIETY WHO, BY HIS OBSERVATIONS, RESEARCHES, AND EXPERIMENTS, PROCURES KNOWLEDGE FOR MEN"—SMITHSON

(PUBLICATION 2706)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1922

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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CHARLES D. WALCOTT,
Secretary of the Smithsonian Institution.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 1

EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1919

(Publication 2581)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1920

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1919

INTRODUCTION

An important phase of the Institution's work, in carrying out one of its fundamental purposes, the "increase of knowledge," is the scientific exploration by members of the staff of regions in this country and abroad previously imperfectly known to science. The more important of these field researches carried on during 1919 are here described briefly, for the most part by the explorers themselves. Naturally the great war held in abeyance a number of proposed expeditions, some of which it has since been possible to send out on the resumption of a peace status.

GEOLOGICAL EXPLORATION IN THE CANADIAN ROCKIES

Geological explorations were continued in the Canadian Rocky Mountains during the field season of 1919 with two objects in view: (1) The discovery of an unmetamorphosed, undisturbed section of the Upper Cambrian formations north of the Canadian Pacific Railway; and (2) the collection of fossils to determine the various formations and to correlate them with the Upper Cambrian formations elsewhere.

The party going from Washington consisted of Dr. and Mrs. Charles D. Walcott and Arthur Brown, who has accompanied them for a number of years.

Early in July an attempt was made to reach Ghost River northeast of Banff, Alberta, but this failed owing to the extensive outbreak of forest fires in that region.

In August the party proceeded north from Lake Louise over Bow Pass down the Mistaya Creek to the Saskatchewan River, and thence up to the head-waters of the Middle Fork in the area about Glacier Lake, where a wonderfully well preserved Upper Cambrian series of rocks was found that had been cut across in pre-glacial time by a deep east-and-west canyon valley, at the head of which were two beautiful glaciers, which are illustrated by the panoramic view figure 1 (Frontispiece), and more in detail by figures 5, 7, 8, 9, and 10.

[illegible] Albert [illegible] ott, 1910

The character of the mountains about the head-waters of the Middle Fork of the Saskatchewan is illustrated by figure 2, where a glacial stream flows out through a deeply eroded valley with high ridges and peaks rising in steep slopes and cliffs. The position of the camp in Glacier Lake canyon is shown in figure 3, and the outlook to the west toward the glacier from the camp by figure 5, and to the east by figure 4, where the dark massive bulk of Mount Murchison rises in cliffs above the canyon of the Mistaya River along which the trail from Bow Pass descends.

FIG. 2.—View looking up the Middle Fork (Howse River) of the Saskatchewan River to Howse Pass (5,000′) on the Continental Divide.

In the distance beyond Howse Pass the peaks of the Van Horne Range and Mount Vaux of the Ottertail Range, and on the right and above the Pass Mount Conway, and to the extreme right the eastern ridge of Mount Outram.

Locality.—View taken from the upper slope of Survey Peak above Glacier Lake, about 48 miles (76.8 km.) northwest of Lake Louise station on the Canadian Pacific Railroad, Alberta, Canada.

Photograph by Mr. and Mrs. C. D. Walcott, 1919.

The measured geological section begins at the foot of the ridge at the extreme left of figure 1, and was measured in the cliffs and slopes, and thus carried to the side of the Mons glacier shown in the central portion of figure 1, the upper limit of the section being above the narrow vertical F-shaped snow bank directly over the glacier. The evenly bedded rocks sloped at an angle of from 10 to 20 degrees, westward, which accounts for the great thickness measured, although the elevation above the canyon bed was not more than 3,500 feet.

FIG. 3.—Walcott camp located in the brush beside Glacier River, 1 mile (1.6 km.) below the foot of Southeast Lyell Gacier, which is shown more distinctly in figure 5. Photograph by Mrs. C. D. Walcott, 1919.

The glaciers.—The Southeast Lyell Glacier is beautifully shown in figure 1, and also in figure 5, and more in detail by figure 6, where it is cascading over a high cliff. Figure 1 is a profile view of Lyell Glacier from the Continental Divide on the right to where it abuts against the low cliff on the left. In figure 6 the foot of the glacier is shown, along with large amounts of débris forming the terminal moraine, also the dark mass of broken rock and débris carried on the back of the glacier, which is shown in figures 1 and 6.

A portion of the great snow field from which both Lyell and Mons glaciers flow is shown on the slope of Mons Peak on the left side of figure 5. This snow field extends back of Division Mountain,

Fig. 4.—Mount Murchison as seen from camp on Glacier River, from a point one mile (1.6 km.) above the head of Glacier Lake.

Locality.—The view is from a point about 47 miles (75.2 km.) northwest of Lake Louise station, on the Canadian Pacific Railroad, Alberta, Canada.

Photograph by Mrs. C. D. Walcott.

FIG. 5.—View looking westward from Walcott camp up Glacier Lake Valley to Southeast Lyell Glacier and Division Mountain, which is on the Continental Divide. The great snow field extends around back of Division Mountain, connecting the névé of Lyell and Mons Glaciers.

Locality.—The view is from back of the Walcott camp at a point about 48 miles (76.8 km.) northwest of Lake Louise station, on the Canadian Pacific Railroad, Alberta, Canada.

Photograph by Mrs. C. D. Walcott, 1919.

Fig. 6.—View of Southeast Lyell Glacier from the Glacier Lake Canyon bottom below the foot of the glacier. *Locality*.—The view is taken from a point about 50 miles (80 km.) northwest of Lake Louise station, on the Canadian Pacific Railroad, Alberta, Canada.

Photograph by Mr. and Mrs. C. D. Walcott, 1919.

dividing Mons and Lyell glaciers, and continues along the Continental Divide for many miles, contributing to glaciers both on the Pacific and Eastern sides of the Rockies.

Fig. 7.—View of the ice fall of Southeast Lyell Glacier, taken from the surface of the glacier below the fall. The locality is the same as for figure 6. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

Mons Glacier is named from Mons Peak, shown in figures 5 and 8. It flows over the high cliffs (see fig. 8), and creeping down the slope, spreads out in a fan-like form toward its lower end. Seen in profile, this portion of the glacier resembles a great animal sliding down the sides of the broad canyon. The foot of Mons Glacier with the stream flowing from beneath it is illustrated by figure 11.

FIG. 8.—View of Mons Peak (10,114′) and the upper snow fields of Mons Glacier, also the cascade of the glacier over the cliffs below. The summit of the peak is more than 2 miles (3.2 km.) back of the glacier, the intervening space being occupied by a great snow field from which the glacier flows. The locality is about the same as for figures 2 and 5. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

These views (figs. 5, 8, 9, 10 and 11) illustrate a glacier from its névé at the base of Mons Peak (fig. 8) to its foot (fig. 11), where the retreating ice is making its stand against the force of the summer sun and wind.

Geological section.—The geological section, which is beautifully exposed in the mountain ridge of figure 1, is of such interest that it is included in this brief account of the exploration in the vicinity of

FIG. 9.—View of Mons Glacier from the lower end of the east moraine of the Southeast Lyell Glacier. This view shows the crevassing and terracing of the ice where it goes over the cliff; also its extension and lateral crevassing where it abuts against the rocks below. The crevassing of the Lyell Glacier is also beautifully shown as well as the broken rock and débris on the ice, which is also finely shown in the panoramic view, figure 1. The locality is about the same as for figure 6. Photograph by Mr. C. D. Walcott, 1919.

FIG. 10.—Profile view of Mons Glacier taken from the surface of the lower portion of Southeast Lyell Glacier. The glacier looks like a gigantic animal sprawling down the slope of the mountain. The locality is about the same as for figure 6. Photograph by Mr. C. D. Walcott, 1919.

FIG. 11.—Foot of Mons Glacier from canyon down through which the glacier formerly extended to unite with the south end of Northeast Lyell Glacier. The locality is about the same as for figure 6. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

FIG. 12.—Mount Forbes as seen from the north, looking across the lower end of Glacier Lake Canyon Valley. The locality is the same as for figure 2, from the upper slope of Survey Peak above Glacier Lake, about 48 miles (76.8 km.) northwest of Lake Louise station, on the Canadian Pacific Railroad, Alberta, Canada. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

FIG. 13.—Leaving Glacier Lake camp with the camp outfit and specimens on the pack horses, ready for the four days' trip to the railway. Photograph by Mrs. C. D. Walcott, 1919.

FIG. 14.—Mount Ball (10,825′) on the Continental Divide from the southwest slope of the Sawback Range, looking across Bow Valley.

Locality.—About 17 miles (27.2 km.) west of Banff, Alberta, Canada. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

Glacier Lake. The rocks exposed in the highest cliffs of Mount Forbes and Mons Peak belong to the great Carboniferous system of rocks of this region. Below this series occur the Devonian rocks, the snow-capped cliffs shown in figure 1 above Mons Glacier, forming a belt 1,000 feet or more in thickness, and below these are the strata of the Sarbach formation of the Ordovician system, and beneath the Sarbach the five formations assigned to the Upper Cambrian series. Attention should be called here to Mount Murchison, figure 4, where there is almost the same series as that exposed in the cliffs on the long mountain slopes of figure 1. To the left of Mount Murchison in figure 4 there is a low ridge formed of strata of Middle Cambrian age which passes beneath the rocks of Mount Murchison.

FIG. 15.—Mountain sheep in game sanctuary, Rocky Mountains Park, Alberta, Canada. Photograph by Mr. and Mrs. C. D. Walcott, 1919.

FIG. 16.—Cirkut camera in use on the south slope of the Sawback Range, looking across Bow Valley, Alberta, Canada. Photograph by Mrs. C. D. Walcott, 1919.

GLACIER LAKE SECTION, ALBERTA

	Formation	No.	Stratum	Thickness feet
Ordovician	Sarbach. (1120 feet) (341.3 meters).	1	Thin-bedded gray limestone.	700 (est.)
		2	Argillaceous shale.	420
Upper Cambrian	Mons. (1480 feet) (467.2 meters)	1*a*	Calcareous shale and limestone.	235
		1*b*	Massive bedded gray limestone.	740
		1*c*	Limestone and shale.	320
		1*d*	Oolitic limestone.	185
	Lyell. (1700 feet) (518.9 meters).	1*a*	Massive bedded gray limestones.	1,270
		1*b* 1*c* 1*d*	Light gray thick-bedded limestone.	430
Upper Cambrian	Sullivan. (1440 feet) (464.3 meters).	1*a*	Compact gray limestone.	325
		1*b*	Shale with interbedded layers of limestone.	975
		1*c* 1*d*	Oolitic limestone and shales.	140
	Arctomys. (1386 feet) (422.4 meters).	1*a*	Laminated limestones.	520
		1*b*	Purple, green, and gray shale with layers of laminated limestone.	866
	Murchison. (220 + feet) (67 meters).	1	Gray and bluish-black limestone, Base concealed.	220+

Total thickness Cambrian strata..6,226

On returning, a camp was made in the Bow Valley below Lake Louise at the foot of the Sawback Range, where a brief examination was made of the up-turned Carboniferous, Devonian, and Cambrian formations, and fossils were collected, many of which are identical with those found in the Glacier Lake section. One of the views across Bow Valley is of Mount Ball (fig. 14), which is one of the massive peaks on the Continental Divide where the Middle Cambrian rocks have a great development.

The preliminary study of the fossils in the several formations correlates them with the Upper Cambrian formations of Wisconsin and Minnesota and the Upper Cambrian section in southern Idaho, and to a more limited extent with that of the central belt of Pennsylvania.

GEOLOGICAL AND PALEONTOLOGICAL EXPLORATIONS AND RESEARCHES

Field-work in the Department of Geology has been considerably restricted by prevailing conditions during the season of 1919. Research work has, however, continued on the collections accumulated either in years past or obtained through gift or purchase in more recent times.

One of the most interesting acquisitions to the geological collections during the year 1919, was some 15 kilograms of the meteoric stone which fell at Cumberland Falls, Kentucky, in April of this year. The stone, which proved to be a coarse breccia of enstatite fragments and a dark chondritic stone, has been studied by Dr. Merrill, and a paper giving his results is now in press.

Owing to the fact that the division of Mineralogy has been without a head for two years, a large amount of work upon the collections has been necessary and hence only a limited amount of field and research work was possible. On his own initiative, two field trips were undertaken by Assistant Curator Foshag, one to the mica mines about Amelia, Virginia, where a considerable amount of study material was collected. This included a large number of specimens of the rare mineral microlite and an exhibition specimen of manganotantalite, the latter species not before represented in the Museum's exhibition series. The old iron mine at Brewster, N. Y., was also visited and some material for study collected. The work of the division in the Museum's laboratory consisted in an investigation of the hydrotalcite minerals, resulting in the establishment of the true chemical nature of this group. Shorter researches on miscellaneous minerals were also carried on. Work is now under way on the study of the mineralogy of serpentine and its relation to the chlorite group, and also the correlation of the chemical composition and the optical properties of rhodonite, the latter in collaboration with Dr. E. S. Larsen of the U. S. Geological Survey.

In October various localities in Connecticut were visited by Assistant Curator Earl V. Shannon, including the vicinity of Long Hill in Trumbull, where tungsten has been mined in years past. Extensive collections comprising much interesting material were obtained which will be studied and described. The trap quarries of Meriden, Conn., were also visited and extensive collections of the zeolites and other secondary minerals secured. The pegmatite localities of Collin's Hill in Portland; the workings of the old cobalt mine and the old lithia mine in Chatham, and a number of feldspar quarries in this region were visited and collections of the representative minerals secured. Much of the material collected as above has been carefully examined and descriptions will appear in forthcoming numbers of the Proceedings.

FIG. 17.—Transporting fossil specimens in Southeastern Indiana. Photograph by Bassler.

Explorations for paleontological material were limited during 1919 to two short field trips by Dr. R. S. Bassler, Curator of Paleontology, who continued the work of former years in securing certain large showy specimens of fossils and rocks required for the exhibition series. Dr. Bassler spent a portion of June in southeastern Indiana, first proceeding to the locality where at the end of the field season of 1918 he had cached for safe keeping, because of inability to secure help in getting them to a freight station, several large exhibition slabs crowded with brachiopod shells. These slabs were found undisturbed, but transportation conditions proved equally bad as in the summer before and it became necessary to employ the primitive method shown in figure 17. By the use of burlap covering and an abundant supply of weeds for padding, each slab was finally slid along the rails for a considerable distance to the nearest station.

FIG. 18.—Fossiliferous strata of the Richmond formation in southeastern Indiana. The slab indicated is now on exhibition at the National Museum. Photograph by Bassler.

The same area in Indiana, namely, the vicinity of Weisburg where the early Silurian rocks are well exposed, was then explored for further desirable exhibition specimens. Water worn slabs crowded with animal and seaweed remains are abundant in all the creeks of this richly fossiliferous region, but large rock specimens with their surfaces unweathered are comparatively rare. Fortunately for the present purposes, heavy freshets in the spring of 1919 had uncovered the richly fossiliferous layers along the creek shown in figure 18, and here several additional well-preserved exhibition slabs were secured and transported to the freight station by the rail route mentioned before. One of these specimens, a slab several feet in length and width, is worthy of special mention, as its surface is crowded with impressions of the branching fossil seaweed *Buthotrephis,* and with excellent examples of the dumbbell seaweed *Arthraria.* The discovery of this specimen was most fortunate as a large slab containing an assemblage of these ancient plant remains has long been needed for the exhibition series of fossil plants.

In October, 1919, Dr. Bassler was detailed to proceed to Dayton, Ohio, in order to prepare for shipment to the Museum the largest entire American trilobite so far discovered. This unique specimen (fig. 19) was discovered in the Richmond formation in the excavations for the Huffman Conservancy Dam 6 miles east of Dayton, which forms a part of the greatest engineering project ever undertaken for controlling stream flow, with the exception of the Assouan Dam along the Nile. Following the destructive floods in the Miami valley in 1913, the Miami Conservancy District was organized to prevent a repetition of this disaster through the control of the Miami River and its tributaries by dams extending entirely across their valleys. This operation involving an expense of over fifteen million dollars has been under way for three years, and will require three years more for its completion. The view (fig. 20) showing the excavations in which the trilobite was found illustrates only the beginning of one of these dams. This particular dam when completed, will extend a distance of a mile entirely across the river valley. Normally the water will flow in its usual channel, but in flood times it will be retained and allowed to escape gradually.

The trilobite which was found lying on its back in a hard clay bed in the central part of the excavation was unearthed by the pick of a workman, who believed it to be a petrified turtle. Mr. Arthur E. Morgan, Chief Engineer of the Miami Conservancy District, recognized the true nature and scientific value of the so-called turtle and presented it to the Smithsonian Institution, where it now forms a most instructive and unique exhibit in the hall of invertebrate paleontology. The value of the specimen is further increased by the fact that it has become the type of the new species *Isotelus brachycephalus* described by Dr. August F. Foerste of Dayton, Ohio.

During the summer of 1919, Mr. Frank Springer resumed his field researches upon the fossil echinoderms of the Ohio Valley, which had been interrupted by the war, with the special object of securing additional material from the remarkable crinoidal fauna of the Laurel formation of the Niagaran for use in his monograph on the Silurian crinoids. The principal work was done at St. Paul, in Shelby County, Indiana, where Mr. Springer's assistant, Dr. Herrick E. Wilson, continued the systematic collecting and detailed study of the strata begun several years ago. Collecting in the beds at this locality is laborious and difficult, and specimens are not abundant, but they exhibit in some respects a strong parallelism with those of the Swedish and English Silurian, which renders

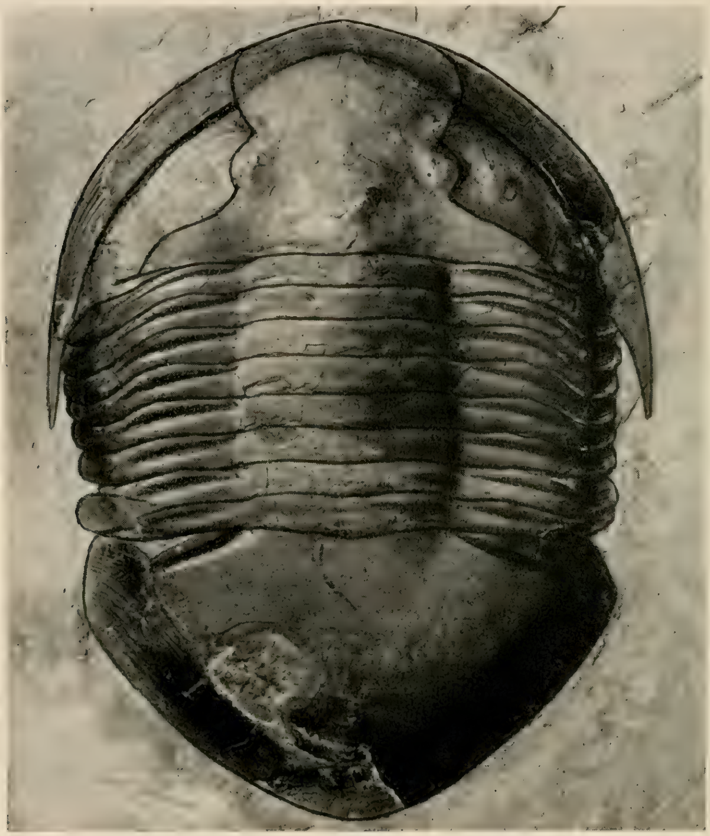

FIG. 19.—The type specimen of *Isotelus brachycephalus* Foerste, the largest known entire American trilobite. About ¼ natural size. Photograph by Bassler.

their comparative study one of much interest. Important new material was obtained which is added to the collection of echinoderms deposited in the National Museum. Mr. Springer's monograph of the Crinoidea Flexibilia, now being published by the Smithsonian Institution, has been printed and only awaits binding to be ready for distribution. It will be in two quarto volumes, one of them containing 79 plates.

The Section of Vertebrate Paleontology has been unable to undertake any field explorations during the past year, and the time of the staff has been largely employed in preparing and mounting for exhibition material otherwise obtained.

FIG. 20.—View of small portion of Huffman Conservancy dam near Dayton, Ohio, showing excavation in which the largest trilobite was found. Photograph by courtesy of Arthur E. Morgan, chief engineer.

Through the acquisition from the veteran collector of fossils, Mr. Charles H. Sternberg, of an excellent skeleton of the large swimming lizard *Tylosaurus dyspelor* and a skull of the primitive horned dinosaur *Monoclonius,* an interesting addition to the exhibition collection was made. Figure 21 shows the *Tylosaurus* skeleton in process of being mounted for exhibition by Mr. N. H. Boss. It will form a panel, in half relief, and will occupy the wall space in the northeastern part of the main exhibition hall of fossil vertebrates. The diving pose given the skeleton was largely determined by the position of the articulated tail as found in the ground.

Tylosaurus was a long, slender-bodied reptile some 25 feet in length, having the limbs modified into short swimming paddles, with a long, powerful, compressed tail. It was predatory in habits, living on fishes and probably also on the smaller individuals of its own kind. One of the unique features of the skeletal structure is the presence near the middle of the lower jaw of a joint which permits it to bow outward. This feature in connection with the loose articulation at the extremities allowed the jaws to expand and thus enabled the animal to swallow large objects. In life the body was covered by small horny scales. A study of this specimen is being made by Mr. C. W. Gilmore, and the results of his investigations will be published in the Proceedings of the U. S. National Museum.

Fig. 21.—The swimming reptile *Tylosaurus dyspelor* in process of preparation for exhibition. Photograph by Bassler.

In figure 22 is shown another of the recently mounted skeletons—that of the large extinct Rhinoceros-like mammal from the Tertiary (Oligocene) deposits of western Nebraska, named by Osborn *Brontotherium hatcheri*. The bones of this skeleton were found embedded in a fine sandstone. An idea of the amount of painstaking work involved in the collection, preparation and mounting of such a large fossil skeleton may be gained by the fact that after the bones were collected and freed from the enclosing sandstone, 258 working days were spent in restoring the missing parts, posing the skeleton and making and fitting the supporting iron work.

The National Museum has now the distinction of having the largest existing collection of Titanothere remains. The specimens were brought together by the late J. B. Hatcher, working under the direction of Prof. O. C. Marsh, at that time United States Paleontologist, and it is peculiarly fitting that the only skeleton complete enough for mounting should pertain to the species named in his honor.

FIG. 22.—The Rhinoceros-like mammal *Brontotherium hatcheri* mounted in the laboratory of vertebrate paleontology. Photograph by Bassler.

Among other important investigations in the mammalian division of the year is a study by Mr. Gidley of the Peccaries of the Cumberland Cave deposit. This includes the description of three new species, the redefinition of the Pleistocene species hitherto described, and the partial revision of the entire peccary family (Tayassuidae), the latter involving redefinitions of the two living genera of this group, and of the two suilline families Suidae and Tayassuidae. An important outcome of this preliminary investigation has been to emphasize the fact that the entire group, and especially the Pleistocene species of American suillines, is in need of thorough revision.

EXPEDITION TO SOUTH AMERICA IN THE INTERESTS OF THE ASTROPHYSICAL OBSERVATORY

Dr. and Mrs. C. G. Abbot sailed from New York on May 2, by way of the Panama Canal to Antofagasta, Chile. The expedition had three objects. First, to observe the total eclipse of the sun of May 29 at La Paz, Bolivia; second, to enable Dr. Abbot to confer with the officials of the Argentine Weather Bureau in relation to the use of the observations of the solar radiation for the purpose of forecasting weather conditions; third, in order that a visit might be paid at the observing station of the Smithsonian Institution at Calama, Chile, which is maintained by the Hodgkins Fund under the direction of Mr. A. F. Moore and assisted by Mr. L. H. Abbot.

Landing at Antofagasta, the journey was continued by the English railroad up into Bolivia over that desert which Darwin describes in his "Voyage of the Beagle." Although the travelers had visited the Sahara Desert in southern Algeria, and the deserts of the southwest of the United States, there was still reserved for them a stronger impression of a void wilderness in the Nitrate Desert of Chile. Neither bird, beast, insect nor crawling thing, nor any vegetation could be seen as far as the eye could reach.

Stopping a day at the observing station at Calama, in order to repack the apparatus required for the eclipse expedition, and joined by Mr. A. F. Moore, director of the observing station, they went on to La Paz. The plateau of Bolivia is eminently the country of mirage. The railroad appeared to rise out of a lake and to run into a lake at no distant point beyond, and all of the mountains appeared to be islands rising out of the lake. The desolation, while not equal to that of the Nitrate Desert of Chile, was yet very marked. Near La Paz the country becomes cultivated with fields of grain and vegetables, and villages of people are passed by on either side. The mountains take on a new grandeur, especially the great mountain Illimani, which rises to a height of 22,000 feet or more.

However one may have been impressed with the grandeur of the mountains, he is unprepared for the view of the great canyon in which La Paz lies. In most respects it is comparable with the Grand Canyon in Arizona, but with several added charms. First of all, on the farther side lies the great chain of the Andes, to which Illimani belongs, snow-covered although so far within the tropics, while on the nearer slope of the canyon all is green with vegetation, trickling brooks running down, and the beautiful city lies upon its cluster of hills all surrounded by the colors and broken features which might result by combining the Grand Canyon of the Colorado with the Garden of the Gods near Colorado Springs.

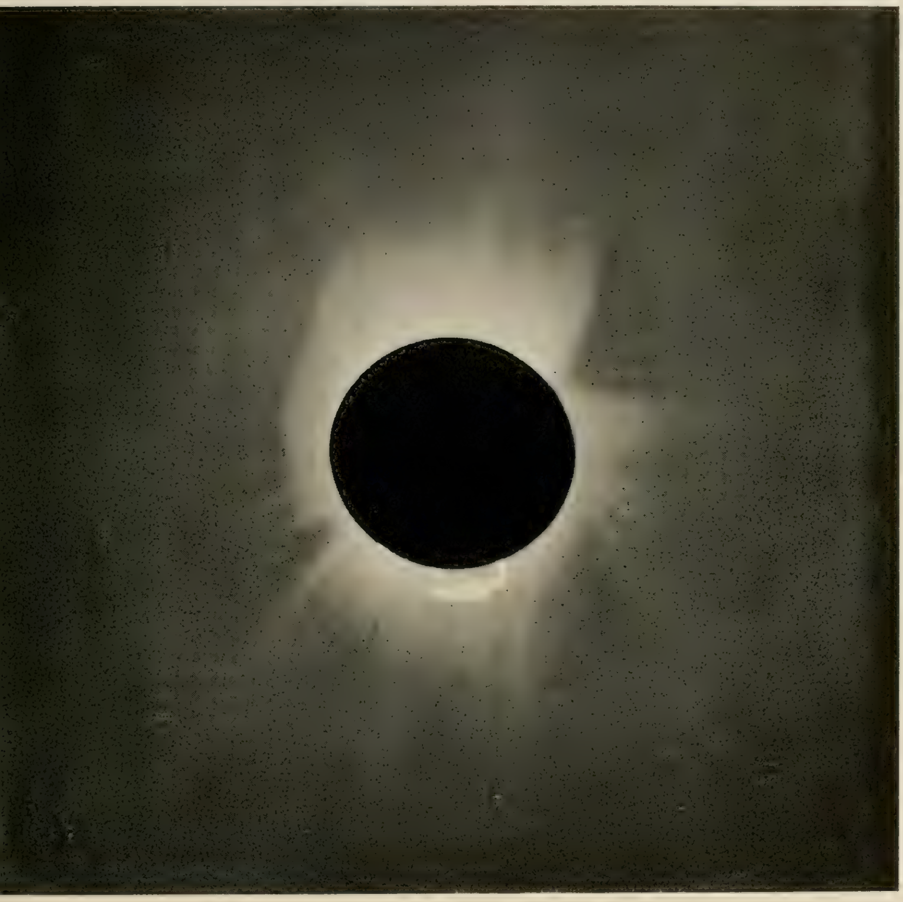

Fig. 23.—Total solar eclipse of May 29, 1919.

By the kind assistance of the manager of the English railroad the eclipse station was located at El Alto, situated on the rim of the canyon at about 14,000 feet elevation. There the apparatus was set up, and on the day of the eclipse very satisfactory observations were made, both photographs of the phenomenon and measurements of the brightness of the sky and the nocturnal radiation. The accompanying photograph shows in but a feeble way how splendid was the eclipse phenomenon on this occasion. The corona extended at least two diameters of the sun in almost all directions, with a great profusion of fine streamers. Underneath the sun, that is to say towards the east, there hung a sickle-shaped solar prominence of hydrogen and calcium gases, extending fully 150,000 miles outwards from the sun and over 300,000 miles long, which cast its crimson glory over all. The background against which this splendid phenomenon was seen was a range of mountains, perhaps 50 miles distant, which raised their snow-covered heads fully 20,000 feet in altitude.

From La Paz, Messrs. Abbot and Moore proceeded at once to La Quiaca, Argentina, where they inspected the meteorological observatory and conferred with Messrs. Wiggin and Clayton, Chief and Chief Forecaster, respectively, of the Argentine Meteorological Service. Under Mr. Clayton's direction a system of forecasting by the aid of daily telegraphic reports of the intensity of the radiation of the sun as observed at Calama, Chile, has been worked out with encouraging success.

Both Mr. Wiggin and Mr. Clayton were firmly convinced of the great value of solar radiation observations for forecasting. Arrangements were tentatively entered into for the transfer of the Smithsonian observing station at Calama to the Argentine Government, to be located at La Quiaca thereafter. At the present time, however, these arrangements have not yet been completed by the higher officials of the Government of Argentina.

From La Quiaca the travelers returned to the observing station at Calama, Chile, where Dr. and Mrs. Abbot remained about a month before returning to the United States, during which time Dr. Abbot worked over the results obtained with a view to discovering some means of measuring the intensity of the solar radiation without the long and tedious process of observing and computing which has hitherto been necessary. In this he was so fortunate as to discover, with the aid of Mr. Moore, a method by means of which suitable observations taken within a period of 10 minutes may be reduced within a period of 2 or 3 hours. Thus the intensity of the solar radiation outside the atmosphere may be determined with greater accuracy than by the former method which required about 3 hours of observing and about 15 hours of computing.

FIG. 24.—Disembarking at a Chilean Port.

FIG. 25.—Mine Storehouse Near Calama.

FIG. 26.—Lock at the Panama Canal.

FIG. 27.—Chilean Family at Calama.

Mt. Wilson observations.—As usual, the station at Mt. Wilson was occupied from May until October by Mr. L. B. Aldrich, who carried on there the usual measurements of the " solar constant of radiation," and some others intended to determine the intensity of the nocturnal radiation and the intensity of skylight.

AUSTRALIAN EXPEDITION

The zoological work by Mr. H. C. Raven in Borneo and Celebes, which has been made possible through the generosity of Dr. William L. Abbott, came to an end in 1918, as explained in the last Exploration Report (p. 35). At the close of the war Mr. Raven did not wish to return immediately to the field. Doctor Abbott therefore arranged to send Mr. Charles M. Hoy to Australia for the purpose of collecting vertebrates, especially those which are in danger of extermination. From the point of view of the national collection of mammals there is probably no field-work of similar scope that could approach this in importance. The fact has long been recognized, but the means for putting such a project into execution have hitherto been

Fig. 28.—A pair of adult duckbills, the male (at left) showing the spurs on hind feet.

lacking. The remarkable Australian mammal fauna is now represented in the museum by only about 200 specimens. Very few of these have been collected in accordance with present-day methods, and no species is represented by adequate series of adults and young, of skeletons and material in alcohol. Not only is this true of our collection, but it is equally true as regards other museums in America. So many of the Australian mammals are now rapidly approaching extermination that in future there will be few opportunities for securing the material needed for a proper representation of the fauna.

Mr. Hoy spent about two months in Washington assembling his outfit and preparing for his trip. He left for San Francisco early in May and arrived in Sydney about the end of the month. The period from June to November has been passed at various localities in New South Wales. While no specimens have yet been received (December 31, 1919), it is evident that the work has been very successful. The following passages from Mr. Hoy's letters and reports will give an idea of the conditions under which it has been carried on:

Fig. 29.—Two young duck-bills in their nest.

> "Travel is rather difficult just now. Each state has its own quarantine restrictions, on account of the 'flu' and it is quite difficult to get from one to the other. Then too a seaman's strike is on, making travel by boat very uncertain. The railroads are run by the state governments and each state has a different gauge road and different rates.
>
> "I have a great chance to get Platypus (duck-bill). A Mr. Burrell, whose hobby is Platypus is going after them on the first of October. As he has

kindly offered to take me with him and is only interested in the natural history, it will be a great chance for me to get not only the adults but also the young and possibly an egg. Mr. Burrell is after their nesting habits and is taking men along to dig out the burrows. It is safe to say that there is not another man who knows as much as he about the duck-bill.

"Nine weeks were spent in the Wandandian region (19 miles S. W. of Norwra, N. S. W.) with the result of but one hundred and thirty one (131) mammals, and one hundred and twenty-four (124) birds collected. Among the mammals ten genera and twelve species are represented in my collection.

"The greatest agent working toward the extermination of the native animals is the fox, next comes the cattle and sheep men who distribute poison by the cartload in the effort to reduce the rabbits. This has also caused or helped to cause the extermination of some of the ground inhabiting birds. Another great agent is the bush fires which sweep over the country. These are often lit intentionally in order to clear out the undergrowth and thus increase the grass.

FIG. 30.—An Australian marsupial with parachute membrane like that of the flying squirrel.

"Owing to the great increase in the price of rabbit skins and the consequent increase in trappers the rabbits are fast ceasing to be a pest, and in some sections have become quite scarce. The foxes, which are everywhere numerous, after killing off the native mammals are now turning to the rabbits, which also helps in their reduction. The extermination of the native mammals has apparently gone much farther than is generally thought. Many species that were plentiful only a few years ago are now almost, if not altogether, extinct. Diseases have also played a great part in the extermination. The native bear died in thousands from a disease which produced a great bony growth on their heads. A mysterious disease also spread through the ranks of the native cat, *Dasyurus viverrinus;* the domestic cat also played a great part in their extermination. Even adult specimens of *Dasyurus* were often dragged in by the family cat.

"The only mammals caught in traps were *Mus assimilis* and *Phascologale flavipes.* The others were all shot or snared. As the majority of the mammals taken were nocturnal and arboreal, the headlight proved to be a valuable and indispensable part of my outfit. The hunting of kangaroos and wallabies was greatly handicapped through the lack of a rifle.

FIG. 31.—An Australian marsupial resembling a very large flying squirrel.

"*Perameles nasuta* has been practically exterminated throughout N. S. W., but they are still to be found in Mosman, one of Sydney's suburbs, so I made a trip out there and was able to get a fine female with two young in her pouch. This was trapped inside the Taronga Park Zoo grounds with the kind permission of Mr. A. S. Le Souëf.

"The fact of *Perameles nasuta* being found at Mosman is probably due to the isolation of that district from the rest of N. S. W. by the city of Sydney, thus keeping out the introduced foxes.

"The country at Bulliac is a good example of what the cattle men will do in a few years time in killing off and burning the timber and the consequent destruction of animal life. Five years ago Bulliac was a virgin forest but then the railroad was built and now it is devoid of living trees for miles on each side of the track except for small and scattered patches in the more inaccessible gullies which form the last resort of the fast disappearing mammals. There are very few game laws in Australia and no one gives any attention to the ones that are in order. The Bulliac trip has clearly shown that the edge of the settlements, and even a short way into the wilds, is no better than the older settled parts and in order to get results one must go into the wilds. It is the killing and burning of the brush, by the cattle men, that does the most to kill off the animals, and they are yearly reaching farther and farther away from the railroads. One thing that was very noticeable was the great abundance of the introduced rats. They seem to have driven out or killed off practically all the native rats and I found them everywhere.

FIG. 32.—Skinning a kangaroo.

"A trip was made primarily for the eggs and young of the Platypus. Fifty miles of bank was searched and approximately one hundred burrows were dug out only six of which contained young. These six burrows furnished eleven young of which Mr. Harry Burrell, of Sydney, with whom the trip was made, secured 7 while I secured 4. The intense drought which has scarcely been broken for over twelve months (it is the worst since 1862) has advanced the breeding of the animals somewhat so we were too late for eggs. The Platypus although scarce is not by any means nearing extinction and if they continue to be protected there is every hope that they will never become extinct. Young *Hydromys* were also looked for but the drought seems to have interfered with their breeding and but two embryos were obtained. The adults themselves were very scarce and but six specimens were obtained.

The accompanying photographs show some of the characteristic Australian mammals obtained by Mr. Hoy.

G. S. MILLER, JR.

THE COLLINS-GARNER CONGO EXPEDITION

The Collins-Garner Congo Expedition returned to this country in May, after having spent more than two years in the collecting of natural history material in French Congo. Mr. C. R. Aschemeier, who represented the Smithsonian Institution, brought back with him the bulk of material collected. Among other things Mr. Aschemeier collected about 2500 birds and mammals, which added invaluable material to the museum collection.

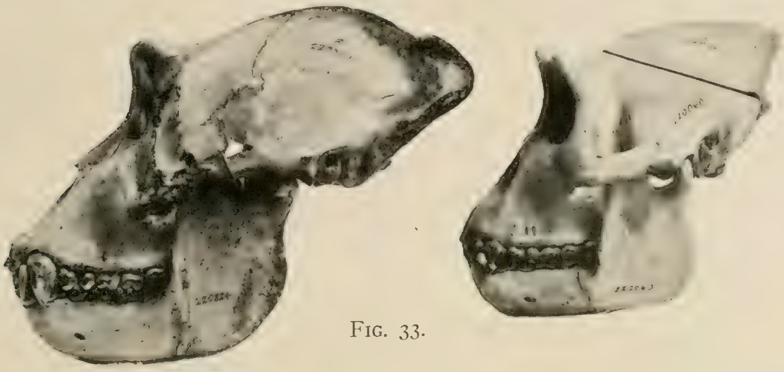

FIG. 33.

FIG. 34.

FIGS. 33, 34.—Skulls of gorillas collected by Aschemeier in French Congo. Young adult male at left; adult female at right.

EXPLORATIONS IN SANTO DOMINGO

Dr. W. L. Abbott continued his investigations at the eastern end of the Island of Haiti, making two visits during the year 1919. His first visit was to the Samaná Bay region and to the mountains in the vicinity of Sánchez and Constanza, and covered the interval from February to June. On his second trip (July to October) he stopped at Sosua, on the north side of the island, where he made a search for certain birds needed to fill gaps in the material already collected; thence to the Samaná Peninsula, after which he went to the islets Saona and Catalina, off the southeastern corner of Santo Domingo. Before returning to Philadelphia, he spent a few days at Lake Enriquillo, where he secured a few water birds of interest.

The material gathered on these two trips was varied in character, embracing the several groups of vertebrates, as well as mollusks, insects, and plants, with a plentiful series of archeological objects from caves in the Samaná district. Of birds alone, he obtained 278 study skins, 87 alcoholics and skeletons, and 56 eggs. Four species of birds in this collection represented forms not hitherto possessed by the Museum, and three or four other species were not previously known to occur on the island. Probably the most noteworthy objects in the bird collection were four eggs of the *Dulus dominicus,* known variously as the Sigura, Palm Slave, or Palm Chat, a bird somewhat larger than an English Sparrow, of sombre colors, but structurally different enough from other birds to occupy a family by itself. It is common and noisy, and lives in colonies, and its enormous "apartment house" nests are sufficiently noticeable to attract the attention of the most casual person. The discovery of the Palm Chat was almost coincident with that of America, for Columbus and his men must have seen these birds and their nests when a landing was made on this island at the end of 1492. Oviedo, the official historian of the Indes, early made its acquaintance, and devoted a chapter to it in his "Hystoria natural y general de las Indias yslas," published in 1535. The Sigura was thus one of the earliest, and at that time one of the best-known birds of the new continent. Various authors of later date have described the bird, its habits and nests, but thus far, apparently no correct description of the eggs has been given, although a French writer, in 1851, reported them to be white and unmarked.

The eggs sent by Dr. Abbott are authentic, and will be described in detail elsewhere, but the illustration here given (fig. 35) will convey a general idea of their appearance, and it may be remarked that the eggs are rather large for the size of the bird, measuring, roughly, about one inch by three-quarters of an inch in diameter. The description of the nest, as furnished to Dr. Abbott by the man who made the actual examination, indicates a radical departure from other known types of birds' nests, but a careful study of the interior of the mass by a competent observer will be required before the strange arrangement of the individual nests can be considered as accurately known. Dr. Abbott writes: "The communal nest was built in a small royal palm, about 25 feet from the ground. The nest was about 4½ feet in diameter, and about the same in height. Built of a loose mass of sticks from 1 to 2 feet long, about the thickness of bone knitting needles. There appeared to be but one entrance, from above. A local man (John King) climbed the tree and gave me the description of the *internal* construction of the nest. The entrance passage was narrow and crooked and led into a large central chamber about the size of a small bucket. The nests were placed around this on shelves of softer materials (fine bark, etc.). All four eggs were in one nest. The other five nests were still empty.

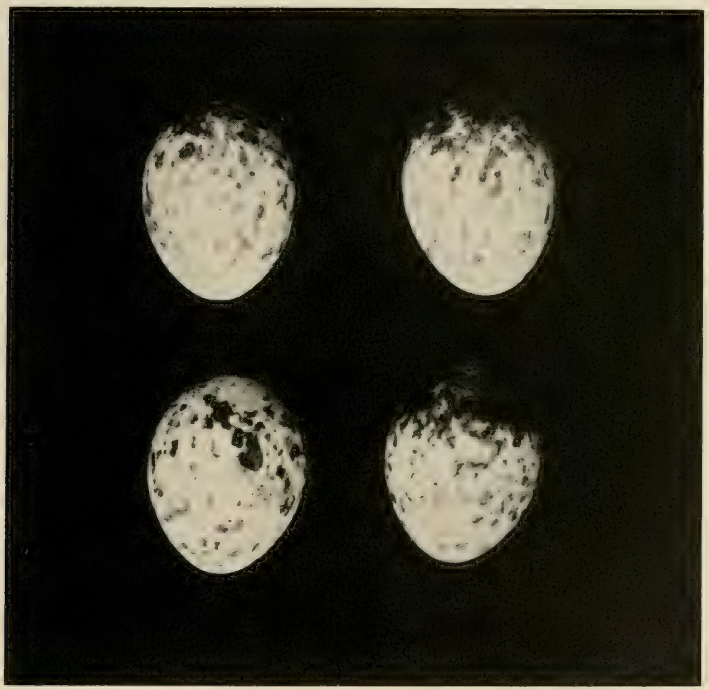

FIG. 35.—Eggs of the Palm Chat (*Dulus dominicus*).

"It is difficult to get into these nests, the huge smooth palm trunk (2 feet in diameter) must be climbed, and then it is difficult to crawl over the huge mass of sticks which lie interlaced amongst the crown of leaf stalks.

"Most of the nests are in far larger palms than this one, and the nests are frequently much larger in size, and probably contain much larger colonies."

FIG. 36.—Dense forest of giant cedar (*Thuya plicata*) near Lake McDonald, Glacier National Park.

BOTANICAL EXPLORATION IN GLACIER NATIONAL PARK, MONTANA

Mr. Paul C. Standley, assistant curator in the division of plants, spent the summer of 1919 in Glacier National Park, Montana, under the authority of the National Park Service, for the purpose of studying the vegetation of the region. The information thus obtained is to serve as the basis of a popular account of the plants to be published by the National Park Service, and it is expected that a complete and more technical account of the flora will be published by the National Museum. All the portions of the Park usually seen by tourists were explored, and 4,000 specimens of flowering plants and ferns were obtained, representing over 900 species.

Aside from the scenic features of Glacier Park, one of its chief attractions is found in the plant life. Especially striking is the display of flowers above or near timber line, where the meadows are solid masses of brilliant color, formed by Indian paint-brushes, monkey-flowers, fleabane, asters, harebells, heather, larkspur, gentians, fireweed, columbine, and a host of other plants. The most characteristic plant, perhaps, is the beargrass (*Xerophyllum tenax*, fig. 37), which occurs abundantly at middle altitudes and in alpine meadows. It is usually about 3 feet high and bears enormous plume-like racemes of creamy-white flowers. The narrow, tough leaves were used by the northwestern Indians in making baskets, hence the name of Indian basket-grass which is sometimes applied to the plant.

FIG. 37.—Beargrass, Glacier National Park.

The Continental Divide, which traverses the Park, has a marked influence upon plant distribution. On the east slope, whose drainage is partly into the Missouri River and partly into Hudson Bay, the flora is of the Rocky Mountain type, like that of Wyoming and Colo-

Fig. 38.—Sperry Glacier, Glacier National Park. There are over 60 glaciers in the Park. Photograph by R. E. Marble.

Fig. 39.—St. Mary Lake, Glacier National Park. Photograph by Fred H. Kiser.

rado; while on the west slope, whose streams drain into the Columbia River, the flora is more obviously related to that of the Pacific Coast. The forests about Lake McDonald are very dense and are composed of unusually large trees. Although not nearly so extensive, they are much like those of the humid regions of Oregon and Washington.

FIG. 40.—Gunsight Lake from Gunsight Pass, Glacier National Park. Photograph by R. E. Marble.

Fig. 41.—Trail to Swiftcurrent Pass, Glacier National Park; Swiftcurrent Glacier in the distance. Photograph by Scenic America Company, Portland, Oregon.

In the vegetation there are represented four of the life zones recognized by biologists. The Transition Zone is indicated on the west slope by small areas of yellow pine timber, and east of the Park are the prairies of the Blackfoot Indian Reservation, which extend also within the Park boundaries along the stream valleys. The plants here are chiefly herbs, with a few shrubs, and they belong mostly to species which have a wide distribution over the Great Plains. By far the largest portion of the Park is covered with the characteristic vegetation of the Canadian Zone, which is the heavily forested area. Above the Canadian Zone, around timber line (6,000 to 7,500 feet), lies a narrow belt belonging to the Hudsonian Zone. The trees here are mostly low and stunted, and their branches frequently lie prostrate upon the ground. Above this belt, and occupying the highest, exposed slopes, lies the Arctic-Alpine Zone, whose vegetation is composed chiefly of small herbaceous plants, with a few dwarfed shrubs, mostly willows. Many of the species of this zone are widely distributed in alpine or arctic regions of North America, and some of them occur also in similar situations in Europe and Asia.

EXPLORATIONS AND CERION STUDIES ON THE FLORIDA KEYS

Dr. Paul Bartsch, curator of marine invertebrates, U. S. National Museum, joined Dr. Alfred G. Mayer, the Director of the Tortugas Marine Biological Laboratory, of the Carnegie Institution, in New York on December 28, when they sailed south for Key West to make an examination of the Cerion colonies discussed in previous Smithsonian exploration pamphlets. The breeding experiments presented an entirely new phase, in the crossing, on one of the keys, of the native species, *Cerion incanum* (Binney) with one of the introduced Bahama species, *Cerion viaregis* Bartsch. It was this discovery that made it desirable to start an entirely new set of experiments. Furthermore, the anatomical differences discovered in the dissections of Cerions also made it desirable to gain material from all the colonies now existing on the Florida Keys, in order that these might be subjected to anatomization, to determine if *Cerion incanum* is really one species, or a complex, shell characters alone being insufficient to determine this point. It was for this double reason that a return was made to Florida on May 2, and an exploration of the keys adjacent to Miami at once undertaken.

On the 3d Capt. Tracy and Dr. Bartsch started in the "Darwin," a shallow draught launch of the Carnegie Institution, for an exploration of the shores of the mainland of the lower peninsula and the outside keys. This was rendered comparatively easy, since they were fortunate enough to find the mosquito pests practically absent. Between May 3 and 6 they examined every sandspit on the mainland along Key Biscayne Bay, Card Sound, Little Card Sound and Barnes Sound. They then turned the southern portion of Barnes Sound and came up along the outer keys, examining them in turn. They crossed Key Largo at several places and walked long stretches in its interior.

No Cerions were found on the mainland between Miami and the point where the railroad enters the keys, but two colonies were discovered on keys a very short distance from the mainland in Barnes Sound. One of these is situated on a sandspit covered with grass and shrubbery on Middle Key, while the other one was found in a clearing on the southeastern point of Main Key. No Cerion colonies were discovered on the keys forming the eastern perimeter of Barnes Sound, Little Card Sound, Card Sound and Key Biscayne Sound, excepting Porgee Key, where a goodly quantity were obtained, some of which have been dissected and published upon in the bulletin on "Experiments in the Breeding of Cerions" recently issued by the Carnegie Institution. In addition to Cerions, collections of all the other species of land mollusks available were made wherever found at

FIG. 42.—Nest of swallow-tailed kite (*Elanoides forficatus forficatus*) between Flamingo and Coot Bay, Cape Sable, Florida.

all the places visited, especial stress being laid upon the securing of series of the most beautiful of our American landshells, the tree snail Liguus, anatomical material of all of which was preserved in order that this group may also be subjected to a close scrutiny in an anatomical way. What is said for Liguus also applies to the equally large, though less brilliantly colored Oxystyla.

On the 7th the "Anton Dohrn" left Miami for Indian Key, spending the night off Rodriguez Key, and reaching Indian Key early on the following day. By 10 o'clock Capt. Tracy, McIvar, the Assistant Engineer, and Dr. Bartsch were off in the "Darwin" with the skiff in tow for the Cape Sable region. They skirted the outside of the Lower Matecumbe Key, passed through the viaduct and then headed across the extensive flats of Florida Bay. The first stop was made on Sands Key, where a burned out colony of Cerions and a well flourishing colony of Oxystyla and Liguus were found.

FIG. 43.—Characteristic vegetation where the prairie and hammock meet, Coot Bay region, Cape Sable, Florida.

The expedition next headed for Flamingo City, which was reached at sundown. On May 9 they explored the region about Flamingo City and the coast for several miles to the east, for Cerions, and other mollusks. Cerions were not found, but large numbers of beautiful Liguus and Oxystylas were noted everywhere. A trip was then made by wagon to Coot Bay.

Coot Bay is a fine sheet of water fringed by tall mangroves, showing even at this season a sprinkling of water fowl. The evaporation from the lake at night undoubtedly keeps the adjacent region supplied with moisture, and is responsible for the large number of epiphytic plants which render the region a veritable hanging garden. Orchids and tilandsias fairly draped and seemed to almost smother the trees and shrubs. Here we saw quite a number of rare birds, and among them the swallow-tailed kite, of which no less than six specimens were observed in the air at one time.

On the 10th an exploration was made of the region between Flamingo and the middle of the bight between Middle Cape and West Cape, but the search was rewarded with only a couple of dead specimens occupied by hermit crabs which probably had been drifted in here by the winds from the Sands Key colony. Liguus were found in many places, and so were Oxystyla and other species.

Fig. 44.—Young great white heron (*Ardea occidentalis*) on the lookout for his parents.

On the evening of the 10th the party headed for Indian Key, stopping again at Sands Key, where they found a most remarkable flight of Florida yellow throats. Every tree and every shrub seemed to have on every branch one or more of these little fellows. On the morning of the 11th sail was set from Indian Key for the Newfound Harbor group, where the next two days were spent in examining the chain of keys that extends southwest from Big Pine Key, for Cerions and other mollusks. A very flourishing colony was found on the northeast point of the first key southwest of Big Pine Key, where were gathered no less than 75 specimens in a square foot of beach, covered by grass. Another colony was found on the second key southwest of Big Pine Key. A colony was discovered likewise on the third key southwest of Big Pine Key. The fourth key is a mere clump of mangroves and did not contain Cerions. On the fifth key southwest of Big Pine Key a colony had been planted in 1912, and it is here that the crossing between the native and Bahama species has

FIG. 45.—A nest of Ward's heron (*Ardea herodias wardi*) in gumbo limbo tree.

taken place. On the sixth key no Cerions were found, but there was secured the new clapper rail which has since been described as *Rallus longirostris helius,* by Dr. Oberholser. Here, also, the pictures of the Ward's heron (*Ardea herodias wardi*) nest and young were taken. This key might really be called Rail Key. In the seventh no Cerions were found, but the great white heron (*Ardea occidentalis*) was found breeding, and it was here that we secured our photographs of this bird and the specimen, which was shipped to the Zoological Park at Washington by parcel post from Key West. It is believed that this is the first time this species has been shown in any zoological garden. The eighth and last key is a mere clump of mangroves without Cerion possibilities.

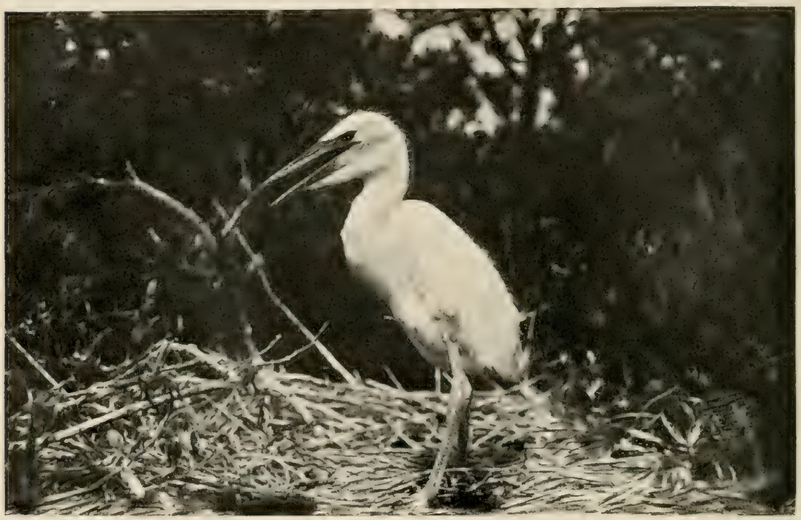

FIG. 46.—Young great white heron (*Ardea occidentalis*) in the nest in a mangrove thicket.

On the evening of the 12th the expedition headed for Key West. A large collection of Cerions was made near the Bureau of Fisheries station, to be used for breeding purposes at the Tortugas.

A new set of experiments was started on Loggerhead Key, Tortugas. Ninety cages of bronze wire, 2′ x 3′ x 3′ high, were constructed in which were placed one specimen each of two species. In addition to this nine cages 6′ x 8′ x 3′ high were built, in which 50 each of the two species were placed.

On the 19th opportunity presented itself to return to Key West on a submarine chaser.

A summary of the results so far obtained from the breeding experiments has recently been published as a bulletin by the Carnegie Institution. The results are rather startling, and incline one, contrary to the views previously held by most people, to the belief that Cerions are not easily influenced, if at all, by environmental factors. The cross obtained in the Newfound Harbor colony opens up an entirely new vista in the problem of speciation, and it was this which was responsible for the starting of the new set of breeding experiments.

Incidental to these investigations, which have been conducted since 1912, a list of the birds observed on the various keys has been kept and published annually in the Year Book of the Carnegie Institution.

FIELD WORK ON THE MESA VERDE NATIONAL PARK, COLORADO

The field-work of Dr. J. Walter Fewkes, Chief of the Bureau of American Ethnology, at the Mesa Verde National Park, in the summer of 1919, was devoted to the excavation and repair of the picturesque cliff dwelling, Square Tower House, known for many years as Peabody House, and two low prehistoric mounds situated among the cedars on top of the plateau. This work was a continuation of that of previous years and was carried on in cooperation with the National Park Service of the Department of the Interior. As Square Tower House has several unique structural features, the summer's work has added to the educational attractions of the Park. At least two new types of hitherto unknown small-house ruins were discovered, and it is believed that a new page has been added to the history of the Mesa Verde cliff people. Dr. Fewkes was assisted in his field-work by Mr. Ralph Linton, a temporary assistant, who contributed much to the success of the work.

The main object was to gather data that may aid one to better comprehend the Indian civilization that arose, flourished on the Mesa Verde, and disappeared from the plateau over four centuries ago.

Square Tower House is situated in a shallow cave at the head of a spur of Navaho Canyon opposite Echo Cliff, about 2 miles south of Spruce Tree Camp. It has long been considered by tourists one of the most attractive cliff dwellings of the park, but its inaccessibility has deterred all but the most venturesome from descending to it from the rim of the canyon. Part of the old Indian trail (fig. 47) was indicated by shallow foot holes cut in the almost perpendicular cliffs, and previous to the past summer this was the only means of access.

Without mutilating the vestiges of this primitive trail another was made in the cliff near it, around which was constructed a balustrade (fig. 48), with ladders conveniently set to aid those who wish to visit the ruin.

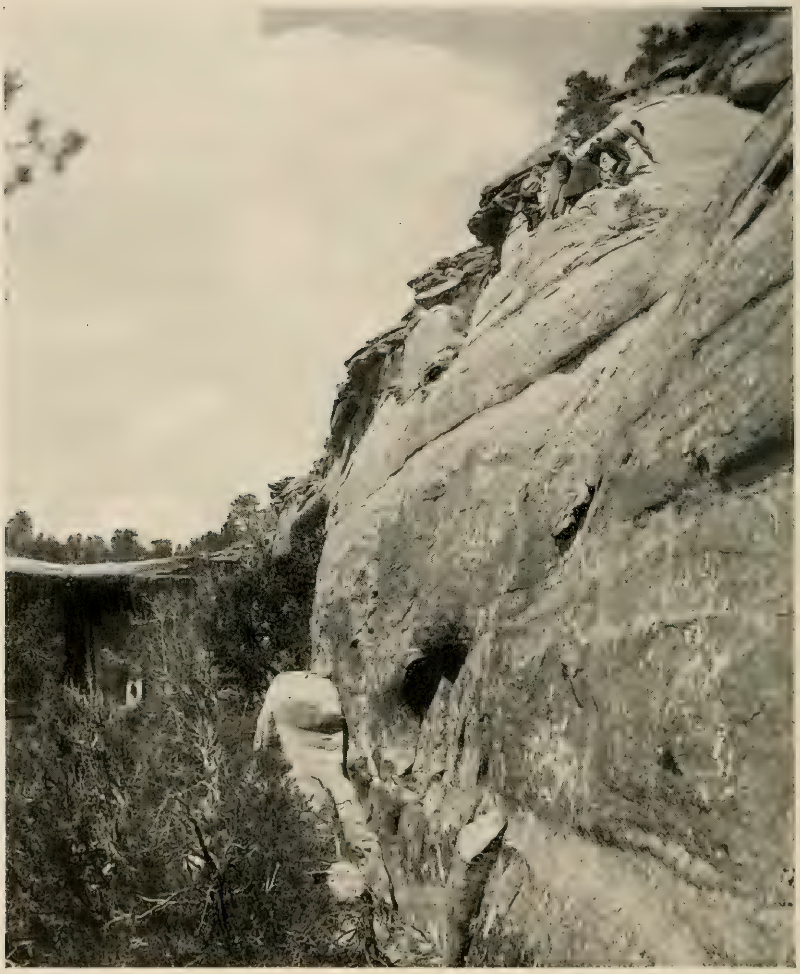

FIG. 47.—The Indian trail from the canyon rim to Square Tower House. The cliff below is almost perpendicular for over a hundred feet. A party of vistors aided by a rope is shown climbing along the trail. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande R. R.

Square Tower House (fig. 49) measures 140 feet in length and averages three stories high, with seven circular subterranean sanctuaries or kivas. The floor of the eastern end of the cave is composed of large boulders fallen from the roof; that of the western end is lower and comparatively level. The original entrance to the building, like that of the Cliff Palace, Far View House, and Sun Temple,

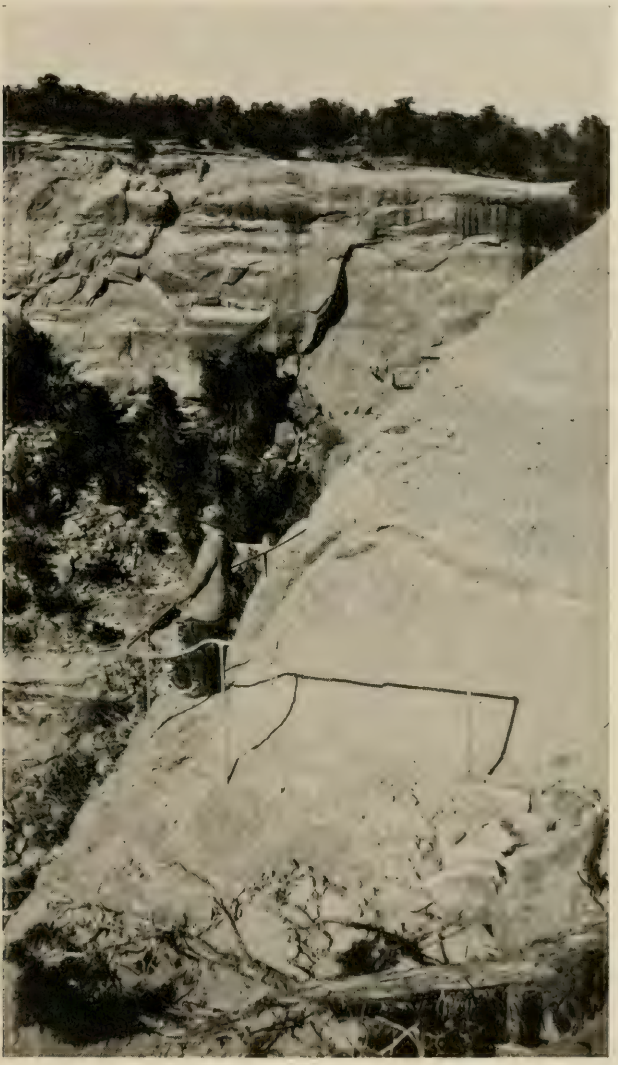

FIG. 48.—The footpath blasted in the cliff at the most difficult part of the ancient trail where the tourists are represented in figure 47. Photograph by Fred Jeep.

is a recess in the front wall. On the western end of the ruin there protrude radiating walls of basal rooms, one story high, suggesting a terrace. The rear wall of the cliff rises almost perpendicularly from the floor with no recess back of the buildings. The destructive effects of water dripping from the canyon rim are most marked midway in the length of the building where the walls (fig. 50), now reduced to their foundations, were formerly at least two stories high.

The walls of the ruin were in bad condition when the work began: great gaps in the masonry of the tower having rendered it in danger of falling. The interiors of the rooms were choked with fallen stones and the dust of ages. Two months given to excavation and repair have put the ruin in fine condition, exhibiting a good example of the best type of Pueblo architecture (figs. 51 and 52). The special attractions of Square Tower House are the remains of the roofs of two kivas and the high tower rising midway in its length.

FIG. 49.—Square Tower House before excavation and repair, from Canyon rim.

The original roof beams (fig. 53) of these two kivas are almost wholly intact. Considering how few kiva roofs on the mesa have survived destruction in the lapse of time, especial care was exercised to preserve these and to indicate their mode of construction, and a model (fig. 54) has been made, photographs of which, in successive stages of construction, are given (figs. 54, 55). A good understand-

FIG. 50.—View of Square Tower House from the west, before excavation and repair. Photograph by Fred Jeep.

ing of the construction of a typical kiva is especially important, as it distinguishes cliff houses of the Mesa Verde from those found elsewhere in the Southwest as well as in foreign lands.

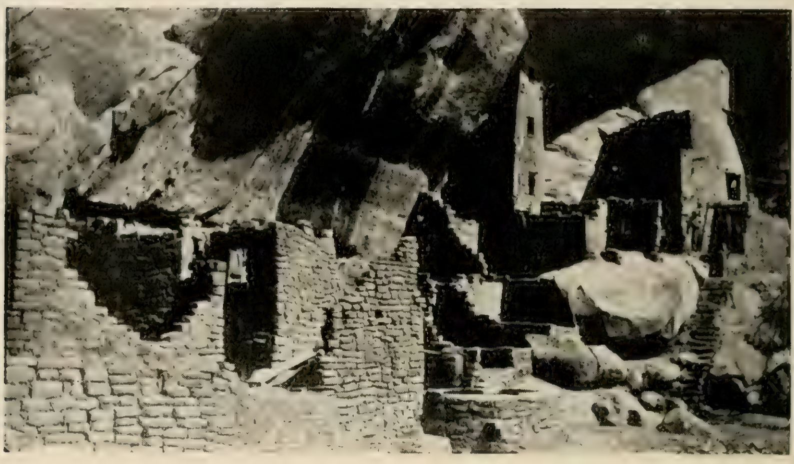

Fig. 51.—Square Tower House excavated and repaired as seen from the southwest. Photograph by Fred Jeep.

Fig. 52.—View of the Tower completely repaired. Photograph by Fred Jeep.

The kivas of Square Tower House are circular, subterranean in position, and entered by a hatchway. Each kiva has a fire hole *F*, and near it an opening in the floor called the sipapu, *L*, which is very sacred because it symbolizes the entrance to the underworld. Over it in Hopi ceremonies is erected the altar, and through it the priests call to their kin in the underworld. A most instructive feature in the structure of the kiva is the means of ventilation. Between the fire hole and the wall there is an upright slab of stone, *H,* a wall of masonry, or simply upright sticks covered with clay. The function of this object is to deflect pure air which enters the room from a shaft opening outside, *G;* the ventilator is morphologically the survival of the doorway of the earth lodge or prototype of the kiva.

Fig. 53.—View from below of one sector of original roof logs of kiva A. Photograph by Gordon Parker.

A characteristic feature of the kiva is the roof, which rests on six mural pilasters, *C;* the intervals between which are called banquettes, *B,* that (*A*) over the ventilator being wider and broader than the others. The pilasters support logs, D, D^1, D^2, laid one above another in the form of cribbing. Short sticks, D^3, are placed at right angles to the cribbing to prevent sagging. Upon this cribbing are laid logs over which is spread cedar bark to support the clay covering the roof. The hatchway, which also served for the passage of smoke, is situated in the roof above the fire hole. In the construction of this roof, men of the Stone Age in America were not far from the discovery of the principle of the dome.

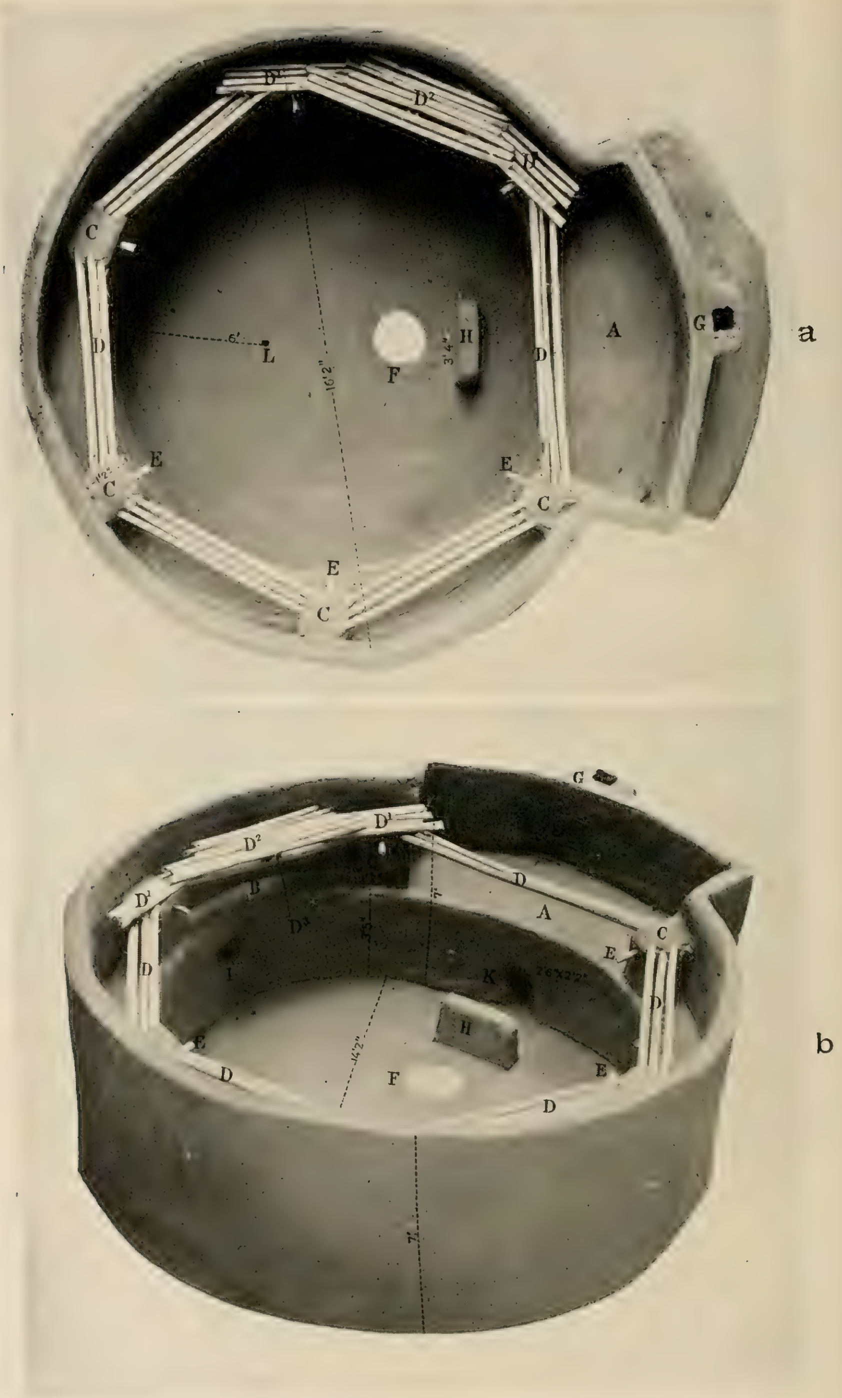

Fig. 54.—Model of a typical prehistoric kiva of the pure pueblo type. The photograph shows the model from above (*a*) and from the side (*b*), with first roof beams in place. Photographs by De Lancey Gill.

A, large banquette.
B, small banquettes.
C, pilasters to support roof cribbing.
D, beams of lower level of roof.
*D*¹, beams of second level of roof.
*D*², beams of third level of roof.
*D*³, logs to prevent sagging of roof.
E, pegs for ceremonial paraphernalia.
F, fire hole.
G, external opening of ventilator.
H, fire screen, or pure air deflector.
I, niches for sacred meal.
K, floor entrance to ventilator.
L, ceremonial floor opening or *sipapu*.

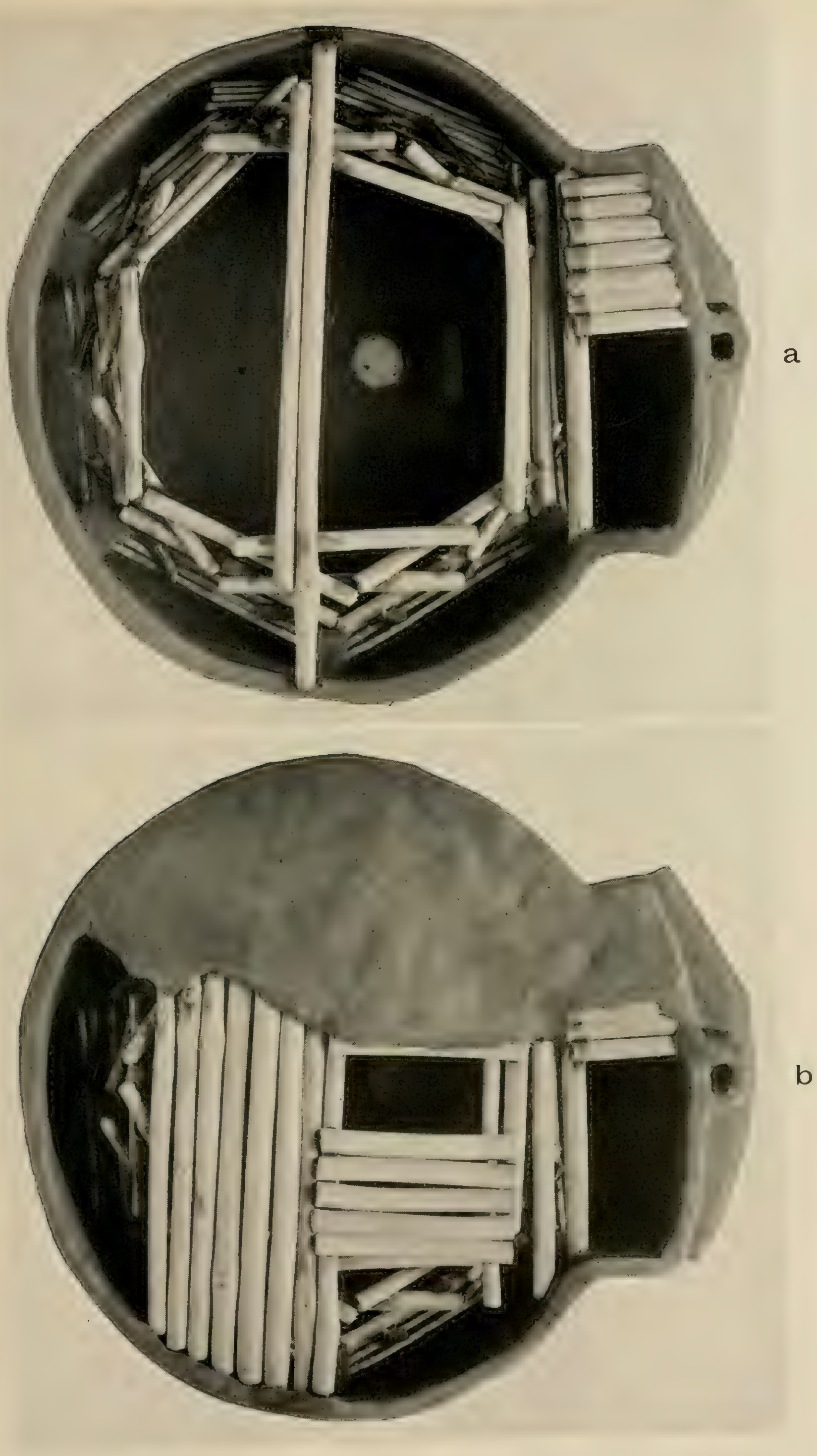

Fig. 55.—Model of typical kiva of the pure pueblo type; *a* shows construction of roof beams; *b*, half-covered roof and hatchway. Photographs by De Lancey Gill.

The most striking feature of Square Tower House is the tower from which it takes its name. The cave in which it is situated having no recess at its back, there is consequently no refuse heap in the rear, such as was utilized at Spruce Tree House for mortuary purposes. The rear wall of the tower is formed by the perpendicular cliff (fig. 56). As shown by windows, doorways, and remnants of

FIG. 56.—Middle section of Square Tower House from the Crow's Nest. Photograph by Fred Jeep.

flooring, this tower is four stories high. The inner plastering of the lowest story is painted white with a dado colored red; its roof is likewise well preserved.

A room near the western end, (fig. 57) of the ruin has doors and windows closed with secondary masonry, and in the rubbish, half filling the neighboring kivas, human bones were found, indicating that the western end of the ruin was deserted and used for mortuary purposes before the remainder of the ruin was abandoned.

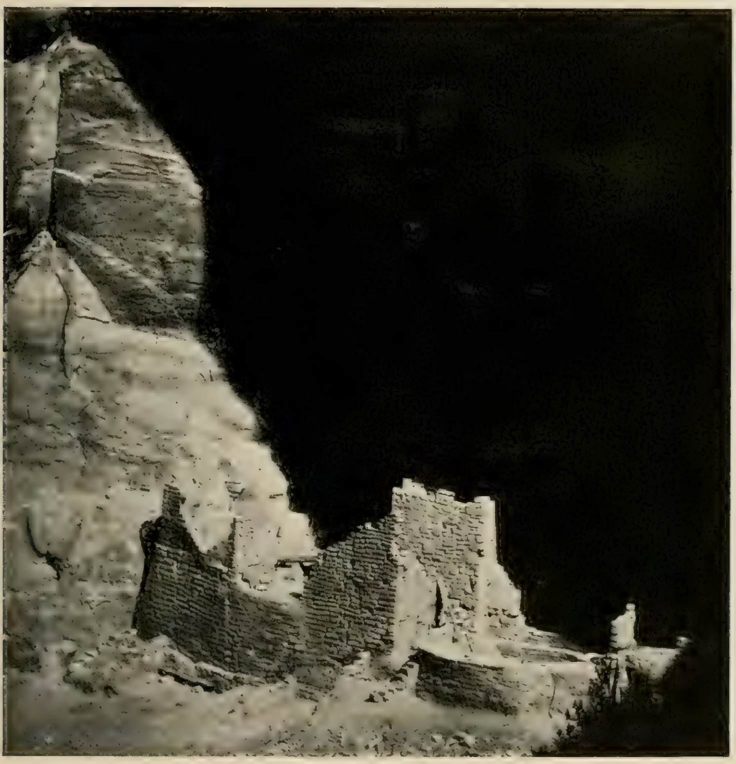

FIG. 57.—Western end of Square Tower House, excavated and repaired. Photograph by Fewkes.

There is no archeological evidence that the tribes to the east, north, and west of the cliff dwellers and stone house builders of the Pueblo area were stone masons. On the south of the area, in the valley of the Gila, Santa Cruz, and San Pedro, looking toward Mexico, the ancients built their houses of earth and logs, and while the prehistoric buildings on the southern tributaries of the San Juan resemble those on the Mesa Verde they are quite different from the pueblos now inhabited. A logical interpretation of the geographical distribution of ruins with kivas like those of Square Tower House would not be that the knowledge of stone masonry was introduced from Mexico, but that the craft was acquired after the original inhabitants entered the country, and that the pure pueblo type, or that with kivas like those of Square Tower House, was born, cradled, and reached its highest development in the area where it was found. But we may take another step, and point out that the prototype of these prehistoric kivas has a morphological likeness to "earth lodges."

FIG. 58.—Wall of Earth Lodge A, showing adobe plastering on earth; the horizontal log is a roof beam. Photograph by T. G. Lemmon.

The discovery of Earth Lodge A in this area by my assistant, Mr. Ralph Linton, was important, considering the light it may throw on the genesis of cliff dwellings. This ancient prototype (fig. 58) of a kiva is a semicircular isolated room with a slightly depressed floor in which is a centrally placed firepit, the surrounding walls being either adobe plastered on the earth or molded into clumps shaped like rolls. In this rude sunken wall were set at an angle posts, now charred at the free ends, all that remains of the supports of roof and sides.

Earth Lodge A was not only excavated but a shed (fig. 59) was built over it for permanent preservation. While it is interpreted as the prototype of a kiva, it was formerly the dwelling of a family or other social unit dating to an epoch much older than that of the cliff dwellers. On opposite sides of the fire hole at the periphery of the floor, but within the outer walls, are small square or rectangular cists made of stone slabs set on edge. The indications are that these were covered with sticks and clay, suggesting the so-called slab houses. The pottery found in these cists is very crude, undecorated, and not of the cliff house type.

FIG. 59.—Shed built over Earth Lodge A to protect it from the elements, north end, entrance opposite. Photograph by Fred Jeep.

There are many sites resembling that of Earth Lodge A before excavation awaiting investigation on the top of Mesa Verde. Near it was a mound which when opened proved to be a unit-type house. The crude masonry and rough pottery found in it indicate an advance on the walls of an earth lodge, but the former is inferior to that of a kiva of the highest development, suggesting that it is an intermediate form between Earth Lodge A and Square Tower House. The spade revealed that after this room was first deserted débris had filled the depression a few feet deep on which a new fire hole and a grinding bin had been made of stone slabs on edge in the middle of the depression. Later on it was again abandoned and human bones had been thrown on the débris that formed over the grinding bin, indicating that the depression had become a dump place. Last of all, these were also covered by accumulated sand and soil, leaving only the top stones of a pilaster projecting above the surface.

Fig. 60.—Idol of the germ-god set by author in cement at head of the stairway, near kiva B. Photograph by Fred Jeep.

The pottery found in this crudely constructed kiva is more varied, but still an advance on that excavated in Earth Lodge A. It may be classified as black and white, and corrugated, but so inferior to that typical of cliff houses that it can be readily distinguished. From this

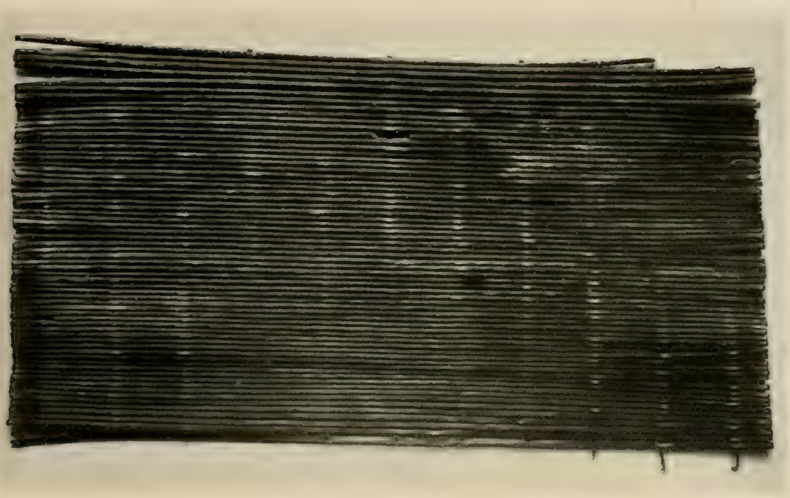

FIG. 61.—Mat made of sticks found with a skeleton in room west of kiva D. Photograph by De Lancey Gill.

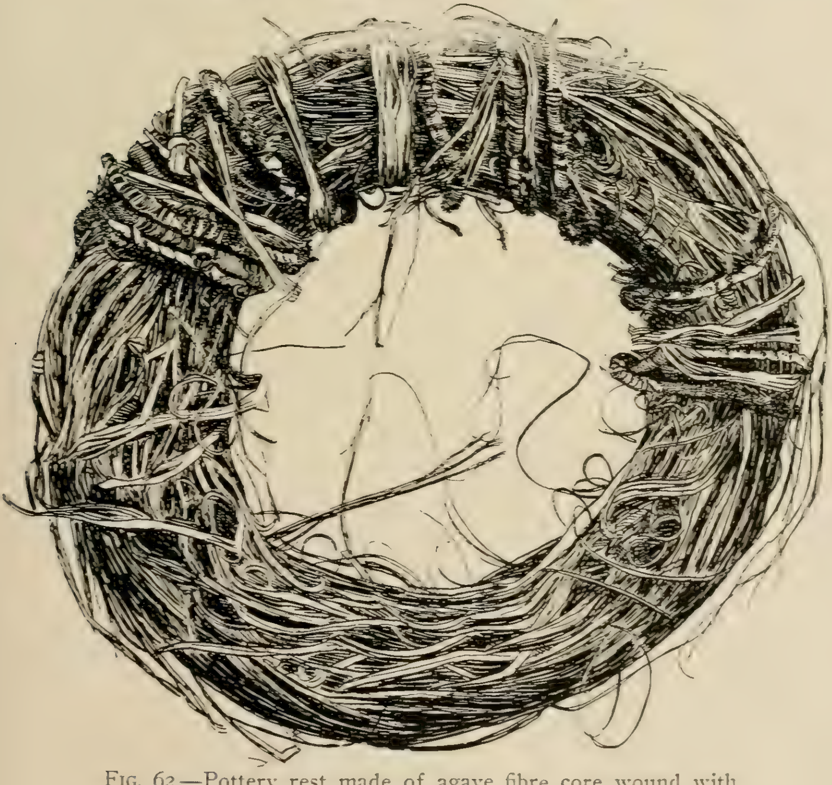

FIG. 62.—Pottery rest made of agave fibre core wound with feathered string.

ruin was taken a shard with a fine swastika, showing the antiquity of this design so rarely found in Mesa Verde.

The general facies of the collection of artifacts from Square Tower House is the same as in other cliff dwellings on the park, and although a few specimens are different from those already known, the majority corroborate, as far as age is concerned, the testimony of the buildings. A broken fragment of the rim of a vase of the sugar bowl pattern, a type peculiar to the upper San Juan area, was obtained from the Unit-Type House. Fragments of food bowls corrugated on the outside, black and white on the interior, belong to a type hitherto rare. No collector has thus far reported a prehistoric pipe from Mesa Verde, but a stumpy straight tube of unburnt clay, more like a " cloud blower " than a pipe, betrayed the fact that the cliff dwellers, like other Indians, smoked ceremonially.

Fig. 63.—Stick with carved extremity.

On their altar at the great winter solstice ceremony at Walpi, one object of which is the increase of life by calling back the sun, the Hopi now employ an idol representing the god of germination. This idol is half oval in shape, the surface being painted with symbols of corn. A similar undecorated idol (fig. 60), found at Square Tower House, one of the best ever collected, was cemented by the author in a conspicuous place at the head of the stairway.

An almost perfect reed mat (fig. 61), resembling those often deposited with the dead, was found in a room of Square Tower House. Good specimens of feathered cloth were wrapped around skeletons of infants. A fine pottery rest (fig. 62), and a stick which shows excellent carving on one end (fig. 63), occur in the collection; there are also many bone needles, basket fragments, and other objects similar to those elsewhere described.

FIG. 64.—Incised maze on one side of an artificially worked cubical stone found with idol of the germ-god. The dotted line does not exist on the specimen, but was placed there to enable the reader to trace the meander. Photograph by T. G. Lemmon.

A cubical stone with an incised design (fig. 64) found in the same room as the idol of the germ god, is worthy of special mention as the maze or labyrinth depicted upon it is unlike any pictograph yet described from the Southwest.

Theoretically, Earth Lodge A is supposed to resemble forms of dwellings that have survived to our day among non-pueblo tribes.

It has, however, an instructive feature they do not possess, viz., cists made of slabs of stone set on edge. Evidences are accumulating of a culture antecedent to the pure pueblo type in which vertical masonry predominates, but we must await more knowledge of the construction of the houses of this epoch before speculating on the early relations of the builders of vertical and horizontal masonry.

Fig. 65.—Square Tower House repaired, as seen from the west. Photograph by T. G. Lemmon.

ARCHEOLOGICAL EXCAVATIONS IN ARIZONA

In continuation of work in Arizona for the Bureau of American Ethnology, Dr. Walter Hough began excavation of an important ruin in Grasshopper Valley, 14 miles west of Cibecue on the White Mountain Apache Reservation, Arizona. The ruin consists of two great mounds covered with brush and showing portions of walls.

The inhabitants, as shown by the skeletal remains, were Pueblo Indians. Among the discoveries were a temporary camping place of a clan while their houses were being constructed; the use of heavy masonry retaining walls to prevent the thrust in the earth covered with the great structure of the pueblo; and the determination that the house plans, sometimes called " foundations," and thought to be unfinished structures, are remains of open air sheds, such as those now in use by the Pimas. The presence of two very large débris

FIG. 66.—Retaining wall of ancient pueblo at Grasshopper Valley, Arizona.

FIG. 67.—Outlines of open-air sheds, ancient pueblos at Grasshopper Valley, Arizona.

lenses, forming low mounds at 300 yards from the pueblo, is considered somewhat remarkable.

The artifacts consist of flint implements, stone axes, bone implements, and the usual variety of small objects. Of pottery, red and gray preponderate; also found are pure yellow (Hopi type); black outlined with white on strong red (Chevelon type); obscure yellow gray on brown with black designs (Gila type); and green glaze design on white (Rio Grande type). Analysis of the shards from the 20 excavations made show that the great ruin and the neighboring members of the group may be differentiated on the basis of the pottery fragments.

ARCHEOLOGICAL INVESTIGATIONS IN UTAH AND ARIZONA

Early in May, 1919, provision was made by the Bureau of American Ethnology for continuation of an archeological reconnoissance of northwestern Arizona, inaugurated several years ago, but interrupted by the recent world war. As in previous years, the work was directly in charge of Neil M. Judd, curator of American archeology, United States National Museum. Plans for an extensive survey of the arid regions immediately north of the Rio Colorado were necessarily abandoned because of the exceptionally dry season. Mr. Judd then proceeded to Cottonwood Canyon near Kanab, Utah, where, in 1915, he had hastily examined several shallow caves containing prehistoric remains.

As unforeseen conditions prevented completion of the reconnoissance originally contemplated, so unexpected difficulties also handicapped the Cottonwood Canyon investigations. Work continued during two weeks only, but in this short period twelve or more caves were visited and five of them were examined with considerable care. Most of the standing walls in these caves (fig. 68) were of the customary stone and mortar construction, but others were found in which adobe had been utilized almost exclusively. A third type of architecture was that in which the walls were formed of upright posts, bound together with horizontal willows and plastered over with adobe mud. In such dwellings the heavy roof was ordinarily supported by larger posts, placed as part of the wall or entirely within it. In these ruins (fig. 69) and in the remains of other houses which had preceded them, sandstone slabs were invariably utilized for the inner base of the walls, the remainder being either of stone and mud or wattled construction. Although dwellings of the three types above mentioned

FIG. 68.—Isolated rooms forming part of a small cliff village in Cottonwood Canyon. Several of the rooms were repaired after excavation; the darker portions show the extent of these restorations.

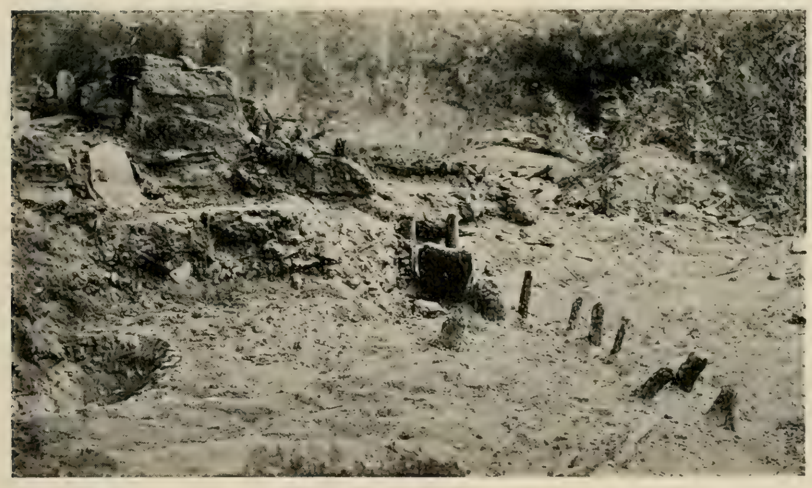

FIG. 69.—At the upper left are the broken walls of dwellings built above the remains of a circular room. Fragments of wall posts and one roof support are shown at the right; the fireplace at the left. In the immediate foreground and in the middle of the view will be seen upright slabs which formed part of the lower inner wall.

seem to indicate different stages in constructional experience, they could be and were found in the same cave. In such cases there was nothing to suggest any considerable lapse of time between the periods represented by the successive years of occupancy; neither could it be determined from the refuse in and about the dwellings that more than one people had taken part in their construction.

From the minor antiquities collected it does not appear that the degree of culture reached by the ancient inhabitants of Cottonwood Canyon differed essentially from that of other primitive peoples farther to the north.[1] The pottery, generally, is of a type closely related to the pre-Pueblo peoples south and east of the Rio Colorado, and indicates a higher degree of experience than that noted among the ruins at Beaver or Paragonah, for example. Wooden agricultural implements, basketry, cotton cloth and other objects commonly found in cliff ruins of the southwest are likewise of the well-known Pueblo type. The results of these recent excavations tend to confirm, therefore, the belief that in western Utah there is certain evidence of a prehistoric people which originated some place in the northwest and

FIG. 70.—Masonry walls built above the ruins of a circular kiva, previously destroyed by fire. The banquette or bench surrounding the room will be noted in the foreground; also, the charred fragments of several wall posts and one roof support.

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[1] Smith. Misc. Coll., Vol. 66, No. 3, 1915; Vol. 66, No. 17, 1916; Vol. 68, No. 12, 1917.

journeyed southward; that during the course of their long-continued migrations they changed rather rapidly from a semi-nomadic to a sedentary life as they approached the Rio Colorado. Having gained the "red rock" country and having found, for the first time, natural caves that increased the protection afforded by their small dwellings, they became more closely related, if not identical, in culture to those people commonly recognized as the ancestors of the modern Pueblo Indians.

FIG. 71.—Walls of rectangular dwellings built above the remains of a circular room. The upright slabs in the foreground formed the inner wall base of the latter structure.

FIELD WORK ON THE IROQUOIS OF NEW YORK AND CANADA

Mr. J. N. B. Hewitt left Washington May 12, 1919, on field duty. On the Onondaga reservation near Syracuse, N. Y., he found only fragmentary remnants of the League rituals, laws and chants, aggregating less than 2,000 native terms; but these rituals, laws and chants are so much broken and wasted away, and their several remaining parts are so confused and intermixed the one with the other that with these remains alone it would be quite impossible to obtain even an approximate view of their original content, forms, and settings. The texts which Mr. Hewitt has recorded among the Canadian Iroquois aggregate more than 125,000 native terms. During the two weeks spent on this reservation Mr. Hewitt recorded in Onondaga text all the doctrines of the great Seneca religious reformer of the close of the 18th century, Skanyodaiyo (the so-called "Handsome Lake," but which is literally "It is a beautiful Lake").

Mr. Hewitt left this Onondaga reservation May 31, 1919, going directly to the Grand River Grant, Ontario, Canada, where the other tribes of the six Iroquois tribes dwell. There he resumed his intensive study and analysis of his recorded texts relating to the institutions of the League, recording variant passages and terms when encountered. He also obtained in detail the pattern of the wampum strings in beads which are used in the Requickening Address of the League. Twenty-eight strings, at least, are necessary. On each string the blue and the white beads are arranged according to a definite pattern.

An effect of the war of the American revolution on the tribal integrity of the Six Nations of Iroquois was that every tribe, except the Mohawk, was sundered into two independent bodies; and one part of each of the divided tribes became resident on a separate reservation in the State of New York, and its public affairs became measurably dissociated from those of the parts of the other tribes dwelling in New York, while the complementary tribal parts removed to Canada, where they finally settled on the Grand River Grant. So that at first there were two Onondaga tribes, the one in New York and the other in Canada, two Seneca tribal groups, the one in New York and the other in Canada, two Oneida tribes, two Cayuga tribes, and two Tuscarora tribes, similarly dispersed.

This disrupting of tribal integrity resulted in sundering the League Federal Council into two independent units. Since the tribes in New York State severally occupied individual reservations, often far removed one from another, each tribe was thrown more on its own resources than previously; and the Federal Council composed of the New York tribes was convened only when some matter affecting all these tribes became urgent; and this situation naturally tended to efface the concrete knowledge of the basic federal laws and principles of the League from the minds of the New York tribes, so that within 50 or 60 years after this, the laws and the rituals of the original League had become largely obsolescent, if not wholly forgotten, in New York State.

Conversely, the tribes of the Six Nations of Iroquois who removed to Canada and settling on the Grand River Grant elected to transact their affairs at a semi-federal council composed of all tribal and all federal chiefs (whose titles were not then held in New York State).

This arrangement naturally tended strongly to preserve the traditional and the concrete knowledge of the distinctively federal institutions and laws and rituals. But, even here, a living and constructive knowledge of the institutions of the League is less definite and is often displaced by dubious modern interpretations. So it has become increasingly difficult, indeed, to obtain from the variant extant versions of laws, traditions, rituals, songs and institutions, their most probable original form.

The Onondaga tribes of New York State, dwelling 8 miles southward from Syracuse, occupy the ancient seat of the Federal Council of the League of the Iroquois. In the original structure of the League, and still exercised by both the Canadian and the New York federations, the Onondaga chiefs as a body exercised functions approximating those of the presiding judge of a modern court sitting without a jury, and had power to confirm or to refer back (but not to veto) for constitutional reasons the decisions or votes of the Federal Council.

OSAGE TRIBAL RITES, OKLAHOMA

In the spring of 1919 Mr. Francis LaFlesche, Ethnologist, spent a month among the Osage Indians, gathering further information concerning the ancient rites of that tribe and collected two rituals, one from Wa-tsé-mo^{n}-i^{n}, pertaining to the origin of the people of the black bear gens, and one from Mo^{n}-zho^{n}-á-ki-da of the Peace gens of the Tsi′-zhu division, as to the origin of that people.

The ritual obtained from Wa-tsé-mo^{n}-i^{n} contains 582 lines, divided into 29 sections and arranged in groups according to subjects. The first group of five sections describes the descent of the people from the sky to the earth. The second group of four sections tells of the appeal of the people to certain water insects who promise help. The third group of eight sections speak of the Great Elk who brought to light four different colored soils which he gave to the people to use in this rite as symbols. The next group of a single section tells of the wanderings of the people, of their meeting a man whom they learned had descended from the stars and who gave to the people certain sacred gentile names. Although they were warriors whose business it was to destroy, they resolved to make the stranger their chief, saying to one another: "There shall be in him no anger, no violence and he shall be a man of peace."

The fifth group of three sections speaks of the parts of the swan that were dedicated for use as a war standard. From this sacred bird were taken personal names. The sixth group of four sections recounts the finding of four different kinds of rock in their consecration for symbolic purposes. The seventh, a single section, speaks of the finding of a female buffalo, the consecration of parts of its body and skin for ceremonial purposes. The eighth group of three sections recounts the search for a suitable kind of stone out of which to make a ceremonial knife. On his third search the man chosen for

FIG. 72.—Wa-tsé-mo^n-i^n. Member of the Black Bear Gens.

the duty returned with a red flint out of which was shaped a round-handled knife and consecrated to ceremonial uses.

The ritual given by Mo^n-zho^n-á-ki-da contains 248 lines, divided into 20 sections and arranged, according to subjects, into eight groups. In the story told by Mo^n-zho^n-á-ki-da the people of the Peace-maker gens awakened in mid-heaven to a realization that they were a people when a desire came upon them to descend to earth where they might come into bodily existence. The first three sections record the downward journey, of the people finding the first and second heavens (counting downward) to be blank, but in the third heaven they met the Man-of-mystery (the god of rain), who promised them aid in their struggles upon the earth. The sixth section tells of the further descent of the people, of their meeting the great Buffalo Bull who, out of pity, gives them certain roots to use in healing their bodily ailments. These medicinal roots are used to this day. The great animal then gave them various kinds of corn and squash. The five sections following speak of the journey of the people over the earth, of their coming to certain trees, to the waters of a river where they met the spirit of waters, to water-plants each of which they adopt as life-symbols. The next, a single section, tells of the coming of the people to a dead animal which they adopt as a symbol. The significance of the incident is not clear. In the next two sections is told of the people coming to the center of the earth, meaning mid-summer, the time greatest in fruitfulness (August), and to a "beautiful house" which was to be their sanctuary. The next group is a single section and speaks of the encounter of the people with another dead animal (an elk), the meaning of which is not clear. The next two sections speak of the people again coming to the center of the earth, meaning another month (September), which, together with August, makes mid-summer. The people at last reach another "beautiful house" with many openings, wherein are to be sent all the children of the people to be given their gentile personal names and assigned to their proper places in the tribal and gentile order.

ETHNOLOGICAL STUDIES IN OKLAHOMA, NEW MEXICO, AND CALIFORNIA

The year was spent by Mr. J. P. Harrington, ethnologist, in continuation of his studies of Southwest Indian languages and ethnology. During the first five months of the calendar year he was engaged in the study of the Ventureño and other Chumashan dialects of California. Especial attention was given to the ethnology as well as to the language, the linguistic studies proving to be the key to the unearthing of considerable important ethnological data, notably on subjects pertaining to material culture, sociology, and the little habits of daily life and thought which are really fully as important as the larger and more striking features of ethnology.

FIG. 73.—Ventureño Man.

The months of July, August and September were spent in New Mexico in study of the Tano-Kiowan problem, and with as conclusive and gratifying results as could be desired. The entire structure and vocabulary of Tanoan and Kiowa is one and the same, and points to genetic unity at no exceedingly remote period in the past. A peculiar series of phonetic shifts and changes occurring in these languages was fully investigated, and interesting studies in comparative vocabulary were made.

FIG. 74.—Hoop and pole game of the Ventureño Indians.

MUSIC OF THE PAWNEE, OKLAHOMA

In May, 1919, Miss Frances Densmore went to Pawnee, Oklahoma, to begin a study of the music of the Pawnee Indians who live in that vicinity.

She arrived at the time of the Buffalo ceremony which is held every spring by the Pawnee, having for its original purpose the securing of buffalo for food. The ceremony was held in an earth lodge of the old type (figs. 75 and 76). Only initiates could be present on the first day when the "painting of the buffalo skull" took place, but, through the courtesy of the man in charge of the ceremony, Miss Densmore attended the Buffalo dance and the Lance dance which were held a few days later. These constituted the second and third portions of the ceremony. During the Buffalo dance the buffalo skull with its ceremonial decorations lay in front of the "altar." Participants in the ceremony were seated in four groups, men in each group having their bodies similarly decorated with symbolic designs. The principal singer was Wicita Blain, a blind man, who at a subsequent time recorded a number of the songs used on this occasion. These were old songs which he had received by inheritance, and the words contain interesting examples of native poetry. Blain also recorded ceremonial songs of the Bear dance, which were his by right of inheritance.

One of the leading participants in the Lance dance was John Luwak, chief of the Chaui band (fig. 77), who recorded numerous old songs of various classes. Some unusually attractive songs were heard during the Lance dance, but it was learned on inquiry that they had been recently composed by the younger men of the tribe. As old songs were desired these were not recorded. One of the old Lance dance songs was obtained, with the words, " Father, the band of the dead is coming." This was sung when the lance bearers danced around the lodge. The study was limited to the music, no study of the ceremonies being undertaken at this time.

FIG. 75.—Pawnee ceremonial earth lodge. Photograph by Miss Densmore.

Three other gatherings were attended by Miss Densmore, *i. e.,* a hand game and two victory dances.

The victory dances were of unusual interest as they celebrated the return of young men who had served in the recent war. Forty Pawnee enlisted; 39 returned without having suffered any casualty, and one died of disease in France. Many of the men had been at the front, several volunteered for a certain duty of special danger, the son of a chief served with the heavy artillery in a responsible position, and wherever opportunity offered, they seemed to have made a creditable record. All appeared to be in the best of health. A member of the tribe said he " believed this was because the people had prayed for them, both in private and at all their public gatherings." The first victory dance was the occasion of the public rejoicing of the women of the tribe, especially those whose relatives had been in the war. This was similar to the scalp dances of the old times, and about 40 women were in the dancing circle. War trophies were carried aloft on poles, as scalps were formerly carried. In accordance with old custom the soldiers presented their trophies to their nearest kinswomen. One woman held a pole with a long knife fastened at the end like the head of a spear, while below the knife was hung the metal helmet which, with the knife, was taken from the enemy by her son. As the women danced they lifted their trophies high in the air, and expressed their enthusiasm in shrill cries. It was a scene of free, native rejoicing. Miss Densmore was the only white person present. Many war songs were sung, former deeds of valor were related by the old warriors and the dancing continued for several hours. The Pawnee are an emotional people, and some of the older members of the tribe lamented with sobs and crying the diminution of the tribe and the passing of the old ways.

The second victory dance took place several days later and was entirely different in character. Many spectators attended, and the building was crowded to its utmost capacity. At this dance the returned soldiers were the principal interest, many appearing in native costume and dancing the war dance. One such young man told Miss Densmore that he had been at a government school practically all his life and never before had joined in a native dance. The gathering opened with an impressive native ceremony, then speeches were made by the chiefs of the bands, gifts were given and received in a ceremonial manner, and the son of a chief was adopted by a prominent member of the tribe, receiving an old and honored name. The young man went through the simple ceremony with quiet dignity, wearing the khaki uniform in which he had served in Europe. Once the space around the entrance was cleared and a woman led in a white horse, presenting it to a soldier; later a pair of white horses were similarly presented. An interesting little drama was the " consoling " of the parents of the young man who died in France.

The singing at the victory dances was characterized by songs with words concerning the recent war, including mention of airplanes.

submarines and the enemies of the allied nations. These words were usually sung to old melodies. One woman advanced alone to a place in front of the chiefs and, without the drum, sang such a song which she had composed for the occasion. Two similar songs were recorded by Luwak who related the dreams in which he heard them. He said he "prayed daily to Tirawahat," saying, "help our boys over there so they will all come back strong and so I may live to see them again." One night he fell asleep after such a prayer and in his sleep "someone told him that it would not be long before he would see the Pawnee boys again." In his dream he saw thousands of white people rejoicing and heard them singing this song, "even the oldest people were dancing and waving flags." A few days later he heard of the signing of the armistice, with its celebration, and accepted it as the fulfilment of his dream. He related the dream and sang the song at a gathering opened with an impressive native ceremony, then speeches learned by the people.

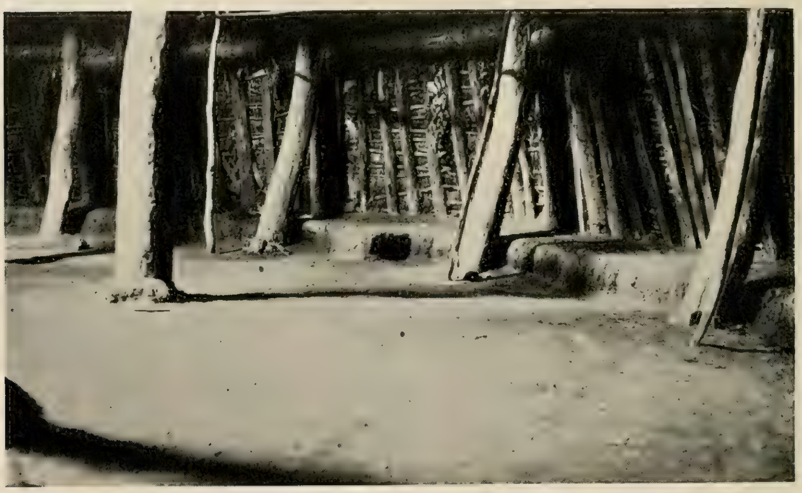

FIG. 76.—Pawnee ceremonial earth lodge, interior, showing location of the "altar." Photograph by Miss Densmore.

MATERIAL CULTURE OF THE CHIPPEWA OF CANADA

In July, 1919, Miss Densmore visited the Manitou Rapids Reserve in Ontario, Canada, through the courtesy of Mr. J. P. Wright, Indian agent at Fort Frances, Ontario. Chippewa from other localities in Ontario were also interviewed. The purpose of this trip was to

FIG. 77.—John Luwak, chief of the Chaui band, Pawnee.

obtain data on the bead patterns, use of native dyes, medicinal herbs and other phases of material culture among the Canadian Chippewa for comparison with similar data already collected among the Chippewa of Minnesota. Numerous old geometrical bead patterns were noted which show an entirely different character from those in use among the Minnesota Chippewa, and only two patterns were duplicated. An interesting observation on native dyes consisted in the use of a bright green dye made from four plants. Specimens of three of these plants were obtained, but the fourth grew at a considerable distance. A birchbark article decorated with roots colored with the dye was also obtained. Green vegetable dye is not known among the Minnesota Chippewa, so far as the present inquiry has extended. The simpler medicinal herbs are the same as among the Chippewa of Minnesota, but interesting variants of general customs were observed.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 2

TWO NEW EAST AFRICAN PRIMATES

BY
N. HOLLISTER

(Publication 2582)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 22, 1920

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

TWO NEW EAST AFRICAN PRIMATES

By N. HOLLISTER

All of the East African monkeys and lemurs in the collection of the United States National Museum have now been critically examined, and two forms have been found which require description. One of these was collected by the Smithsonian African Expedition in 1909, and one by the Paul J. Rainey Expedition in 1911.

GALAGO SOTIKÆ sp. nov.

Type from Telek River, Sotik, British East Africa. No. 184205, U. S. Nat. Mus. Male, adult, skin and skull. (Basal suture closed.) Collected May 22, 1911, by Edmund Heller (Paul J. Rainey African Expedition); Orig. No. 1830.

Allied to *Galago braccatus* Elliot and *Galago albipes* Dollman, but larger, with longer tail, larger hind foot, and larger ears. Darker than *braccatus* and without the brightly colored limbs of that species. General coloration much as in *albipes,* but legs and feet less buffy cinnamon and toes less whitish, not sharply marked from color of feet.

Color of type specimen.—General color of upperparts mouse gray, washed with buffy; underfur deep mouse gray. Nose light gray; eye rings and ears blackish. Arms and hands buffy gray, much like color of back and sides; legs slightly lighter than back, with suffusion of buffy yellowish along inner side and extending over top of feet; toes paler gray, with less intermixture of buff. Underparts gray, heavily washed with pale yellowish buff. Tail brownish gray, more brownish over terminal half, and slightly lighter below.

Skull and teeth.—Skull averaging larger than in *Galago braccatus,* with considerably larger auditory-mastoid bullæ. Upper tooth row slightly longer but last molar relatively smaller.

Measurements of type specimen.—Head and body, 200 mm.; tail vertebræ, 295; hind foot, 76; ear, 46. Skull: Greatest length, 49.4; condylobasal length, 43.6; greatest breadth, 32.9; zygomatic breadth, 32.8; mastoid breadth, 26.3; interorbital breadth, 5.4; length of mandible, 28.2; upper tooth row, canine to m^3 inclusive, 16.8.

Three specimens from the type locality.

LASIOPYGA PYGERYTHRA CONTIGUA subsp. nov.

Type from Changamwe, six miles inland from Mombasa, British East Africa. No. 163327, U. S. Nat. Mus. Male, adult, skin and skull. (Basal suture closed but not obliterated.) Collected November 30, 1909, by Edgar A. Mearns (Smithsonian African Expedition) ; Orig. No. 7321.

Nearest to *Lasiopyga pygerythra tumbili* Heller, but larger, with larger skull and actually smaller teeth. Tail more grayish, less yellow, than in *tumbili*, the longitudinal stripe above much less well-marked, and the underside of tail gray, not tawny yellow.

Color of type specimen.—Face, lips, and chin black ; brow band and cheeks buff, more or less mixed with gray ; head, neck, and upperparts of body yellowish buff, somewhat mixed with gray ; rump and hips more grayish, less buffy ; underparts buffy. Arms and legs outside speckled gray and buff, the inner sides clear buff ; hands and feet blackish, the fingers and toes clear black. Tail above speckled gray and buff, beneath gray, the median line above not sharply marked as in related forms ; a bright chestnut bay spot beneath at base, and the tip black.

Skull and teeth.—Skull larger than that of *Lasiopyga pygerythra tumbili;* palate longer, extending backward considerably beyond plane of last molars ; mandible much longer and heavier. Teeth actually smaller than in *tumbili.*

Measurement of type specimen.—Head and body, 570 ; tail, 720 ; hind foot, 150. Skull (with measurements of type of *L. p. tumbili* in parentheses) : Greatest length, 110 (104) ; condylobasal length, 88.5 (81.2) ; zygomatic breadth, 72.6 (70.0) ; postorbital constriction, 46.8 (43.9) ; mastoid breadth, 59.8 (60.0) ; breadth of braincase, 57.6 (53.2) ; palatal length, 44.2 (41.2) ; length of mandible, 77.0 (70.3) ; upper molar-premolar row, 24.8 (26.4) ; middle molar, 6.0×6.0 (6.8×6.8) ; lower molar-premolar row, 33.0 (32.5).

Three specimens from the type locality.

Compared with a series of eight examples of typical *tumbili* from the Taita Hills, these three specimens from the coast region near Mombasa are easily distinguished by the less sharply bicolored tails ; gray, not yellowish, underside of tail ; and the distinctly larger skull with smaller teeth.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 3

REPORTS UPON TWO COLLECTIONS OF MOSSES FROM BRITISH EAST AFRICA

(With Two Plates)

BY

H. N. DIXON, M. A., F. L. S.

(Publication 2583)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
SEPTEMBER 1, 1920

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

REPORTS UPON TWO COLLECTIONS OF MOSSES FROM BRITISH EAST AFRICA

By H. N. DIXON, M. A., F. L. S.

(With Two Plates)

I. THE MOSSES OF THE DÜMMER-MACLENNAN EXPEDITION TO MOUNT ELGON, 1918

Several sets of the mosses collected on this recent expedition to Mount Elgon have been issued. I have received part of one through Mr. T. R. Sim, of Maritzburg; and I have also had through my hands the sets belonging to the U. S. National Museum and to the Kew Herbarium. The material in many cases is poor, but in others it is good; and though the whole collection is not large, consisting of about 50 numbers (many of which, however, contained several species), it contains some interesting novelties, notably a species of *Holomitrium* quite distinct from any of the African species, a fine new *Bryum* of the Rosulata group, and an interesting new *Braunia*. The types of these and of the other novelties are in the U. S. National Museum; duplicate types are in my own herbarium.

An unusual feature of this collection is the number of species generally rupestral, which were here epiphytic. This is notably the case with *Grimmia ovata* Web. & Mohr, *Amphidium cyathicarpum* (Mont.), *Anomobryum robustum* (the species of this genus are normally rupestral or terrestrial), *Bryum alpinum* Huds., *Hedwigia albicans* (Web.), and *Ectropothecium lateriticolum* Broth. The suggestion may be hazarded that these mosses formed the ancient flora of the crater, at the time when it was mostly unclothed with vegetation, and that as the phanerogamic vegetation increased and covered the rock surface the mosses were driven to the only substratum left for them, viz, the stems of the tree heaths, and other wood, living or dead.

In the following list the abbreviation c. fr. = fruiting, and st. = sterile.

DICRANACEAE

CERATODON PURPUREUS (L.) Brid.

Nos. 2391f, 3393b, 3414c. Mostly fruiting. The capsules are frequently subsymmetrical, very little strumose, and only lightly plicate, as I have found also in specimens collected by Scott-Elliot in Central Africa; but these characters are far from constant and may indeed be pathological.

HOLOMITRIUM MACLENNANI Dixon, sp. nov.

(Pl. I, fig. 2.)

Sat robustum; habitu *H. crispuli* Mart. brasiliensis; laxiuscule caespitosum, pallide olivaceo-viride. Caulis rigidiusculus, *densifolius,* circa 3 cm. altus, parce divisus; folia e basi erecta ovata subvaginante *squarrosa,* siccitate crispula, undulata, suberecta, superne in acumen *latiusculum actum* sensim angustata, marginibus inferne revolutis, supra dense *arguteque et grosse inaequaliterque dentata;* costa sat valida, infra apicem desinens; cellulae superiores ovales, dorso *papillis numerosis dense scaberulae;* basin versus sensim elongatae, infimae aurantiacae, laeves, juxtacostales lineares, marginem versus latiores, breviter rectangulares, pellucidae, ad alas decurrentes *perpaucae paullo dilatatae indistinctae.*

Seta 1-1.5 cm. alta, foliis perichaetialibus peraltis, circa tertiam partem setae saepe attingentibus, convolutis. Theca subcylindrica, circa 3.5 mm. longa. Peristomium e dentibus *irregularibus inaequalibus, in crura plura inaequalia, longa, pallida, brevissime interne nodosa fissis* instructum. Annulus multiplex.

Hab.: Heath Zone, 12,000 ft., epiphytic, rare; No. 3445.

A fine species, differing in the coarsely toothed, broadly pointed, squarrose leaves from all the African species except *H. acutum* Wright, to which it is allied; that species, however, has the leaves more narrowly pointed, less sharply serrate, and with the base less widely vaginant, and the perichaetia are much shorter. The peristome teeth here are more or less equidistant, but very variable, sometimes showing a tendency to approximation in pairs; they are very irregular, but the capsules are overripe and it is difficult to know how much of the irregularity is due to wear. Each tooth is made up of two, three, or more vertical, filiform, red laminae, more or less coherent, without transverse bars below, and without striolations; above they are pale, and closely articulate with shortly protuberant internal nodules.

DICRANOWEISIA AFRICANA Dixon, sp. nov.

(Pl. I, fig. 1.)

Corticola; densissime caespitulosa, circa 1 cm. alta, flavo-viridis. Folia conferta, madida erecta, sicca crispata, e basi *anguste oblonga* sensim acuminata, carinata, acuta; marginibus *inferne vel medio leniter revolutis,* supra planis, integris; costa latiuscula, variabilis, *tenuis, indistincte definita.* Cellulae superiores majusculae, 6-8 μ latae, breviter rectangulares vel isodiametricae, angulis rotundatis, laeves; basilares omnes laxiores, lineares vel rectangulares, angulos versus saepius dilatatae, numerosae, *partem basilarem maximam occupantes.*

Autoica. Bracteae masculae internae perconcavae convolutae, obtusae. Perichaetium parvum, e foliis externis paullo brevioribus, latius acuminatis, minus acutis, internis *brevibus, late vaginantibus, obtusis* instructum. Seta *brevis,* 5-6 mm. longa, theca (vetusta) *parva, anguste elliptica, microstoma.* Operculum et peristomium non visa.

Hab.: On tree heaths, in crater, 13,000 ft.; No. 3396.

The only two species of the genus hitherto found in Africa are the widely distributed *D. cirrata* and *D. crispula.* The latter differs in the plane margins of the leaves. The present species is very near *D. cirrata,* but appears to be distinct in the denser tufts, smaller size of all its parts, shorter capsule, and distinctly weaker nerve.

CAMPYLOPUS ACROCAULON (C. M.) Par.

Heath Zone and moorland, 12,000-14,000 ft.; Nos. 3412d, 2391e, 3398b, 3407d, 3762. I determine these from the description alone, having seen no specimens of the original plant from Kilimanjaro. Sterile only. The color of the plant, length of stem, and evolution of auricles vary considerably.

CAMPYLOPUS CAGNII Negri

Moorland in crater, 13,500 ft.; No. 3425, c. fr. I determine this with some hesitation from Negri's description of the sterile plant from Ruwenzori. It appears to agree with that in every respect but one: the leaves are given as 7.2 mm. in length, while here they are only 4 to 5 mm. long. The crowded, rigid, almost entire leaves, only the comal (fructiferous) ones finely setaceous, are rather characteristic; the nerve is smooth at back. Capsules aggregate; calyptra smooth at base.

POTTIACEAE

? TRICHOSTOMUM sp.

No. 3444c. A rather distinct, sterile plant, with somewhat sheathing, flexuose, suberect, fragile leaves, and trichostomoid areolation, may belong here, but its generic position is somewhat doubtful. The description of *T. usambaricum* (Broth.) Broth. reads much like it, but I have not seen specimens.

LEPTODONTIOPSIS FRAGILIFOLIA Broth.

Heath Zone, epiphytic, 12,000 ft.; Nos. 3447g, 3772c; also No. 3756 in the Kew set. St. A very distinct plant.

TORTULA CAVALLII Negri

Nos. 3406, 3410, 3424, 3430b; mostly c. fr.

TORTULA EU-BRYUM (C. M.) Dixon

Tree heaths in crater, 13,500 ft.; No. 3426. With numerous setae and a few old capsules, apparently small for the size of the plant. It has not been found before in fruit. (Some of Dümmer's specimens issued under this number do not belong here but to *T. Cavallii.*)

GRIMMIACEAE

GRIMMIA OVATA Web. & Mohr.

Nos. 3403, 3403b, 3409d, 3412c, 3418; mostly c. fr. Most or all of these gatherings were epiphytic, on bark of trees, a very curious condition.

ORTHOTRICHACEAE

ANOECTANGIUM sp.

Heath Zone, epiphytic, 12,000 ft.; No. 3759d. A small, delicate species, with numerous setae and a few capsules in very old, poor condition. It has the appearance of *A. Wilmsianum* (C. M.), but shows larger, more pellucid cells, more tapering, short-acuminate leaves, etc.

AMPHIDIUM CYATHICARPUM (Mont.) Broth.

On tree heaths; No. 3422b, c. fr.; No. 3444c (p. p.), st.

ZYGODON EROSUS Mitt.

No. 3412b, st. I have seen no specimens of Mitten's plant, but from the description there can be hardly a doubt that this belongs there.

ORTHOTRICHUM UNDULATIFOLIUM C. M.

Tree heaths, western crater lip, 13,000 ft.; No. 3407c, c. fr. jun. From the description there can be no doubt, I think, that this is C. Müller's plant.

ORTHOTRICHUM LEIKIPIAE C. M.

Tree heaths in crater, 13,000 ft.; No. 3417b (p. p.), c. fr. A fertile stem mixed with *Braunia*. The endostome segments are as described by C. Müller, unusually broad, almost, in fact, connivent at base. The plant is no doubt nearly allied to *O. speciosum*.

MACROMITRIUM HYALINUM Broth.

No. 3766, c. fr.

MACROMITRIUM ABYSSINICUM C. M.

Tree heaths, 12,000-13,000 ft.; No. 3413, c. fr.; No. 3756b, forma *laxiramea,* c. fr.

After careful comparison of *M. hyalinum* Broth. with *M. abyssinicum* I feel very doubtful whether the two can be kept separate. Brotherus rests his species on the smaller size and the very acute leaves, often with hyaline tip. Comparison of Holst's Usambara plant, however, with *M. abyssinicum* (No. 431, Schimp. Iter Abyssin., in Schimper's herbarium) shows no difference, or at any rate no constant difference, in leaf. The Central African plant appears as a rule to run rather smaller than the Abyssinian specimens, but this is by no means constantly the case and Dümmer's No. 3413 is as robust as any of these. No. 3766 is smaller and agrees in dimensions with Holst's plant, and I have retained it provisionally under *M. hyalinum.*

No. 3756b is a very peculiar plant. The stems are elongate, robust, distantly and fairly regularly pinnate, apparently pendulous, with none of the habit of a *Macromitrium,* but closely resembling some forms of *Papillaria*. The leaves are very acutely long-acuminate, often with the apex half-twisted, and when dry somewhat recurved. I do not think, however, that the leaf form must be considered as of any importance in comparing it with *M. abyssinicum* (type), as the leaves with which one is familiar there are the branch leaves, while owing to the peculiar growth of this plant the bulk of the leaves probably, and of course those of the primary stem, are of the nature of stem leaves. A seta and capsule in my specimen are identical with those of *M. abyssinicum,* while the specimen of No. 3413 in the Washington set indicates a distinct transition between this form and ordinary *M. abyssinicum*. It is, therefore, probably only a remarkable form of that.

FUNARIACEAE

FUNARIA VOLKENSII Broth.

Moorland, 13,500-14,000 ft.; Nos. 2391b, 3414b, both c. fr.

BRYACEAE

BRACHYMENIUM FLEXIFOLIUM B. & S.

Tree trunks in crater, 13,000 ft.; No. 3423, c. fr. This agrees with the Abyssinian specimens of Schimper's at Kew, especially with No. 452. No. 29 has the outer teeth more strongly bordered, the endostomial membrane paler and more pellucid, and the leaves with rather smaller cells, and wider border. No. 452, however, agrees quite well with Dümmer's plant in the peristome and cells, though the border is somewhat wider, showing that these characters are variable and not correlated, while here and there a leaf on Dümmer's No. 3423 has the border exactly as in the Abyssinian plant. Moreover, another specimen of Schimper's (No. 552) has the leaves exactly as here.

The outer teeth are densely barred, trabeculate within; the inner membrane is rather low, the processes linear, distant.

BRACHYMENIUM STENOTHECUM Dixon, sp. nov.

(Pl. I, fig. 3.)

§ ORTHOCARPUS. Robustum, infra densissime tomentosum. Folia confertissime interrupteque comosa, sicca erecta, haud torquescentia, *paullo flexuosa,* inferne rubella, *anguste oblonga,* infra *haud angustata,* supra *parum dilatata non spathulata,* breviter et acute acuminata, marginibus inferioribus anguste recurvatis, superne dentibus argutis tenuibus sat distincte dentatis, *limbo lato flavido e cellulis 6-8-seriatis* angustissimis incrassatis circumdata; cellulae superiores breviter hexagonae, 40-50 μ longae; circa 3-4 × 1. Costa infra valida, supra sensim angustata, in cuspidem *perangustam flexuosam breviusculam integram* excurrens.

Synoicum. Seta *3-4 cm. alta,* flexuosa; theca *elongata, sat angusta,* cum collo ad 6-7 mm. longa, inclinans vel subpendula, e collo *praelongo* in setam sensim attenuato *anguste elliptica* vel fusiformis, microstoma, castanea, operculo brevi, conico, obtuso; exothecium e cellulis parvis, valde irregularibus, inaequalibus, parietibus flexuosis instructum. Peristomii dentes fusco-aurantiaci, apicibus peracutis pallidis; opaci, plus minusve pallide marginati, dense lamellati, intus alte trabeculati; endostomii membrana sat alta, aurantiaca, processubus *brevibus, inperfectis, irregularibus.* Spori 25-30 μ.

Hab.: Moorland in crater, 13,000 ft.; Nos. 3399, 3421, 3768.

The densely imbricate leaves, erect and little altered when dry, little broader above and not narrowed to base, with broad border and the long, narrow, subpendulous capsule, with very distinct collum, distinguish this from the allied synoicous species, most of which have the leaves twisted, or at least highly flexuose, when dry. *B. abyssinicum* C. M. has the leaves much narrowed to base and entire above, the capsule smaller, etc.

I have figured the peristome, showing a process in the most perfect condition, but they are mostly fragmentary and more or less adherent to the outer teeth.

ANOMOBRYUM ROBUSTUM Dixon, sp. nov.

(Pl. I, fig. 4.)

E robustioribus generis. Stirps circa 2-2.5 cm. alta, pallide viridis, subnitida. Caules julacei, foliis *dense confertis ad 1.25 mm. longis, suborbicularibus,* cochleariformibus, obtusis vel obtusissime apiculatis, marginibus superioribus indistincte sinuolatis; costa apud basin 60-70 μ lata, rubella, medium folium versus multo tenuior, sed parum angustata, *circa tertiam quartam folii* attingens. Areolatio superior e cellulis *angustissimis, vermicularibus,* parietibus firmis nec incrassatis instructa, inferior per tertiam partem folii laxissima.

Seta circa 1.5 cm. alta; theca e collo longo, infra in setam sensim angustato atque illic curvato, oblongo-elliptica, leniter curvata, infra orificium paullo contracta, badia, operculo *purpureo, obtuso, nitido.* Peristomium externum e dentibus aurantiacis, dense trabeculatis, externe striolatis instructum, internum membrana praealta, hyalina, laevi, circa $\frac{2}{3}$-$\frac{3}{4}$ dentium altitudinem aequante; processubus brevibus, *inferne latis, superne raptim angustatis, filiformibus, subintegris, vel angustissime rimatis;* ciliis plerumque binis, *subaequilongis, articulatis nec nodosis, superne tenerrime papillosis.* Spori parvi.

Hab.: Bamboo Zone, 9,000 ft., epiphytic; No. 3764.

The comparatively large densely crowded leaves give the stems a robust appearance, and in this as well as in structural details it is a markedly distinct species. *A. promontorii* (C. M.) Dixon has much narrower, smaller leaves, a longer nerve, acute lid, etc.

BRYUM ARGENTEUM L.

Nos. 3752, 3752b, c. fr. These plants afford rather more interest than it usually falls to the lot of this ubiquitous species to present. They show in the same gathering a form with the leaves widely rounded at summit and obtuse, without any trace of apiculus or hair-point, and others with long hyaline hair-points, practically identical with var. *lanatum* B. & S.; and all transitions between these extreme forms occur, even (with the exception of the form with the longest hair-points) within the limits of a single tuft.

It was gathered at an elevation of 12,000 ft., on the roofs of the mud huts of the Ratmen. The Ratmen or Molemen—as their name "Mese" signifies—are a small tribe of very primitive savages inhabiting the extinct crater of this mountain.

BRYUM ALPINUM Huds.

Nos. 2391d, 3422, 3444b; No. 3422b (sparingly fruiting). These plants were—a very unusual thing for this species—epiphytic, on tree heaths. They differ somewhat from our northern *B. alpinum* in being robust, with the nerve very stout, excurrent in a short, acute or obtuse point, the leaves usually acute, subdenticulate at apex; these characters however are not constant and are not correlated, while some of the tufts are quite ordinary *B. alpinum*. The fruit also agrees exactly. I have no hesitation, therefore, in placing them under *B. alpinum*, which occurs also in South Africa, where, as in the Northern Hemisphere, it shows considerable variation.

BRYUM BREVINERVE Dixon, sp. nov.

(Pl. 2, fig. 8.)

§ ROSULATA. *E robustioribus generis,* habitu *B. spinidentis* Ren. & Card., vel *B. perspinidentis* Broth. Caulis validus, usque ad 10-12 cm altus, inferne tomentosus, sat dense *regulariter foliosus, vix, nisi sub floribus, comosus;* flexuosus vel hic illic geniculatus; folia *erecto-patentia,* sicca flexuosa, contracta; 6-7 mm. longa, e basi angusta *decurrente, late obovata, obtusa, apiculo perbrevi plerumque reflexo;* marginibus inferne anguste reflexis, superne sat conferte interrupteque et breviter acuteque dentata; costa ad basin valida, rubra, raptim angustata, *supra perangusta, infra apicem sat longe desinens,* rarissime percurrens. Areolatio densa, e cellulis superioribus anguste hexagonis circa 60 μ longis instructa, infimis elongatis, angustis, hexagono-rectangularibus, nec valde laxis; marginalibus supra seriebus 3-4 perangustis, incrassatis, *limbum bene notatum, aliquando rufescentem,* inferne evanescentem, instruentibus. Fructus ignotus.

No. 3408b. Cliff base in thicket, western side of crater, alt. 13,500 ft.

A very fine species, quite distinct in leaf form and structure, and especially in the short nerve, from any of its allies.

BARTRAMIACEAE

BARTRAMIA RUVENZORENSIS Broth.

Tree heaths in crater, 13,000 ft.; No. 3422c. Bamboo heath zone, 10,000 ft., No. 3444, c. fr.

BARTRAMIA STRICTULA C. M.

Moorland, 14,000 ft.; No. 2391c, st. This seems to agree with C. Müller's description of the above species. It is probably not distinct from the South African *B. substricta* Schimp.

BREUTELIA STRICTICAULIS Dixon, Smiths. Misc. Coll. 69^2: 21. 1918

Cliff base in thicket, 13,500 ft.; No. 3408, st.

BREUTELIA SUBGNAPHALEA (C. M.) Par.

Cliff base in thicket, 13,500 ft.; No. 3415, c. fr. This agrees perfectly in the vegetative characters; the seta is about 1 cm. long. C. Müller says only, "seta perbrevi," which would seem to apply; the seta in the Kew specimen of the original plant is perhaps slightly shorter.

The peristome, not described by C. Müller, is double, the outer teeth well developed, red-brown, the inner fragmentary, pale orange-brown.

POLYTRICHACEAE

POLYTRICHUM PILIFERUM Schreb.

Polytrichum nano-globulus C. M., Flora, **71**: 408. 1888.

Nos. 2391, 3407e, 3414; all c. fr.

POLYTRICHUM HOEHNELII C. M.

Nos. 3409, 3776 (Kew set); both c. fr. This species, while closely allied to *P. commune,* seems really distinct in the marginal toothing of the leaves and in their position when dry, more or less spirally contorted with the points rigidly spreading—"horride patentia."

POLYTRICHUM KENIAE Dixon, Smiths. Misc. Coll. 69²: 21. 1918

Moorland, 13,000 ft.; No. 3411, st. The present specimen agrees well with the plant from Mt. Kenia, except that the sheathing leaf base is not so elongated as in that; I have perhaps overrated the importance of that character in the description.

HEDWIGIACEAE

HEDWIGIA ALBICANS (Web.) Lindb.

Nos. 3407, 3409b, 3419; all c. fr. These were growing on tree heaths, an unusual station for what is commonly so rupestral a species.

BRAUNIA BRACHYTHECA Dixon, subsp. nov.

(Pl. I, fig. 5.)

Habitus, folia etc., omnino *B. diaphanae,* capensis, et *B. secundae,* americanae. Differt solum thecae forma, *latissime elliptica* vel *subglobosa,* submicrostoma, *omnino fere sine collo,* sicca vetusta *subplicata,* ore latiore, suburceolata.

Hab.: On tree trunks in crater, 13,000-13,500 ft.; Nos. 3398, 3413b, 3413c; all c. fr. Nos. 3407, 3407b, 3417b (p. p.), st.

The vegetative characters, perichaetial leaves, and seta are so exactly similar to *B. diaphana,* that I thought at first, in view of the paucity of the capsules on my specimens, that it was possibly a case of malformation of fruit. However, further material from the U. S. National Museum and from Kew entirely confirmed the normality of the structure, and Mr. Sim writes to me that the capsules on his three specimens—eight in all—are identical in the subglobose form, scarcely tapering at neck, all except one being more or less striate when old. In *B. diaphana* the capsule is narrowly elliptic, or fusiform, being narrowed to the mouth, and with a well-defined very gradually tapering neck (cf. pl. I, fig. 5b). Though often somewhat wrinkled when old, moreover, it has no sign of regular striae.

Mitten,[1] in describing the mosses collected in Central Africa by Bishop Hannington, refers a Kilimanjaro plant "perfectly fruited" to Hedwigia (§Braunia) *secunda* Hook., and raises the question, "Are the *B. sciuroides* of Europe, the *B. indica* so luxuriant in the Nilgiri Mts., and the Abyssinian *B. Schimperi,* really different, or are they not most probably slight variations of one wide-spread

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[1] Journ. Linn. Soc. Bot. **22**: 310. 1886.

species?" So far as my observation goes, *B. sciuroides* and *B. Schimperi* stand on a somewhat different footing from the others; but the Indian plant is most certainly identical with that which occurs in several parts of Africa, and which has generally been known as *B. diaphana*. It is especially frequent in South Africa, where it fruits commonly. The fruit is described by Thériot;[1] and Brotherus[2] says of it, "Kapsel unbekannt." I have several fruiting specimens from South Africa, however, and the fruit occurs on several specimens in the British Museum and Kew collections. Both vegetatively and in the fruit the Indian plant is exactly identical with the African, and as Mitten finds the Kilimanjaro plant identical with the Mexican there can be no doubt that they must all fall under the name *B. secunda*. As regards the Indian and African plants at least, I do not find even the "slight variations" which Mitten allows them. The leaves vary in the degree of plication. They may be quite without a hyaline point, or they may have a short hyaline tip, even occasionally a quite long, flexuose hair-point, and the perichaetial leaves vary much in length; but none of these characters shows any constancy, nor are they correlated in any way with geographical distribution.

In the course of studying the Indian plant, however, I stumbled upon a very unexpected thing: In the British Museum collection, in Herb. Wilson, there are two specimens of an undetermined moss, labelled "Indies, *Winterbotham*," which are identical with my *B. brachytheca*. I find no reference to it in any bryological works, and it appears to have remained, otherwise than in Wilson's herbarium, quite undetected. It can scarcely be supposed that two independent species, *B. secunda* and *B. brachytheca*, would exist side by side both in Africa and in India, especially with the very restricted range that appears to appertain to *B. brachytheca;* and I have therefore thought it best to consider the latter as a subspecies of *B. secunda*.[3]

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[1] Bull. Soc. Bot. Genève II. **9**: 135. 1917.

[2] Engl. & Prantl, Pflanzenfam. 1^3: 718. 1905.

[3] It may be as well to give here the more important part of the synonymy of *B. secunda*, so far as it bears on our African plant:

BRAUNIA SECUNDA (Hook.) B. S. G. Bryol. Eur. (29-30:) Braunia 3. 1846.
Hedwigia secunda Hook. Musc. Exot. *pl. 46.* 1818-1820.
Neckera macropelma C. M. Syn. **2**: 104. 1851.
Braunia macropelma Jaeg. Adumbr. **2**: 87. 1869-1870.
Hedwigia indica Mitt. Journ. inn. Soc., Bot. **3**: Suppl. 123. 1859.
Braunia indica Par. Ind. 149. 1894.
Neckera diaphana C. M. Syn. **2**: 105. 1851.
Braunia diaphana Jaeg. Adumbr. **2**: 87. 1874-1875.

LEUCODONTACEAE

ANTITRICHIA KILIMANDSCHARICA Broth.

Heath Zone; Nos. 3413d, 3756, 3758b, 3772. No. 3756 is in good fruit, which has not been described, but I do not find any difference from that of *A. curtipendula.* The others are sterile.

NECKERACEAE

NECKERA PLATYANTHA (C. M.) Par.

Heath Zone, principally; Nos. 3443, 3449, 3754, 3756f, 3759; mostly c. fr. The perichaetial bracts may be three times as long as the capsule, which, however, is not always concealed, as it may protrude laterally from the perichaetium (Cf. pl. I, fig. 6).

NECKERA SUBMACROCARPA Dixon, sp. nov.

(Pl. I, fig. 7.)

Habitu foliisque *N. platyanthae* (C. M.) et *N. macrocarpae* Broth.[1] simillima, huic quoque speciei cauli *paraphylliis numerosis* praedito similis et affinis, fructu tamen longe aliena. Perichaetium 8-10 mm. longum, bracteis externis thecam longe superantibus. Theca immersa, vel saepe e perichaetio lateraliter emergens, e seta pro more *praelonga,* 2-2.5 mm.; theca *2-3 mm.,* aurantiaca; operculum conicum breviter curvirostratum. Peristomii dentes longi, angusti, supra dense tenereque infra grossius papillosi, *non striolati,* intus trabeculati; endostomii membrana perbrevis, pallida, laevis; processus anguste lineares, *circa dimidiam partem dentium longitudinis aequantes,* pallidi laeves, carinati, haud rimosi, plus minusve nodosi. Spori 25-30 μ.

Hab.: Heath Zone, 12,000 ft., epiphytic; No. 3443b.

Dümmer writes on the label " Frequent "; but this is by confusion with *N. platyantha,* which in habit is identical or nearly so; the two were growing intermixed, and the Washington specimen under this number was entirely *N. platyantha,* which is evidently a frequent moss on Mount Elgon, in the Heath Zone.

At first sight the fruit of the two species does not show any great difference, but on examination it will be seen that in *N. platyantha* the capsule is almost sessile and is hidden at the base of the perichaetium, with the bracts two or three times its length; in *N. submacrocarpa* the capsule itself is about the same length, but both

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[1] Wissensch. Ergebn. Deutsch. Zentral Afrika Exped., 1907-1908, **2:** 162. 1914.

vaginula and seta being extremely long, together about equalling the capsule length, it is much less immersed, often not even hidden.

The differences from *N. macrocarpa* Broth. may be tabulated thus:

	Seta	Theca	Teeth	Processes
N. macrocarpa	1 mm.	3-5 mm.	striolate at base	equalling teeth
N. submacrocarpa	2-2.5 mm.	2-3 mm.	papillose to base	half length of teeth

Brotherus gives for his species certain characters derived from form of leaf, and branching, which do not quite agree with the present plant. I am not inclined, however, to lay much stress on these differences, as the branching and form of leaf apex appear to vary considerably within the limits of the same species in this group; they certainly do in *N. platyantha*. In fact the whole group of African species, *N. Hoehneliana, N. Valentiniana,* and the above mentioned plants, are in my opinion quite inseparable from one another by vegetative characters alone. For this reason I feel some doubt as to the validity of *N. subplatyantha* Broth.,[1] which appears to be separated from *N. platyantha* on vegetative characters alone. I have not, however, seen the plant itself.

ENTODONTACEAE

LEVIERELLA FABRONIACEA ABYSSINICA (Broth.) Dixon

Heath Zone, epiphytic, 12,000 ft.; No. 3765, c. fr.

FABRONIACEAE

FABRONIA sp.

Tree heaths in crater, 13,000 ft.; No. 3420. The quantity is too small for determination; it appears near *F. Leikipiae* C. M., but has a very unusual range of denticulation, as among the leaves even of a single plant.

HOOKERIACEAE

DALTONIA MILDREADII Broth. in Wissensch. Ergebn. Deutsch. Zentral Afrika Exped., 1907-1908, 2: 164. 1914

No. 3423b; c. fr.

HOOKERIOPSIS VERSICOLOR (Mitt.) Broth.

Without number. In quantity, and fruiting well.

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[1] Op. cit. 161.

THUIDIACEAE

THUIDIUM PALLIDISETUM Dixon, Smiths. Misc. Coll. 69[8]: 8. 1918

Without number. The material agrees perfectly with Dümmer's original plant from Kipayo. The leaf cells are perhaps a little more distinct and pellucid.

HYPNACEAE

STEREODON CUPRESSIFORMIS (L.) Brid.

Nearly a dozen numbers contained this cosmopolitan species, in very varying forms. Three of them (Nos. 3445b, 3756g, 3756h) represent a slender form, with narrow leaves and slender tapering branches, which I have no doubt is the *Hypnum Hoehnelii* of C. Müller; but they cannot be separated from the species, though perhaps quite deserving of varietal rank, and I should call it *Stereodon cupressiformis* (L.) var. **Hoehnelii** (C. M.) Dixon, comb. nov.

ECTROPOTHECIUM LATERITICOLUM Broth.

Without number. In good though somewhat old fruit. I have not seen a specimen of the original plant, but the present specimen agrees perfectly with the description. The only point of doubt would be in the habitat, since the specific name of Brotherus implies a station on stonework or brickwork; but this is not of great importance, and it becomes still less so in view of the prevailing tendency towards an arboreal habitat shown by the mosses of this locality.

RHAPHIDOSTEGIUM ELGONENSE Dixon, sp. nov.

(Pl. 2, fig. 9.)

§ Aptychus. Stirps, quoad species africanae spectantur, *R. brachytheciiformi* (C. M.) et *R. rivuletorum* (C. M.) proxima. Sat robustum, *flavo-aureum,* ramis *turgidis,* brevissime cuspidatis; folia dense imbricata, saepius vix secunda, rarius paullo assurgentia, apicibus falcatis, 1.25-1.5 mm. longa, ovato-oblonga, supra cito angustata, *breviter acute acuminata,* saepe semitorta, concava, marginibus *anguste explanatis, planis, vel angustissime recurvis,* integerrimis; areolatio perangusta, *pellucida, cellulis basilaribus aurantiacis,* alaribus trinis *magnis inflatis,* supra-alaribus nonnullis majusculis pellucidis.

Autoicum. Folia perichaetialia *foliis caulinibus subsimilia,* paullo latiora, magis sensim acuminata, acumine latiore, *subintegro,* interna erecta. Seta 1.25-1.5 cm. longa, laevis. Theca *suberecta, cylindrica, vix curvata,* operculo curvirostro, subaequilongo.

Hab.: Heath Zone, 12,000 ft., epiphytic; Nos. 3447, 3770.

It is rather difficult to diagnose the somewhat numerous species of this section; but if habit, length of seta, form of capsule, and leaf outline are taken into account, it will be found that there are no African species very near this plant. *R. brachytheciiforme* (C. M.) is more robust, with a foliation strikingly like that of *Brachythecium albicans,* and a different coloring. *R. rivuletorum* is smaller, of different habit, greener, with less crowded leaves, and horizontal or subpendulous capsule.

BRACHYTHECIACEAE

PLEUROPUS SERICEUS (Hornsch.) Broth.

Heath Zone, 12,000 ft., epiphytic; Nos. 3759b, 3759c; st.

BRACHYTHECIUM VELLEREUM (Mitt.) Par.

Heath Zone, 12,000 ft.; No. 3756c. On tree heaths in crater, 13,000 ft.; No. 3441. Both fruiting. I have compared this with Mitten's plant, and there is no doubt of its identity. It is a very striking species, but it is certainly autoicous. Mitten describes his plant as dioicous, and I have found fruiting stems on which I have been unable to detect male flowers, but there is no question that it is normally autoicous.

I suspect *B. gloriosum* (C. M.) Par., of which the sterile plant only was described, to be the same thing.

BRACHYTHECIUM UGANDAE Dixon, sp. nov.

Subgen. SALEBROSIUM. Robustum; *luteo-aureum, nitidum,* habitu *B. salebrosi.* Caules suberecti, irregulariter distanter ramosi, flexuosi, *subteretes,* acutiusculi. Folia e basi subcordata late ovato-lanceolata, in acumen anguste nec longe tenuiter acuminatum sat cito attenuata, integerrima, profunde plicata, marginibus planis vel *superne* anguste recurvis; costa basin versus sat valida, cito multo attenuata, circa dimidian partem folii attingens. Cellulae angustissimae, pellucidae, alares *multae, majusculae,* subquadratae, inanes vel obscuriusculae, *bene notatae.* Flores masculi majusculi, turgidi.

Autoicum. Perichaetia magna, foliis erectis, in acumen filiforme flexuoso-recurvum integrum attenuata. Seta 1.5-1.75 cm. longa, laevis; theca badia, *suberecta, leniter curvata, oblonga,* operculo brevi, obtuso.

Hab.: Tree heaths, 13,500 ft.; No. 3430. Bamboo Zone, 7,000 ft.; No. 3763. Heath Zone, 12,000 ft.; Nos. 3768b, 3775. All c. fr.

Very near to *B. salebrosum* (Hoffm.) and perhaps not specifically distinct; but as that species has not been recorded from tropical Africa, and as the present plant exhibits certain characters of distinction, notably the golden, glossy coloring, the terete branches, and a suberect, only slightly curved, narrower capsule, I have provisionally treated it as distinct.

BRACHYTHECIUM DÜMMERI Dixon, sp. nov.

(Pl. 2, fig. 10.)

Subgen. CIRRIPHYLLOPSIS. Habitu *B. stricto-patentis* C. M. capensis vel formarum gracillimarum *B. implicati* (Hornsch.). Gracile, laete viride, vix nitidum, dense pinnatum, ramis circa 1 cm. longis. Folia *madida rigidiuscule erecto-patentia,* e basi cordato vel hastato *triangularia,* sensim longe acuminata, ubique denticulata; ramea brevius latiusque acuminata, *dense et argute denticulata,* concaviuscula, vix striata, nec plicata; marginibus planis vel basin versus angustissime recurvis; costa basi sat valida, superne foliis caulinis multo, rameis paullo attenuata, circa secundam tertiam partem folii attingens. Cellulae superiores perangustae, inferne seriebus pluribus multo breviores, laxiores, pellucidae, alares sat numerosae, parvae, subquadratae.

Autoicum. Perichaetia majuscula, archegoniis numerosis, foliis *erectis, latis, in acumen subfiliforme reflexum, denticulatum raptim angustatis.* Seta 1-1.5 cm. longa *papillosa.* Theca horizontalis, fusca, *brevis,* vetustate sub ore contracta, operculo conico, obtuso.

Hab.: Heath Forest Zone, 12,000 ft.; epiphytic; Nos. 3, 3425b, 3447e, 3760, 3761; all c. fr.

Brachythecium stricto-patens C. M., which this resembles in having the leaves rigidly subpatent when dry, differs in its smooth seta and dioicous inflorescence; *B. implicatum* in its larger size and strongly striate-plicate leaves. *B. atrotheca* Duby is more robust, with wider, less rigid leaves and wider cells.

RHYNCHOSTEGIELLA ALGIRIANA (Brid.) Broth.

Epiphytic, on wood, Heath Zone, 12,000 ft.; No. 3447b; c. fr. Also No. 3773 in the Kew set. This plant is exactly our European and Northern African form, golden green. The epiphytic habit is unusual, but is not unknown with us (the var. *scabrellum,* indeed, is usually so). *R. Holstii* Broth., from Usambara, etc., is a green plant of a slightly different habit; but I can find no structural differences, and I am strongly disposed to consider it only a slight form of the same thing.

II. A SMALL COLLECTION OF MOSSES FROM THE ABERDARE MOUNTAINS

The mosses in the following list were collected near Mount Kenia by Mr. A. Y. Allan in 1910, and were sent me for determination by Rev. D. Lillie. Although the collection is small it is of unusual interest, containing as it does the type of a new genus.

CAMPYLOPODIUM EUPHOROCLADUM (C. M.) Besch.

Nos. 395b, 398. This species has not previously been found in Africa. It is known otherwise from Java, Tahiti, New Caledonia, New Zealand. The second specimen above cited has very young fruit and old setae.

[*Campylopodium khasianum* (Mitt.), a very closely allied species, indeed doubtfully distinct, differs in its fruit only, so far as I have been able to observe; the vegetative characters described by Mitten do not appear to hold good. There is the possibility, therefore, that the African plant may belong there; but *C. euphorocladum* being a plant of much wider distribution (and not improbably including *C. khasianum*) I have thought it best to refer this plant to the former.]

DICRANUM JOHNSTONI Mitt.

Dicranum Stuhlmannii Broth. Bot. Jahrb. Engler **20:** 177. 1894.

No. 400, c. fr. I have compared this with the original of *D. Johnstoni* (Kilimanjaro, *H. H. Johnston* 52), and it agrees perfectly. It is also identical with *D. Stuhlmannii* (*Stuhlmann* 3290b, and *Volkens* 1166, det. Brotherus). Mitten's description of the leaves of his species as "linearia, sensim loriformi-angustata," and "unlike any form of *D. scoparium* from the narrower lower portions of the leaf," is very misleading, and is no doubt the cause of Brotherus having redescribed the plant. As a matter of fact, in Johnston's specimen the leaves, though occasionally (abnormally) narrow at the base, are usually dilated there quite as in *D. Stuhlmannii* and other species.

The fruit has not hitherto been described. Perichaetium about 6 mm. long, tubular, the bracts convolute with spreading points; seta about 2 cm. long; capsule erect, symmetrical, cylindric, with very gradually tapering neck and no struma, dark chestnut-brown, lightly plicate when dry and old; lid finely subulate, erect or suberect; deoperculate capsule about 4 mm. long.

CAMPYLOPUS JOANNIS-MEYERI (C. M.) Par.

No. 397; c. fr.

FISSIDENS LINEARI-LIMBATUS C. M.

No. 403; st. From the description this would seem to agree exactly with the original plant, collected in the same district.

KLEIOWEISIOPSIS Dixon, gen. nov.

Stirps habitu *Astomi* Hampe, sed cellulae superiores majusculae, et folia superne distincte denticulata. Paroica; antheridia 3-4, infra fructum, in folii perichaetialis axilla. Theca fere sessilis, in seta brevissime sita, immersa, minima, globosa, microstoma, operculo rostellato, annulo male evoluto persistente, calyptra parva, cucullata; peristomium nullum. Spori majusculi.

KLEIOWEISIOPSIS DENTICULATA Dixon, sp. nov.

(Pl. 2, fig. 11.)

Caespitosa seu dense gregaria; minuta. Stirps (vetusta) sordide pallideque luteo-viridis; circa 5 mm. alta, plerumque ad caulis basin divisa. Folia erecto-patentia, sicca subcrispata, inferiora brevissima, supra sensim longiora, superiora (fructifera) 3-4 mm. longa, *e basi concava latiore linearia, latiuscule breviterque acuminata,* obtuse acutata, carinata, marginibus planis, superne *plus minusve grosse et sat distanter denticulata.* Costa infra circa 60 μ lata tenuis, superne angustata, sat pellucida, percurrens. Cellulae superiores 9-13 μ, isodiametricae et subquadratae vel breviter rectangulares, seriebus longitudinalibus regularibus dispositae, *pellucidae, perdistinctae, laeves,* basilares omnes *perlaxae, rectangulares, hyalinae.*

Theca *profunde immersa;* vaginula circa 200 μ, seta 60-100 μ, theca 400 μ longa. Operculum *subaequilongum, conico-rostellatum, curvatum, acutum.* Calyptra *parva, late cucullata.* Spori 18-22 μ, fusci, conferte non alte papillosi. Exothecium e cellulis tenerrimis instructum; infra orificium series 1-2 cellularum pellucidarum persistentium quasi annulum imperfectum sistentes.

No. 395. With *Campylopodium euphorocladum.*

A remarkable little plant, the position of which is somewhat doubtful. In areolation and denticulation the leaves are very similar to those of some species of *Rhabdoweisia,* and on this account it might be placed in the Dicranaceae. On the whole, however, it seems to be best placed in the Pottiaceae, near *Astomum* and the subgenus *Kleioweisia* of *Hymenostomum.*

The plant is paroicous; but I suspect it may be heteroicous, as I have seen what seems to be a male flower below the fertile flower.

The capsule is, accurately speaking, neither cleistocarpous nor stegocarpous. The lid is perfectly differentiated, and there is a distinct row of subannular cells at the orifice; these may be in more than one series. On the other hand, the lid is probably not normally functional; the capsule wall is of extremely delicate texture and under pressure breaks up without the lid being detached, and this appears to be the case also under normal conditions.

It is unfortunate that the altitude is not recorded. The association of the plant with *Campylopodium* would seem to indicate a comparatively low level.

TORTULA ERUBESCENS (C. M.) Broth.

No. 399; st.

POLYTRICHUM COMMUNE L.

No. 394; st.

BRAUNIA SECUNDA (Hook.) B. S. G.

Nos. 401, 404; st. Presumably this species.

EXPLANATION OF PLATES

PLATE I

FIG. 1. *Dicranoweisia africana.* *a,* Leaf, × 20; *bb′,* apex, × 50; *c,* capsule, × 6.

FIG. 2. *Holomitrium Maclennani.* *a,* Plant, × 1, (left moist, right dry); *b,* leaf, × 20; *c,* cells, × 200; *d,* peristome teeth, × 50.

FIG. 3. *Brachymenium stenothecum.* *a,* Stem, dry, × 1; *a′,* do., moist, × 1; *b,* leaves, × 10; *c,* apex, × 40; *d,* part of peristome, × 50.

FIG. 4. *Anomobryum robustum.* *a, a′,* leaves, × 20.

FIG. 5. *Braunia.* *a, B. secunda, b, B. brachytheca;* capsules, × 3.

FIG. 6. *Neckera platyantha.* *a, a′,* Capsule with perichaetium, × 2.

FIG. 7. *Neckera submacrocarpa.* *a,* Capsule with perichaetium, × 2.

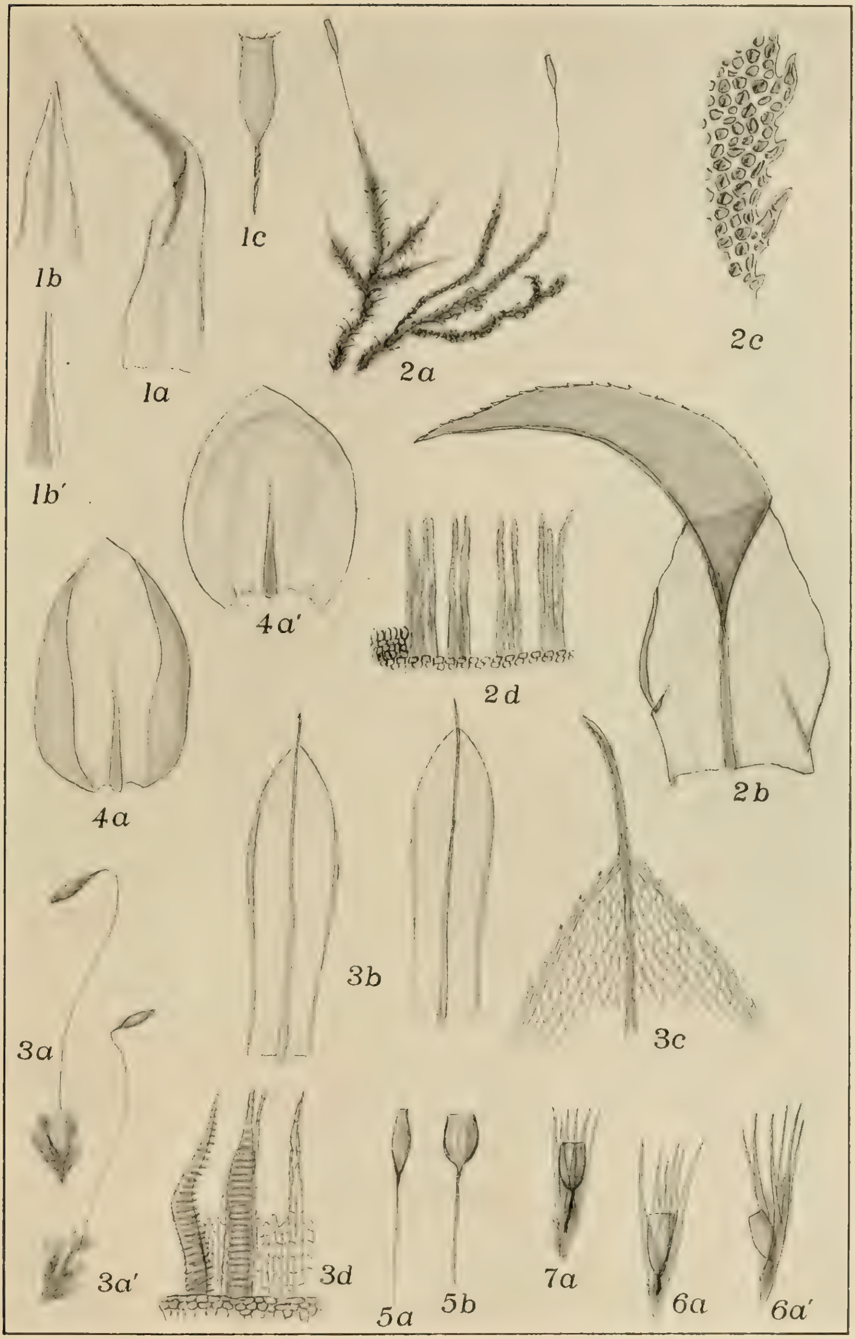
PLATE II

FIG. 8. *Bryum brevinerve.* *a,* Stem, × 1; *b,* leaf, × 10; *c,* cells in upper part, × 50.

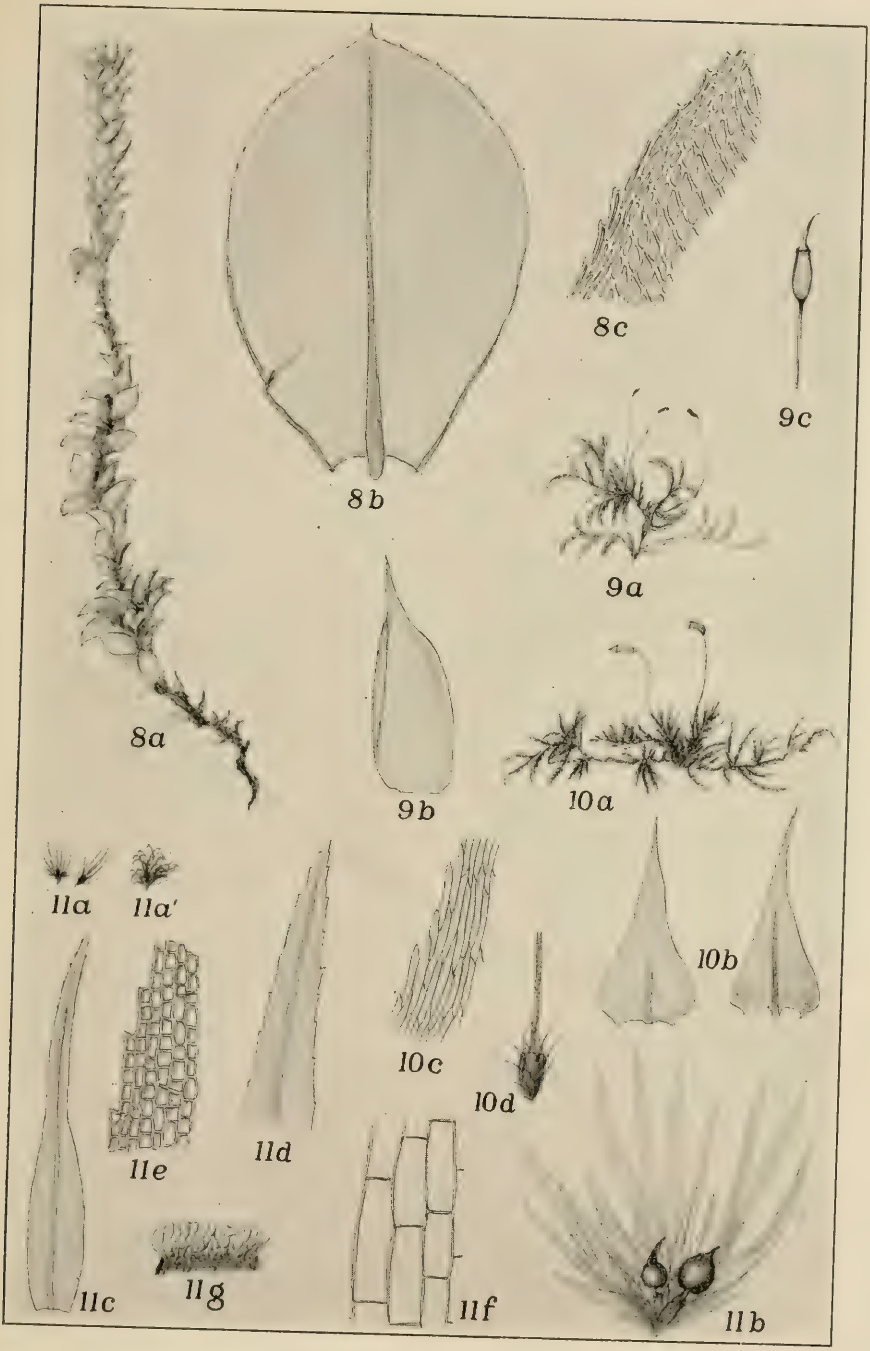
FIG. 9. *Rhaphidostegium elgonense.* *a,* Stem, × 1; *b,* leaf, × 20; *c,* capsule, × 5.

FIG. 10. *Brachythecium Dümmeri.* *a,* Stem, × 1; *b,* stem leaves, × 20; *c,* cells, × 200; *d,* perichaetium, × 5.

FIG. 11. *Kleioweisiopsis denticulata.* *a,* Plant (moist), × 1; *a′,* do. dry, × 1; *b,* plant, × 8; *c,* leaf, × 20; *d,* leaf apex, × 40; *e,* upper cells, × 200; *f,* basal cells, × 200; *g,* cells at orifice of capsule, × 200.



BRITISH EAST AFRICAN MOSSES



BRITISH EAST AFRICAN MOSSES

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72 NUMBER 4

DIAGNOSES OF SOME NEW GENERA OF BIRDS

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(Publication 2588)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 6, 1920

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

DIAGNOSES OF SOME NEW GENERA OF BIRDS

By ROBERT RIDGWAY

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OROAËTUS gen. nov. (Buteonidæ)

Type: *Falco isidori* Des Murs.

Similar to *Spizaëtus* Vieillot,[1] but rectrices much broader, the width of middle pair equal to about one-fourth their length (from point of insertion); feathers of legs longer, those of thighs plume-like; wing-tip relatively longer, the longest primary exceeding outermost (distal) secondary by more than one-fourth the length of wing; tip of tail truncate; occipital plumes shorter, subcuneate; adults with under parts striped, upper parts uniform black, and tail mottled grayish with a broad terminal band of black; size larger (wing more than 500 mm.).

(Ὄρος, mountain; ἀετός, eagle.)

Species: *Oroaëtus isidori* (Des Murs).

The type and only known species of this genus has been referred by Sharpe and others to *Lophotriorchis* Sharpe (type, *Astur kienerii* Geoffroy-St. Hilaire), but it would be difficult to find two forms of this group (Spizaeti) more conspicuously different in structural details or even in appearance. *Lophotriorchis* differs in (1) the very broad cere, its width on top nearly if not quite equal to its length; (2) relatively very much smaller bill; (3) densely bristled loral region; (4) five outer primaries with inner webs deeply and abruptly emarginated (instead of six obliquely sinuated); (5) very different relative length of anterior toes, the inner (without claw) not extending beyond the penultimate articulation of the middle toe, the outer very little longer, the middle toe (without claw) three-fourths as long as tarsus instead of only about two-thirds as long; (6) tip of tail distinctly rounded instead of truncate. In short, practically the only character, apart from those common to the whole group, possessed by the two genera consists in the unimportant ones of a similar crest and striped under parts of adults.

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[1] With "*Falco mauduyti* Daudin" = *F. ornatus* Daudin as type (subsequent designation by Gray, 1840).

PHÆOAËTUS gen. nov. (Buteonidæ)

TYPE: *Falco limnaetus* Horsfield.[1]

Similar to *Lophotriorchis* in abrupt emargination of five outer primaries and densely bristled loral region, but differing conspicuously in having the cere much narrower (across top); relatively much larger and more produced bill; in very different proportionate length of toes, the inner (without claw) extending to decidedly beyond penultimate articulation of middle toe; tail about three-fourths (instead of less than two-thirds) as long as wing; wing-tip shorter, the longest primary exceeding outermost (distal) secondary by less than one-third the length of wing; middle toe (without claw) less than half (instead of three-fourths) as long as tarsus; toes and claws much stouter, the latter relatively shorter and less acute, and uniform dusky coloration.

(Φαιός, brown, dusky; ἀετός, eagle.)

SPECIES: *Phæoaëtus limnaetus* (Horsfield).

MORPHNARCHUS gen. nov. (Buteonidæ)

TYPE: *Leucopternis princeps* Sclater.

Similar to *Leucopternis* Kaup but differing in relatively shorter and stouter tarsus (less than twice as long as middle toe without claw), circular nostril, cuneate feathers of head and neck, and very different coloration, the head, neck, chest and upper parts plain black, the under parts (posterior to chest) white narrowly barred with black; loral and orbital regions nearly nude.

(Μόρφνος, dusky, dark; ἀρχός, a leader or chief.)

SPECIES: *Morphnarchus princeps* (Sclater).

PERCNOHIERAX gen. nov. (Buteonidæ)

TYPE: *Falco leucorrhous* Quoy and Gaimard.

Somewhat like *Rupornis* Kaup, but relative length of anterior toes very different, the outer toe (without claw) not longer than the inner and extending to barely beyond penultimate articulation of middle toe (instead of to beyond middle of penultimate phalanx); middle toe relatively longer (more, instead of less, than half as long as tarsus); tarsus less (instead of more) than one-fourth as

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[1] This species is the type of *Limnaëtus* Vigors, which name is antedated by *Limnætus* Bowdich, the latter a synonym of *Buteo*.

long as wing, its upper portion more extensively feathered in front (for one-half instead of only one-third, or less, the length of tarsus), the naked portion of acrotarsium with much fewer (about 7 instead of 12-13) transverse scutellae; cere much narrower across top, and coloration radically different, the adults and young being conspicuously different, the former mostly plain brownish black or blackish brown, the latter with under parts buff or light ochraceous conspicuously striped with dusky.

Also resembling somewhat the smaller species of *Buteo,* especially *B. brachyurus* (which it resembles more in coloration than in structural details), but these differ in (1) having the wing-tip (distance from tip of distal secondary to that of longest primary) equal to much more than one-third the length of wing; (2) only three outer primaries with inner webs emarginated; (3) first (outermost) primary equal to eighth (instead of equal to tenth); (4) tarsus less than one-fourth as long as wing (instead of more than one-fourth as long), and also in possessing several of the characters distinguishing *Rupornis* from *Percnohierax.*

(**Περκνός**, dark-colored, dusky; **Ἱέραξ**, a hawk.

Species: *Percnohierax leucorrhous* (Quoy and Gaimard). (Monotypic.)

HAPALOCREX gen. nov. (Rallidæ)

Type: *Rallus flaviventris* Boddaert.

Very small Ralleæ (wing about 66-69 mm.) with longest feather of alula falling short of tips of longest primary coverts; bill nearly as long as head; toes very long (the combined length of first two phalanges of middle toe as long as tarsus, the hallux, without claw, half as long as tarsus), and with a white superciliary stripe and black loral stripe.

(**Ἁπαλός**, delicate; *κρέξ*, a crake.)

Species: *Hapalocrex flaviventris* (Boddaert). (Monotypic.)

LIMNOCREX gen. nov. (Rallidæ)

Type: *Porzana cinereiceps* Lawrence.

Small Ralleæ (wing about 70-78 mm.) with longest feather of alula extending decidedly beyond tips of longest primary coverts; nostril narrowly elliptical; tarsus shorter than middle toe without claw (but longer than combined length of first two phalanges of middle toe); outermost primary as long as (sometimes longer than) distal secondary; bill subcuneate (tapering) in lateral profile, the culmen elevated and more or less arched basally; and with sides, flanks, and under tail-coverts conspicuously barred black and white.

(Λίμνη, a pool, marsh; κρέξ, a crake.)

Species: *Limnocrex cinereiceps* (Lawrence); *Limnocrex albigularis* (Lawrence); *Limnocrex exilis* (Temminck).

(Possibly the following species, which I have not seen, may also be referable to this genus: *Porzana œnops* Sclater and Salvin; *P. levraudi* Sclater and Salvin, and *Rallus leucopyrrhus* Vieillot.)

THRYOCREX gen. nov. (Rallidæ)

Type: *Corethrura rubra* Sclater and Salvin.

Small Ralleæ (wing about 81-85 mm.) with bill not conspicuously deeper at base than at gonydeal angle, its width at posterior end of nostril equal to decidedly more than half its depth at same point; malar antia slightly anterior to the broadly rounded (convex) loral antia; longest feather of alula extending beyond tips of longest primary coverts; outermost primary not projecting beyond tip of distal secondary; tarsus longer than middle toe without claw, and under parts plain cinnamon-rufous.

(Θρύον, a rush; κρέξ, a crake.)

Species: *Thryocrex rubra* (Sclater and Salvin). (Monotypic.)

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 5

NEW SELAGINELLAS FROM THE WESTERN UNITED STATES

(WITH SIX PLATES)

BY
WILLIAM R. MAXON

(PUBLICATION 2589)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 22, 1920

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NEW SELAGINELLAS FROM THE WESTERN UNITED STATES

By WILLIAM R. MAXON

(With Six Plates)

Within the past twenty years a considerable number of species have been proposed in the group of *Selaginella rupestris,* nearly all of which, judged by a critical comparison of their essential though minute characters, are undoubtedly well founded. In all, about twenty-five species have been described from the United States. These are so various in gross form and habit, and under a dissecting microscope or even by use of a good hand lens show such remarkably diverse and constant leaf and sporophyll characters, that it is hard to conceive of their ever having been regarded as, for the most part, " forms " of a single species. Extensive collecting, especially in the Rocky Mountain region, is still necessary in order to clear up the relationship of a few doubtful forms, and it is likely that exploration in the Southwest will yield additional new species, since the plants as a group are decidedly xerophilous or, at least, are able to withstand long periods of drought, and so may be sought in those arid out-of-the-way places that appeal chiefly to the natural history collector. Specimens from any part of the southern and western United States will, indeed, be gratefully received by the writer.

Of the six species here described the first is one of the interesting assemblage of species growing together, often intimately associated, in the Organ Mountains of New Mexico; the second is a plant of the desert region of southern California, confused by Underwood with a similar species from Zacatecas, Mexico; the third, long known to the writer as distinct, is a related plant from Arizona; the fourth and fifth are species of southern California, brought to light by the energetic field work of a small group of enthusiastic botanists; and the sixth is a strongly marked plant, not uncommon in the Glacier National Park, recently discovered during the course of intensive botanical collecting in that region. In the lack of a monograph or a synoptical account of the group as represented in the United States, it has seemed especially desirable to accompany the descriptions by illustrations. These, besides assisting in identification, will serve to show very well some of the more diverse forms assumed by members of this group. All the illustrations are at natural size and represent the type specimens in each instance, excepting only that of *S. arizonica* which is of *Thornber* 315.

SELAGINELLA NEOMEXICANA Maxon, sp. nov.

(Pl. 1)

Plants strongly assurgent, 10 to 20 cm. long, the main stem rooting sparingly at the extreme base, freely ramose, all the branches erect or ascending, several times pinnate, subequal; stems (leaves excluded) mostly 0.2 to 0.5 mm. in diameter, the older ones readily defoliate. Leaves uniform, rigidly ascending on all sides, subdistant in attachment, imbricate but not wholly concealing the axis, 2 to 2.75 mm. long (seta included), the blades subulate-attenuate, 1.7 to 2.5 mm. long, 0.37 to 0.5 mm. broad at the base, setigerous (the seta 0.3 to 0.47 mm. long, whitish-hyaline from a greenish-lutescent base, straight, sparingly serrulate), thin-herbaceous, spongiose at the base, subglaucous, flat above, dorsally convex toward the narrowly obtuse apex, sparingly pilose at the base of the deep narrow median groove, ciliate, the cilia 12 to 20 on each side, slender, rigid, nearly straight, mostly 0.06 to 0.125 mm. long, spreading or slightly ascending, the apical ones reduced and more oblique. Spikes numerous, terminating the main branches, 1 to 2 cm. long, about 1.5 mm. thick, recurved, sharply quadrangular; sporophylls glaucous, yellowish brown with age, readily detached, 2.4 to 2.7 mm. long (seta included), the blade 2.2 to 2.4 mm. long, 0.9 to 1.2 mm. broad, ovate, evenly long-acuminate, setigerous (the seta 0.2 to 0.47 mm. long, greenish-lutescent with a white tip, slightly scabrous), strongly concave, with a deep dorsal groove throughout, freely short-ciliate, the cilia 25 to 32 on each side, close, stout, rigidly ascending, mostly 0.045 to 0.075 mm. long, the upper ones reduced. Megasporangia abortive or wanting. Microsporangia very numerous; microspores yellow, about 0.022 mm. in diameter.

Type in the U. S. National Herbarium, No. 591262, collected in the Organ Mountains, Dona Ana County, New Mexico, at an altitude of about 1,800 meters, January 9, 1909, by E. O. Wooton. There are at hand three additional sheets of specimens collected in the same range of mountains by Mr. Wooton on September 28, 1902, September 11, 1904, and March 3, 1907, the last mentioned associated with *S. rupincola* Underw.

The present species has hitherto been referred doubtfully to *S. bigelovii* Underw., of southern California, and this is clearly its relationship. *Selaginella bigelovii* differs, however, in its more compact habit and rigid, funiform branches, and more particularly in details of leaf structure, the cilia being strongly oblique, very rigid, short (mostly 0.03 to 0.04 mm. long), and pointed, often incurved; also, the setae are strongly scabrous throughout. Similar differences are found in the sporophylls, those of *S. bigelovii* being coriaceous, distinctly carinate, and tipped with a strongly scabrous seta.

SELAGINELLA EREMOPHILA Maxon, sp. nov.

(Pl. 2)

Plants wholly prostrate, the main stems up to 10 or 12 cm. long, coarsely radicose at intervals throughout, freely branched, forming a close mat, the principal basal divisions subequal, divaricate, 2 or 3 times pinnate, the ultimate sterile branches very short, mostly 2 to 4 mm. long, about 2 mm. broad, involute upon drying; stems, branches, and minor divisions all densely leafy, of pronounced dorsoventral aspect. Leaves crowded, in six ranks, those of the under side the largest, about 2 mm. long, 0.5 mm. broad, exactly lanceolate, acutish, not setigerous, ciliate (the cilia about 25 on each side, white, spreading, mostly 0.075 to 0.125 mm. long), yellowish brown, imbricate, oblique-spreading, strongly secund upon drying; leaves of the upper side close-set, subimbricate, *nearly vertical,* straight or slightly curved, deltoid-subulate, acutish, not setigerous, 1 to 1.4 mm. long, 0.4 to 0.47 mm. broad at the base, at first bright green and subglaucous, soon turning yellowish brown, flat above, broadly convex beneath and sulcate in a median line nearly or quite to the tip, ciliate, the cilia 6 to 12 on each side, weak, mostly spreading, about 0.1 mm. long, similar minute hairs tufted at the base of the midrib and extending sparingly along the dorsal groove. Spikes numerous, arcuately ascending, 6 to 10 mm. long, 1 mm. thick or less; sporophylls deltoid, acute or acutish, not setigerous, mostly 1.2 to 1.4 mm. long, 0.9 to 1 mm. broad, convex, subcarinate and sulcate dorsally, ciliate, the cilia 12 to 18 on each side, spreading or weakly ascending, mostly 0.09 to 0.125 mm. long, rarely reaching the apex. Megasporangia few, inferior, mostly basal; megaspores light yellow, 0.36 to 0.4 mm. in greatest diameter, the commissural faces finely and deeply reticulate, the outer face coarsely but sharply and deeply reticulate, the ridges about 0.016 mm. broad; commissural costae prominent, long. Microsporangia numerous; microspores dull yellow, about 0.039 mm. in diameter, long remaining associated in tetrads.

Type in the U. S. National Herbarium, No. 867484, collected in Palm Canyon, Riverside County, California, April 4, 1917, by Ivan M. Johnston (No. 1047); distributed as *Selaginella parishii* Underw.

Mr. Johnston's notes accompanying the specimen read, "Very common in rock crevices and in their shade; Lower Sonoran Zone. It is very hard to find a rock which hasn't a large colony of this at its foot. It grows with *Selaginella bigelovii*."

The following additional specimens of *S. eremophila,* all from the Colorado Desert region, are in the National Herbarium:

California: Mountain Spring, San Diego County, alt. 900 meters, May 14, 1894, *Mearns* 3162. Top of Granite Mountain, seven miles east of Julian, April 17, 1918, *Bethel.* Base of San Jacinto Mountain, March, 1908, *Saunders.* Palm Canyon, eastern base of San Jacinto Mountain, March, 1919, *Hall.* West Canyon, Riverside County, alt. 200 meters, April 18, 1907, *Parish* 6111. Tahquitz, near Palm Springs, December 25, 1903, *Dudley.*

Selaginella eremophila is the plant of southern California (rare in herbaria) which has been called *S. parishii.* Underwood in describing *S. parishii,*[1] however, cited three collections, two of these from the Colorado Desert (*Parish* 1200; *Saunders*), and the third from Zacatecas, Mexico (*Palmer* 306). The California plant is specifically distinct from the Mexican element, which, having been designated by Underwood as the type, must bear the name *S. parishii.* The dissociation of Mr. Parish's name from so characteristic a species of the Colorado Desert flora is especially regrettable.

Of the species hitherto described, *S. eremophila* is closely related only to *S. parishii,* of Zacatecas, and *S. landii* Greenm. & Pfeiffer,[2] of Jalisco, both of which have a very similar dorso-ventral aspect. *Selaginella parishii* is a more lax plant, with the ultimate branches 2 to 3 mm. broad, and larger, narrower leaves, whose characters may be summarized as follows: Leaves of the under side 2.2 to 2.5 mm. long, with about 18 cilia upon each side, these *oblique,* 0.078 to 0.125 mm. long; leaves of the upper side 1.3 to 1.6 mm. long, 0.35 to 0.43 mm. broad, with 4 to 8 cilia on each side, these *oblique,* 0.06 to 0.09 mm. long. The sporophylls, moreover, are broadly cordate-deltoid, 1.5 to 1.7 mm. long, 1.3 to 1.4 mm. broad, with 25 to 30 very oblique, close-set cilia on each side, those of the lower two-thirds 0.1 to 0.17 mm. long, forming a conspicuous fimbriate border. The megaspores are pale yellow, about 0.42 mm. in diameter, and delicately reticulate.

Selaginella landii is represented in the National Herbarium by a portion of the type, *Barnes & Land* 2024 (San Esteban Mountains, 32 kilometers from Guadalajara, Jalisco) and by another collection

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[1] Bull. Torrey Club **33:** 202. 1906.

[2] Ann. Mo. Bot. Gard. **5:** 205. *pl. 11, 12.* 1918.

(*Rose & Painter* 7499) from the same locality. The essential characters are as follows: Stems very firm, stiff, the branches rigid, not intricate; leaves of lower side closely appressed-imbricate, lance-attenuate, 2.7 to 3.2 mm. long, 0.6 to 0.7 mm. broad, with about 15 to 20 slender, mostly ascending cilia on each side in the lower half or two-thirds (these 0.06 to 0.12 mm. long), the apical third with pungent serratures; leaves of the upper side crowded, rigidly vertical or recurved, narrowly deltoid, evenly acuminate, 1 to 1.2 mm. long, 0.4 to 0.5 mm. broad, with about 13 to 16 cilia on each side, these mostly oblique and incurved, 0.055 to 0.085 mm. long, the upper ones passing into broad pungent serratures; sporophylls deltoid-ovate, narrowly long-acuminate, 1.7 to 2 mm. long, 0.85 to 1 mm. broad, variable in ciliation, sometimes with as many as 20 stiff, rigidly ascending, mostly incurved cilia in the basal half (these 0.03 to 0.06 mm. long) and elsewhere serrate, or with short ascending teeth along the whole margin above the extreme base (here with a few cilia). Megaspores yellow, subglobose, about 0.33 mm. in diameter, rugulose-reticulate, the ridges projecting sharply, less than 0.008 mm. broad.

These three species, *S. eremophila, S. parishii,* and *S. landii,* while readily distinguished specifically, are by no means typical members of the group of *S. rupestris,* and together with the next species (*S. arizonica*) form a fairly well-defined subgroup. The pronounced dorso-ventral habit and subdimorphous leaves are doubtless to be associated with their strongly xerophilous habitat.

SELAGINELLA ARIZONICA Maxon, sp. nov.

(Pl. 3)

Plants wholly prostrate, the main stems up to 20 cm. long, rooting at intervals throughout, pinnately branched, the branches 1 to 1.5 cm. apart on each side, the lower and middle ones 2.5 to 6 cm. long, twice pinnate, the ultimate branches broadly subclavate, short, subdistant, all the parts densely leafy, dorso-ventral, involute. Leaves crowded, in six ranks, those of the under side the largest, appressed-imbricate, oblique laterally, linear-lanceolate, acuminate, not setigerous, 2.5 to 2.8 mm. long, 0.5 to 0.6 mm. broad, thin-herbaceous, yellowish brown, evenly ciliate, the cilia 18 to 22 on each side, oblique, up to 0.11 mm. long, the apical ones reduced; leaves of the upper side subulate, 1.8 to 2.2 mm. long, 0.3 to 0.44 mm. broad, evenly attenuate to the acutish, whitish-marginate, short-setigerous apex (the seta dirty white, stout, 0.15 to 0.28 mm. long, serrate, often reflexed, present only in the young leaves, caducous), ciliate (the cilia 4 to 8 on each side, ascending, pungent, 0.04 to 0.09 mm. long, passing into short serratures at the apex), at first bright green, grayish with age, rigidly herbaceous from a thick spongiose base, rigidly ascending, with age nearly vertical in the older branches, flat above, slightly convex dorsally and deeply sulcate nearly to the tip. Spikes ascending, terminating the short ultimate divisions of the larger branches (or the divisions wholly fertile), sometimes numerous, 2 to 5 mm. long; sporophylls narrowly ovate-deltoid, 1.5 to 1.95 mm. long, 0.75 to 0.85 mm. broad, evenly long-acuminate, at first barely setigerous (the seta 0.15 to 0.25 mm. long, broad, pointed, serrulate, dirty white), subcarinate, ciliate, the cilia 18 to 22 on each side, stout, rigidly ascending, mostly 0.03 to 0.06 mm. long, the upper ones greatly reduced, dentiform. Megasporangia numerous, basal, or sometimes interspersed among the microsporangia; megaspores pale yellow, subglobose, 0.36 mm. in greatest diameter, coarsely reticulate on the outer face (the ridges sharp and narrow), finely reticulate on the commissural faces; commissural costae long, delicate. Microsporangia numerous; microspores orange, about 0.035 mm. in diameter.

Type in the U. S. National Herbarium, no. 694327, collected at the foot of Soldier Trail, Santa Catalina Mountains, Arizona, altitude about 960 meters, July 28, 1914, by Forrest Shreve. Other specimens in the National Herbarium are as follows:

ARIZONA: Sabino Canyon, Santa Catalina Mountains, alt. 870 meters, June 15, 1903, *Thornber* 315. Ventana Canyon, near Tucson, 1913, *Cook*. Pimo Canyon, near Tucson, February, 1913, *Parish* 8513. Arivipa Canyon, April, 1873, *P. F. Mohr*. Santa Catalina Mountains, April 3, 1894, *Toumey*. Roosevelt Dam, on steep rocky slopes, August 3, 1910, *Goodding* 722. Salt River Mountains, alt. 600 meters, November 9, 1913, *Bailey*. Ray, 1913, *Bailey*.

Selaginella arizonica is related to *S. eremophila*, and to *S. landii* and *S. parishii*, whose characters are given in detail under the last preceding species. The disparity in size between the leaves of the under and upper sides is far less in *S. arizonica* than in the others, and it alone of the four species has the leaves and sporophylls at all setigerous. It is a much larger and coarser plant than *S. eremophila* and differs in nearly all technical leaf characters.

SELAGINELLA ASPRELLA Maxon, sp. nov.

(Pl. 4)

Plants forming a loose mat, the main stems 3 to 6 cm. long, creeping but not prostrate, rooting at intervals throughout, with a few laxly ascending branches, these close, usually intricate, 1 to 2.5 cm. long, twice pinnate, the ultimate divisions 3 to 7 mm. long, oblique, slender, all the parts scantily leafy; main branches (leaves excluded) about 0.6 mm. thick, tardily defoliate. Leaves uniform, rigidly ascending on all sides, subdistant, decurrent, subimbricate, 2.75 to 3.2 mm. long (seta included), the blades narrowly deltoid-subulate, 1.85 to 2.3 mm. long, 0.55 to 0.7 mm. broad at the base, long-setigerous (the seta 0.7 to 0.9 mm. long, white-hyaline, slender, subflexuous, serrulate-ciliate throughout, the cilia up to 0.04 mm. long), chartaceous, inflated, concave above, broadly convex beneath, with a deep median groove, very strongly glaucous, with a more or less well-defined whitish-hyaline border (0.045 to 0.075 mm. broad at the middle of the leaf), ciliate, the cilia 16 to 23 on each side, spreading, straight or often curved, mostly 0.05 to 0.09 mm. long, the upper ones distant, shorter, oblique. Spikes numerous, loosely aggregate at the ends of the short apical branches, 1 to 2 cm. long, 1.5 to 2 mm. broad, arcuate, sharply quadrangular; sporophylls laxly imbricate, strongly glaucous, yellowish brown with age, 2.5 to 3 mm. long (seta included), the blade narrowly ovate-deltoid, evenly long-acuminate, 1.9 to 2.2 mm. long, 0.85 to 1 mm. broad at the base, long-setigerous (the seta stiff, straight, 0.6 to 0.8 mm. long, whitish, strongly scabrous), carinate, with a deep dorsal groove, strongly whitish-marginate, ciliate, the cilia 25 to 35 on each side, slightly oblique, mostly 0.03 to 0.06 mm. long, the apical ones few and reduced. Megasporangia few, mostly basal; megaspores pale to bright yellow, subglobose, about 0.375 mm. in diameter, lightly reticulate on all faces, the meshes broad, with low ridges; commissural costae prominent. Microsporangia very numerous; microspores bright orange, about 0.033 mm. in diameter.

Type in the U. S. National Herbarium, No. 867507, collected at the west end of Ontario Peak, San Antonio Mountains, southern California, altitude about 1,800 meters, in rocky ground, March 25, 1918, by Ivan T. Johnston (No. 1815). Other material, all from the same range of mountains, has been examined, as follows: San Antonio Canyon, in shelter of rock on the dry, open canyon floor, alt. 1,725 meters, July 28, 1917, *Johnston* 1595; Ontario Peak, in crevices of a sunny, exposed granite cliff, alt. 2,475 meters, December 22, 1917, *Johnston* 1807. The last-mentioned specimen is dwarfed, and the leaf parts scarcely attain the size given in the description.

Selaginella asprella is a strongly marked species, without any very close relatives. Of western United States species it is related only to *S. bigelovii* Underw., *S. rupincola* Underw., and *S. neo-*

mexicana Maxon, all of which are much larger plants of essentially erect growth and differ, besides, in numerous technical characters. The very slender, rigid branches and spaced, half-appressed, strongly setigerous leaves give the plant a scant, harsh aspect, which has suggested the specific name.

SELAGINELLA LEUCOBRYOIDES Maxon, sp. nov.

(Pl. 5)

Plants very closely prostrate, the stems short-creeping, 1 to 2 cm. long or less, closely aggregate, simply pinnate, the divisions thick, strongly cespitose, erect, only 2 to 7 mm. long, or the terminal ones bearing erect elongate spikes, all the parts densely leafy. Leaves crowded, closely appressed-imbricate, mostly incurved, glaucous, linear-subulate, uniform as to shape, variable in size, the basal ones 2.8 to 3.25 mm. long (seta included), 0.44 to 0.53 mm. broad, the upper ones mostly 2 to 2.8 mm. long (seta included), 0.42 to 0.5 mm. broad, all short-setigerous at the acutish whitish thickened apex (the seta stout, white, not translucent, subflexuous, 0.125 to 0.28 mm. long, strongly scabrous, often reflexed), ciliate (the cilia 8 to 16 on each side, those of the basal half spreading, 0.6 to 0.13 mm. long, the upper ones shorter, distant, ascending), thick, rigidly herbaceous, flat or broadly concave above, convex beneath (strongly so toward the apex), the median groove deep, broad, nearly percurrent. Spikes relatively numerous, aggregate, 5 to 10 mm. long, about 1.5 mm. thick, erect, nearly straight; sporophylls rigidly appressed-imbricate, deeply concave, narrowly to broadly deltoid-ovate, evenly long-acuminate, about 2 mm. long, 0.8 to 1 mm. broad, short-setigerous (the seta white, rigid, pointed, subentire, about 0.15 mm. long or less), ciliate-serrulate; cilia or teeth 20 to 25 on each side, the basal cilia not more than 0.046 mm. long, pungent, oblique, passing gradually into oblique hyaline teeth toward the apex. Megasporangia few, basal; megaspores subglobose, bright yellow, about 0.47 mm. in diameter, the outer face obscurely reticulate, the commissural faces manifestly so; commissural costae short, elevated. Microsporangia numerous; microspores orange, about 0.039 mm. in diameter.

Type in the U. S. National Herbarium, No. 982453, collected at Bonanza Mine, Providence Mountains, southeastern California, alt. 840 meters, in crevices, rocky mountain side, March 30, 1920, by P. A. Munz and R. D. Harwood (No. 3789). The following additional material is at hand:

CALIFORNIA: Surprise Canyon, Panamint Mountains, Inyo County, alt. 1,400 meters, April 14, 1891, *Coville & Funston* 628. Vicinity of Bonanza King Mine, east slope of Providence Mountains, Mojave Desert, alt. 960 meters, May 11-24, 1920, *Munz, Johnston & Harwood* 4226.

The relationship of *Selaginella leucobryoides* is difficult to determine, since the plant differs not only in megaspores but in most foliage characters from all other species of the Pacific Coast region. The most striking characteristics are the extremely short, pure white but opaque seta of the leaves and the condensed, rosette-like arrangement of the very short branches. In habit and color there is a strong suggestion of the tufted growth of some of the smaller species of *Leucobryum*.

The Panamint Mountains plant collected by Coville and Funston (No. 628) was mentioned as a critical form by Underwood in his initial work upon the United States species allied to *S. rupestris* It is clearly a reduced state of the present species, differing from the type only in its lesser size. The leaves are only 1.65 to 2 mm. long and 0.35 to 0.44 mm. broad; the seta and cilia characters are identical. The plant collected by Munz, Johnston, and Harwood (No. 4226) also comes from a higher elevation than the type collection and is somewhat smaller.

SELAGINELLA STANDLEYI Maxon, sp. nov.

(Pl. 6)

Plants closely prostrate, the main stems up to 6 cm. long, finely radicose, pinnately branched, the larger basal branches up to 2.5 cm. long and with a few short alternate divisions, the upper branches simple or once dichotomous, all the divisions cespitose, rigidly arcuate-ascending. Leaves crowded, imbricate, rigidly appressed, those of the older stems of a characteristic bronze color, relatively large, the blades broadly acicular, acutish, up to 2.5 mm. long and 0.6 mm. broad, with a short lutescent seta; leaves of the branches mostly dull green, oblong-linear, 2.1 to 2.5 mm. long (seta included), 0.35 to 0.45 mm. broad, setigerous at the narrowly obtuse apex (the seta 0.6 to 0.78 mm. long, lutescent throughout, coarsely serrulate-scabrous), ciliate (the cilia 10 to 14 on each side, hyaline, stiff, oblique, mostly 0.05 to 0.06 mm. long, passing into pungent serratures toward the apex), rigidly herbaceous, flat above, convex beneath and reddish along the deep median groove, especially toward the cymbiform apex. Spikes numerous, mostly geminate, erect from a curved base, 7 to 11 mm. long, about 1.5 mm. thick; sporophylls deltoid to ovate-deltoid, 1.8 to 2 mm. long, 0.9 to 1 mm. broad, acuminate, setigerous at the acutish tip (the seta 0.2 to 0.4 mm. long, stout, rigid, scabrous, lutescent from a darker base), ciliate, the cilia close, 16 to 21 on each side, stiff, rigidly ascending, up to 0.08 mm. long. Megasporangia few, basal; megaspores orange-yellow, 0.46 to 0.5 mm. in diameter, oblate-spheroidal, rugose in all aspects, the commissural costae short and prominent. Microsporangia very numerous; microspores dull orange, about 0.032 mm. in diameter.

Type in the U. S. National Herbarium, No. 1028638, collected in the vicinity of Sexton Glacier, Glacier National Park, Montana, altitude 1,950 to 2,220 meters, on a moist rocky slope, August 7, 1919, by Paul C. Standley (No. 17228). Other material studied is as follows:

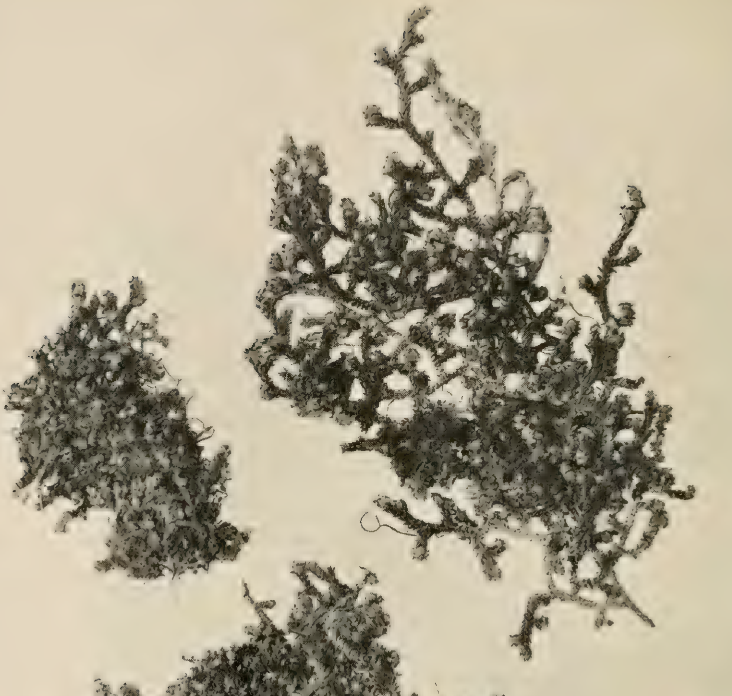
MONTANA (Glacier National Park): Gunsight Pass and vicinity, alt. 1,775 to 2,100 meters, August 25, 1919, *Standley* 18136; August 25, 1917, *Ulke*. Along the trail from Many Glacier Hotel to Piegan Pass, alt. 1,500 to 2,160 meters, August 11, 1919, *Standley* 17483. Vicinity of Iceberg Lake, alt. 1,740 to 1,950 meters, July 11, 1919, *Standley* 15363. Ptarmigan Lake, alt. 1,800 to 1,900 meters, August 3, 1919, *Standley* 16970.

ALBERTA: Tunnel Mountain, alt. 1,650 meters, June 11, 1906, *Brown* 95.

The writer takes pleasure in dedicating this excellent species to Mr. Paul C. Standley, who, in the course of his botanical exploration of Glacier National Park, assembled an extraordinarily rich collection of material in this group, the specimens comprising (besides *S. standleyi*) *S. montanensis* Hieron., *S. densa* Rydb., and *S. wallacei* Hieron., all in ample series.

Superficially *S. standleyi* most resembles *S. watsoni* Underw., of the high mountains of Utah, Nevada, and California, in which also the leaves have lutescent setae. It is at once distinguished from *S. watsoni,* however, by the fact that the setae (which are even darker) are not only 2 to 3 times as long but are strongly serrulate-scabrous nearly throughout, those of *S. watsoni* being smooth or nearly so. The sporophylls also have longer and scabrous setae, and the blades are much more freely ciliate, the cilia being stiff, very oblique, and subpersistent nearly to the apex, in marked contrast to *S. watsoni.*

SELAGINELLA NEOMEXICANA Maxon



SELAGINELLA EREMOPHILA Maxon

SELAGINELLA ARIZONICA Maxon

SELAGINELLA ASPRELLA Maxon

SELAGINELLA LEUCOBRYOIDES Maxon

SELAGINELLA STANDLEYI Maxon

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 6

EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1920

(Publication 2619)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1920

INTRODUCTION

Investigation of the unexplored regions of the earth and extending scientific knowledge of imperfectly known localities have from the beginning been an important phase of the Institution's activity in the "increase of knowledge." This pamphlet serves as an announcement of the more important expeditions sent out during the calendar year 1920, and more detailed accounts of the scientific results are later published in the Proceedings of the U. S. National Museum, Bulletins of the Bureau of American Ethnology, and other series of publications issued under the direction of the Institution.

Not only has our knowledge of little known regions been increased through the numerous expeditions sent out by the Institution during the 75 years of its existence, but also the collections in natural history and anthropology in the Museum have been greatly enriched thereby. The urgency of some of the field-work is illustrated by the Australian expedition herein briefly described. The remarkable Australian mammal life has been but meagerly represented in the National Museum and the rapid extermination of the native animals through various agencies renders increasingly difficult the securing of an adequate collection. However very satisfactory shipments are being received from the present expedition and it is hoped that a good representation will be secured for the Museum before it is too late.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

During the field season of 1920, geological exploration was continued by Secretary Charles D. Walcott in the Canadian Rocky Mountains, with two main points in view, (1) the determination of the character and extent of the great interval of non-deposition of sedimentary rock-forming material along the Front Range of the Rockies west of Calgary, Alberta; (2) the clearing up of the relations of the summit and base of the great Glacier Lake section of 1919[1] to the geological formations above and below. The party going from Washington consisted of Dr. and Mrs. Walcott and Arthur Brown.

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[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.


Mt. Peechee (9,815')
Mt. Inglismaldie
Cascade Mt. (9,825')

[illegible]

FIG. 2.—Cliffs rising above the northern shore of the head of Lake Minnewanka. Photograph by C. D. Walcott, 1920.

FIG. 3.—Eastward facing cliffs above Ghost River on the Rocky Mountain front. The Ghost River formation is on top of the great lower cliff, and the Devonian limestones in the broken cliffs above. Photograph by C. D. Walcott, 1920.

Fig. 4.—A great headland on the north side of Ghost River, which flows out of the mountain through a broad U-shaped canyon valley. Photograph by C. D. Walcott, 1920.

Early in July work was begun along Ghost River northeast of Banff and about 53 miles (85 km.) west of Calgary, Alberta. The route taken was along the north shore of Lake Minnewanka (fig. 1, Frontispiece) and through the Devils Gap to Ghost River, which here runs north and south at the foot of high eastward-facing cliffs of Cambrian limestone, capped by limestones of Devonian age. Lake Minnewanka is a beautiful sheet of water (fig. 2) in the broad bottom of a pre-glacial river channel, the eastward extension of which forms the Devils Gap.

The Rocky Mountain front (fig. 3) is formed of masses of evenly bedded limestone that have been pushed eastward over the softer rocks of the Cretaceous plains-forming rocks. This overthrust is many miles in extent and occurred long ago before the Devils Gap, Ghost River Gap and other openings were cut through the cliffs by running water and rivers of ice. Great headlands (fig. 4) and high buttes (fig. 5) have been formed by the silent forces of water and frost, many of which stand out against the western sky as seen from the distant foothills and plains.

FIG. 5.—Devils Head (9,204 ft.), a butte rising above the cliffs of Fig. 3 on the north side of Ghost River Gap. Photograph by C. D. Walcott, 1920.

It was among these cliffs that we found that the first great cliff (figs. 3 and 4) was of lower Middle Cambrian age, and that resting on its upper surface there were 285 feet (86 m.) of a yellowish weathering magnesian limestone, here named the Ghost River formation, which represents the great lost interval between the Cambrian below and the Devonian above. Sixty miles to the west, over four miles in thickness of limestone, shales and sandstones (22,670 feet (6,890 m.)), occur in the lost interval of the Ghost River cliffs.

Fig. 6.—Western side of cliffs at the eastern end of upper valley of Clearwater River, 22 miles north of Lake Louise Station. The Devonian limestones cap the ridge on the right with Ordovician rocks beneath and Upper Cambrian in the lower cliff. Photograph by C. D. Walcott, 1920.

FIG. 7.—A contented outfit on a Sunday afternoon near the head of the Clearwater River. Photograph by C. D. Walcott, 1920.

FIG. 8.—Photographing far above timber line (9,400 ft.) over Pipestone Pass. Photograph by Mrs. Mary V. Walcott, 1920.

FIG. 9.—Result of an hour's fishing in Lake Minnewanka near Banff. Photograph by Mrs. Mary V. Walcott, 1920.

FIG. 10.—The avalanche lily forces its way up through the hard snow, and its beautiful slender green leaves and yellow flowers fairly cover the thin outlying margins of the winter's snow. Photograph by Mrs. Mary V. Walcott, 1920.

Fig. 11.—Our pack horse "Pinto" preferred to take a short cut at the ford and went down in deep water and was dragged out. Getting ready to get her up. Photograph by Mrs. Mary V. Walcott, 1920.

Fig. 12.—Getting "Pinto" up on her feet in shallow water. Photograph by Mrs. Mary V. Walcott, 1920.

Returning to the Bow Valley, the party left the Canadian Pacific Railroad at Lake Louise and went north over Pipestone Pass to the Siffleur River, which is tributary to the Saskatchewan. In the northward-facing cliffs 25 miles (40 km.) east of the Glacier Lake section of 1919, and 40 miles (64 km.) north of Lake Louise, a geological section was studied that tied in the base of the Glacier Lake section of 1919 with the Middle and Lower Cambrian formations. Returning up the canyon valley of the Siffleur River to the wide upper valley of the Clearwater River, a most perfectly exposed series of limestones, shales, and sandstones of Upper Cambrian and later formations was found (fig. 6) which cleared up the relations of the upper portion of the Glacier Lake section to the Ordovician formations above.

The field season was marred by forest fire smoke in July and August, and almost continuously stormy weather in September. Some of the incidents of the trail are illustrated by figures 7-12. The trout of Lake Minnewanka (fig. 9) increased our food supply for days while on Ghost River, and the camp on the Clearwater was a paradise for man and beast (fig. 7). On Pipestone Pass the avalanch lily was found forcing its way up through the hard snow (fig. 10), and in a treacherous ford of the Pipestone River, Arthur's war bag and the sugar and flour got a soaking.

The party is indebted in many ways to the officials of the Rocky Mountains Park, and to the officials of the Canadian Pacific Railroad, all of whom gave assistance whenever it was possible to do so.

GEOLOGICAL FIELD-WORK IN THE UNITED STATES

Dr. R. S. Bassler, Curator of Paleontology, U. S. National Museum, was engaged in field-work in Ohio and Illinois during the latter half of June and the first part of July, with the result that two large, instructive exhibits and important additions to the study series of fossil invertebrates were obtained. Proceeding first to Northside, Ohio, Dr. Bassler made arrangements for the shipment to Washington of a large, well-preserved fossil elephant skull which had been purchased by the Museum through the efforts of Dr. E. O. Ulrich, Associate in Paleontology. This specimen, discovered in glacial gravels near Cincinnati some years ago, was long the prize exhibit of a local saloon; in fact, it was so highly regarded for advertising purposes that repeated offers of a considerable sum for its purchase were invariably refused. With the coming of prohibition, its former usefulness departed and the Museum was able to secure it for a nominal amount. Teeth of this species (*Elephas columbi* Falconer) are contained in our collections, but such a complete skull is of rare occurrence, there being only one or two others in North American museums. The specimen is further valuable in giving evidence as to the proper position of the tusks in the skull, a subject of long controversy.

The second important exhibit secured during the trip was a slab, measuring four by eight feet, of highly fossiliferous limestone from the Richmond formation of Early Silurian age as exposed near Oxford, Ohio. Such a specimen had long been desired for the exhibition halls to show the advancement in life from the primitive Cambrian forms, represented in the large Cambrian sea-beach sandstone exhibit, to the higher and more complex species of succeeding geological periods, but notwithstanding the numerous occurrences of fossiliferous limestone of Ordovician and Silurian age, it was not until 1920 that a layer affording slabs of suitable size and sufficient perfection of preservation was brought to the attention of the Museum. This was discovered by Dr. W. H. Shideler, Professor

FIG. 13.—Beginning of excavation for exhibition slab of Richmond limestone near Oxford, Ohio. Photograph by Bassler.

of Geology at Miami University, Oxford, Ohio, who most generously assisted in quarrying out the specimen. As shown in the accompanying photograph (fig. 13) representing the beginning of the excavation for the thin bedded, fossiliferous layer desired (marked *x*), numerous large blocks of stone had to be removed before the real task of quarrying the slab was begun. The work was completed successfully and the exhibit is now being installed in the hall of invertebrate paleontology. The perfection of the fossil shell remains on this slab is evidenced in figure 14, which, however, shows only in a small degree the distinctness of the shells upon the rock background.

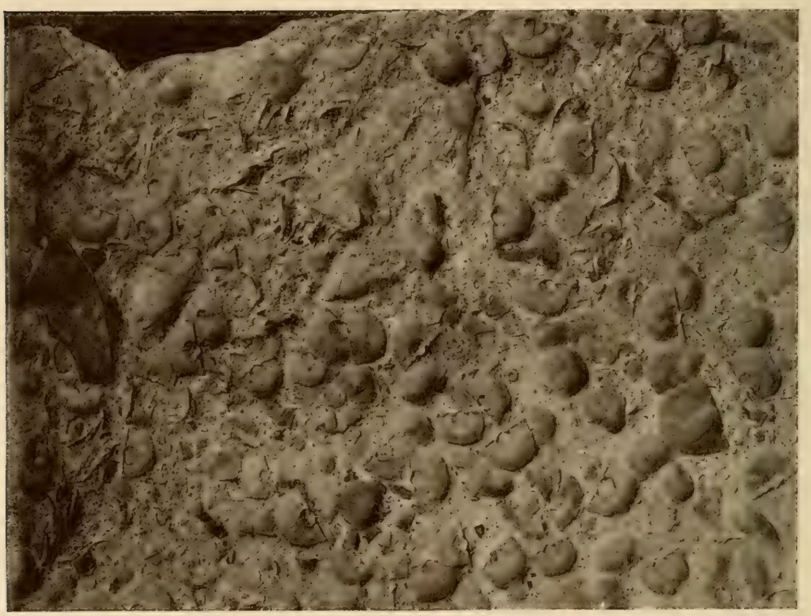

Fig. 14.—Surface of fossiliferous limestone slab, one twenty-fifth natural size. Photograph by Bassler.

Upon the completion of the quarrying operations at Oxford, Dr. Bassler proceeded to Chicago, Illinois, where he was engaged in the preparation of casts of type specimens of fossils contained in the collections of the Walker Museum, University of Chicago. The paleontological collection of the National Museum, which includes the celebrated Walcott, Ulrich, Springer, Harris, Nettelroth, and Rominger collections, is especially rich in type specimens of Early Paleozoic fossils, but nevertheless the Walker Museum possesses many unique types not represented at all in Washington. Permission to prepare casts of these and thus advance our study series toward the completeness which the National collections should attain, was generously granted by Dr. Stuart Weller, Director of the Walker Museum. In two weeks time Dr. Bassler was enabled to finish casting all of the Ordovician and Silurian types, leaving the remaining Paleozoic species for a future trip. The work was done quickly by using the modeling compound (plastocene) to make the mold from which the cast is prepared. After dusting the fossil with talcum powder the modeling compound is carefully pressed upon it and then withdrawn, thus securing a clear-cut impression into which the plaster is poured. Bubbles can be avoided by first pouring thin plaster of Paris into the mold and distributing it uniformly with a camel's hair brush. The thicker plaster is then introduced as usual to fill the cavity. When dry the modeling compound is torn away, thus leaving the complete cast but also, unfortunately, destroying the mold.

Field-work in vertebrate paleontology was limited to a short trip made by Mr. J. W. Gidley, Assistant Curator, in the latter part of August to Williamsburg, Virginia, where scattered remains of a fossil whale had been found in the Miocene strata outcropping nearby. It was at first hoped that an entire skeleton could be secured here, but careful search proved the bones to be so scattered and fragmentary that no exhibition material was available although some interesting additions to the collection of fossil vertebrates and some excellent Miocene shells for the exhibition series were obtained.

Mr. William F. Foshag, of the Division of Mineralogy, at his own expense made sundry trips into interesting mineral localities in California and secured a considerable quantity of desirable material for the Museum's collections, including an excellent series of borax minerals.

FIELD-WORK IN ASTROPHYSICS

In astrophysical research the Institution was unusually active. Early in 1920, Dr. Abbot had a long discussion and correspondence with Professor Marvin, Chief of the United States Weather Bureau, on the applications of solar radiation measurements to meteorology now being officially practised in Argentina and Brazil on a basis of daily telegraphic reports from the Smithsonian observatory near Calama, Chile. Professor Marvin felt strongly the inadequacy of existing solar radiation observations as a basis for studies of the dependence of temperature on the solar variation. While the Chilean results might be excellent, still they were for the most part not checked by independent observations. The Mount Wilson work yielded results on less than a third of the days, and might well be affected by variations of atmospheric humidity incident to the site so near the Pacific Ocean and the cities about Los Angeles. These objections could not but be admitted by Dr. Abbot, and led him to make a great effort to strengthen the observations of solar variation.

Mr. John A. Roebling, of New Jersey, had indicated a strong interest in the work. In conference with Dr. Abbot in May, 1920, he generously gave the sum of eleven thousand dollars for the purposes first, of removing the station theretofore on the plateau near Calama, Chile, to a nearby mountain high enough above the plain to avoid dust and smoke; second, of removing the "solar constant" outfit from Mt. Wilson to the best mountain site available in the United States; third, the balance for any other objects closely associated with these investigations.

FIG. 15.—Montezuma solar observing station near Calama, Chile. Dwelling house, shop and garage.

FIG. 16.—Montezuma solar observing station. Entrance to spectrobolometer tunnel. Also pyrheliometric apparatus.

Under the zealous and able management of Director A. F. Moore, a new observing station was selected and prepared at a place called Montezuma, about 8 miles south of Calama on a mountain rising about 2,000 feet above the local level, and about 9,500 feet above sea

FIG. 17.—Montezuma solar observing station. Coelostat and pyrheliometric apparatus.

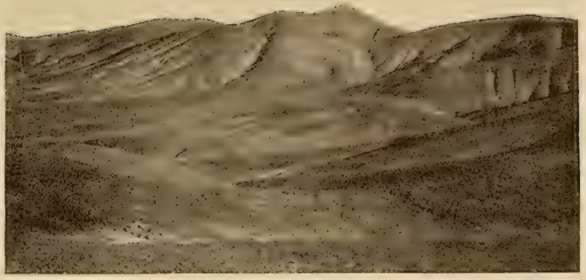

FIG. 18.—Montezuma solar observing station. The peak on which the observatory is located.

FIG. 19.—Hauling materials from Calama for the solar observing station at Montezuma.

FIG. 20.—Solar observing station at Montezuma. Dwelling house.

Fig. 21.—Town of Wenden, Arizona. Mt. Harqua Hala in the background.

Fig. 22.—Packing apparatus to Mt. Harqua Hala.

level. The instruments are arranged in a tunnel excavated horizontally in solid rock near the summit of the mountain. Observers' quarters, computing rooms, garage and shop are located some three hundred feet lower in a sheltered ravine. These quarters can be reached by the auto truck in 50 minutes drive from Calama. No road had to be constructed, as there are no trees in the region, and a way was found smooth enough, and of sufficiently easy grade, without working. Within about two months of receipt of the Institution's telegram, Mr. Moore completed these arrangements, removed the outfit from its former location and recommenced observing August 5, 1920, at Montezuma with the loss of but ten days for the removal. He regards the new site as excellent, and expresses doubt if a better one could be found in the whole world.

FIG. 23.—Observatory on Mt. Harqua Hala.

In December, Mr. Moore returned to the United States, turning over the Directorship of the Chile Station to Mr. Leonard H. Abbot, formerly assistant, who is now assisted by Mr. Paul Greeley. Telegrams giving the values of solar radiation observed are sent as heretofore to Buenos Aires and forwarded from there to Rio de

Janeiro. Both the Argentine and Brazilian Weather Bureaus employ them with approval for forecasting purposes.

Dr. Abbot, with the advice and assistance of the U. S. Weather Bureau, which carried on special observations in several localities for the purpose, selected a site on Mount Harqua Hala, near Wenden, Arizona, as the best place to relocate the Mount Wilson outfit. A building, partly underground, was erected there in July and August by local contractors. Messrs. Abbot and Aldrich occupied the Mount Wilson Station as usual from July 1 to September 15, when the outfit was removed to Mount Harqua Hala, where observations were begun on October 2, 1920. Dr. Abbot took charge and continued observing until January 25, 1921, assisted by Mr. Fred A. Greeley. Mr. Aldrich then relieved Dr. Abbot, and it is expected will himself be succeeded about May 1, 1921, by Mr. A. F. Moore, formerly at Calama.

Fig. 24.—Coelostat and pyrheliometer, Mt. Harqua Hala.

Thus the Institution has now in charge two first-class solar radiation observatories, which are to be operated continuously hereafter until the question of the value of the solar variation as a meteorological datum is definitely settled. Heretofore the measurements have been secured on nearly 70 per cent of the days at Harqua Hala and on nearly 80 per cent at Montezuma. The agreement of results on days in common has hitherto been remarkably close and leads to the hope of surely detecting solar variations as small as 1 per cent.

The conditions of living at Montezuma, while lonely, are not excessively so. Frequent motor trips to the city of Calama for supplies, and occasional visits to the copper mine at Chuquicamata, where great kindness is experienced, help to break the monotony. At Mount Harqua Hala, however, the isolation is excessive. There is a single neighbor, Mr. Ellison, a mining prospector located a mile away, on whose three burros depends the transportation for the observatory. It is 11 miles from Wenden to the foot of the mountain trail, which is 5 miles more in rising about 3,000 feet. Mail is received only about once in two weeks, when supplies are ordered by heliograph signaling with Morse code to the merchants in Wenden, at the cost of several hours hard work with the lights. Water must be hauled from Mr. Ellison's camp, over a mile distant and 850 feet below, except when at rare intervals rain falls. The two observers

FIG. 25.—Top of Mt. Harqua Hala after a snowstorm, showing fog-bank in the background.

cook, wash, cut firewood from the small oak bushes and dwarf yuccas about, and repair or alter the building or the apparatus as occasion requires, besides carrying on the solar investigation.

During the occupation of Mount Wilson in 1920, many pieces of research were successfully carried through by Messrs. Abbot and Aldrich besides the measurements of solar variation. One of the most interesting was the perfecting of the solar cooker begun several years ago. A parabolic cylindrical mirror with polished aluminum surface of about 100 square feet focuses the sun's rays upon a blackened tube filled with mineral oil communicating to an iron reservoir of oil in which are two baking ovens. A continuous circulation of the heated oil keeps the ovens hot enough to perform all cooking operations except frying. Excellent bread, meat dishes, vegetables, cereals, canned fruits and vegetables and preserves were cooked there by Mrs. Abbot, who had charge of this part of the experiments and who was much envied for her cool kitchen and novel appliance by the ladies of the mountain. This solar cooker was constructed on Dr. Abbot's plans largely at the cost of grants from the American Academy of Arts and Sciences in Boston, and the National Academy of Sciences. It has proved successful, but must be regarded

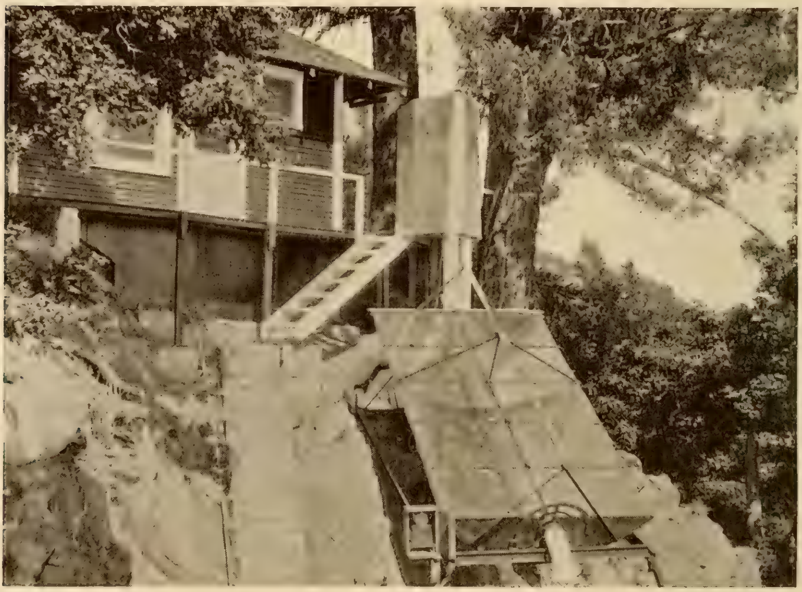

FIG. 26.—Solar cooker on Mt. Wilson.

at least for the present as rather a luxury for rural and relatively cloudless regions, than as a generally useful appliance.

ZOOLOGICAL EXPLORATION IN AFRICA

The generosity of friends of the Smithsonian Institution made it possible to engage Mr. H. C. Raven, well known for his previous work in Borneo and Celebes, to accompany the "Smithsonian African Expedition, under the direction of Edmund Heller in conjunction with the Universal Film Manufacturing Co.," which sailed from Brooklyn, July 16, 1919, on the steamship City of Benares, and arrived in Cape Town, August 13.

FIG. 27.—The Chimpanzee was one of the most interesting animals in the forest. Their calling and shouting could frequently be heard early in the mornings and on moonlight nights. Adult female, Uganda, July, 1920.

FIG. 28.—A fine leopard secured at Masindi, in Uganda, by jacking, June, 1920.

FIG. 29.—The large gray and black civet is a beautiful animal which is seldom seen owing to its nocturnal habits. Budongo Forest, June, 1920.

FIG. 30.—One of the specimens of *Genetta* collected during the time we were encamped on the Kafue River about sixty miles above its confluence with the Zambesi, in Northern Rhodesia, December, 1919.

FIG. 31.—The "standard-wing night jar." Masindi, Uganda, June, 1920.

FIG. 32.—*Lates,* a large perch of Lake Tanganyika.

FIG. 33.—Kaffirs cleaning elephant skeletons at the camp of Major Pretorius, in the Addo Bush. The South African Government has ordered the destruction of these animals—the only herd of the kind in the world today, living so far beyond the confines of the tropics, with the exception of the few in the Knysna Forest. Kenkel Bosch, Cape Colony, September, 1919.

FIG. 34.—Wahutu men dancing at Nyanza on the shore of Lake Tanganyika. Their voices, jingling bells on the ankles and stamping feet add excitement to the scene.

FIG. 35.—Among the Wahutu who live on the coast of the lake and the Watuzi of the mountains it is customary for a few of the best dancers to come forward that their skill in jumping and whirling may be demonstrated to better advantage.

In the vicinity of Cape Town, Mr. Raven was able to collect only insects and invertebrates, and from there he went to the Addo Bush, where 19 days were spent in collecting small mammals and birds. Going through Durban and Johannesburg, Mr. Raven spent two weeks collecting at Ottoshoop in the Transvaal, after which he proceeded to Victoria Falls, and from there he left for the Kafue River region, where he camped for several weeks. After spending some weeks along the Congo, he reached Lake Tanganyika, where camp was made for about a month. The next stop of any length was in Uganda, where a few days over a month were spent in collecting in the Budongo Forest. As the whole forest was in the sleeping-sickness area, it was necessary to get a special permit from the district commissioner to enter it, and the native boys had to be examined by a

Fig. 36.—A young chief of the Wahutu ready to lead his men in the dance. Nyanza, Lake Tanganyika, February, 1920.

FIG. 37.—The Watuzi of the mountainous region northeast of Lake Tanganyika in one of their very picturesque dances. Each man carries a long lance or two, and a bow with one or more arrows.

FIG. 38.—Women of Liri on the Albert Nile repairing the wall of a hut with mud. The walls are made with wooden supports and between these are placed rows of stalks of elephant grass partly buried in the ground and fastened together with grass. The whole is then covered with mud and a roof built so that it overhangs and protects the walls from the erosive effect of rain.

doctor before entering the area and again on leaving it. Work here was finished on July 14, 1920, after which Mr. Raven returned to the United States, sailing from Cairo, September 2, and arriving in New York, September 17.

FIG. 39.—A Dinka woman and her child at Shambe on the upper Nile. It is a rather common sight to see the natives cleaning their teeth with a bit of stick. Sometimes they pound the end or split it with a knife so that it becomes brushlike.

Though not numerically large the collections are of unusual interest on account of the manner in which they supplement those obtained by other expeditions in which the Smithsonian Institution has been interested. Among the most important material may be mentioned 697 mammals (including 272 specimens from South Africa, a region hitherto very imperfectly represented in our collections; 152 from

FIG. 40.—The Victoria Falls of the Zambesi River. Above the falls the river is about a mile wide but drops over a cliff nearly four hundred feet into a narrow gorge which in some places is less than one hundred and fifty yards in width.

FIG. 41.—A native village at Port Bell in Uganda, with Lake Victoria Nyanza in the distance and to the right an acacia tree in which a colony of weaver birds have made their nests.

FIG. 42.—Primitive irrigating machinery, on the Blue Nile at Khartoum, August, 1920. Oxen, donkeys or camels are used to turn such water wheels.

FIG. 43.—Sheep grazing near the temple of Medina Habu in Upper Egypt.

Lake Tanganyika; the chimpanzee of Uganda), 567 birds, 206 reptiles, and 193 fishes. The photographs here reproduced were all taken by Mr. Raven, who has also prepared the legends which accompany them.

BOTANICAL COLLECTING IN AFRICA

Dr. H. L. Shantz, Botanist, Office of Seed and Plant Introduction, Bureau of Plant Industry, United States Department of Agriculture, was also a member of the Smithsonian African Expedition, and his chief objects were to secure live plants of agricultural value for introduction into the United States, to study the agricultural methods of both natives and Europeans, and to collect plants for the National Herbarium of the United States National Museum. This work began at Cape Town, August 13, 1919, and terminated at Port Said, September 2, 1920.

The vegetation of the Cape region has long been known to European botanists, and has received more attention than that of any other portion of Africa. It is difficult to imagine a region which has so many striking features. The wealth of Proteas and Ericas alone would make this region unique. Lilies of various and beautiful types, Iridaceae, Amaryllidaceae, and Orchidaceae, each represented by many genera and species, the Arum lily or calla, which occurs everywhere in wet soil, and Pelargoniums, which here cover the mountain sides, make of this Cape region a natural botanical garden, so rich and varied that any botanist will here find plants of absorbing interest. At Kirstanbosch there has been established the National Botanic Gardens now under the direction of Dr. R. H. Compton. If the well-laid plans are fully carried out, it will be possible to find here all of the more interesting indigenous plants of South Africa, and to this garden will come botanists, horticulturists, and agriculturists interested in South African plants. American botanists would be proud if we had anywhere in our country a garden to compare with it.

East of Port Elizabeth in the Addo Bush, which is a low thorn thicket of trees and vines about 15 to 20 feet high, are food plants of especial interest. Among the succulents, none are more interesting than the speckbroom (*Portulacaria affra*), a source of forage for the wild elephant herd of the bush as well as for other large herbivora, ostriches, cattle, sheep, or other domesticated animals. This plant has been introduced into the United States and is doing especially well in southern California in the lower chaparral zone and should greatly improve the forage value of the natural range. Here are many interesting plants such as the picturesque *Acacia horrida,* with its large white spines, the Boer Bean, *Schotia speciosa,* the young beans of which are cooked and eaten, also many interesting Aloes, Lilies, Cotyledons, and Euphorbias. The elephants' foot (*Testudinaria elephantipes*) and many species of asparagus also occur here.

The Karroid plateau was seen only during the rest period, when its vegetation, which consists of desert grasses and shrubs, is in appearance identical with portions of the Great Basin in Nevada. Especially interesting features of this desert are the great number of species of Mesembryanthemum, several of which are edible, and the Karroo bush (Pentzia), a valuable forage plant, areas of which resemble in general appearance our Bud Sage areas of Nevada and Wyoming.

Fig. 44.—On the Karroid Plateau, west of De Aaar. This desert shrub, known as Karroo bush (Pentzia), is a valuable forage plant, resembling our bud sage of the Nevada and Utah deserts. Cattle, sheep and ostrich are the chief grazing animals.

Passing northwest to the region about Kimberley, there is a scattered growth of Acacias, over an open desert grass type similar in some ways to the vegetation of west Texas and portions of Arizona and New Mexico. The high grasslands of the Transvaal, on the other hand, with a grass vegetation dominated by *Themeda forskalii,* reminds one of *Andropogon scoparius* areas in the drier portions of our prairies. Here corn is the principal crop and the large ranches with houses far apart, each with a clump of trees, make the resemblance to our prairies in the earlier days even more striking.

The portion of the Transvaal north of Pretoria, known as low Veld, consists of a scattered growth of relatively small trees over a grass cover composed of rather coarse tall grasses. This is one of the most widely distributed types and an exceptionally interesting one. The grasses are burned off each year and only such trees as can resist the fires can maintain themselves under this condition. This type becomes somewhat modified at Lourenço Marques, where the vegetation, although quite luxuriant, still showed signs of a prolonged drought period. Here, as in the region north of Pretoria, the Kaffir Orange (*Strychnos pungens*) is abundant, and there are many species of Acacia and Combretum. The Cashew Nut (*Anacardium occidentale*) is everywhere a prominent tree and has the appearance of being indigenous, although introduced from South America. It forms a large evergreen tree and is never cut down by the natives, who prize it both for the fruit and for the nut, from which they secure both food and a strong alcoholic beverage. Another tree of unusual interest is the Morula (*Sclerocarya caffra*), which has a valuable oil and edible nut, with a fruit useful for making jam and an alcoholic drink.

Of the more strikingly beautiful trees of this section are the red flowered and fernlike-leaved *Delonix regia,* the beautiful blue flowered Jacaranda, and the Mahogany Bean (*Pahudia quanzensis*) which produces in its large pods a large black bean with a brilliant scarlet cup-shaped aril at the base and is one of the important timber trees.

The vegetation at Salisbury reminds one of the low Veld above Pretoria, a grassland with scattered trees, singly or often in clumps. At Bulowayo the grasses are less luxuriant and the trees smaller and more xerophytic. The vegetation about Victoria Falls, except for the small forest irrigated by spray from the falls, is also xerophytic in character. At Kafue the grasses seem more luxuriant but the trees are much as at Victoria Falls. Here a number of important fruits were secured, most of which are still undetermined. A nut tree of unusual interest, because of its value for food and oil and the remarkably light weight of the wood, was secured here. It has been known as the Manketti Nut (*Ricinodendron rautanenii*). Here also occurs the Beobab (*Adansonia digitata*), the largest tree in Africa, useful to natives as a source of Bast fiber and as food. The acid white pulp which fills the fruit and surrounds the seed is eaten or dissolved in water to produce a refreshing drink.

The dry, open forest around Elizabethville gives way, before Bukana is reached, to the tall grass and scattered trees which form the great Savanna, which surrounds the tropical forest of the Congo. The Lualaba is lined with oil palms (*Elaeis guineensis*) throughout almost the whole of its course, and during much of the time swamps of Papyrus are abundant along its course. Most interesting were the great numbers of wild Sorghum grasses, some of which may prove valuable in our dry-land agriculture. The oil palm, which belongs to the native who planted it, is probably the most useful native plant in all Central Africa, and its oil is used by the natives as food and for making soap with which to wash their clothes.

Fig. 45.—Two large mango trees (Empe oribo) at Kigoma on Lake Tanganyika. The trees bear two crops of fruit a year, a large crop in January and February, and a small crop in August and September. The fruits are large, fully five inches long, of excellent flavor and with practically no fiber around the seed. The building in the back is the railway station.

The dense tropical forests which cover much of the central Congo were seen at Kindu on the Congo River, where they form a dense canopy, but where the undergrowth is not entirely shut out. At Kigoma and Ujiji, on Lake Tanganyika, the grassland is dotted with large mango trees, the fruit of which is large and of excellent quality. These trees were probably introduced by Arab slave dealers and merchants, and probably all originated as seedlings. Along the shore of Tanganyika in Urundi many plants were collected. In the highland back of the lake at N'gano N'gano, the rolling hills are covered

FIG. 46.—Watuzi chiefs dressed for the dance. They are, from left to right, Kikovio (son of Ararawe), Mizambo (a Bagamwa or prince of the fourth generation) and Ararawe (brother of the head chief, Andugu).

The dress consists of an undergarment of bark cloth, made from the bark of a fig tree, of two skins of leopard or serval cat, one over the shoulder and one around the loins. Each carries a long bow, decorated with banana fiber, two arrows and a long spear.

They live largely on cattle, and inhabit the high mountain grasslands of Urundi. They are exceedingly tall, slender and athletic men, are alert and pleasant and are almost untouched by white influence.

with excellent grasses of high forage value, and support thousands of cattle. The Watuzi who inhabit this region are one of the least known but most interesting tribes in all Africa. They are tall, slender, athletic men, with thin lips and straight noses, and are probably the best athletes in the world, especially at high jumping, which is one of their chief accomplishments. Many grasses and many bulbous plants from this region give promise of value as plant introductions. A great variety of bananas, beans, and cereals are grown by these natives.

Fig. 47.—A grove of cocoanut palms at Dar es Salam, Tanganyika Territory, with a native (Swahili) hut in the background.

The whole region about Dar es Salam and for fifteen or twenty miles inland is occupied by an almost continuous cocoanut palm grove. The notches in the trees facilitate the gathering of the nuts.

At Dar es Salam, a broad strip of coast is given over largely to the cultivation of the coconut palm, although the streets are often lined with wild figs, *Delonix regia,* and *Terminalia catappa.* Zanzibar is given very largely to the cultivation of cloves, and here are also grown many tropical fruits, and there is a small but exceedingly interesting botanical garden. Tanga is somewhat similar to Dar es Salam in vegetation.

FIG. 48.—Bank of the Victoria Nile at Masindi Port in Uganda. A luxuriant growth of papyrus, water-lilies, morning glories and other water plants. Much of Lake Kioga is covered with this type of vegetation.

While the vegetation of the north shore of Lake Victoria is rich and varied and reminds one of that seen in the Congo and on Lake Tanganyika, the outstanding features in Uganda are the areas of elephant grass, *Pennisetum purpureum,* and the immense tracts of bananas which extend for miles and miles, for bananas are relatively as important to Uganda as corn is to Illinois.

There are several small tropical forests in Uganda, and at Entebbe an unusually interesting botanical garden. The flame of the forest (*Spathodea*), a prominent tree through much of tropical Africa, the kidurii (*Antiaris toxicaria*), and many other trees are prominent here. At Entebbe one may see Para rubber, Çera rubber, Cacao, sugar cane, yams, corn, rice, wheat, and other temperate crops harvested at the same time.

The principal results of the expedition were the collection of about 1,000 botanical specimens for the National Museum, and the introduction of about 1,600 plants for growth as agricultural plants in this country; the more important being forage plants, nut plants, fruits, and vegetables. The acquaintance was made of many men interested in plants and agriculture, throughout the Continent, who can be of service in connection with securing additional material. First-hand observations were made of the methods of agriculture pursued by African tribes as well as the Europeans, and a large number of photographs were taken which illustrate the natural vegetation and agricultural crop methods.

FIG. 49.—The Uaso Nyiro River at Archer's Post. It flows through a semi-desert country abounding in big game animals. It is lined throughout by groves of Dum Palm.

AUSTRALIAN EXPEDITION

During the past year Mr. Charles M. Hoy has continued the work of collecting material in Australia, under about the same conditions as those mentioned in the last report on explorations. In this period collections were made at the following localities:

"Farina, S. A.: Work in the Farina district was done at Lindhurst, 30 miles east of the town of Farina. Nineteen days were spent there, resulting in the collection of 110 birds and 64 mammals. A few reptiles and insects were also collected."

"Kangaroo Island, S. A.: Twenty-six days were spent, in the field, on Kangaroo Island with the result of 85 mammals, 51 birds, and miscellaneous reptiles, amphibians, and marine specimens collected."

FIG. 50.—Aboriginal grave yard, North Australia.

"Port Lincoln (Eyres Peninsula), S. A.: Twenty-two days were spent in the field resulting in the collection of 86 birds and but 15 mammals. A few miscellaneous specimens including reptiles, crustacea, etc., were also obtained."

"Busselton, W. A. (50 miles south): Camp was pitched 50 miles south of the town of Busselton, on the edge of the Government Timber Reserve. Forty days were spent in camp (May 14–June 23). The weather was the worst that I have experienced. During the whole 40 days, there were only three days free from rain. Over 18 inches fell in that time. It was impossible to keep things dry and even the tent fly went green with mould. Despite these handicaps, however, a pretty fair collection was obtained. The collection contains 94 mammals, 46 birds and a few miscellaneous alcoholic specimens (reptiles and land shells)."

FIG. 51.—A rufous rat-kangaroo from New South Wales.

FIG. 52.—Phascogale, a mouse-like marsupial from New South Wales.

FIG. 53.—A young kangaroo. Photographed on Kangaroo Island, Australia.

FIG. 54.—An Echidna or "spiny anteater" photographed on Kangaroo Island, Australia. The long bird-like beak projects from behind the plant which conceals the animal's face.

"Derby, W. A. (32 miles southeast): Twenty-three days were spent in the above locality, August 7-29. The locality visited was very poor in both mammal and bird life and a collection of only 43 mammals, 68 birds and 10 reptiles secured."

FIG. 55.—A native of North Australia.

In the last letter received from Mr. Hoy, from Port Darwin, Northern Territory, dated September 25, 1920, he writes, in part, as follows:

> "I have decided to work the Northern Territory and then go overland to Queensland via the old wagon road. I will travel in a buckboard and will go south from here, to the Catherine River, then east along the Roper, and then to the McArthur. On reaching the latter river I will go south along the river, then to Anthony's Lagoon and east across the tableland to some point in Queensland—most likely Gloncurry. The trip will take about four months and will have many advantages. The road is an easy one, being an old established route with plenty of good water along the way, and the trip ought to be productive of very good results."

During the year two shipments were received from Mr. Hoy, the last one arriving here in September. A total of 440 mammals, well prepared, several of which were hitherto unrepresented in our collection, together with series of skeletal and embryological material; 570 bird skins, with 24 additional examples in alcohol, and smaller collections of reptiles, amphibians, insects, marine specimens, etc., were received.

Up to the time of Mr. Hoy's visit to Australia the Museum had received not over 900 specimens of birds from that country; the majority of these were old, mounted, and without precise data, some of them dating back to the time of the Wilkes Exploring Expedition. About 350 mounted birds, displayed at the Centennial Exposition in Philadelphia in 1876, by the several Australian colonies, and presented to the National Museum at the close of the exposition, formed the largest single contribution to our collection; the remainder of the material consists of many smaller lots, obtained by gift or exchange at long intervals. About 140 species, including several of the distinct forms of Kangaroo Island, are represented in the material received from Mr. Hoy, all well prepared and with adequate data. Some of them are quite new to the Museum collection, and others, such as the lyre bird, have not previously been available in our study series.

BIOLOGICAL EXPLORATION IN HAITI

Dr. W. L. Abbott, of Philadelphia, accompanied by Mr. E. C. Leonard, of the National Museum, as botanical collector, made a visit of exploration to southern Haiti from February to July, 1920. Dr. Abbott undertook this visit chiefly that he might study the bird life of Gonave Island, hoping to complete certain series he had collected on a former visit. The island is about 30 miles long and 10 miles broad, and consists of a low mountain range bordered by a belt of foothills that merge gradually on the north coast to a level beach fringed by mangroves, but on the south slope descend rather abruptly into the sea. Dense thorn thickets cover the arid mountain sides and foothills, while the uplands, called La Table, open into large grassy tracts with only occasional trees or shrubs. Due to the scarcity of water and, in many places, to large outcrops of bare coral rock, the island is poorly adapted to agriculture, but the grassy uplands furnish excellent grazing. The forests yield a fair amount of lignum vitae. The party spent three weeks on the north coast, working around Anse Galette and Etroite, and later a week on the south coast in the vicinity of a small fishing village called Pikmi.

The regions visited on the mainland were St. Marc, Etang or Manneville, Fond Parisien, La Mission, Furcy, and Pétionville, with Port au Prince as base.

FIG. 56.—Royal Palm groves of Fond Parisien.

Etang is on the northwest shore of Etang Saumatre, a large lake nearly 20 miles east of Port au Prince, bordered on the west by the plains of the Cul de Sac, on the north by the mountains of Grand Bois, and on the south and east by the foothills of La Selle Mountains. The lake is about 50 feet below sea level and very salty. Among the interesting natural features of the region is a series of large springs, flowing into the lake through a belt of marshy meadows which are covered by a short sod composed almost entirely of several species of sedges. An excellent opportunity was offered to study both the arid cactus forests and cat-tail marshes that occur in the Cul de Sac.

The large royal palm groves of Fond Parisien, situated on the southeast shore of Etang Saumatre, give it a picturesque appearance.

In old French times Fond Parisien was considered one of the most beautiful spots in Haiti, but a flood has covered the greater part of this once fertile district with stones and gravel, transforming it into a desert. The large areas of black mucky swamp land to be found here are utilized in sweet potato farming, while some cotton is grown in the drier parts.

FIG. 57.—"Strangler plant" (a species of *Clusia*) on a large leguminous tree near Pétionville.

La Mission is a day's journey to the south from Fond Parisien. The most striking features of this region are the open pine forests

FIG. 58.—Pic de Bromt (called " ~~Morne de Wézan~~). A new species of grass was found growing on the summit of this mountain.

'Morne St Vincent')

FIG. 59.—Weaver bird and nests in a thorn tree. Fond Parisien.

and occasional wet thickets, the latter sheltering a luxuriant growth of ferns. The natives are, however, rapidly destroying the pine trees both by burning the forests repeatedly and by girdling the pines for splinters, which are sold in the markets as kindling.

Furcy and Pétionville are not far from Port au Prince. Both are easily accessible and are among the few localities which have been visited by naturalists.

Nearly 10,000 specimens of plants were collected, as well as a number of land shells and insects.

The birds obtained by Dr. Abbott during this expedition numbered 201 skins, with a few alcoholic specimens and skeletons. By far the most interesting ornithological observation made was the discovery in some abundance of an introduced weaver bird, *Hyphantornis cucullatus* (Müller), a native of West Africa. This species was found at several points in Haiti, where it occurs in colonies and affects much the same type of country as do related species in Africa. Nearly completed nests, without lining, were found about the middle of May, but no eggs had been deposited at this date. They are strongly woven of narrow strips of palm or banana leaves, and have an entrance at the side. An illustration of the manner of nesting is shown in figure 59. Two smaller species of west African weavers, belonging to other genera, are known to occur in Porto Rico, where they have existed for many years, but the date and circumstances of their introduction, as well as those of the species discovered in Haiti, are at present unknown.

MALACOLOGICAL FIELD-WORK IN CALIFORNIA AND THE HAWAIIAN ISLANDS

On the way to the First Pan-Pacific Scientific Congress held in Honolulu, August 2-20, 1920, Dr. Paul Bartsch, curator of mollusks, U. S. National Museum, stopped for three days in Glacier National Park, where some collections were made.

He also spent a day on shipworm investigation about Mare Island, where he had placed at his disposal, by the commandant of the station, a tug and pile extractor, and the necessary officers and men to make every minute of his stay count, the result being a careful examination of pilings throughout the stretch of San Pablo Bay and the adjacent shores of San Francisco Bay. This investigation resulted in establishing the fact that the mollusk which has been doing the damage estimated at some $25,000,000 last year is a new species of *Teredo,* which Dr. Bartsch has named *Teredo beachi* in honor of the commandant of Mare Island.

Dr. Bartsch, in preparing a monograph on the land shells of the *Epiphragmophora californiensis* group, was very much puzzled how to account for the presence of two very closely related subspecies at Pt. Pinos, California. He took this occasion to visit Pt. Pinos, and there found that the two subspecies do not occupy the same habitat. The smaller of the two was found in great abundance under plants on two of the rocks lying off the Point, separated from the mainland by a gap across which one could easily leap, while the larger subspecies, which was rather rare, was found on the ground, buried beneath needles and vegetable detritus. Two subspecies of the *Epiphragmophora tudiculata* group were found to occupy a similar range.

Fig. 60.—The home of *Epiphragmophora californiensis* Lea, a species of land shells, off Pt. Pinos, California.

Mr. Henderson and Dr. Bartsch arrived in Honolulu a few days prior to the meeting, and this time was used for collecting land, fresh-water, and marine shells on the island of Oahu. They also collected mullusks during their sojourn about the wonderful crater of Kilauea, on the occasion of the visit by the congress to the island of Hawaii. Several stations were likewise made between Kilauea and the Kohala coast. A large number of marine shells were secured from the rocky shores of Honaunau Bay.

Since the first accommodations to be secured for the return were dated September 8, the intervening time between the close of the congress and this date was spent in collecting specimens. Dredgings were made in Pearl Harbor, where the commandant placed one of the dredges at their command. They were also rendered the necessary assistance in making a search for shipworms, with the result that a new species of *Teredo* was discovered, which has been named *Teredo parksi,* in honor of Admiral Parks, in charge of Yards and Docks, U. S. N. They also dredged in Maunalua Bay, on the south side of Oahu and in Kaneohe Bay, on the east side of the same island. Specimens were also collected on various occasions at Haleiwa Beach, on the north end of Oahu, and the beach and shallow water adjacent to their cottage at Waikiki were thoroughly scratched over. Trips were also made into various parts of the mountains, where land shells of many kinds were secured.

Another excursion carried them to the island of Maui, where marine shells were collected wherever possible along the shore, and land shells were secured on their ascent of the magnificent extinct volcano of Haleakala.

One of the very interesting observations made on this trip to the Hawaiian Islands was the finding of an existing marine flora and fauna at a considerable elevation above the level of the sea on the gently sloping bench at the southeast point of Hanouma Bay. This flora and fauna consist of algae, quite a number of species of mollusks, crustaceans, echinoderms and other marine organisms, which occupy pools and puddles kept ever moist and supplied with fresh water by the spray from the breaking surf, which incessantly pounds that shore. Dr. Bartsch considers this an important observation, since the occurrence of fossiliferous laminae bearing marine organisms between sheets of lava has been held to indicate that they were deposited at or below sea level and their occurrence above this has been held as evidence of elevation. We have here an instance which indicates that this is not necessarily the case, for such a lamina would be produced if a new outpouring of lava were to cover up the place mentioned.

BOTANICAL EXPLORATION IN JAMAICA

In February, 1920, Mr. William R. Maxon, Associate Curator in the Division of Plants, United States National Museum, and Mr. Ellsworth P. Killip, aid, were detailed to make botanical collections in Jamaica. The expedition was made possible largely through the co-operation of the New York Botanical Garden, the Gray Herbarium of Harvard University, the Field Museum of Natural History, the University of Illinois, the Arnold Arboretum,

FIG. 61.—Windsor Plantation, south of Port Antonio.

FIG. 62.—Residence at Cinchona.

FIG. 63.—Higher peaks of the Blue Mountains as seen from the southwest; Mossman's Peak (unexplored) at the left, separated from Blue Mountain Peak (2,225 meters) by Portland Gap.

FIG. 64.—In the heart of the Blue Mountains. The denuded areas are landslips due to erosion in areas long under cultivation in coffee.

and Mr. Oakes Ames in contributing to the field expenses of the work. Two months were spent in the island, and upwards of 10,000 specimens were brought back, representing about 1,700 collection numbers. The material has been shared among the contributing institutions, the ferns and flowering plants having already been fully identified.

Fig. 65.—Fern-covered bank on trail to Morce's Gap. The tree ferns in the center are *Cyathea pubescens.*

From headquarters in Kingston field-work was carried on in several widely separated parts of the island, the courtesy of free transportation on the Jamaica Railway having been extended by the colonial government. Through the kindness of Mr. J. G. Kieffer, general manager of the United Fruit Company in Jamaica, a house on the company's plantation at Windsor, in the rich banana region south of Port Antonio, was placed at the disposal of the party. About 10 days was spent here, trips being made to Mooretown, Mill Bank, Cuna Cuna Pass, and the northern foothills of the John Crow range.

FIG. 66.—A characteristic fern (*Dicranopteris bifida*), growing in vinelike masses near Morce's Gap.

The most productive period was one of three weeks in March, spent in the Blue Mountain region, with headquarters at the botanical station at Cinchona, the lease of which had been renewed by the Smithsonian Institution in January, 1920. Located on a projecting southern spur at an altitude of 1,500 meters, equipped with a serviceable laboratory and most comfortable living quarters, Cinchona served as an excellent base for botanical exploration in the Blue Mountain region, most of the peaks lying within fairly easy reach. Extensive collections were made on John Crow Peak, at New Haven Gap and Morces Gap, and in the vicinity of Cinchona, as well as on trips to Thompson's Gap, Hardward Gap, and the summit of Blue Mountain

Peak. Over 800 numbers were collected in this region. In preparation for a projected work by Mr. Maxon on the ferns of Jamaica, particular attention was paid to this group, nearly 200 species being here collected.

Other regions visited include Hollymount, on the upper slopes of Mount Diabolo, in the central part of the island, the coastal territory of Montego Bay, and the southern border of the " Cockpit Country," the last a wild, little inhabited, wooded area of innumerable limestone sinks lying southeast of Montego Bay. Collections at Cook's Bottom, Mulgrove, Mocho, and Ipswich yielded a number of new or otherwise very interesting species. Just before leaving Jamaica Mr. Maxon made a brief visit to Pigeon and Great Goat islands, lying off Old Harbour.

Much of the success of the trip is due to assistance extended freely by officials of the United Fruit Company, acknowledgment of which is gratefully rendered.

BOTANICAL EXPLORATION IN BRITISH GUIANA

Mr. A. S. Hitchcock, Custodian of Grasses, visited British Guiana, making the trip through the co-operation of the United States Department of Agriculture, the New York Botanical Garden, and the Gray Herbarium. He left New York, October 4, 1919, and arrived at Georgetown, October 22, stopping on the way at St. Thomas, St. Croix, St. Kitts, Antigua, Guadeloupe, Dominica, Martinique, St. Lucia, and Barbados. He left Georgetown, February 2, 1920, and arrived in New York, February 16, stopping four days in Trinidad and one day at Grenada.

Six weeks were spent at Georgetown, and other points along the coast; three weeks at the Penal Settlement on the Mazaruni River, from which were visited Bartica, Kalacoon, and Kartabo; two weeks on a trip up the Demerara, Essequibo, and Potaro rivers to Wismar, Rockstone, and Tumatumari; and ten days on a visit to the Northwestern Distict, including Morawhanna on the Barima River, Issorora, the Rubber Station on the Aruka River, and the Yarikita Police Station on the Venezuelan border.

Four sets of plants were collected including 1,134 numbers, with extra sets of the grasses. On account of the extremely damp climate it was necessary to use artificial heat in drying the specimens. Two oil stoves were kept burning night and day, the specimens being between corrugated paper. After drying, the plants were sprinkled with naphthalene powder to prevent subsequent molding.

British Guiana has an area of about 90,000 square miles, is about 400 miles deep, and extends about 250 miles along the coast (Lat. 1°-8° N., Long. 57°-61° W.). There are three counties: Demerara, including the drainage system of the Demerara River and to the Abary River on the east; Essequibo, including the drainage system of the Essequibo River and all to the west; and Berbice, including the drainage system of the Berbice River and east to the Courantyne River. Georgetown, at the mouth of the Demerara River, has a population of about 60,000. The only other city is New Amsterdam, at the mouth of the Berbice River, with a population of about 9,000. The entire population of the colony is about 300,000, about 4,000 of whom are whites. The bulk of the population consists of East

FIG. 67.—St. Thomas. The wall is covered with coralita (*Antigonon leptopus*), an ornamental vine with handsome racemes of pink flowers. The palms are royal palms.

Indians (42.7 per cent) and negroes (39 per cent). The chief product of the colony is sugar, which, together with the by-products rum and molasses, constitutes about three-fourths of the exports. Other products are gold, rice, balata, timber, and cattle. The country is fairly healthy, the death rate being about 35 per 1,000 (14.8 per 1,000 among whites). Yellow fever is absent, but malaria and dysentery are prevalent.

FIG. 68.—Antigua. An old sugar mill. These old stone mills, formerly used for crushing the cane, are common on the islands. Oxen were attached to the long beam. The crushing or grinding is now done in modern sugar factories.

The rainfall at Georgetown is about 90 inches, with a dry season September to November, and another short dry season in the spring. The temperature at the same place is, in the daytime, about 88° F. in the summer, falling four to six degrees at night, and in winter four to six degrees lower. The temperature at night in winter rarely falls below 75° (the minimum record for 35 years is 69°).

The coastal region of the colony for 10 to 40 miles inland is a flat plain scarcely above sea level. Back of this there is a belt with hills as much as 200 feet high. Toward the southwest the land rises and at the Venezuelan-Brazilian border culminates in the famous Mt. Roraima, a table mountain rising to a height of 8,500 feet. With

FIG. 69.—Georgetown, British Guiana. One of the main streets with rows of rain tree (*Samanea saman*).

FIG. 70.—Morawhanna, British Guiana. A typical village of the interior.

the exception of the savannas of the southern part of the country (Rupununi District) and a few other small areas, the whole country is covered with dense virgin rain-forest.

Communication in the interior is almost entirely by boat along the numerous streams, but unfortunately is hindered by falls and rapids above the influence of the tide (30 to 60 miles).

FIG. 71.—A giant mora tree (*Dimorphandra excelsa*) in the virgin forest of British Guiana, near Tumatumari. The base is broad and buttressed. Attached to the trunk is a species of Marcgravia.

The scientific activities of the colony are mainly under the control of Prof. J. B. Harrison, Director of Science and Agriculture, who extended to Mr. Hitchcock many courtesies.

The Jenman Herbarium, an important collection of British Guiana plants, is at the office of the director in Georgetown. There is an excellent botanical garden with a large collection of trees and shrubs, including a very fine series of palms.

COLLECTIONS OF LIVING ANIMALS FOR THE NATIONAL ZOOLOGICAL PARK

As in former years, friends of the Smithsonian Institution, while on expeditions abroad, collected and sent to Washington interesting living animals for the National Zoological Park.

Mr. W. J. La Varre, who has before made collections of this kind, visited South America and explored the upper waters of the Amazon. He left the United States in June, 1919, and traveled directly to Manaos, Brazil, the jungle metropolis about 1,000 miles up the Amazon at the mouth of the Rio Negro. From Manaos he ascended the Rio Negro, by small steamer and launch, into Venezuela. He found much of interest, but no trace of the so-called " cannibals " of the region, or of anything savage, either beast or man. The natives, poor, half-breed rubber gatherers—Spanish, Portuguese, Negro, and Indian mixtures—treated him cordially and most hospitably, sharing their rude homes of thatch with him and giving him as much of their food as they could possibly spare. Six months were spent with these

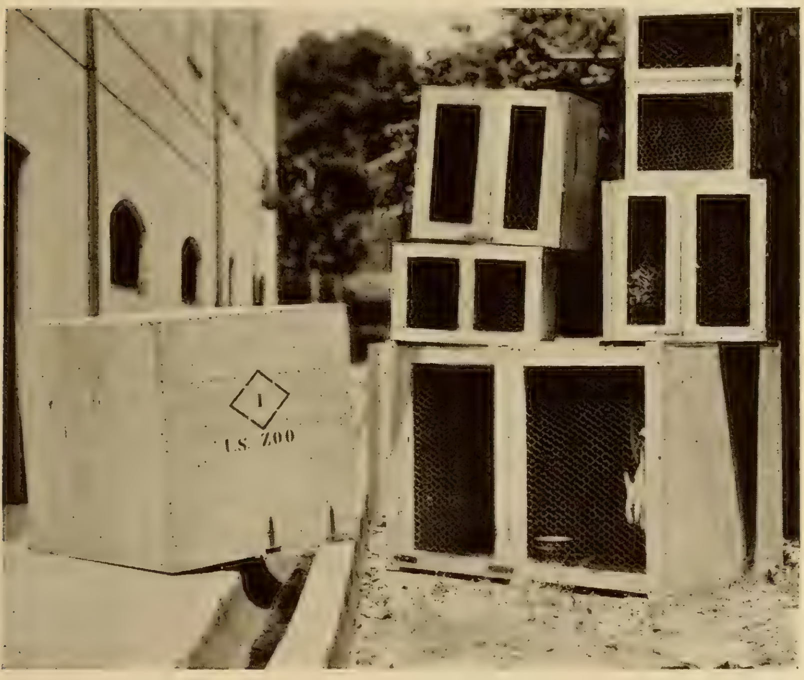

FIG. 72.—Animals for the National Zoological Park awaiting shipment at Manaos, Brazil. Photograph by La Varre.

FIG. 73.—Girls of the Rio Negro, Brazil. Photograph by La Varre.

FIG. 74.—Native Batalao of rubber gatherers, Rio Negro, Brazil. Photograph by La Varre.

kindly, primitive people, in geographical and zoological research, exploration, and hunting.

The general scarcity of mammal life along these famous rivers was surprising. So many rubber gatherers live here that the country has, in fact, been hunted out, and the natives themselves are often hard pressed for food. Pacas and peccaries were plentiful, and numbers were shot for use in the camp. Tapir tracks were crossed several times, and small deer were occasionally killed by the natives.

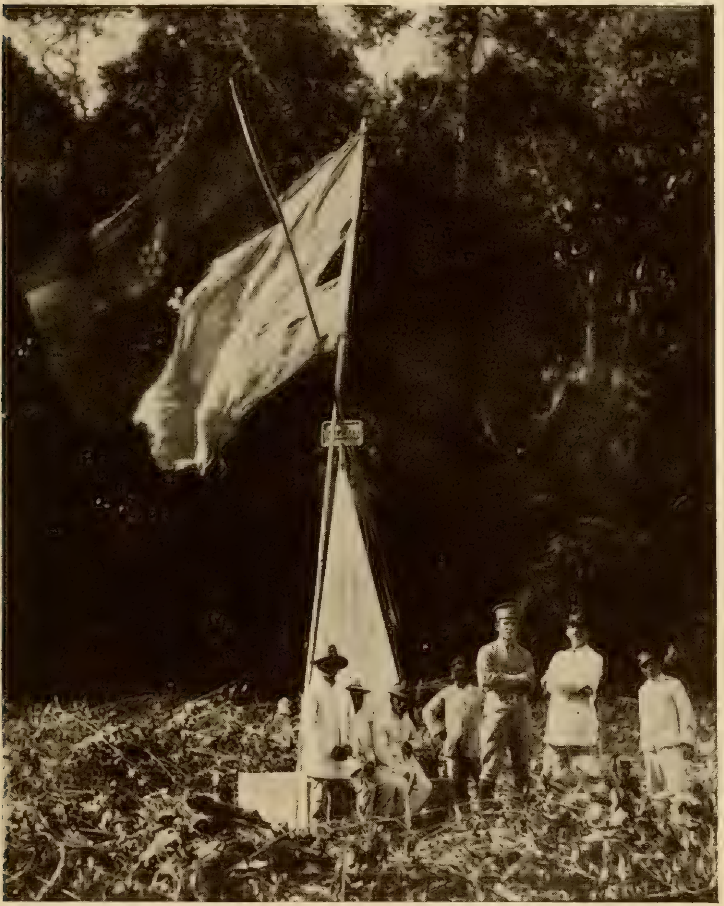

FIG. 75.—Border marker between Brazil and Venezuela, with government officials of both countries. Photograph by La Varre.

Curiously enough, only two wild monkeys were observed, although examples of various species were commonly seen in the possession of natives. Birds, on the contrary, were plentiful—among the conspicuous species were toucans, curassows, macaws, and parrots. Mr. La Varre left the jungle in February, and arrived in the United States near the end of March, 1920. His collection of living animals, which he presented to the park, included a specimen of the rare black-headed ouakari monkey (*Cacajo melanocephalus*), a species never before represented in the collection. This monkey is a member of the only genus of short-tailed monkeys inhabiting the New World, and is very seldom seen in captivity.

Fig. 76.—White-backed Trumpeter (*Psophia leucoptera*) from the Rio Negro, now in the National Zoological Park. Photograph by La Varre.

Other animals in the La Varre collection are capuchin and squirrel monkeys, an ocelot, two margay cats, egrets, a scarlet ibis, and a number of parrots and paroquets. A large living specimen of the rare and curious matamata turtle, a gift to the park from Mr. A. T. S. Hore, of Manaos, was brought home with the lot. Another American resident of Manaos, Mr. Edward B. Kirk, also contributed some interesting birds, among which was a fine specimen of the very rare white-backed trumpeter (*Psophia leucoptera*) from the Rio Negro.

A second collection of living Neotropical animals was brought to the park by Dr. William M. Mann, of the Bureau of Entomology, United States Department of Agriculture, who visited Honduras in the spring of 1920. Dr. Mann's duties in other lines naturally absorbed most of his time, but he succeeded in landing in good condition a number of valuable animals. His collection included pacas, agoutis, kinkajous, squirrels, a mantled howler monkey, and some reptiles, among which was a specimen of Rossignon's snapping turtle, a species rarely taken by collectors.

Other valuable animals were collected and presented to the park by Hon. Henry D. Baker, American Consul at Trinidad, British West Indies, and by Mr. Isaac Ellison, of Singapore, Straits Settlements. Mr. Ellison succeeded in landing and placing in the park a thrifty young male orang-utan, three years old. This is one of the most interesting and valuable gifts received in many years. The animal has now become thoroughly adapted to his new home and promises to become a most unusually attractive addition to the collection.

The National Zoological Park also shared in the large collection of African animals collected and brought to America for the New York Zoological Society by Mr. A. K. Haagner, director of the National Zoological Gardens at Pretoria, South Africa. Included in the lot received at Washington are a lechwe antelope and a specimen of the Rhodesian baboon, recently discovered and described by Mr. Haagner.

ANTHROPOLOGICAL EXPEDITION TO THE FAR EAST

Under the auspices of the Smithsonian Institution and in connection with the Rockefeller Foundation and the Peking Union Medical College, Dr. Aleš Hrdlička made an extensive trip to the Far East during the first half of 1920. The objects of this trip were continuation of the studies relating to the origin of the American aborigines; examination of the oldest skeletal and other human remains in Japan; the furthering of the interests of physical and medical anthropology in China; and a personal visit to the rapidly disappearing full-blooded Hawaiians. The countries visited included Japan, Korea, Manchuria, northern China, the boundary of southern Mongolia, and the islands of Oahu and Hawaii in the Hawaiian Archipelago.

In Japan especial attention was given on one hand to the physical characteristics of the people, and on the other to the prehistoric anthropological collections. The latter have by now assumed considerable importance. They are deposited in the universities and medical schools of Tokio, Kyoto, Sendai, Osaka, and Kumamoto,

FIG. 77.—Average types of Japanese children. Photographs presented by Mr. Tsunawo Araki.

and are being steadily added to by new explorations in prehistoric mounds and shell heaps. They date all from the Neolithic period, nothing earlier having thus far been discovered in eastern Asia; and they show both an old diversity, as well as more or less relation to the Aino and to the Japanese.

FIG. 78.—Japanese child.

In Korea special facilities were obtained for visiting the museum at Seoul, which was found unexpectedly rich in Korean and Turkestan antiquities. The people represent quite a distinct subtype of the yellow-brown stem from that of the Japanese as well as that of the Chinese; they are more like the western Siberian or southeastern Russian Tatars.

One of the most interesting features in Korea are the mound burials of the people. These mounds are all hemispherical, in contradistinc-

FIG. 79.—Of the best in Central Japan. Photographs presented by Mr. Tsunawo Araki.

tion to the conical mounds of Manchuria and northern China. They are of various sizes; they occur singly, in clusters, and in whole "cemeteries"; they are frequently assiduously cared for, and many are most picturesquely located on the slopes of hills, where they appear to the best advantage. The Koreans are a modern race of mound builders. The country is full of archeological remains, including some big mounds and dolmens, and deserves much closer scientific attention than it has so far received.

FIG. 80.—A Korean Hamlet. From a few houses to large villages, they cluster in the nooks of the hills like mushrooms.

The Manchus and the northern Chinese, particularly those of the Chihli Province, are for the most part tall, well-built people, quite different in bearing and even in physiognomy from the southern Chinese, though there is no sharp delimitation. They, too, present a fruitful field for detailed anthropological investigation.

The southern or inner Mongolians were found to be a rather mixed lot, more so than the northern Mongolians who were visited by Dr. Hrdlička in 1912. A series of photographs was secured here as well as in Korea and Japan. In Japan, through the kind help of Dr. Tsunawo Araki, there was obtained a large collection of portraits of Japanese children, while the Tokyo Dental College, through the good offices of Professor Mitsuru Okada, contributed several hundreds of portraits of its students.

China, for the anthropologist and archeologist, is one vast open museum, in which something of absorbing interest is met with at almost every step. In addition the people, and particularly the students in colleges, impress one with their native abilities. China in the future may well be relied upon to give the world many a philosopher and scholar of distinction.

Fig. 81.—Mounds near a Korean village. At sunrise on special days it is not unusual to find before each mound a prostrate figure in devotion before the grave of a father or mother.

The stay at Peking was principally devoted to assisting in the development of the medico-anthropological work at the Union Medical College, and the organization of the "Anatomical and Anthropological Association of China." The college has an excellent staff of well-trained young workers such as Drs. Cowdry, Black, Howard, and others, the majority of whom are seriously interested in those branches of anthropology which are nearest the medical sciences; and there are bright prospects for anthropological work in other parts of China, due to the presence there of English-speaking (mostly American)

FIG. 82.—Babies and their nurses at Sen Sen, Korea.

FIG. 83.—A young matron of a good family, with baby and servant, at Sen Sen, Korea.

medical missionaries, who are naturally interested in investigations of that nature.

While at Peking, certain investigations were carried on, with the help of Professor Davidson Black, on Chinese teeth; and a conference was held with the representatives of several Chinese ministries, as well as of the Chinese Geological Survey and the Peking Union Medical College, on the subject of the foundation at Peking of a "Museum of Natural History of China," the establishment of which would mean so much for the progress of the Chinese themselves, and for facilitating the work of foreign men of science in the Chinese Republic. There exists already, under the direction of Dr. V. K. Ting, a very creditable geological museum, which could serve as a nucleus of the more comprehensive institution.

FIG. 84.—A Korean girl.

FIG. 85.—The surgical class at Severance College, Seoul, Korea, Dr. A. I. Ludlow operating.

FIG. 86.—Chunhuzes. A rare photograph of the North-Mongolian brigands.

On the return trip a stop was made at Hawaii, and with the kind assistance of the staff of the Bernice Pauahi Bishop Museum at Honolulu, and particularly of Dr. Gregory and Mr. Stokes, some studies were carried out on the native Hawaiians in several of the most favorable localities. It was found that the Hawaiians, even where free from historic admixture with whites or negroes, present an old blend of several ethnic elements (yellow-brown, Indo-European, and Negro or Negrito); this blend, however, has already reached a degree of approach to physical unity which permits the student to deal with it as with a racial subvariety or subtype. But this subtype is rapidly vanishing through new contacts.

FIG. 87.—Chinese woman with artificially deformed feet, at Peking. This crippling deformation is still extensively practised by the Chinese. A Chinese woman without deformed feet is not regarded as "comme il faut."

FIG. 88.—Full-blood Hawaiian.

FIG. 89.—Full-blood Hawaiian.

FIG. 90.—Full-blood Hawaiian.

FIG. 91.—Full-blood Hawaiian.

THE OJIBWA OF MINNESOTA

During the fall of the past year, Dr. Aleš Hrdlička was called once more to Minnesota to assist the Department of Justice in settling the subject of mixed bloods and pure bloods among the Ojibwa. (See Smithsonian Explorations for 1917.)

The whole work, now concluded, presents a good illustration of the practical value of anthropology in certain directions. The results are outlined in the following extracts from a letter to the Institution from Mr. R. C. Bell, Special Assistant to the Attorney General:

> The Department of Justice in 1910 instituted approximately 1500 suits in the United States Court for the District of Minnesota involving Indian lands. This litigation to January, 1916, has cost the government a very large sum and little had been accomplished.
>
> The blood status of the Indians became the determining factor and it was ascertained that all the available evidence (principally testimony as to genealogy) on this issue was found unreliable and always unsatisfactory. Consequently, the Department of Justice, in the spring of 1916, procured the services of Dr. Hrdlička to make a physical examination of the Indians and report his conclusions as to their status. The doctor spent more than three months in this work and examined approximately 800 individuals.
>
> The Department of Justice, the Department of the Interior, and counsel for the defendants agreed to accept his findings as a basis for settlement, and the litigation now has been terminated, resulting in the recovery of more than $1,000,000 in land and money for the Indians; besides, the cost of the work since 1916 has been insignificant in comparison to the cost prior to that time.
>
> Furthermore, a commission was created by an Act of Congress to make a roll of the allottees of the White Earth Reservation. The law required, in addition to much other information, that the blood status of the Indians be given. This roll, which affects the title to approximately 725,0000 acres of land, has been completed; and the commission in preparing it followed the findings of the doctor. Only those thoroughly familiar with the situation can appreciate the far-reaching importance of this work.

FIELD-WORK ON THE MESA VERDE NATIONAL PARK

The Chief of the Bureau of American Ethnology, Dr. J. Walter Fewkes, continued his field-work on the Mesa Verde National Park, Colorado, during June, August, and September, 1920, in cooperation with the National Park Service of the Department of the Interior. Excavation and repair work was done on the Fire Temple Group and Oak Tree House, ruins in Fewkes Canyon and at Cedar Tree Tower, situated about a mile north of Spruce Tree House, leading to important contributions to our knowledge of the culture of cliff dwellers.

He was ably assisted in this work by Mr. J. A. Jeancon, who made the originals of the ground plans of the Fire Temple Group and Cedar Tree Tower here published.

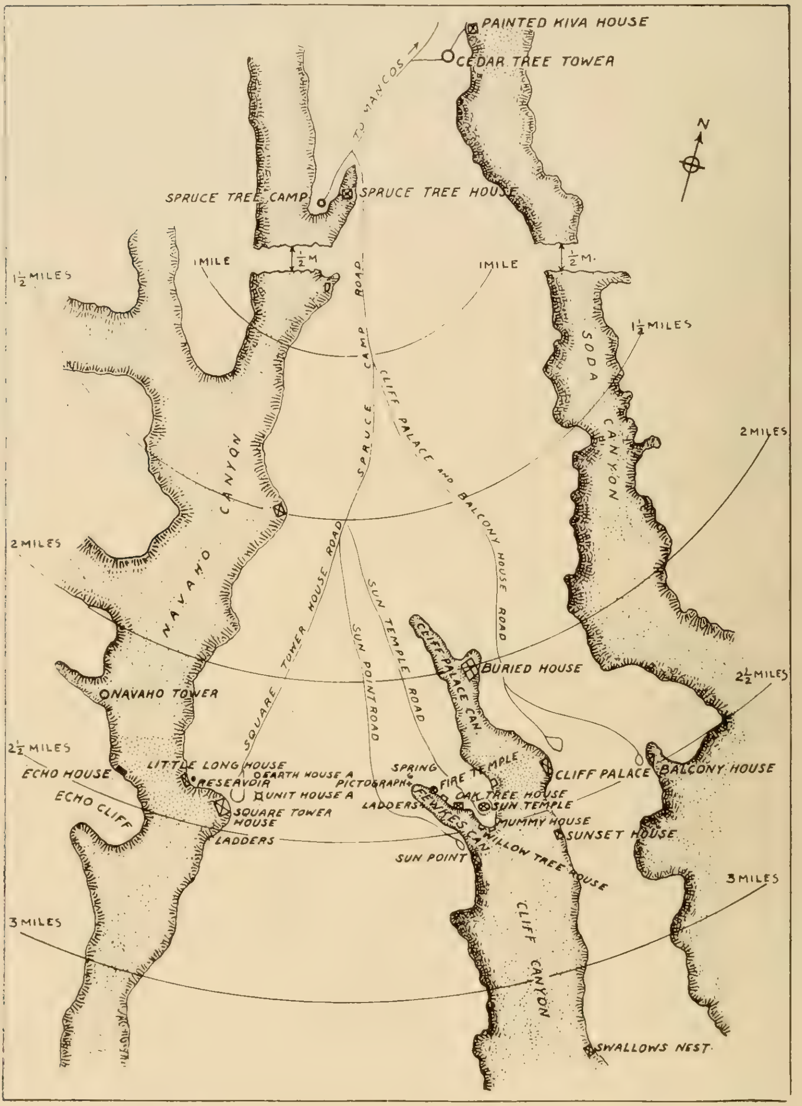

FIG. 92.—Map of Sun Temple Area in the Mesa Verde National Park, Colorado.

The opening of Sun Point Road along the south rim of Fewkes Canyon (fig. 92) is a most important addition to the park from the tourist's point of view. For about a quarter of a mile along this road one can look down into Fire Temple (fig. 94) and Fire Temple House, Oak Tree House (fig. 103), and the two ruins under Sun Temple, the walls of one of which, Willow Tree House, are in the same condition as when the cliff dwellers left the mesa; the other, Mummy House, on a lower level, is notable for its fine masonry. On the point across Fewkes Canyon, rise in full view the walls of Sun Temple, and beyond it, nestling in the cliff, is the magnificent Cliff Palace. The fine cliff dwelling Sunset House ("Community House"), a prominent ruin in Cliff Canyon, is likewise conspicuous. The road along Fewkes Canyon from which these prehistoric buildings are visible has already become a very popular drive, being only about two and a half miles from Spruce Tree Camp. The accom-

FIG. 93.—Ladders into Fewkes Canyon from Sun Point Road, opposite Fire Temple. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

panying map (fig. 92) shows the relative position and approaches to the above mentioned ruins. A fine trail, one of the most beautiful in this area, was developed under the north rim of Fewkes Canyon, to connect the above ruins. Three ladders (fig. 93) placed in the cliff opposite Fire Temple enable the traveler to reach this trail, which ends in ladders on the canyon rim opposite Cliff Palace near the point

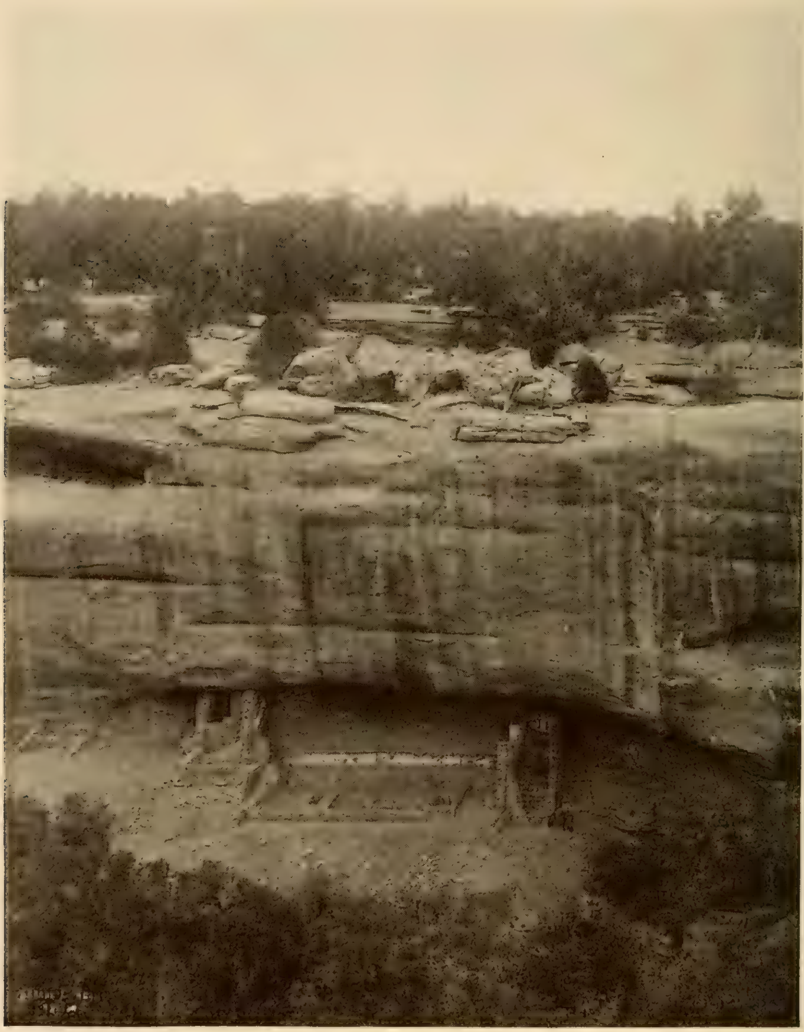

FIG. 94.—Fire Temple from Sun Point Road. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

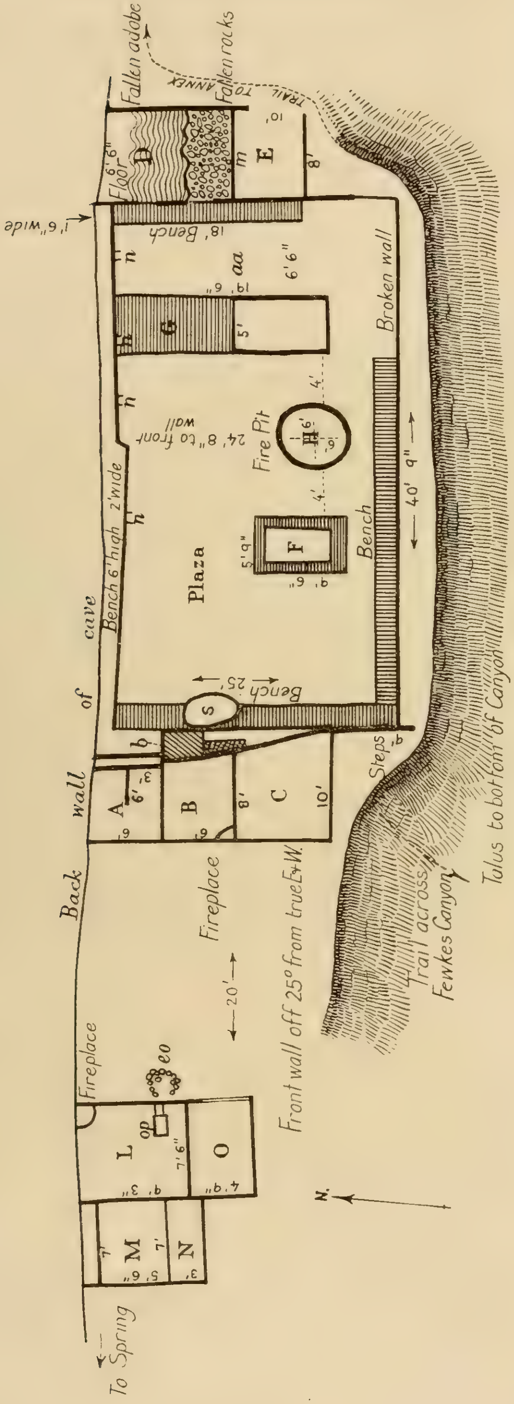

FIG. 95.—Ground plan of Fire Temple.

where the discoverers stood when their eyes first beheld this most impressive cliff dwelling of the Southwest.

The most important discovery of the past season was the determination by excavation that a large cliff house was not a dwelling, but specialized for some communal purpose. This ruin (fig. 98) was devoted to fire worship, a cult which up to this year, although suspected, had not been demonstrated as existing among cliff dwellers—at least no specialized building for that function had been recognized.

In 1915 there was discovered on the promontory opposite Cliff Palace a building with semicircular ground plan that was interpreted as a specialized religious structure and called Sun Temple. While work on it was in progress a reconnoissance was made of cliff houses situated in the canyon below, to one of which was given the name Painted House. Like Sun Temple, it was suspected of having also been dedicated to some religious cult of the cliff dwellers, but its true significance was not apparent until the spade of the archeologist last season verified this suspicion and revealed its true purpose. Painted House, upon excavation, proved to be one of the most exceptional cliff ruins yet recognized in the Southwest. The results of the excavation have led Dr. Fewkes to designate it Fire Temple, and by

Fig. 96.—Western end of Fire Temple Court, half excavated. Photograph by Fewkes.

implication to regard it a temple of the eternal fire. Attention should be called to the importance of the discovery that the cliff dwellers had a New Fire Cult and possibly that rites of new fire and conservation of the same existed among prehistoric people of the Mesa Verde.

The rites of kindling the new fire among the descendants of the cliff dwellers, as the Hopi, occur in July and November and are known as the Lesser and Greater fire ceremonials. The act in both is performed by means of a fire stick or drill made to rotate in a notched board; the same kind of fire sticks have been found in Spruce Tree House, Square Tower House, and elsewhere.

FIG. 97.—Eastern end of Fire Temple Court. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

Probably it is to the Lesser Fire ceremony at the East Mesa of the Hopi that we should look for the nearest survival of the cliff dweller's rite, as in it we find the personation of a phallic being, Kokopelli, whose picture was well preserved up to a few years ago on the wall of the secret chamber of the Fire Temple where fire was created. This Lesser New Fire, called Sumykoli, is celebrated by a fraternity of fire priests, now extinct, known as the Yaya priesthood. The Yaya priest at Hopi carries in his hand during this ceremony a rattle of

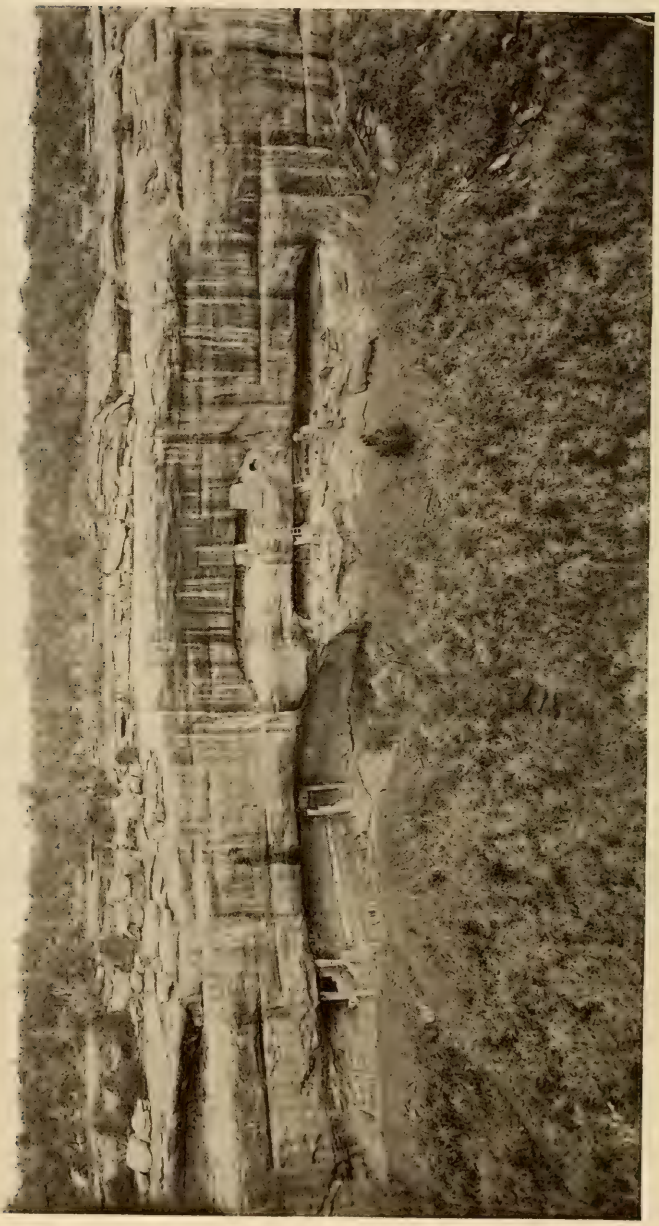

FIG. 98.—Fire Temple Group of Ruins. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

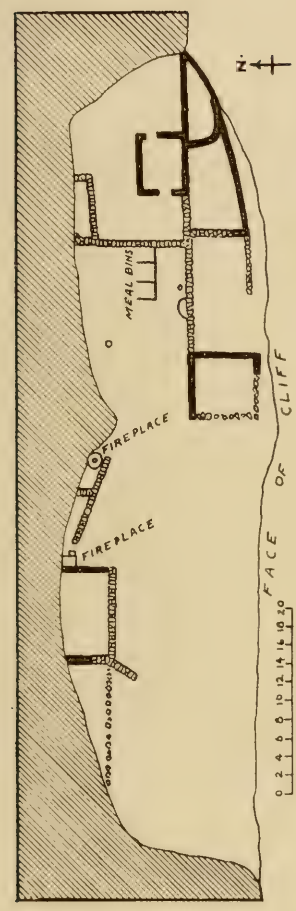

FIG. 99.—Ground plan of Upper Cave of Fire Temple House.

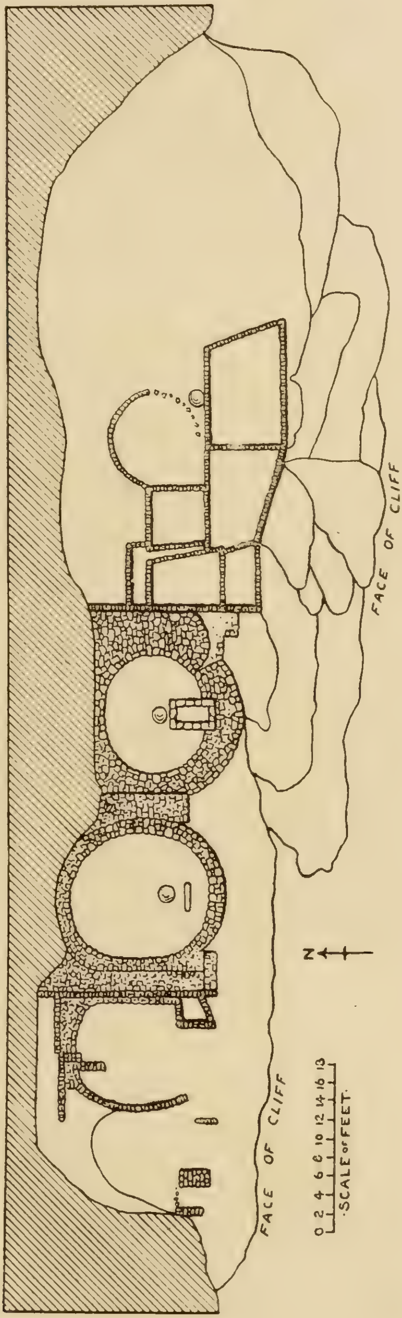

FIG. 100.—Ground plan of Lower Cave of Fire Temple House.

exceptional construction. Two of these, now in the museum of the Brooklyn Institute, were found in a cliff dwelling in the Chelly Canyon, which seems to indicate that there formerly existed among the cliff dwellers of that canyon a fire priesthood like the Hopi Yaya. As the cliff dwellers of Chelly Canyon and those of the Mesa Verde were closely related it is a fair conclusion that the latter also had a well-developed New Fire Cult, and possibly a Yaya priesthood.

The masonry of Fire Temple points to an early epoch in the evolution of the Mesa Verde culture, possibly one contemporary with the first settlement in Cliff Palace cave, but anterior to the erection of the unfinished Sun Temple, which marks a later or culminating phase of cliff house development. Architectural features that Fire Temple shares with Sun Temple may be interpreted by the close relationship of fire and sun cults among the cliff dwellers. Earth Lodge A, excavated in 1919, is the ancient type in the evolution of buildings on the mesa antedating stone walls, and there are evidences of successive stages illustrating cultural epochs from the crude Earth Lodge A, which the earliest colonists constructed, to those of horizontal ma-

FIG. 101.—Western end of Fire Temple Court. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

sonry (fig. 108), the highest products of the mason's craft in prehistoric North America. This evolution may have occurred on the area now reserved as a national park, but was not limited to it.

After the abandonment of Fire Temple and the desertion of buildings of the culminating epoch that followed, people of like culture may have still inhabited the great pueblos at Aztec and in the Chaco. But these in time also succumbed and were deserted before the arrival of the white man. Their descendants were amalgamated with nomadic or non-pueblo peoples and their survivors still inhabit the modern pueblos along the Rio Grande. Both blood and culture suffered changes in this mixture, and architectural features remain to especially indicate the modifications. The Hopi, Zuñi, and modern Rio Grande pueblos have no specialized buildings like Sun Temple nor Fire Temple for sun or fire cults, although they have ceremonial rooms where they formerly kindled the new fire annually. They no longer conserve the fire in this room, but there are legends that they did so in former times, pointing to a remote cultural connection between the cliff dwellers and their modern survivors, the Pueblos.

FIG. 102.—Bins for grinding corn in upper cave of Fire Temple House. Photograph by J. A. Jeancon.

The general form and arrangement of rooms at the east and west ends of the central court of Fire Temple differ from any cliff ruin or pueblo in the Southwest. Significant facts show that the building (fig. 97) is unique, as will readily appear from the following statements. Excavations in other cliff houses of the same size reveal household utensils, as pottery, and other domiciliary objects. No cooking places, grinding bins, or household implements were found in the extensive work at Fire Temple. Moreover, every cliff house of size on the Mesa Verde has one or more specialized generally circular subterranean rooms for ceremonies. There were no kivas in Fire Temple. But the one exceptional positive feature in this ruin that separates it widely from the cliff dwelling is stronger than these negative evidences. In no cliff house, and indeed in no pueblo, do we find a similar large circular fire pit filled with ashes in the center of a rectangular court. This structure would seem to be the key to the meaning of the whole building. That great fires were once built in this fireplace, as the abundant ashes indicate, no one can doubt. This fireplace is too large for an oven for culinary purposes and although we know that the cliff people sometimes cremated the dead the absence of calcined human bones would disprove the theory that

FIG. 103.—Oak Tree House from Sun Point Road. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

it was used as a crematory. A natural conclusion would be that it was constructed for ceremonies connected with fire.

The significance of the two low-walled rectangular enclosures one on each side of the central fire pit, is unknown. Each was partially filled with soil and ashes when excavated and it is suggestive to record that the stratum of earth above them as well as the whole surface of the hardened floor of the court was filled or covered with charcoal and burnt brush. Great fires must have raged over the whole court in addition to that in the fireplace, after the temple was deserted.

FIG. 104.—Cedar Tree Tower before excavation. Photograph by J. A. Jeancon.

We find several other facts that fit in very well with the interpretation that this building was a fire temple. On the east and west ends of the court (figs. 97, 101) there are banquettes, the former evidently seats for those who watched the ceremonial performance in the court. There are niches in the rear wall where possibly sacred objects may have been placed; a wall of the cliff bears triangles and zig-zag paintings, symbols of sex life; but, most important of all, on the wall of one of the rooms at the west end of the court there are paintings in red, one of which, now erased, represented a phallic being still associated with New Fire ceremonies among the Hopi, while others represent fire itself. At the New Fire ceremony among the Hopi one of the four fraternities that celebrate it is the order of Horn Priests, who wear on their heads imitations of the horns of mountain sheep. A large number of paintings of mountain sheep cover the walls of the west room of Fire Temple where fire was supposed to be kindled.

The massive walled buildings at the east and west (fig. 94) ends of the court formerly reached to the roof of the cave, and although two stories high no wooden beams for flooring occur in their construction. Wherever a lower story existed it was filled in with rubble on top of which was laid an adobe floor. On the white plastering, which is well preserved, there are numerous figures in red, mostly triangles and symbols of lightning; female and male symbols similar to those in sacred rooms.

Fig. 105.—Cedar Tree Tower after excavation. Photograph by J. A. Jeancon.

Just west of Fire Temple there is a group of rooms from which utensils were excavated. In the floor of one of these rooms is a vertical shaft which opens outside the house walls like a ventilator. The former use of this structure is unknown.

Although Fire Temple was not inhabited there were undoubted dwellings nearby. A hundred feet east of it there are two low caves, one above the other, in which may have lived those who once made

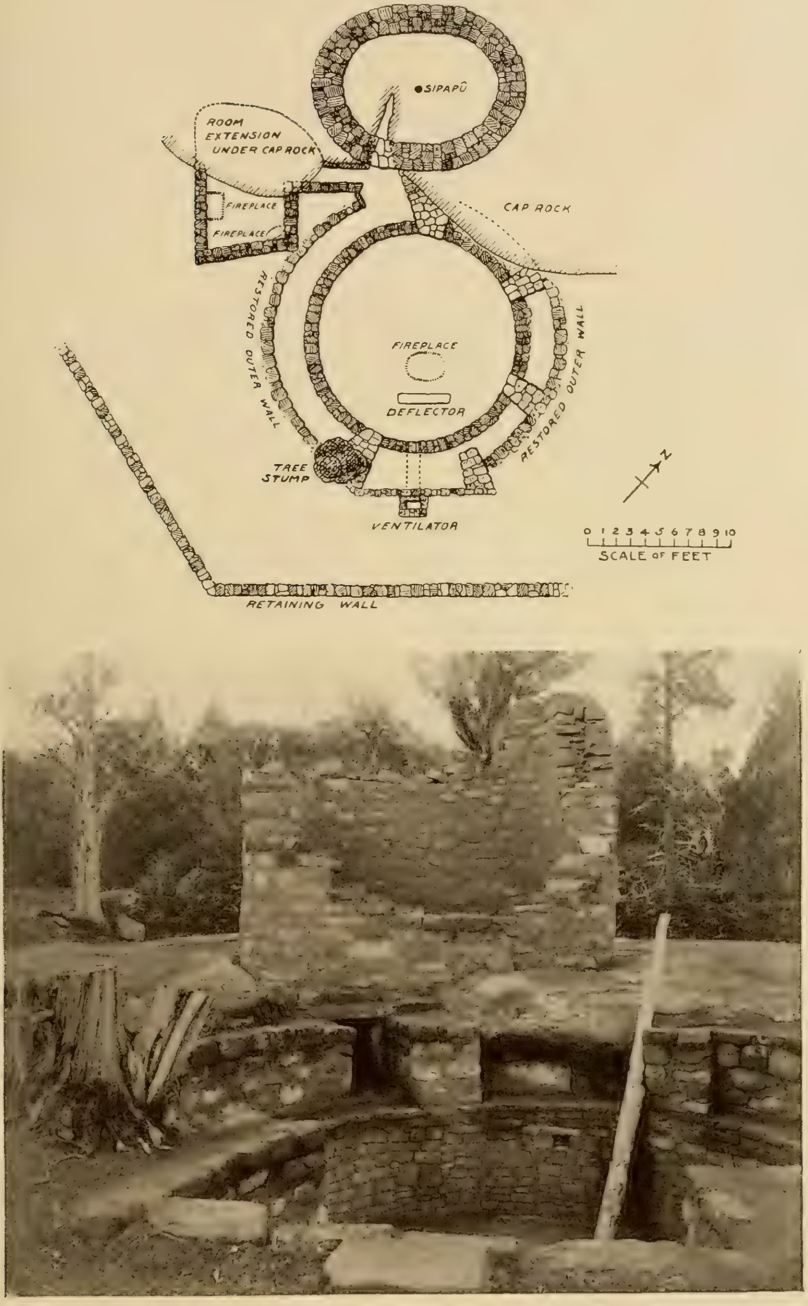

Fig. 106.—Below, Cedar Tree Tower and kiva; above, ground plan of Cedar Tree Tower and kiva. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

use of this sanctuary. Dr. Fewkes has called the ruin (fig. 98) situated in these caves the Fire Temple House and supposes it was the habitation of the fire priests and their families. The rooms in the lower cave were fitted for habitation, and it had two, possibly three, circular ceremonial rooms; but the upper cave (fig. 99) is destitute of kivas. The large rooms of the upper house (fig. 100a) may have been granaries for storage of provisions, although possibly some of its rooms were inhabited. In the rear of the large rooms identified as granaries was found a small room with a well-preserved human skeleton accompanied with mortuary pottery. One of these mortuary offerings is a fine mug made of black and white ware beautifully decorated; a specimen worthy of exhibition with the best in any museum. In the rear of the cave were three fine grinding bins (fig. 102), with metates still in place.

The upper house is now approached from the lower by foot-holes in the cliff and a ladder shown in the illustration. Evidences of a secondary occupation of kivas in the lower house appear in double walls and those of crude masonry without mortar, forming a rectangular room built diagonally across the room. The plastering on the rear walls of the lower house is particularly well preserved, but there are very few rooms in addition to the kivas. One of the kivas has in place of a deflector and ventilator shaft a small rectangular trench enclosed by a well-made wall, as in Sun Temple.

Work was done on the large cliff ruin, Oak Tree House (fig. 103), on the trail an eighth of a mile east of Fire Temple Group. Three new kivas were excavated to their floors and the walls repaired, adding to the four already known. No signs of these buried kivas were visible when work began. All these kivas show fine masonry; after the most easterly had been used as a sanctuary for a time it was abandoned and five well-preserved grinding bins were set in the floor so as almost to conceal it. The upright slabs of stone and metates of these structures were reset, showing fine examples of these prehistoric mills. Many other novel features were brought to light in the excavation of Oak Tree House, which may be regarded as one of the most instructive ruins of the park. One of the exceptional features of Oak Tree House is a fragment of a circular wall in the rear of the cave, made of willow and other sticks set in mortar, like what is called "stick and adobe" construction in other regions.

The ground plan of one of the kivas is semicircular and shows a rectangular room on the straight side communicating with the chamber by means of two passageways. The ventilator opens directly into this room, whose function is unknown.

In one of the grinding bins there was excavated a bundle of grass, *Koeleria cristata,* of exactly the same form as the brushes with which Hopi maidens sweep their metates after grinding meal; one more resemblance between cliff dweller and Hopi customs.

In his classic on the "Cliff Dwellers of the Mesa Verde," Baron G. Nordenskiöld figured and described a nameless ruin designated a tower (fig. 104), situated in the cedars about a mile north of Spruce Tree House. To this ruin the author has given the name Cedar Tree Tower, on account of an ancient cedar tree (fig. 105) hanging over the top of the north wall. Nordenskiöld closes his brief description with the remark, "Perhaps it should be regarded a religious building."

Fig. 107.—Section of floor of Cedar Tree Tower, showing ceremonial opening. Photograph by J. A. Jeancon.

The desirability of testing this surmise of the talented Swede led the author, in August, 1920, to excavate this tower and the area about its base, which led to the discovery that although it appeared to stand alone there were two subterranean rooms connected with its base situated on the west and south sides. The larger of these rooms (fig. 106) had all the structural features of a typical kiva of a Mesa Verde cliff dwelling. This subterranean structure, its floor excavated in solid rock, was circular with pedestals for supports of a roof, the beams of which were absent, and had a central fire hole, ventilator, and deflector. It communicated with the tower by a subterranean

Fig. 108.—Square Tower House. Photograph by G. L. Beam. Courtesy of the Denver and Rio Grande Railroad.

passage which bifurcated, one branch opening through the tower floor, the other into a square room situated on the southwest side, also subterranean, partially constructed under a large rock forming a

FIG. 109.—Yucca House National Monument, Lower House; Mesa Verde in the distance. Photograph by W. H. Jackson. Courtesy of the U. S. Geological Survey.

veritable cliff chamber. In the middle of the solid rock floor of the tower which served as the foundation of the tower walls a circular hole or *sipapû* (fig. 107), symbolic of the entrance to the underworld, had been drilled, affording evidence that the tower was used for ceremonials. A distant view down Soda Canyon may be had from the top of the tower, although it is situated some distance from the rim of the mesa and shut in by a dense growth of cedars and pinyons.

An automobile road constructed around Cedar Tree Tower was continued through the cedars to join the Mancos road. Several ladders were placed in position and a trail opened down the steep wall of Soda Canyon from Cedar Tree Tower to Painted Kiva House, an instructive cliff dwelling about a quarter of a mile away, formerly practically inaccessible. To the west of the Mancos road about the same distance from Spruce Tree House as Cedar Tree Tower there is another tower of the same type, but with walls of adjacent rooms projecting above ground. Several other similar towers have been reported on the mesa, in the Mancos, McElmo, and Hovenweep Canyons, and elsewhere. The relation of a tower to kivas and other buildings of Square Tower House is shown in figure 108.

A preliminary examination was made of the ruin at Aztec Springs now called Yucca House National Monument, in the Montezuma Valley, with a view to future excavation and repair of this important site. As no satisfactory photograph of this ruin has ever been published a view of the Lower House of this ruin taken in 1874 by W. H. Jackson is by his permission given in figure 109. It is planned to begin work on the Lower House of this great ruin in the spring of 1921.

FIELD-WORK AMONG THE HOPI INDIANS

Dr. Walter Hough, curator of ethnology, U. S. National Museum, spent the month of June among the Hopi Indians of Arizona, a tribe with which he has been associated for 25 years. At present some of the Hopi tribes are making rapid progress toward assimilating the culture of the white man, while others; though becoming more and more affected, show changes to a lesser degree. As these changes have taken place through peaceful assimilation and were not forced by war or other disruptive agency they present an interesting field for ethnological research on normal modifications of social structures due to contacts. Some notes on this subject are appended.

Material Welfare

The Hopi have prospered during the last quarter of a century. From the period when they knew almost nothing of money the Hopi have advanced to a complete familiarity with United States currency. Purchases can be paid for with check. Some of the more advanced have bank accounts. The Hopi were always acquisitive and frugal, and their habits have put them in a rather good financial condition. Their agricultural products have had a better market and the prices are less subject to the former fixed low valuations of the local trader.

Social Changes

The most effective cause of social changes was the enforced attendance of children at government schools and the sending of children to distant Indian schools. Causing considerable friction at first, this has now been accepted in most cases as advantageous.

A result not prevised is the weakening of the clan discipline whose former regulative authority was silent but powerful. The weakening of this authority produced much laxity for a time and it was found necessary to appoint policemen and a " judge." The government found it necessary to send away girls not noticeably under parental discipline to schools until they should become discreet. This measure was quite opportune and had a beneficial effect.

Decay of Native Ceremonies

In this connection there is ensuing a rapid decay of native ceremonials. The heaviest loss to the native cult is felt by the death of the old men of a former generation. Very shortly there will be no one of the tribe who has not had training in school and more and more of these will evade the call of the native religion.

Some fraternities have suspended operation and others are very weak. Notably the woman's harvest ceremony at Walpi has passed out and the Snake Society there is about to discontinue.

Christianization

Missions to the Hopi were carried on from time to time during a period of several hundred years without appreciable results. When the disintegration due to government control had progressed missionary efforts began to bear fruit.

The Baptist mission at Polacca has a stone church and a considerable and growing number of converts. Other branches of this mission are doing well.

A slight cleavage is observed between the Christians and non-Christians but no friction. The Hopi are agreed to let things work out as they will.

ARCHEOLOGICAL INVESTIGATIONS IN UTAH, ARIZONA, AND NEW MEXICO

During May and early June, 1920, Neil M. Judd, curator of American archeology, United States National Museum, continued his archeological reconnoissance of the arid region north of the Rio Colorado, Arizona, in behalf of the Bureau of American Ethnology. Attention was chiefly directed to the Toroweap Valley and several caves in an extensive lava flow on the east slope of Mt. Trumbull; to the unwatered mesa known as Pariah Plateau; to certain portions of House Rock Valley not previously visited[1] and to the upper two-thirds of Bright Angel Creek. In addition, a number of caves in Cottonwood Canyon and Kanab Creek, Kane County, Utah, were examined for evidence of ancient habitations.

FIG. 110.—Ruin surmounting a circular butte of white sandstone near the eastern rim of Paria Plateau and not far from the Rio Colorado. Note the upright slabs in the foreground—a frequent feature of prehistoric dwellings in this region.

In Bright Angel Creek several open ruins and three groups of cliff houses were inspected; a complete survey was found impossible on account of unexpected high water which prevented access to the narrow, walled-in portion adjoining the Grand Canyon of the Colorado.

In contrast to the conditions which were encountered in this beautiful gorge, lack of water and forage for pack animals seriously

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[1] Smithsonian Misc. Coll., Vol. 70, No. 2, 1918.

FIG. 111.—Cliff dwellings on the west side of Bright Angel Creek, above the mouth of Beaver Creek. Through the doorway of the right-hand room will be seen a bench, made from a cottonwood log, which forms an unusual feature of the ruin.

FIG. 112.—A group of small storage cists near several ancient ruins at the foot of the upper falls, Ribbon Falls Canyon, Bright Angel Creek. The inaccessible cliffs surrounding this section of the canyon form an amphitheater whose narrow entrance was guarded by a second fall over one hundred feet in height.

restricted investigations in the other sections above noted. The hurried inspection of the Mt. Trumbull region was made in an automobile, it being impracticable to use horses in this parched country during the summer months. Exposed pueblo ruins bordering the east rim of Pariah Plateau and overlooking the Painted Desert proved more numerous than was anticipated. In size, in arrangement of rooms and in the quality of their masonry these ancient dwellings are superior to those seen elsewhere in northwestern Arizona; likewise, potsherds examined at each site exhibit greater perfection of form and a higher decorative technique. These two factors—architectural and ceramic remains—alone are sufficient to connect the former inhabitants of this region with the pre-Puebloan peoples east of the Rio Colorado and to warrant the expectation that additional investigations will disclose the approximate points at which the Colorado River was crossed in ancient times.

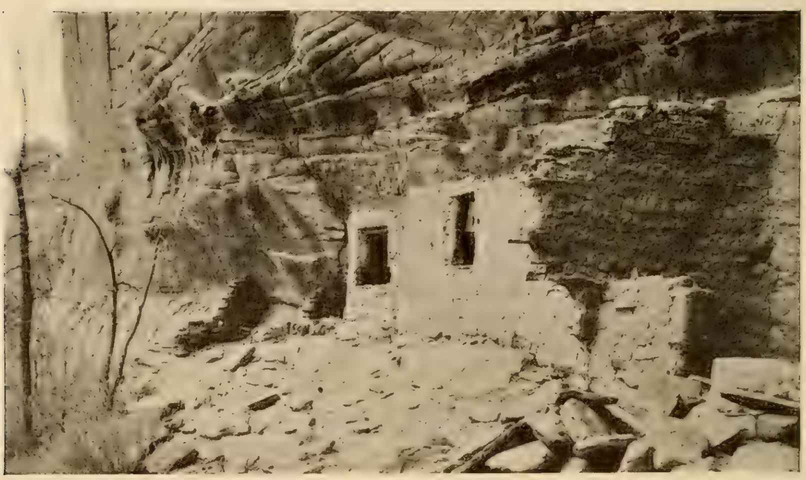

Fig. 113.—Part of a cliff village in a cave on the east side of Cottonwood Canyon, near Kanab, Utah. The village includes nineteen rooms and a nearby spring furnished excellent water for the ancient inhabitants.

Following his researches for the Bureau of American Ethnology, Mr. Judd proceeded to New Mexico as director of an archeologic reconnoissance of the Chaco Canyon National Monument. This survey was conducted under the auspices of the National Geographic Society and had for its prime object close examination of the aboriginal remains in the above monument with a view toward selection of a possible site for exhaustive investigation and permanent repair.

The Chaco Canyon National Monument was created by presidential proclamation March 11, 1907, and includes 18 major ruins of very great significance in the study of ancient Pueblo life. Unlike the vast majority of cliff houses and other ruins found elsewhere, each of these huge buildings was constructed along preconceived plans and as a community enterprise. The studied arrangement of their rooms and the perfection of their masonry rank them as the very finest examples of prehistoric architectural accomplishment in the United States. Not only did the ancient inhabitants of Chaco Canyon excel as builders with stone, but the lesser objects, found in and about the great communal dwellings, show that they had attained remarkable skill as makers of pottery, ornaments and implements of various

Fig. 114.—Grand Canyon of the Colorado from the lower Toroweap valley, southeast of Mt. Trumbull. Evidence of prehistoric habitations were not lacking in this region but the dwellings were widely separated and poorly preserved.

FIG. 115.—The north wall of Pueblo Bonito, viewed from the northeast. This is the largest and justly the most famous of all the Chaco Canyon ruins; it covers nearly three acres of ground and some of its walls still stand to a height of forty feet. When occupied Pueblo Bonito probably contained as many as 800 rooms, sheltering over 1200 individuals.

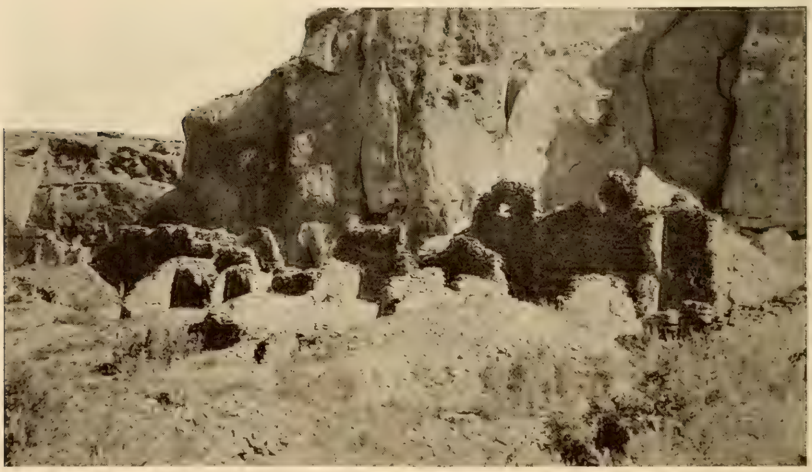

FIG. 116.—The north-central portion of Pueblo Bonito, from the southeast, showing its position relative to the north wall of Chaco Canyon. Sections of fourth story walls appear in the above illustration. Like most of its neighboring ruins, Pueblo Bonito was constructed in a series of terraces overlooking a central court or plaza; the outer wall was pierced by small windows above the first floor but had few doorways.

FIG. 117.—A portion of Kimmenioli ruin, showing the present condition of its walls. About 135 ground floor rooms are still traceable; originally the building was three, perhaps four, stories high. Although one of the finest in the national monument this great communal dwelling is not so well known as some of its neighbors in Chaco Canyon which is situated some ten miles to the north and east.

FIG. 118.—Pueblo del Arroyo, occupying an insecure position on the very edge of Chaco wash, 300 feet west of Pueblo Bonito. Flood waters have exposed the remains of an older dwelling beneath the walls of the larger structure and now threaten the latter. View from the north.

sorts. The beauty and technique of such specimens warrant the belief that these canyon dwellers had reached a plane of esthetic as well as social development not surpassed elsewhere in the Southwest.

Although the 18 major ruins constitute the main feature of this national monument there are, in addition, hundreds of "small house" remains scattered throughout the entire Chaco Canyon district. In culture as well as in architecture these lesser dwellings were closely allied to the larger structures. Talus pueblos and small cliff houses are to be found along the north side of the canyon; elsewhere the mud walls of a "pit house" have been disclosed—a crude, semi-subterranean shelter—older than any of the other habitations yet observed in this region. Certain it is that comprehensive investigations in the Chaco Canyon drainage will add largely to present knowledge concerning the prehistoric pueblo peoples of the southwestern desert country.

FIG. 119.—Part of Pueblo Pintado, as seen from the northwest. This ruin was visited by Lt. J. H. Simpson, August 26, 1849, on his memorable advance into the Navaho country; the large timbers noted by Simpson and other early explorers have since been torn from the walls, causing obvious destruction to the latter.

MUSIC OF THE PAPAGO AND PAWNEE

In February, 1920, Miss Densmore went to the Papago Reservation in southwestern Arizona to continue her study of Indian music for the Bureau of American Ethnology, residing for more than four weeks at a government station called San Xavier Mission. The Papago tribe was selected partly because of its desert habitat (fig. 120), the intention being to compare the phonographic records of Papago songs with those of Arabian songs obtained from Arabs who were temporarily in Washington, D. C. (Subsequent results proved the value of this comparison.) According to the last census there are 7,465 Papago Indians on the reservation, but not one " mixed-blood " family. It is said further that there has never been any intermarriage between this tribe and Mexicans or Spanish. Their manner of life is becoming modified, but many primitive customs remain and were observed. A primitive burial place was found by Miss Densmore.

FIG. 120.—Habitat of Papago Indians. (Photograph by Miss Densmore.)

These burial places were constructive on the side of a mountain and consisted of low walls of rocks, roofed with timber and tightly closed with stones. Bodies were removed after a time to make room for other burials. A skull and a few bones remained in the tomb examined.

The subjects studied were: (1) Songs used in treating diseases caused by spirits of dead Apaches and Papago; (2) songs connected with the " purification " of returned warriors who had killed Apaches, and (3) songs connected with dreams, games, and dances. Musical instruments formed a subject of special investigation. A native flageolet was obtained (fig. 12) together with the tradition concerning its origin. The music of this instrument was phonographically recorded and has been transcribed. The Papago beat upon an over-

FIG. 121.—Papago playing on native flageolet.

turned basket instead of a drum, striking the basket with the palms of one or both hands. "Rasping sticks" are sometimes used with such a basket, as shown in figure 122.

FIG. 122.—Papago and native musical instruments.

After a brief stay in Phoenix, Arizona, Miss Densmore went to Camp McDowell (formerly Fort McDowell) and was present at a gathering of Mohave Apaches, explaining her work and securing their consent to record songs on a subsequent visit. The adobe buildings of the old fort are in ruins, but a few of the smaller and more substantial buildings remain.

From Arizona Miss Densmore went to Pawnee, Oklahoma, arriving April 12, a few days before the Morning Star Ceremony. This is one of the most important ceremonies of the year as it is held for the purpose of securing good crops. At this time the "Morning Star Bundle" is opened and its contents displayed for several hours, while the proper rituals are sung. Miss Densmore was allowed to enter the lodge for a brief time and to view the sacred articles (it is said only one other white person has been accorded this privilege). During the remainder of the ceremony, which lasted many hours, she stayed outside the lodge (fig. 123) and make manuscript notes of the songs. An approach to two-part music, heard at this time, had not been previously observed. While at Pawnee a sufficient number of songs was recorded to complete the musical study of that tribe.

FIG. 123.—Pawnee lodge of Morning Star Ceremony. (Photograph by Miss Densmore.)

In November, 1920, Miss Densmore returned to Arizona to resume work among the Papago. The principal work was done at Vomari, a point near the Mexican border and 80 miles from the railroad. Interesting material was collected also at Sells, formerly known as Indian Oasis. Among the subjects studied were: (1) The Papago expeditions to the Gulf of California for salt and for "medicine power," each sort of expedition having its songs; and (2) the rain-making ceremonies, including the manufacture of tizwin. In connection with the latter a visit was made to Santa Rosa, at the extreme north of the reservation, where a tizwin camp and lodge were photographed. A specimen of the cactus syrup used in making tizwin was obtained, as well as a large basket which had been used in serving this wine.

Many sites of legendary or geographic interest were photographed, Miss Densmore travelling more than 360 miles by auto on this trip.

The most important result of this expedition was the hearing of a form of three-part music at a Papago dance. This was said to be a native musical custom. So near an approach to polyphonic music has not been hitherto observed by Miss Densmore and the subject will receive further investigation.

OZARK CAVES AND MOUNDS IN MISSOURI

During the summer of 1919 the work of cave exploration in the Ozark region was continued by Mr. Gerard Fowke, for the Bureau of American Ethnology. Almost his entire time was given to a thorough examination of two large caves in Pulaski County. The first, known as Miller's cave, is three miles northeast of Big Piney postoffice. The opening is in the vertical face of a high cliff fronting Big Piney River, with a steep talus slope beginning 30 feet below the floor of the cave and extending to the water's edge. The perpendicular wall below, with a projecting ledge which forms the roof, prevents a direct entrance, and the interior can be approached only through another cave whose opening is in a ravine near by. A narrow passage, barely large enough to admit a man in a crawling or crouching position, connects the two, and it is only through this that access can be gained to the main cave. The inmates were absolutely safe from molestation, as one man could defend this opening against any number. A little stream flowing along the foot of the east side of the cavern ensured a supply of water at all times: game was plentiful in the neighborhood: the river abounded in fish; and fertile, level bottom lands, easily cultivated, on either side of the stream furnished much corn and other farm products.

A ditch and enbankment across an isthmus guarded a peninsula on the opposite side of the river, and on both sides low house mounds and abundant debris furnished proof of two large village sites. Whether there was any connection between the villages and the cave dwellers cannot be determined.

A bed of clean, pure ashes whose depth ranged from 3 to 6½ feet, according to the irregularities of the clay, was found in the cave reaching from wall to wall, a width varying from 45 to 70 feet. This bed was so loose as to be almost like a snow bank; but for the most part they were as compact as if much trampled over while wet. When solidly packed, the mass would measure fully 800 cubic yards in volume; but when loosened by excavation, 200 cubic yards more. All the wood had to be carried from either the top or the bottom of the hill, which is about 400 feet high, and passed through the small opening from the other cave. It is safe to say no more fuel would be used than was strictly necessary. When it is considered how little fire is requisite for the needs of an Indian household, and that the limited space suitable for residence would not provide sufficient room for more than half a dozen families at a time, it is quite clear that this amount of ashes meant a very long occupancy. Even with continuous habitation, several centuries would be required for such a quantity to accumulate; and if residence was desultory and intermittent, as is customary with roving or hunting tribes, or if it was only a winter home for some of those living in the villages mentioned, the period would be greatly lengthened. Yet the remains found in these ashes were of the same character from top to bottom. The artificial objects found numbered about 75 mortars, more than 200 pestles, hundreds of flint knives or spear heads, numerous implements of bone, antler, and shell; quantities of crude pottery fragments, a few tomahawks, and two pipes. While the many mortars and pestles indicate much use of grain, seeds, and nuts, at the same time the great amount of mammal, bird, and fish bones showed that a large part of their sustenance was derived from animal food. Of more than 20 skeletons found in various stages of decay, only two were of aged individuals, most being remains of children or young persons. The skulls were of low type. Not an ornament of any sort was found except a few rude ones of bone or shell. Some of the human bones, mostly those of children, were charred and broken, and mingled with the debris of food animals and ashes as if the flesh had been used for food, and the broken bones thrown aside with the refuse. There was no evidence of the cremation of bodies; the condition of these bones points to the practice of cannibalism.

The second cave explored is situated a mile south of Waynesville, on land belonging to Dr. J. W. Sell, and was probably a temporary camping place. Its opening is on a hillside facing Roubidoux creek, and is easily accessible from either the top or the bottom of the hill. A few rods back from the entrance, water stands on the floor throughout the year: so that only the front part of the cave was used for shelter. At the entrance is a pile of earth washed from the sloping surface of the hill above, over the ledge that forms the roof. This accumulation spreads for 50 feet into the cave, but not so far on the outside, because there it washes down the slope. From its surface to the clay floor on which it rested the greatest depth was a few inches over six feet. From top to bottom there was found in this cave the ordinary debris of an Indian campfire. Buried at various depths here and there, in the portion within the cave were 14 human skeletons, most of them so decayed that only a few fragments were remaining. They are of persons of various ages; some of the skulls were low, small, and flat.

A long period of occupancy is indicated by the conditions here as at Miller's cave. While the amount of earth heaped in front of the cave does not seem large, yet it all has come from a space not exceeding 6,000 square feet in area and most of this is bare rock with humus of decayed vegetation existing only in the crevices or on the few flat surfaces. All the other water from the hill runs to the slopes and does not reach the cave. A violent storm passed over the region soon after the work was concluded, in which 12 inches of rain fell in three days, yet not more than a wheelbarrow load of soil was washed down over the roof to the pile already there. It is evident that centuries would be required to build up the mass, throughout which these traces of man's presence are scattered promiscuously.

During all the period these caves were in use no improvement took place in the fabrication of stone implements or pottery. Specimens found nearest the top of the ashes or dirt could not be distinguished from those of the same class from the rock or clay floors. The inhabitants remained in the same plane of culture.

The thousands of small mounds extending southward from the upper swamp region of Missouri have long been a puzzle to archeologists and until recently it has been supposed that in this state they are confined to the southeastern portion: but in the course of Mr. Fowke's field-work they have been found to extend to the north and west as well. Groups of them have been located in Oregon, Dent, Phelps, Pulaski, Osage, and Morgan counties, the latter along the Benton County line. Their purpose has not yet been determined, although Thoburn's hypothesis that they are due to the Pawnees, whose line of migration was through the area in which they occur, and are the remains of earth-covered houses, seems the most tenable yet advanced. This theory implies that when this tribe passed beyond the region in which suitable timber for supporting the weight of the earth, and also earth adapted to such use, could be procured, they were compelled to substitute for them small poles overlaid with grass.

Comparison with the typical modern Pawnee earth lodge, a photograph of which Miss Densmore published in her account of fieldwork for 1919, corroborates Thoburn's interpretation of these Missouri mounds.

ARCHEOLOGICAL RECONNOISSANCE IN HAWAII

With an allotment from the Bureau of American Ethnology, Mr. Fowke spent the entire summer of 1920 in the Hawaiian Islands, making a careful examination of all ancient works of whatever nature, that could be visited with the time and opportunities at his command.

While there is abundant evidence everywhere that the old Hawaiian people were extremely industrious, using vast quantities of stone in the construction of their temples, houses, garden enclosures, fish ponds, and taro terraces, there was nothing discoverable among all these remains which could be attributed to a prehistoric tribe, or to any other race than that found in possession when the islands were first known to the white man.

FIG. 124.—Pawnee ceremonial earth lodge, exterior. Photograph by Miss Densmore.

The five principal islands were visited and explored as thoroughly as was possible in the circumstances. It was not practicable to examine every feature of interest, where there is so much demanding attention; but at no place could there be discovered any indication which would seem to justify excavation with the expectation of unearthing beneath the top soil remains which might differ in general character from those on the surface. There being no difference between remains belonging to the historic period and those superficially showing evidence of great age, it is logical to conclude that when that branch of the Polynesian race, now known as Hawaiians, left their home in the distant South Seas and migrated to these islands, they found the territory without inhabitants; and there is no reason whatever for supposing that any people culturally different from the historic Hawaiians had ever previously lived on the islands.

FIELD-WORK AMONG THE FOX AND PLAINS CREE INDIANS

Dr. Michelson, ethnologist of the Bureau of American Ethnology, began field-work among the Fox Indians at Tama, Iowa, about the middle of June. His main purpose was to restore phonetically a text containing the autobiography of an Indian woman written in the current syllabary which he had obtained in the summer of 1918, to correct the translation where there was need, to elucidate some ethnological references contained in the text, to clear up some grammatical obscurities, and to work out the verbal stems so far as was feasible in the field. All this was successfully accomplished, and Dr. Michelson left for Saskatchewan in the latter part of July for a preliminary investigation of the Plains Cree. The results of this investigation show that the Plains Cree are tall and have a cephalic index

FIG. 125.—The dwelling in which the White Buffalo Dance of the Fox Indians is held. The building is the typical "bark" house used by the Fox in the summer and early fall.

FIG. 126.—An aged Plains Cree (File Hills Agency).

FIG. 127.—Tipi of the Plains Cree (File Hills Agency).

of about 79, and evidently are the same type as the one which formerly occupied the Mississippi Valley, thus confirming the results of Dr. Boas, announced in 1895. The general grammatical principles which have been worked out for Fox apply also to Cree. In some respects Cree is more archaic than Fox, in others less so. Ethnologically the Plains Cree are about half way between more typical Indians of the Plains, such as the Blackfeet, and the Central Algonquins. An analysis of the myths and tales which cluster around the culture hero shows that we practically have the myths and tales of the culture heroes of the Blackfeet and Ojibwa combined. All this is just what one would expect from the geographical position of the Plains Cree.

ARCHEOLOGICAL EXPLORATIONS IN TENNESSEE

Mr. W. E. Myer, of Nashville, Tenn., spent September and October, 1920, making explorations for the Bureau of American Ethnology in the Cumberland Valley around Nashville. He discovered on the H. L. Gordon farm, one mile northeast of Brentwood, in Davidson County, the remains of an ancient Indian walled town. These were situated in a woodland and had never been disturbed by the plow. Their partial exploration brought to light some new and interesting details of the life of the inhabitants. Traces of 87 house circles and faint indications of several more could be made out. This town covered 11.2 acres and was surrounded by an earthen embankment which formerly supported a palisaded wall, equipped with circular towers every 55 feet.

The ancient inhabitants, for some unknown reason, had deserted this village and the site had never afterward been occupied or disturbed. The deserted structures had gradually fallen down and the remains slowly buried under from 10 to 14 inches of earthmold. In some of these circles portions of beautiful, smooth, hard-packed, glossy-black floors were found. In the centers were the ancient fire-bowls, yet filled with the ashes of the last fires kindled in these homes before their owners left them forever. Near these fire-bowls often could be seen the metates, mullers and other household utensils, just as left the last time used. Underneath the floors were the stone slab graves of the little children, one of which is shown in figures 128 and 129.

A level open space was found near the center of the town and on the western side of this plaza was a low flat-top mound that had originally supported some important building. Adjoining this mound on the west was an earth circle which probably outlined the ruins of the town house. At the center of this sacred structure, on the unique black glossy floor, an ancient altar (fig. 130) was found. It was still filled with the pure white ashes of what had once been the sacred fire.

Fig. 128.—Child's grave after removal of infiltrated soil, before disturbing mortuary vessels.

This altar was carefully preserved and is now in the Bureau of Ethnology. The Gordon site is of much interest because here we have an ancient Indian village just as the original inhabitants left it.

The Fewkes Group

Mr. Myer also partially explored an unnamed Indian village group at Boiling Spring Academy in Williamson County, Tenn. At the request of many citizens of Tennessee Mr. Myer named this site the Fewkes Group, in honor of Dr. J. Walter Fewkes, who had visited it and recognized its possibilities a few months before.

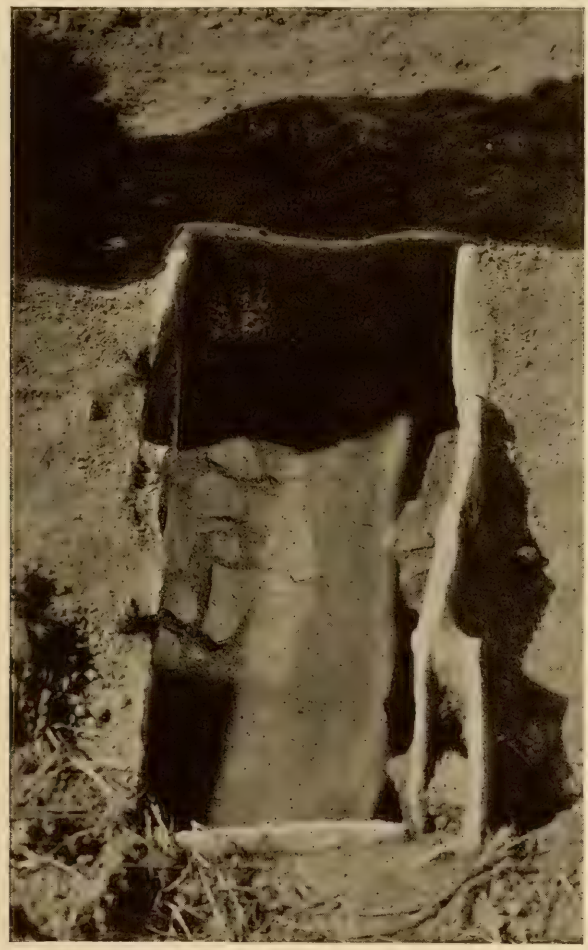

FIG. 129.—Child's grave after removal of body. Note floor composed of broken pottery.

At least two different peoples have lived on this site. The earlier people built the mounds and most of the other remains. At a later date a small band of some other tribe located here. The earlier people buried their dead either in hexagonal or almost circular stone slab graves, the bodies closely flexed. The later band used rectangular stone slab graves with the body extended full length on its back.

The Fewkes Group consists of four mounds, one on each of the four sides of a level plaza, the traces of about a dozen house circles, and a small remnant of what was once a considerable stone slab cemetery.

Fig. 130.—Altar.

Mound No. 2 on the map is a low oval mound situated on the western side of the plaza. The site of this mound had been lived upon for some time before any mound was raised. At last the mound was commenced and raised to a height of three feet and a building for domestic purposes erected thereon. This building was later torn down and then the mound was raised three feet higher. The mound was again used for domestic purposes for a period. Then a town house or sacred ceremonial house was built on it. This sacred building also had one of those rare, beautiful floors made of clay, smoothed, then hardened by fire, and finally covered with a coating which is yet black and glossy. In the center of the building, on this beautiful floor, an altar was found. It was similar to the altar shown in figure 130.

This building had walls made of cane stalks with the leaves attached, which had been woven in and out between the upright posts which supported the roof. These canes may have had a coating of earth, though no trace of it could be found, and the walls also had a covering of woven cane matting. In some way the building was destroyed by fire. Earth was thrown on the remains in time to smother its still glowing embers, which produced a large amount of powdery charcoal containing fragments of cane stalks with the leaves attached, and portions of the woven cane matting. After this sacred building was burned the mound was raised one and one-half feet or more in height. All trace of its last use has been destroyed by 85 years of cultivation.

FIG. 131.—Mortuary vessel from child's grave.

The low mound, No. 3, on the south side of the plaza, was a burial mound belonging to the first settlers. The mortuary vessel shown in figure 131 came from a hexagonal grave in this mound.

Mound No. 1 on the north side of the plaza is 180 feet across the base and 25 feet high. It is the most conspicuous mound in the group. Lack of funds prevented its exploration.

House circle No. 6 was one of the group of buildings, Nos. 6, 10, and 11, whose functions were doubtless closely interwoven. No. 6 contained in its center an altar or fire-bowl.

There was evidence that this town had either been taken by an enemy and burned, or the ancient inhabitants, forced to flee, had burned their homes to prevent their falling into the hands of the invader.

FIG. 132.—House circle No. 17. Cleared floor of wigwam, showing ancient fire-bowl. Body of child was found by side of upright stone. Its head rested within edge of fire-bowl. Top edges of upright stone slab sides of another coffin in corner to right of women.

House circle No. 17, shown in figure 132, was a typical dwelling. It was evidently the home of a neat housekeeper. No broken animal bones, pottery, fragments, or other evidences of untidiness littered the floor. The floor was of hard-packed clay and a fire-bowl was sunk in the center of the floor. At this fire-bowl a puzzling burial was unearthed. A child, about eight years of age, was buried by the side of the upright stone slab, with its head resting just within the extreme edge of the fire-bowl, whose rim had been cut away at this point to admit the top of the child's head. The fire-bowl was found still filled with ashes, and although the ashes covered the top of the child's head, the head showed not the faintest trace of the action of fire. The graves of two infants were also found in the floor of this house.

At both the Gordon and the Fewkes groups every piece of bone and every fragment of pottery was carefully saved and location noted. These thousands of fragments will give a reliable record of the food animals and practically a complete list of all the sizes, colors and shapes of their domestic pottery.

Both these sites, when explorations were completed, were accurately restored to their original shape for the benefit of coming generations. The interesting altars, fire-bowls, building post-holes, and vestiges of domestic life were carefully preserved, and again covered up so as to allow their future study. It is strongly urged by the citizens of Tennessee that the Fewkes Group be made a national monument.

Mr. Myer discovered a great Indian fortress on the long, narrow point of land between the Harpeth and Cumberland rivers, at their junction, in Cheatham County, Tennessee. This fortress consists of a thin, double-faced bluff, about three-quarters of a mile in length, and only from 10 to 250 feet wide along its tall and narrow summit. It faces both rivers and has nearly perpendicular sides along its entire length on both streams. It can be scaled with very great difficulty and at only a few places. The Indians protected these few places of ascent with breastworks or mounds. This was a central place of refuge for a series of scattered Indian settlements extending about six miles up and five miles down the Cumberland River and about five miles up the Harpeth.

The four pipes from this region are unlike any found elsewhere in the valley, and probably the culture of the ancient people who used this fort was different from any other known at present in the Cumberland Valley.

On a recent visit Dr. Fewkes examined the great unexplored mound group on Harpeth River at the mouth of Dog Creek, in Cheatham County. This group is the remains of one of the important prehistoric settlements east of the Mississippi.

There is a great mound, with wide earthen platforms, capping a hill in the up-stream end of this settlement. A portion of the hill has been artificially shaped so as to give greater prominence to the works on top of it. Surrounding these works on the summit are the ruins of a large edifice and other important remains. This portion of the settlement covers about 40 acres and is said to be connected by an embankment with the remainder of the mounds in Mound Bottom, about two miles down the Harpeth. The Mound Bottom portion, shown in figure 133, covering about 50 acres, contains Mound No. 2 with large platform; Mounds Nos. 1, 4, 5, and 6; cemetery No. 7, and other traces of a considerable population.

Fig. 133.—Mound Bottom. Other great mounds belonging to this unexplored group.

ARCHEOLOGICAL EXPLORATIONS IN NEW MEXICO

During July, and a part of August, Mr. J. A. Jeancon, special archeologist of the Bureau of American Ethnology, made a reconnoissance and conducted intensive archeological work at Taos, New Mexico. While it has been known for a long time that there was excellent archeological as well as ethnological material to be obtained in this valley, no archeological research has been done there before the present work in the summer of 1920.

The great number and variety of sites seem to indicate a long period of occupancy of the region. These sites are well-defined small house groups, each indicating one, two, or more rooms. There are also great communal groups as that at Bagley ranch and the Arroyo Hondo. The mounds are sometimes over 20 feet in height; the pottery sherds scattered over these sites range from the primitive black-and-white ware to what appears to be the so-called biscuit ware.

A small pueblo ruin at Llano was selected for excavation and, while the yield of pottery was small, many interesting facts were obtained. The ruin is located on the south bank of the Little Rio Grande, one mile and a half from the plaza of Ranchos de Taos. Situated on the edge of a high mesa it commands a magnificent view of the country for miles around, excepting to the east, where the view is cut off by the mountains. The fields which probably furnished the villagers well-watered agricultural areas are situated in the valley below.

The excavation showed that there had been two occupations on the site. In several places the remains of earlier old walls show beneath the present walls, indicating that the first and second buildings had totally different ground plans. All of the walls (fig. 134) were made of a mixture of wood ash, small stones (about the size of pebbles ordinarily found in gravel), and adobe which when exposed to the air becomes very hard. The walls of the second occupation are not as well made as those of the first, but the floors of both resemble those of the older villages still inhabited, where the blood of animals was used to give them temper and polish.

FIG. 134.—Ruin at Llano, Taos Valley.

The general plan of the ruin recalls those of southwestern Colorado. The kiva at Llano (fig. 135) was completely surrounded with rooms and when the roof was intact its surface was a small plaza surrounded by the buildings of the main group. An evidence of the two occupations is that the more recent kiva was built inside the older, and the space between their walls had been filled in with rubbish. No roof timbers remained in the ruin, but there were in the kiva four upright posts upon which the former roof rested. In about the center of the kiva there was an excellent fireplace, and in the floor directly adjoining the fireplace a plastered pit (fig. 135), an unusual adjunct to the fireplace, the purpose of which is unknown. Between the fireplace and the pit is a stone slab, one foot high and about nine inches wide. The excavations brought to light a very small number of the undecorated sherds of white ware; the black-and-white pottery is unusually hard and fine, but the black or rather brownish-black ware used for cooking and storage is very soft. The forms of and designs on the black-and-white pottery strongly suggest the San Juan ware.

Fig. 135.—Kiva at Llano, Taos Valley.

During the month of May, 1920, Mr. Jeancon made a satisfactory reconnoissance in the country lying south and southwest of Dulce,

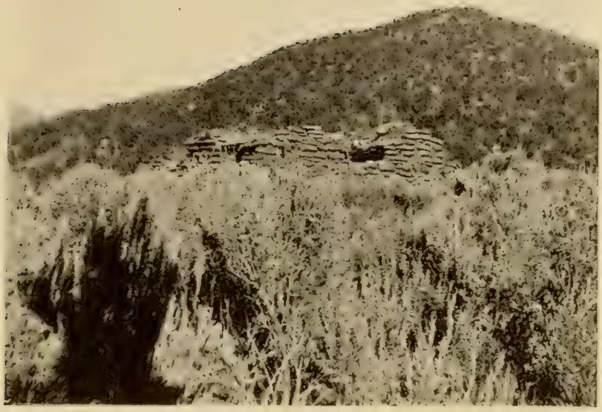

FIG. 136.—Ruin in La Jara Canyon.

FIG. 137.—Ruin in La Jara Canyon.

New Mexico. He found in Burns, La Jara and other canyons indications of two periods of occupation evinced by the pottery which belongs to the old pre-Spanish black-and-white and the hard-coiled wares. The houses of the earlier period were "earth lodges" of a primitive type. The house remains point to the second occupation and are in many cases built on the tops of high masses of sandstone (fig. 136), and show the crudest workmanship. A common site for buildings is the edge of high points (fig. 137), along the terraced (natural) sides of the canyons. All of the later sites give an impression that they were more or less defensive and hastily erected. Associated with these buildings are remains of metal objects, apparently of Spanish manufacture; many of the beams in the houses plainly show the marks of metal tools. The pottery has a bluish-black color, closely resembling a modern vitrified brick, and is so hard that when struck it rings with a clear bell-like tone. The surface suggests old Hopi ware and the decorations are similar to the older Zuñi and Acoma designs.

Fig. 138.—Dulce Ruin.

The pottery and associate remains probably do not antedate the reconquest of the Southwest by the Spaniards in 1690. It is known that some of the pueblo people fled from the Spaniards at the time of the great rebellion and took refuge in the mountains to the north. It is probable that further investigation will show that in this area the ruins ascribed to the second period were built and inhabited by refugees from Zuñi and Acoma.

ARCHEOLOGICAL EXPLORATIONS IN EASTERN TEXAS

Archeological field-work was carried on in 1920 by the Bureau of American Ethnology in co-operation with the University of Texas under direction of Professor Pearce and Professor Engerrand. Several localities in Texas were visited and considerable intensive work done in the eastern part of the state.

The region in eastern Texas to which most attention was given was in the vicinity of the little city of Athens in Henderson County. Judge A. B. Watkins of that city has long taken a keen interest in the history and archeology of the region and was of great help to Professor Pearce in his field-work. A number of aboriginal objects, complete specimens of pottery, clay pipes, conch-shell cores, fine arrowheads and human bones were obtained from an ancient burial ground two miles northeast of Frankston on the De Rossett Farm. One of the objects found was a "turkey call" or whistle made from the drumstick of a turkey. This is identical with those used not many years ago by old white hunters on the frontier and Professor Pearce feels sure that the white man's use of this device was borrowed from the Indian. Professor Pearce finds that the east Texas region contains numerous mounds, village sites and burial places, among which may be mentioned Nacogdoches, Panola, Bowie, Wood and other counties.

Three interesting mounds on the Morrall Farm four miles east of Cherokee County were investigated. The highest of these mounds has an altitude of about 35 feet above the level valley or field in which they are all located and is about 80 feet across at the base. This mound is very steep and even now after long erosion its sides rise at an angle of 45°. Mound B is 180 feet long by 75 feet wide and rises only 15 feet above the general level. The other three mounds in the vicinity of Athens have been ploughed into and have no regularity in form.

On the Quate tract east of De Rossett farms there are Indian mounds which were not regarded as very ancient. Several mounds situated in Harrison County on the farm of Mr. Lane Mitchell, of Marshall, were examined and remains of earth lodges with central fire pits were reached. These mounds are probably very ancient.

Numerous other sites were explored, yielding a collection of pottery, stone implements and other objects, illustrating the life of the prehistoric aborigines of eastern Texas.

Everything found implies that the Indians of this region lived in relatively settled villages, had considerable agriculture, made pottery extensively and of a high-grade, and were altogether in a considerably higher stage of culture than were those who occupied the prairies and plains.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 7

SEA-LILIES AND FEATHER-STARS

(With 16 Plates)

BY
AUSTIN H. CLARK

(Publication 2620)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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PREFACE

Of all the animals living in the sea none have aroused more general interest than the sea-lilies and the feather-stars, the modern representatives of the Crinoidea. Their delicate, distinctive and beautiful form, their rarity in collections, and the abundance of similar types as fossils in the rocks combined to set the recent crinoids quite apart from the other creatures of the sea and to cause them to be generally regarded as among the greatest curiosities of the animal kingdom. They have usually been considered as the rare, curious and decadent remnants of an interesting animal type once important but now trembling on the verge of extinction, and it is from this melancholy viewpoint that they are discussed in practically all the text-books.

The discoveries of the last few years have shown that the living crinoids, far from being rare or few in numbers, are abundant both as individuals and as species, and that in all localities where the somewhat exacting conditions under which they can exist are met they occur, sometimes in enormous numbers. The requirements necessary for the maintenance of crinoidal life are unfortunately of such a nature that, though quite generally distributed in the deeper waters of the oceans, they become rare or very local in the littoral, which, together with the great difficulty of preserving them in anything approaching satisfactory form, has served to keep them enshrouded in mystery while animals of other types engaged the attention of investigators.

NUMBER AND SYSTEMATIC ARRANGEMENT OF THE RECENT CRINOIDS

There are known from the seas of the present day 576 described species of crinoids which are distributed in 142 genera and 28 families and subfamilies; of these, 76 species, included in 22 genera and 6 families, are stalked, while 500 species, included in 120 genera and 22 families and subfamilies, belong to the unstalked or comatulid type.

The systematic arrangement of the families and higher groups is as follows:

Order Inadunata.
    Family Plicatocrinidæ (*Calamocrinus, Ptilocrinus* [fig. 42], *Thalassocrinus, Gephyrocrinus* and *Hyocrinus*).
Order Articulata.
    Family Bourgueticrinidæ (*Rhizocrinus, Bythocrinus, Democrinus, Bathycrinus, Ilycrinus* and *Monachocrinus* [fig. 39]).
    Family Phrynocrinidæ (*Phrynocrinus* and *Naumachocrinus*).
    Family Apiocrinidæ (*Proisocrinus* [fig. 40] and *Carpenterocrinus*).
    Family Pentacrinidæ.
        Section I: Pentacrinites (*Metacrinus, Isocrinus, Endoxocrinus, Comastrocrinus* [fig. 41] and *Hypalocrinus*).
        Section II: Comatulids (see below).
    Family Holopodidæ (*Holopus*).

The comatulid section of the family Pentacrinidæ in the recent seas has become so numerous, so widely spread and so diversified that it alone has acquired all the characteristics of an order. It is thus subdivided:

Suborder Macrophreata.
    Family Atelecrinidæ.
    Family Pentametrocrinidæ (figs. 49, 50).
    Family Antedonidæ (including the subfamilies Antedoninæ [figs. 47, 48], Thysanometrinæ, Perometrinæ, Heliometrinæ, Zenometrinæ, Insometrinæ and Bathymetrinæ).

Suborder Oligophreata.
    Family Charitometridæ.
    Family Thalassometridæ (including the subfamilies Ptilometrinæ [fig. 46] and Thalassometrinæ).
    Family Calometridæ (fig. 45).
    Family Tropiometridæ.
    Family Colobometridæ.
    Family Mariametridæ.
    Family Stephanometridæ.
    Family Himerometridæ.
    Family Zygometridæ.
    Family Comasteridæ (including the subfamilies Capillasterinæ, Comactiniinæ [fig. 44] and Comasterinæ).

THE INTERRELATIONSHIPS OF THE CRINOID SPECIES

The various crinoid species are of very different relative value. In some comatulid genera, especially those including species with many arms, if any one character whereby the species are commonly differentiated be plotted on a species curve the several species will be found to be indicated not by a series of separate triangles, but by a succession of more or less marked nodes which are united to the mass forming the adjacent nodes by coalesced bases in thickness equal to from 10 to 60 or more per cent of the maximum height of the neighboring nodes. Such variability and lack of absolute fixity in any one character is as a rule reflected in all the characters, and thus there results a species group or genus which may be compared to a small mountain system rising out of a plain each peak of which represents a recognized form. In such a genus every character varies between two extremes, but there is often no correlation whatever between the different characters. Thus every sort of combination is possible and a very large variety is found, though the tendency is for the characters to form more or less definitely correlated groupings and to crystallize into certain definite types.

This type of variability is not connected with the geographical origin of the specimens except in a very general way; it is chiefly seen in the multibrachiate species of the Oligophreata, and in specimens of these species from the East Indian region, though there are one or two good examples in the Caribbean Sea. In the Indo-Pacific many species which occur in numerous well-marked varieties in the Malayan region when extending their range outside of this region gradually become more and more fixed and definite in their characters so that individuals from, for example, Madagascar or southern Japan, are all found to be practically uniform in their various features and to represent the mean of the two extremes seen in a series from the central East Indian region.

Thus it is evident that in a number of crinoid genera, as in many groups among the fixed and arborescent marine organisms, we have to deal not only with the usual and well-recognized geographical variation and the formation of geographical " subspecies," but also with the formation of " varieties " which are strictly comparable to the accepted " varieties " among the plants. Such difficult and intricate genera as *Cratægus, Aster,* etc., have their representatives among the crinoids, though in the latter the number of included species is not by any means so large.

Many plants form marked local varieties correlated with the physical and chemical character of their immediate environment—the type of soil, amount of sunlight, average temperature, amount of moisture, etc.—and several of these varieties may often be found within a relatively limited area, as in certain species of *Aster*. Many crinoids do exactly the same thing as a result of local variations in the food supply, the amount and kind of illumination, and the temperature.

FORM AND STRUCTURE OF THE CRINOIDS

Typically a crinoid is rather abruptly divided into a slender and more or less flexible column which supports at its summit a pentaradiate head or crown (figs. 39-42) the five divisions of which each may bear anywhere from one (figs. 42, 50) to nearly forty (fig. 17, left), but most commonly two (figs. 39, 43, 46-48), flexible arms along the ventral side of which, giving off branches to the slender alternating lateral appendages or pinnules, runs a narrow ciliated groove (fig. 36, left), the grooves from all the arms of each division uniting and running in a single groove across the so-called ventral disc to the mouth (figs. 4, 5). The cilia in these grooves pick up and convey to the mouth the minute plankton organisms, both animal and vegetable, which serve the crinoid as food.

A single living crinoid (*Holopus*), lacking the column altogether, is attached directly by the crown, the basal portion of which becomes much elongated. In the Plicatocrinidæ the column continues throughout life to add new segments just beneath the crown and never, so to speak, matures. In the large group to which all the living crinoids except the Plicatocrinidæ belong the column increases to a definite size, the topmost columnal then enlarging and becoming permanently attached to the crown, forming a sort of apical plate. This is the general law which, like all of nature's laws, must be liberally interpreted, for it is subject to curious modifications. In some types, as in *Bathycrinus,* maturity comes slowly and several of these topmost columnals, progressively increasing in width with the growth of the crown, are formed before a fixed attachment occurs. In the group including the pentacrinites (fig. 41) and the feather-stars (figs. 43-50) two widely different extremes are found. The pentacrinite column is extremely precocious. It reaches the mature stage and forms the definite topmost columnal when the crown is still extremely immature and, so to speak, as yet lacks the instinct to attach itself to the column. The column therefore continues to grow and forms a second topmost columnal as in *Bathycrinus,* though in this case the two are separated from each other by a number of intercalated columnals. The second, like the first, fails to become attached to the crown and, the rapidity of stem growth increasing, a continuous series of these topmost columnals is formed each of which immediately after its appearance is pushed away from the crown by the formation of another one above it, the column becoming so enormously overdeveloped that the animal cannot nourish it all and so it dies away at the distal end as rapidly as new segments are added beneath the crown. As they are pushed backwards the numerous elements which nature intended for topmost columnals become separated by a definite number of intercalated segments from which they are always to be distinguished by their larger size and the presence of a whorl of five long jointed processes ending in a strong hook, the so-called cirri. In the feather-stars the column is just as precocious as in the pentacrinites, reaching maturity and forming the definite topmost columnal at a very early stage (fig. 55). But in this group attachment occurs. The column, being mature, has ceased its development; the crown is as yet very small and young; the topmost columnal has become attached to the latter and now forms an integral part of it, and it continues to develop with it regardless of the conditions in the column of which it was once a part. The crown becoming too large and heavy for the column, the latter breaks away just beneath the enormously enlarged topmost columnal, now called the centrodorsal, and the animal becomes free. The further development of the soft structures of the column takes place entirely within the centrodorsal (fig. 7) from which the numerous cirri, here crowded together instead of spaced in whorls of five as in the pentacrinites, are extruded (fig. 10).

Feather-stars mostly attach themselves to foreign objects by means of their usually stout and hook-like cirri which are most commonly from one-fourth to one-third the length of the arms (figs. 33, 34), though in a few species they are longer than the arms (figs. 32, 46). In some the cirri are very numerous, long, slender and nearly straight, forming collectively a sort of disc which, on the principle of a snowshoe, supports the animal on soft ooze or mud (fig. 35), and in one family (Comasteridæ) they are frequently quite absent, the centrodorsal being atrophied and sunken in so that its now flat surface does not project beyond the dorsal surface of the crown (fig. 11). Pentacrinites attach themselves to arborescent marine animals by their cirri, like the comatulids, or lie upon the sea floor with the column more or less coiled and the crown raised high above it. The other crinoids, except *Holopus,* are either attached to solid objects by the expanded and encrusting basal columnal or terminal stem plate (Plicatocrinidæ, Apiocrinidæ, and Phrynocrinidæ), or send out from the distal portion of the column a mass of root-like processes by which, plant-like, they are able to maintain an erect position on muddy bottoms (Bourgueticrinidæ). It is curious that in some of these if the crown be lost before the stem dies a mass of roots is produced from the upper end of the column similar to those at the lower end.

The crown of a crinoid is composed primarily of three alternating circlets of five plates, excepting in the Plicatocrinidæ in which there are only two, calling to mind the bracts, sepals and petals of a flower. The plates of the lowest circlet (infrabasals) are small, often only three in number, and frequently, or perhaps usually, absent in mature animals; the plates of the second circlet (basals) are larger and more constant, though in the feather-stars they become transformed into an internal septum (fig. 7, shown cut across just above the cavity within the centrodorsal) with no hint of their original significance, and in the Plicatocrinidæ there are frequently only three of them; the plates of the third circlet (radials) are always highly developed, and are structurally the basal plates of the arms. In a few types each of these is doubled so that there are ten of them instead of only five (compare figs. 49 and 50).

Following the radials there is a linear series of ossicles which rarely remains undivided (figs. 42, 49, 50), almost invariably forking on the second (figs. 39, 46-48); this gives ten arms, the commonest number among the crinoids; but each of these may again divide on the second or fourth segment beyond the first division (very rarely on any other) (figs. 40, 41) and this process may be repeated in extreme cases as many as eight or nine times (fig. 17, left). Ordinarily all of the five groups of arms are alike and all of the arms are of the same length, but in the Comasteridæ the arms arising from the left posterior radial, sometimes from both posterior radials, are frequently shorter than the others, sometimes scarcely more than a third as long (fig. 44), and they are further peculiar in lacking the ambulacral groove (fig. 36), in bearing more numerous and more developed gonads, and in ending in a terminal brachial bearing a pair of pinnules instead of in a growing tip as do normal arms.

From the second onward the arm segments bear on alternate sides long slender jointed processes called pinnules (figs. 1, 44, 48), which, in the comatulids, are of three types. At the base of the arms and on the second ossicle of division series composed of four elements are the so-called oral pinnules which lack the ambulacral groove and are variously modified into very sensitive tactile organs (figs. 47, 48, 51) or into stout spines (fig. 52) extending over and protecting the disc; following these and more or less abruptly differentiated from them are the shorter genital pinnules (figs. 1, 51, 52), with, or, more rarely, without (fig. 36, left) an ambulacral groove, on which the gonads are developed; there are usually between six and twenty of these on each side of the arm, and distally they pass gradually into the longer and usually very slender distal pinnules (figs. 1, 51, 52) which serve purely as food gatherers. In a few types one or more of the earlier pinnules are lacking (fig. 43), while in the Comasteridæ (figs. 15, 43) the oral pinnules bear curious comb-like structures recalling the pectinate antennæ of certain insects. In the crinoids other than the comatulids the pinnules are much more nearly uniform in structure and in function; in some types (*Metacrinus, Hypalocrinus, Comastrocrinus* [fig. 41] and *Proisocrinus* [fig. 40]) they are rudimentary or even quite lacking on the terminal portion of the arms. In one comatulid (*Comatulella brachiolata*) many of the pinnules are modified into stout organs resembling cirri which assist the animal in clinging to arborescent marine organisms.

The various ossicles which together form the crinoidal skeleton are tied together by more or less closely packed bundles of fibrillæ the ends of which take the form of loops within the calcareous substance. Between most of the brachials or ossicles of the arms there is found in addition to the ligaments a pair of ventral muscle bundles and between the ossicles of the pinnules there are sometimes a few muscle fibers or a small muscle bundle. Excepting in *Holopus* more or fewer of the brachials are united in pairs by ligament fibrillæ only; such unions, known as syzygies, are extremely close, at right angles to the axis of the arm, and with the joint faces marked with radiating ridges; two brachials so united usually appear as a single one with a thin dotted line across it (fig. 54). Crinoids seem to have the power of severing the syzygies at will, and arm fracture almost invariably takes place at these unions. As a rule syzygial pairs are regularly distributed throughout the crinoid arm, the first being composed of the third and fourth brachials; their number decreases with specialization and with increase in the number of arms.

In addition to the primary bony framework including the ossicles of the crown—calyx plates, brachials and pinnulars—and stem and cirri crinoids have two other skeletal systems; one, superficial, takes the form of very numerous spicules which may increase in size to definite plates sometimes mutually in contact protecting the soft ventral integument; along the ambulacral grooves, especially on the pinnules, these become more regular and better developed than elsewhere (figs. 18-26) and often form large and definite side and covering plates (figs. 27-31) the former lying in the perisomic wall and the latter, hinged to them by ligaments, in the lappets which line the ambulacral grooves and capable of being closed down over them; the other skeletal system is the internal, consisting of numerous spicules and networks occurring more or less plentifully in the bands of connective tissue traversing the body wall and in the walls of the digestive canal.

In a very large 10-armed feather-star in which side and covering plates are developed there are visible externally about 600,000 distinct skeletal elements each of which arises from a separate center of ossification; of these about 87,000 belong to the primary and about 513,000 to the secondary or perisomic skeletal series. In a large comasterid with no side and covering plates visible there may be as many as 700,000 primary skeletal elements, while in the very small antedonids the number probably never falls below 10,000. The greatest of the figures, however, is insignificant when compared with the number of ossicles in the larger pentacrinites where, in the recent species, nearly two and one-half millions are found. These figures, large as they are, must be approximately doubled when the internal skeleton is taken into consideration.

The internal structure of all the crinoids which have been studied is very similar. The mouth, at the point of convergence of the ambulacral grooves coming onto the disc from the arms (figs. 4, 5), usually central or subcentral but often excentric or even marginal in the Comasteridæ (fig. 12), leads downward through the gullet into the digestive tube (fig. 13) which, turning to the right, makes somewhat more than one complete coil (four in some of the Comasteridæ), the posterior portion bending upward and slightly forward to end at the summit of the so-called anal cone situated on the disc between two of the ambulacral groove trunks. Except for its canal-like prolongations into the arms the body cavity is filled with a mass of mesenteries, bands and septa so that it is reduced to a minimum, and in some cases, as in *Isocrinus,* has entirely disappeared.

Within the centrodorsal in the comatulids (fig. 7) and just over the summit of the column in the other types lies the chambered organ;

its central axis from which the partitions dividing it into five sections arise is continued irregularly upward to the vicinity of the mouth as the so-called axial organ, a cord of connective tissue including a number of open spaces or lacunæ. Five slender prolongations, one from each of the chambers of the chambered organ, accompany the axial organ for some distance, ending blindly, and each cirrus includes a median vessel from the same organ.

Except at the point where the axial organ leaves it the chambered organ is completely encased in a mass of nerve fibrillæ from which the large dorsal nerves of the arms and pinnules and their various derivatives as well as the cirrus nerves arise (fig. 9); while over this nervous envelope and along the nerve cords lie multitudes of wandering cells which play an important part in the regeneration of lost members. The envelope of the chambered organ and its derivatives, including also a closely associated nerve ring about the mouth which sends off very numerous branches including two cords running along the ventral surface of each arm, form the chief nervous system of the crinoids, but beneath the ambulacral grooves of the disc, arms and pinnules there is second quite independent nervous system consisting of a continuous thin layer of nerve fibrillæ.

The water vascular system of the crinoids consists of a ring canal about the mouth and vessels radiating out from it under each of the ambulacral grooves which they follow in their course to the pinnule tips, sending off branches into the delicate tentacles. Attached to the ring canal is a row of little tubes which open into the body cavity, and communication between the body cavity and the sea water outside the body is maintained by a number of calyx pores (5 in *Rhizocrinus,* 1500 in *Antedon mediterranea,* and still more in larger species) which pierce the body wall.

The blood vascular system of the crinoids is very highly developed, though the blood vessels are nothing more than intercommunicating cavities or gaps in the connective tissue of the mesenteries, bands and cords which in all directions traverse the body wall, the walls of the digestive tube, the axial organ, etc.

The so-called genital cord forms an irregular pentagon about the mouth from which five branches are given off, these running beneath the water tubes into the arms and pinnules; but it is only in certain of the lower pinnules in most comatulids or at the pinnule bases and rarely in the arms in the stalked types that the sexual products are developed. It has already been mentioned that in the short posterior arms of certain of the Comasteridæ the ambulacral grooves are absent; when this occurs the ambulacral nerves, water vessels and tentacles are also absent, but the genital cord is here especially developed.

Along the ambulacral grooves, except in most of the Comasteridæ, and usually also internally along the digestive tube, is a usually regular row of little round bodies, conspicuously colored in preserved specimens though usually colorless in life, called sacculi (fig. 4) which remind one strongly of the glandular dots on the leaves and petals of certain plants such as the species of Hypericaceæ. They are assumed to be excretory organs.

VIVIPAROUS CRINOIDS, AND SEXUAL DIFFERENTIATION

Three antarctic comatulids are viviparous, the young developing in special pouches or marsupia formed on the pinnules in two, but on the arms themselves in one. In all three of these the two sexes are easily distinguished by superficial external examination. Besides these three comatulids only six echinoderms are known to exhibit sexual dimorphism, four irregular echinoids, one holothurian, and one ophiuran. Excepting for one of the echinoids (*Anochanus*) all are from antarctic or subantarctic regions.

THE DEVELOPMENT OF THE COMATULIDS

The early stages of the comatulid larvæ are passed within the egg membrane and the developing eggs usually hang from the bases of the genital pinnules like little bunches of grapes. It is only after the formation of the elements of the skeleton—the rudiments of the terminal stem plate, a number of columnals, the infrabasals, basals and orals—that the larva emerges as a small barrel or bean-shaped creature with five transverse ciliated bands, an anterior tuft of long cilia, and a deep ventral groove (fig. 56).

In the best-known species (*Antedon adriatica*) the length of the free-swimming life varies very greatly, even in different individuals of the same brood; some attach themselves after a few hours and immediately proceed to further development, while others are to be found still swimming about after a lapse of as much as four and a half days. As a rule the free-swimming existence terminates after a few hours and is rarely as long as two or three days; larvæ still swimming at the end of that time are abnormal and incapable of fixation.

After attachment the larva soon assumes the form of a curious little stalked creature composed of a delicate column attached by a spreading base and supporting a calyx consisting of three or five, or often no, infrabasals which are very small, delicate, and difficult of detection, five large united basals forming a cup in which the visceral mass is enclosed, and five equally large orals superposed upon them which may be opened outward or closed together over the mouth. The plates of the radial series appear first as minute spicules in the angles between the basals and orals, one in each of these angles, or sometimes two in the right posterior angle. These grow very rapidly and two additional plates appear beyond them, the outer giving rise to two plates each of which forms the base of a rapidly growing arm. The additional plate in the right posterior area, known as the radianal, is always present, often appearing before any of the radials, but sometimes, as in *Antedon,* not being formed until a relatively advanced stage has been reached; it grows very slowly and by the growth of the radial just to the right of it it is shoved gradually upward and to the left, so that when the radials have come into lateral contact and have united into a ring it occupies a position at the edge of the disc where it is soon resorbed. Though small and soon disappearing in the young comatulid this is a very important plate in many fossil types. The arms at first are very different from the arms of the adults; they are composed of a series of exactly similar brachials without pinnules and with all the articulations between them the same, without muscles, and crossing the arm at right angles. Pinnules first appear at the tip of the growing arm after from nine to fourteen brachials have been formed, these being followed by the pinnule on the second brachial and considerably later by the pinnules on the intervening brachials (fig. 55). The first cirri appear on the now enlarged topmost columnal just before, simultaneously with, or just after, the first formation of the pinnules. Just before the appearance of the pinnules and cirri and before the disappearance of the radianal the larval comatulid is a remarkably perfect replica of a fairly typical representative of the Flexibilia Impinnata, but after the appearance of the pinnules and the cirri the crown undergoes a most extraordinary transformation and rapidly assumes all the characters of the adult comatulid, at various periods between five or six months and two and one-half years breaking away from the column and becoming a free-living feather-star.

The fully grown pentacrinoid young of different species show great variation, and range between 15 mm. and 65 mm. in total length; in some the column is very short and relatively stout, not more than one-third of the total length, and composed of as few as 10 segments, while in others it is very slender and much elongated, reaching four-fifths of the total length and being composed of more than 65 segments.

In the comatulids and in the pentacrinites (possibly excepting *Metacrinus*) with more than 10 arms the young always have 10 arms only until a considerable size is reached; increase in the number of arms is accomplished by breaking off each of the original 10 arms at the articulation between the first and second (more rarely between the third and fourth) brachials and forming on the stump an axillary ossicle from which two arms arise, one or both of which may still further divide.

REGENERATION

In the crinoids, especially in the feather-stars, the replacement of lost parts by regeneration reaches an unusual extreme. It is most highly developed in the comatulids, pentacrinites and bourgueticrinites, and least in the Plicatocrinidæ and, so far as we know, in *Holopus.*

In the pentacrinites it is very common in *Metacrinus,* nearly as common in *Isocrinus,* less noticeable in *Endoxocrinus,* and relatively rare in *Comastrocrinus* and in *Hypalocrinus.* This is not necessarily the result of a greater inherent ability to regenerate on the part of *Metacrinus* and *Isocrinus,* but is correlated with the fact that they run up into the shallowest water where the wave action makes itself felt, for the proportion of regenerated individuals decreases rapidly with depth regardless of species.

Although inhabitants of deep water the species of *Ilycrinus* and *Bathycrinus* lose the radials, arms and visceral mass very readily and specimens are frequently found regenerating from the basal ring. Similarly the species of *Bythocrinus, Rhizocrinus* and *Democrinus* lose their arms so easily that it is very difficult to secure individuals with the arms still attached to the basiradial cone.

The family Apiocrinidæ as represented in the recent seas is known from two specimens, each representing a different genus. One of these (the type of *Proisocrinus ruberrimus*) is perfect, the other (the type of *Carpenterocrinus mollis*) is only a fragment. Similarly the family Phrynocrinidæ is known only from two specimens each representing a different genus. One of these (the type of *Phrynocrinus nudus*) is perfect, though the arms were broken during capture, while the other (the type of *Naumachocrinus hawaiiensis*) lacks the arms beyond the radials and the terminal stem plate.

Among the comatulids regeneration is very common in all littoral species, but with increasing depth it becomes less and less frequent. Broadly speaking it appears to occur to a much greater extent in the Macrophreata than in the Oligophreata, though partially regenerated cirri have been mostly recorded in the latter. It is quite possible that this is connected with the large chambered organ of the Macrophreata; and it is also possible that it is the small size of the chambered organ which to a large degree limits the extension of the pentacrinites and such comatulids as the Thalassometrinæ and the Charitometridæ toward the surface, since as a result of wave action breakage is most common in the littoral and without a large chambered organ a crinoid, unless unusually tough, could not repair its injuries with sufficient rapidity to survive.

The most common mutilations are the loss of the visceral mass and of more or less important portions of the arms, the fracture in the latter case almost invariably occurring at a syzygy. Loss of the visceral mass appears to cause the animal no inconvenience whatever, and it is entirely replaced in a little more than three weeks.

ASYMMETRY

There are four types of deviation from the normal pentamerous symmetry of the crinoids. These follow the following lines:

1. A rearrangement of the five primary groove trunks upon the disc whereby (a) the left posterior increases in size and gives off more branches than any of the others; (b) as a result of the anterior migration of the mouth the two posterior become much longer and the anterior much shorter than the others and a condition of bilateral symmetry is attained; (c) correlated with the anterior migration of the mouth, all of the primary groove trunks become merged into a horseshoe-shaped ring which skirts the lateral and anterior borders of the disc, giving off branches to the arms, the mouth being in the right center of the ring so that the ambulacra on the left are more developed than those on the right, or the ambulacra leading to the left posterior ray disappear altogether so that the ambulacra on the right are more developed than those on the left.

2. A dwarfing, or an overdevelopment, of the left posterior, more rarely of both posterior, radial with the accompanying post-radial series.

3. The intercalation of additional radials and post-radial series which alternate with the original five, and the associated dropping out of one of the five radials.

4. The suppression of two of the primarily five basals.

Asymmetry is almost universal in the comatulid family Comasteridæ, which includes the most specialized of all the recent types; in this family the first and second types occur, though the latter is much less common.

Asymmetry is characteristic of the genus *Promachocrinus,* which is probably rightly considered as the most specialized genus in the subfamily Heliometrinæ; here the first and third types occur.

Asymmetry is equally characteristic of the genus *Thaumatocrinus,* the most specialized genus of the family Pentametrocrinidæ; in this genus the third type is found.

Asymmetry exists in all of the recent genera of the Plicatocrinidæ, the first, second and fourth types being represented; the third also occurs in the fossil representatives of this family.

Asymmetry is characteristic of both of the recent genera of Apiocrinidæ, which are the most highly specialized genera in the family; in these the second type occurs.

Asymmetry of the second type is characteristic of *Holopus.*

Asymmetry characterizes both of the species of *Rhizocrinus* existing in the present seas, and one of the species of *Monachocrinus;* in these the third type is found.

It appears that, no matter in what form it may manifest itself, in the recent crinoids asymmetry is an attribute of the most specialized types in the groups in which it occurs. From the conditions in the Plicatocrinidæ, the last remnants of the once abundant Inadunata, it would appear that asymmetry is an attribute of phylogenetically decadent types—types in which type senescence has so far advanced as to inhibit the normal course of development.

Although occurring everywhere except in the Arctic Ocean and in the Mediterranean, Bering, Okhotsk and Japanese seas, asymmetrical types are most frequent and most highly developed (1) in warm and shallow water from southern Japan southward throughout the Malayan archipelago to northern Australia and thence westward to Ceylon, and (2) in the Antarctic and in the cold abysses.

Though present among species inhabiting the western Atlantic from North Carolina to Brazil, and characteristic of many forms living at intermediate depths in the western Pacific and in the Indian Ocean, in these it is never more than slightly developed, even though they may be very closely related to types in which it is, in other situations, carried to an extreme.

Briefly stated among the recent crinoids any wide departure from the normal close approximation to true pentamerous symmetry indicates unfavorable conditions of one or other of two main types which are not mutually exclusive; these two types are:

1. *Internal unfavorable conditions,* induced by incipient phylogenetical degeneration through type senescence, as in the Plicatocrinidæ which in the recent seas represent the otherwise almost exclusively palaeozoic Inadunata; and

2. *External unfavorable conditions,* taking the form of

   a. Phylogenetically excessive cold, and

   b. Phylogenetically excessive warmth.

THE COMPOSITION OF THE CRINOID SKELETON

The skeleton of the crinoids has the composition of a moderately magnesian limestone, the proportion of magnesium carbonate to calcium carbonate appearing to be a function of temperature and rising from 7.26 per cent in the coldest water to as high as 13.74 per cent in the tropical littoral. A trace of phosphate of lime appears always to be present, but whether or not it is an essential constituent is uncertain.

THE DISTRIBUTION OF THE CRINOIDS

The modern distribution of the crinoids has been chiefly the result of the gradual differentiation in the conditions of different sections of a once uniform sea area resulting in the evolution of more or less distinct faunal units through the selective extirpation of different types in different regions; combined with this there has been under the changing conditions the evolution of a few new types and the further specialization of others, some of which, efficient and aggressive, have apparently extirpated the previous crinoidal inhabitants from all the regions into which they have been able to extend their range.

Changing geological and meteorological conditions affect chiefly the shallow water of the littoral and sublittoral regions; the intermediate depths are but slightly affected, and the abysses not at all. Thus faunal differentiation is most marked in shallow water, much less marked in water of intermediate depth, and but vaguely indicated in the abysses.

One of the results of the gradual change in conditions in a once nearly uniform ocean has been the discontinuous distribution of many marine types occurring in two or more widely separated localities which have been subjected to less modification than the intermediate regions but which are now separated by impassable thermal or other barriers. This is well brought out in many marine types and in the crinoids is illustrated by the curious correspondence between the fauna of Australia and that of the Caribbean Sea.

After the differentiation of a fauna land barriers sometimes appear isolating a certain section from the main range. It is thus that we account for the reappearance of Arctic types in the Okhotsk and Japanese seas.

Geographically the littoral crinoids are divisible into a number of more or less well-marked faunas corresponding in the main to those indicated by other marine types. In those regions where the temperature of the water is more or less uniform from the surface to great depths, as in the Arctic, the Antarctic, the Mediterranean, etc., the littoral crinoids descend with it and there is then a uniformity in the crinoid fauna from the surface almost or quite to the abysses; but where the temperature decreases rapidly with depth, as along the tropical shores, the bathymetric extension of the littoral types is very limited and the littoral fauna is underlain by an intermediate fauna consisting for the most part of more ancient and more conservative types which is fairly uniform the world over, though it reflects the broader divisions of the local overlying faunas. It is from this intermediate fauna that the littoral faunas on the one hand and the abyssal faunas on the other appear to have been derived.

The distribution of the crinoids appears to be governed entirely by temperature, pressure playing no part whatever.

There seems to be a close correlation between the bathymetric (or thermal) range and the geographical range of the same type, a form with a restricted bathymetrical range having a similarly restricted geographical range and the reverse.

THE PALEONTOLOGICAL HISTORY OF THE LIVING CRINOIDS

Of the four great divisions of the crinoids, the Camerata, the Flexibilia, the Inadunata and the Articulata, two, the Inadunata and the Articulata, are represented in the present seas.

The Inadunata are almost entirely confined to the Paleozoic, ranging from the Ordovician to the Carboniferous, with one of the 18 families (Poteriocrinidæ) represented in the Trias and another (Plicatocrinidæ) known only from the Upper Jurassic and from the recent seas.

The Plicatocrinidæ (including the living genera *Calamocrinus, Ptilocrinus, Thalassocrinus, Gephyrocrinus* and *Hyocrinus* and the fossil genus *Plicatocrinus*) are at present entirely confined to the deep and cold abysses; all of the species are very rare, most of them having only been dredged once and none of them more than twice. The Jurassic representative of this family is also very rare, and its remains are commonly associated with those of hexactinellid and lithistid sponges so that it also probably lived at considerable depths. No representatives of the Plicatocrinidæ are known from the Cretaceous or from the Tertiary.

The Articulata are entirely post-paleozoic, all from the Jurassic or later except the pentacrinites, which are also represented in the Trias.

The Phrynocrinidæ are not represented as fossils; the ranges of the other families and of the genera including both recent and fossil species are as follows:

Bourgueticrinidæ: Upper Jurassic to Recent.
  Rhizocrinus: Cretaceous (New Jersey); Eocene (Europe); Recent.
  Democrinus: In a recent breccia at Guadeloupe which also contained a human skeleton; Recent.
Apiocrinidæ: Jurassic, Cretaceous and Recent.
Pentacrinidæ: Trias to Recent.
  Isocrinus: Triassic and Jurassic; Recent.
Zygometridæ: Jurassic to Recent.
  Catoptometra: Jurassic to Recent.
  Eudiocrinus: Jurassic to Recent.
Holopodidæ: Jurassic to Recent.
  Holopus: Tertiary to Recent.

THE FOSSIL REPRESENTATIVES OF THE RECENT CRINOID GENERA

Only a very few crinoid genera include both recent and fossil species, and these are divided into two groups, (1) those occurring only in the western Pacific (*Eudiocrinus, Catoptometra, Proisocrinus* and *Carpenterocrinus,* the species of the two last being apparently congeneric with certain species of *Millericrinus*) and (2) those confined to the western, or western and boreal, Atlantic (*Isocrinus, Rhizocrinus* and *Holopus*). The recent distribution of these types is thus seen to be the same as that of the living king or horseshoe crabs (Xiphosuridæ).

Excepting only *Proisocrinus ruberrimus* and *Carpenterocrinus mollis,* all of the species of these genera are chiefly represented in shallow water, and these two are the only ones which do not occur within 100 fathoms of the surface; indeed the species of three of the five other genera are entirely confined to water of less than 155 fathoms depth.

The maximum representation is between the shore line and 200 fathoms, especially between 50 and 150 fathoms; as, taking the ocean as a whole, we find at a depth of 200 fathoms a temperature of 50.1° F. and at 100 fathoms a temperature of 60.7° F. it is evident that these genera are most abundantly represented within the optimum temperature for crinoid life, which is between 50° and 65° F. It is interesting to observe that (excepting for *Proisocrinus* and *Carpenterocrinus,* each only known from a single dredge haul at temperatures of 36° and 40° F.) the only increase in the numbers falls between 50° and 64°, that is, within the optimum temperature for crinoids, and is particularly emphasized between 56° and 64°, the emphasis within the optimum temperature range being between 60° and 65°.

THE COURSE TAKEN BY SPECIALIZATION AMONG THE CRINOIDS

The dominant feature of the progressive specialization among the crinoids from the earliest times to the present day has always been a process of progressive simplification in structure, the result of a process of progressive atrophy or suppression affecting some part or other of the organism. Thus the more specialized types differ from the more generalized through the atrophy or suppression of some important structural element, while the later groups are differentiated among themselves according to the lines which this atrophy or suppression has followed.

The (recent) Articulata are distinguished from the Inadunata by the sudden cessation of stem growth (with an apparent, though not real, exception in the pentacrinites) after the stem has attained a definite and fixed length, and by the extreme atrophy of the calyx involving in most cases the complete disappearance of certain essential elements; the comatulids are differentiated from all the other (recent) types by the suppression of the column excepting for the proximal or topmost columnal which becomes permanently attached to the calyx; *Holopus* is differentiated from all other (recent) genera by the suppression of the column, the infrabasals and the basals, the stalk being formed by the coalesced and elongated radials; the Phrynocrinidæ differ from the Bourgueticrinidæ in the complete suppression of the radicular cirri, and the Bourgueticrinidæ differ from the Phrynocrinidæ in the suppression of the terminal stem plate.

THE OCCURRENCE OF LITTORAL CRINOIDS

Except on sandy and exposed muddy shores littoral crinoids occur in all possible situations. Their one essential requirement is pure, well-aërated water having a relatively high minimum salt content and well provided with minute plankton organisms, and wherever this condition is met within the range of the littoral species they may be looked for in the water just below the low-tide mark or in protected situations; sometimes they even occur in regions left bare at low tide.

Along the shores of the Indian Ocean from southeastern Africa, Madagascar and Mauritius to Suez, India and the Malay archipelago, along the coasts of Australia, especially in the north, and thence northward to Fokien and southern Japan, littoral comatulids of many species are abundant—about 30 are known from Singapore alone—particularly on reefs and rocky shores, less commonly in sheltered situations and in eelgrass, though their occurrence is commonly more or less local and they are frequently not to be found in apparently ideal places. A few species have been found by shore collectors in New Caledonia, Lord Howe Island, Fiji, Samoa, the Marshall, Gilbert (Kingsmill), Pelew, Caroline, Society and Hawaiian Islands, but throughout Oceania they appear to be relatively rare. None are known from the Japanese coasts north of Tokyo Bay, from the Asiatic coasts north of Fokien, from the northern or eastern shores of the Pacific, or from New Zealand.

In the Atlantic basin littoral crinoids occur from Scandinavia and Great Britain to the Gulf of Guinea, including the Mediterranean area (but not the Black Sea) and the islands of the European and African coasts, and in the region of Cape Town, and in the west from the Bahamas and Florida to southern Brazil; but in the west they are extraordinarily rare, there being, except in the case of *Tropiometra,* but six records, one from the Bahamas (*Nemaster*), one from the Tortugas, Florida (*Nemaster*), one from St. Thomas (*Antedon*), one from Dominica (*Nemaster*) and two from Brazil (*Nemaster* and *Antedon*).

Of all the comatulids the preëminently littoral genus is *Tropiometra,* and wherever this genus occurs, from South Africa to Australia, Oceania and southern Japan, and from the southern Caribbean to south Brazil and St. Helena, it is commonly found along the shores, often in great abundance. In the western Atlantic, from Tobago, Trinidad and Venezuela to southern Brazil, it is the only really common littoral form.

A close second to *Tropiometra* is found in the genus *Antedon,* ranging from Scandinavia and Great Britain to the Gulf of Guinea, including the offshore islands and the entire Mediterranean basin, and also found from St. Thomas to Brazil, all the species of which occur along the shores, where they are often locally abundant. Only two specimens of the American species are known, one from shore collections at Rio de Janeiro, the other from shore collections at St. Thomas.

The species which have actually been captured along the shore number no less than 152, representing 38 genera and 12 families and subfamilies, while 93 more undoubtedly occur there, making a grand total of 245 shore-living types already known. Of these 227 are from the Indo-Pacific region (including two from South Africa), eight are from the region between the Bahamas and Florida and Brazil, six are from the northeastern Atlantic north of the Gulf of Guinea, and four are from southern Australia.

The favorite localities for shore-living comatulids are more or less shaded situations, holes and crevices in reefs, beneath stones, in half-submerged caves, on piling beneath wharves, and in the irregularities on the outer side of breakwaters; but they are sometimes found among gorgonians or eelgrass, on mangrove roots, and occasionally on mud.

THE RELATION OF THE COMATULIDS TO TEMPERATURE

In the recent seas the comatulids range from the very warm water of the tropical littoral to water with a temperature of only 28.7° F., considerably below the freezing point of fresh water.

The species of the genera of the Oligophreata are especially developed in the warm waters of the present seas, and they are peculiarly characteristic of the warm waters of the tropical coasts. The species which occur in this warm water are almost without exception highly specialized, and they are especially remarkable for a great reduplication in the number of their arms, of which they may have as many as 150 or even more, and also for their large size.

A study of the ontogeny of the most extreme of these types shows that the essential characters of the adults appear at an extraordinarily early age, and also suggests that these characters do not indicate a true phylogenetic progress which will eventually lead to the evolution of new types, but rather a more or less pathological hyperdevelopment, an abnormal exaggeration of the normal phylogenetical tendencies, which will lead nowhere, but will terminate simply in the extinction of the species in which it appears. The fundamentally aberrant or unbalanced nature of these types is strongly indicated by the invariable conservation of some primitive character, for example spiny borders on the brachials, a regular distribution of the syzygies in the arms, a very primitive type of cirri or of pinnules, etc.

The species of the genera of the Macrophreata are mostly developed in the colder waters of the recent seas, and this suborder includes all the comatulids of the polar regions and of the abysses. The species which are found in very cold water are almost without exception very primitive, and they are especially remarkable for a reduplication of the radials, a conservation of the carination of the ossicles of the division series and of the arms, a conservation and an exaggeration of the spines which ordinarily are found only among the young, an abnormal shortness of the brachials and of the segments of the pinnules and of the cirri, as well as for their very large and very primitive pentacrinoids in which the radianal plate approaches its original position beneath the right posterior radial; the greater part of these species are remarkable for their very large size, and they include among their number the largest living crinoids known; their arms are never more than 10 in number except in the forms with 10 radials, which may have 10 or 20.

A careful study of these types, together with a detailed comparison between their characters and the characters shown by other species found in water abnormally cold for their immediate phylogenetic stock shows that the apparently primitive characters are without doubt the result of a repression or an inhibition of the normal phylogenetic development; furthermore, in combination with these characters we always find other characters which indicate a condition of very marked specialization, as for example a large number of proximal pinnules which are provided at their tips with more or less developed terminal combs, both of which characters are otherwise only found in the comatulids of very warm water at the opposite end of the temperature scale, and a great specialization of the centrodorsal.

The species of very cold water thus resemble the species of very warm water in the possession of a fundamentally aberrant structure, for they preserve and exaggerate certain very primitive characters while at the same time they show a high degree of specialization along other lines.

However extraordinary it may appear, in their unbalanced type of specialization the comatulids of the coldest water agree more nearly with the species inhabiting very warm water—nearly all of which belong to the other suborder—than with any of the species of the intermediate waters, and the largest species, the smallest species, and the species with the greatest number of segments in the arms, pinnules and cirri are found equally at both extremes of temperature.

The Oligophreata and the Macrophreata are both represented by six families between the temperatures of 50° and 55° F., but the Oligophreata predominate at all temperatures above this, while the Macrophreata predominate at all temperatures below.

In the Oligophreata the greatest number of families is found between 60° and 65°, and in the Macrophreata between 50° and 66°. For all the comatulids the greatest representation is between 55° and 65°, with the emphasis on 60°-65°.

It would therefore appear that the temperature range included between 55° and 65° represents the temperature phylogenetically most suitable for the recent crinoids. It is a very curious fact that the comatulids found between 55° and 65° are all of medium size, none very large and none very small, and that they all show well-balanced and conservative characters.

So far as we can see it is with the recent species which are found within these temperature limits that the fossil crinoids best agree, and one might hazard the guess that it was principally, if not entirely, within these temperatures that the crinoids of the post-palæozoic faunas, characterized by a very great development of the Articulata, were developed.

FOOD

Duchassaing records that the stomach contents of a specimen of *Isocrinus decorus* which he fished up in relatively very shallow water at Guadeloupe consisted only of the remains of small crustaceans.

Bronn, summarizing previous accounts, wrote that the stomach contents of *Isocrinus* were made up of the remains of small crustaceans, while those of the comatulids consisted of diatoms such as *Navicula, Bacillaria, Actinocyclus* and *Coscinodiscus,* of *Tethya,* and of many types of entomostraca.

W. B. Carpenter said in 1866 that in the very numerous specimens of *Antedon bifida* from Arran of which he examined the contents of the digestive cavity he never found anything other than microscopic organisms, and the abundance of the horny rays of *Peridinium tripos* made it evident that in this locality that organism is one of the principal articles of food. But in specimens from other localities he found a more miscellaneous assemblage of alimentary particles, the most commonly recognizable forms being the horny casings of entomostraca or of the larvæ of higher crustaceans.

In his account of *Hyponome sarsii* (the visceral mass of *Zygometra microdiscus*) Lovén states that in the ambulacral grooves he found masses consisting of minute crustaceans, larval bivalves, and other remains of food.

In 1876 W. B. Carpenter wrote that the contents of the alimentary canal of *Antedon bifida* both in the pentacrinoid stage and in the adult consists of minute entomostraca, diatoms, spores of algæ, etc., but in his Lamlash specimens especially of *Peridinium tripos,* which was usually very abundant in that locality. He also notes that the contents of the alimentary canals of the various types of pentacrinites examined by him are of the same nature.

P. H. Carpenter says that the food of a crinoid is considerably varied in its nature according to the character of the sea bottom on which it lives. The horny casings of entomostraca and the larvæ of larger crustacea are frequently to be found in the digestive tube together with the frustules of diatoms, spores of algæ, etc. In sections of *Bathycrinus, Rhizocrinus, Isocrinus* and *Endoxocrinus* from deep water the silicious skeletons of radiolarians may be found in considerable abundance and variety. Foraminifera also form a staple article of food for these deep-sea species, for he frequently found *Globigerina, Biloculina* and other types beneath the covering plates of the food grooves on the arms and pinnules, while the remains of their soft parts occur in the intestines of decalcified specimens.

Seeliger believes that he recognized in the earliest food of the larvæ of *Antedon adriatica* half-digested infusorians and different pelagic larvæ. Bury found the stomach of the very young pentacrinoids of *Antedon mediterranea* so filled with diatoms that the cutting of sections was rendered very difficult.

Dr. Edwin Kirk states that in the case of a number of specimens of *Comanthus japonica* which he examined the contents of the intestine were almost wholly comminuted animal matter.

At Maër Island, Torres Strait, Dr. H. L. Clark examined the stomach contents of four comatulids (species undetermined). He found that in each case the greater part of the food material was green algæ, chiefly unicellular though some linear forms (thread algæ) were also noted; a few diatoms were detected, and some foraminifera. In one of the stomachs several radiolarians were seen, in another a piece of a red alga, and in a third some fragments of minute crustaceans. Dr. Clark also examined the stomach contents of *Tropiometra picta* at Tobago which he found to consist of a mixture of vegetable and animal food, the former predominating. The plants were diatoms and unicellular green algæ, with occasional fragments of seaweeds; of animals, crustaceans were most frequently noted, but a few foraminifera were also seen; the crustaceans were minute amphipods, copepods and crab zoæas.

Dr. Th. Mortensen found that a relatively large percentage of the pentacrinoids of *Isometra vivipara* have in their stomachs the half-digested, but still perfectly recognizable, remnants of the larvæ of the same species; he even found very young pentacrinoids with the vestibule recently ruptured and the arms not yet developed with embryos almost as large as themselves in their mouths. He remarks that on account of the large number of pentacrinoids found attached in clusters to the tips of the upturned cirri—as many as 99 in one specimen—this danger to the embryos is very real, and probably quite a large number of them perish in that way.

LOCOMOTION

Excepting for the pentacrinites all of the stalked crinoids are firmly attached to foreign objects or rooted in the mud and therefore incapable of locomotion. The pentacrinites have such long and heavy stems which are usually so entangled with the objects on the sea floor and with the stems of other individuals that they are to all intents and purposes as firmly fixed as are the other stalked types. But the comatulids, attached by their highly mobile dorsal cirri, are able to detach themselves and move about, though as a rule they remain pretty constantly in one place and rarely change their position except as a result of some unusual stimulation.

Among the comatulids locomotion is of two types, swimming and crawling; swimming is the more usual, and apparently all littoral comatulids can swim. In swimming the arms of each pair beat the water alternately and at first quite rapidly, as much as 100 times a minute, but the animal soon tires and the longest distance recorded as covered by a swimming comatulid is less than 3 meters. The swimming of the feather-stars has been likened to the flitting of small birds in shrubbery as contrasted with sustained flight.

The young of two species, *Dorometra nana* and *Comanthus parvicirra* (twice) have been captured while swimming at the surface from ships at anchor or in plankton hauls.

Crawling is accomplished by a combined pulling and pushing, and in the comasterids the long anterior arms are extended forward and used for pulling while the short and stout posterior arms are used for pushing. The rate of progress has been calculated as 85 mm. a minute, or 5 m. an hour.

COLOR

Of all the animals in the sea there are none that exceed in beauty and variety of coloration the shallow water crinoids. Flower-like in form and almost flower-like in the fixity of their habit, they are also flower-like in the variety and distribution of their pigments. But with depth the diversity of hue diminishes so that we find the color range of the species of the deeper water relatively restricted while the individuals themselves, losing the almost universal spottings and bandings of the littoral types, become comparatively plain.

Though crinoids resemble flowers in the diversity and brilliance of their colors, their color types are quite the reverse of flower-like. In a particolored flower the center or eye is more or less abruptly lighter or darker than the remaining portions, or the petals are longitudinally striped; cross-banding of the petals is very rare. Among the crinoids particolored specimens are usually cross-banded, regularly or irregularly, and though the tips of the pinnules may be of a different color from that of their bases a true longitudinal striping of the arms is very rare and a conspicuous eye is never developed.

The published records show in the feather-stars the following frequency for the various colors; the numbers in parentheses show the individuals entirely of the color given, the others all the records for that color both in unicolor and in variegated types:

Yellow	194	(47)	Black	43	(3)
Brown	138	(24)	Orange	39	(5)
White	126	(1)	Gray	22	(1)
Red	80	(8)	Violet	15	(6)
Green	74	(7)	Blue	15	(0)
Purple	70	(10)			

While white and yellow occur in all possible combinations, orange does not occur with violet, black or green; red does not occur with black; purple does not occur with black, gray or green; violet does not occur with orange, black, gray or brown; black does not occur with orange, red, purple, violet, gray, green, or brown; gray does not occur with purple, violet, black, green or brown; green does not occur with purple, black or gray; and brown does not occur with red, violet, black or gray.

It is of course true that this apparent incompatibility of colors is partly due to a lack of observations and to a misinterpretation of the colors as recorded, and the foregoing list must therefore be accepted with considerable reservation.

In particolored comatulids the distribution of the colors on the arms and pinnules falls into several well-marked types, which may be arranged as follows:

I. Arms and pinnules uniform in color.
  a. Arms and pinnules uniform in color, but differing in color from the cirri.
  b. Arms and pinnules uniform in color, but the ventral and dorsal surface of different colors.
II. Pinnules of a different color from that of the arms.
  a. The distal portion of the pinnules (and usually also the arm tips) is of a different color from that of the proximal portion and the arms.
  b. All of the pinnules are of a color different from that of the arms.
III. Arms and pinnules irregularly spotted, mottled and blotched.
IV. Arms with more or less regular and uniform spots.
  a. Spots confined to the division series and arm bases.
  b. Numerous small spots generally distributed.

V. Arms with a median dorsal stripe.
  - *a.* A broad median stripe, lighter or darker than the color on either side of it.
  - *b.* A narrow median stripe, always very dark.

VI. Arms conspicuously and regularly cross-banded.
  - *a.* With several more or less irregular broad bands.
  - *b.* With a broad approximately central band.
  - *c.* With broad alternating bands of equal width.
  - *d.* With narrow alternating bands of equal width.
  - *e.* With narrow well-spaced bands.

As a general rule the coloration of the pinnules follows that of arms, but in a few types they are banded on each segment and in at least one case this is a good specific character.

The cirri are usually unicolor, less commonly dull at the base, becoming gradually or abruptly brighter distally, and rarely show distinctive color types; when this occurs the color types are usually a reflection of the color types of the division series and arm bases and very rarely distinctive.

Particolored cirri, except those which are merely brighter distally, fall into the following classes:

I. Each cirrus segment with a transverse band.

II. Cirri unicolor, but of a color not found in the calyx or arms.

III. Cirri blotched or spotted.
  - *a.* Cirri with irregular blotches or irregular bands.
  - *b.* Cirri with small spots.

IV. Cirri longitudinally striped.

A study of the development of the colors seems to indicate that all colors except gray and black may arise directly from white, and that yellow, red and brown usually arise directly from white, while violet arises as often from white as from any other color. All colors may develop from yellow; gray and black are developed only from yellow, and purple and green arise more frequently from yellow than from any other color. Red frequently develops into purple, and occasionally into yellow, violet and green. Brown develops into green and, less frequently, into violet. Orange develops into brown.

At a depth of 55 fathoms in the sea the relative proportion of the red rays is considerably diminished, and at 300 fathoms they have almost completely disappeared. In a discussion of colors, color combinations and color types and their relation to depth, therefore, it would seem that bathymetric divisions of 0-55 fathoms, 55-300 fathoms, 300-600 fathoms and 600 fathoms and over would be as satisfactory as any.

A tabulation of the colors according to depth shows that black does not occur below 55 fathoms; red, violet, gray and white do not occur below 300 fathoms; purple, green and orange do not occur below 600 fathoms; yellow and brown occur at all depths.

Yellow and brown are relatively much more frequent below 300 fathoms than above; purple, green, orange, gray and white occur in about the same relative proportions down to 300 fathoms, at that point decreasing abruptly or disappearing altogether; red, violet and black decrease abruptly below 55 fathoms.

No colors are more frequent between 55 and 300 fathoms than elsewhere. The proportion of uniformly colored species increases markedly with depth, while the corresponding decrease in variegated species is even more abrupt. All of the color types given occur only above 300 fathoms. The median dorsal stripe is most common between 55 and 300 fathoms. Distinctively colored pinnules and regular crossbands occur in about the same proportion down to 300 fathoms. Distinctively colored cirri and irregular spotting or mottling are much more common above 55 fathoms than below. Regular spotting occurs only above 55 fathoms.

Whereas the development of color in the crinoids seems to have a more or less definite relation to illumination, it appears to have no relation whatever to the temperature of the water in which the crinoids live. The various color types are almost entirely confined to water of high or intermediate temperature; but this is undoubtedly due to the fact that the crinoids of the colder parts of the oceans belong to groups in which color patterns are not developed even in their tropical representatives. This supposition is emphasized by the occurrence of several well-marked and beautiful color types in the species of the genus *Antedon* which are quite as well developed in the Scandinavian species as in those inhabiting the shores of northwestern Africa and the Mediterranean.

From the evidence at hand the following conclusions seem justified:

White, which is the original color of the pentacrinoid young and occurs frequently in the adults, denotes the more or less complete absence of pigment.

Yellow is the color of practically all of the more primitive forms, and of many of the more specialized, throughout life, and with very few exceptions (occurring in the brilliantly illuminated littoral) of small specimens and of advanced pentacrinoids. Orange or red, in reality an intensification of the yellow, is the color of a few primitive forms, and of nearly all the young which are not yellow.

After the full size has been reached a dusky factor makes its appearance which may be generally diffused or more or less localized, and deepens, alters, or obscures the original colors.

Illumination of the habitat results in an intensification of the natural colors and the very early appearance of the dusky age factor, as well as in the appearance of a blue factor resulting in the formation of bright greens, purples and violet, which may deepen to black.

All the comatulids living below the limit of light penetration exhibit the basic colors, white, orange or red, only, which, though they may become more intense toward the calyx and arm bases, are never otherwise diversified. Each of these colors, however, may be modified by the dusky age factor, resulting in " dusky purple," greenish or brownish yellow, brown, orange brown, crimson, or red brown. The blue factor is absent in these species, but in the group as a whole it gradually increases from the limit of light penetration to the surface, causing the appearance of greens, purples and violets of increasing intensity.

Geographically the maximum development of color diversity appears to be in the Malayan and north Australian region, and thence westward to Ceylon; but it is here also that the maximum development of littoral types is found. The whole littoral and intermediate fauna from east Africa to Oceania and southern Japan is notable for the diversity in the coloration of the endemic forms.

On the other hand, throughout the vast extent of the east and north Pacific we find the minimum diversity of crinoid coloration; all of the comatulids are unicolor, most of them yellow, becoming yellow brown, a few purplish brown or red; all of the stalked forms are yellow.

The crinoids of the Caribbean Sea as we know them to-day are much less highly colored than those of the Indo-Pacific region, and this holds good for stalked as well as for unstalked types. But here the groups which furnish the majority of the most variegated species are absent. In the remaining portions of the Atlantic, outside of the region of the Cape of Good Hope where the Indo-Pacific fauna intrudes for a short distance, we note especially the presence of the highly colored species of *Antedon,* which range collectively from Rio de Janeiro to St. Thomas and from the Gulf of Guinea to Norway, including the Mediterranean basin; of the green or white species of *Leptometra* which occur from Madeira to Scotland, including the Mediterranean basin; and of the small green or gray species of *Hathrometra* which are found from Chesapeake Bay and Portugal northward.

The coloring matter of crinoids is freely soluble in fresh water and in alcohol. It is possible to keep certain species for some time in water fresh enough to dissolve out a considerable amount of pigment without apparent injury, while many may be partially decolorized in a stream of fresh water while still alive.

As a general rule comatulids preserved in alcohol, no matter what their original colors may have been, become brown, usually a yellowish, more rarely a purplish, reddish or greenish brown, later slowly fading out to grayish white. The bands and spots often persist for some time, though with entirely changed color values, but they eventually disappear. On account of the wonderful diversity of the colors in life and of the altogether extraordinary alteration of the colors by preservation the greatest care is necessary in identifying living specimens, especially from descriptions based upon preserved material, for the color may or may not be a good specific index; it usually is not.

THE SIMILARITY BETWEEN CRINOIDS AND PLANTS

Although they are animals possessing a relatively high type of organization the crinoids are so plant-like in their outward form that it seems worth while to explain briefly the extent of and the reasons for this curious and striking similarity.

The roots of the stalked crinoids are of several different types varying from a large encrusting mass with digitiform processes about its borders to a long slender taproot buried in the mud from which very numerous delicate lateral roots are given off. Every type of crinoid root can be matched among the plants, though the crinoid root performs only one of the functions of the plant root, and that is to hold the organism in place.

The stem of some of the stalked crinoids, such as *Proisocrinus,* is long, smooth, slender, and enlarged toward the base, and thus strikingly similar to the stems of many of the commonest palms, this similarity being heightened by the numerous pinnate arms like palm leaves at the summit. The pentacrinite stems with their whorls of five cirri at regular intervals call to mind the stems of many plants with narrow whorled leaves, in combination with their lily-like crowns, especially such lilies as *Lilium philadelphicum.* From their resemblance to palms the stalked crinoids are commonly called " sea-palms " in French and Spanish, while their usual appellation in English is " sea-lilies."

The food of the crinoids consists of the minute plankton organisms suspended or moving slowly about in the surrounding water. In order to obtain an adequate supply of these organisms they must intercept the maximum amount of water without, however, impeding its flow, for it must pass by them constantly and continuously in order to furnish them with a supply of oxygen without which they would soon perish, as well as to deliver to them the requisite amount of food. As the maximum area is included within a circle the crinoids have developed a circular food-collecting apparatus consisting of slender pinnules which, spread out in the form of a circular net, filter the maximum amount of water while at the same time they interrupt the flow of water to the minimum degree. In this circular food-collecting apparatus composed of a vast number of slender filaments we see at once the influence of the same factors which have determined the development of the submerged filiform-dissected leaves among the water plants; and the similarity becomes more striking still when we call to mind such carnivorous plants as the species of *Utricularia*.

The crinoid crown is almost entirely a food-collecting apparatus; the essential organisms of the animal are reduced to a minimum and subordinated to the development of a structure offering a maximum area for the interception of food particles. This is not by any means a peculiarity only of the crinoids, for all of the other fixed and arborescent animals, the sponges, cœlenterates, polyzoans, tunicates, protochordates, etc., have similarly subordinated, as it were, their whole being to the specialization of the mechanism for collecting mobile food to such a degree that they may be differentiated often down to genera, and sometimes even down to species, by the characters found in the food-collecting apparatus alone without consideration of their other structures. The polyp or polypoid individual more or less flower-like in form or else capable of maintaining a strong inflowing current of water is a physical necessity correlated with a fixed existence, and the contrast between the requirements of a fixed and an active life are nowhere better illustrated than in the echinoderms through the comparison between the crinoids on the one hand and the echinoids, asteroids and ophiuroids on the other.

Terrestrial plants live rooted in the earth from which and from the surrounding atmosphere they derive all the substances necessary for their existence. But the medium about them is so light that some special provision must be made for the fertilization of their ova. Thus while the crinoids, and all the other fixed marine animals, have had to specialize, so to speak, on the development of an adequate apparatus for food collection, the plants have had to devote their energies to the problem of securing cross fertilization. This is largely accomplished through the intermediary of insects of various types, more rarely by small birds, which transport the pollen through the air, and the plants have developed all sorts of artifices by which they make their flowers attractive to these creatures. The result of this necessity has been to localize in the flowers the chief differential characters of the plants just as the same characters have in the crinoids and in the other plant-like animals been chiefly segregated in the commonly flower-like food-collecting mechanism.

The polyps of the plant-like animals cover the maximum area with their arms or tentacles in order to collect the maximum amount of food, while the flowers cover the maximum area with their petals in order to attain maximum visibility, with the common result of a circular expanse of symmetrically arranged parts in both cases. To increase their efficiency by mass effect the polyps of plant-like animals are often spiked, sometimes spirally arranged on the axis, and occasionally grouped in umbels or in imperfect racemes like flowers, while to counteract unusual external stresses of waves or wind both flowers (*Raoulia,* etc.) and polyps (brain-corals, etc.) are sometimes in the same way gathered together in great more or less globular and highly resistant masses.

A very large proportion of the conspicuous flowers are pentapartite, with five sepals and five petals alternating with them, and commonly bracts beneath the sepals; crinoids are also pentapartite, with five basals and five arm-bearing radials alternating with them, and commonly infrabasals beneath the basals. Some flowers are tetrapartite, like the crucifers; some crinoids are the same, like *Tetracrinus.* Many flowers are hexapartite, as are also some crinoids, like *Hexacrinus.* The reason for the most common occurrence of five in both cases is probably that in the pentapartite division there lies the maximum strength.

The basals of the crinoids normally enclose the visceral mass much as in many flowers the sepals enclose the ovary, and sometimes (*Isocrinus,* etc.) they imbricate over the bases of the radials as the sepals imbricate over the bases of the petals.

In many crinoids the arm bases are firmly united by interbrachial plates or so closely pressed against each other that they may almost be said to possess a gamopetalous corolla.

In a few fossil crinoids (*Petalocrinus* and *Crotalocrinus*) all the arms borne by each radial are united into a single, broad, flat plate which may be highly flexible, and the crowns of these crinoids resemble flowers to a most astonishing degree.

At the base of the petals in the flowers are the stamens, while at the bases of the arms in the comatulids are the elongated oral pinnules which are usually bent inward over the sometimes central high anal tube which in many cases looks very much like a pistil.

The essential part of the plant is the flower; roots, stem and leaves may be dispensed with in the parasitic types, but the flower must be developed. In the crinoids the great essential is the food-collecting apparatus; everything else may be reduced to a minimum, but that must remain at an irreducible maximum. In the family Rafflesiaceæ the whole plant is reduced to nothing but a flower, which may be very large, as much as three feet in diameter; in the comatulids the animal is little else than arms and pinnules, and the diameter of the expanded animals in one species is about three feet.

Since the spermatozoa of the crinoids escape into the sea while the ova remain attached to the pinnules of the female it is evident that in this group conditions exist in a way comparable to those found in wind-pollinated plants, and it is interesting to note that the crinoids possess many scores of entirely separate and distinct gonads arranged in a series along both sides of each arm on the pinnules or at the bases of the pinnules remotely suggesting the arrangement of many wind-pollinated flowers in catkins.

The ciliation of the crinoid larvæ may be compared with the development of the fibers on the seeds of such plants as the cotton, and the development of the long anterior tuft of cilia with the coma on such seeds as those of the milkweed (*Asclepias*) or fireweed (*Epilobium*).

The color of the crinoids has already been discussed, but there are one or two points regarding color which are of interest in this connection.

Many of the species of Comasteridæ are asymmetrical, one or two of the arm clusters being more or less, sometimes very much, shorter than the others, the animal developing a secondary bilateral symmetry from an original pentamerous symmetry. Many flowers also develop a bilateral symmetry from an original pentamerous symmetry, as is well seen in our species of Orchidaceæ, Scrophulariaceæ, Menthaceæ, etc., and in all intermediate stages comparable to those seen in the Comasteridæ, in the Campanulariaceæ and Solanaceæ. Because of the coiled digestive tube the visceral mass in the center of a crinoid never shares the pentamerous symmetry of the rest of the animal, and in the pentapartite flowers the similarly placed ovary, excepting only in the Crassulaceæ, is out of harmony with the radial symmetry of the other structures.

Flowers facing directly upward or directly downward are always regular, insuring maximum visibility from all directions; irregular flowers always are directed more or less laterally. Crinoids which rest on muddy bottoms and therefore face directly upward (as *Pentametrocrinus*) or which have pendent crowns (as *Ptilocrinus*) are also symmetrical since this means maximum efficiency in combing the water which may pass across them in any direction.

Among our native flowers (in eastern North America) the various colors represented fall into three distinct groups on the basis of the proportion of irregular to regular flowers included, as follows:

GROUP I: ABOUT ONE-QUARTER OF THE FLOWERS IRREGULAR

	Red	White	Green
Per cent of regular flowers..................	78	73	72
Per cent of irregular flowers................	22	27	28

GROUP II: NEARLY ONE-HALF OF THE FLOWERS IRREGULAR

	Brown	Yellow	Orange
Per cent of regular flowers..................	57	56	56
Per cent of irregular flowers................	43	44	44

GROUP III: MORE THAN THREE-QUARTERS OF THE FLOWERS IRREGULAR

	Blue	Purple
Per cent of regular flowers............................	24	21
Per cent of irregular flowers..........................	76	79

The proportion of variegated flowers is much higher in irregular than in regular types since in the irregular types every artifice which will increase the visibility must be adopted. The proportion of variegated crinoids is very much higher in the irregular than in the regular species because they are all from shallow water and it is in the shallow water that the colors of crinoids are best developed. From a minimum in the coldest regions the proportion of irregular flowers increases to a maximum in the tropics; from a minimum in the coldest water the irregular crinoids increase to a maximum in the tropical littoral.

About three-quarters of all our blue, violet and purple flowers are irregular; since blue, violet and purple seem to be the most conspicuous colors so far as insects are concerned a flower loses less in visibility by being of these colors than it would by being of other colors. Blue is only recorded from irregular crinoids, and violet and purple are much more common in irregular than in regular types, as a result of the occurrence of the former only in shallow water.

In the crinoids the pigment is not confined to the exterior of the animal as in most active types, including the other echinoderms, but occurs more or less generally distributed throughout the body just as pigment is distributed throughout the interior of many plants. The coloring matter of the crinoids is, in part at least, a lipochrome, and other lipochromes occur in a number of flowers just as indigo, occurring in many different plants, is also found in the Polyzoa and other animals, and just as cellulose or a very closely allied substance is found in the tunicates.

Many flowers have a sweet and attractive odor, and certain crinoids (*Tropiometra* and others) also exhale a pleasant plum-like aroma, though this is not so marked as in the case of certain polyzoans (*Flustra*); as this pervades the whole animal it is perhaps better to compare these types with such plants as those of the families Menthaceæ or Myricaceæ, most of which are aromatic. But among the fixed animals these plants more nearly parallel the sponges in this respect, while the sharp principle pervading the cruciferous plants calls to mind the very acrid secretions found in the cœlenterates.

Many plants, like nettles, have stinging hairs; in the crinoids the secretion from the glands connected with the hair-like papillæ on the tentacles appears to possess stinging qualities. Just as cattle will not eat nettles, so the fishes carefully avoid the crinoids.

The petals of certain flowers, as in the Hypericaceæ, are dotted with so-called glands containing excretory products and often arranged in regular rows. Along the ambulacral grooves in the crinoids is a row of minute glandular bodies also containing excretory products.

Similarity of habit and the resultant similarity or at least parallelism in the problems to be met have given rise to a very close correspondence in many features between the fixed and sessile animals and the plants, though the means by which this close correspondence has been attained differ very widely in the two classes of organisms.

PARASITES AND COMMENSALS

A very large number of organisms belonging to very diverse groups are found more or less associated with the crinoids. The relation between these types and the crinoid hosts runs by imperceptible gradations all the way from true parasitism, in which the organism feeds directly upon the body tissues or fluids of the host, to the most casual or even accidental association.

The animals associated with the crinoids may be grouped as follows:

I. *True parasites.*—Animals which (1) live upon the tissues or body fluids of the crinoids and occur either (a) internally or (b) externally; (2) occur internally, though not feeding directly upon the tissues of the host; or (3) while living externally upon the surface of the body and not feeding directly upon the tissues or fluids of the host are more or less permanently fixed in position and cause more or less extensive malformations, sometimes becoming encysted.

This class includes a few "worms," a number of myzostomes, a few crustaceans, and the parasitic gasteropods.

II. *Semiparasitic commensals.*—Animals which feed upon minute organisms and have to a greater or lesser extent adopted the habit of sucking up the food particles from the streams flowing down the ambulacral grooves of the crinoid to the mouth, or of temporarily entering the digestive tube and feeding upon the contained matter.

This class includes the polynoid and ophiuran parasites, most of the crustacea, and most of the myzostomes.

III. *Nonparasitic commensals.*—Animals which, while usually, or commonly, found living upon or among the crinoids lead an entirely independent existence and for the most part are found living under similar relations with other organisms.

Here are included the foraminifera, sponges, corals, hydroids, polyzoa, barnacles, tunicates and *Rhabdopleura,* as well as certain shrimps.

IV. *Casual associates.*—Animals which normally occur hiding among, crawling over, or attached to other usually arborescent organisms (fig. 62) from which they may or may not derive nourishment, or which normally occur attached to any available support, and which occasionally stray among or upon, or attach themselves to, the crinoids, but remain otherwise entirely independent of them.

This class includes a vast number of organisms of very diverse types.

As in the case of the other arborescent marine types, and in general among the animals that live by filtering the smaller plankton from the sea water, the crinoids are chiefly subject to indirect parasitism, that is to say, the creatures depending upon them for their existence appropriate the food particles which the crinoids have collected in the ambulacral grooves, or even which they have swallowed, instead of consuming the tissues or body fluids directly. Of the animals which derive a part or all of their nutriment from the body or from the efforts of the crinoids about 10 per cent are directly parasitic, and about 90 per cent are indirectly parasitic in varying degrees.

Of the animals which are parasitic on the crinoids nearly all may be described as casual parasites, for they belong to genera or families other representatives of which are nonparasitic; that is to say, they are merely particular species which have found an easy existence in preying upon the crinoids, though this mode of life has not induced any special modification of their structure.

There is a curious and interesting correspondence between the relations of the fixed marine organisms (including the crinoids) and their parasites and commensals and those between parasitic and epiphytic flowering plants and their hosts. The barnacles, most hydroids, polyzoans, etc., correspond very closely to the epiphytic plants, especially those of the families Orchidaceæ and Bromeliaceæ. *Rhabdopleura* and certain hydroids are quite vine-like in habit, ascending crinoid stems as vines do the trunks of trees. Most parasitic plants appropriate the unelaborated sap of the host and convert it to their own ends; most parasites of the fixed marine organisms in the same way appropriate the concentrated but undigested microplankton in or approaching the stomach of the host. On land most animals are parasitized by animals of an inferior organization; but among the fixed marine animals the parasites for the most part belong to a phylum with a superior organization and sometimes even to the same phylum (cœlenterates parasitic on cœlenterates, crustaceans parasitic on crustaceans, ophiurans parasitic on crinoids, etc.). The relations between the fixed marine animals and their parasites are thus more nearly the same as those between parasitic flowering plants and their hosts. On land the various animal groups are definitely parasitic or nonparasitic; but many plant families, such as the Scrophulariaceæ, Santalaceæ, etc., and even many single genera, such as *Pedicularis, Melampyrum, Gerardia,* etc., include both parasitic and nonparasitic species, just as do many families and genera, such as *Synalpheus, Periclimenes,* etc., occurring with the fixed marine animals.

The three types of parasites which are of especial interest are the gasteropods (*Stilifer, Stylina, Sabinella* and *Melanella*), *Enterognathus* and the myzostomes (figs. 57, 58).

The family Melanellidæ to which *Stilifer, Stylina, Sabinella* and *Melanella* belong includes species showing all gradations between free-living nonparasitic types and shell-less parasites living entirely within the body of the host. As parasites the Melanellidæ occur only upon the echinoderms, in which group, however, they are found on species of all the classes. Most of the parasitic forms, including all of those occurring on the crinoids, are characterized by extraordinarily delicate shells. Some of the species are permanently fixed in one position on the body of the host, but others, including all those found upon the crinoids, appear to move about and to bore into different parts of the host. It is not a little curious that, apart from *Melanella capensis* and *Stylina comatulicola,* all the species parasitic on the crinoids are always attached to the calyx plates, or to the cirrals, brachials and pinnulars instead of to the soft ventral integument.

The curious copepód *Enterognathus* occurs only in crinoids, but the family to which it belongs is well known as a parasite (or commensal) of the tunicates, most of the species living in the branchial chamber of these animals.

The myzostomes form a group of very highly specialized polychæte annelids and are the chief parasites of the crinoids, to which animals they are almost exclusively confined. On the crinoids they are, with one possible exception, always ectoparasitic, though they may form soft or calcified cysts within which they are almost completely isolated from the outer world. An organism, possibly a myzostome, has been reported in the ovarian cavity of *Notocrinus virilis*. If this really is a myzostome, which is not unlikely as similar endoparasitic species occur in starfishes (*Asterias, Stolasterias* and *Ceramaster*) and astrophytons (*Gorgonocephalus cucnemis* and *G. arcticus*), we find in the crinoids the five following groups of myzostome species:

1. Wandering species which move about freely and actively over the body of the host, as *Myzostomum cirriferum*.
2. Sedentary species which rarely, if ever, leave the spot where they have settled, as *M. parasiticum*.
3. Cyst-producing species which cause the formation of galls or swellings on the arms or disc, as *M. cysticolum*.
4. Entoparasitic species inhabiting the digestive tract, as *M. pulvinar*.
5. Entoparasitic species living in the ovaries, as *Protomyzostoma polynephris* does in the astrophytons.

Thus in the crinoids we find a single group of animals which, broadly speaking, play the part of the fleas, lice, jiggers and bots, intestinal worms and flukes combined as we know them among the land vertebrates.

A comparison between the myzostomes and the species of *Thrips,* occurring only on flowers, is also interesting.

In the vertebrates the blood with its multitudes of red corpuscles which when destroyed are promptly and continuously renewed is the logical food of practically all the parasites which do not inhabit the intestinal canal. The dilute blood of the crinoids, without structures corresponding to the red corpuscles, has none of the features which make the blood of the vertebrates such a reservoir of concentrated food. But the uncountable myriads of minute organisms flowing continuously downward along the ambulacral grooves and into the mouth form a stream of nutrient fluid in many ways analogous to the vertebrate blood stream, and it is from this source that the myzostomes as well as most of the other parasites derive their subsistence.

The species in each group parasitic on the crinoids in those cases in which our information is sufficient to permit us to speak with a reasonable amount of certainty follow bathymetrically and geographically the distribution of the classes to which they belong quite regardless of that of their hosts, and apparently, excepting possibly in the case of *Stelechopus,* the most primitive of the myzostomes parasitic on the most ancient of the living crinoids, there is not the slightest correlation between the systematic position of the parasite and that of the crinoid.

An undetermined internal worm, a parasitic ostracod, *Laphystiopsis, Anilocra, Cirolana* (fig. 60), *Cyclotelson* (fig. 61), *Synalpheus, Periclimenes, Pontoniopsis, Galathea* (fig. 59), *Ophiactis, Ophiomaza, Ophioæthiops, Ophiophthirius, Ophiosphæra, Sabinella* and *Polynoë* are known as parasites on crinoids only in the Indo-Pacific region, though *Laphystiopsis,* a parasitic ostracod (on fish), *Sabinella, Synalpheus, Periclimenes, Galathea, Anilocra, Cirolana, Ophiactis* and *Polynoë* also occur in the Atlantic.

Collocheres, Enterognathus, Stylina and *Hemispeiropsis* are known as parasites on crinoids only from the Atlantic; but all of these are small and must be especially searched for; probably all occur in the Indo-Pacific.

Mortensen's parasitic worm of doubtful affinities is only known from the Antarctic; but only *Notocrinus virilis* offers a suitable habitat for it.

Thus while the myzostomes occur wherever crinoids are found the majority of the other parasites and commensals on crinoids are confined to the Indo-Pacific region, though many are very closely related to nonparasitic Atlantic species. The chief reasons for this are probably the absence of a richly developed littoral crinoid fauna in the tropical Atlantic comparable to that in the Indo-Pacific region, and the plating of the ambulacra in most of the tropical Atlantic types, including the littoral species, which renders them unavailable as a source of food to most of the parasitic forms.

It is interesting to note that, with the exception of the myzostomes and the gasteropods, the great majority of the organisms which are directly or indirectly parasitic upon the crinoids are confined to the littoral zone. The reason for this is probably to be found in the development of side and covering plates along the ambulacral grooves of the pinnules, arms and disc of the crinoids from intermediate and great depths which enables the animals to convert the ambulacral grooves into closed tubes and prevents the appropriation of food particles by the ectoparasitic crustaceans, the ophiurans, and the polynoid worms.

The larger commensals living on the crinoids are usually striped or banded, and resemble them more or less closely in color, though in many cases the closely related noncommensal species are quite plain. This may or may not be the case with the myzostomes.

In regard to the parasites and commensals of the comatulids there is one curious feature which stands out very prominently—the majority of the records, especially of the larger and more vigorous types, are based upon species of the family Comasteridæ, probably the most specialized of all the comatulid types.

COMMENSALISM OF THE CRINOIDS

A number of small comatulids and the young of certain others may be considered as truly commensal, living as they do in the cavities of large sponges and gathering the minute organisms brought to them by the currents flowing into the afferent openings of the host. Many others habitually cling to gorgonians or withdraw into crevices in corals where they live symbiotically, but quite independently of the supporting organism.

ECONOMIC VALUE OF THE LIVING CRINOIDS

Economically the crinoids serve no useful purpose—at least up to now they have been put to none. They cannot be eaten, and they are not, so far as we know, eaten by any fish or other animal that serves as human food.

As a result of their ordinarily fixed mode of life it is possible that they might be used to furnish an index of the density of the finer plankton content of the water in which they live, though it is probable that other more generally distributed animals with more or less similar feeding habits would serve the purpose better.

Because of their beauty and delicacy of form as well as on account of their rarity they are frequently preserved and offered for sale as curios in Japan and China and, less frequently, in India, Oceania, Australia and the West Indies.

In southern Japan crinoids are frequently brought up on the long lines used for fishing in deep water in Sagami Bay. The comatulids, because of their beauty and delicacy of form, are called "komachi"—a name originally borne by an exceptionally well-favored lady of the court upwards of a thousand years ago—while the local stalked crinoid (*Metacrinus rotundus*) is known as the "bird's foot." The former when well preserved are sometimes sold as curios, while the latter always meet with a ready sale at extraordinarily high prices on account of their rarity combined with their paleontological interest.

In China comatulids are sometimes offered for sale which have been brought from a considerable distance.

At Barbados the local species of *Isocrinus,* especially *I. asteria,* and *Holopus rangii,* are occasionally to be found in the curio shops.

Among the Slavic peoples red is the color about which all their abstract ideas of beauty, and hence of idealism, revolve. The delicate and often gorgeously colored red Adriatic Feather-Star (*Antedon adriatica*) occurs more or less abundantly along the coasts of the largely Slavic provinces of Istria and Dalmatia where it is frequently found in the fishermen's nets and is sometimes brought up on their hooks. Its beauty of form, and particularly its red color, especially commend it to the local fishermen, who commonly take it to market and exhibit it along with the fish offered for sale.

EXPLANATION OF PLATES

PLATE 1

FIG. 1. A Feather-Star (*Antedon adriatica*) with the terminology of its parts explained.

2. Lateral view of the centrodorsal and articular faces of the radials of of a Feather-Star (*Himerometra martensi*) with the terminology of its parts explained. Fossil Feather-Stars usually consist of this portion of the animal only.

3. The same, in ventral view.

4. The naked incised disc of *Cenometra bella* with the terminology of its parts explained.

5. The plated entire disc of *Neometra multicolor* with the terminology of its parts explained.

6. Lateral view of the centrodorsal and articular faces of the radials of *Pentametrocrinus japonicus.*

7. Longitudinal section of the same.

8. Ventral view of the same (compare with fig. 3).

9. The dorsal nervous system of *Tropiometra macrodiscus.*

10. The proximal portion of *Nanometra bowersi* showing the difference between the large cirri about the periphery of the centrodorsal and the small one near its apex.

11. Dorsal view of the centrodorsal, radials and arm bases of a specimen of *Comatula rotalaria* showing the centrodorsal reduced to a stellate plate.

12. The disc of a specimen of *Comatula micraster* with four grooved and six ungrooved arms.

13. The ambulacral grooves and the digestive tube of *Antedon bifida* (adapted from P. H. Carpenter).

14. The arm tip of *Pterometra trichopoda.*

FIG. 15. The terminal comb on the oral pinnules of *Leptonemaster venustus* in external, internal and ventral view.

16. The tip of an outer pinnule of *Capillaster multiradiata* in lateral and dorsal view, showing the long spines.

17. The division series and arm bases of *Comanthus bennetti* with, on the right, homologous ossicles shown similarly shaded.

PLATE 2

FIG. 18. The calcareous deposits in the perisome bordering the ambulacral grooves and in the tentacles of the pinnules of *Dorometra parvicirra.*

19. The same in *Leptonemaster venustus.*

20. The same in *Eudiocrinus junceus.*

21. The same in *Heterometra bengalensis.*

22. The same in *Amphimetra discoidea.*

23. The calcareous deposits in the perisome bordering the ambulacral grooves in *Psathyrometra antarctica.*

24. The same in *Pentametrocrinus varians.*

25. The same in *Eumorphometra concinna.*

26. The same in *Sarametra triserialis.*

27. The side and covering plates of *Glyptometra tuberosa;* the latter (above) are hinged to the former and can be closed down over the ambulacral grooves.

28. A side plate of *Strotometra hepburniana* in (upper) interior and (lower) dorsal view.

29. Interior view of two side plates of *Pachylometra distincta.*

30. Ventral view of a portion of a pinnule of *Pachylometra distincta* showing the side and covering plates, the latter closed down over the ambulacral groove.

31. Lateral view of the side and covering plates of *Pachylometra distincta,* the latter partially closed down.

PLATE 3

FIG. 32. Diagram showing the relative proportions of the arms and cirri in *Asterometra macropoda;* the cirri are adapted to clinging to very rough bottom.

33. Diagram showing the relative proportions of the arms and cirri in *Comactinia echinoptera;* the short, strong and stout cirri are well fitted to hold the animal securely.

34. Diagram showing the relative proportions of the arms and cirri in *Pentametrocrinus tuberculatus;* the animal is very different in every way from the preceding, but the cirri are of the same type.

35. Diagram showing the relative proportions of the arms and cirri in *Pentametrocrinus varians;* the cirri collectively form a sort of circular mat supporting the animal on soft ooze.

36. The grooved anterior (left) and ungrooved posterior (right) arms of a specimen of *Comatula pectinata,* drawn to the same scale.

37. A cirrus of *Capillaster multiradiata* in dorsal (upper) and lateral (lower) view, showing the dorsal spines.

38. A smooth cirrus in dorsal (upper) and lateral (lower) view.

PLATE 4

FIG. 39. Crown and upper part of the column of *Monachocrinus sexradiatus.*

PLATE 5

FIG. 40. Crown and upper part of the column of *Proisocrinus ruberrimus.*

PLATE 6

FIG. 41. Crown and upper part of the column (above) and central portion of the column (below) of a pentacrinite, *Comastrocrinus springeri.*

PLATE 7

FIG. 42. Crown and upper part of the column (*a*), and middle (*b*) and lower (*c*) part of the column of *Ptilocrinus pinnatus;* in life the upper part of the column is recurved so that the crown points directly downward.

43. *Comatilia iridometriformis,* a species of Comasteridæ with some of the pinnules at the base of the arm lacking.

PLATE 8

FIG. 44. A specimen of *Comatula pectinata* from Singapore showing long anterior and short posterior arms (compare with fig. 36).

PLATE 9

FIG. 45. *Neometra acanthaster,* one of the Calometridæ.

PLATE 10

FIG. 46. *Asterometra macropoda,* one of the Ptilometrinæ.

PLATE 11

FIG. 47. *Antedon adriatica,* one of the Antedoninæ.

PLATE 12

FIG. 48. *Compsometra incommoda,* one of the Antedoninæ.

PLATE 13

FIG. 49. *Thaumatocrinus jungerseni,* a ten armed species of Pentametrocrinidæ.

PLATE 14

FIG. 50. *Pentametrocrinus diomedeæ,* a five armed species of Pentametrocrinidæ.

PLATE 15

FIG. 51. An arm of *Heterometra compta,* showing the difference between the oral, genital and distal pinnules.

FIG. 52. An arm of *Stephanometra echinus,* showing the stout and spine-like oral pinnules.

53. An arm of *Stylometra spinifera,* showing the mid-dorsal overlapping spines.

54. Four syzygial pairs from the arm of *Stylometra spinifera,* showing the progressive increase in the individuality of the two elements distally.

55. Pentacrinoid larva of a large Feather-Star, *Heliometra glacialis* (after Levinsen).

56. Ventral view of a larva of *Antedon mediterranea* early on the eighth day (adapted from Bury).

57. *Myzostomum costatum,* dorsal view (after Boulanger).

58. The same, ventral view (after Boulanger).

59. *Galathea elegans* (after Potts).

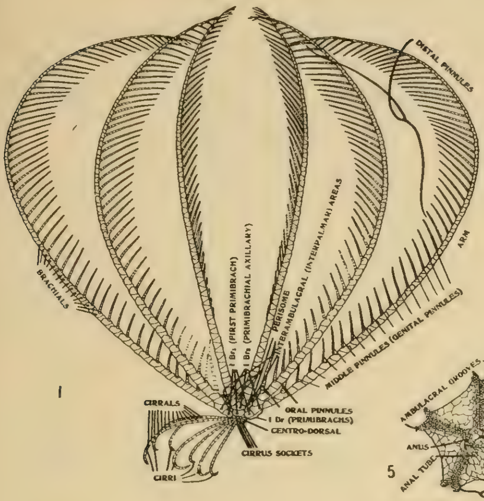
60. *Cirolana lineata* (after Potts).

61. *Cyclotelson purpureum* (after Potts).

62. *Scalpellum pentacrinarum* (after Pilsbry).

PLATE 16

A specimen of *Nemaster iowensis* captured in shallow water in the Bahamas (Cat. No. 36164 U. S. N. M.).



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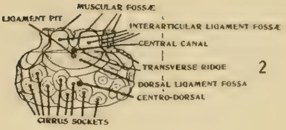

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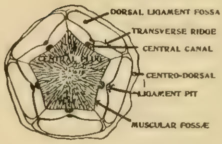

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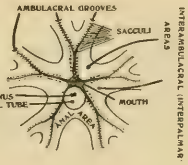

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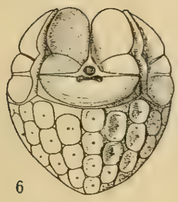

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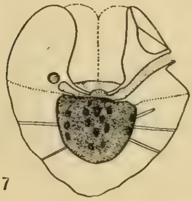

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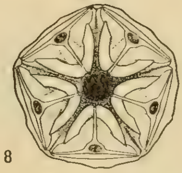

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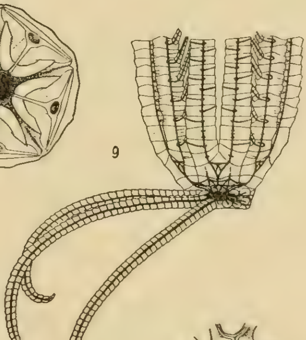

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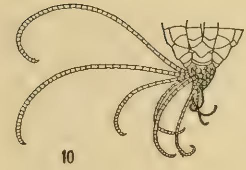

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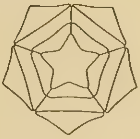

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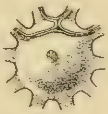

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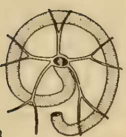

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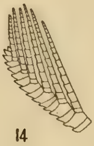

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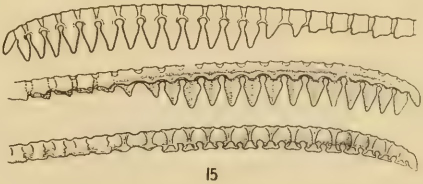

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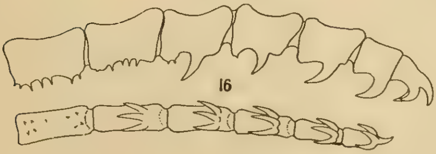

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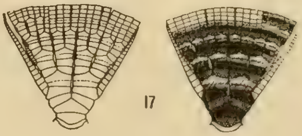

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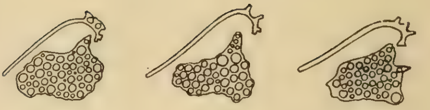

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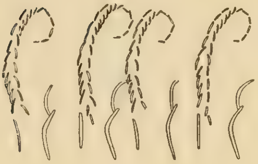

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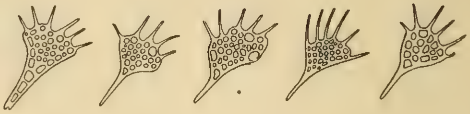

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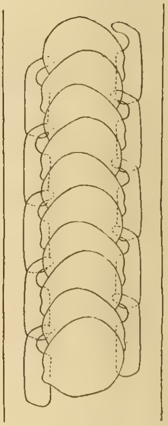

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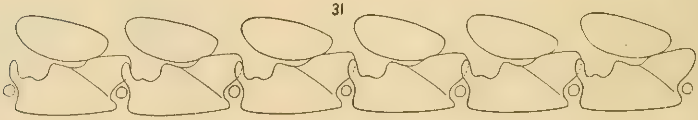

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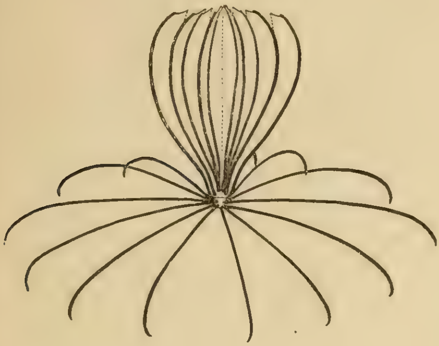

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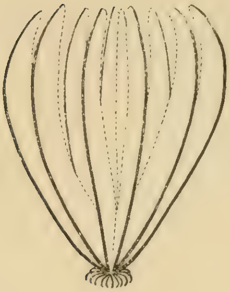

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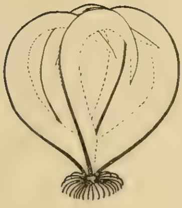

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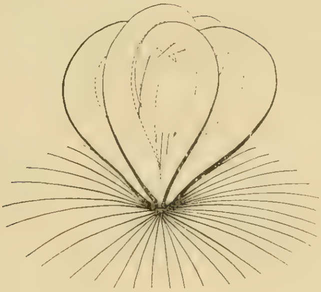

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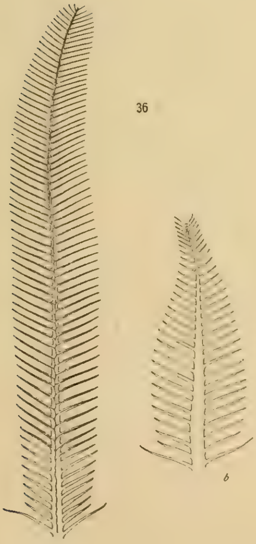

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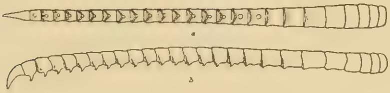

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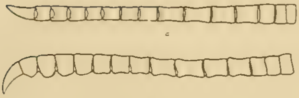

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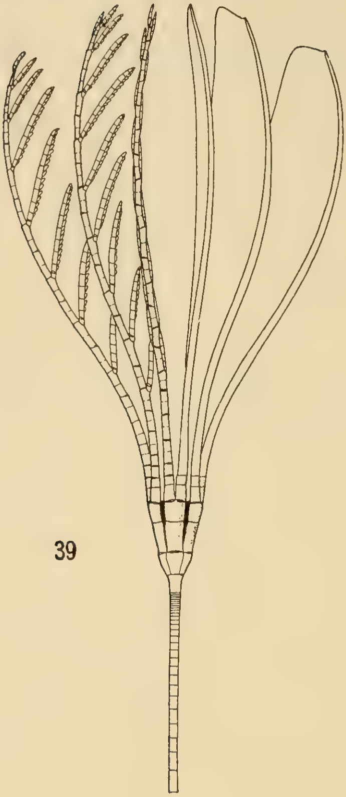

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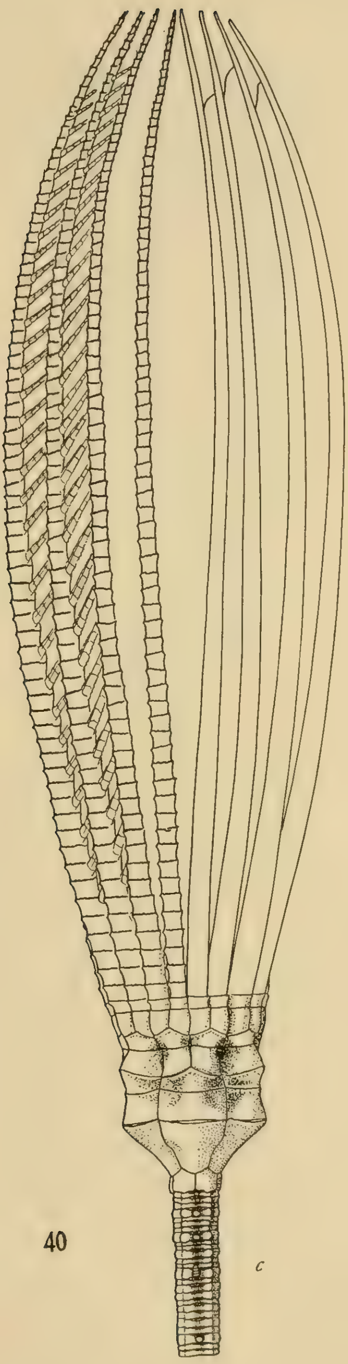

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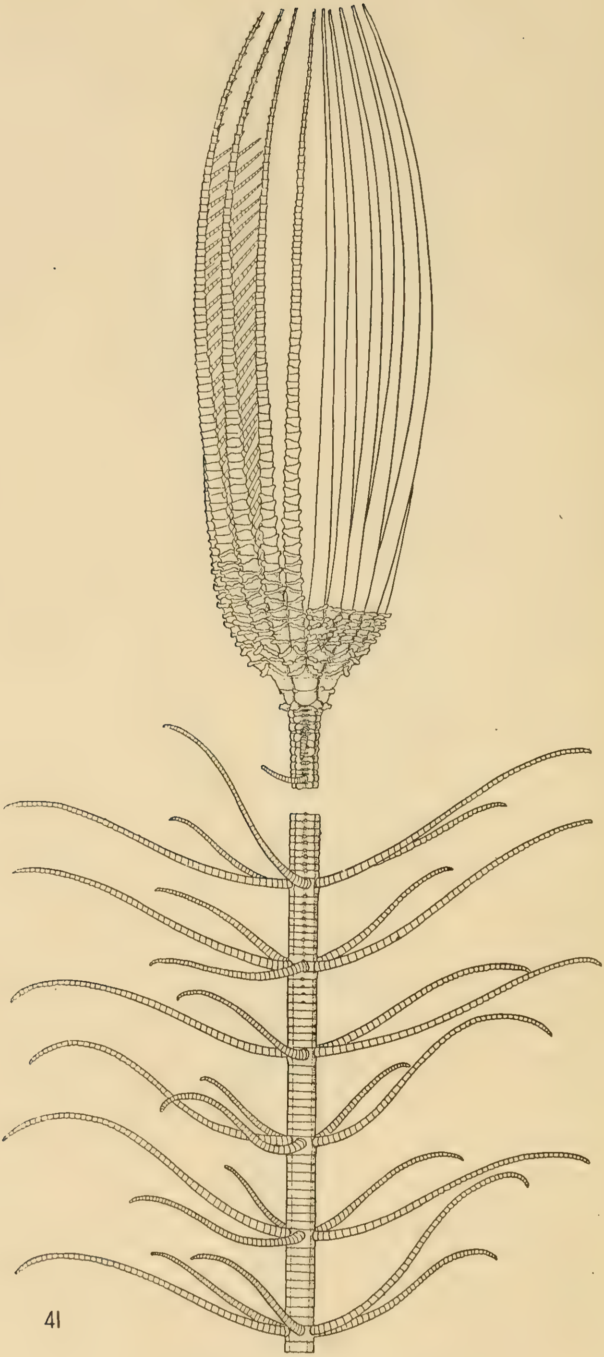

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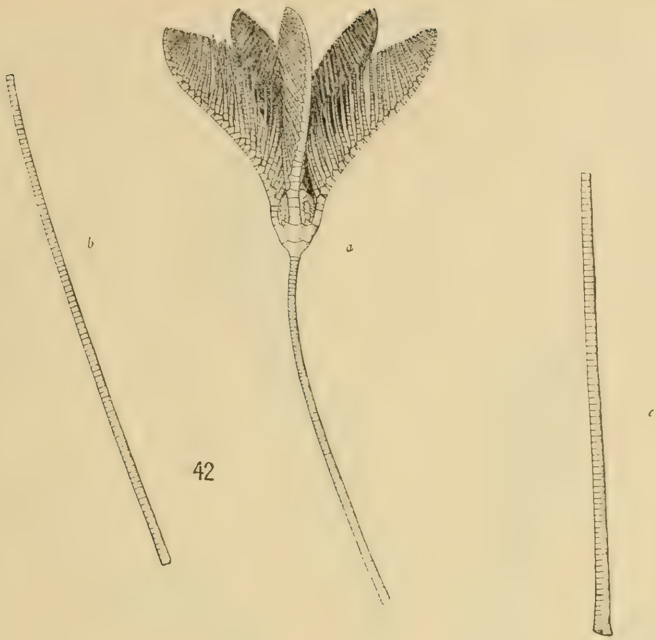

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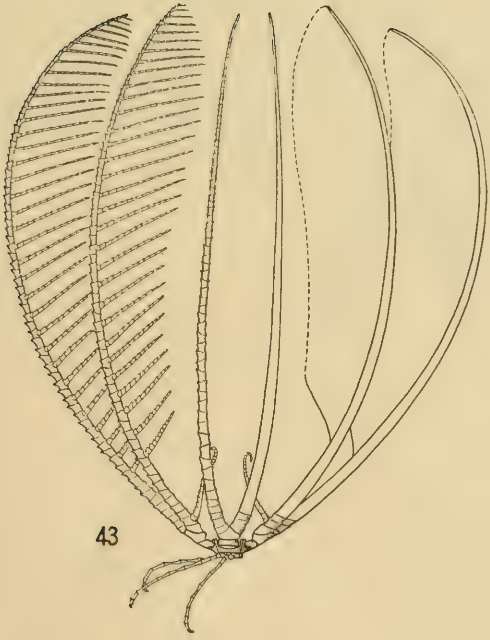

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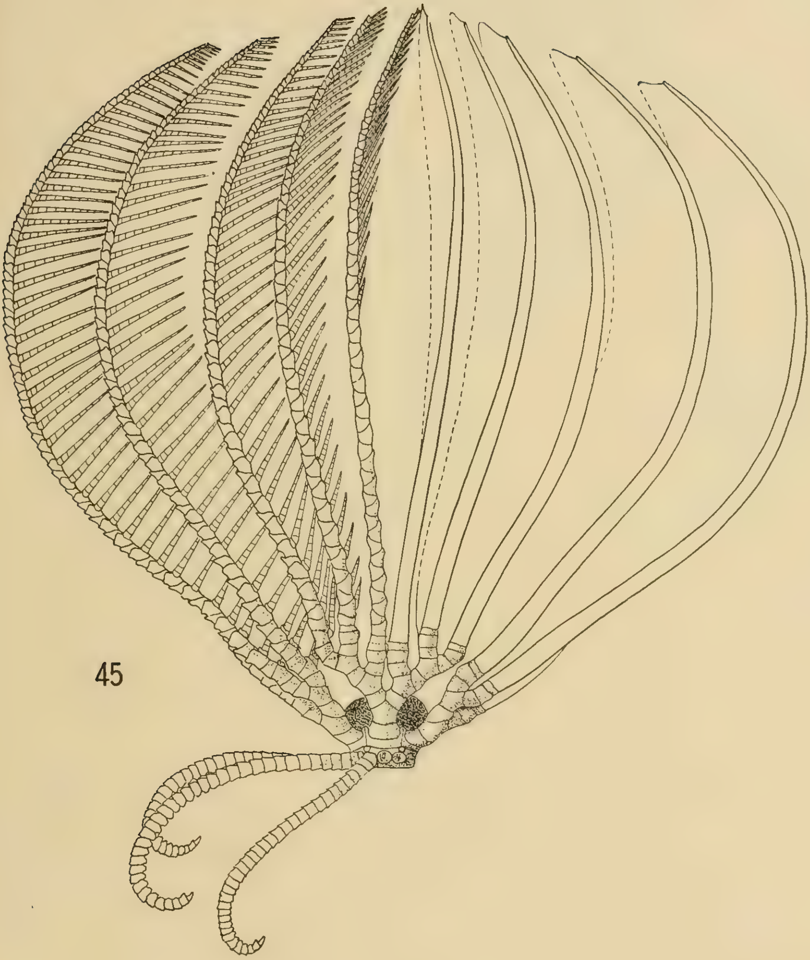

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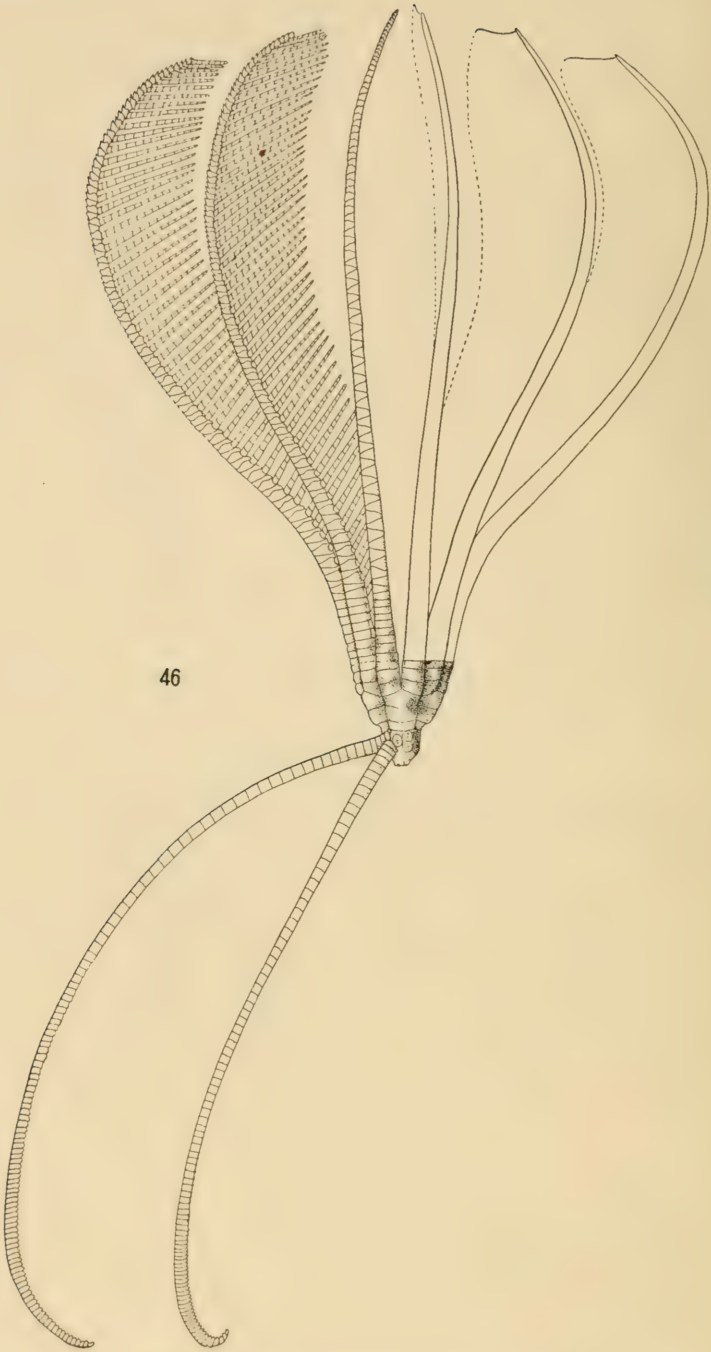

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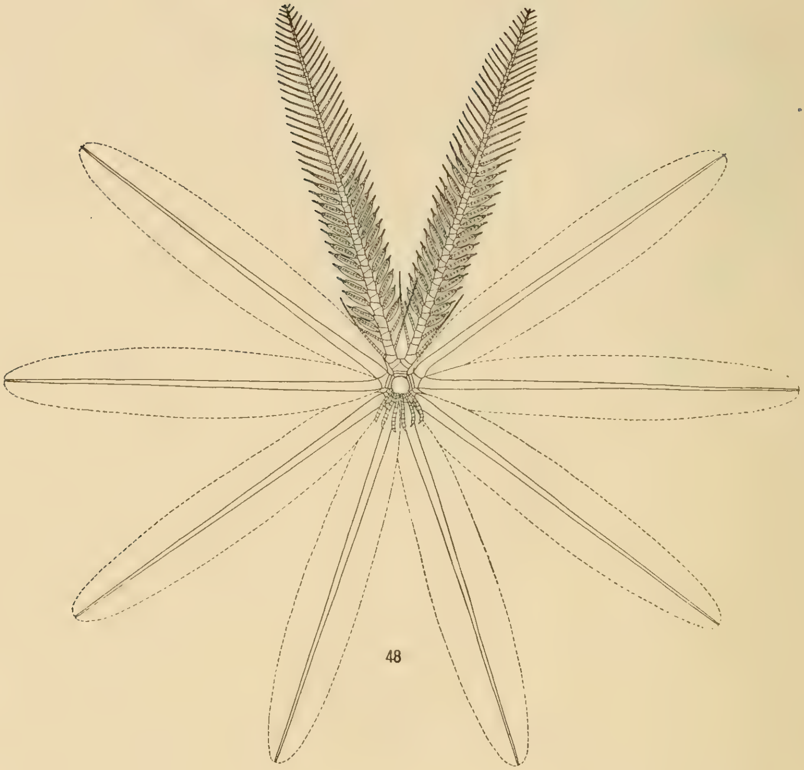

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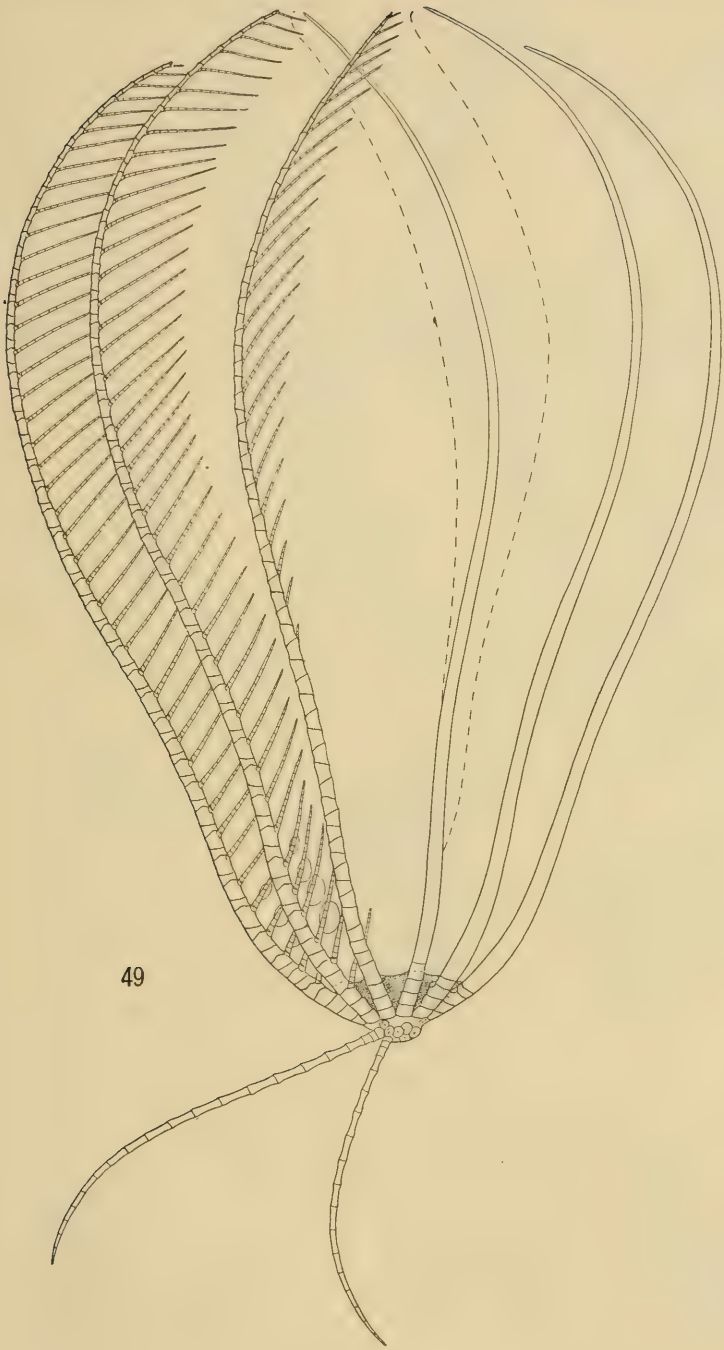

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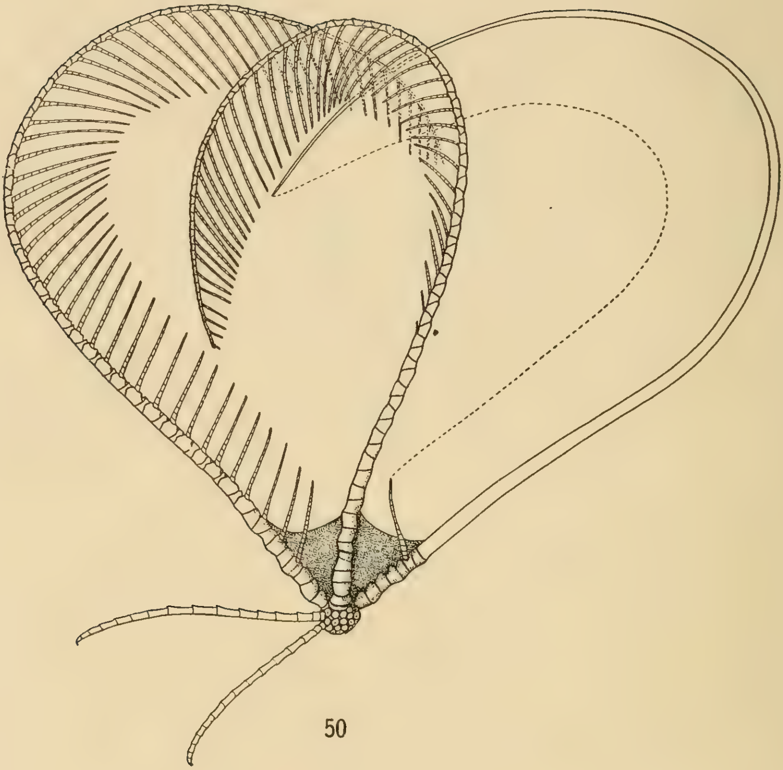

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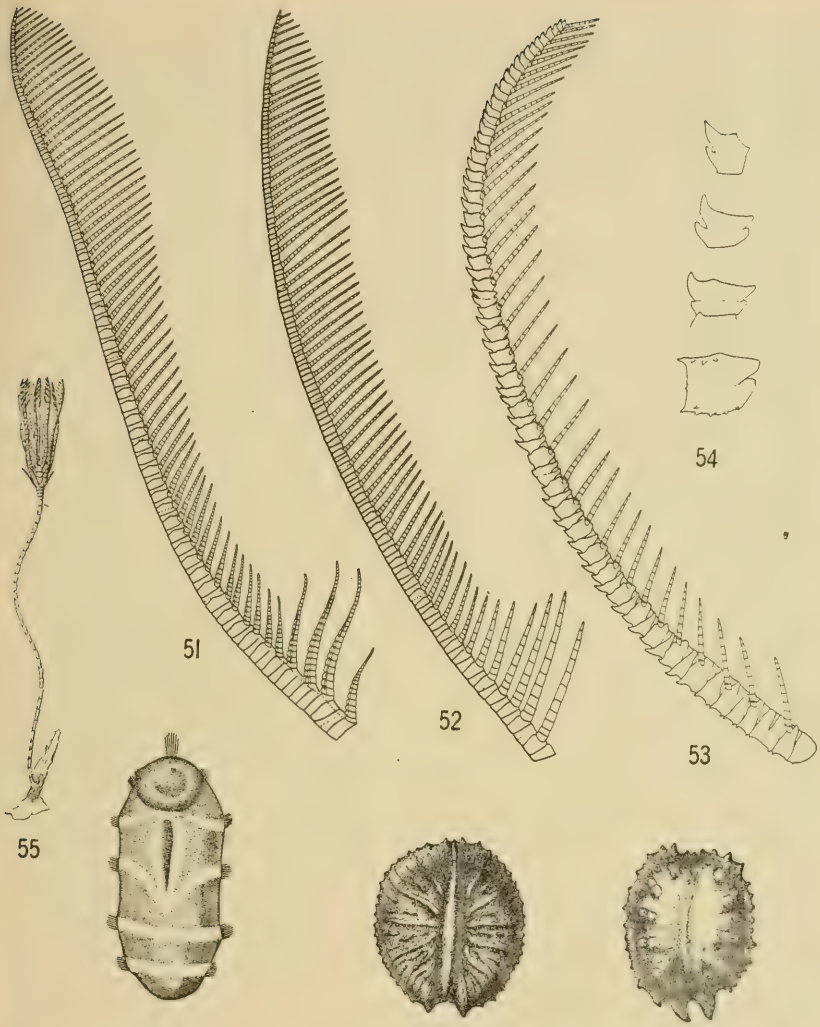

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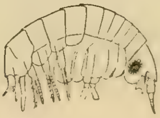

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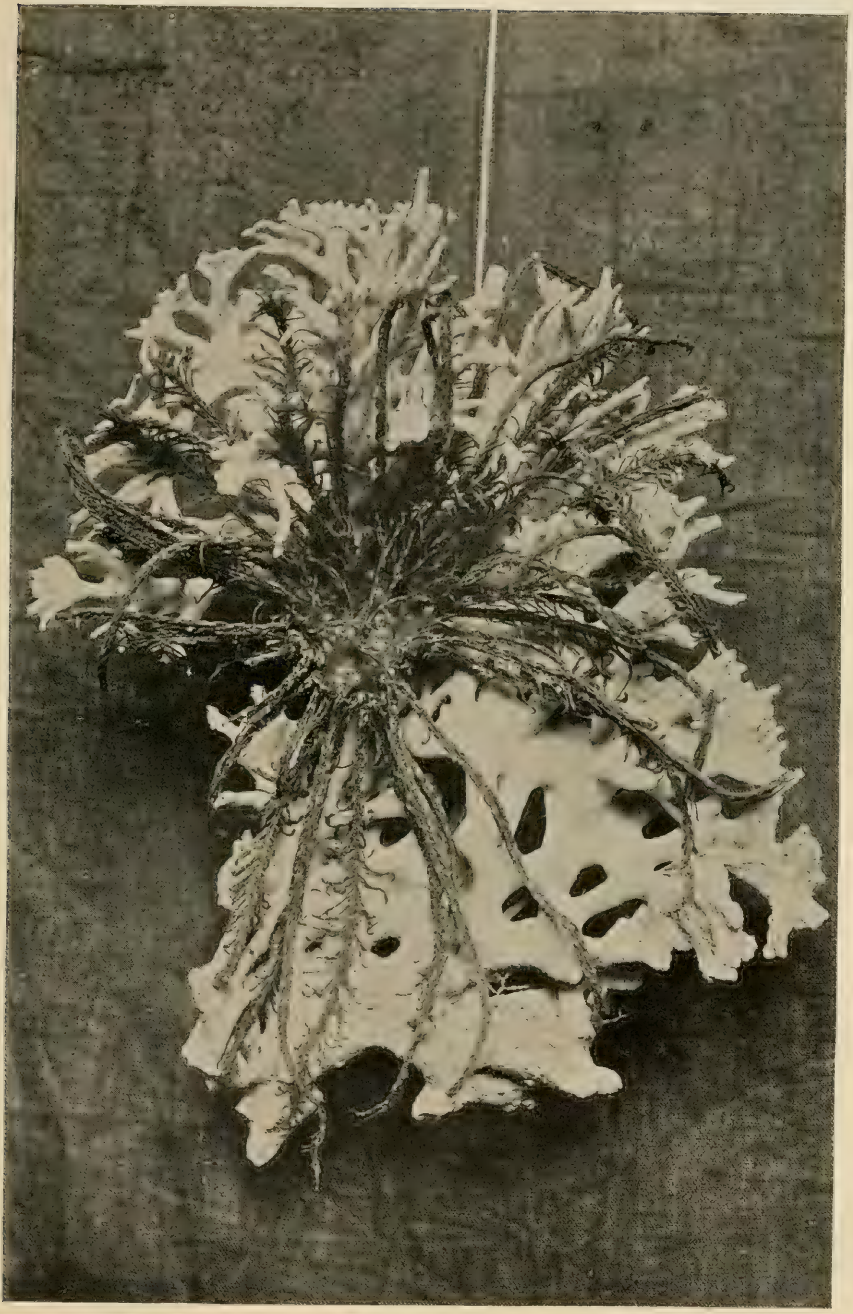

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 8

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(PUBLICATION 2650)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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By HERLUF WINGE

[Translated by GERRIT S. MILLER, JR.]

In translating Doctor Winge's "Udsigt over Hvalernes indbyrdes Slægtskab" (Vidensk. Medd. fra Dansk naturh. Foren., vol. 70, pp. 59-142, 1918) my aim has been to give the author's ideas as clearly and exactly as possible rather than to make smooth English sentences. I have been much aided by the kindness of Dr. Leonhard Stejneger, who has compared the entire MS with the original, making himself responsible in particular for the rendering of the adverbs *ret, sikkert, vel,* and *vist,* whose idiomatic shades of meaning present many difficulties to one whose acquaintance with Danish is limited to the printed language. Doctor Winge has also examined the translation, expressed his approval of it, and made some useful suggestions for its improvement. I have added an index, a few bibliographical references, and in some instances the generic names which are correct according to the International Code of Nomenclature. Brackets are used to distinguish all additions to the original text.—G. S. M., Jr.

The Cetacea[1] originated[2] from the *Hyænodontidæ,* the most primitive family of the Carnivora, by way of the most typically carnivorous members of the group such as *Pterodon* and *Hyænodon.* The oldest known whales have such a great likeness to *Hyænodon* and its nearest relatives that there can be no doubt about the relationship. Aquatic habits have given the cetaceans their special peculiarities and have caused their differentiation from the Hyænodonts.

As an inheritance from the highest Hyænodonts, and as an indication of relationship with exactly these animals, the most primitive whales retained a series of special peculiarities which the Hyænodonts had developed in the course of their differentiation from the insectivorous stage. They still had about the same dentition as the Hyænodonts. All the teeth were fitted for flesh eating; the incisors and canines were strong and hooked, the anterior cheekteeth strong, elongated, compressed, smooth-edged; the molariform cheekteeth, especially those of the upper jaw, had a peculiar form and all of them were nearly alike. In the upper molars the 4th and 5th cusps [paracone and metacone] were coalesced to form a trenchant longitudinal ridge, the 1st and 2d cusps [parastyle and mesostyle] were reduced, the 3d cusp [metastyle] was a compressed ridge, and the

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[1] Notes are at end of paper, pages 47-93.

6th cusp [protocone] was reduced or absent. All of the upper molariform teeth including the third premolar still had the inner root, though this was in process of reduction. All the teeth of the typical [eutherian] dentition were present, 11 in each jaw [44 in all]. The jaws were elongated in harmony with the long, well-developed toothrows. The temporal fossa was very large, widened out by a powerful temporal muscle. It was bounded by a high sagittal crest, by a strong, backward-projecting occipital crest, and by an abruptly outstanding, posteriorly heavy *processus zygomaticus squamæ.*

In addition to these peculiarities the most primitive whales had two high characters which were perhaps inherited from the Hyænodonts; at any rate they are to be found in the latter group, though less pronounced: a rather large supraorbital process, and a bony palate lengthened backward far under the posterior nares.

Radical alterations have taken place during the change from Hyænodont-like carnivores to true whales. In many of the mammalian groups there have arisen forms modified for life in the water; but no other aquatic mammals are modified to the same degree as the cetaceans, nor has any other become so exclusively aquatic; only to breathe do they raise the nose above the water in which they otherwise are hidden.

The cetacea have used the tail as the chief implement of locomotion; the hind limbs are put wholly out of service; the fore limbs are scarcely used for much else than steering and balancing.

The tail becomes enormous, long and thick, powerfully muscled. It is formed in agreement with the manner in which it is wielded: with strokes from side to side, or up and down, or with a sculling motion. Throughout most of its extent it becomes compressed, but at the tip it acquires a powerful, horizontal, caudal fin constructed of skin folds (not present in quite young embryos of recent cetaceans). At the front of its upper margin, in the region where the tail joins the back, there may occur a special erect skin fold in the form of a longitudinal crest, a dorsal fin. Most of the caudal vertebræ lose the atrophied appearance which they have in primitive mammals; they acquire powerful centra, heavy, flat-outspread transverse processes, high dorsal arches with large, compressed spinous process, and articular processes which are distinct though not mutually fitting together. The ventral arches with the inferior spinous processes become so large that they approach the upper arches in size. Only the outermost caudal vertebræ, which lie almost inclosed in the caudal fin, retain the degenerate character. The tail has an influence on the dorsal vertebræ also. Its powerful muscles, which have their origin in part on the sacral and dorsal vertebræ, and are also in connection with the muscles of the back, widen their place along the spinal column and stimulate the vertebræ to increase in bulk. The sacral and lumbar vertebræ come to resemble the largest, most anterior caudal vertebræ exactly, apart from the lower arches. On a few of the hindmost thoracic vertebræ, which in the ancestral forms are without, or as good as without, transverse processes, there grow out powerful transverse processes on a line with and similar to those of the lumbar vertebræ (parapophyses, apparently corresponding to the lower section of the double, rib-bearing "transverse process" of the anterior thoracic vertebræ, which supports the rib's capitulum; but in reality they most probably correspond to the upper and lower sections combined), and on their tip they eventually bear the attachment surface for the rib. Apparently this surface may be either for the attachment of the tuberculum or of the capitulum or of the two coalesced, but in reality it is perhaps always for the two combined (or, more correctly, not separated). The transverse processes of the anterior thoracic vertebræ (diapophyses, the upper portion of the double "transverse processes"), which in the beginning are quite short, may eventually grow long, pushing far out to the side the articular surface for the rib's tuberculum which they bear at their extremity. On all the thoracic vertebræ the spinous processes finally become high and strong.

The hind limb atrophies completely, and disappears. At length only quite insignificant parts of its skeleton are found, hidden deep under the skin, finally in the form of a mere little rod-shaped bone, a remnant of the pelvis.[3] In small embryos the hind limb can, however, still be distinguished externally.

The disappearance of the hind limb has a great influence on the vertebral column. No longer does a pelvic bone come in contact with any of the vertebræ. In consequence the sacral vertebræ completely lose their peculiarities: their characteristic strength, their mutual firm connection, their robust transverse processes with flattened areas for the hip bones. They are formed exactly like the adjacent dorsal and caudal vertebræ. The movements of the spinal column become changed in character. Bending of the column in the vertical plane, which depends especially on the movements of the hind legs, is reduced or abandoned, and as a result the differences in slant—forward or backward—of the spinous processes as good as disappear, so that all the processes alike are directed upward. The zygapophyses become reduced and in large part lose their mutual articulations.

The fore limb, which no longer comes in contact with the earth or bears any load, is changed into a flipper whose single function is that of striking against the water. The entire arm becomes an oar blade. Of the fore limb's articulations the shoulder joint only is used; it retains its ball-and-socket structure. All the other articulations are held stiff. They degenerate, become flat and immovable, or are wholly effaced. Practically the only function of the upper arm is to support the forearm and hand. It becomes short and heavy. Its middle portion retains its terete form, but its lower end is compressed in agreement with the bones of the forearm. The radius and ulna become very simply-formed, compressed bones, losing muscle crests, sinew furrows and all pronounced articular surfaces; even the olecranon may wholly disappear. The mutual position of the two bones is somewhat altered, so that they eventually lie exactly fore and aft of each other. The hand is set somewhat supine, fore edge downward. The carpal bones become compressed, or more correctly flattened, pieces [like sections of a mosaic]. They are rather indifferent as to form and number, and are immovable. The folds of skin between the fingers are lengthened out to the finger tips; and the hand stiffens. The claws disappear. The first and fifth fingers are somewhat inclined to be stunted, but the other fingers, particularly the second, tend to lengthen and to form new joints at their tips, so that the number of phalanges may increase far beyond the typical three. The metacarpals and phalanges are shaped almost alike, as more or less flattened pieces of bone.[4] The shoulder blade degenerates only slightly. In the most primitive whales it already has the form which, with few exceptions, is found among the highest. It is broadly fan-shaped, with a prominent, antrorse acromion, and a large coracoid, but on the other hand almost without *crista scapulæ*. Rarely it becomes narrower or lacks both acromion and coracoid.

The fact that the fore limb does not act as a support for the body results in lessening the limb's pressure on the chest. Another result is that the spinous processes on the anterior thoracic vertebræ lose their special height. Still another result is that the connections between the ribs and both the thoracic vertebræ and the sternum have a tendency to become loose or to disappear. Perhaps this tendency is also brought out by the fact that the water pressure on the chest during diving changes strongly. The ribs may lose the capitulum, and the costal cartilage may practically disappear. When this happens the sternum loses an essential stimulus and becomes reduced and atrophied.

The head, during swimming, is held directed as firmly as possible forward. The neck is not moved, and for this reason it becomes short and stiff. During motion through the water the head is pressed from the front; it is forced backward against the cervical vertebræ, which thereby are squeezed excessively together and pressed back against the anterior dorsal vertebræ, with the ribs of which they may even come in connection. Most of the cervical vertebræ may become almost as thin as paper. The odontoid process of the axis becomes short and blunt; the articular surface between the bodies of the atlas and axis becomes almost flat. And there arises a strong tendency to coalescence of the cervicals.[5] The occipital condyles lose their projecting form and become almost flat, only quite weakly convex, pressed in against the wall of the braincase; and the concave surface of the atlas likewise becomes flattened out. The occipital crest in its capacity as an attachment for the upper neck muscles is restricted; the points of attachment for the lower neck muscles on the basal part of the occipital bone are effaced, and the under side of the occipital bone is formed more as a sheath around the gullet and windpipe.

The pressure of the water on the head when the cetacean swims has a highly modifying effect on the skull.

From above the water presses especially during the animal's constant rising to the surface to breathe. This gives the skull a tendency to acquire a flat and broad upper surface, with thick bones. The size of the horizontally outspread supraorbital process of the frontal, which pushes itself far out over the orbit, becomes particularly noticeable. The facial part of the cheek bone may likewise become peculiarly flattened out.

From in front the water presses during forward motion, the more strongly as the motion is faster. Its effect is to develop an unusual strength in those bones of the face which project furthest forward, the intermaxillary, maxillary, and vomer, as well as in the cartilaginous nasal partition which the vomer embraces. This strengthening may show itself in different ways: in the noticeable lengthening forward of the bones in question, in their solid ossification, in their tendency to coalesce. It also appears in the backward spreading of the intermaxillary and especially of the maxillary. The latter may extend itself out over the facial part of the zygoma and over the frontal, which it almost entirely covers to the hinder margin, so that the supraorbital foramen may pierce not only the frontal as in other mammals.

but the maxillary as well. The cartilaginous nasal partition, the mesethmoid, has a tendency to ossify. The incisive foramen is narrowed and closed. In the palate the maxillary pushes itself far backward, forcing the palatine behind it; the palatal surface of the palatine is thus shortened. But at the same time the maxillary acts on the palatine in such a way that it also increases in thickness. The braincase is acted on from the front by the pressure of the water against the forehead; from behind it is pressed by the cervical vertebræ and the neck muscles. In this manner it becomes so squeezed that it acquires a short, broad form. Pressure is exercised especially on the frontal and on the supraoccipital and interparietal. These bones widen out at the expense of the parietal, whose innermost part is squeezed quite narrow and eventually obliterated. The exoccipital also grows, especially noticeably downward, where it broadens out shield-like behind the mastoid and the tympanic. The mastoid is compressed inward between the exoccipital and the squamosal, by both of which it is so overgrown that at last it is no longer visible on the outer surface of the braincase.

The water pressure on the head from in front has also a great influence on the soft parts of the face and through them on the skull. It assists in shifting the nasal apertures. The cetacean has tried, with the help of the nose muscles, to draw the apertures as high as possible up on the head's upper side, in order to be able easily to get them raised above the water. The result has been that the nasal cartilage has caused resorption of the anterior border of the nasal bones and has forced them further and further back. The cartilage has also worked itself back between the anterior median part of the frontals, pushing the plates of the ethmoid behind it. Thus at last the nares have acquired a position which appears to be on the forehead but which in reality is close in front of the anterior wall of the braincase. The moving of the nasal cartilage has been accelerated in those cases where the facial adipose cushion which originally lay in front of the nares and which in the first place was merely a little filling out of fatty connective tissue has been stimulated to growth by the pressure of the water, becoming very large, pushing the nasal cartilage backward, pressing it against the front wall of the braincase and disintegrating the nasal bones and the plates of the ethmoid. The nasals then become tuberformed and are pressed into the frontals. The adipose cushion together with the nasal muscles and other neighboring structures may exercise an enormous influence on the skull, the anterior and upper sides of which it modifies to form its bed, the "facial depression."

The water acts in a very special way where the whale lets it stream into the mouth for the purpose of catching the small animals which it carries in with it. In such cases it brings about huge increase in the size of the jaws together with many other remarkable peculiarities.

For smelling there comes to be no use; this sense is not exercised, and the nose is therefore formed in accordance with the needs of breathing only. The ethmoid degenerates. The numerous folded laminæ of which it originally consisted disappear, while the cribriform plate loses its nerve perforations and becomes a solid lamina of bone on the front wall of the braincase. The nose becomes a simple passage for air. The air, which is exposed to strongly varying pressure and temperature, has a tendency to provide itself with greater space by widening out the nasal passage and Eustachian tube wherever it meets with least resistance. It may form air-sacs, partly on the upper side of the skull over the facial bones, partly on the under side behind the palate. Here an air-sac may spread itself forward along the outer side of the pterygoid and palatine and backward along the outer margins of the body of the sphenoid and the basal part of the occipital, pushing itself out under the *ala parva, ala magna* and the squamosal, and bounded more or less by plate-like outgrowths from all the bones mentioned. The bony palate is lengthened backward still more by the pushing out from the pterygoids of laminæ which extend into the soft palate beneath the nasal passages. This clearly takes place partly under the action of the tongue, but doubtless still more under the influence of the larynx. The fact that the two original outer nostrils finally coalesce into one is an indication of the nose's degeneration.

The lacrimal bone is reduced and eliminated, or it fuses with the cheek bone as in many other aquatic mammals, probably because the bone is no longer acted upon by a lacrimal duct.

The outer ear disappears from lack of use; the outer auditory aperture is so strongly contracted that it may be difficult to find. The bones of the inner ear acquire a peculiarity which is found again in several other mammals that live in the sea, and which certainly in some manner or other must be dependent on aquatic life. They are formed of unusually thick, stony-hard masses of bone; this is especially remarkable as regards the tympanic, the inner wall of which is thickened in a peculiar way.[6]

The dentition degenerates because the chewing of food is given up as not easy to carry on satisfactorily under water. Most animals chew with open mouth; under water the chewed food would be washed away from between the teeth. The dentition is therefore chiefly used for grasping the food and holding it fast. In the most primitive whales the mouth did service as an implement for catching fish. The jaws were used in exactly the same manner as in the shell-drakes, *Mergus,* and they were produced forward as a long slim beak, a kind of tweezers, influenced not only by the use to which they were put, but also by the pressure of the water during swimming forward. The *Hyœnodon*-like dentition which the most primitive whales inherited, with teeth of considerable size, diversified form, and of typical number, at first becomes more simple. The upper molariform teeth lose the inner cusp and the inner root, and the crown undergoes compression. A further step in the reduction is that the crowns of the cheekteeth, or at least of most of them, acquire a serrated anterior and posterior margin. Next the two remaining roots, foremost and hindmost, of the cheekteeth fuse into one, and the serrations of the crowns are reduced and obliterated. The size at the same time is reduced, and the form becomes simply conical so as to resemble that of the incisors and canine, which in their turn undergo reduction. While this is happening the number of teeth in the long jaws is increased, no doubt because in the place of the few quite large teeth there spring up many smaller ones; scarcely by the actual splitting up of the few. Perhaps also in the beginning some of the milk teeth came to take a place in the series with the permanent ones, without, however, the entire milk dentition's intercalation in the permanent set. The number of teeth grows greater and greater, far beyond the typical, while the individual teeth become smaller and smaller. Those at the front and back of the series become especially stunted, frequently disappearing from the intermaxillary. The enamel covering of the teeth becomes thin or disappears entirely. What later happens to the dentition depends on the use to which it is put. It may happen that there comes to be no use whatever for it, and that it consequently disappears. Or it may, wholly or in part, be once more put to heavy use and be modified to this end; or a single tooth may take on power while all the others atrophy.

The succession of teeth, which in the most primitive whales took place in the ordinary way, ceases. It is not clear how this happens. Judging from investigations of the teeth in embryos of the higher cetaceans it might appear, at least sometimes, as if it were retained milk teeth that are found in the adult animal's dentition—as if the successors to the milk teeth had disappeared. Such, however, is scarcely the explanation. Most probably it is really the actual permanent set that is found in the adult, while those that precede and follow (both of which have been demonstrated) disappear.[7]

The fact that mastication ceases and that the teeth become stunted has a great influence on the chewing muscles and the jaws. It was necessary for the first whales as fish catchers to be able to open the mouth wide. The masseter muscle which has the tendency to limit the opening of the mouth was therefore little used, and it became restricted; together with the muscle the region of its origin became shrunken. This region is the anterior and median part of the zygoma; it is transformed into a slender bridge of bone. The temporal muscle has been more used, but it also shows the tendency to be reduced by lack of vigorous use, and it draws itself backward quite low on the side of the braincase, losing its influence on the zygomatic process of the squamosal. This process shrivels up like the coronoid process of the mandible, the muscle's point of insertion. In cases where the under jaw becomes very large the temporal muscle may acquire renewed strength and may spread its region of origin out over its surroundings in an unaccustomed manner. With the atrophy of the teeth they cease to influence the body of the mandible, which consequently loses its original height. The alveoli become less defined and the partition walls between them may disappear so that there arises a common dental furrow. The articular condyle of the mandible weakens, loses its cylindrical form, and the articular surface becomes an almost flat area pointing backward at the similarly formed glenoid fossa on the squamosal, which as good as loses its postglenoid process and is otherwise inclined to suffer reduction. It may happen, however, that the lower jaw becomes huge and that its articular condyle acquires corresponding heaviness. In such cases the condyle is curiously modified, losing the true articular surface. This is grown over by articular ligament, and the lower jaw stimulates the squamosal to grow out in prodigious size, bearing, instead of the true articular surface, an area of attachment on a projecting foot. The symphysis menti. long in the most primitive whales, is restricted. The under jaw's degeneration is also no doubt indicated by the huge gaping posterior entrance to the mandibular canal, which is mostly filled with loose connective tissue. It is not clear what the reason is for this peculiarity, which was already present in the most primitive cetacea and is found in all the later ones though sometimes in a rather disguised form; possibly it might in some way depend on the air-sacs of the nasal passages which lie exactly internal to this part of the lower jaw.

Whales lose their hair covering because it ceases to be of use; at most some few degenerated vibrissæ remain.[8]

It holds good for the cetacea as for other groups of mammals that the most primitive forms have much less brain than the later ones; in the highest whales the brain is extremely well developed.

It likewise holds good for the cetacea as for others that the earlier forms are smaller than the later, though dwarfs may at any time be developed. Ordinarily whales increase noticeably in size as they become more highly developed; the highest forms have reached gigantic proportions.

Judging by their greater or less resemblance to the Hyænodonts the cetacea are mutually related essentially as follows:[9]

Cetacea.

- I. The number of teeth is not more than typical [44]. Braincase not telescoped, not shortened.
  - **Archæoceti.**
    - **Zeuglodontidæ.**
      - *Protocetus, Prozeuglodon, Zeuglodon.*
- II. The number of teeth is or has been more than typical. Braincase telescoped, shortened.
  - A. Nasal bones forming a roof over hinder part of nasal cavity. Maxillary not covering frontal.
    - **Mystacoceti.**
      - **Balænidæ.**
        - BALÆNINI: *Balæna, Neobalæna.*
        - BALÆNOPTERINI: *Rhachionectes, Plesiocetus, Cetotherium, Balænoptera, Megaptera.*
  - B. Nasal bones pressed into fore wall of braincase, not or scarcely forming a roof over any part of nasal cavity. Maxillary covering frontal.
    - **Odontoceti.**
      - 1. Teeth not alike, the most posterior less simply formed than the most anterior.
        - **Squalodontidæ.**
          - *Agorophius, Squalodon, Neosqualodon, Prosqualodon.*
      - 2. Teeth now or formerly alike, simple in form.
        - a. Temporal fossa large, not covered over by frontal and maxillary; zygomatic process of the squamosal heavy, primitive in form.

Platanistidæ.

Pontistes, Pontoporia, Lipotes, Inia, Saurodelphis, Platanista.

b. Temporal fossa relatively small, covered anteriorly by the widened frontal and maxillary; zygomatic process of the squamosal reduced, losing its primitive form.

α. Occipital wall not especially elevated.

Delphinidæ.

Delphinodon, Champsodelphis, Schizodelphis, Heterodelphis, Eurhinodelphis, Argyrocetus, Delphinapterus, Monodon, Steno, Prodelphinus, Delphinus, Tursiops, Tursio, Lagenorhynchus, Orca, Orcella, "Grampus," Pseudorca, Globiceps, Phocœna, Neomeris.

β. Occipital wall highly elevated.

Physeteridæ.

XIPHIINI: *Argyrodelphis, Mesoplodon, Xiphirostrum, Chonoxiphius, Xiphius, "Berardius," Hyperoodon.*

PHYSETERINI: *Hoplocetus, Physeterula, "Cogia," Physeter.*

In the form of a genealogical tree [see pp. 45-46]:

Physeteridæ.
|
Delphinidæ.
|
Platanistidæ.
|
Squalodontidæ.
|
Balænidæ.
|
Zeuglodontidæ.

Zeuglodontidæ [Basilosauridæ].—Of all known cetacea the Eocene Egyptian *Protocetus* of the family *Zeuglodontidæ* is the most primitive. It is known from a rather complete skull without the lower jaw, and from a few vertebræ and ribs. In all that is known it stands so near to the *Hyænodontidæ* that there would scarcely have been any reason to separate it from them had it not been evident that it was one of the first members of the cetacean series. The number of teeth in the upper jaw is, as in *Stypolophus* and *Pterodon,* the typical 11, since m^3 is present, while it has disappeared in *Hyænodon,* the highest genus of *Hyænodontidæ.* But the form of the teeth is most nearly as in *Hyænodon,* more shearing than in other members of the family. The difference from *Hyænodon* is chiefly a result of the fact that heavier use has been made of that part of the toothrow which serves for grasping the food and that consequently the incisors and anterior cheekteeth have increased in size. The incisors have become about as heavy as the canine, the premolars have become heavier and more elongated than formerly, while the molars are weakened and m^2 has lost its predominance. The mouth was already used mostly as a pair of forceps; the long, narrow, but strong, beak-shaped jaw, in which the teeth have abundant space, bears witness to the fact. The anterior nasal aperture is already forced considerably backward; but it has, however, only reached a point scarcely half way to the anterior margin of the orbit, and it has kept a rather primitive form. The nasal bone is long and narrow, roofing over a large part of the nasal cavity. The intermaxillary is strengthened anteriorly, its body is lengthened, likewise its nasal process, though this process does not reach to the frontal. Otherwise the intermaxillary does not show much deviation from the conditions ordinarily found in carnivores. The maxillary also is lengthened and thickened, but is not otherwise modified to any noticeable degree. Posteriorly it does not push itself out over the facial part of the zygoma or over the frontal, which it merely forces slightly backward. On the palatal surface it has not crowded the palatine bone, which has retained its original length. The incisive foramina seem to have disappeared. The forehead is pressed quite flat, and the supraorbital process of the frontal has become very broad; otherwise the forehead is unmodified. The anterior and median part of the zygoma is already well on its way to become slender, but the zygomatic process of the squamosal is still robust. It bears a considerable postglenoid process, though the articular surface for the lower jaw has begun to assume the peculiar vertical position that it has in the higher whales. The temporal fossa has on the whole remained primitive in size and form. It is bounded by high crests. The braincase is not compressed antero-posteriorly; the frontal and supraoccipital are not widened so as to encroach on the parietal. The mastoid is still visible on the outer wall of the braincase. Occipital crest well developed, projecting. Occipital condyles not pressed flat. On the basal part of the occipital the impressions where the lower neck muscles were attached are essentially unmodified in character, and the under side of the occipital bone's basal part is not shaped for sheathing the gullet and larynx. On the other hand the exoccipital has already acquired a noticeable widening out to the side. The hinder part of the nasal cavity appears to be wholly undisturbed; it must contain a well-developed ethmoid. The bony palate is already prolonged backward by plate-like outgrowths from the lower margin of both the palatine and the pterygoid. No doubt an air-sac formed by an enlargement of the nasal passage lay on the outer side of the pterygoid, but whether it was enclosed by outgrowths from the adjacent bones is doubtful. The tympanic bone had already acquired the characteristic cetacean thickening of the inner wall. The cervical vertebræ are mutually free, not strongly compressed. The odontoid process of the axis is strong, projecting. The spinous processes of the dorsal vertebræ differ noticeably among themselves as to their slant, some of them sloping strongly backward, others upright or directed a little forward; those on the hindmost dorsal vertebræ are rather low. Zygapophyses apparently well developed. No projecting transverse processes on the hindmost thoracic vertebræ. Centra of ordinary size. On the tip of the transverse process of a sacral vertebra there is present a rather large area of attachment for the ilium, although the process has otherwise already lost much of its original character. On such ribs as are present in the fossil there is a well-developed capitulum; the hindmost ribs lack the tuberculum and are articulated with the corresponding vertebræ by the capitulum.

Prozeuglodon (*Zeuglodon osiris, Prozeuglodon atrox* partim[10]), also Eocene, Egyptian, has departed in dental characters not a little from *Protocetus*. In the number of teeth the difference is only that m^3, small in *Protocetus,* is here absent. The form of the teeth has undergone greater change: pm^1 has lost the compressed form of the crown and has become simply conical with a single root like the incisors and canine; pm^2 has acquired a serrate posterior margin; pm^3, pm^4, m^1 and m^2 are strongly serrated on both the anterior and posterior margins of the crown; in pm^3 and pm^4 the inner heel is much reduced and in the two molars it has entirely disappeared. The lower jaw is also known; it contains the typical 11 teeth. Incisors, canine, and pm_1 approximately uniform, simply conical; pm_2, pm_3

and pm_4 with compressed crown and serrated anterior and posterior margins; m_1, m_2 and m_3 also with compressed crown, its anterior margin smooth, its posterior margin serrate. Tooth succession occurred in the ordinary way as it assuredly did in *Protocetus* also. In all characters the skull agrees essentially with that of *Protocetus*. The basal part of the occipital appears, however, to be more adapted to the larynx and gullet. A few peculiarities of *Prozeuglodon* which are not clearly demonstrated in *Protocetus* are: the presence of an elongated, compressed incisive foramen on each side; the presence of a distinct lacrimal bone; and the presence to the outside of the pterygoid and in front of the tympanic of a considerable pit bounded by high ridges springing from the surrounding bones, evidently the impression of an air-sac. The under jaw already has nearly the same peculiar form as in many highly developed cetaceans with long symphysis menti; it has, however, a relatively large coronoid process. But the mandibular condyle is placed low and is turned backward, and the strange gaping hinder entrance to the mandibular canal is present. Of the rest of the skeleton rather more is known than of *Protocetus,* among other parts most of the vertebral column and the fore limb down to the hand. There is a great similarity to *Protocetus*. A difference from this genus is that no sacral vertebra is found with the transverse process plainly acted upon by the ilium. The skeleton of *Prozeuglodon* throws light on certain conditions that are not understood in *Protocetus*. The sternum is of considerable size, with several joints. The shoulder blade is essentially as in the higher whales. The humerus has retained relatively much of the original form: distinctly separated greater and lesser tubercles, a distinct deltoid crest, and a well-developed hinge-shaped lower articular surface. Radius and ulna have correspondingly well-developed articular surfaces for the humerus, are relatively only a little compressed, and have distinct articular surfaces for the carpal bones; the ulna has a rather large olecranon.

Zeuglodon [*Basilosaurus*] (*Z. cetoides, Z. isis*), known rather completely as to the skeleton, occurs in Eocene strata of both the Old and New Worlds. In most respects it resembles *Prozeuglodon*. But it has acquired a highly remarkable peculiarity in the vertebral column. While the centra in *Prozeuglodon* are not in any direction strikingly altered in form, in *Zeuglodon* the centra of most of the hinder thoracic vertebræ, of the lumbar vertebræ, sacral vertebræ and all but the outermost of the caudal vertebræ, have become remarkably large and especially greatly elongated, while the vertebral arches have remained short, standing about midway on the centra, the arches.

in common with the spinous processes, widely separated from each other. Thus in *Zeuglodon* the body has acquired an altogether peculiar length, putting one in mind of the snakes. The posterior thoracic vertebræ seem to have developed considerable transverse processes which bore the ribs on their extremities. In size also *Zeuglodon* went further than its relatives. Of the hind limb there is known a small, quite atrophied pelvic bone with articular surface for the femur, and an even more degenerated little rod-shaped femur.[11]

The genera of Zeuglodonts together form the section Archæoceti, the source from which all the higher cetaceans have originated. *Protocetus* has scarcely a single peculiarity, apart from its large size, that one would not expect to find in an ancestral stock for the higher whales. The same is true of *Prozeuglodon.* On the other hand *Zeuglodon,* a descendant of *Prozeuglodon,* has followed its own line away from the starting point of the other whales, deviating particularly in its remarkable vertebræ.

The peculiarities which especially place the Zeuglodonts lower than all other cetaceans are that the teeth are still present in the typical number, and that the braincase is not telescoped and shortened. Of all other whales it holds good that they, so far as they are known, have the number of teeth raised above the typical (or that they are descended from cetacea in which it had been raised), and that they have the braincase more or less compressed antero-posteriorly. As regards the form of the teeth *Protocetus* no doubt stands lower than all other cetaceans; but *Prozeuglodon* and *Zeuglodon* are in this respect scarcely more primitive than the lowest members of the higher families. Of all the many other primitive characters that are found in the Zeuglodonts some are, it is true, no longer to be found in the higher families, not even among the extinct lowest forms; but for most of them this does not hold good.

Zeuglodontidæ[12] [Basilosauridæ].

I. Crowns of cheekteeth with smooth, not serrate, margins.
    Protocetus.
II. Most of the cheekteeth have serrate anterior and posterior margins to the crowns.
    A. Centra of thoracic, lumbar, and caudal vertebræ not elongated.
        Prozeuglodon.
    B. Centra of posterior thoracic, of lumbar and caudal vertebræ elongated.
        Zeuglodon [*Basilosaurus*].

Balænidæ.—The group Mystacoceti with the single known family *Balænidæ* includes whales that stand near to the Zeuglodonts; but the most primitive members of the group had already advanced a step further than the Zeuglodonts. They presumably had the number of cheekteeth raised above the typical. With that change there followed others. The most primitive Mystacoceti must have already had the nasal aperture pushed further back than in the Zeuglodonts. The intermaxillary probably extended further back. The maxillary must have been somewhat more broadened out posteriorly. The parietal was slightly encroached upon, and the braincase was a little telescoped. The spinous processes of the dorsal vertebræ presumably slanted to a less degree in different directions. The joints at the elbow and wrist must have almost wholly lost their primitive structure, etc. Taken all in all, however, the most primitive Mystacoceti must have been in general like the most primitive Zeuglodonts.

Of the many forms which the group Mystacoceti must have included no others are known than a little circle of highly developed genera very specially modified in their own direction; but in spite of their remarkable development they have retained many primitive features which are no longer found in the other, higher families. This holds good especially in the structure of the face. Although the narial aperture is drawn backward into proximity with the anterior wall of the braincase the nasal bone is not wholly misshapen. It retains part of its long, narrow form and it still roofs over the hind part of the nasal cavity which may yet inclose very considerable remnants of the ethmoid plates. The anterior part of the nasal cavity, bounded by the intermaxillary, maxillary and vomer, is also relatively primitive in structure, more open than usual, with less tendency to closing together of the bones. And the maxillary, although it has expanded backward, and shoved itself somewhat back both above and beneath the frontal, has nevertheless not in any way covered the frontal's broad supraorbital process. A distinct lacrimal is present, but this is not unknown among higher cetacea. The zygomatic arch has retained more of its primitive form and strength than elsewhere. Two outer nasal apertures are still found; they are not mutually united. The basal part of the occipital is also to a somewhat less degree modified than in other recent cetacea, being less specialized to accommodate larynx and gullet.

That which more than anything else has left its impress on the known Balænids is their habit of not hunting after single large fish, but of swimming with open mouth into shoals of small fish, crustaceans, or other small creatures, which they allow to stream into the mouth in multitudes along with the water. They seek to retain the edible contents when they close the mouth and the water flows out again between the lips. The water has thereby acquired great power to act upon the mouth cavity from within; it distends the opening enormously; the jaws grow and acquire a disproportionately large size in comparison with the braincase; the branches of the mandible are bowed strongly outward to the sides and are widely divergent from each other behind, while the connection between them in front becomes quite loose. The gigantic lower jaw wears so upon the ligaments which bind its articular head to the squamosal that the ligaments are incited to growth. They become uncommonly strong and spread themselves over the original gristle-covered articular surfaces on the jaw and the squamosal, both of which surfaces they entirely cover. They cause the squamosal to grow out as a huge process which bears the attachment surface for the lower jaw on its free margin. By the enlargement of the mouth cavity the squamosal together with the articular head of the lower jaw is pushed far out to the side and so far back that at last its free postero-external extremity comes to lie further back than the occipital condyles. The squamosal in its turn presses strongly on the parts which lie behind it: on the mastoid which is squeezed inward, and on the exoccipital which is pushed backward. In proportion to the size of the under jaw the temporal muscle increases and pushes its region of origin forward over the supraorbital process. There has been no use whatever for the teeth; they atrophy so completely that finally they are to be found only in the embryo as a long series of insignificant, small, pin-shaped teeth, hidden under the skin and soon resorbed. On the other hand the inflowing and outflowing water acted as a stimulant on the corneous papillæ of the roof of the mouth. The papillæ along the margin of the upper jaw are so stimulated that they have grown out as a close-set series of "whale-bones": high, crosswise-placed, corneous plates, the inner margin of which is frayed out into threads. The entire set of whale-bones functions as an excellent instrument for catching the solid material that flows with the water into the open mouth. The palate is strongly acted upon by the instreaming water, by the larynx, and by the tongue, which is pressed against it when the water is to be expelled. The palatine bone grows and forces itself backward, pushing back the pterygoid behind it; and the pterygoid pushes and presses that which lies still further back; namely, the tympanic bulla and the region of attachment of the neck muscles on the basal part of the occipital. The palatine may push itself wholly back under the base of the occipital, and the muscle attachment may come to lie about on a line with the posterior margin of the occipital condyle.

In other respects also the known Balænids have reached particularly high. The supraorbital process of the frontal acquires an unusual breadth, no doubt for the special reason that it follows the eye, which, by the widening of the mouth cavity, is pushed out to the side. The supraoccipital becomes very large and strongly slanting forward under the influence of pressure by the water and by the muscles of the neck. The transverse processes of the thoracic vertebræ become widely projecting; this is especially noticeable as regards the hindmost thoracic vertebræ (where the processes are parapophyses, while on the anterior vertebræ they are diapophyses). The ribs have a strong tendency to lose the capitulum and to restrict their connection with the sternum. In most of the recent members of the family the capitulum is absent from all the ribs, even the more anterior, although an evident collum is present (it is, however, doubtful whether it is really the capitulum that is absent from the hindmost ribs; more likely the single articular head which appears to be the tuberculum is in reality either the capitulum alone or the capitulum and tuberculum undifferentiated). The sternum is so reduced that it consists of the manubrium alone. The first finger has a tendency to atrophy. Etc.

In the section Balænini are found the most primitive of the family's known genera: *Balæna* and *Neobalæna.* With them the anterior facial part of the skull has kept relatively much of the form ordinarily present in mammals. This is especially true of the intermaxillary and still more of the maxillary, which is quite slender in front and not depressed. Body and tail are rather short, not quite so well fitted for rapid swimming as in the others. The hand is more primitive. Of the hind limb's skeleton there are present, at least in *Balæna,* relatively quite considerable remnants, among other parts a stunted femur and the upper end of the tibia. The mouth is shaped somewhat differently than in the others; it is formed as an enormous barrel or bag, bowed outward on all sides. Not only are the rami of the lower jaw bent outward, but the upper jaw with the whole facial part of the skull is also bent, arched highly upward. Both the upper jaw and the branches of the lower jaw assume the structure of stays in the walls of the pouch-like mouth cavity. The whale-bone plates acquire a remarkable length. Finally the head becomes more preponderant as regards the body than in other whales. The cervical vertebræ are pressed together unusually strongly; they coalesce.

Balæna appears in some respects to stand on a lower level than *Neobalæna.* Its slender under jaw seems better to agree with the condition primitive to the cetacea than does the strikingly massive, strongly compressed under jaw of *Neobalæna* in which the mandible presumably must be especially influenced by the large under lip. Its relatively few, ordinarily formed, slender ribs, and its correspondingly rather long series of lumbar vertebræ are also undoubtedly primitive characters; in *Neobalæna* the ribs have become unusually numerous and the number of lumbar vertebræ is reduced to a few bones, while the ribs, or at least most of them, have become remarkably broad and have to a remarkable degree lost connection with the vertebræ so that they lie loose among the muscles. *Balæna* is no doubt the more primitive also in the short, broad form of the hand. The first finger is either (in *B. australis*) rather well developed, containing two phalanges in addition to the metacarpal, or (in *B. mysticetus*) reduced, though still retaining the metacarpal.[13] The other fingers are not much lengthened; in the median digits, however, especially in the third, the number of phalanges may be increased to four or five. The form of the phalanges is terete, not compressed. In *Neobalæna,* the hand appears to have essentially the same structure as in *Balæna,* but the first metacarpal is said to be absent, and the entire hand has become narrower. The lack of a dorsal fin in *Balæna,* in contrast with *Neobalæna,* is, presumably, also a primtive character; though the fin may have been lost. But in the adaptation of the head as a pouch for catching small animals *Balæna* has reached far beyond *Neobalæna.* In the more primitive of the two certainly known species of *Balæna, B. australis,* the modification is a little less noticeable than in the higher species, *B. mysticetus;* the head is slightly smaller, the upper jaw is somewhat less bowed upward, etc. In *B. mysticetus* the head becomes so huge that in full grown individuals it reaches a third or more of the animal's total length, the upper jaw is thrown upward in an enormous arch, the palatine and pterygoid are forced backward under the hindmost part of the basioccipital, etc. The coracoid process of the scapula may be absent (in *B. australis*).

Neobalæna must assuredly have originated from *Balæna,* but from one of the most primitive species of the genus, in which the head was only a little increased in size; but since then it has gone its own way, developing peculiarities in the form of the lower jaw, in the ribs, vertebral column and hand.

In the genera of the section *Balænopterini* the intermaxillary and also the maxillary are rather strongly flattened anteriorly so that the facial part of the skull has lost its primitive pointed form. Body and tail are uncommonly long, adapted to more rapid swimming with stronger muscles. Among the alterations produced by these muscles are the higher spinous processes on the dorsal and caudal vertebræ. The hand is shaped more like an oar blade. The fingers are laid more closely together and the third and fourth may have the number of phalanges increased; the first digit has completely disappeared. The skeleton of the hind limb is more reduced. The mouth is modified in its own way; its outbowing in the upward direction is slight or absent, that to the sides and downward is conspicuous. The floor of the mouth cavity has become to a high degree expansible, and the intermaxillary and maxillary, like a broad, more or less flattened lid, cover over the pouch which it forms. The Balænopterines stand lower than the known Balænines in the condition of the cervical vertebræ: the bones retain their freedom.

Among the known Balænopterines, *Rhachionectes* is one of the most primitive. Its nasal bone is still relatively very well developed. The breadth of the intermaxillary and maxillary in front is rather slight. The supraorbital process is relatively weak and not strongly flattened. The braincase is relatively only slightly telescoped so that on the middle of its upper side there can be seen not a little of the frontal. The supraoccipital is not especially large or forward-slanting. The articular surface for the lower jaw on the squamosal is not pushed out especially far downward and backward, and, when seen from beneath, has not entirely covered the mastoid or pushed the exoccipital very far backward. Bony palate relatively not strongly lengthened behind. The point of attachment for the neck muscles on the basal part of the occipital is still tubercular, and the basioccipital on the whole is only to a slight degree shaped to accommodate the larynx and gullet. In contrast with its nearest recent allies *Rhachionectes* stands lower in a few other respects also: an evident capitulum is still found on some of its anterior ribs; the skin beneath its mouth cavity is not thrown into longitudinal folds; the dorsal fin is not present; the hand is relatively short, and the number of phalanges is only a little increased. It has perhaps high specializations in its decidedly heavy under jaw, which slightly suggests *Neobalæna,* and in its somewhat upwardly arched facial portion of the skull.

Plesiocetus from the Tertiary of Europe, and presumably from that of North America also, is best known from the skull. To a high degree it resembles *Rhachionectes,* but appears to differ in having a considerably more reduced nasal, like the higher Balænopterines.

Cetotherium, also from the Tertiary of Europe and presumably of America, which is likewise known from scarcely anything else than the skull, is a very near relative to *Plesiocetus.* It is slightly more specialized, with the articular surface for the lower jaw on the squamosal pushed somewhat further backward, pressing more against its surroundings, and covering the mastoid; but otherwise it scarcely differs except in trifles.

As a pronounced contrast to *Rhachionectes* the genus *Balænoptera,* on the other hand, stands much higher: with much smaller nasal; with intermaxillary and maxillary more broadened in front; with broader and flatter supraorbital process; with more telescoped braincase in the median upper part of which there shows itself only a little of the frontal; with larger, more forward-slanting supraoccipital; with the articular surface for the lower jaw on the squamosal pushed much further backward, wholly covering the mastoid and shoving the exoccipital more to the rear; with bony palate strongly lengthened backward; with point of attachment for the neck muscles on basal part of occipital compressed, flattened; with the basioccipital more shaped to the larynx and gullet; with the skin under the floor of the mouth cavity thrown into longitudinal folds; with a dorsal fin; with the hand more lengthened; with frequently more phalanges in the median fingers.

Magaptera stands yet higher than *Balænoptera.* Its body is relatively not much elongated, a fact which points to its origin among the most primitive species of *Balænoptera.* But in the structure of the fore limb it has reached far beyond its relatives. On account of some special use or other, perhaps most likely from rapid turning about in the water, the arm has grown to an enormous length. The forearm has become very much stretched out, and the hand is yet more conspicuously lengthened, the number of phalanges in the third and fourth finger increased in addition. The scapula has lost both the coracoid process and the crest.

Balænidæ.[14]

I. Intermaxillary and maxillary narrow anteriorly, not flattened.
  Balænini.
    A. Mandible slender. Ribs not broad. First metacarpal present.
      Balæna.
    B. Mandible robust. Most of the ribs broad. First metacarpal absent.
      Neobalæna.

- II. Intermaxillary and maxillary broad anteriorly, flattened. *Balænopterini.*
  - A. Nasal relatively well developed. *Rhachionectes.*
  - B. Nasal reduced.
    - 1. Area of insertion of neck muscles on basal part of occipital tubercular.
      - a. Articular surface for lower jaw on squamosal not strongly pushed backward, not covering the mastoid when seen from below. *Plesiocetus.*
      - b. Articular surface for lower jaw on squamosal more pushed backward, covering the mastoid. *Cetotherium.*
    - 2. Area of insertion of neck muscles on basal part of occipital compressed.
      - a. Hand not especially elongated. Shoulder blade with crest. *Balænoptera.*
      - b. Hand greatly elongated. Shoulder blade without crest. *Megaptera.*

Squalodontidæ.—The Squalodonts must have originated from among the most primitive Balænids which still had the teeth shaped like those of the Zeuglodonts but increased in number, and which had not yet begun to get the mouth refashioned into a catching-bag. Their differences from the most primitive Balænids are due especially to stronger pressure of the water on the facial part of the skull; most likely the Squalodonts were from the beginning more rapid swimmers than the Balænids. The nasal passage is pushed much further back, not by muscle action alone, but probably especially by the influence of the facial adipose cushion. The water both stimulates the cushion to growth and presses it against the nasal passage. The nasal bone is completely atrophied, almost tubercular in form, and pressed into the frontal in the fore wall of the braincase, not or almost not covering over any part of the nasal cavity. The plates of the ethmoid are probably pushed wholly away and the lamina cribrosa has probably become a solid bone-plate without perforations or almost so. The nose muscles, the pneumatic diverticulum from the nasal passage, the adipose cushion of the snout, in short all that covers the skeleton of the face, is pressed by the water in against the bones and has moulded the upper side of the whole face as its bed, especially hollowed out posteriorly. This bed, the "facial depression," extends backward along the sides of the nasals on the forehead. The beginning is traceable of a remarkable peculiarity which, in the more advanced cetaceans may become conspicuous to a high degree: an asymmetry in the structure of the face. The head must no doubt be so held during motion that the water comes to press not quite equally on both sides, but more strongly on the right side than on the left. The facial cushion therefore becomes larger on the right side than on the left, extends its bed most on the right side, forces the nasal passage to bend over to the left, and causes the bones of the face to develop somewhat dissimilarly on the two sides.[15] The maxillary has pushed itself posteriorly up over the frontal to such an extent that it almost wholly covers it, also spreading out over the supraorbital process. The zygoma appears to have been quite slender. The two nasal apertures were presumably united into one. In all of these points of difference from the Balænids the Squalodonts agree with the higher cetacea, of whose most primitive forms they remind one in nearly everything, so far as they are known, except in the condition of the teeth.

The Tertiary North American *Agorophius,* which is only known from a very incomplete skull, almost without teeth, appears to be the most primitive member of the family. The number of teeth is not known, but certainly, to judge by the other peculiarities of the genus, it must have been greater than typical. Its braincase is much less telescoped than in the other Squalodonts, also less than in any of the known Balænids, somewhat suggesting the Zeuglodonts in being relatively strongly constricted anteriorly between the large temporal fossæ, and in having the parietal form a considerable part of its roof. In the other Squalodonts the braincase, so far as it is known, is so telescoped and so broadened out to the sides that there is a wide area between the temporal fossæ although these are relatively large; also the parietal in the middle of the roof of the braincase shows itself at most as a narrow band. In other respects *Agorophius* appears to agree well with *Squalodon.*

Squalodon is known rather completely from skulls from Tertiary strata in both the Old and New Worlds. Almost nothing is known of other parts of the skeleton. The teeth are well developed, heterodont. In each jaw there are three incisors with conical crown and single root, a canine of similar form and size, and 11, or sometimes in the upper jaw 12, cheekteeth. Of these last the four or five anterior have conical crown and single or bifid root, and the seven posterior have compressed crown with more or less serrate anterior and posterior margin (or only the posterior margin serrate), and two roots, an anterior and posterior. The fact that the number of cheekteeth is most often 11 might indicate that the increase above the typical number, seven, was produced by the intercalation of four milkteeth in the series with the seven permanent teeth; but there is no decisive evidence either for or against this explanation, as the tooth succession is not known. If the number exceeds 11 a true increase must have taken place. As in the most primitive of the higher whales the jaws are very elongate, narrow; the intermaxillary and maxillary are not especially closed together, and the mesethmoid is not ossified in front; the symphysis menti is long (the rami of the mandible may have grown together); the facial depression does not extend very far backward, the braincase is relatively only a little telescoped, the temporal fossa is considerable, the zygomatic process of the squamosal strong, the occipital condyle projecting.

The Tertiary European *Neosqualodon* is only known from pieces of jaws. It has the number of serrate cheekteeth raised to at least 11; otherwise the characters of the dentition are not known.

The Tertiary Argentinian *Prosqualodon,* known from the more essential parts of the skull, differs from *Squalodon* in having a much shortened face, with the facial depression relatively strongly broadened behind. The number of teeth appears to be somewhat reduced. It is no doubt a little more primitive than *Squalodon* in the less strongly telescoped form of the braincase proper.

Squalodontidæ.[16]

I. Braincase only slightly telescoped.
    Agorophius.
II. Braincase strongly telescoped.
    A. Face long.
        1. Number of cheekteeth relatively little increased above the typical [44].
            Squalodon.
        2. Number of cheekteeth increased above the typical 44.
            Neosqualodon.
    B. Face shortened.
        Prosqualodon.

Platanistidæ.—The Platanistids no doubt originated from the most typically defined Squalodonts such as *Squalodon.* The most important and perhaps in the first place the only distinction between the Platanistids and their precursors among the Squalodonts is that the teeth in the Platanistids are to a higher degree structurally degenerated. They have lost their heterodonty, have become smaller but more numerous, all of them nearly simply conical with a single root. On the other hand the Platanistids have retained most of the other peculiarities in which the Squalodonts show themselves to be relatively primitive. Especially noticeable in comparison with higher cetacea are the following characters: facial depression rather narrow, not much widened laterally behind, so that its outer margin covers over the temporal fossa to a slight degree only; temporal fossa rather large; zygomatic process of the squamosal robust; all these peculiarities are no longer or scarcely ever found among cetacea of the higher families. The braincase appears to be rather small and not very much compressed antero-posteriorly, this also in contrast with the higher whales. In common with the most primitive forms of the higher cetacean families the Platanistids have, so far as they are known, such peculiarities: as the mutual independence and rather considerable size of the cervical vertebræ; as the conspicuous lack of uniformity in the shape of the dorsal vertebræ (for instance the long, broad transverse processes of the lumbar vertebræ in contrast with the rather short processes of most of the thoracic vertebræ; only on a few of the hindmost thoracic vertebræ do there occur robust transverse processes, parapophyses, which bear ribs at their tips in the Platanistids that are known in this respect); as the well-developed heads to the anterior ribs, and probably also the coalescence, or more correctly the non-separation, of the tuberculum and capitulum on the hinder ribs; as the rather large, ossified costal cartilages; as the rather well-developed sternum; as the presence of the first finger, the metacarpal at least of which is found; as the rather slight lengthening of the middle fingers, etc.

In one single direction the known Platanistids have developed themselves highly. They have used the jaws as a kind of delicate forceps to seize and hold prey that did not make very strong resistance. The jaws grow to an unusual length but become noticeably slender, fine, though solid. The intermaxillary and maxillary press close together, covering over the anterior part of the mesethmoid, and they have a tendency to coalesce. The maxillary has pushed itself forward anteriorly beyond the tip of the intermaxillary. In the lower jaw the symphysis menti becomes very long, and the rami of the mandible are inclined to grow together. The teeth that lie at the front of the jaws are inclined to increase in size, probably because the tips of the jaws come to be the most used part of the forceps. In another respect also the known Platanistids stand high: the sides of the facial depression are inclined to grow upward. Perhaps they also stand high in the tendency of the pterygoid to widen itself out unusually far backward in the outer wall of the air-sac behind the palate, reaching back to the squamosal; a circumstance that may call to mind both lower and higher whales, Balænids and Physeterids.[18]

The genus of Platanistids which has removed itself least from *Squalodon* appears to be the Tertiary South American *Pontistes,* which is known from most of the skull. In relation to one or another of its nearest allies it has the following primitive characters: the teeth, judging from the alveoli, were small, simply formed, the anterior not enlarged; the toothrows stand rather distant from each other, as the palate is relatively broad; the outer margin of the facial depression, especially the longitudinal crest on the maxillary above the orbit, is relatively low. A character which must be considered advanced in comparison with the nearest relatives is the specially large number of teeth, about 40 in each jaw if one judges rightly from the fragments of toothrows that have been found.

Near to *Pontistes* but on a slightly higher level is *Pontoporia* (*Stenodelphis*). The teeth have become smaller but more numerous, about 55 in each jaw. Those in front have a slight tendency to be enlarged. The toothrows are placed nearer together and the palate is narrower. A high specialization, which also holds good for the other recent members of the family, is the complete absence of the olecranon.

Lipotes (known from external characters, skull, and cervical vertebræ) and *Inia* are near relatives of *Pontoporia.* Their face is shorter, the number of teeth is less (about 30 in each jaw in the former, about 26 in the latter), the anterior teeth show scarcely any tendency to be enlarged. It might appear as if the two genera were, in these characters, less specialized; but the explanation is presumably another. The two genera most likely originated from forms that more nearly resembled *Pontoporia,* and that had the strongly narrowed palate and numerous small simply conical teeth, although not so many as in *Pontoporia. Lipotes* and *Inia* appear to have used the teeth in a special manner, most probably for the crushing of food, and the teeth have therefore regained some of their earlier strength, have grown and become massive, with wrinkled enamel. In compensation, however, they have become less numerous and the most posterior in the jaws have acquired a form which is anything but primitive: the base of the crown is more or less tubercularly widened out inward. The narrow palate is retained. The lateral margin of the facial depression is considerably more upturned than in *Pontoporia,* and the posterior border, especially in the median region formed by the frontal, is far more elevated.

Lipotes as compared with *Inia* is surely the more primitive in the greater slenderness of the teeth; on the contrary it is the less primitive in having the facial depression relatively strongly widened behind.

Saurodelphis (*Saurocetus, Pontoplanodes*), Tertiary, Argentinian, known from most of the skull, appears to have also originated from *Pontoporia*-like animals, but it has gone in another direction than *Inia.* It has retained the slender face with the narrow palate, but the number of teeth is reduced to about 20 in each jaw. At the same time the teeth are enlarged; in any event they have acquired roots that are more widened antero-posteriorly; this is especially true of a number of the anterior teeth in each jaw. In these teeth the root appears to be in process of dividing in two, so that in cross-section it is almost 8-shaped, a form which, especially as regards the anterior teeth, is quite the opposite to primitive. The lateral margin of the facial depression is trenchant and highly upraised, even more than in *Inia.* The hinder margin of the depression is not only elevated in the middle as in *Inia,* but is also pushed further back.

Platanista also probably traces its origin back to *Pontoporia*-like creatures. It has gone further than any other member of the family in the direction of making over the jaws into delicate forceps. The face is so slender and the palate so narrowed that the right and left toothrows in the upper jaw lie closely side by side; they may even, especially at the extreme rear, where the teeth are undergoing atrophy, be pushed into each other. Somewhat similar conditions obtain in the lower jaw. The number of teeth is about 30 in each jaw. Several teeth at the front of each jaw have acquired high, pointed crown and compressed, enlarged root. The outer margin of the facial depression has grown upward, higher than in any other genus, especially that part of it which runs along the outer margin of the maxillary over the orbit and front of the temporal fossa. This part has shaped itself quite fantastically as a huge plate which rises high upward and bends in over the posterior part of the face, which it covers like a mask, since each plate nearly meets its fellow from the opposite side. On the other hand the posterior margin of the depression is not particularly highly elevated. The eye is atrophied; touch more than vision probably guides in the capture of prey. The hand's unusually broad, rounded-off outline, with the especially short, uniform, well-developed and wide apart fingers, might appear more primitive than in other members of the family; but possibly it may be the story of a partial reversal from an earlier more flipper-like condition.

Platanistidæ.[17]

- I. Upper toothrows well separated throughout. Maxillary with longitudinal crest not excessively large.
  - A. All the teeth with terete or scarcely compressed root.
    - 1. Longitudinal crest on maxillary relatively low. Frontal behind nasal only a little elevated.
      - a. Palate relatively broad. About 40 teeth in each jaw.
        Pontistes.
      - b. Palate relatively narrow. About 55 teeth in each jaw.
        Pontoporia [*Stenodelphis*].
    - 2. Longitudinal crest on maxillary relatively high. Frontal behind nasal rather strongly elevated.
      - a. Teeth relatively slender.
        Lipotes.
      - b. Teeth relatively robust.
        Inia.
  - B. Teeth with compressed root; in some of the anterior teeth the cross-section of the root is almost 8-shaped.
    Saurodelphis.
- II. Upper toothrows placed close together, especially behind, so that teeth from the right and left sides may be pushed in among each other. Maxillary with longitudinal crest excessively large, completely covering over the face.
  Platanista.

Delphinidæ.—The most important character—perhaps in the beginning the only one—which has separated the Delphinids from the most primitive Platanistids from which they sprang is the widening out of the facial depression. This broadens posteriorly to such an extent that its floor wholly covers over the temporal fossa like a roof formed by the frontal and maxillary together. A second peculiarity, which in any event soon showed itself, is the reduction of the temporal muscle through lack of use; its fossa becomes smaller and the zygomatic process of the squamosal becomes less projecting and less robust, losing, moreover, its primitive arched form. In the more advanced members of the family many other modifications may appear. The facial part of the skull, which begins by being long and narrow, almost compressed, used as forceps, may become still longer. Or the use as forceps may grow less and be exchanged for service as an implement for rooting in the sea bottom; followed by alteration in the form of the face. Or the mouth is used merely to clap together around the prey; followed by flattening and shortening of the face. In each instance the facial cushion contributes to the flattening of the facial part of the skull. The extreme tip of the intermaxillary has the tendency to be restricted, to be grown over by the maxillary and to lose the teeth which at first were implanted in it. Its upper margin may extend in over the anterior part of the mesethmoid and coalesce with its fellow of the opposite side. The symphysis menti has a tendency to be weakened and shortened. The teeth are inclined to a further reduction, and they may disappear; but they may also be again applied to special work and be modified in various ways. The braincase increases in size and is more subject to pressure from in front and from behind. The nasal passage may be pushed further back. The nasal bone, which in the most primitive Delphinids retained a slight trace of its earlier function as a cover for the nasal cavity, becomes in most cases quite sunk into the frontal. The occipital condyle, which at first is rather projecting in the usual manner, becomes flattened out and pressed in against the wall of the braincase. The cervical vertebræ may coalesce. The thoracic vertebræ acquire unusually long transverse processes which are especially noticeable on the hindmost of the series. Most of them are diapophyses except the most posterior ones; these are parapophyses. Only the anterior ribs retain the capitulum. On the hindmost ribs the capitulum disappears entirely, and the rib is articulated with the tip of the long transverse process by the tuberculum only. (As in the Platanistids the single articular head on the very hindermost ribs is presumably formed by the capitulum or by the capitulum and tuberculum undivided.) The flippers may be lengthened. Etc. The pterygoid varies capriciously. It is true that it always spreads inward under the posterior nares; but it is sometimes rather widely separated from its fellow of the opposite side, sometimes almost in contact with it, while probably after having been in the latter condition it may withdraw. The number of vertebræ also varies in a quite capricious manner.

One of the most primitive Delphinids is no doubt the Tertiary North American *Delphinodon,* the skeleton of which is known rather completely. In comparison with its various relatives it has the following primitive peculiarities. The teeth are present in large numbers. They are small and nearly simply conical, some of them, however, with wrinkles or small projections on the base of the crown, probably mementos of the crown's formerly serrate margins and of its also otherwise less simple form. The facial part of the skull is rather long and narrow. As in the related forms which are lowest in this respect the anterior end of the intermaxillary was probably freely projecting, tooth bearing, and not grown over by the maxillary. The upper margin of the intermaxillary does not come in contact with its fellow. The symphysis menti is long; nasal slightly projecting; cervical vertebræ distinct. It shows a peculiarity of its own in having a longitudinal crest on the projecting lateral part of the basioccipital.

The Tertiary European *Champsodelphis* (judging chiefly from *Ch. ombonii, Acrodelphis*) presumably stands near to *Delphinodon.* It is known from scarcely anything else than scanty remains of the skull. It shows high specialization in the modification of the rostrum to serve as an implement for boring or rooting in the sea bottom. The facial part of the skull has acquired an unusual length and slenderness; the teeth have probably disappeared from the intermaxillary, and the upper margin of this bone was probably in contact with its fellow through a considerable part of its extent.

The Tertiary European *Schizodelphis* (judging from *S. sulcatus, Cyrtodelphis*), also known practically from the skull only, must be a near relative of *Champsodelphis* with which it appears to have most of its peculiarities in common, both the primitive characters and the special modifications. Its most important difference appears to be that its teeth have gone still further in the direction of simplicity; the only reminders of earlier, less reduced form that have remained behind are a slight widening out of the crown's base, which may be found on some of the teeth, and the trenchant character of its anterior and posterior margins.

The Tertiary European *Heterodelphis,* which is known from rather considerable parts of the skeleton, undoubtedly stands close to *Schizodelphis.* Its teeth have become still more simple, with purely conical crowns.

In the Tertiary European *Eurhinodelphis,* which is known from most of the skull and from parts of the rest of the skeleton, the transformation of the snout into a rooting implement has reached the highest limit. The rostrum, both upper jaw and lower jaw, has grown forward anteriorly as a long slender point, still more noticeably than in any of the other genera. The intermaxillary has extended itself, awl-shaped and toothless, far forward beyond the maxillary. The tip of the lower jaw appears to be formed in a corresponding manner. The teeth are simply conical.

No doubt the Tertiary South American *Argyrocetus* is very nearly related to *Eurhinodelphis.* It is known from a defective skull, and appears to differ in trifles only.

The genera just mentioned of the group Eurhinodelphini form a contrast with the group Monodontes. The latter includes the genera *Delphinapterus* and *Monodon,* which must have originated from the oldest Eurhinodelphines in which the tip of the snout had not been remodeled as a rooting implement. In common with the Eurhinodelphines (at least with *Delphinodon, Heterodelphis, Eurhinodelphis,* and *Argyrocetus,* which are known in this respect) the Monodonts alone among the Delphinids have the primitive character that the cervical vertebræ are mutually independent. Other indications of low origin seem to be shown by the Monodonts in the form of the teeth (in which one of the genera may recall *Delphinodon* and others), in the decidedly short spinous and transverse processes of the thoracic vertebræ, in the relatively short fingers, and perhaps also in the absence of the dorsal fin. But in the flat and broad form of the face, probably resulting from their habit of not using the jaws for much else than to clap together on tender cuttlefish, the Monodonts are more highly developed than their progenitors among the Eurhinodelphines. The same is true of their lack of the olecranon.[18]

The most primitive of the known Monodonts is *Delphinapterus.* It shows its primitiveness in relation to its nearest ally by its rather ordinary dentition: the teeth are present in relatively considerable numbers, about 10 in each jaw; they are small and conical, but in the upper jaw they are directed forward in a peculiar manner. The teeth have disappeared from the intermaxillary.

In *Monodon* the teeth, with a single exception, are in process of atrophy and disappearance; only a few of them are present in the young. One of the foremost teeth in each maxilla has had its peculiar destiny: it has grown forward as a "ramming-tooth," at first no doubt uniformly in the right and left jaw and in the male and female, probably used, in a similar manner to the upper canine in the walrus or to the tip of the snout itself in the Eurhinodelphines, for rooting in the sea bottom. Such a function might be initiated by forward-slanting anterior teeth like those in *Delphinapterus,* but later it must have been restricted to the ramming-tooth in the left jaw of males. The work of the males may possibly be of service to the females because the species is gregarious. The ramming-tooth has become a kind of male secondary sexual character and has grown to an exaggerated size as the well-known " unicorn horn." As a memento of an earlier condition the ramming-tooth is still found in a reduced form in the right upper jaw of the male, and in both upper jaws of the female; in rare instances it may even now be found in the male well developed on both sides [when the spiral of the two tusks is parallel].

All the other Delphinids are contrasted with the Eurhinodelphines and Monodonts by the partial or complete coalescence of the cervical vertebræ, the atlas and axis being always united. The genera in question constitute a compact group, rich in forms, which traces its origin back to low Eurhinodelphines.

Lowest of all stands the section Delphini, whose most primitive known genus is undoubtedly *Steno.* This has still the primitive Eurhinodelphines' long, but not exaggeratedly long, narrow, scarcely flattened fore-face, with long toothrows and long symphysis menti. It is indeed scarcely distinguishable from the primitive Eurhinodelphines except by its partly ankylosed cervical vertebræ. The circumstances which place it low among its nearest relatives are the facts that the teeth have fluted enamel, and that the symphysis menti is long. The peculiarity of the enamel is presumably a slight reminiscence of an earlier, less-reduced condition.

Very near *Steno* comes *Prodelphinus* (probably including *"Sotalia"*), not differing in much else than that the enamel is smooth, not fluted, and that the symphysis menti is shortened.

Delphinus differs from *Prodelphinus* in scarcely anything else than a peculiar palate form: at the inner side of the toothrow the bony palate is hollowed out into a long longitudinal furrow which is especially deep behind. The intermaxillaries have a relatively strong tendency to coalesce and to cover over the mesethmoid. A few small teeth may be found in the intermaxillary as in *Steno* and *Prodelphinus;* in most of the Delphinids the teeth have wholly disappeared therefrom.

In contrast to the Delphinines the other higher Delphinids have the skull's fore-face shorter and more depressed. As a beginning the difference is only slight, but it finally increases so as to become very noticeable. At the same time that the anterior facial part of the skull is shortened, because the mouth is no longer used as a pair of forceps but as a "clap-trap," it becomes flatter and broader, while its upper side is more pressed upon by the facial cushion. The cushion becomes larger, especially widening itself out anteriorly and pushing into the originally slender "beak." The intermaxillaries, in their anterior portion particularly, together lose their structure as an upstanding roof-ridge, and finally become quite flat, each of the bones widened out.

The genera of the section Legenorhynchi depart so slightly from the more primitive members of the section Delphini, such as *Prodelphinus,* that there would scarcely be any reason to set them apart in a special group were it not evident that they represent the beginning of new series of forms.

Doubtless *Tursiops* occupies the lowest position. The anterior facial part of the skull is indeed broader than in *Prodelphinus,* but it has, however, not lost its form as a roof-ridge, and it has still a considerable length.

Near *Tursiops* probably belongs *Tursio* [*Lissodelphis*], which also has the fore-face rather long, though more flattened. Another difference is that it lacks the dorsal fin, either because it has lost it or has never acquired it.

Lagenorhynchus (to which should probably be joined *Cephalorhynchus* and *Sagmatias,* and perhaps *"Feresa"*) has gone a step further than *Tursiops* and *Tursio* in the direction of shortening and flattening the rostrum.

Among the Delphinids in which the process of shortening and flattening the rostrum has been more perfected the members of the section Globicipites are contrasted with those of the section Phocænæ by reason of their greater primitiveness. In them the crowns of the teeth have retained their primitive conical form, while in the Phocænans the crowns have become entirely peculiar.

Orca [*Orcinus*] is the one among the Globicipites which has retained most of the ordinary dolphin type in the structure of the rostrum, particularly as regards the narrowness of the intermaxillary. The rather short, rounded-off form of the hand might appear to be primitive also, but various circumstances strongly indicate that it has arisen through the shortening of an ordinary, pointed, porpoise flipper: the number of phalanges in the second finger is rather large; the finger is merely more strongly arcuate than usual. In the transformation of the dentition to a conspicuously powerful biting implement *Orca* has gone further than any other genus of the family. It has habituated itself to living on large prey such as seals and the smaller cetaceans, and it even slashes into the largest. The teeth are, it is true, relatively few, about 12 in each jaw, but in compensation they are massive.

Orcella has reached higher than *Orca* in the great breadth of the intermaxillary, but it must have originated at a level lower than that on which *Orca* stands, since its teeth are small and rather more numerous, while its hand is essentially like an ordinary porpoise hand. The genus gives the impression of being a dwarf form with noticeably large braincase in proportion to the face.

The following genera of Globicipites must have originated from Delphinids that were essentially like *Orcella* but without the dwarfing. Each has gone its own way. There is, however, one peculiarity that unites them: the hand has acquired an uncommon length and narrowness, though in different degrees, at last with an unusual number of phalanges in the second finger.

In "*Grampus*" the intermaxillary has retained a breadth similar to that in *Orcella*. Although the hand is long and narrow there are only about eight phalanges in the second finger. The chief peculiarity of the genus lies in the atrophy of the dentition: only a few and rather small teeth remain. These are at the front of the mandible, and with age they may entirely disappear.

In *Pseudorca* the hand is essentially as in *Grampus*. But the intermaxillary has acquired a very noticeable breadth anteriorly, and the dentition is developed in a similar manner as in *Orca*.

The intermaxillary is conspicuously wide in *Globiceps* [*Globicephala*] also; it may be even wider than in *Pseudorca*. Peculiarities of *Globiceps* are: that the nostril is pushed unusually far backward, that the dentition is atrophied so that only a few, about 10, small teeth remain, situated at the front of the jaws, and that the hand is conspicuously long, with as many as 14 or more phalanges in the second finger.

The section *Phocænæ* presumably originated among the most primitive *Globicipites* or perhaps *Lagenorhynchi*. That which places this group in contrast not only with the *Lagenorhynchi* but also with all other Delphinids is the peculiar form of the teeth. The teeth are present in large number and are of small size. Some of the foremost and hindmost may have about the usual conical crown, and all of them are single rooted. Most of the teeth, however, have the crown compressed, widened out fan-wise or leaf-wise, and often with notches in the margin; a form which is not only unique among the cetacea, but the contrary to the forms found among the most primitive cetacean genera.[19]

Phocæna is, besides, a little broad-snouted porpoise, rather evenly developed in all directions. A few small teeth may be present in the intermaxillary.

Neomeris (*Neophocæna*) is nearly related to *Phocæna*. It differs in having acquired a yet shorter and broader face, in having a noticeably spacious braincase, and in lacking the dorsal fin, which it doubtless has lost.

Delphinidæ.[20]

- I. Atlas and axis mutually free.
  - A. Face long and narrow, not flattened.
    EURHINODELPHINI.
    - 1. Intermaxillary (undoubtedly) not specially elongated in front of maxillary.
      - 1. Face not noticeably elongated.
        Delphinodon.
      - 2. Face noticeably elongated.
        - a. Teeth with slight traces of less simple forms.
          - *α*. Crowns of teeth partly with remains of lateral cusps.
            Champsodelphis.
          - *β*. Crowns of teeth without lateral cusps.
            Schizodelphis.
        - b. Teeth purely conical.
          Heterodelphis.
    - 2. Intermaxillary with tip produced far forward in front of maxillary.
      Eurhinodelphis, Argyrocetus.
  - B. Face relatively short, broad and flat.
    MONODONTES.
    - 1. Several teeth present in each jaw, none of them especially elongated.
      Delphinapterus.
    - 2. Almost toothless, a single tooth in the upper jaw of males a gigantic ramming-tooth.
      Monodon.

II. Atlas and axis coalesced.

A. Anterior facial region, formed mostly of intermaxillary and maxillary, long and narrow, not or scarcely flat, nearly roof-shaped; intermaxillary in particular relatively narrow.

DELPHINI.

1. Crowns of teeth rough; symphysis menti long.

Steno.

2. Crowns of teeth smooth; symphysis menti short.

a. Palate without grooves.

Prodelphinus.

b. Palate with a longitudinal groove on each side.

Delphinus.

B. Anterior facial region, formed mostly of intermaxillary and maxillary, becoming relatively short, broad and flat; intermaxillary in particular broad.

1. Face relatively only a little shortened.

LAGENORHYNCHI.

a. Fore-face, beak, relatively long.

α. Rostrum not wholly flattened. Dorsal fin present.

Tursiops.

β. Rostrum more flattened. Dorsal fin absent.

Tursio [*Lissodelphis*].

b. Fore-face relatively shorter.

Lagenorhynchus.

2. Face more strongly shortened.

a. Crowns of teeth conical, terete, pointed.

GLOBICIPITES.

α. Intermaxillary not especially broad proportionally.

Orca [*Orcinus*].

β. Intermaxillary more or less noticeably broad.

1. Flippers not or scarcely lengthened and pointed.

Orcella.

2. Flippers lengthened, pointed.

α. Intermaxillary not conspicuously broad anteriorly.

"Grampus."

β. Intermaxillary strongly broadened anteriorly.
(1) Nostril not pushed especially far back. Teeth not atrophied. Flippers quite short.
Pseudorca.
(2) Nostril pushed unusually far back. Teeth somewhat atrophied. Flippers very long.
Globiceps [*Globicephala*].
b. Crowns of teeth in part compressed, widened out leaf-wise.
PHOCÆNÆ.
a. Face relatively long and narrow. Braincase relatively small.
Phocæna.
β. Face relatively short and broad. Braincase large.
Neomeris [*Neophocæna*].

Physeteridæ.—The *Physeteridæ* probably originated from the most primitive Delphinids, from Delphinids in which the margin of the facial depression must have been so widened that it covered the temporal fossa, but which at the same time retained these primitive features: zygomatic process of the squamosal relatively large and somewhat arcuate; teeth small and conical, but still with traces of notching on the margin of the crown; teeth in the intermaxillary well developed; anterior part of mesethmoid free, not covered over by the intermaxillaries; free though stunted lacrimal; separate cervical vertebræ; rather short transverse processes on the thoracic vertebræ; a well-developed capitulum on all the ribs, etc. The character that already places even the most primitive Physeterids on a higher plane than the Delphinids is a result of stronger action of the facial cushion. It appears as if the *Physeteridæ* had from the very first trained themselves to swifter, more violent swimming than other whales, and that the fat-pad in front of the nose had therefore been pressed in with greater force against the facial part of the skull. The pad, together with the nasal muscles, etc., has modified the face to an unusual degree. Especially the posterior margin of the facial depression is transformed, more or less conspicuously elevated. The crookedness in the posterior nasal passage and in the facial bones becomes more conspicuous than in other whales. The resistance of the water has acted upon the skull in other ways also, different in the different groups; there is a tendency toward strengthening and coalescence of the bones of the face, toward the appearance of projecting osseous protuberances, etc.

The members of the family, so far as they are known in this respect, show a peculiarity in the relation between the ribs and the transverse processes on the posterior thoracic vertebræ, in which they form a contrast to at least the living forms of Delphinids. While in the Delphinids the hinder ribs apparently lose the capitulum and retain the tuberculum (the most posterior, probably having their own history, have never had more than a single head), in the Physeterids it is the tuberculum that disappears, while the capitulum remains. On one or two of the hindmost ribs it may happen that the capitulum and tuberculum can be seen at the same time, each in contact with its "transverse process"; but the tuberculum with its corresponding process, a diapophysis, is in course of atrophy.[21]

The genera of the section Xiphiini stand lowest. In them the occipital wall, which forms the posterior margin of the facial depression, is highly elevated in a section at the middle only, behind the nares, and is not pushed very far back in relation to the nares. In the contrasted *Physeterini* the occipital wall is heightened through its whole extent and more pushed backward. Likewise a primitive feature of those Xiphiines that are known in this respect is that a more or less distinct lacrimal bone is present, though in an atrophied condition, spreading out especially in the roof of the orbit.

The essentially most primitive genus of the Xiphiines is no doubt the Tertiary South American *Argyrodelphis* (*Notocetus, Diochotichus*), of the group Argyrodelphini, not known from much else than the skull. It stands lower than all other known Physeterids in having a relatively robust and arcuate zygomatic process of the squamosal and in the character of the dentition. There is a long row of small, well-developed, conical teeth in both upper and lower jaw, some of them bearing notches on the margin of the crown. On the contrary, as compared with one or another of the other genera, it is advanced in having the occipital wall pushed rather far back, in having a rather large cushion-shaped outgrowth on the maxillary above the orbit, and in having the intermaxillaries spread inward over the mesethmoid and coming into mutual contact with age. The cervical vertebræ were free.

In all other Xiphiines the zygomatic process of the squamosal is smaller and more atrophied, the teeth in the upper jaw disappear, while of those in the lower jaw one or two only remain in each ramus and these are particularly modified. A peculiarity of at least the living forms of the section is the unusual size of the air-sac at the outer side of the pterygoid, which is shaped to fit it. Somewhat of a peculiarity likewise is partly the height of the spinous processes on the dorsal and caudal vertebræ (while the transverse processes are relatively rather short), and partly the small size of the hand. The former character indicates unusually heavy dorsal and caudal muscles, or perhaps a widening out of the muscles in a different direction—more upward than sideways—than in the Delphinids with specially long transverse processes. The latter makes it appear that the hand is somewhat disused. The cervical vertebræ are inclined to coalesce as in the Physeterines.

In the members of the group Xiphii, as contrasted with the Hyperoodontes, the bones of the face have remained primitive to the extent that no raised longitudinal crest is present on the maxillary in front of and above the orbit; at most there is found in the corresponding place a weak cushion-shaped elevation. But in other ways the bones of the face have increased in strength and have permitted themselves to be moulded by the pressure of the water.

In a few respects *Mesoplodon* is the most primitive among the Xiphii. To be sure, the facial cushion, by pressing back against the occipital wall, has caused the median part of the wall, formed for the most part of projecting outgrowths of the intermaxillaries, to be abruptly elevated. But the cushion has not acted on the wall to such a degree that the upper margin together with the nasal bones has been either very strongly forced back or caused to bend forward in any noteworthy manner; neither has it formed for itself any distinct pit around the nares. Moreover the intermaxillaries have retained their original relation to the mesethmoid, which they do not grow over. On the other hand the rostrum acquires increased strength by the ossification, as age advances, of the mesethmoid, and its coalescence with the surrounding bones into a stony-hard mass. Of the teeth in the upper jaw there is found in *Mesoplodon* at most a series of quite small remnants, more or less hidden in the skin and scarcely leaving any traces in the bones. In the lower jaw there is found only one well-developed tooth. This is situated at the front of the mandible and is peculiarly modified, having a large, compressed crown and a big root which sometimes, presumably in the male especially, may grow to a disproportionate size and to a high degree affect the form of the jaw.

The Tertiary European *Xiphirostrum* (*"Ziphirostrum," "Mioziphius"*), which is known from parts of the skull, has in a single respect gone further than *Mesoplodon,* near to which it otherwise stands: the intermaxillaries have grown over the mesethmoid and come in contact with each other along their upper margins. But *Xiphirostrum* must have taken its origin from whales that were less far advanced than the known species of *Mesoplodon;* as the mesethmoid is not ossified anteriorly; the teeth in the upper jaw are slightly less atrophied, leaving traces behind them in the maxillary; and at the front of the lower jaw there are two well-developed teeth on each side.

Chonoxiphius (*"Choneziphius"*), likewise Tertiary European and known from parts of the skull, stands near to *Xiphirostrum.* It has gone further in the modification of the face. The facial cushion has begun to modify a special area around the nares for its bed. Here the lateral margins of the premaxillaries are caused to grow slightly upward, so that they together, and the bones that lie between, form a special pit, a structure the first traits of which, more or less evident, are found in many other toothed cetaceans. In the middle of the pit there has arisen an erect longitudinal crest, evidently formed from the posterior part of the mesethmoid. (The under jaw is probably not known.)

Xiphius (*"Ziphius"*) appears to have originated from whales which stood on about the same level as *Mesoplodon.* Its deviations are of two principal kinds: (1) the median part of the occipital wall is forced further back and raised higher upward, so that the nasal bones, which are even more modified than in other Xiphiines and are widened out plate-wise in front, once more come to form a forward-bent roof over the nasal cavity, and (2) the lateral margins of the intermaxillaries have grown upward as in *Chonoxiphius,* but much more conspicuously, bounding a deep pit. As in *Mesoplodon* the anterior part of the mesethmoid becomes ossified with age.

In the genera of the group Hyperoodontes, which must have originated from the lowest Xiphii, the bony crest, a faint indication of which is found in many toothed cetaceans running along the upper surface of the maxillary in front of and over the orbit, becomes so stimulated to growth by resistance of the water that it gradually swells up to a huge hump which spreads itself over most of the face in front of the nares. Each hump is closely appressed to its fellow of the opposite side, leaning inward over the intermaxillary and mesethmoid so as to turn a broad shock-receiving surface forward. The nares and middle part of the occipital wall are forced unusually far backward toward the posterior boundary of the braincase.

The most primitive genus of the group is "*Berardius*." The longitudinal crest on the upper surface of the maxillary is well developed and erect, but the face, however, has retained essentially its ordinary form. At the front of the lower jaw are found two rather well-developed teeth.

In *Hyperoodon* the face becomes with age wholly abnormal, since the longitudinal crest on the maxillary elevates itself to a height which exceeds even the highest part of the occipital wall. In the lower jaw at the front is found only a single tooth (apart from embryonic conditions).

The genera of the section Physeterini must have originated among the most primitive Xiphiines, from Xiphiines in which the dentition was still rather well developed, with teeth in the intermaxillary as well as the maxillary; in which the intermaxillaries were free from each other and from the surrounding bones; in which the mesethmoid was not ossified, etc. Their peculiarity is that the pressure of the facial cushion on its surroundings acts differently than in the Xiphiines, and even more strongly. The facial cushion, especially that part of it which is formed by the adipose mass, widens out still more, particularly outside of and behind the nasal passages. It pushes the median part of the occipital wall far back behind the nares, while at the same time the margins of the facial depression, at the back and at the sides, grow high upward. The bones which form the bottom of the facial cushion's bed are strongly acted upon by the stimulating mass of the cushion. They widen out. This holds good especially of the bones in the rostrum, and chiefly of the anterior part of the maxillary. The lower jaw on the contrary retains its primitive narrowness.

The genera of the group Hoploceti are extinct, Tertiary, and are only incompletely known, chiefly from fragments of skulls. It may be concluded that the skull in essential respects is modified in the same manner as in the highest group of Physeterids, the Physeteres, but to a distinctly less noticeable degree. They are also less advanced than the Physeteres in the development of the dentition, there being a long row of well-developed teeth in both upper and lower jaws, while the upper teeth of the Physeteres have atrophied.

In the European and American *Hoplocetus* (*Balænodon, Physodon, "Scaldicetus,"* etc.) the teeth are covered with enamel.

The European *Physeterula* has lost the enamel, it appears.

In the genera of the group Physeteres the influence of the facial cushion on the skull has led to fantastic results. The dentition also is modified in a strange manner. In the lower jaw the teeth continue to be well developed; but in the upper jaw they atrophy and disappear either wholly or essentially so. It is not clear what the reason can be for this difference between the upper and lower jaws. Perhaps the difference is connected with the great lateral broadening out of the maxillary whereby the upper toothrows are so pushed outward that they lose their interaction with the lower toothrows which retain their ancestral position in the closely appressed mandibular rami. There has been no hard work for the upper teeth which might have maintained them in spite of all; the lower teeth together with the palate must have proved sufficient, as the task is indeed scarcely anything else than to grasp the cuttlefish which appear to be the favorite food for this whole family as well as for various other cetaceans, especially for those with more or less degenerate dentition.

"*Cogia*" is in some respects the most primitive of the genera. In the upper jaw there is still found, or may be found, a tolerably well-developed tooth. In the skull there remains a rather considerable, curved remnant (although very narrow and compressed) of the heightened osseous ridge which elsewhere in the toothed whales lies between the nares and the occipital wall; the adipose cushion has not yet wholly destroyed it. Neither has the cushion so grown around the outer nasal passage that it has pushed the orifice away from its accustomed place, nor has it to any noticeable degree pressed the roof of the braincase down. The anterior part of the face has become broader than usual, but it is still rather short, or, more strictly speaking, has been further shortened. On the other hand the lateral margin of the facial depression, over the braincase, is pushed unusually far out to the side and raised conspicuously high upward; it has also acquired a unique thickness.

In *Physeter* nothing has remained of the upper teeth except small vestiges hidden in the skin. The fat-cushion, which has grown gigantically, has caused the bones of the rostrum to grow far forward and to broaden themselves strongly at the side. The posterior margin of the facial depression is more abruptly elevated than in any other whale and is pushed further back. The fat-cushion has completely overgrown and leveled off the bony wall which elsewhere lies between the nares and the occipital wall. The soft outer nasal passage is pushed forward so that the blow-hole lies far to the front. The adipose cushion has forced the roof of the braincase down by its weight, and the whole braincase has sunk down below its original level, so that the spinal marrow, or medulla oblongata, has to bend down in an S-shaped curve to connect with the brain. The skull has acquired a noticeably large size in proportion to the body, and most of its bones have become conspicuously ponderous; this is especially noticeable as concerns the zygoma. Just as *Physeter* is the largest of all the toothed whales and pushes through the water with greater force than any other, it is the one on which the resistance of the water has had the most powerful influence. But it is a question whether this high development is not a menace to the creature's life. Irresistibly the water's pressure has caused the facial cushion to grow to a disproportionate degree and in its turn to call forth a skull the size of which is without relation to brain and body. The fate of *Physeter,* the most highly developed toothed whale, is much like that of *Balæna,* the strangest whale-bone whale; the difference is that the pressure of the water in the one has acted most strongly on the outer side of the head, in the other most strongly on the inner walls of the mouth. Both animals are developed with such extravagant one-sidedness that they appear to be in danger of certain extinction even if their extirpation were not being worked at by man.

Physeteridæ.[22]

I. Occipital wall highly elevated in middle only, its position close behind the nares.

  XIPHIINI.

    A. Dentition primitive: a long row of rather uniform small teeth in both upper and lower jaw. Zygomatic process of the squamosal well developed.

      ARGYRODELPHINI.

        Argyrodelphis.

    B. Dentition atrophied: most of the teeth disappear, leaving one or two in each lower jaw specially modified. Zygomatic process of the squamosal somewhat reduced.

      1. Longitudinal crest on maxillary above and in front of orbit absent or slight.

XIPHII.
- a. Intermaxillaries not or scarcely forming a cup-shaped depression around nares.
  - α. Intermaxillaries not covering mesethmoid in front.
    Mesoplodon.
  - β. Intermaxillaries mutually in contact, covering mesethmoid in front.
    - (1) No pit formation around nares.
      Xiphirostrum.
    - (2) Indication of pit formation around nares.
      Chonoxiphius.
- b. Intermaxillaries with an elevated outer margin forming a deep cup around nares.
  Xiphius.

2. Longitudinal crest on maxillary above and in front of orbit well developed, swollen.

HYPEROODONTES.
- α. Longitudinal crest on maxillary relatively weak.
  "Berardius."
- β. Longitudinal crest on maxillary huge.
  Hyperoodon.

II. Occipital wall spreading itself, highly elevated, across entire braincase, and pushed far back behind nares.

PHYSETERINI.

A. Upper toothrow well developed.

HOPLOCETI.
1. Teeth with enamel.
   Hoplocetus.
2. Teeth without enamel.
   Physeterula.

B. Upper toothrow atrophied.

PHYSETERES.
1. Distinct remains of the longitudinal crest that originally extended from the nares to the occipital crest.
   "Cogia."
2. Longitudinal crest behind nares wholly flattened out, obliterated.
   Physeter.

The Hyænodonts, the nearest stock-forms of the cetacea among terrestrial mammals, lived at the beginning of Tertiary times in the northern parts of both the Old and New Worlds. They had spread over Europe and North America and were found in northern Africa as well. The whales must have made their appearance somewhere within the territory occupied by the Hyænodonts, and probably in the oldest part of the Tertiary; in agreement with this the most primitive cetacean that is yet known, the Hyænodont-like *Protocetus* of the family **Zeuglodontidæ,** is found in Egypt in Eocene strata. Likewise one of the next links in the chain of cetacean development, *Prozeuglodon,* was Egyptian, from the Eocene. But soon the members of the family must have spread widely; in any event the highest genus, the almost fantastic, snake-like *Zeuglodon* [*Basilosaurus*], appears to have found its way during the Eocene to all oceans.

The Zeuglodonts died out early in the Tertiary. Their highest forms left no descendants; but from the more primitive genera of the family sprang the new family **Balænidæ.** The oldest, tooth-bearing forms of Balænids are as yet scarcely known. In Miocene times, however, the family had already produced the specialized whalebone-bearing forms, a side branch on the cetacean genealogical tree, and they soon spread themselves to all the seas of the globe, where they still are found. Some of the recent genera are essentially cosmopolitan, even in the sense that individual species occur in all seas. This holds good in part only of *Balæna,* one of whose species, the more primitive, *B. australis,* is almost cosmopolitan, while the second, the more specialized, *B. mysticetus,* is confined to the northern polar oceans. It is literally true of *Balænoptera* and *Megaptera.* Two of the recent genera are confined to a smaller range: *Neobalæna* a relatively high genus that lives in the South Sea, where it likely originated, and *Rhachianectes* a relatively low genus, in many respects recalling extinct Miocene forms. It lives in the northern part of the Pacific, perhaps as a kind of last remnant from an early day. The reason why the Balænids, in spite of their rather primitive structure, are not wholly extinct, supplanted by the more specialized cetacea, is probably because they have chosen a peculiar food supply: the small creatures of the sea. Therefore they do not have very many competitors among their kind.

From the most primitive, tooth-bearing Balænids the family **Squalodontidæ** branched off in Tertiary times. It had its flourishing period in the Miocene, widely distributed in the oceans. The whole family disappeared before the end of the Tertiary, chiefly, it would appear, because it passed onward into its successors.

The descendants of the primitive Squalodonts are the members of the family **Platanistidæ** which appeared early in the Tertiary and was soon widely distributed. Most of the genera have died out again; only four, *Pontoporia* [*Stenodelphis*], *Lipotes, Inia* and *Platanista,* have come down to the present time. These have doubtless avoided being crowded out by higher cetaceans purely because they have chosen a peculiar habitat, rivers and estuaries, which they have been almost alone in utilizing.

Early in the Tertiary the family **Delphinidæ** branched off from primitive Platanistids. Extinct genera, especially in the Miocene, are known from localities that were even then far apart; at present the family is universally distributed, many of the genera and species being nearly cosmopolitan. The family seems to be having its flourishing period now. Only a few of the recent genera have ranges that are somewhat restricted, as *Delphinapterus* and *Monodon* in the Arctic Ocean, *Tursio* [*Lissodelphis*] in the Pacific, *Orcella* in the rivers of Southeast Asia and in the neighboring sea, *Neomeris* [*Neophocæna*] on the eastern and southern coast of Asia and the east coast of Africa.

Early in the Tertiary the family **Physeteridæ** originated from the most primitive Delphinids. It had already reached its climax in the Pliocene, widely distributed. Only rather few genera, but these very highly developed, have come down to the present day. They are widely distributed, essentially cosmopolitan.

NOTES

[1] (P. 1.) The present treatise on Cetacea is a continuation of the series of memoirs on the other orders of mammals which have appeared in E Museo Lundii, vols. 1-3, 1887-1915, and in the Vidensk. Medd. Dansk Naturhist. Foren., vol. 68, 1917. Part of the opinions that are here expressed have been previously published in the Vidensk. Medd. Dansk Naturhist. Foren. for 1882, pp. 29-31, 40 and 53-55; *ibid.*, for 1909, pp. 5-9; Meddelelser om Grønland, pt. 21, 1902, pp. 364-368; Danmarks Fauna, Pattedyr, 1908, pp. 9-10, 200-209.

[2] (P. 1.) On the origin of the Cetacea very different opinions have been put forward. The idea of Brandt and others that the Cetacea are the lowest, most reptilian mammals is now shared by scarcely any one. Likewise the old idea of the relationship with sea-cows was long ago laid aside. Flower's early opinion that the whales originated from seals, an opinion which he shared with others, was disputed by Winge (Vidensk. Medd., 1882, pp. 53-55) and almost abandoned by Flower himself. It was not taken up by others except in a way by D'Arcy Thompson. D'Arcy Thompson's opinion (On the Systematic Position of Zeuglodon; Studies from the Museum of Zoology in University College, Dundee, vol. 9, 1890, pp. 1-8, with illustrations) that the Zeuglodonts, really the most primitive whales, are not Cetacea, but near relatives of the seals, is disproved by Lydekker (Proc. Zool. Soc. London, 1892, pp. 560-561) and Dames (Ueber Zeuglodonten aus Aegypten, etc.; Palaeont. Abhandl., herausgeg. von Dames u. Kayser, vol. 5, pt. 5, 1894, section pp. 204-210). Flower's ideas about the whale's relationship to particular ungulates proper other than sea-cows have also shown themselves to be incorrect. The author who has most extensively examined the question in earlier times is Max Weber in his book: Studien über Säugethiere, ein Beitrag zur Frage nach dem Ursprung der Cetaceen, 1886, which contains a review of earlier work on the subject. His own conception of the history of the Cetacea was then "dass sie einem generalisirten Säugethiertypus im mesozoischem Zeitalter entstammen, der zwischen Carnivora und Ungulata mitten inne steht, wohl aber nähere Beziehungen zu Carnivora hatte" (*l. c.*, p. 241). In his work Die Säugethiere, 1904 (p. 581), Max Weber sets forth the idea that "primitive Condylarthrer" were perhaps most nearly the precursors of the whales.

Solid ground was first reached with the discovery of *Protocetus atavus* described by Fraas (Neue Zeuglodonten aus dem unteren Mitteleocän von Mokattam bei Cairo; Geol. u. Palæont. Abhandl., herausgeg. von Koken, vol. 10, pt. 3, 1904. There could be no doubt that *Protocetus* came from Hyænodonts and that it was itself a forerunner of the Zeuglodonts. Curiously, however, Fraas thought that the origin of the Cetacea was not thereby explained. He considered both *Protocetus* and with it the other Zeuglodonts as a side branch from the carnivores which did not lead in the direction of the true whales. There seems now, however, to be unanimity of opinion that *Protocetus, Prozeuglodon,* etc., are some of the long sought progenitors of the whales. In spite of all differences from the higher Cetacea there is a multitude of resemblances to them which it would be impossible to explain except on the basis of relationship. One has only to think of the striking likeness in such peculiarly formed bones as the tympanic and scapula; their characters in the fossils are exactly those that one would expect to find in ancestral Cetacea.

It has been said that the whalebone whales and the toothed whales might have separate "diphyletic" origins; Kükenthal in particular has spoken for this view (Ueber die Anpassung von Säugethieren an das Leben im Wasser; Zool. Jahrbücher, Abth. für Systematik, etc., vol. 5, 1891, pp. 373-399, especially p. 384, and elsewhere). In face of the host of agreements in numerous structural relationships which are found in the two groups this idea is an impossibility. Just one little bone like the tympanic, with its thickened inner wall, its mussel-shaped outgrowth around the outer auditory aperture, its petrous process which reaches out under the mastoid, and other details, all of the most peculiar form, and all essentially identical in all Cetacea, is sufficient evidence of the near relationship of all whales.

Kükenthal has put forward a "Versuch, den Bau des Walkörpers von biologischen Gesichtspunkten aus zu erklären," most elaborately in Die Wale der Arktis, Fauna Arctica, vol. 1, pt. 2, 1900, section pp. 181-203.

[3] (P. 3.) We owe to Abel a special treatise on the skeleton of the hind limb in Cetacea: Die Morphologie der Hüftbeinrudimente der Cetaceen; Denkschr. d. math. -naturw. Klasse d. k. Akad. d. Wissensch. Wien, vol. 81, 1907, pp. 139-195, with illustrations. A supplement is given by Lönnberg: The Pelvic Bones of Some Cetacea; Arkiv för Zoologi, vol. 7, No. 10, 1910, pp. 1-15, with illustrations.

[4] (P. 4.) Much information about the structure of the hand in the Cetacea has been collected by Kükenthal (Die Hand der Cetaceen; Denkschr. d. med. naturw. Ges. zu Jena, vol. 3, pt. 1, 1889, pp. 23-69, pl. 3, and the section "Die Brustflosse," in Vergl. -anat. u. entwickelungsgesch. Unters. an Walthieren, *ibid.*, pt. 2, 1893, pp. 267-312, with illustrations) and Kunze (Ueber die Brustflosse der Wale; Zoologische Jahrbücher, Abt. für Anatomie, etc., vol. 32, pt. 4, 1912, pp. 577-651, pls. 33-35), both of whom give references to earlier works.

Kükenthal regards it as most probable that the large number of phalanges in the Cetacea has originated as follows: That the diaphyses and epiphyses in an ordinary hand whose fingers had mostly three phalanges have loosened themselves from each other, and have become independent and uniform, all of them ossified. This explanation cannot possibly be right. It is immediately contradicted by the fact that in cetacean hands with many-jointed fingers there can be found both diaphyses and epiphyses, ossified, in the larger of the phalanges that are present, as Kükenthal himself has observed. If one examines series of adult cetaceans' hands or of embryo hands, it is quite impossible to detect anything that could point in this direction. It certainly should be possible to find, somewhere or other, transition forms which would show indication that the phalanges were of unlike origin, some of them diaphyses, others epiphyses; but of this there is not the slightest evidence. Neither is it probable that the forerunners of the whales among terrestrial animals, had, even when young, epiphyses at both ends of all the phalanges, as would be needed in order to explain even tolerably the large number of joints in the Cetacea. It is true that in the Cetacea there have arisen supernumerary ossified epiphyses, more epiphyses than in their ancestors. But let it be noted that this has only happened in those Cetacea that already had acquired many-jointed fingers. (The objection to the "epiphysis-hypothesis" that it could at most explain the presence of only 12 joints in the fingers, including the metacarpal, and that it therefore cannot hold good where the number of joints is more than 12, is met by Kükenthal with the admission that in such instances the number of joints is actually increased out beyond the finger tips. *l. c.*, 1893, p. 311.)

Another explanation which is more probable Kükenthal himself sets forth but regards as less happy: "Würde man die Entwickelungsgeschichte allein zur Lösung der Frage heranziehen, so würde sich der Schluss ergeben, dass ausser den vier typischen Fingerelementen sich immer neue anlegen, indem sie sich, in distaler Richtung aufeinander folgend, in dem sich immer weiter vorschiebenden embryonalen Bindegewebe entwickeln, so dass die letzte Phalanx die jüngste ist" (*l. c.*, 1893, p. 311). Kükenthal finds a reason to reject this opinion in the fact that Leboucq and he have occasionally found something on the outermost tip of one of the digits of a long-fingered porpoise hand which might be interpreted as the weakest remnant of a nail. Should it prove that remnants of a nail are found on the extreme tip of the finger, says Kükenthal, this "hypothesis" concerning the origin of the many phalanges cannot be correct, "denn dann entspricht die Spitze der Walflosse und damit die Spitze von deren Fingern auch der Spitze der Finger der typischen Vorderextremität" (*l. c.*, 1893, p. 312). This objection cannot hold; there is certainly nothing to prevent that the atrophied remnant of a nail should constantly retain its position on the finger tip as this pushes outward further and further, whatever the method by which the finger is elongated.

[5] (P. 5.) A special treatise on the cervical vertebræ of the Cetacea is due to Reche: Ueber Form und Funktion der Halswirbelsäule der Wale; Inaugural-Diss., 1904, with illustrations. See also De Burlet: Beitrag zur Entwickelungsgeschichte der Wirbelsäule der Cetaceen; Morphol. Jahrb., vol. 50, pt. 3, 1917, pp. 373-402, with illustrations.

[6] (P. 7.) On the tympanic bone and its surroundings in the Cetacea, see especially: Van Kampen, De Tympanaalstreek van den Zoogdierschedel, 1904, pp. 299-316. Contains references to earlier papers on the subject. On the ear-bones themselves, see especially: Doran, Morphology of the Mammalian Ossicula Auditus; Trans. Linn. Soc. London, ser. 2, Zoology, vol. 1, 1878, pp. 450-464, pls. 62, 63.

[7] (P. 9.) The opinion that the increase in the number of teeth in the Cetacea above the typical eutherian number was perhaps initiated by the intercalation of milk teeth in the permanent set was expressed in 1882 (Vidensk. Medd. for 1882, pp. 31 and 40) at a time when no trace of tooth succession had yet been detected in whales. The same opinion was maintained by Max Weber (Urspr. der Cetaceen, 1886, pp. 195 and 199), but he abandoned it (Die Säugethiere, 1904, p. 567) after Kükenthal had demonstrated indications of the tooth succession. Kükenthal had found traces of germs of both forerunners and successors to the teeth which stand in the Cetacea as the permanent set (but which he considered as milk teeth). Perhaps the idea is wrong; but there is nothing in that which has thus far been discovered which

makes its abandonment necessary, inasmuch as only a part of the milk dentition, only four cheekteeth, were ever supposed to be intercalated in the permanent set (it was expressly said that an increase in the number of cheekteeth by other means, by division or by the formation of new elements, was necessary as an explanation when the number exceeded 11 in each jaw); and the milk dentition could perhaps be made whole again after having given up some of its contents. In any event it is impossible to trace in detail the destiny of the tooth-germs through their erratic course during atrophy; there are many possibilities.

In spite of all investigations during recent years into the development of cetacean dentition both embryologically and phylogenetically, no certain conception has been reached. Only this is certain, that the cetacean dentition is derived from the typical carnivore's, that the teeth are increased in number while their size is decreased and their form made more simple, and that the tooth succession has essentially ceased, although in embryos there can still be detected traces of several sets of teeth, as in many other mammals, faint mementos of their forefathers among the reptiles. But of how the changes have in detail come about we can only partly guess.

Abel is the author who has most recently reviewed the present question. He believes that he can more nearly show how the high number of teeth has arisen in the Cetacea; in the whalebone whales he thinks it came about in one way, and in the toothed whales, or at least in the Physeterine series, in another. But his arguments are not irrefutable.

As regards the whalebone whales Abel starts from Kükenthal's investigations. As has long been known from observations by Geoffroy Saint-Hillaire and especially by Eschricht, there is found in embryos of all recent whalebone whales, hidden in each jaw, a long row of small atrophied teeth with conical or knob-shaped crowns, which are resorbed without ever erupting. Frequently some of these small teeth are seen to be mutually united; most often it is two that come together but in rare instances as many as four may unite. A part of his observations on the embryonic teeth of *Balænoptera musculus,* the species which he has had especially good opportunity to investigate, Kükenthal summarizes in the following words: "Die Zahl der Zähne im Oberkiefer des letzteren Embryos (that is, the largest of those examined) ist 53; sie liegen sämmtlich in gleich weiten Abstanden von einander. Bei den kleineren Embryonen beträgt die Zahl der Oberkieferzähne, wenn wir die mit zwei resp.

drei Höckern versehenen Zähne als je einen Zahn rechnen, etwas weniger, und zwar haben alsdann die kleinsten Embryonen die geringste Zahnzahl. Zählen wir jedoch in jedem Oberkiefer die einzelnen Höcker, so erhalten wir gleichzeitig für jeden Kiefer die Zahl 53, dieselbe Zahl, welche wir auch bei dem grössten untersuchten Embryo, der keine Doppelzähne besass, aufgefunden haben. Ich habe aus dieser Thatsache bereits den Schluss gezogen, dass sich im Laufe der individuellen Entwickelung der Bartenwale die Zähne theilen, und dass somit aus den verhältnismässig wenigen, aber mehrhöckerigen Zähnen der jüngsten Stadien viele, aber einspitzige Zähne werden. Aus den ursprünglichen Backzähnen entwickelte sich also durch Theilung derselben ein anscheinend homodontes Gebiss. (Unters. an Walthieren; Denkschr. med. naturw. Ges. Jena, 1893, p. 431). On this Abel builds further. He considers that *Patriocetus* (see pp. 70-72), a Tertiary whale with rather well-developed dentition, with unicuspid incisors and canines, and with serrate margins to the cheekteeth, is an ancestral form of the true whalebone whales—their immediate precursor. In passing to the whalebone whales its teeth would be split up and the marginal cusps would be transformed into independent teeth: "Wie wir gesehen haben, besteht das Gebiss von *Patriocetus ehrlichi* aus sieben zweiwurzligen und siebenspitzigen Backenzähnen, von denen die drei hinteren als Molaren und die vier vorderen als Praemolaren zu deuten sind. Daran schliessen sich vorne ein einspitziger Eckzahn und die drei einspitzigen Schneidezähne an. Im ganzen stehen also 11 Zähne in jedem Kiefer.—Wenn wir die Spitzen der Zähne susammenzählen, so dass wir nicht nur die Kronenspitzen der vier vorderen Zähne, sondern auch die sieben Zacken der sieben zweiwurzligen Backenzähne als Einzelspitzen rechnen, so ergibt sich eine Gesamtsumme von 53 Spitzen, also genau derselben Zahl, die wir bei dem in Einzelzähne aufgelösten Gebiss des Finwalembryos wiederfinden.—Nach diesem Befunde kann es keinem Zweifel mehr unterliegen, dass das Patriocetus-Gebiss mit elf Zahnindividuen und zusammen 53 Schmelzspitzen den Ausgangspunkt des Bartenwalgebisses darstellt und dass die Entstehung des letzteren in der Weise erfolgt, dass die elf Zähne sich im Verlaufe der ontogenetischen Entwicklung in 53 Teile spalten, so dass also schliesslich aus einem siebenspitzigen Backzahn sieben einzelne Spitzen durch Teilung und fortschreitenden Zerfall hervorgehen. (Die Vorfahren der Bartenwale; Denkschr. Akad. Wissensch. Wien, mathem. naturw. Kl., Bd. 90, 1914, pp. 186-187).—Several objections must be raised to Abel's presentation of the subject.

Everyone who has had to do with counting the teeth of cetaceans knows how variable the numbers may be. It is almost a miracle that Kükenthal should have been able to find five or six embryos, or perhaps more, of *Balænoptera musculus,* each of which had 53 teeth or tooth cusps in the upper jaw (see Kükenthal's more special account in Jenaische Zeitschrift für Naturwissenschaft, vol. 26, 1892, p. 481, together with his paper of 1893, *l. c.;* in three other jaws the numbers were less, a circumstance said to be accounted for by the fact that some of the teeth had been resorbed). But even if it should prove that *B. musculus* always had 53 teeth in each jaw of the embryo this fact would be without bearing on the question of the original dentition in the whalebone whales. It will occur to nobody to regard *B. musculus* as one of the most primitive species of the genus; on the contrary it is one of the highest, being one of the largest and most elongated. Other species are found in the genus that stand on a lower level; this holds good especially of *B. rostrata,* and in this species Eschricht has found the number of teeth in two embryos to be respectively $\frac{40}{40}$ ± and $\frac{44}{40}$ (Unders. over Hvaldyrene, pt. 3, 1845, pp. 314 and 316-317). In two embryos of the same species Kükenthal found 41 in the lower jaw (Jen. Zeitschr., 1892, pp. 485-486). In two embryos of one of the highest species of the genus, *B. gigas* (*sibbaldii*) Kükenthal found 50 in the upper jaw (*l. c.,* p. 486). In several embryos of *Megaptera boops* Eschricht has found from 46 to 51 teeth in each side of the upper jaw, and in the lower jaw rather fewer, the least number 42 (*l. c.,* pp. 311 and 316). Abel says, it is true: "Bei jenen Bartenwalen, deren Kiefer eine geringere Zahl als 53 Zahnindividuen aufweisen, handelt es sich entweder um fruhere Embryonalstadien, wie bei dem von C. Julin beschriebenen Embryo von Balænoptera rostrata von etwa 48 cm. Lange (41 Zähne), oder um Reduktionserscheinungen" (*l. c.,* p. 188); but this assumption is entirely inadmissible. Abel himself probably had an inkling of it; he adds: "In dieser Frage müssten noch eingehendere Untersuchungen auf breiterer Grundlage angestellt werden, um unsere bisherigen Kenntnisse in dieser Richtung zu erweitern."

Neither can all of what Abel says about the number of teeth or cusps in *Patriocetus* stand before a closer examination. It is not certain that *Patriocetus* had 11 teeth in each jaw; none of the skulls that have been found has entire jaws, the anterior part is lacking in them all. The number 11 is therefore only a guess, and scarcely very likely; judging from the rest of the cranial characters one would expect a departure from the typical dentition—more teeth. Of the cheekteeth there are only known a few that are tolerably complete; that every one of them had seven marginal cusps is mere conjecture and not probable; in other cetacea with serrate teeth, both Zeuglodonts and Squalodonts, the number of cusps varies strongly; no cetacean is known in which the same number of cusps is found on all the cheekteeth. Some dissociated teeth that probably are correctly referred to *Patriocetus* (*Squalodon ehrlichii*), figured by Suess (Neue Reste von Squalodon aus Linz; Jahrb. d. k. k. geol. Reichsanstalt, vol. 18, 1868, pp. 287-290, pl. 10, figs. 1-3) and reproduced by Brandt (Unters. foss. u. subfoss. Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, No. 1, 1873, pl. 31, figs. 11-13), also show other numbers, one of them 9, another 10. Moreover it is doubtful whether *Patriocetus* can be regarded as an ancestor of the whalebone whales; it is not precluded that with more exact acquaintance it will show itself to stand on a higher level, nearer to the typical Squalodonts, closely connected with *Agorophius* (see note, p. 72). In short the whole calculation about the 53 teeth in the whalebone whales and the 53-tooth cusps in *Patriocetus* rests on the weakest foundation.

It is also a question whether Kükenthal and Abel are on the whole right in their conception of the many small teeth of the whalebone whales as having originated by the division of fewer, larger, serrate teeth. There is indeed scarcely any doubt that a division of the tooth germ might be able to take place at an early stage of a tooth's development; but that a tooth which had already acquired serrate margins should be able to divide is not probable; in the case of the whalebone whales at any rate there is nothing convincing in this respect—quite the contrary; and other cases are not known. The " double-teeth " of the embryo whalebone whales are the ones that are conceived to be serrate teeth in course of division; but they could be better explained in another manner. Their position in the toothrow is quite erratic—sometimes far to the front, sometimes in the middle or far back. The number of cusps is most often two, only in rare instances as many as four. The cusps have the appearance of being of equal rank, none can be called the chief cusp. In short, the cusps in the double teeth appear to be small, atrophied, unicuspid teeth which have quite casually come near each other and grown together, something which might be able to take place with special ease in the youngest stages of the embryo when the tooth germs are crowded together in relatively short jaws. That double teeth were produced by the fusion of single teeth was already supposed by Eschricht (*l. c.,* p. 312). Should it be the case that there has taken place in the whalebone whales a splitting up of serrate teeth, the corresponding ancestral forms must probably have had teeth in which the cusps on the fore and hind margins of the crown had great independence and a size very nearly the same as in the principal cusp. In that event it would not be easy to regard *Patriocetus* as an ancestor; since in it the cusps on the fore and hind margins particularly are weak in proportion to the main cusp, and apparently in course of atrophy.

Abel gives the following as his conception of the manner in which the many small teeth of the Odontoceti, or at least of the Physeterids, have arisen: "Dieser Spezialisationsweg des Gebisses (in the whalebone whales) ist fundamental von jenem verschieden, den wir in der Phylogenese des Physeteridengebisses finden. Wie ich 1905 gezeigt habe, tritt auf dem Wege zur Entstehung der Squalodontiden zunächst eine starke Vermehrung der mehrwurzeligen, vorn und hinten gezackten Backenzähne ein, so dass sich das primitive Archaeocetengebiss durch Vermehrung der Backenzähne im Prämolarenabschnitt zu dem polyodonten Squalodontidengebiss umformt. Aus den Squalodontiden sind die Physeteriden hervorgegangen, bei welchen das Gebiss eine Reduktion erfährt; dieser Spezialisationsweg führt aber zu einer Vereinfachung der Krone, Verschmelzung der bifiden Wurzeln, Reduktion der Zackenreihen am Vorder- und Hinterrande der Kronen zu einer krenelierten Leiste und endlich zum ganzlichen Verlust der Schmelzkappen" (*l. c.,* p. 187). Here Abel is no doubt right in the main. It can only be objected that it cannot exactly be said that Abel in his more special account (Die phylogenetische Entwicklung des Cetaceengebisses und die systematische Stellung der Physeteriden; Verhandl. Deutsch. Zool. Gesellsch., 1905, pp. 84-96, and Les Odontocètes du Boldérien; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 3, 1905) has demonstrated that it is precisely in the premolar region that the number of teeth has been increased in the Squalodonts; neither is it probable that the Physeterids originated directly from the Squalodonts. They appear to have branched off at a higher level; probably they had their root in common with the Delphinids.

There is no reason at the present stage for believing that the increase in the number of teeth beyond the typical formula should have had a different origin in the Mystacoceti and Odontoceti. In view of the great resemblances that are everywhere found between the two groups it is not likely that in this respect there would be a difference. The method by which the increase has come about in the Odontoceti no doubt holds good for the Mystacoceti as well; the most primitive forms of probably both groups had serrate teeth in augmented numbers.

[8] (P. 10.) It has become usual to believe that the precursors of the cetaceans were armored mammals with well-developed osseous dermal plates. Heated support for this idea is brought forward by Kükenthal (especially in the section "Ueber Rudimente eines Hautpanzers bei Zahnwalen," in Vergl. -anat. u. entwickelungsgesch. Unters. an Walthieren, part 2, Denkschr. d. med. naturw. Ges. zu Jena, vol. 3, pt. 2, pp. 251-258, pl. 16) and by Abel (especially in the section "L'armure dermique," in Les Dauphins Longirostres du Boldérien, Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 1, 1901, pp. 17-32, with illustrations). Kükenthal has investigated recent cetaceans; Abel more particularly the extinct forms. (In Abel is found reference to previous literature on the subject.) Kükenthal imagines that the Cetacea originated from armored land-mammals with armor suggesting that of the Dasypodids, and that as sea dwellers they have lost the armor more or less completely; Abel thinks, in agreement with Dollo, that the armature did not occur in the terrestrial precursors of the cetaceans, but that it arose in the first whales as part of their adaptation to aquatic life along the coast, and that afterwards it was lost in the more strictly marine members of the group.

What we have to build upon is the following:

Together with the first lot of *Zeuglodon* bones found in Alabama came a few pieces of limestone containing some plate-like, very irregular bones of various sizes. Accounts of these bones are due especially to Joh. Müller (Ueber die fossilen Reste der Zeuglodonten von Nordamerica, 1849, p. 34, pl. 27, fig. 7), Carus (Das Kopfskelet des Zeuglodon hydrarchus; Nova Acta Acad. Caes. Leop. Carol., vol. 22, pt. 2, 1850, pp. 382-383, pl. 39A, fig. 5), Dames und Jaekel (section Ueber den Hautpanzer der Zeuglodonten, in Dames, Ueber Zeuglodonten aus Aegypten, Palaeontol. Abhandl., herausgeg. v. Dames u. Kayser, vol. 5, pt. 5, 1894, pp. 219-221, with illustration) and Abel (1901, *l. c.*, pp. 24-27). From the beginning the possibility has been thought of that the plates were dermal bones of *Zeuglodon*. They have, however, most often been regarded as doubtful; perhaps they were bones from the carapace of a sea turtle like *Psephophorus* or something of the sort; usually no one has dared to say anything positive. Abel was the first to consider it as proved that they were dermal bones of *Zeuglodon;* of one of the specimens in question he thinks that it can be nothing else than a piece of armor from the fore angle of a dorsal fin, because the plates are bent toward each other like a roof, in a manner and form that is not possible on any part of a turtle's carapace. As a not unessential ground for believing in the occurrence of armor in *Zeuglodon* he reckons the occurrence in the recent Delphinids *Neomeris* and *Phocæna* of structures which Kükenthal explains as remnants of armor.

At Radoboj in Croatia some remains have been found of a small dolphin-like cetacean, *Delphinopsis freyerii,* established and described by Joh. Müller (Bericht über ein neu entdecktes Cetaceum aus Radoboy, Delphinopsis Freyerii; Sitzungsber. k. Akad. Wissensch. Wien, math. naturwiss. Cl., vol. 10, 1853, pp. 1-6 of separate), and again fully discussed and figured by H. v. Meyer (Delphinopsis Freyerii Müll. aus dem Tertiär-Gebilde von Radoboj in Croatien; Palaeontographica, vol. 11, 1863, pp. 226-231, pl. 34) whose illustration is reproduced by Abel (*l. c.*), who also has personally examined the remains. It was only imperfect remains that were found, not much more than pieces of a flipper lying in a slab of stone; around the bones of the hand lie numerous small disk-shaped bodies a millimeter or less in diameter, the underside of which is covered with minute projecting granules arranged in parallel lines. Joh. Müller seems to have left undecided the question whether these bodies were of organic or inorganic origin, although he leaned mostly to the opinion that they were osseous scales from the skin. But H. v. Meyer maintained that they were inorganic. His reason for this opinion was especially that scattered among them there lie bodies of entirely similar appearance only without markings, and these bodies are undoubtedly inorganic. Abel on the contrary is convinced that the small, striated disks are dermal ossicles.

In *Neomeris,* which lacks or as good as lacks the dorsal fin, the skin of the back in the place where the fin is found in its relatives, and also somewhat further forward and backward, is divided into small, rather regularly placed plates, each bearing a small elevation. Similar small knobs are found, though not always, in the nearly related genus *Phocæna,* along the anterior surface of the dorsal fin and sometimes also scattered in other regions. Kükenthal, who has closely examined these structures, thinks that they are a kind of scale, although they have in their intimate formation only to a slight degree the characters that are found in scales. The explanation given is that they are scales which are in process of atrophy—on the way to disappearing. A concurrent reason to regard them as scales is that traces of a scaly covering are found in some extinct whales, *Zeuglodon* and *Delphinopsis*.

But to Kükenthal's and Abel's conception there is something to oppose.

It has been shown that the Hyænodonts, the most primitive carnivores, are the precursors of the Cetacea among terrestrial mammals. Remains of Hyænodonts are found in great numbers in many localities; but there has never been discovered the slightest indication that any Hyænodont or any other carnivore has been armored. Remains of Zeuglodonts are found in various parts of the world, but nowhere except in the case of the specimens from Alabama have dermal ossicles been demonstrated in connection with the skeletons. If there had been a dermal armature it certainly would have been found somewhere or other. Besides, it cannot be said to be proved that the plates from Alabama are not those of some kind of turtle. Anyone who has seen the roof-shaped keel on a *Psephophorus* carapace, and has seen the fragments of the carapace mixed up together, will not allow himself to be persuaded by Abel's word in this connection. Finally it is improbable that *Zeuglodon* had a dorsal fin, since this fin may be absent (probably not-developed rather than lost) in diverse recent cetaceans, both Balænids and Delphinids.

The minute plates in *Delphinopsis* are altogether too uncertain to give any evidence. Their characters are, besides, so far from recalling what is otherwise known of dermal bones that one is tempted rather to regard as an error their determination as such structures.

The small callosities in the skin of *Neomeris* and *Phocæna* are scarcely the remains of a dermal armature, they are rather entirely new structures. It is too suspicious that nothing of the sort should be present in lower Cetacea, but that it should be in exactly some of the very highest that it is found. The structure of the callosities, moreover, gives no real support to the idea that they are scales.

Altogether there is no proof that the Cetacea or their ancestors among the mammals ever have had dermal armature.

[9] (P. 10.) For comparison a few of the most important and most independent synopses of the groups of Cetacea are here given.

A fundamental work in the direction of throwing light on the mutual relationships of the Cetacea is due to Flower, who, however, took into consideration the recent forms only. In 1866 (69), in his paper on *Inia* and *Pontoporia* (Trans. Zool. Soc. London, vol. 6, p. 115), he gave the following synopsis:

Cetacea.

- I. *Mystacoceti* or *Balænoidea.*
  - *Balænidæ.*
    - Balæninæ: Balæna, Eubalæna.
  - *Balænopteridæ.*
    - Megapterinæ: Megaptera.
    - Balænopterinæ: Physalus, Sibbaldius, Balænoptera.
- II. *Odontoceti* or *Delphinoidea.*
  - *Physeteridæ.*
    - Physeterinæ: Physeter, Kogia.
    - Ziphiinæ: Hyperoodon, Berardius, Ziphius, Dioplodon, Micropteron.
  - *Platanistidæ.*
    - Platanistinæ: Platanista.
    - Iniinæ: Pontoporia?, Inia.
  - *Delphinidæ.*
    - Beluginæ: Monodon, Beluga (=Delphinapterus).
    - Delphininæ?: Phocæna, Neomeris, Grampus, Orca, Pseudorca, Lagenorhynchus, Delphinus, Delphinapterus (=Tursio), Globicephalus.

His conception of the relations between the genera in the family *Delphinidæ* Flower developed more fully in 1883 (Proc. Zool. Soc. London). His arrangement there was as follows:

- A.
  - a. Monodon, Delphinapterus (Beluga).
  - b.
    - α. Phocæna, Neomeris.
    - β. Cephalorhynchus, Orcella, Orca, Pseudorca, Globiceps, Grampus, Feresia, Lagenorhynchus.
- B.
  - a.
    - α. Delphinus.
    - β. Tursiops, Clymenia, Steno.
  - b. Sotalia.

Flower followed essentially the same arrangement as that of 1866 and '83, but with greater clearness as to the genera, in 1891, in "An Introduction to the Study of Mammals Living and Extinct" which be published in association with Lydekker. The arrangement is as follows:

Cetacea.

Mystacoceti, Balænoidea.

Balænidæ: Balæna, Neobalæna, Rhachianectes, Megaptera, Balænoptera. Extinct Genera: Cetotherium, Herpetocetus.

Archæoceti.

Zeuglodontidæ: Zeuglodon.

Odontoceti, Delphinoidea.

Physeteridæ.

Physeterinæ: Physeter, Cogia. Extinct: Physeterula, Eucetus, Physetodon, Scaldicetus, Physodon, Hoplocetus.

Ziphiinæ: Hyperoodon, Ziphius, Mesoplodon, Berardius. Extinct: Choneziphius.

Squalodontidæ: Squalodon.

Platanistidæ: Platanista, Inia, Pontoporia. Extinct: Palæopontoporia (Pontistes), Champsodelphis, Schizodelphis, Priscodelphinus, Lophocetus, Ixacanthus, Rhabdosteus, Agabelus.

Delphinidæ.

Group A. Monodon, Delphinapterus, Phocæna, Neomeris, Cephalorhynchus, Orcella, Orca, Pseudorca, Globicephalus, Grampus, Feresia, Lagenorhynchus.

Group B. Delphinus, Tursiops, Prodelphinus, Steno, Sotalia.

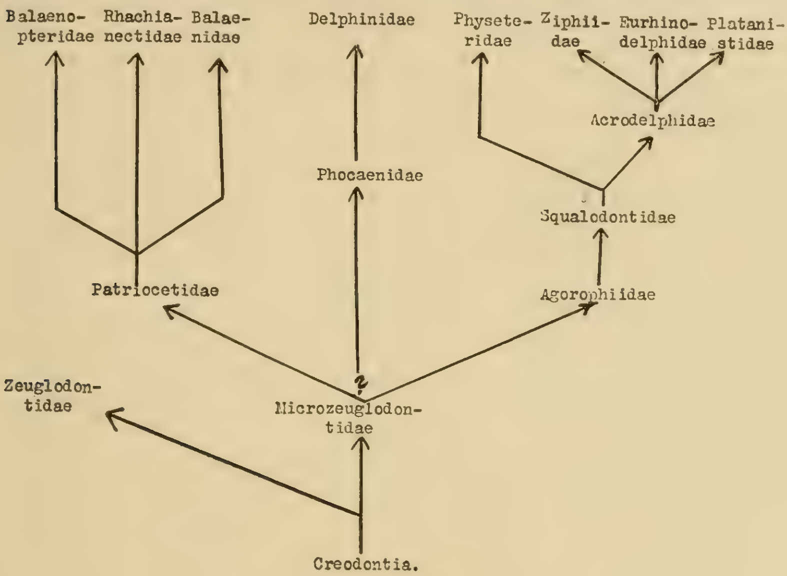
Max Weber (Die Säugethiere, 1904) agrees closely with the conception of Flower and Lydekker. One of the greatest differences is that a special family, *Rhachianectidæ* is established for *Rhachionectes* and also a family *Delphinapteridæ* for *Delphinapterus* and *Monodon.*

Abel has made special researches on the fossil Cetacea, and he has tried to determine their positions in relation to the recent forms. Besides what he has said on the subject in his special monographs, he has more or less completely set forth his ideas in the papers: Die Stammesgeschichte der Meeressäugetiere; Meereskunde, Sammlung volkstümlicher Vorträge, 1907; Grundzüge der Palaentologie der Wirbeltiere, 1912; and Die vorzeitlichen Säugetiere, 1914. He has not given any general synopsis except in the following genealogical tree, published in his work Die Vorfahren der Bartenwale, 1914

(Denkschr. k. Akad. Wissensch. Wien, math. -naturw. Kl., vol. 90, p. 221):

Die Stämme der Wale.

I. Mystacoceti (auct.) (Blütezeit im Pliocän.)
II. Delphinoceti (nov.) (Blütezeit in der Gegenwart.)
III. Squaloceti (nov.) (Blütezeit im Miocän.)



(To the *Acrodelphidæ* are referred, among the living genera, *Delphinapterus* and *Monodon*, *Inia* and *Pontoporia*.)

True's paper On the Classification of the Cetacea (Proc. Amer. Philos. Soc., Philadelphia, vol. 47, 1908, pp. 384-391) is mostly an account of the opinions which Abel had expressed in 1905, with some objections and some assent.

To cetaceans both recent and fossil have been given various generic names in addition to those which appear in the present article. These names are partly well known as synonyms of others; but partly the corresponding animals are so slightly known that no certain opinion can be had about them. References to all the names theretofore used for cetaceans are found in Trouessart, Catalogus Mammalium tam viventium quam fossilium, 1897-99, with supplement, 1904-5, and in Palmer, Index Generum Mammalium, 1904; many names are also to be found in Beddard, A Book of Whales, 1900; detailed references to the North American fossil genera are due to Hay, Bibliogr. and Catal. of the fossil Vertebrata of North America, Bull. U. S. Geol.

Surv., No. 179, 1902. Incorrectly formed names which cannot be accepted as finally settled are, in the present treatise, marked with " ".

[10] (P. 13.) The backbones of the Egyptian *"Zeuglodon" osiris* with its short vertebræ (especially Stromer, Beitr. Paläontol. u. Geol. Oesterreich-Ungarns, etc., vol. 21, 1908, pl. 4, fig. 1), and those of the American *Z. cetoides* with its long vertebræ (especially Gidley, Proc. U. S. Nat. Mus., vol. 44, 1913, p. 81) differ to such a degree that according to ordinary standards the placing of these animals in the same genus, as has hitherto been done, is certainly out of the question. *Z. cetoides* is the type of the genus *Zeuglodon*. By accident no special name has been proposed that can with full right be used for the genus to which *"Zeuglodon" osiris* belongs. But the name *Prozeuglodon* seems to have become vacant and may therefore with some propriety be used. It was proposed by Andrews (especially Tert. Vertebr. of the Fayûm, Egypt, 1906) for a lot of Eocene cetacean remains from Egypt which he united under the name *P. atrox*. But according to Stromer, the type of the species, a skull, and some of the other remains belong to the previously described *Zeuglodon isis,* which is probably correctly called *Zeuglodon,* while still others are referable to *"Z." osiris*. In a way therefore *"Z." osiris* has also been called *Prozeuglodon*. Possibly the name *Doryodon* (*"Dorudon"*) might be used for the genus in question with short vertebræ, or, if there are several genera with short vertebræ, for one of them (see, among others, Leidy, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 7, 1869, pp. 428, 431, and Lucas, Proc. U. S. Nat. Mus., vol. 23, 1900, p. 331). But *Doryodon* is still not sufficiently known, not even after True (Bull. Mus. Comp. Zool., vol. 52, 1908, pp. 65-78, pls. 1-3) has examined the fragments on which Gibbes founded the genus; the remains in question are altogether too incomplete. For the American *"Zeuglodon brachyspondylus minor"* Joh. Müller and Stromer, also with short vertebræ, which True compares with *Doryodon* and finds different, True (*l. c.*) proposes to erect a new genus, *Zygorhiza;* but the relationship between it and *"Zeuglodon" osiris* is not at all clear.

[11] (P. 15.) The pelvis and femur of *Zeuglodon cetoides* are described and figured by Lucas (Proc. U. S. Nat. Mus., vol. 23, 1900, pp. 327-331, pls. 5-7). Both right and left innominates were found associated with a backbone lying in the position relative to the vertebræ in which one would expect to find them. In spite of this circumstance Abel explained the bones in question as the coracoid of

a gigantic bird which he called "*Alabamornis*" *gigantea* (Ueber den als Beckengürtel von Zeuglodon beschriebenen Schultergürtel eines Vogels aus dem Eocän von Alabama, Centralblatt für Mineralogie, Geologie und Paläontologie, 1906, pp. 450-458, with illustrations). Stromer (Beitr. z. Paläont. u. Geol. Oesterreich-Ungarns, etc., vol. 21, 1908, p. 146) has expressed doubts as to the correctness of Abel's interpretation, and Gidley (Proc. U. S. Nat. Mus., vol. 44, 1913, pp. 649-654, with illustrations) who has re-examined the specimens, has entirely thrown it over. It can hardly be doubted that Lucas and Gidley are correct.

[12] (P. 15.) On the Zeuglodontidæ [Basilosauridæ] see especially:

Joh. Müller: Ueber die fossilen Reste der Zeuglodonten von Nordamerica mit Rücksicht auf die europäischen Reste aus dieser Familie, 1849, pp. 1-38, pls. 1-27.

Carus: Das Kopfskelet des Zeuglodon hydrarchus; Nova Acta Acad. Cæs. Leop. Carol., vol. 22, pt. 2, 1850, pp. 373-390, pls. 39A & B.

Brandt: Untersuchungen über die fossilen und subfossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, No. 1, 1873, pp. 291-313, 334-340, pl. 34. *Zeuglodon.*

Hector: Notes on New Zealand Cetacea, recent and fossil; Trans. and Proc. New Zealand Inst., 1880, vol. 13, 1881, pp. 434-436, pl. 18. "*Kekenodon.*"

Lydekker: On Zeuglodont and other Cetacean Remains from the Tertiary of the Caucasus; Proc. Zool. Soc. London, 1892, pp. 558-561, pl. 36. *Zeuglodon*=in part *Microzeuglodon.*

Dames: Ueber Zeuglodonten aus Aegypten und die Beziehungen der Archæoceten zu den übrigen Cetaceen; Palaeontologische Abhandlungen, herausgeg. von Dames und Kayser, vol. 5, pt. 5, 1894, pp. 1-36, pls. 1-7.

Lucas: The Pelvic Girdle of Zeuglodon, Basilosaurus cetoides (Owen), with notes on other portions of the skeleton; Proc. U. S. Nat. Mus., vol. 23, 1900, pp. 327-331, pls. 5-7.

Abel: Les Dauphins Longirostres du Boldérien des Environs d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 1, 1901, pp. 8-9, 24-32. On the dentition and dermal armature in *Zeuglodon.*

Stromer: Zeuglodon-Reste aus dem oberen Mitteleocän des Fajûm; Beiträge zur Paläontologie und Geologie Oesterreich-Ungarns und des Orients, vol. 15, pts. 2 and 3, 1903, pp. 65-100, pls. 8-11. *Zeuglodon*=in part *Prozeuglodon.*

E. Fraas: Neue Zeuglodonten aus dem unteren Mitteleocän von Mokattam bei Cairo; Geologische und Palæontologische Abhandlungen, herausgeg. von Koken, vol. 10, pt. 3, 1904, pp. 199-220, pls. 10-12. *Protocetus* and *Mesocetus*, later called *Eocetus*.

Abel: Les Odontocètes du Boldérien d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 3, 1905, pp. 21-25. On the dentition in the Zeuglodonts.

Andrews: A descriptive Catalogue of the Tertiary Vertebrata of the Fayûm, Egypt, 1906, pp. 235-357, pls. 20-21. *Zeuglodon, Prozeuglodon.*

Stromer: Die Urwale (Archaeoceti); Anatomischer Anzeiger, vol. 33, 1908, pp. 81-88, pl. 1. A short synopsis of the most important part of the contents of the next paper. In the explanation of plates the name *Zeuglodon* (*Dorudon*) *osiris* is used; in the succeeding paper this use of "*Dorudon*" is abandoned.

Stromer: Die Archaeoceti des Aegyptischen Eozäns; Beitr. Paläontol. u. Geol. Oesterreich-Ungarns u. des Orients, vol. 21, 1908, pp. 106-178, pls. 4-7. *Protocetus, Eocetus, Zeuglodon, Prozeuglodon.*

True: The fossil Cetacean, Dorudon serratus Gibbes; Bull. Mus. Comp. Zool., vol. 52, 1908, pp. 65-78, pls. 1-3. *Dorudon* (=*Doryodon*) and *Zygorhiza*.

Gidley: A recently mounted Zeuglodon skeleton in the United States National Museum; Proc. U. S. Nat. Mus., vol. 44, 1913, pp. 649-654, pls. 81, 82 and text figures.

Kekenodon was established by Hector (1881, *l. c.*) on remains from Eocene strata in New Zealand. That which has been found is not much else than a lot of loose teeth which show strong similarity to *Zeuglodon;* but it is impossible to get any certain idea of the exact generic relationships. Hall (Proc. Roy. Soc. Victoria, n. s., vol. 23, pt. 2, 1911, p. 262) refers it to the *Squalodontidae* but gives no reasons.

Microzeuglodon was established by Stromer (Beitr. Paläont. u. Geol. Oesterreich-Ungarns, vol. 15, 1903, p. 89) and accepted by Abel (Odontocètes du Boldérien, 1905, p. 35). The basis of the genus is Lydekker's *Zeuglodon caucasicus* (Proc. Zool. Soc. London, 1892, pp. 559-561, pl. 36), based on a few remains, not certainly belonging together, found in Tertiary strata in the Caucasus: a small piece of a lower jaw with four cheekteeth, only two of which are tolerably complete, a humerus and a caudal vertebra. The teeth are serrate on both fore and hind margins of the crown. Abel referred it at first to the Squalodonts, later he put it in a separate family. It plays an important part in Abel's studies of cetacean descent, whether rightly or not time will perhaps tell; meanwhile the genus is altogether too slightly known for anything positive to be built on it.

Eocetus described by Fraas (first called *Mesocetus* Fraas, not of Van Beneden, not of Moreno) is thought to be a connecting link between *Protocetus* and *Zeuglodon,* with long vertebræ. The remains are still too uncertain for judgment to be passed.

[13] (P. 19.) Kükenthal (Vergl. -anat., etc., Unters. an Walthieren; Denkschr. medic. -naturw. Ges. Jena, vol. 3, pt. 2, 1893, p. 291) thinks that the bone in the hand of *Balæna mysticetus,* which is ordinarily regarded as a remnant of the first finger, a first metacarpal, is not that, but a finger before the first finger, a *præpollex,* in spite of the fact that the same bone in *Balæna australis* (as can also be seen in two skeletons in Copenhagen) may bear two well-developed phalanges, something that is not elsewhere seen in any "*præpollex.*" As to the longest finger, which is usually reckoned as the third, he believes that it is not the third but the second, and that the third is absent. The reason for this remarkable interpretation is probably a desire to find agreement with *Balænoptera,* in which he thinks he has proved that the third finger is the one which is absent, and not the first as is generally supposed. If the first finger were present in *Balæna* in a more or less atrophied condition, it would be reasonable to suppose that it was this finger which is absent in the nearly related *Balænoptera,* which has only four digits; but that belief Kükenthal will not allow. Occasionally he has found in *Balænoptera musculus* something resembling a few atrophied phalanges lying loose in the palm between the fingers that are usually called the third and fourth. These structures Kükenthal regards as remnants of the third finger and thus to be proof that it is the third finger which is absent in the tetradactylous hand. Protest against Kükenthal's interpretation has already been made by Braun and Kunze (see Kunze, Zool. Jahrb., Abth. f. Anat., etc., vol. 32, 1912, pp. 639-641). There can be no doubt that there is here a case of malformation, a supernumerary digit, a kind of doubling of one of the fingers. Tendencies in this direction are indeed not rare in cetaceans, which on the whole show great indifference as to details in the structure of their abnormal hand.

[14] (P. 21.) On the Balænidæ see especially (Of the numerous works that deal with cetaceans there are many others that might have a claim to be mentioned. The choice that has been made here and in the corresponding lists for other families is somewhat arbitrary.

Most attention has been paid to indicating papers that describe the various forms of cetaceans, and especially to those which contain illustrations of the fossil members of the order.):

Cuvier: Recherches sur les Ossemens fossiles, ed. 4, vol. 8, pt. 2. 1836, pp. 250-321, pls. 226-228, with figures of skulls and other skeletal parts of *Balæna, Balænoptera, Megaptera, Plesiocetus,* mostly under other names.

Eschricht: Undersøgelser over Hvaldyrene, 2 den Afhandl., Anatomisk Beskr. af de ydre Fosterformer hos to nordiske Finhval-Arter; Kgl. Danske Vidensk. Selsk. naturv. mathem. Afhandl., pt. 11, 1845, pp. 203-279. 3 dje Afhandl., Om Fosterformerne i Bardehvalernes Ernærings- og Forplantelsesredskaber; *ibid.,* pp. 281-320, pls. 1-4. 5 te Afhandl., Finhvalernes Oesteologi og Artsadskillelse; *ibid.,* pt. 12, 1846, pp. 225-396, pls. 4-16. *Balænoptera, Megaptera.* Figures of skulls and other skeletal parts, of embryos and adults, of external and other characters.

Eschricht and Reinhardt: Om Nordhvalen (*Balæna mysticetus* L.); Kgl. Danske Vidensk. Selsk. Skrifter, ser. 5, naturv. mathem. Afd., vol. 5, 1861, pp. 433-592, pls. 1-6. Figures of the exterior, the entire skeleton, the skull of adult and young and other parts of *Balæna,* of the skull of *Balænoptera* and *Megaptera.*

Malm: Monographie illustrée du Baleinoptère trouvé le 29 Octobre 1865 sur la côte occidentale de Suède, 1867, pp. 1-110, pls. 1-20, with figures of the exterior, some skeletal parts and other features of *Balænoptera carolinæ=B. gigas, sibbaldii.*

Eschricht: Ni Tavler til Oplysning af Hvaldyrenes Bygning, med Forklaring af Reinhardt; Kgl. Danske Vidensk. Selsk. Skrifter, ser. 5, naturv. mathem. Afd., vol. 9, 1, 1869. On plates 1 and 2 are found figures of the skull of embryo *Balæna japonica=B. australis.*

Van Beneden and Gervais: Ostéographie des Cétacés vivants et fossiles, text and plates, 1868-80, pp. 1-634, pls. 1-67. As regards illustrations, with respect to both recent and extinct Cetacea, the most sumptuous work that exists. Balænids especially pp. 29-291, pls. 1-17.

Dwight: Description of the Whale (*Balænoptera musculus* Auct.) in the possession of the Society, with remarks on the classification of Fin Whales; Mem. Boston Soc. Nat. Hist., vol. 2, 1871-78, pp. 203-230, pls. 6-7. Exterior and skeleton.

Brandt: Untersuchungen über die fossilen und subfossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, no. 1, 1873, pp. 1-372, pls. 1-34. Contains a section, pp. 18-202, on the then-known fossil Balænids, among them *Cetotherium* and *Plesiocetus*. On *Patriocetus,* see under *Squalodontidæ.*

Brandt: Ergänzungen zu den fossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 21, No. 6, 1874, pp. 1-54, pls. 1-5. Contains a section on the whalebone whales, pp. 2-12, pl. 1.

Capellini: Della Balena di Taranto confrontata con quella della Nuova Zelanda e con talune fossili del Belgio e della Toscana; Memorie dell'Accademia delle Scienze dell'Instituto di Bologna, ser. 3, vol. 7, 1877, pp. 1-34, pls. 1-3, with illustrations of exterior, skull, ear bones, nasal, cervical vertebræ, other skeletal parts, etc. *Balæna tarentina=B. australis.*

Gasco: Intorno alla Balena presa in Taranto nel Febbrajo 1877; Atti della Reale Accademia delle Scienze Fisiche e Matematische, Napoli, vol. 7, 1878, pp. 1-47, pls. 1-9, with figures of exterior, skull, other skeletal parts, etc. *Balæna biscayensis=B. australis.*

Gasco: La Balæna Macleayius del Museo di Parigi; Annali del Museo Civico di Storia Naturale di Genova, vol. 14, 1879, pp. 509-551. *Balæna australis.* Description of skeleton.

Gasco: Il Balenotto catturato nel 1854 a San Sebastiano (Spagna), Balaena biscayensis, Eschricht, per la prima volta descritto; Annali del Museo Civico di Storia Naturale di Genova, vol. 14, 1879, pp. 573-608. Description of skeleton.

Van Beneden: Description des Ossements fossiles des environs d'Anvers, 2 partie, Genres Balænula, Balæna et Balænotus; Annales du Musée Royal d'Hist. Nat. de Belgique, série paleontol., vol. 4, Text, 1880, pp. 1-83, Atlas, 1878, pls. 1-39. 3 partie, Genres Megaptera, Balænoptera, Burtinopsis et Erpetocetus, *ibid.,* vol. 8, 1882, Text, pp. 1-90, Atlas, pls. 1-109. 4 partie, Genre Plesiocetus; *ibid.,* vol. 9, 1885, Text, pp. 1-40, Atlas, pls. 1-30. 5 partie, Genres Amphicetus, Heterocetus, Mesocetus, Idiocetus et Isocetus; *ibid.,* vol. 13, 1886, Text, pp. 1-139, Atlas, pls. 1-75.

Burmeister: Atlas de la Description Physique de la République Argentine, sec. 2, mammif., pt. 1, Die Bartenwale der Argentinischen Küsten, 1881, pp. 3-40, pls. 1-7. Mostly on *Balænoptera.* Figures of exterior, skull, vertebral column and other skeletal parts.

Struthers: On the bones, articulations and muscles of the rudimentary hind-limb of the Greenland Right-Whale, Balæna mysticetus; Journal of Anatomy and Physiology, vol. 15, 1881, pp. 141-176, pls. 14-17; *ibid.*, pp. 301-321.

[Holder: The Atlantic Right Whales: A Contribution; Bull. Amer. Mus. Nat. Hist., vol. 1, No. 4, pp. 99-137, pls. 10-13. May 1, 1883. External characters and skeleton.]

Malm: Skelettdelar af Hval insamlade under Expeditionen med Vega 1878-1880; Bihang till K. Svenska Vet. Akad. Handlingar, vol. 8, No. 4, 1883, section pp. 17-98, with figures of parts of skulls, etc., of *Rhachionectes* and *Balæna*.

Tullberg: Bau und Entwicklung der Barten bei Balænoptera Sibbaldii; Nova Acta Reg. Soc. Sci. Upsal., ser. 3, 1883, pp. 1-36, pls. 1-7.

Delage: Histoire du Balænoptera musculus échoué sur la plage de Langrune; Archives de Zoologie expérimentale et générale, ser. 2, vol. 3 *bis*, 1885, pp. 1-152, pls. 1-21. Exterior and anatomy.

H. P. Gervais: Sur une nouvelle espèce de Mégaptère (Megaptera indica) provenant du Golfe Persique; Nouvelles Archives du Muséum d'Hist. Nat. de Paris, ser. 2, vol. 2, 1887-88, pp. 199-218, pls. 18-20. Figures of skeleton and skull.

Struthers: Memoir on the anatomy of the Humpback-Whale, Megaptera longimana; Reprint from the Journal of Anatomy and Physiology, 1887-89, pp. 1-189, pls. 1-6.

Graells: Las Ballenas en las costas oceánicas de España; Mem. Real Acad. Cien., Madrid, vol. 13, pt. 3, 1889, pp. 1-115, pls. 1-9. Deals mostly with *Balæna biscayensis* (=*B. australis*) from San Sebastian. Figures of exterior, skull, skeleton.

Rios Rial: La Ballena Euskara, 1890, pp. 1-105. *Balæna australis*, mostly on skeletons from San Sebastian.

Lydekker: Cetacean skulls from Patagonia; Anales del Museo de La Plata, Paleontologia Argentina, vol. 2, 1893, pp. 2-4, pl. I. *Cetotherium*.

Struthers: On the rudimentary hind-limb of a Great Fin-Whale, Balænoptera musculus, in comparison with those of the Humpback-whale and the Greenland Right-Whale; Journal of Anatomy and Physiology, vol. 27, 1893, pp. 291-335, pls. 17-20.

Struthers: On the carpus of the Greenland Right-Whale, Balæna mysticetus, and of Fin-Whales; Journal of Anatomy and Physiology, vol. 29, 1895, pp. 145-187, pls. 2-4.

Beddard: Contrib. towards a knowledge of the osteology of the Pigmy Whale (Neobalæna marginata); Transact. Zool. Soc. London, vol. 16, pt. 2, No. 1, 1901, pp. 87-114, pls. 7-9.

Racovitza: Cétacés; Expédition Antarctique Belge; Résultats du Voyage du S. Y. Belgica en 1897-99, Rapports Scientifiques, Zoologie, 1903, pp. 1-142, pls. 1-4. Contains much information on the external characters and the habits of cetaceans, especially whalebone whales, and gives numerous references to earlier papers on the subject.

True: The whalebone whales of the Western North Atlantic compared with those occurring in European Waters with some observations on the species of the North Pacific; Smithsonian Contributions to Knowledge, vol. 33, 1904, pp. 1-332, pls. 1-50. Deals with species of the genera *Balæna, Rhachionectes, Balænoptera, Megaptera.* Numerous illustrations, especially of skulls and exterior. Copious references to earlier works on the subject.

Turner: The Right-Whale of the North Atlantic, Balæna biscayensis: its skeleton described and compared with that of the Greenland Right-Whale; Transact. Roy. Soc. Edinburgh, vol. 48, 1913, pp. 889-922, pls. 1-3, with text figures.

Abel: Die Vorfahren der Bartenwale; Denkschriften der k. Akad. der Wissensch. Wien, Mathem. naturw. Kl., vol. 90, 1914, pp. 155-224, pls. 1-12. *Patriocetus, Agriocetus.* Review of the origin of the whalebone whales.

Roy C. Andrews: Monographs of the Pacific Cetacea, I, The California Gray Whale (Rhachianectes glaucus); Mem. Amer. Mus. Nat. Hist., n. s., vol. 1, pt. 5, 1914, pp. 227-287, pls. 19-28, with figures of the exterior and of all parts of the skeleton.

Roy C. Andrews: The Sei Whale (Balænoptera borealis); Mem. Amer. Mus. Nat. Hist., n. s., vol. 1, pt. 6, 1916, pp. 289-388, pls. 29-42, with figures of the exterior and of all parts of the skeleton.

G. M. Allen: The Whalebone Whales of New England; Mem. Boston Soc. Nat. Hist., vol. 8, No. 2, 1916, pp. 105-322, pls. 8-16, with figures mostly of the exterior. *Balæna, Balænoptera, Megaptera.*

Besides *Plesiocetus* and *Cetotherium* many other genera of fossil Balænids have been described, especially in papers by Van Beneden, Brandt and Cope, but the bases for most of them are scanty. H. Winge (Om Plesiocetus og Sqvalodon fra Danmark, Vidensk, Medd. Naturhist. Foren. 1909) has attempted to estimate the value of a number of the genera in question: *Aulocetus, Mesoteras, Cetotheriopsis, Megapteropsis, "Burtinopsis," Herpetocetus, Eucetotherium, Plesiocetopsis, Cetotheriophanes, Cetotheriomorphus, Idiocetus, Heterocetus, Amphicetus, Mesocetus, Isocetus, Pachycetus, Siphonocetus, Ulias, Tre-*

tulias, Metopocetus, Cephalotropis, Rhegnopsis. It is apparent that as regards most of them there is scarcely any reason for separation from *Plesiocetus* or *Cetotherium* or from recent genera, and that the few which appear to be more peculiar are so slightly known that they can scarcely be classified. True (The Genera of Fossil Whalebone Whales allied to *Balænoptera,* Smithsonian Misc. Coll., vol. 59, No. 6, 1912, pp. 1-8) who later went over the subject came in all essentials to the same conclusion.

Agriocetus is most likely a whalebone whale, but it is too slightly known to be classified. It was described by Abel (1914, *l. c.,* pp. 188-194, pls. 4, 5, 7) from a very imperfect and indistinct skull from Tertiary strata at Linz, referred to *Squalodon* by earlier authors. Abel regards it as a near relative of *Patriocetus,* a step nearer to the true whalebone whales. Only better discoveries will show whether he is right or not.

Perhaps *Patriocetus* belongs to the family *Balænidæ* as it is understood in the present work, but it is not sufficiently known to be definitely placed. It was described by Abel (1914, *l. c.*) who has given a full account of the history of the remnants in question. The basis of the genus was partly some rather imperfect fragments which previously had most often been referred to under the name *Squalodon ehrlichii,* partly a quite well-preserved skull found later, all from Tertiary strata at Linz. If Abel's interpretations and conjectures are right he is no doubt correct in regarding *Patriocetus* as a precursor of the true whalebone whales. Abel refers it to the Archæoceti, or at least leaves the question undecided whether it actually belongs to this group or to the Mystacoceti (Die vorzeitl. Säuget., 1914, p. 88); most probably it should be regarded as a whalebone whale, a Balænid with the dentition still functional. But there is reason for doubt about certain details in Abel's account.

Patriocetus has in the skull a remarkably strong resemblance to *Agorophius,* a resemblance that was seen by Brandt (1873, *l. c.,* p. 324) although the remains then at hand were rather insignificant; and *Agorophius* belongs incontestably to the series of toothed whales as a near relative of *Squalodon.* The peculiarity which places *Agorophius* among the *Odontoceti* in opposition to the *Mystacoceti* is that the maxillary bone pushes itself posteriorly as a thin limina over the supraorbital process of the frontal, but does not stop in front of it, or push itself in under it, or content itself with also covering it with a narrow margin anteriorly. According to the great resemblances which are found otherwise between the skulls of *Agorophius* and

Patriocetus one would expect that the two genera would resemble each other in this particular also; but according to Abel's representation *Patriocetus* is here like the whalebone whales. According to the photographic illustrations which accompany Abel's paper it is scarcely possible to see whether his exposition of the conditions is right or not; the skull is too weathered and obscure. There is, however, a detail in his description of the boundary between the maxillary and frontal, which probably must be wrong or at least must awaken doubt. He says of the maxillary that it, at its postero-internal extremity, does not extend nearly so far backward as the nasal process of the intermaxillary, which, on the contrary, like that of other whales, extends up, far backward, alongside the outer margin of the nasal and beyond. But there is elsewhere no cetacean, either among the *Archæoceti, Mystacoceti,* or *Odontoceti,* in which the maxillary does not reach postero-internally as far back as the intermaxillary or even further, pushing itself up over the frontal. This is an inheritance from ancestors among the carnivores or from yet more distant forerunners. Abel says, it is true (*l. c.,* p. 162) that *Patriocetus* in this regard resembles *Rhachionectes,* one of the recent whalebone whales; but this is an error. In one of the figures of the skull of *Rhachionectes* published by Andrews (1914, *l. c.,* pl. 25) it can be clearly seen that a long process from the maxillary extends along the outer side of the intermaxillary to its hindmost end; and it is so described by Andrews (p. 261). In the second of Andrews' figures the process is not visible; it is obviously broken off, as it is in the figures published by Van Beneden (Bull. Acad. Roy. Sci. etc., de Belgique, ser. 2, vol. 43, No. 2, February, 1877, pl.) and True (1904, *l. c.,* pl. 47, fig. 1), both of which represent the same skull (it is True's figure to which Abel refers). A similar injury no doubt must have been suffered by the skull of *Patriocetus;* and if this process can be broken away without leaving visible traces behind it the same might be possible in the case of a thin plate-like process that originally covered the supraorbital process of the frontal. How readily something of the kind can take place is shown by the type of *Agorophius* (figured by Leidy, under the name *Squalodon pygmæus,* Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 7, 1869, pl. 29, and by True, Smithsonian Inst. Special Publ., No. 1694, 1907, pl.): on the right side of the skull large parts of the plate-like outgrowths from the maxillary over the supraorbital process of the frontal are broken away without having left behind any conspicuous traces on the frontal.

In Abel's treatment of the dentition in *Patriocetus* there are also various doubtful points. He asserts that the complement of teeth is the one which is typical of the placentalia, 11 teeth in each jaw; but it is impossible to see how he has arrived at this conclusion. The best skull in question lacks the anterior part of both upper jaw and mandible, and it is impossible to say how much is lacking, or how many teeth were implanted in the missing parts. Of teeth fixed in the jaws there are known for the most part mere stubs—sometimes nothing but roots. Besides these there are some dissociated teeth whose position in the jaws is not certain. All that can be said is that some of the teeth were simply conical with single root, and that most of the cheekteeth had serrate crown and double roots. Altogether there is not enough known to elucidate all the details of the dentition. It is not probable that Abel should be right in his belief that the teeth were present in the typical number. Such a cetacean as *Patriocetus,* the skull of which was already highly developed in the direction of the most advanced whales, scarcely could have had about the same dentition as the Zeuglodonts. It is much more likely that the number of teeth was increased above the typical as it is or has been in all the *Mystacoceti* and *Odontoceti* which are known in this respect. In order to believe in Abel's representation of the facts we must see more incontestable finds. (See also note 7, pp. 52-54.)

[15] (P. 23.) The asymmetry in the skull of the toothed cetaceans has often been written about. Special treatises on the subject are due to Pouchet (De l'asymétrie de la face chez les Cétodontes; Nouv. Arch. du Mus. d'Hist. Nat. Paris, 1886, pp. 1-16 of separate), Abel (Die Ursache der Asymmetrie des Zahnwalschädels; Sitzungsber. k. Akad. Wissensch. Wien, Math.-naturw. Cl., vol. 111, pt. 1, 1902, pp. 510-526, pl.), Kükenthal (Ueber die Ursache der Asymmetrie des Walschädels; Anat. Anzeiger, vol. 33, 1908, pp. 609-618, with illustrations) and Steinmann (Ueber die Ursache der Asymmetrie der Wale; Anat. Anzeiger, vol. 41, 1912, pp. 45-54, with illustrations); Pouchet and Abel refer to various earlier papers by other writers.

As to the reason for the crookedness Pouchet says: "Nous en ignorons l'origine."

In 1893 Kükenthal said very nearly the same: "Die physiologische Ursache kennt man nicht, vielleicht ist sie in der eigenthümlichen Art der Locomotion vermittelst der Schwanzflosse zu suchen" (Vergleich.-Anat. u. entwickelungsgesch. Untersuch. an Walthieren, pt. 2; Denkschr. med.-naturwiss. Ges. zu Jena, vol. 3, pt. 2, p. 342), a thought that was not at the time carried further. But in 1908 Kükenthal tried to give a more exact explanation. To begin with he thought he could prove that the asymmetry in the bones of the face is found not only in toothed cetacea, but also in the whalebone whales, though only slightly defined. In two skulls of *Balænoptera* (of *B. rostrata* and *B. musculus*) he had found certain of the facial bones just a trifle broader on the right side than on the left. Next he discovered that some embryos of toothed cetaceans, of *Platanista, Steno, Globiceps, Delphinus, Phocæna, Hyperoodon,* had the caudal fin set awry, not level but in such a position that the left fluke " etwas schräg nach aufwärts, der rechte schräg nach abwärts gerichtet war " (p. 614). In 12 embryos of *Delphinapterus* the fin was, on the contrary, horizontal. All the embryos of whalebone whales examined (of *Balænoptera musculus* and *B. gigas*) had the fin oblique in the same manner as the toothed whales. How the fin is in adult cetaceans is said to be not clearly understood; a few observations by other investigators may, however, indicate that the obliquity is present in the adults also. When a whale propels itself forward by means of a sculling movement of the oblique caudal fin it is said to turn at the same time to the left: " Der Wal durchschneidet also bei derartiger schräger Bewegung der Schwanzflosse das Wasser nicht genau in der Richtung seiner Längsachse, sondern sein Weg verläuft von dieser Geraden etwas schräg nach links zu " (p. 616). And from this is said to result an oblique pressure of the water on the head, and consequently the obliquity of the skull, since the bones on the left side are pressed upon more than those of the right side, are made thicker, etc.: " Der Druck der beim Schwimmen durchschnittenen Wassermassen wird auf die linke Seite des Vorderkopfes stärker wirken als auf die rechte. Dieser Druck pflanzt sich durch die elastischen Weichteile des Vorderkopfes hindurch auf die darunter liegenden Schädelknochen fort. Die Wirkung dieses stärkeren Druckes muss sich zunächst in einer Verdickung der entsprechenden Schädelknochen äussern . . . ." (pp. 616-617). That the bones in the left side of the face are not so wide as those of the right side is said to be connected with the fact that the bones of the left side are the thickest: " Es wird dadurch links eine kleinere Fläche als rechts geschaffen, welche den etwas stärkeren Druck auszuhalten hat und damit bis zu einem gewissen Grade einen Ausgleich gegenüber der rechten Seite herbeiführt " (p. 617).

Abel believes that the reason for the asymmetry of the skull in toothed whales is to be found in the atrophy of the nasal bones, etc., and in the shortening of the braincase, but cannot prove that asymmetry would be the necessary result of these causes.

Lillie (section The asymmetry of the Odontocete skull, in Observations on the anatomy and general biology of some members of the larger Cetacea, Proc. Zool. Soc. London, 1910, vol. 2, pp. 781-783, with figure) shows that the pharynx in *Physeter* is asymmetrical, divided by the projecting larynx, which is strongly displaced to the left, into a more spacious right and a narrower left section to accommodate the passage of food. In this circumstance should be found the source of the asymmetry of the face; why, is not further explained.

Steinmann starts from Kükenthal's assertion about the asymmetry in the candal fin. Kükenthal had said nothing as to the cause of this crookedness, but Steinmann believes he has found it in the supposed fact that whales originated from Ichthyosaurs and other marine reptiles with a vertical fin, and that on its way to the horizontal position the fin has come to rest obliquely.

Kükenthal is doubtless the one who has come nearest to the truth. However, there are numerous objections to be raised against his explanation. It cannot be said with any degree of correctness that the skull in the whalebone whales has an asymmetrical face. A series of skulls is before me, representing *Balæna, Balænoptera* and *Megaptera*. Such asymmetry as can perhaps be shown here and there is similar to that which is found in most mammals. I myself have seen many cetacean embryos (in alcohol), representing both whalebone whales and odontocetes (of the former I have examined in this connection embryos of 3 *Balænoptera rostrata*, 2 *B. musculus*, 5 *Megaptera boops*, of the latter numerous embryos representing the genera *Delphinapterus, Monodon, Prodelphinus, Delphinus, Lagenorhynchus, Globiceps, Phocæna, Neomeris;* I have been content with examining the tails externally, I have not cross-sectioned them), but I have not been able to convince myself of the presence of obliqueness in the tail which did not appear to find its explanation in artificial pressure. I have also seen various adult newly dead cetaceans, both whalebone whales and toothed cetacea of different kinds. It is true I did not expressly examine them to observe obliqueness of the tail, but I cannot recall the slightest evidence of its existence. Neither can anything be detected in the numerous photographs of whales that are before me. That obliqueness of the tail can actually be present appears to be proved by Kükenthal's figure of a cut off tail of *Balænoptera*, which shows the flukes placed obliquely in relation to the caudal vertebræ; but it must probably be an exception. Even if it were true that the caudal fin in cetaceans was usually obliquely set this would probably not hinder whales from swimming forward in a straight line if they so wished. That the obliquity of the tail, if it occurs as represented by Kükenthal, does not in any event necessarily carry with it the asymmetry of the skull is proved by the whalebone whales, whose tail is said to be oblique, but whose skull is without asymmetry in spite of Kükenthal's word to the contrary. And that the asymmetry of the face is not dependent on obliquity of the tail is proved by *Delphinapterus,* whose tail, also according to Kükenthal's interpretation, is not oblique, but whose skull is distinguished by a high degree of asymmetry. Should the water's pressure work most powerfully on the *left* side of the head it would be difficult, in spite of Kükenthal's attempt at an explanation, to understand why the bones on the left side of the skull are narrow while those on the right side are broad, or why the nasal passage is pushed over toward the left side, a point that Kükenthal does not try to argue. Of Kükenthal's explanations scarcely anything is left except the knowledge that it is the pressure of the water which is responsible for the asymmetry of the skull in the Odontoceti. Why the water presses obliquely is still unknown, but the reason is not likely to be anything else than a habit in the carriage of the head: the head presumably must be held a little obliquely even when the animal is swimming straight forward; and the pressure must be strongest on the right side.

[16] (P. 24.) On the *Squalodontidæ* see especially:

Grateloup: Description d'un fragment de mâchoire fossile, d'un genre nouveau de reptile (Saurien), de taille gigantesque, voisin d'Iguanodon, trouvé dans le grés marin, à Léognan, près Bordeaux, 1840, pp. 1-8, pl. Separate from Actes de l'Acad. des sciences, belles lettres et arts de Bordeaux, vol. 2. *Squalodon.*

H. v. Meyer: Arionius servatus, ein Meersäugethier der Molasse; Palæontographica, vol. 6, 1856, pp. 31-43, pl. 6. *Squalodon.*

Jourdan: Descr. de restes fossiles de deux grands Mammifères constituant le genre Rhizoprion et le genre Dinocyon; Annales des Sciences Naturelles, sér. 4, Zoologie, vol. 16, 1861, pp. 369-372, pl. 10. *Rhizoprion=Squalodon.*

Van Beneden: Recherches sur les Squalodons; Mém. Acad. Roy. Belgique, vol. 35, 1865, pp. 1-85, pls. 1-4, with figures of the upper jaw of *S. antuerpiensis* (and of the skull of *S. ehrlichii=Patriocetus*).

Van Beneden: Recherches sur les Squalodons, Supplément; Mém. Acad. Roy. Belgique, vol. 37, 1868, pp. 1-13, pl., with figure of the under jaw of *S. antuerpiensis.*

Gervais: Du Squalodon et de sa comparaison avec le Zeuglodon; Zoologie et Paléontologie Générales, ser. 1, 1867-69, pp. 170-182.

Fischer: Descr. d'une mâchoire inférieure de Squalodon Grateloupi; Actes de la Soc. Linnéenne de Bordeaux, vol. 27, 1869, pp. 12-22, pl. 2.

Delfortrie: Descr. d'une nouvelle mâchoire inférieure de Squalodon Grateloupi dans le grés marin de Léognan, Gironde; Actes de la Soc. Linnéenne de Bordeaux, vol. 27, 1869, pp. 133-136, pl. 5.

Leidy: Extinct Mammalian Fauna of Dakota and Nebraska; Journ. Acad. Nat. Sci. Philadelphia, ser. 2, vol. 7, 1869, pp. 416-424, pls. 28-30. *Squalodon* and *Agorophius* (under the name *Squalodon pygmæus*).

Delfortrie: Un Squalodon d'espèce nouvelle dans le Miocène supérieur du Midi de la France; Actes de la Soc. Linnéenne de Bordeaux, vol. 29, 1873, pp. 257-260, pl. 7.

Brandt: Untersuchungen über die fossilen und subfossilen Cetaceen Europa's; Mém. Acad. Sci. St. Pétersbourg, ser. 7, vol. 20, No. 1, 1873. Contains a section on the Squalodonts, pp. 315-332, pl. 31-32. *Squalodon, Neosqualodon* (*S. gastaldii*) (and *Patriocetus, S. Ehrlichii*).

Brandt: Ergänzungen zu den fossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 21, No. 6, 1874. Contains a section on *Squalodon* (and *Patriocetus*), pp. 28-47, pls. 4, 5.

Van Beneden et Gervais: Ostéographie des Cétacés vivants et fossiles, Text and Atlas, 1868-80, pp. 426-454, 519, pl. 28. *Squalodon*.

Zittel: Ueber Squalodon Bariensis aus Niederbayern; Palæontographica, vol. 24, 1877, pp. 233-246, pl. 35.

Lortet: Note sur le Rhizoprion bariensis; Arch. Mus. d'hist. Nat. de Lyon, vol. 4, 1887, pp. 315-319, pl. 25 *bis* and *ter*. *Squalodon*.

Lydekker: Cetacean skulls from Patagonia; Anales del Museo de La Plata, Paleontología Argentina, II, 1893, pp. 8-10, pl. 4. *Prosqualodon*.

Paquier: Étude sur quelques Cétacés du Miocène; Mém. de la Soc. Géol. de France, Paléontologie, vol. 4, pt. 4, Mém. No. 12, 1894, pp. 12-17, pl. 18. *Squalodon*.

Lydekker: On the skull of a shark-toothed Dolphin from Patagonia; Proceed. Zool. Soc. London, 1899, pp. 919-922, with illustrations. *Prosqualodon*.

Dal Piaz: Sopra alcuni resti di Squalodon dell' arenaria miocenica di Belluno; Palaeontographia Italica, vol. 6, 1900, pp. 303-314, pls. 26-29.

Abel: Les Dauphins Longirostres du Boldérien des Environs d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 1, 1901, pp. 9-10. On the dentition in *Squalodon.*

Dal Piaz: Neosqualodon, nuovo genere della famiglia degli Squalodontidi; Abhandl. der Schweizerischen paläontologischen Gesellschaft, vol. 31, 1904, pp. 1-21, pl.

Abel: Les Odontocètes du Boldérien d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 3, 1905, pp. 25-38. On the dentition.

True: Remarks on the type of the fossil Cetacean Agorophius pygmæus (Müller); Smithsonian Inst. Special Publ., No. 1694, 1907, pp. 1-8, pl.

True: Descr. of a mandible and vertebræ of Prosqualodon, etc.; Smithsonian Misc. Coll., vol. 52, pt. 4, 1910, pp. 447-456, pl. 43.

Hall: On the systematic position of the species of Squalodon and Zeuglodon described from Australia and New Zealand; Proc. Roy. Soc. Victoria, n. s., vol. 23, pt. 2, 1911, pp. 257-265, pl. 36. *Parasqualodon, Metasqualodon.*

Abel: Cetaceenstudien, III. Mitteilung, Rekonstruktion des Schädels von Prosqualodon australe (*sic*) Lyd. aus dem Miozän Patagoniens; Sitzungsber. k. Akad. Wissensch. Wien, mathem.-naturw. Kl., vol. 121, pt. 1, 1912, pp. 57-75, pls. 1-3. The account contains various guesses; Lydekker's figures of the type cannot be dispensed with in forming an opinion about the genus. References to several other papers will be found in H. Winge, Vidensk. Medd. Naturhist Foren., 1909, pp. 31-35.

Microsqualodon Abel is said to be identical with *Neosqualodon* Dal Piaz. Abel (Odontocètes du Boldérien, 1905, pp. 35-36) established the genus on the basis of Tertiary remains from Acqui which Brandt had called *Squalodon gastaldii.* In a letter to Abel, however, which Abel printed, Dal Piaz explains that these specimens, which he had had the opportunity to see, must be referred to the earlier described *Neosqualodon.*

Parasqualodon and *Metasqualodon* are proposed by Hall (1911, *l. c.*) to include Tertiary Australian species that previously were referred to *Squalodon: S. wilkinsoni* M'Coy and *S. harwoodii* Sanger. The genera are supposed to be nearly related to *Prosqualodon,* but they are known from loose teeth only and their status is still uncertain.

[17] (P. 28.) On the *Platanistidæ* see especially:

Cuvier: Recherches sur les Ossemens fossiles, ed. 4, vol. 8, pt. 2, 1836, pp. 88-90, 128-132, Atlas, pl. 223, with figures of skull of *Platanista*.

Eschricht: Om Gangesdelphinen; Kgl. Danske Vidensk. Selsk. Skrifter, 5te R., naturv. og mathem. Afd., vol. 2, 1851, pp. 345-387, pls. 1-3. *Platanista*. Figures of exterior, skeleton, skull.

Burmeister: Descripcion de cuatro especies de Delfinides de la costa Argentina en el océano Atlántico; Anales del Museo Público de Buenos Aires, vol. 1, 1864-69, pp. 389-445, pl. 23, 25-28. *Pontoporia*. Figures of exterior, skeleton, skull and other parts.

Flower: Descr. of the skeleton of Inia geoffrensis and of the skull of Pontoporia blainvillii, with remarks on the systematic position of these animals in the order Cetacea; Trans. Zool. Soc. London, vol. 6, pt. 3, 1869, pp. 87-116, pls. 25-28.

Van Beneden et Gervais: Ostéographie des Cétacés vivants et fossiles, Text and Atlas, 1868-80, pp. 454-482, pls. 29-33. On almost all the recent genera.

Anderson: Anat. and Zool. Researches, compr. an Account of the two Exp. to Western Yunnan in 1868 and 1875; 1878; pp. 417-550, pls. 25, 26, 28-32, 34-41. *Platanista*. Figures of exterior, skeleton and soft parts.

Burmeister: Exámen critico de los Mamíferos y Reptiles fósiles denominados por D. Augusto Bravard; Anales del Museo Nacional de Buenos Aires, vol. 3, 1883-91, pp. 138-144, pl. 2, figs. 12A-C. *Pontistes*. Figures of an imperfect skull.

Burmeister: Adiciones al exámen critico, etc.; Anales del Museo Nacional del Buenos Aires, vol. 3, 1883-91, pp. 451-460, pl. 8. *Saurodelphis*. Figures of skull.

Abel: Les Dauphins Longirostres du Boldérien des Environs d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 1, 1901, pp. 1-95, pls. 1-10. Contains a section dealing with the *Platanistidæ* both living and extinct, and on several plates gives figures of their skulls, mostly copied from other papers.

Abel: Cetaceenstudien, II, Der Schädel von Saurodelphis argentinus aus dem Pliozän Argentiniens; Sitzungsber. k. Akad. Wissensch. Wien, mathem.-naturw. Kl., vol. 118, pt. I, 1909, pp. 255-272, pl. I, and text figures. Tries to prove that Burmeister's figures of the skull of *Saurodelphis argentinus* are to a notable degree incorrect. Burmeister is said to have put together parts of two different genera that should bear the names *Saurodelphis* and

Pontoplanodes. At present the problem cannot be said to be solved; but there appears to be no good reason to doubt the correctness of Burmeister's determination. In the present paper his presentation of the subject is followed. A piece of the beak of *Saurodelphis* with the 8-shaped alveoli is in the Copenhagen museum.

Gerrit S. Miller: A new River-Dolphin from China; Smithsonian Misc. Coll., vol. 68, No. 9, 1918, pp. 1-12, pls. 1-13. *Lipotes.*

Ischyrorhynchus was based by Ameghino (Caracteres diagnósticos de cincuenta especies nuevas de Mamíferos fósiles argentinos; Revista Argentina de Historia Natural, vol. 1, 1891, pp. 163-165, with illustrations) on the anterior part of a lower jaw from the "oligoceno inferior del Paraná." The branches of the jaw, which are rather heavy, are grown together in a long symphysis menti; the rows of teeth are further apart than in *Saurodephis* (*Saurocetes*), with which Ameghino associates the genus, and the roots in cross-section are almost what might be called ovate, not 8-shaped; the crowns are known only imperfectly. It is not possible to decide where the genus belongs.

Pontivaga was also based by Ameghino (*l. c.,* pp. 165-166, with illustration) on the anterior part of a lower jaw, from the "oligoceno superior" at Paraná. The branches of the jaw are slender and are grown together in a long symphysis. Each of them contains a long row of small teeth, to judge by the alveoli. Ameghino places the genus in the *Platanistidæ,* in contrast with the *Saurocetidæ,* whether rightly or not cannot be said.

A genus *Proinia* is established by True (A new genus of fossil Cetaceans from Santa Cruz Territory, Patagonia, etc.; Smithsonian Misc. Coll., vol. 52, pp. 441-447, pl. 43, 1910), who regards it as a near relative of *Inia.* Perhaps True is right; but the material on which the genus is based, a few fragments of a braincase and a cervical vertebra all distorted by pressure, is so scanty that an error is very possible.

Hesperocetus is established by True (A fossil toothed Cetacean from California, etc.; Smithsonian Misc. Coll., vol. 60, No. 11, 1912, pp. 1-7, pls. 1-2) on the strength of the anterior part of a long, narrow, lower jaw with long symphysis, with rows of rather strong, conical, slightly hooked teeth with wrinkled enamel. The teeth are placed rather wide apart and are separated by shallow depressions in the margin of the jaw into which the tips of the upper teeth presumably fitted. True refers it provisionally to the family *Iniidæ* (=*Platanistidæ*), perhaps rightly; there are other possibilities.

[18] (Pp. 26 and 31.) True (A Review of the Family Delphinidæ; Bull. U. S. Nat. Mus., No. 36, 1889, p. 10) believes he has observed a peculiarity in the relationships of the pterygoid that should distinguish *Delphinapterus* and *Monodon* from all other Delphinids and recall the Platanistids: "that in the narwhal and white whale the pterygoid bones, instead of merely forming the walls of the posterior nares, extend backward in the form of broad plates across the optic canal and articulate with the squamosals." But the case is different. We have to do with the bones which lie in the outer wall of the air-sac behind the palate. As may be seen in young or youngish skulls of *Delphinapterus* and *Monodon*, the pterygoid shares in the formation of the outer wall of the air-sac at the front only, in contrast with the condition in *Pontistes, Pontoporia* and *Platanista* in which it, recalling the Balænids and Physeterids, forms most of the outer wall (in *Inia* the outer wall appears to be mostly membranaceous). As in other Delphinids the palatine, frontal, ala magna, and squamosal all share in bounding the outer side of the air-sac, each contributing its section (special ossifications may also be present). In the Delphinids under discussion the outer side of the air-sac is merely ossified more extensively than elsewhere, a difference, however, which is one of degree only.

[19] (P. 35.) As reasons for believing that *Neomeris* and *Phocæna* among recent Odontoceti are the ones which stand nearest to *Zeuglodon* and *Squalodon* Abel (Dauphins Longirostres, 1901, p. 36) mentions the following: (1) that they still have traces of "l'ancienne dentition hétérodonte," (2) that teeth are still found (or more correctly may be found) in the intermaxillary, and that the intermaxillary extends further forward than the maxillary, (3) that they still have traces of "l'armure dermique," (4) that the nostrils are not pushed very far backward, and that therefore the parietal still extends up back of the frontal. Against this view there are the following objections: (1) The form of the teeth in the two recent genera is not primitive; fan-like broadened crown and single root is not the form of tooth that is found in the more primitive cetaceans of any kind. Conical crown and a trace of double root, in most of the teeth, is the transitional form between the tooth structure of the more primitive and the less primitive cetaceans. Even the anterior teeth in the jaws of *Phocæna* may have fan-shaped crowns, where in the most primitive whales they are unicuspid and conical. (2) Teeth in the inter-

maxillary, and a slightly projecting intermaxillary, may also be found in *Steno, Delphinus,* and several other of the recent *Delphinidæ.* (3) There is no evidence that cetaceans are descended from mammals with bony armor; the so-called dermal bones that were found on rare occasions with remains of *Zeuglodon* and *Delphinopsis* are too doubtful to prove anything; in the great majority of instances no dermal armor has been found with bones of *Zeuglodon* and other *Archæoceti.* The "dermal armor," that is, the small spots of more or less tuberculate, mosaic-like skin, in *Neomeris* and *Phocæna* is assuredly a new development. (See pp. 56-58.) (4) It cannot be correctly said that the nostrils in *Phocæna* and *Neomeris* lie relatively far forward. It appears so merely because the anterior part of the face is somewhat shortened and the braincase is unusually large. In reality the nostrils lie, with respect to the orbits and other surrounding parts, in the same position as in most Delphinids. Neither can it be said that the parietals are excluded from the upper side of the braincase to a less degree than usual. As may be seen in the young skulls the parietals in *Phocæna* are widely separated by the large interposed interparietal quite as usual in other Delphinids.

[20] (P. 35.) On the Delphinidæ see especially:

Cuvier: Recherches sur les Ossemens fossiles, ed. 4, vol. 8, pt. 2. 1836, pp. 75-170, Atlas, pls. 222-224, with figures of skull and some other skeletal parts, of most of the recent genera.

Schlegel: Beiträge zur Charakteristik der Cetaceen; Abhandlungen aus dem Gebiete der Zoologie und vergl. Anatomie, Heft. 1, 1841, pp. 1-44, pls. 1-6. Contains among other things a synopsis of the Delphinids, with figures of skulls of *Steno, Prodelphinus, Delphinus, Lagenorhynchus,* all under the name *Delphinus.*

J. E. Gray: The Zoology of the Voyage of H. M. S. Erebus and Terror, pts. 3-5, Mammalia, On the Cetaceous Animals, 1846, pp. 13-53, pls. 1-30. Most of the plates give figures of skulls of Delphinids: *Delphinapterus* ("*Beluga*"), "*Feresa*" (*Orca intermedia*), *Orca, Lagenorhynchus, Tursiops* (under the name *Delphinus*), *Prodelphinus* (under the name *Delphinus*), *Delphinus, Steno.*

Burmeister: Descripcion de cuatro especies de Delfinides de la costa Argentina en el océano Atlántico; Anales del Museo Público de Buenos Aires, vol. 1, 1864-69, pp. 367-388, pls. 21-24. *Pseudorca* (under the name *Globicephalus*), *Orca, Phocæna.* Figures of exterior, skulls and other parts.

Owen: On some Indian Cetacea; Transact. Zool. Soc. London, vol. 6, pt. 1, 1866, pp. 17-47, pls. 3-14. Deals partly with the Delphinids. Skulls are figured of "*Sotalia*," *Lagenorhynchus*, *Delphinus*, *Prodelphinus* (all called *Delphinus*), *Orcella* (called *Phocæna*).

J. E. Gray: Synopsis of the species of Whales and Dolphins in the Collection of the British Museum, 1868, pp. 1-10, pls. 1-30. The plates are the same as in the previously mentioned work by Gray.

Van Beneden et Gervais: Ostéographie des Cétacés vivants et fossiles, Text and Atlas, 1868-80, pp. 482-512, 521-605, pls. 34-60, 63, 64. All recent genera and many fossil, among them *Champsodelphis*, *Schizodelphis*, *Eurhinodelphis*.

Eschricht: Ni Tavler til Oplysning af Hvaldyrenes Bygning, med Forklaring af Reinhardt; Kgl. Danske Vidensk. Selsk. Skrifter, 5te R., naturv. mathem. Afd., vol. 9, I, 1869. On plate 8 are found figures of skull and teeth of *Delphinapterus*.

Flower: Descr. of the skeleton of the Chinese White Dolphin, Delphinus sinensis; Transact. Zool. Soc. London, vol. 7, pt. 2, 1870 (72), pp. 151-160, pls. 17, 18. *Prodelphinus* ("*Sotalia*").

Flower: On Risso's Dolphin, Grampus griseus; Transact. Zool. Soc. London, vol. 8, pt. 1, 1872, pp. 1-21, pls. 1-2. Figures of exterior and skeleton.

Brandt: Untersuchungen über die fossilen und subfossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, No. 1, 1873. Contains a section on the Delphinids, pp. 226-290, pls. 24-30, among them *Schizodelphis* and *Champsodelphis*.

Brandt: Ergänzugen zu den fossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 21, 1874, pp. 13-28, pls. 2-4. *Champsodelphis* among others.

Murie: On the organization of the Caaing Whale, Globiocephalus melas; Trans. Zool. Soc. London, vol. 8, pt. 4, 1873, pp. 235-301, pls. 30-38. Exterior and anatomy.

Van Beneden: Mémoire sur un Dauphin nouveau de la Baie de Rio de Janeiro désigné sous le nom de Sotalia brasiliensis; Mém. Acad. Roy. Belgique, vol. 41, 1874, pp. 1-44, pls. 1, 2, with figures of exterior, skeleton, skull. *Prodelphinus*.

J. E. Gray: Feresa attenuata; Journal des Museum Godeffroy, vol. 8, 1875, p. 1, pl. 6, with figures of skull.

Anderson: Anat. and Zool. Researches, compr. an Account of the two Exp. to Western Yunnan in 1868 and 1875; 1878; pp. 358-416, pls. 25, 25-A, 27-30, 33-38, 42, 43. *Orcella*. Figures of exterior, skeleton and soft parts.

Van Beneden: Mémoire sur les Orques observés dans les mers d'Europe; Mém. Acad. Roy. Belgique, vol. 43, 1879, pp. 1-33, pls. 1-4, with figures of exterior, skeleton, skulls. *Orca*.

Flower: On the characters and divisions of the family Delphinidæ; Proceed. Zool. Soc. London, 1883, pp. 466-513, with figures in the text representing the posterior part of the bony palate in several of the genera. One of the most important papers in elucidating the relationship among the recent Delphinids.

Lütken: Kritiske Studier over nogle Tandhvaler af Slægterne Tursiops, Orca og Lagenorhynchus; Kgl. Dansk Vidensk. Selsk. Skrifter, 6te R., naturv. mathem. Afd., vols. 4, 6, 1887, pp. 337-397, pls. 1, 2, also text figures: exterior, skull, other skeletal parts.

Lütken: Spolia Atlantica, Bidrag til Kundskab om de tre pelagiske Tandhval-Slægter Steno, Delphinus og Prodelphinus; Kgl. Danske Vidensk. Selsk. Skrifter, 6te R., naturv. mathem. Afd., vol. 5, 1, 1889, pp. 1-61, plate with a figure of the exterior and skeleton of *Steno;* also figures in the text: exterior, skulls, other skeletal parts.

True: A Review of the Family Delphinidæ; Bull. U. S. Nat. Mus., No. 36, 1889, pp. 1-191, pls. 1-47, with figures of exterior and skulls. In the conception of genera and their mutual relationships agrees closely with Flower's conclusions.

Lydekker: Cetacean skulls from Patagonia; Anales del Museo de La Plata, Paleontología Argentina, vol. 2, 1893, pp. 10-12, pl. 5. *Argyrocetus*.

Guldberg: On the development and structure of the Whale, pt. 1, on the development of the Dolphin; Bergens Museums Skrifter, vol. 5, 1894, pp. 1-70, pls. 1-7. *Lagenorhynchus, Phocæna, Orca*.

Longhi: Sopra i resti di un cranio di Champsodelphis fossile scoperto nella molassa miocenica del Bellunese; Atti della Società Veneto-Trentina di Scienze Naturali, ser. 2, vol. 3, fasc. 2, 1898, pp. 1-60 in the separate, pls. 1-3.

Abel: Untersuchungen über die fossilen Platanistiden des Wiener Beckens; Denkschr. d. k. Akad. Wissensch. Wien, math.-naturw. Cl., vol. 68, 1899, pp. 839-874, pls. 1-4, with figures of skulls. *Cyrtodelphis* and *Acrodelphis=Schizodelphis* and *Champsodelphis*.

Abel: Les Dauphins Longirostres du Boldérien (Miocène supérieur) des Environs d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de

Belgique, vol. 1, 1901, pp. 1-95, pls. 1-10, with figures of skulls. *Cyrtodelphis* (=*Schizodelphis*), *Eurhinodelphis.*

Dal Piaz: Sugli avanzi di Cyrtodelphis sulcatus dell' arenaria di Belluno; Palaeontographia Italica, vol. 9, 1903, pp. 187-220, pls. 28-31, with figures of skulls and teeth. *Schizodelphis.*

Abel: Eine Stammtype der Delphiniden aus dem Miocän der Halbinsel Taman; Jahrbuch der k. k. geol. Reichsanstalt, vol. 55, pt. 2, 1905, pp. 375-392, with text figures. *Palæophocæna.*

Abel: Les Odontocètes du Boldérien d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 3, 1905, pp. 1-155, with text figures. Includes a section on the Delphinids: *Eurhinodelphis, Cyrtodelphis* (=*Schizodelphis*), *Acrodelphis* (=*Champsodelphis*), *Protophocæna, Pithanodelphis.*

C. v. Papp: Heterodelphis leiodontus, nova forma aus den miocenen Schichten des Comitates Sopron in Ungarn; Mitteilungen aus dem Jahrbuche der k. ungarischen geol. Anstalt, vol. 14, pt. 2, 1905, pp. 25-61, pls, 5, 6, also text figures. Skeleton.

Abel: Cetaceenstudien, I, Das Skelett von Eurhinodelphis cocheteuxi aus dem Obermiozän von Antwerpen; Sitzungsber. k. Akad. Wissensch. Wien, mathem.-naturw. Kl., vol. 118, pt. 1, 1909, pp. 241-253, pl. 1, with a figure of the skeleton, partly conjectural.

True: Observations on living White Whales, Delphinapterus leucas, with a note on the dentition of Delphinapterus and Stenodelphis; Smithsonian Misc. Coll., vol. 52, pt. 3, No. 1864, 1909, pp. 325-330, pl. 23, with a figure of the exterior. Discusses among other things the projections on the tooth crowns of *Delphinapterus.*

Lönnberg: Remarks on the dentition of Delphinapterus leucas; Arkiv för Zoologi, vol. 7, No. 2, 1910, pp. 1-18, with illustrations. Taken up in part also in the paper Om Hvalarnes Härstamming; K. Svenska Vetenskapsakademiens Årsbok för År 1910, pp. 219-259, with illustrations.

Roy C. Andrews: A new Porpoise from Japan; Bull. Amer. Mus. Nat. Hist., vol. 30, 1911, pp. 31-51, pls. 1, 2, also numerous figures in the text. *Phocænoides.* Exterior and skeleton.

Bassani e Misuri: Sopra un Delfinorinco del calcare miocenico di Lecce (Ziphiodelphis Abeli Dal Piaz); Atti della R. Accademia dei Lincei, Anno 309, 1912, ser. 5, Memorie della Classe di Scienze Fisiche, etc., vol. 9, fasc. 2, pp. 25-38, pl. 1, with figures of skull.

True: Descr. of a new fossil Porpoise of the genus Delphinodon from the miocene formation of Maryland; Journ. Acad. Nat.

Sci. Philadelphia, ser. 2, vol. 15, 1912, pp. 165-194, pls. 17-26, with figures of skull, parts of the rest of the skeleton, teeth.

Lull: Fossil Dolphin from California; American Journal of Science, ser. 4, vol. 37, 1914, pp. 209-220, pl. 8, also figures in the text. "*Delphinavus*."

Delphinopsis (see note 8) is placed by Abel (Jahrb. k. k. geol. Reichanst., vol. 55, pt. 2, 1905, pp. 384, 387, in the "Subfamily *Phocœninæ*" because it has "dermal armature." The remains are so imperfect and so uncertain that it is impossible to say where it belongs; not even the family can be determined from the specimen; the reference to *Phocœninæ* is pure guesswork.

Rhabdosteus was described in 1867 by Cope, who in 1890 (Amer. Nat., vol. 24, p. 607) gave figures of the specimens on which the genus was based, some remnants of a "beak," from a Tertiary North American deposit. These remains Cope reconstructed in a somewhat arbitrary manner. True (Remarks on the fossil Cetacean Rhabdosteus latiradix Cope; Proc. Acad. Nat. Sci., Philadelphia, vol. 60, 1908, pp. 24-29, pl. 6, and text figures), who has had the specimens in question under revision, together with some others more or less similar, says that Cope has scarcely put them together right. The specimens may recall *Eurhinodelphis* and its relatives; but the remains are altogether too incomplete and uncertain for anything to be decided.

Lophocetus, established by Cope in 1867, best known from Eastman's description (Types of fossil Cetaceans in the Museum of Comparative Zoology; Bull. Mus. Comp. Zool., vol. 51, 1907, pp. 79-94, pls. 1-4), Tertiary, North American, is most often placed in the *Platanistidæ*. Brandt, however, counts it as a Delphinid (1873, *l. c.*, p. 288), most probably belonging to the "Abtheilung der Phocænen," perhaps to the genus *Delphinapterus*. In this determination he has been followed by a few other authors. The most important basis of the genus is a very imperfect skull, without teeth, with alveoli only, so obscure that nothing positive can be said about it. According to what can be seen of the form of the temporal fossa the genus appears to agree best with the Delphinids. On the other hand it does not seem possible to demonstrate anything that would especially recall the Platanistids.

Iniopsis was established by Lydekker (Proc. Zool. Soc. London, 1892, pp. 562-564, pls. 37-38) principally on an imperfect and obscure braincase from a Tertiary deposit in the Caucasus. Lydekker places it in the *Platanistidæ* and finds similarities with *Pontistes, Stenodelphis* (=*Pontoporia*), *Inia*, etc. It appears, however, to be of another type, very near the most usual Delphinid-type, differing from the *Platanistidæ* especially in the roofed over temporal fossa. Its more exact position among the Delphinids cannot yet be determined.

Cyrtodelphis is only a new name for *Schizodelphis* given by Abel in 1899 (*l. c.*) to include a series of species which previously were most often referred to *Schizodelphis,* among them the type of the genus, *S. sulcatus* Gervais. Eastman (Bull. Mus. Comp. Zool., vol. 51, 1907, pp. 83-84) has already protested against this superfluous new name as well as against the following.

Acrodelphis is likewise essentially a mere new name, a synonym of *Champsodelphis.* It was given by Abel in 1899 (*l. c.*). At first *Acrodelphis* was to include the type of *Champsodelphis, Ch. macrogenius* (Laurillard) Gervais or *macrognathus* Brandt. Later, in 1905, Abel excluded the type of *Champsodelphis* from the genus, with doubtful right; but most of the species which he now includes in *Acrodelphis* were earlier called *Champsodelphis.*

Palæophocæna was based by Abel (1905, Jahrb. k. k. geol. Reichsanst., vol. 55, *l. c.*) on an imperfect piece of a braincase and a few fragments of the rest of the skeleton from a Tertiary deposit on the coast of Crimea. Abel considers it proved that this is a near relative of *Phocæna.* Possibly it will sometime turn out that he is right; but for the present there is no means of deciding the question about nearest relationship. The known piece of skull shows only such general features that nothing exact can be said except that it comes from a Delphinid. Only in the form of the teeth have *Phocæna* and its relative *Neomeris* a peculiarity which distinguishes them from other quite ordinarily formed Delphinids; but the teeth in *Palæophocæna* are not known.

Protophocæna is also established by Abel (Odontocètes du Boldérien, 1905, pp. 139-141, with illustrations), on the anterior, very imperfect part of a skull, without teeth, from the Tertiary deposits at Antwerp. Abel refers it to the "*Phocæninæ.*" There is actually nothing whatever, apart from the small size, that could lead one to think of *Phocæna;* on the contrary, the strong cushion-shaped swelling and the widening out which the intermaxillary shows in front of the nasal aperture suggests rather *Lagenorhynchus* or "*Grampus.*" For the present the question about nearest relationship cannot be settled.

Pithanodelphis is established by Abel (Odontocètes du Boldérien, 1905, pp. 142-145, with illustrations) on the basis of *Phocænopsis cornutus* du Bus from Tertiary strata at Antwerp. Abel refers it to the "*Delphininæ.*" That which is known of it is an imperfect piece of a braincase and a few other parts. The characters, so far as they go, agree well with the ordinary dolphin type; the feature which especially distinguishes it is that the maxillary posteriorly is bowed inward unusually strongly behind the nasal. In this respect, however, dolphins show great variation. The more exact position of the genus cannot be determined.

Phocænoides is established by Roy Andrews (1911, *l. c.*) to include two recent species, one a new species, *Ph. truei* from Japan, the other a species which True had called *Phocæna dalli,* likewise from the northern part of the Pacific Ocean. The deviations from typical *Phocæna* are very small; perhaps the most noticeable is that the teeth are smaller, with the fan-like widening of the crown less pronounced. There can scarcely be sufficient ground for generic separation.

Xiphiodelphis ("*Ziphiodelphis*") (see especially Bassani e Misuri and Dal Piaz, 1912, *l. c.*) is established on fragments of skulls from Tertiary Italian deposits. There can be no douht that it is a near relative of *Schizodelphis,* etc., but its more exact position is not yet clear.

Delphinavus is established by Lull (1914, *l. c.*) on an imperfect and compressed, indistinct skeleton from a no doubt Miocene deposit in California. The genus is supposed to stand very near to *Delphinus* in the narrow sense. The form of the palate, however, the only character that distinguishes *Delphinus* from nearly related Delphinids, does not seem to have been ascertained. One of the most important peculiarities is that the atlas and axis are mutually free. According to what is known it is not possible to clear up the relationship of the genus to other Delphinids; but it ought to be especially compared with *Heterodelphis.*

[21] (P. 38.) It is Flower who has especially emphasized the difference between Delphinids and Physeterids with regard to the relationship of the hindmost ribs to the vertebræ. It is likewise he, in his paper on *Inia* (Trans. Zool. Soc. London, vol. 6, 1869, pp. 98-100) and elsewhere, who has pointed out the intermediate position of the Platanistids. The question about the interpretation of the transverse processes, etc., had previously been discussed, among others by Eschricht in his paper on *Platanista* (1851, pp. 369-370). Later it has been extensively dealt with by Gerstaecker (Das Skelet des Döglings, Hyperoodon rostratus, etc., 1887) and it is also taken up by Abel (Sitzungsber k. Akad. Wissensch. Wien, math.-naturwiss. Kl., vol. 118, pt. 1, 1909, pp. 247-249).

[22] (P. 43.) On the *Physeteridæ* see especially:

Cuvier: Recherches sur les Ossemens fossiles, ed. 4, vol. 8, pt. 2, 1836, pp. 117-247, Atlas, pls. 225, 228, with figures of skulls of *Physeter* and *Hyperoodon* and parts of fossil skulls of *Mesoplodon, Chonoxiphius* and *Xiphius* (all under the name *"Ziphius"*).

Eschricht: Undersøgelser over Hvaldyrene, 4de Afhandl., Om Næbhvalen; Kgl. Danske Vidensk. Selsk. naturv. mathem. Afhandl. 11te Del, 1845, pp. 321-378, pls. 5-8, with figures, mostly of soft parts. *Hyperoodon.* On the dentition in the embryo and other things.

Owen: On some Indian Cetacea; Transact. Zool. Soc. London, vol. 6, pt. 1, 1866, pp. 17-47, pls. 3-14. Contains a section on *"Cogia"* under the name *Physeter* (*Euphysetes*). Exterior, skeleton and skull are figured.

Fischer: Mémoire sur les Cétacés du genre Ziphius; Nouvelles Archives du Muséum d'Hist. Nat. de Paris, vol. 3, 1867, pp. 41-79, pl. 4, with figures of skulls of *Xiphius cavirostris.*

Van Beneden et Gervais: Ostéographie des Cétacés vivants et fossiles, Text and Atlas, 1868-80, pp. 303-324, 514-518, pls. 18-27 *bis,* 61-63. All the recent genera and most of the fossils, among them *Xiphirostrum, Chonoxiphius, Hoplocetus.*

Burmeister: Descripcion detallada del Epiodon australe (*sic*); Anales del Museo Público de Buenos Aires, entrega quinta, 1868, pp. 312-366, pls. 15-20. *Xiphius.* Figures of exterior, skeleton, skull, and other parts.

Eschricht: Ni Tavler til Oplysning af Hvaldyrenes Bygning. med Forklaring af Reinhardt; Kgl. Danske Vidensk. Selsk. Skrifter, 5te R., naturv. mathem. Afd., vol. 9, 1, 1869. On plates 6 and 7 are found figures of the skull of adult *Hyperoodon* and of the exterior and skeleton of the fetus.

Flower: On the osteology of the Cachalot or Sperm-whale (Physeter macrocephalus); Trans. Zool. Soc. London, vol. 6, 1869, pp. 309-372, pls. 55-61.

Owen: Monogr. of the British fossil Cetacea of the Red Crag; Palæontogr. Society, vol. for 1869, 1870, pp. 1-40, pls. 1-5, and with figures in the text. Mostly on the skull and "beak" of *"Ziphius"* (=*Xiphius, Chonoxiphius, Mesoplodon, "Berardius"*).

Flower: On the recent Ziphioid Whales, with a descr. of the Skeleton of Berardius arnouxi; Trans. Zool. Soc. London, vol. 8, pt. 3, 1872, pp. 203-234, pls. 27-29.

Turner: On the occurrence of Ziphius cavirostris in the Shetland Seas and a comparison of its skull with that of Sowerby's Whale, Mesoplodon sowerbyi; Trans. Roy. Soc. Edinburgh, vol. 26, 1872, pp. 759-780, pls. 29, 30, with figures of skulls.

Brandt: Untersuchungen über die fossilen und subfossilen Cetaceen Europa's; Mém. Acad. Imp. Sci. St. Pétersbourg, ser. 7, vol. 20, No. 1, 1873. A section, pp. 204-226, gives a synopsis of the then-known fossil Physeterids.

Flower: A further contrib. to the knowledge of the existing Ziphioid Whales, genus Mesoplodon; Trans. Zool. Soc. London, vol. 10, pt. 9, No. 2, 1878, pp. 415-437, pls. 71-73, with figures of skulls and skeleton.

Turner: Report on the bones of Cetacea collected during the voyage of H. M. S. Challenger in the years 1873-1876; Report on the Scientific Results of the voyage of H. M. S. Challenger, Zoology, vol. 1, pt. 4, 1880, pp. 1-45, pls. 1, 2. Mostly on *Mesoplodon*. Figures of skulls and other parts.

De Sanctis: Monografia zootomico-zoologica sul Capidoglio arenato a Porto S. Giorgio; Atti della R. Accademia dei Lincei, Mem. Cl. sc. fisiche, ser. 3, vol. 9, 1881, pp. 160-242, pls. 1-7. *Physeter*. Exterior and viscera.

Capellini: Resti fossili di Dioplodon e Mesoplodon; Memorie della R. Accademia delle Scienze dell' Instituto di Bologna, ser. 4, vol. 6, 1885, pp. 291-306, pl. 1, with figures of "beak" and other parts. *Mesoplodon*.

Capellini: Del Ziphioide fossile (Choneziphius planirostris) scoperto nelle sabbie plioceniche di Fangonero presso Siena; Atti della R. Accademia dei Lincei, Mem. Cl. sc. fisiche, ser. 4, vol. 1, 1885, pp. 18-29, pl. 1, with figures of the skull. *Chonoxiphius*.

Malm: Om Sowerby's hval; Öfversigt af kgl. Svenska Vetensk.-Akad. Förhandlingar, 1885, No. 5, pp. 121-153, pl. 9, with figures of the skull and other parts. *Mesoplodon*.

Gerstaecker: Das Skelet des Döglings, Hyperoodon rostratus, ein Beitrag zur Osteologie der Cetaceen und zur vergleichenden Morphologie der Wirbelsäule, 1887, pp. 1-175, pl. 1, with figures of the vertebræ.

Pouchet et Beauregard: Recherches sur le Cachalot; Nouvelles Archives du Muséum d'Hist. Nat. de Paris, ser. 3, Mémoires, vol. 1, 1889, pp. 1-96, pls. 1-8, with figures of the exterior, skeletal parts, teeth and their development. *Physeter*. Suite, Mém., vol. 4, 1892, pp. 1-90, pls. 1-12, with figures of the exterior, viscera, etc.

Moreno: Lijeros apuntes sobre dos géneros de Cetáceos fósiles de la República Argentina; Revista del Museo de La Plata, vol. 3, 1892, pp. 13-20, in the separate, pls. 10, 11. *Mesocetus*=*Hypocetus, Notocetus*=*Argyrodelphis.*

Forbes: Observ. on the development of the rostrum in the Cetacean genus Mesoplodon, with remarks on some of the species; Proceed. Zool. Soc. London, 1893, pp. 216-236, pls. 12-15.

Lydekker: Cetacean skulls from Patagonia; Anales del Museo de La Plata, Paleontología Argentina, vol. 2, 1893, pp. 4-8, 12-13, pls. 2, 3, 6. *Physodon* (=*Hoplocetus*), *Hypocetus, Argyrodelphis.*

Moreno: Nota Sobre los restos de Hyperoodontes conservados en el Museo de La Plata; Anales del Museo de La Plata, Seccion Zoologica, vol. 3, 1895, pp. 1-8, pls. 1, 2. *Hyperoodon.* Figures of entire skeletons and of skulls.

Benham: On the anatomy of Cogia breviceps; Proc. Zool. Soc. London, 1901, vol. 2, pp. 107-134, pls. 8-11. See also, on the larynx, Proc. Zool. Soc. London, 1901, vol. 1, pp. 278-300, pls. 25-28.

Benham: Notes on the osteology of the Short-nosed Sperm-Whale; Proc. Zool. Soc. London, 1902, vol. 1, pp. 54-62, pls. 2-4. "*Cogia.*"

Grieg: Bidrag til kjendskab om Mesoplodon bidens; Bergens Museums Aarbog, 1904, No. 3, with figures in the text. Exterior, skull and various skeletal parts.

Abel: Die phylogenetische Entwicklung des Cetaceengebisses und die systematische Stellung der Physeteriden; Verhandl. d. Deutsch. Zool. Gesellschaft, 1905, pp. 84-96.

Abel: Les Odontocètes du Boldérien (Miocène supérieur) d'Anvers; Mém. Mus. Roy. d'Hist. Nat. de Belgique, vol. 3, 1905, pp. 1-155, with figures in the text. Deals largely with the Physeterids, especially with *Scaldicetus* (=*Hoplocetus*), *Thalassocetus, Physeterula, Prophyseter,* "*Placoziphius,*" "*Palæoziphius,*" *Cetorhynchus,* "*Mioziphius*" (=*Xiphirostrum*), "*Choneziphius,*" *Mesoplodon.*

Danois: Recherches sur l'anatomie de la tête de Kogia breviceps Blainv.; Archives de Zoologie expérimentale et générale, ser. 5, vol. 6, 1910, pp. 149-174, pls. 5-8, and with text figures.

True: Descr. of a skull and some vertebræ of the fossil Cetacean Diochoticus Vanbenedeni from Santa Cruz, Patagonia; Bull. Amer. Mus. Nat. Hist., vol. 28, 1910, pp. 19-32, pls. 1-5. *Argyrodelphis.*

True: An account of the Beaked Whales of the family Ziphiidæ in the Collection of the United States National Museum, with remarks on some specimens in other American Museums; Bull. U. S. Nat. Mus., No. 73, 1910, pp. 1-89, pls. 1-42. *Mesoplodon, "Ziphius," "Berardius," Hyperoodon.* Figures of skulls and skeletal parts.

Danois: Recherches sur les viscères et le squelette de Kogia breviceps Blainv. avec un résumé de l'histoire de ce Cétacé; Arch. Zool. expér. et génér., ser. 5, vol. 6, 1911, pp. 465-489, pls. 23, 24.

[Schulte: The skull of Kogia breviceps Blainv.; Bull. Amer. Mus. Nat. Hist., vol. 37, pp. 361-404, pls. 35-43. June 28, 1917.]

[Schulte and Smith: The external characters, skeletal muscles, and peripheral nerves of Kogia breviceps (Blainville); Bull. Amer. Mus. Nat. Hist., vol. 38, pp. 7-72, figs. 1-21. February 23, 1918.]

[Kernan and Schulte: Memoranda upon the anatomy of the respiratory tract, foregut, and thoracic viscera of a foetal Kogia breviceps; Bull. Amer. Mus. Nat. Hist., vol. 38, pp. 231-267, figs. 1-16. April 18, 1918.]

[Kernan: The skull of Ziphius cavirostris; Bull. Amer. Mus. Nat. Hist., vol. 38, pp. 349-394, pls. 20-32. August 1, 1918.]

Cetorhynchus was established by Gervais on remains from Tertiary strata in southern France. The most important fragment was the anterior portion of an under jaw (figured in Ostéographie des Cétacés, pl. 57, fig. 12). The genus is discussed by Abel (Odontocètes du Boldèrien, 1905, pp. 94-98), who refers to it a piece of a lower jaw from the Tertiary deposits at Antwerp. The mandible has a long symphysis menti and a long row of close-placed alveoli for rather large teeth. It is a peculiar fact that the alveoli are not completely separated from each other. Only low transverse ridges separate the teeth at their bases; otherwise the teeth lay in a common groove. Abel thinks that he sees in these conditions a beginning to the peculiarities of the *"Ziphius"* group. Perhaps he is right, but there are still other possibilities.

Anoplonassa probably belongs to the group *Xiphii,* quite likely as a near relative of *Xiphirostrum.* It was described by Cope (Proc. Amer. Philos. Soc., vol. 11, 1871, pp. 188-190, pl. 5, fig. 5) on the basis of the anterior part of the mandible from Tertiary deposits at Savannah, Georgia; but it is best known from a paper by True (Observations on the Type specimen of the fossil Cetacean Anoplonassa forcipata Cope; Bull. Mus. Comp. Zool., vol. 51, 1907, pp. 97-106, pls. 1-3). The fragment in question shows the mandibular rami grown together in a very long symphysis menti. They are staff-shaped, each with a cup-like pit left by a large tooth at the very front, a somewhat indistinct alveolus further back, and also with more or less indistinct traces of other teeth in a degenerate dental groove. Abel (Odontocètes du Boldérien, 1905, p. 92) compares *Anoplonassa* with *Palæoziphius;* but True is no doubt right in finding a greater likeness to *"Mioziphius"* (=*Xiphirostrum*). However, *Anoplonassa* is still too slightly known to be exactly placed.

"Palæoziphius" is established by Abel (Odontocètes du Boldérien, 1905, pp. 90-94, with figure) on the basis of a piece of the anterior end of a lower jaw from the Tertiary at Antwerp. The specimen had previously been referred by others to *Champsodelphis* and by Abel himself doubtfully to *Acrodelphis* (=*Champsodelphis*). The jaw has a long symphysis menti and a long series of alveoli left by good-sized teeth. Abel says of it with great positiveness that it belonged to a member of the family *"Ziphiidæ"* (a group that about corresponds to the *Xiphiini* of the present paper; it was, he thinks, one of the first links in the series that leads from the oldest, many-toothed Ziphiids to the living two-toothed forms. His reason for believing this is that he finds the first and seventh alveoli larger than the others, a condition that he considers a first beginning of the condition found in the recent genera of the group. But in the photograph of the jaw it is impossible to see this difference in the alveoli. There is the greatest possibility of a mistake; and it cannot be asserted with any positiveness where the genus belongs.

"Placoziphius" is established by Van Beneden on the basis of pieces of a skull from the Tertiary deposits at Antwerp (figured in the Ostéographie des Cétacés, pl. 27, fig. 11). It is discussed by Abel (Odontocètes du Boldérien, 1905, pp. 85-88), who considers it a near relative of *Physeter*. In this he is no doubt right, but any final decision is still impossible.

Hypocetus was described as a special genus by Moreno (1892, *l. c.*) under the name *Mesocetus* Moreno (nec Van Beneden). It was called *Hypocetus* by Lydekker (1893, *l. c.,* in title and in explanation of plates, *Paracetus* in text). From Ameghino (Énumération synoptique des espèces de Mammifères fossiles de Patagonie, 1894, p. 181) it received the name *Diaphorocetus*. It is based on a much-broken skull from the Tertiary of Patagonia. Of the genus it can be said that it no doubt belongs to the section *Physeterini* as a rather near relative of *Hoplocetus,* but a more exact opinion is scarcely possible.

Thalassocetus is based by Abel (Odontocètes du Boldérien, 1905. pp. 70-74, with figures) on a few pieces of forehead of skulls from the Tertiary deposits at Antwerp. Abel is no doubt right in considering it a near relative of *Hoplocetus* ("*Scaldicetus*"); but the genus is too slightly known to be definitely placed.

Prophyseter is based by Abel (Odontocètes du Boldérien, 1905, pp. 82-85, with figures) on very imperfect remains from the Tertiary deposits at Antwerp. If the interpretation of the bones is right (whereof, according to the photographs, there seems to be some reason for doubt) the remains represent two pieces (perhaps belonging together) of the left side of a snout-tip, a piece of intermaxillary and a piece of maxillary, both with alveoli but no teeth. Abel believes that *Prophyseter* was a relative of *Hoplocetus* ("*Scaldicetus*"), but that it had gone a step further in the direction of *Physeter,* since the upper teeth had begun to degenerate. This refers to the fact that the alveoli in the intermaxillary appear to be in course of obliteration after the disappearance of the teeth. With regard to this there might be other explanations also. The specimens are too doubtful for anything final to be said about the animal's relationship.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 9

NEOABBOTTIA, A NEW CACTUS GENUS FROM HISPANIOLA

With Four Plates

BY
N. L. BRITTON AND J. N. ROSE

(Publication 2651)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JUNE 15, 1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

NEOABBOTTIA, A NEW CACTUS GENUS FROM HISPANIOLA

By N. L. BRITTON and J. N. ROSE

(With Four Plates)

Among the earliest cacti described were those obtained by Plumier, more than two hundred years ago, mostly from the island of Hispaniola, better known as Santo Domingo. These were characterized briefly by him in 1704 and his illustrations of them were published in 1755 by Burmann; Lamarck gave most of them binary names in 1783 under the genus *Cactus*, and in 1828 De Candolle referred all the cereoid forms to the genus *Cereus;* the other species described by Plumier have been referred by various authors to *Mammillaria, Cephalocereus, Pilocereus, Rhipsalis, Melocactus, Pereskia, Opuntia* and *Nopalea.* We have experienced great difficulty in definitely identifying the plants from the illustrations of Plumier, since these are largely diagrammatic. As the type locality is generally given, however, the identification of all of them may eventually be made fairly definite.

In 1920 when Dr. W. L. Abbott and Mr. E. C. Leonard were starting for Haiti, we asked them to collect both living and herbarium specimens of all the cacti met with. As good fortune directed, they spent a considerable time on the Cul-de-sac, where Plumier collected, and so probably obtained several of the species which he described. About 20 species of cacti were observed by them there. One of these, which has proved to be an undescribed genus, is the subject of this article. The Cul-de-sac is the bottom of an old salt lagoon, which now has an altitude of 20 feet or more above the sea. It is a coral formation and an ideal habitat for many kinds of cacti. Here they appear in thickets or literally as forests, forming the dominant feature of the landscape. This region lies north and east of Port-au-Prince, extending from the bay of Port-au-Prince to Lake Saumatre.

After the return of Dr. Abbott and Mr. Leonard in September of the same year with these valuable specimens we wrote, at the suggestion of Mr. Leonard, to Mr. H. M. Pilkington, an American business man then stationed at Port-au-Prince, asking him to procure additional material. In the latter part of December, 1920, Mr. Pilkington returned to New York and brought with him two large boxes of plants, containing two sections of the trunk, several living plants, and fruits of the new genus, as well as specimens of four other species, with field notes and photographs.

NEOABBOTTIA Britt. and Rose, gen. nov.

A treelike cactus with a smooth upright terete trunk and a much branched top, the branches strongly winged or ribbed, normally from the distal end of the preceding branch, but sometimes from below the tip and usually in the same plane; ribs thin and high, very spiny; flowers nocturnal, small, tubular with a narrow limb, borne several together at the distal end of a terminal branch from a small felted cephalium; perianth persisting on the ovary; perianth-tube and ovary bearing small scales with short wool and an occasional bristle in their axils; perianth-segments very small; throat of flower a little broadened at the top, bearing many stamens; style slender; fruit oblong, turgid, nearly naked, deeply umbilicate; seeds minute, black, muricate.

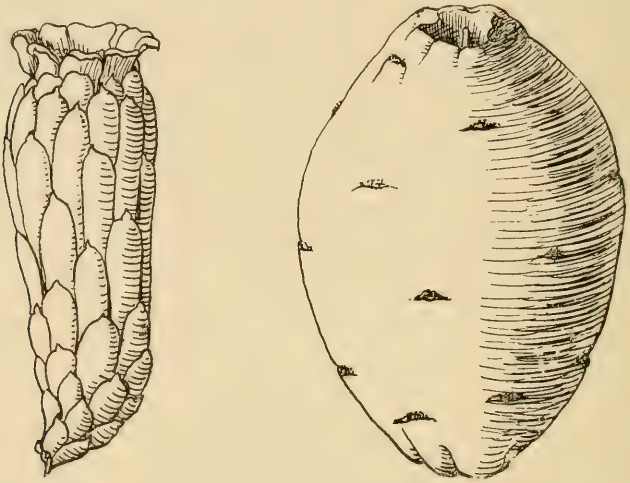

FIG. 1. FIG. 2.

FIGS. 1 and 2.—Flower and fruit of *Neoabbottia*. Natural size.

A monotypic genus of Hispaniola, dedicated to Dr. W. L. Abbott, a patron of natural history.

Type species, *Cactus paniculatus* Lam.

NEOABBOTTIA PANICULATA (Lam.) Britt. and Rose

Cactus paniculatus Lam. Encyl. **1**: 540. 1783.
Cereus paniculatus DC. Prodr. **3**: 466. 1828.

Six to ten meters high or even higher; trunk woody, 30 cm. in diameter, the wood close-grained, yellowish white; bark of the trunk 1.5 cm. thick, brown, not spiny in age, smooth; branches 4 to 6 cm. broad, strongly 4-ribbed, rarely 5-ribbed, occasionally 6-ribbed or winged; ribs thin, 1.5 to 2.5 cm. high, their margins somewhat crenate, the areoles borne at the base of the sinuses, 1.5 to 2 cm. apart; spines 12 to 20, acicular, brownish to gray, 2 cm. long or less; cephalium 1 to 1.5 cm. in diameter, becoming elongated and angled; flowers straight, 5 cm. long, with a limb about 3 cm. broad; tube 6 to 7 mm. long, about 18 mm. in diameter, with walls 5 to 6 mm. thick; inner perianth segments greenish white, short-oblong, about 1 cm. long, obtuse; throat 18 mm. long, covered with numerous filaments, these with a knee near the base and pressing against the style; stamens and style included; ovary and flower tube tubercled, the former with short tubercles, the latter with oblong ones (sometimes 1.5 cm. long), each ending in a depressed areole subtended by a minute scale; areoles bearing a tuft of brown felt and an occasional brown bristle; fruit oblong in outline, 6 to 7 cm. long, 4 to 5.5 cm. in diameter, turgid, nearly naked; rind green, thick, hard; seeds rounded above, cuneate at base, with a large lateral depressed hilum.

Collected near Port-au-Prince, Haiti, on the Cul-de-sac by Dr. W. L. Abbott and Mr. E. C. Leonard, April, 1920 (no. 3500); also at the same locality by Mr. H. M. Pilkington, December, 1920; also a single branch by Dr. Paul Bartsch at Thomazeau in 1917 (no. 221). Here doubtless belongs W. Buch's specimen, described in a note under *Cereus paniculatus* by Dr. I. Urban in his Flora Domingensis.[1]

This plant was described by Plumier[2] as follows: Melocactus arborescens, tetragonus, flore ex albido. This description was repeated by Tournefort,[3] with the addition of a single word, in 1719. Plumier's drawing of this plant was published long after his death by Burmann as plate 192 of the Plantarum Americanum and upon this plate Lamarck based his *Cactus paniculatus,* which De Candolle

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[1] Symbolæ Antillanæ seu Fundamenta Floræ Indiæ Occidentalis, **8**: 462. 1920.
[2] Catalogus Plantarum Americanum, 19. 1703.
[3] Histoire des Plantes, **1**: 653. 1719.

a little later took up as *Cereus paniculatus*. Ever since, the plant has usually passed under the latter name, with an occasional reversal to the earlier one.

Until recently, the species has been known only from this old illustration and these brief descriptions. The Abbott and Leonard material consists of wood sections and herbarium specimens of branches, flowers, fruit, and seeds, supplemented by living specimens and by fruit and flowers in formalin, together with several habit photographs. These convince us that the plant belongs to neither *Cactus* nor *Cereus,* but to an undescribed genus. In habit it resembles *Dendrocereus,* its branches resemble *Acanthocereus,* and the small limb of the flower resembles *Leptocereus;* but the plant differs from all of these in bearing several flowers at the ends of terminal branches and in developing a kind of cephalium. In the last respect it approaches *Neoraimondia,* near which we would place it in our present classification.

Although at first *Neoabbottia* is weak and only 4-angled, suggesting *Acanthocereus,* it forms ultimately a thick woody trunk. The full-grown plant in habit and branches much resembles *Dendrocereus nudiflorus* of eastern Cuba, but it has much smaller and different flowers and seeds.

The following remarks are from the careful field notes of Mr. Pilkington, made in December, 1920.

" Grows to a height of 50 feet, in light sandy arid soil of recent ocean bottom. Known to natives as ' Gadasse.' No use is made of the plant except burning the dead branches for torches. The wood so used is called ' Bois Chandelle ' or ' Bois Flamboyant '—' Candle-Wood ' and ' Flaming-Wood,' from the bright smokeless light. Fruit falls when ripe; rind soon decays, leaving seed in a mass retained in shape by a mucilaginous pulp. The young plant develops a bulbous root with a simple upright stem made up of several joints and later giving off lateral branches which come off from the upper end of other branches; the main stem is 4 to 6-winged, but as it grows older becomes square, pentagonal, or hexagonal, according to the original number of ribs on each joint, and in age terete or nearly so with the ribs showing as mere lines, bearing the scars of the old spines; the branches are more numerous on one side of the main branch and these always lie in the same plane, the ribs when of the same number being opposite those of the main joint. This disposition of the joints causes the main stem to bend or curve and the whole has a striking resemblance to the flat antlers of moose and elk. This arrangement is shown in the mature tree, although the intermingling of the several branches gives the general effect of an ordinary tree-top.

"The natural pruning of the tree comes about through the death of branches caused by epiphytic plants, the breaking off of branches by the weight of a clambering cactus, and the attack of insects which live in the fleshy joints. These insects are much sought after by a red-headed woodpecker.

"Flowers are borne at the extreme tip of the terminal joints and never from the sides, the fruit appearing therefore always at the tips. A single fruit always grows directly in line with a rib, but when several fruits grow from the same terminal bud they are compelled to radiate at right angles to the axis of the joint. Four fruits from one joint is the highest number observed, two only usually appearing to be normal. As the ovary develops the flower shrinks, dries, and appears finally as a brown protuberance attached to the apex of the mature fruit. The old flowers at length fall off the mature fruit, leaving a well-defined umbilicus. The fruit measures 6¾ to 7 inches in circumference. When ripe it is waxy, smooth, yellow with faint streaks of pink radiating from the base; flesh same color as rind, glutinous, firm, slightly acid to taste, hardly edible.

"Seeds are embedded in a secretion which in water produces a remarkable bulk of mucilaginous jelly, which is mildly acid and not unpleasant to taste. Fruit does not seem to be attacked by birds and is never eaten by natives. Successive crops of fruit appear from this same bud cluster at the top of the terminal joint, each crop absorbing some of the substance of the joint; the joint shrinks and solidifies, the ribs become furrows, the center enlarges, and finally all becomes a woody mass of varying dimensions, as long as 3 inches, thus forming what you have called a 'cushion,' but which is really an atrophied joint after several years of fruit-bearing."

The nature of the cephalium is not well understood, but it seems to be an abortive joint. It first appears like a large felted areole from which several flowers are produced; it slowly elongates and finally becomes 7 cm. long or more, still producing the flowers at the tip. When very old most of the felt wears off, leaving a stubby 4 or 5-angled joint; the areoles, however, are not borne on the angles as in normal branches, but in the depressions or furrows between the ridges. In these furrows the areoles form a continuous band of felt from the base to the top of the joint. One of these flower-bearing joints which Mr. Pilkington has sent is 5 cm. long and we have estimated that it has borne 20 sets of flowers and fruits and may possibly be 20 years old. While all the flowers we have seen are terminal, it is possible that they may sometimes occur from other places on the terminal joint. In one specimen examined we have found an enlarged areole near the base and one on the side of the terminal joint, which suggests that they had been flower-bearing. Plumier's illustration, which is not accurate, shows numerous lateral flowers. The stubby flowering joints, while usually solitary, appear sometimes in pairs.

EXPLANATION OF PLATES

Plate 1

Plumier's original illustration of *Neoabbottia paniculata*, reduced; reproduced from plate 92 of Burmann's Plantarum Americanum.

Plate 2

Neoabbottia paniculata (Lam.) Britt. & Rose. A. B. Two types of growth.

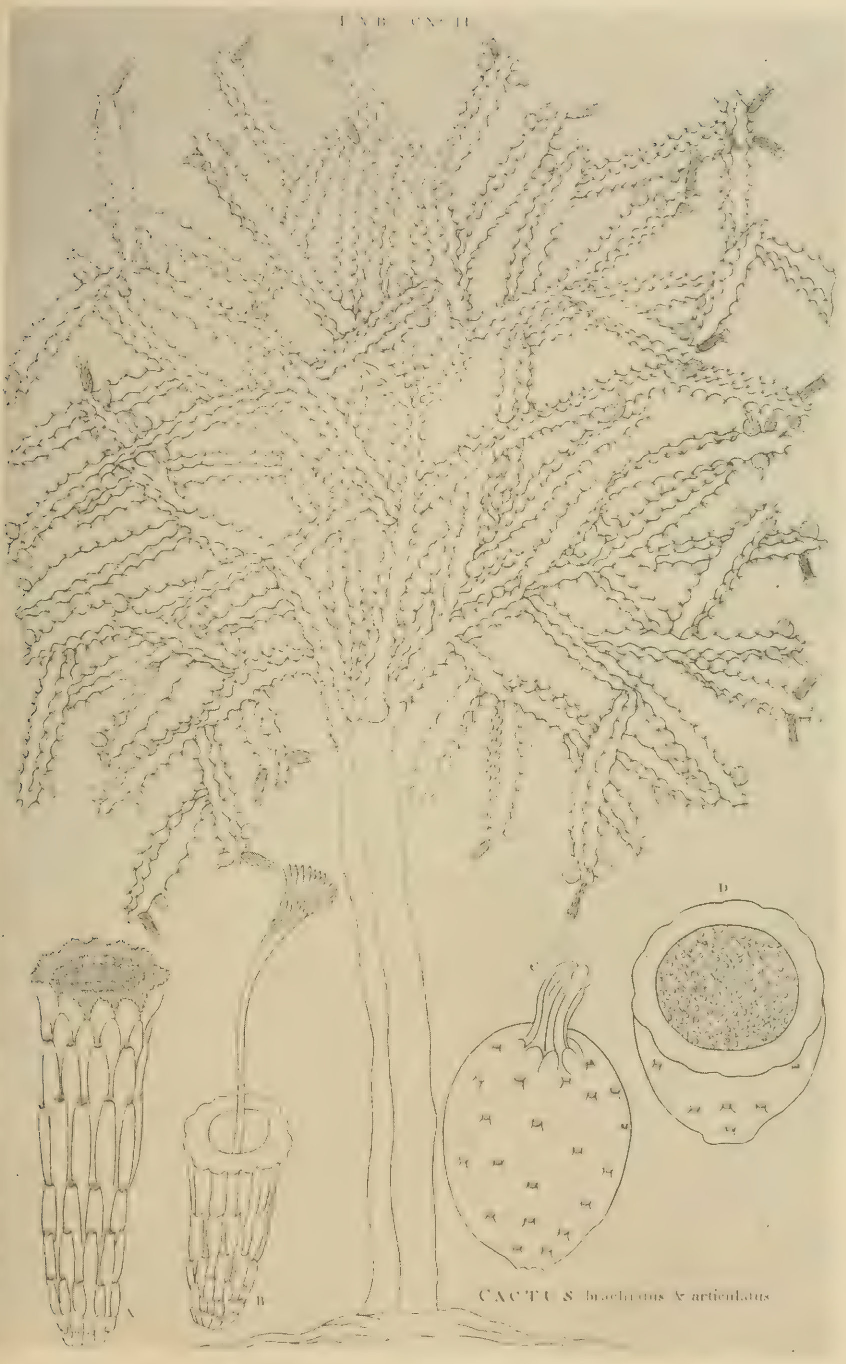
Plate 3

Neoabbottia paniculata (Lam.) Britt. & Rose. A, a plant growing in the open; B, a plant growing in a thicket.

Plate 4

A. *Neoabbottia paniculata* (Lam.) Britt. & Rose. Upper part of a plant.

B. *Neoabbottia* and *Cephalocereus*. a, An elongated branch of *Neoabbottia;* e, a terminal branch of *Neoabbottia*, fruiting for the first time; c and f, stubby branches of the same, which have produced fruit for many years; b and d, small plants of *Cephalocereus polygonus*, growing epiphytically on *Neoabbottia*.

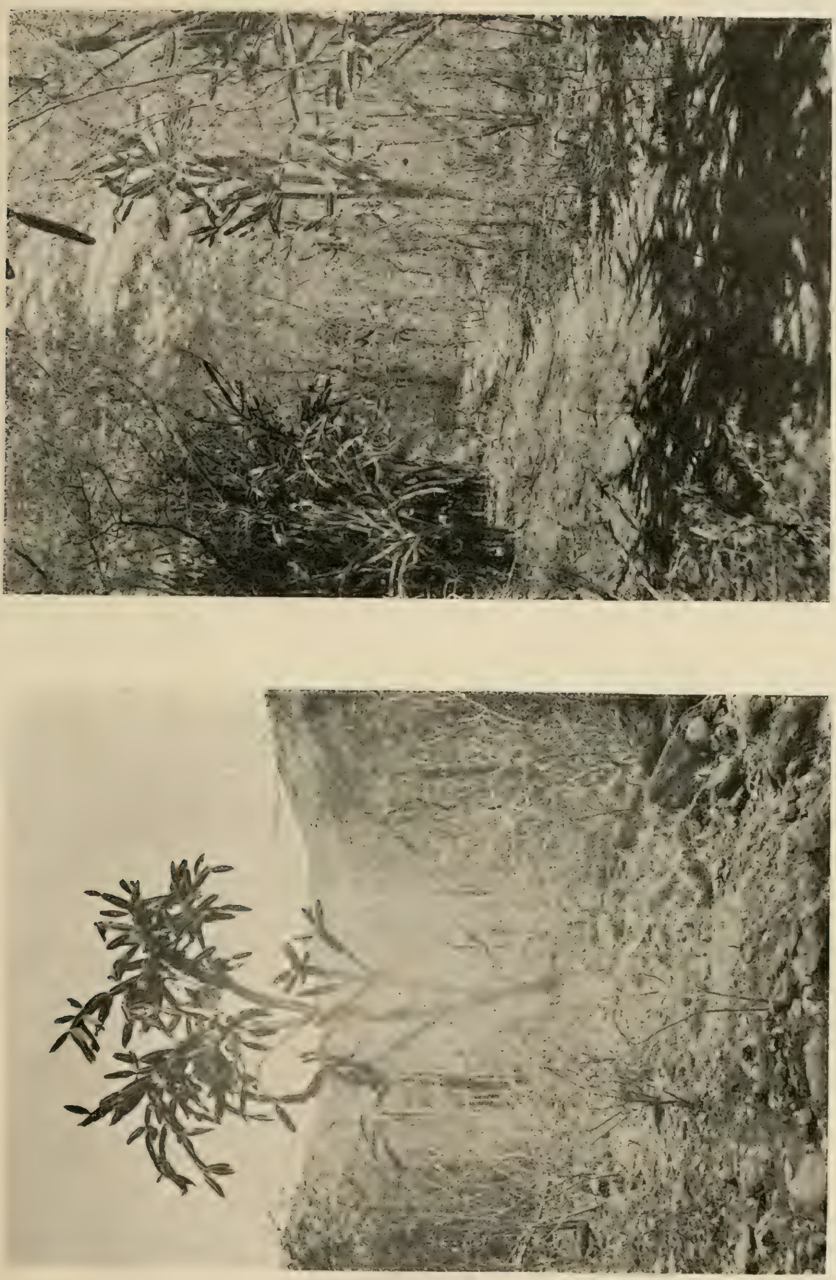


NEOABBOTTIA PANICULATA (LAM.) BRITT. AND ROSE

A

B

Neoabbottia paniculata (Lam.) Britt. and Rose

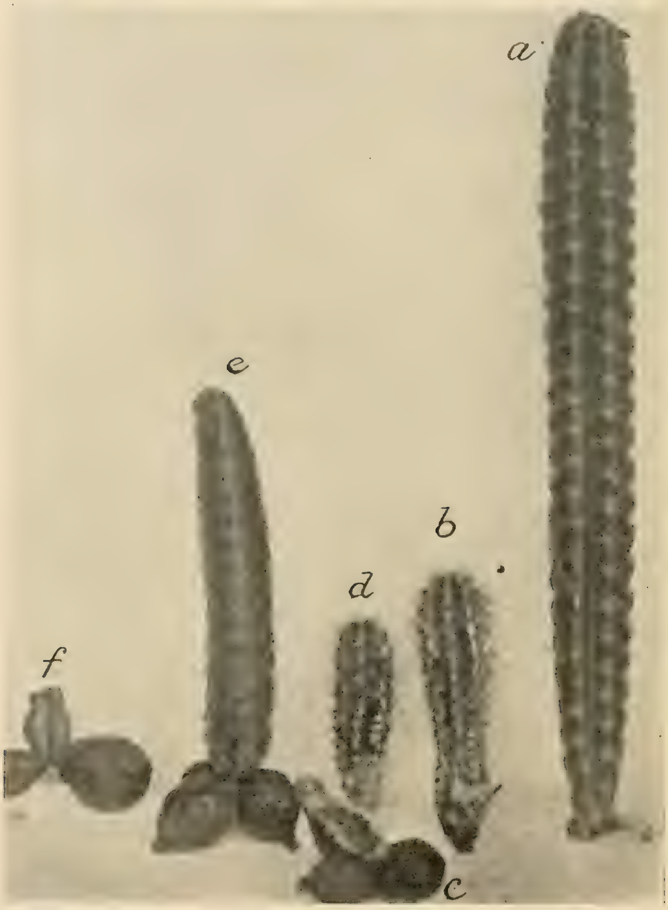


A

B

NEOABBOTTIA PANICULATA (LAM.) BRITT. AND ROSE

A. NEOABBOTTIA PANICULATA (LAM.) BRITT. AND ROSE



B. NEOABBOTTIA AND CEPHALOCEREUS

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 10

THE CIRCULATORY SYSTEM IN BONE

With Six Plates

BY
J. S. FOOTE, M. D.

(Publication 2652)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
AUGUST 20, 1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

THE CIRCULATORY SYSTEM IN BONE

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Omaha, Nebraska

(With 6 Plates)

INTRODUCTION

This article on the circulatory system in bone is the result of a continued study of the comparative histology of bone published in a monograph entitled " A Contribution to the Comparative Histology of the Femur," Smithsonian Contributions to Knowledge, Vol. 35, No. 3, 1916.

In that monograph were described the structural bone types and the type combinations as they were observed in cross sections of the femora of various animals from amphibians to and including man.[1] The circulation within the bone substance was not seen at that time, as cross sections do not show it properly.

In 1919 a casual preparation of a tangential section of the femur of a domestic turkey disclosed a very remarkable circulation in the bone substance and it was this disclosure that led to further examination of tangential sections of the bones of different animals, the drawings and descriptions of which are here presented.

Later (1919-20) the structure of and circulation in the bone of the fish, as seen in the Mascalonge, Esox, were studied, compared with the bone types of later vertebrate animals and added to the list of bones examined.

THE CIRCULATORY SYSTEM IN BONE

The circulatory system in bone, as usually described, is limited to the blood vessels of periosteal membranes, medullary canals and diplöe of long and cranial bones respectively, little being known about the circulation within the bone substance itself.

The circulation described in this article is situated in the bone substance of the mandible and cranial bones of the fish, Mascalonge, Esox, in the walls of the long bones of the amphibian, reptile, bird,

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[1] Number of sections of femora described and drawn in the monograph, 440.

bat, other mammals and man, in the cranial bones of man, in the inner wall of the 9th rib and in the infra- and supra-spinous fossae of the scapula of man. The blood supply of the lower jaw and cranial bones of the fish is derived from the dermal vessels which enter the bone at various points and assume parallel positions in the bone substance, while the blood supply of the long bones of the higher vertebrates comes from two sources, viz. the periosteal vessels which send off many small branches into the bone through entering canals (canals of Volkmann and other canals), and the medullary arteries which pass obliquely through the walls of the shafts into the medullary canals where they divide into ascending and descending branches from which small vessels are sent off into the walls of the bones and here become continuous with the vessels from the periosteum.

The blood supply of the flat bones, such as the cranial, is derived from the vessels of the pericranial and endocranial membranes which send off branches into the outer and inner tables of these bones communicating by way of the central medullary diplöe.

From a study of a large number of bone sections[2] there are found to be three structural types and various type combinations[3] which enter into the formation of bone: these are the first, composed of lamellae; the second, composed of laminae; and the third, composed of Haversian systems. These three types are combined in various proportions in the bones of different animals. The circulations which are found to be present in the different types of bone also present variations which are sufficiently distinctive in character to form two circulatory types, viz., the branching, and the plexiform. The branching type, composed of tree-like branches, is found in the first type bones, the plexiform, composed of small, large and irregularly shaped meshes enclosed by small vessels, is found in the second and third type bones, while combinations of the branching and plexiform circulations are present in structural type combinations.

In the demonstration of the circulations some difficulty arises in the preparation of the bone slides. In small animals like the frogs or other animals of the same size it is practically impossible since the long bones are almost always round and tangential sections of them are necessarily flat. In large animals the long bones have flat areas of sufficient extent to make satisfactory slides.

In the preparation of bone sections for the purpose of showing the circulation, a flat surface of bone is selected and as large a piece as

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[2] Number of sections of bones examined up to the present, 1000.

[3] A Contribution to the Comparative Histology of the Femur, by J. S. Foote, M. D., Smithsonian Contr. to Knowl., Vol. 35, No. 3, 1916.

possible is sawed out, tangential to the diameter of the bone, and ground down to a suitable thinness which is determined by the appearance of the circulation.

It is not the thinnest possible section, measured in microns, that is most desirable, but one of sufficient clearness to show the circulation. During the grinding process it is necessary to examine the section at short intervals in order to ascertain just when to terminate the process.

The following sections taken from the bone of fish, amphibian, reptile, bird, mammal, and man have been studied, described, and drawn for the purpose of showing the structure and the circulation which belongs to it.

CROSS AND TANGENTIAL SECTIONS OF THE LOWER JAW AND TANGENTIAL SECTION OF THE CRANIAL BONE OF THE MASCALONGE, ESOX, A FISH OF WISCONSIN WATERS

CROSS SECTION OF A PORTION OF THE LOWER JAW

Pl. 1, Fig. 1a

The section is composed of parallel disks of bone substance situated between vascular channels or clefts. The bone substance does not show the presence of lacunae with their canaliculi. Very minute parallel canaliculi extend across the disks from one channel or cleft to another. A wave effect is given to the section by the undulating forms of the clefts. This arrangement of channels in the bone substance produces a very fine channel circulation. At short intervals within the clefts, as at C, figure 1, plate 1, may be seen small objects from which radiate minute canaliculi presenting the appearance of the canaliculi radiating from their lacunae, but these are in the vascular clefts and not in the bone substance.

TANGENTIAL SECTION OF A CRANIAL BONE OF THE MASCALONGE

Pl. 1, Fig. 1b

In this section are seen parallel rows of objects of various shapes situated in the bone substance. Some of them are circular with dark crescents on one side, while others are very irregular in shape. No canaliculi extending outward from them can be seen. For this reason they cannot be lacunae in the bone substance, as osteoblasts occupying such lacunae would be without a blood supply. On account of their general circular character these objects appear to be different sections of the vascular clefts of the bone and if any bone-producing cells are present they must be within the vascular clefts.

CROSS SECTION OF ANOTHER PORTION OF THE LOWER JAW OF THE MASCALONGE SHOWING THE EARLY DIFFERENTIATIONS OF HAVERSIAN SYSTEMS

Pl. 1, Fig. 2

These are small vascular canals surrounded by clear areas—in some instances lamellated, in others, homogeneous. Between the vascular canals is the bone substance with very fine channels. The vascular canals with surrounding clear areas become Haversian systems as vascular differentiation progresses. This early form of Haversian differentiation has a wide distribution since it is found in bone sections from fish to and including man. It is much more prominent in the lower orders of vertebrates than in the higher. Thus two early phases of the circulation are found in the bone of the mascalonge, viz., the channeled and early Haversian differentiation.

TANGENTIAL SECTION OF THE INNER RIDGE OF THE LOWER JAW OF THE MASCALONGE SHOWING THE BLOOD VESSELS

Pl. 1, Fig. 3

The blood vessels vary in size. They are parallel with each other. Some are branching. Around the outside of their delicate connective tissue walls are seen fine plexuses of nerves. Between the vessels is seen a fine channeled bone substance without lacunae.

CROSS AND LONGITUDINAL SECTIONS OF THE FEMUR OF A MEDIUM SIZED BULLFROG, RANA CATESBEIANA

(The large, medium sized and small bullfrogs have different degrees of bone differentiation.)[4]

CROSS SECTION SHOWING THE STRUCTURE

Pl. 1, Fig. 4

The type of bone is an early first. The inner wall is composed of bone substance in which are radiating, vascular, bush-like channels extending from the external to the internal circumferential lamellae and between which are round or oval lacunae with short branching canaliculi embedded in the bone substance and communicating with the bush-like radiations by means of their canaliculi. The bush-like vascular radiations appear to be segmented in some instances due to their oblique positions and the plane of the cross section. In the outer wall these radiating channels are absent and the bone is composed of lamellae with oval lacunae and radiating canaliculi.

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[4] *Idem.*

LONGITUDINAL SECTION OF THE SAME FEMUR SHOWING THE CIRCULATION

PL. 1, FIG. 5

The oblique entering canals in the shafts of the femora of bull frogs, for the passage of the medullary arteries, are found in the bone of the large and medium sized but not in the small animals. As the femur of the frog is small and round the circulation in a tangential section could not be seen. The general plan, however, is shown in a longitudinal section of the inner wall as represented in figure 5, plate 1. The letter C is placed at the center of the shaft. In this wall are two sets of six or seven oblique vascular canals entering the shaft from the periosteal surface and united in such a manner as to form slanting m-shaped converging loops. These loops, beginning near the extremities of the shaft, converge toward the lineal center and medullary surface. From these loops and their stems minute canaliculi are sent off into the bone substance where they communicate with the lacunae. Between the two sets of converging loops are short segments of loops extending across the wall transversely. In the outer wall the loops are not seen in longitudinal section nor are the radiating vascular channels seen in the cross section of this wall.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF THE REPTILE, ALLIGATOR MISSISSIPPIENSIS

CROSS SECTION SHOWING THE STRUCTURE

PL. 1, FIG. 6

This section is composed of three wide, concentric rings of incompletely differentiated Haversian systems alternating with two narrow, concentric laminae. The vascular canals surrounded by clear areas similar to those seen in the bone of the fish are early forms of Haversian systems. The laminae are more advanced in differentiation than the Haversian systems. The bone, as a whole, shows an early second and third type structure.

TANGENTIAL SECTION OF THE SAME FEMUR, SHOWING THE CIRCULATION

PL. 1, FIG. 7

The circulation is in the form of a vascular plexus. The section is situated below the periosteal surface near the posterior ridge. Several entering canals, without surrounding lamellae, are seen in cross section in the bone substance through which periosteal vessels pass into the bone. The vascular plexus is very extensive and has a general longitudinal direction. The meshes are irregular in size and shape. In some portions of the section vascular expansions are found. The blood vessels are round and occupy similarly shaped channels in the bone substance. They are composed of very thin connective tissue walls, without smooth muscle, and are striated spirally and longitudinally. The exact purpose of the vascular expansions is not clearly understood. They are found too frequently to be accidental, and, as will be noted later, are more prominent in the branching than in the plexiform types of circulation. They may have an important physical value.

CROSS AND TANGENTIAL SECTIONS OF A SECOND TYPE BONE OF BIRDS AS SEEN IN THE FEMUR OF A DOMESTIC TURKEY, MELEAGRIS GALLOPAVO

CROSS SECTION SHOWING THE STRUCTURE

Pl. 1, Fig. 8

The section is composed of concentric laminae separated and crossed by vascular canals. The wall of the bone is divided into nearly equal segments by large radiating canals extending from the medullary canal to the periosteal surface. From these canals are sent off lateral, small, parallel canals which divide the wall of the bone into laminae. The laminae are interrupted in the anterior wall and posterior ridge by incompletely differentiated Haversian systems. It was the femur of the turkey which first called attention to the variations in structure and circulation.

TANGENTIAL SECTION OF A FEMUR OF THE TURKEY, SHOWING CIRCULATION

Pl. 1, Fig. 9

This section consists of a very rich, small-meshed plexus of vessels situated between the laminae and having a general longitudinal direction. In the central portion of the section two plexuses can be seen, one above the other, with a lamina of bone between them. This is one of the most extensive circulations observed in long bones and with such a blood supply as is here shown, this becomes a vascular organ of great importance.

RECONSTRUCTION OF A SECOND TYPE BONE WITH ITS INTERLAMINAR CIRCULATION

Pl. 2, Fig. 10

This figure shows a reconstruction of a second type bone with its circulation. The drawing represents three concentric laminae with two interlaminar plexuses of blood vessels. The vessels are uniform in size, composed of thin connective tissue walls and the vascular expansions are not at all prominent. It is difficult to understand why such a rich blood supply should be required in bone for its nutrition.

CROSS AND TANGENTIAL SECTIONS OF AN EARLY DIFFERENTIATION OF A THIRD TYPE BONE IN BIRDS AS SEEN IN THE FEMUR OF A TURKEY BUZZARD, CATHARTES AURA SEPTENTRIONALIS

CROSS SECTION SHOWING THE STRUCTURE

Pl. 2, Fig. 11

This bone is more advanced in differentiation than that of the domestic turkey since it is composed of third type structural bone units instead of the second. These units are enclosed between the external and internal circumferential lamellae and form nearly the whole bone structure.

TANGENTIAL SECTION OF THE FEMUR OF THE SAME ANIMAL SHOWING THE CIRCULATION

Pl. 2, Fig. 12

The meshes of the circulatory plexus are longer and enclose larger bone areas than those seen in the femur of the turkey. The vascular expansions are not as prominent as they are in some of the other bones, but may be seen here and there. A general plexiform plan of circulation is evident, but an elongation of the meshes in the central portion shows a slight variation in the circulatory distribution.

TANGENTIAL SECTION OF THE FEMUR OF A DOMESTIC CHICKEN, GALLUS

Pl. 2, Fig. 13

The type of structure is a first and early third. Several entering canals without surrounding lamellae are present. The circulation appears as a rich plexus of small blood vessels coming off from a central vessel which extends lengthwise of the section. The meshes of the plexus are small, round, oval or irregular in shape and the lacunae of the bone substance are round or oval with short, branching canaliculi.

TANGENTIAL SECTION OF THE FEMUR OF A PRAIRIE CHICKEN, TYMPANUCHUS AMERICANUS, SHOWING THE CIRCULATION

PL. 2, FIG. 14

The type of bone is first. A few entering vascular canals, without surrounding lamellae, are seen in the bone substance. The circulation is a rich plexus of blood vessels with small, round and irregularly shaped meshes. It is situated nearer the periosteal than the medullary surface. The lacunae of the bone substance are round or oval and have short bushy canaliculi.

TANGENTIAL SECTION OF THE FEMUR OF A DOMESTIC DUCK, ANAS DOMESTICA, SHOWING THE CIRCULATION

PL. 2, FIG. 15

The type of bone is an early second. The section has two rich plexuses of blood vessels, one above the other, with bone substance between them. The meshes are quite regular in form and somewhat larger than those found in the other birds examined. Here and there are seen entering vascular canals without surrounding lamellae. The lacunae of the bone substance are round or oval with short bushy canaliculi.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF A FRUIT BAT, PTEROPUS (CELEBES)

CROSS SECTION SHOWING THE STRUCTURE

PL. 2, FIG. 16

The section is composed of a wide central ring of lamellae perforated in the inner wall by a few vascular canals extending lengthwise of the bone. Internal circumferential lamellae surround the medullary canal and poorly differentiated external lamellae surround the section. The lacunae are oval with straight canaliculi.

TANGENTIAL SECTION OF THE SAME FEMUR SHOWING THE CIRCULATION

PL. 2, FIG. 17

In this section are seen the vascular canals of the inner wall extending from above downward and inward. The canals are parallel with each other and some of them are branched. They were absent in the outer wall.

CROSS AND TANGENTIAL SECTIONS OF A SECOND TYPE BONE IN MAMMALS AS SEEN IN THE FEMUR OF A LAMB, OVIS

CROSS SECTION SHOWING THE STRUCTURE

Pl. 2, Fig. 18

The section is composed of concentric laminae which are more completely differentiated than they are in birds. Here and there the laminae are interrupted by Haversian systems of a late differentiation and the concentric canals between the laminae are widened at intervals and around them are incompletely differentiated lamellae forming an early aberrant type of Haversian system. The posterior ridge is composed of Haversian systems of a late differentiation.

TANGENTIAL SECTION OF THE FEMUR OF THE SAME ANIMAL SHOWING THE CIRCULATION

Pl. 2, Fig. 19

The circulatory plan of arrangement in this bone is not precisely like that observed in the second type bone in birds. While it is plexiform in character there is about it more or less irregularity in distribution approaching the branching type of circulation. Near the sides of the drawing the plexus has a long mesh; while in the central portion it has more of a branching character. The vascular expansion seen in the center of the drawing gives the impression of a distributing point in the circulation. A few entering vascular canals are seen.

CROSS AND TANGENTIAL SECTIONS OF ANOTHER SECOND TYPE BONE IN MAMMALS AS SEEN IN THE FEMUR OF THE MEXICAN BURRO

CROSS SECTION SHOWING STRUCTURE

Pl. 2, Fig. 20

The section is composed of concentric laminae interrupted by Haversian systems of different degrees of differentiation. The structure is similar to that seen in the femur of the lamb and a large number of other mammals which have the same type bone.

TANGENTIAL SECTION OF THE FEMUR OF THE SAME ANIMAL, SHOWING THE CIRCULATION

Pl. 2, Fig. 21

The type is plexiform and the meshes of the plexus are much more regular in shape than those seen in the femur of the lamb. There is no evidence of a branching character. The vascular expansions are not as prominent as they were in the femur of the lamb.

TANGENTIAL SECTION OF THE FEMUR OF AN ELK, ALCES AMERICANUS, SHOWING THE CIRCULATION

Pl. 3, Fig. 22

The type of bone is second. Several perforations in the bone substance for the passage of blood vessels are present. Some of them are surrounded by enclosing lamellae and some are not (Volkmann's canals). The circulation is an extensive plexus of blood vessels with round and irregularly shaped meshes. It has a general direction lengthwise of the bone.

TANGENTIAL SECTION OF THE FEMUR OF A BELGIAN HARE, LEPUS, SHOWING THE CIRCULATION

Pl. 3, Fig. 23

The type of bone is an early second and third. Entering vascular canals through which blood vessels are seen to pass and ramify in the bone substance are present in the central portion of the section. The canals are not surrounded by lamellae. The circulation is a combination of a branching and plexiform distribution. The vascular expansions are prominent. One is seen in a vessel shortly after entering the bone. It is a matter of observation in bone circulations that the type of circulation varies with the type of structure.

TANGENTIAL SECTION OF THE FEMUR OF A BULLDOG, SHOWING THE CIRCULATION

Pl. 3, Fig. 24

The type of bone is second and third. Entering vascular canals, without enclosing lamellae, are seen in the bone substance through which blood vessels are passing. The circulation is a dense branching and plexiform combination. The vessels are small in diameter, frequently branching, the union of their branches producing a plexiform effect.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF A MONKEY, MACACA RHESUS

CROSS SECTION SHOWING THE STRUCTURE

Pl. 3, Fig. 25

The type of bone is first and third. The section is composed of lamellae interrupted by Haversian systems of early and late differentiations. Crescents of late Haversian differentiation are found bordering upon the medullary canal in the anterior inner and posterior outer wall. The lacunae of the bone are long with straight canaliculi. The principal structure is lamellar and the type is much more first than third.

TANGENTIAL SECTION OF THE SAME FEMUR, SHOWING THE CIRCULATION

Pl. 3, Fig. 26

A few entering vascular canals without surrounding lamellae are present. The circulation is a dense branching type which, here and there, presents a slight appearance of the plexiform distribution. The blood vessels are large and trunk-like in places and a very few vascular expansions are present.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF A 9 MONTHS' HUMAN WHITE FETUS

CROSS SECTION SHOWING THE STRUCTURE

Pl. 3, Fig. 27

The section is composed of short laminae with central canals widening and shortening until they are transformed into Haversian systems. External circumferential lamellae surround the section (posterior wall excepted) and directly underneath the lamellae is a row of advanced differentiations of Haversian systems. The medullary canal is small, irregular in shape and situated in the anterior half of the section. The posterior wall is composed of Haversian systems of advanced differentiations and in the mid line where the walls of the bone unite is a narrow radiating layer of bone substance which disappears as complete union takes place.

TANGENTIAL SECTION OF THE SAME FEMUR SHOWING THE CIRCULATION

Pl. 3, Fig. 28

The circulation is plexiform in type, the general direction of which is longitudinal and slightly oblique. The vessels forming the plexus have short branches which seem to disappear in the bone substance within the meshes. Vascular expansions are present, one being shown in the left central portion of the figure.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF A WHITE CHILD 9 YEARS OLD

CROSS SECTION SHOWING THE STRUCTURE

Pl. 3, Fig. 29

The type of bone is first and third. Around the periphery of the section is a wide crescent shaped band of lamellae enclosing numerous vascular canals of the earliest Haversian differentiation, such as were observed in the bone of the fish, plate 1, figure 2. Around the medullary canal are the internal circumferential lamellae forming an enclosing ring of irregular widths. Within this ring are also found vascular canals of early Haversian differentiation extending longitudinally. Between the external and internal lamellae above described, is a ring of Haversian systems of late differentiation, deficient in the anterior wall and increasing in width in the outer lateral wall as it reaches the posterior ridge. The lacunae are long and narrow with straight canaliculi.

TANGENTIAL SECTION OF THE SAME FEMUR SHOWING THE CIRCULATION

Pl. 3, Fig. 30

Entering canals with and without enclosing lamellae are of frequent occurrence. The circulation is a combination of the branching and plexiform types. The central portion is branching and the lateral, plexiform, vascular expansions are not as prominent as they are in many other sections. The section shows the circulatory combination of type conforming to the structural type combination.

CROSS AND TANGENTIAL SECTIONS OF THE FEMUR OF ADULT MAN, A WHITE MALE

CROSS SECTION SHOWING THE STRUCTURE

Pl. 4, Fig. 31

The bone is third type in differentiation with the exception of a portion of the anterior wall where the remains of first type bone are found. The section is composed of completely differentiated Haversian systems, some of which are senile. The external circumferential lamellae are fragmentary, while the internal are complete.

TANGENTIAL SECTION OF THE SAME FEMUR, SHOWING THE CIRCULATION

Pl. 4, Fig. 32

The type of circulation is plexiform with wide, irregularly shaped meshes. Entering vascular canals surrounded by lamellae are seen here and there in the section. Vascular expansions are prominent. This section is taken from the bone represented in plate 4, figure 31, near the periosteal surface of the left side of the drawing and near the posterior ridge. It is difficult to think of the circulation as shown in plate 4, figure 32, as belonging to that locality.

TANGENTIAL SECTION OF THE FEMUR OF MAN, A WHITE MALE, SHOWING CIRCULATION

Pl. 4, Fig. 33

The type of bone is first and third. Numerous entering vascular canals with and without enclosing lamellae are present. The circulation is a dense branching and plexiform distribution of blood vessels with small meshes of various shapes. Vascular expansions are numerous and large. The lacunae of the bone substance are round, oval, and long and narrow with the canaliculi which belongs to each degree of differentiation. The density of the circulation varies in different bones of the same structural type and also in bones of different type combinations.

TANGENTIAL SECTION OF THE FEMUR OF MAN, A WHITE MALE, SHOWING THE CIRCULATION

Pl. 4, Fig. 34

The type of bone is first and third. The type of circulation is branching, changing to plexiform. Entering canals, for the most part without enclosing lamellae, are few in number in this section. The circulation shown in the drawing is situated in the external lamellae which encloses the internal third type differentiation. It is a large branch dividing into many small ones which, by uniting, form a plexiform distribution.

TANGENTIAL SECTION OF THE FEMUR OF MAN, A WHITE MALE, AGE 50, WHO DIED OF PULMONARY TUBERCULOSIS

Pl. 4, Fig. 35

The type of bone is third. The type of circulation is essentially branching although a coarsely plexiform arrangement can be distinguished. Entering canals with and without enclosing lamellae are seen in the bone substance. The blood vessels are irregular in size and shape and show varicose enlargements very frequently. Whether or not this varicose condition and irregularity in the circulation in bone are indices of similar changes in the general circulation cannot be told; but they may be thought of in connection with the pathological condition present in this individual.

THE CIRCULATION IN FLAT BONES

CROSS, LONGITUDINAL, AND TANGENTIAL SECTIONS OF A HUMAN FRONTAL BONE

CROSS SECTION SHOWING THE STRUCTURE

Pl. 4, Fig. 36

The bone is composed of outer and inner tables united by a central cancellous diplöe. The two tables are composed of first type bone enclosing a few Haversian systems in cross section and a few short segments of blood vessels. The diplöe is a coarse, cancellous bone with large, small, and irregularly shaped cavities enclosed by first type bone walls. The walls are composed of lamellae in which Haversian systems are seen in cross section. This section was taken from the vertical portion of the frontal bone.

LONGITUDINAL SECTION OF THE SAME FRONTAL BONE, SHOWING THE STRUCTURE

Pl. 4, Fig. 37

This section has practically the same structure as the cross section, as may be seen by comparing the drawings. This section is cut at right angles to that seen in plate 4, figure 36. It is taken from the same region, and Haversian systems, in cross section, are found in both situations. The Haversian systems therefore run at right angles to each other, which can hardly be accounted for on mechanical grounds.

TANGENTIAL SECTION OF THE OUTER TABLE OF THE SAME FRONTAL BONE TAKEN FROM THE SAME REGION AS FIGURE 36, PLATE 4, SHOWING THE CIRCULATION

Pl. 4, Fig. 38

The section is situated nearer the external surface of the bone than the diplöe. Numerous entering canals with and without enclosing lamellae are found in the bone substance. The circulation is branching in type. The vascular expansions are large and numerous and appear to form physical centers of distribution. The blood vessels are relatively large and frequently branch.

ENTERING VASCULAR CANALS OF THE OUTER TABLE OF THE FRONTAL BONE

Pl. 5, Fig. 39

There are two forms, the one at the left in the drawing without enclosing lamellae (Volkmann's canals), and the one at the right with enclosing lamellae. The Volkmann's canals are smaller than the others. As soon as the blood vessels pass through the external surface of the bone they send off branches into the planes of their divisions and form the branching distributions there.

TANGENTIAL SECTION OF THE INNER TABLE OF THE SAME FRONTAL BONE, SHOWING THE CIRCULATION

Pl. 5, Fig. 40

In this section the bone is perforated by numerous entering canals with and without enclosing lamellae. The blood vessels from the cerebral surface enter the bone by these canals and find their way to the diplöe. The circulation within the bone is branching in type and situated nearer the cerebral surface than the diplöe. Many vascular expansions are present with their incoming and outgoing vessels.

TANGENTIAL SECTION OF THE OUTER TABLE OF A HUMAN PARIETAL BONE, SHOWING THE CIRCULATION

Pl. 5, Fig. 41

The section is taken from the central portion of the bone. The type of bone is first. Entering vascular canals surrounded by lamellae are numerous. The circulation is branching in type. Vascular expansions are large and numerous. Those in the center give the impression of distributing points in the circulation.

TANGENTIAL SECTION OF THE INNER TABLE OF THE SAME PARIETAL BONE SHOWING THE CIRCULATION

Pl. 5, Fig. 42

The section is situated nearer the cerebral surface than the diplöe. Entering vascular canals with enclosing lamellae are numerous. The circulation is branching in type and not as dense as that of the outer table. The vascular expansions are many and large. The type of bone is first.

TANGENTIAL SECTION OF THE SQUAMOUS PORTION OF THE TEMPORAL BONE OF MAN, SHOWING THE CIRCULATION

Pl. 5, Fig. 43

The type of bone is first. Entering canals with and without enclosing lamellae are present. The circulation is branching in type and the vascular expansions are large and very numerous. The expansions vary in size and frequency of occurrence in different sections. In some instances they are very small and few in number, in others, large and numerous, and they are much more prominent in the branching than in the plexiform type of circulation. They are especially prominent in this section.

TANGENTIAL SECTION OF THE OUTER TABLE OF A HUMAN OCCIPITAL BONE, SHOWING THE CIRCULATION

Pl. 5, Fig. 44

The section is taken a short distance above the foramen magnum. The circulation is a dense branching type situated near the external surface of the bone. There are many vascular expansions from which branching vessels take their departure. Entering canals with and without surrounding lamellae are present in the first type bone substance.

TANGENTIAL SECTION OF THE INNER TABLE OF THE SAME OCCIPITAL BONE, SHOWING THE CIRCULATION

Pl. 5, Fig. 45

The type of bone is first. Entering canals with and without surrounding lamellae are numerous. The section is situated near the cerebral surface. The circulation is branching in type and very dense in character. Large branches extend in different directions and from these, small branches are sent off into the bone substance. The vascular expansions are not as numerous as those in the outer table, figure 44.

TWO VASCULAR EXPANSIONS AS THEY WERE SEEN IN THE OUTER TABLE OF THE OCCIPITAL BONE

Pl. 5, Fig. 46

The vascular expansions are observed in all branching and in many sections of the plexiform type of circulation. They are nearly always filled with fat globules with dark, wide contours which are so closely faceted together that they completely occupy the expansion cavities. This would, of course, block the circulation if it existed in the living bone. The condition was misleading in significance until it was noticed that the fat globules were found in ground sections and not in thin unground bone plates; so that they are probably produced by the melting heat of friction during the grinding process and fill the expansions. The expansions probably have a physical value as distributing centers in the circulation or they may be for the purpose of establishing and maintaining a circulatory equilibrium in bone.

TANGENTIAL SECTION OF A HUMAN INFERIOR MAXILLA, SHOWING THE CIRCULATION

Pl. 5, Fig. 47

The section is taken from the bone just in front of and below the left central incisor tooth. The type of bone is first. Entering canals with and without lamellae are present. The circulation is a branching plexiform type having a slanting direction from above downward and forward. The meshes are long and irregular in shape. Vascular expansions are numerous.

TANGENTIAL SECTION OF THE INFRA-SPINOUS FOSSA OF A HUMAN SCAPULA, SHOWING THE CIRCULATION

Pl. 6, Fig. 48

The type of bone is first with here and there an Haversian system. A few entering canals with enclosing lamellae are seen in the section. The circulation is a branching and plexiform type, the former predominating. Vascular expansions are prominent. The one in the center of the drawing suggests a distributing center.

TANGENTIAL SECTION OF THE SUPRA-SPINOUS FOSSA OF THE SAME SCAPULA, SHOWING THE CIRCULATION

Pl. 6, Fig. 49

The type of bone is first. A few entering canals with and without surrounding lamellae are present. The circulation is branching in type with a few vascular expansions. It takes an oblique direction from above downwards and toward the vertebral border.

CROSS AND TANGENTIAL SECTIONS OF THE 9TH RIB OF ADULT MAN, MALE WHITE

CROSS SECTION SHOWING THE STRUCTURE

Pl. 6, Fig. 50

This is a third type bone composed of Haversian systems of a late degree of differentiation. The systems extend lengthwise of the rib and enclose a cancellous center.

TANGENTIAL SECTION OF THE INNER WALL OF THE SAME RIB, SHOWING THE CIRCULATION

Pl. 6, Fig. 51

The section is taken from the posterior third of the bone. The circulation is an elongated plexus. In the center of the section is a vascular expansion which suggests a center of distribution for the blood vessels.

DEVELOPMENTAL ADVANCES IN THE CIRCULATION DETERMINE THE STRUCTURAL TYPES OF BONE

It is generally supposed that bone is preeminently mechanical in function on account of its position in the body and its rigid character. It forms the skeleton of the animal body, supports its weight, gives attachment to muscles by means of which locomotion is possible, serves as a framework upon which the viscera are hung, affords protection and gives efficiency to the laboratory of chemical activities constantly in operation during life. It is chiefly for these reasons that we attribute a mechanical function to bone. This thought is further strengthened by the microscopic structure so familiar to us either from personal observation or from text books of histology, in both of which bone is represented, usually, as composed of Haversian systems.

There are however, as shown before, three structural types of bone, the first, second, and third.

The first type is composed of bone substance or lamellae, the second of laminae which are produced by a vascular separation of lamellae into parallel divisions, and the third, of Haversian systems which are produced by arranging lamellae around small central vascular canals called Haversian canals. The Haversian system, therefore, is the most complex and highly organized bone unit. The types of structure follow the advancing changes in the circulation, since the second type bone is not recognizable until the first has been separated into laminae by parallel vascular canals. There are two general types of circulation, the branching and the plexiform, each one giving an individual character to the type of bone it produces. Bone derived from connective tissue membranes retains the branching circulation of those membranes, while bone derived from cartilage has the plexiform circulation.

In going from a branching to a plexiform type of circulation, the type of bone advances from the first to the second or third. The blood supply in a plexiform circulation is greater in volume than it is in a branching circulation, for the reason that there are more blood vessels in a given area in the former than in the latter. This increased blood supply adds an increased physiological value to the bone units of structure and is the foundation of advancement in tissue values: so that blood supply is determined by the extent, plan of distribution, or type of circulation and the type of tissue, physiologically considered, by the blood supply, or in this particular instance, the type of bone is determined by the type of circulation.

THE STRUCTURAL UNITS OF BONE—FIRST, SECOND, AND THIRD, OR LAMELLAE, LAMINAE, AND HAVERSIAN SYSTEMS—ARE NOT ESSENTIALLY MECHANICAL

If all bones were Haversian system bones, or, if there was any one bone which always has Haversian systems as the predominating structural units, no matter in what individual it was found, we might be convinced that their constant presence was sufficient evidence of a mechanical function. But when we know that there are three bone units of structure and that no one of them is constantly present in bones of different animals as the only unit, and not even in bones of individuals of the same birth,[5] the idea of a purely mechanical function of bone is severely shaken if not abandoned. The three units, the lamella, lamina, and Haversian system, are found in bones of various animals in such great proportional and locational confusion that their mechanical purposes disappear and we are obliged to look further for an explanation of their strange and unexpected occurrences.

Again, if we examine these units from a mechanical viewpoint and then observe their locations in the bones of different animals we will find that they are *not* always found where the same mechanical conditions would require them and are very often found where they could serve no mechanical function of any importance. Lamellae are layers of bone substance, laminae are strata composed of lamellae, and Haversian systems are hollow cylinders composed of a variable number of lamellae enclosing a central canal. Of the three units, therefore, the Haversian systems offer the most mechanical service by construction and are the best adapted to support weight, withstand muscular stress, and serve the general requirements of a skeleton. We would, then, naturally expect to find them constantly present in such long bones as the femur, tibia and fibula of quadrupeds and bipeds and generally absent from the flat bones of the head and face. But in these respects we are disappointed. They are found, as a pure type, in the long bones of only a few mammals and are absent as predominating units in the long bones of a large number of mammals including the three races of man, black, yellow-brown and white.[6] Haversian systems in their later degrees of differentiation are not found at all in amphibians, reptiles, birds, bats, monotremes, marsupials and many of the edentates, although the same mechanical functions are demanded by their vocational habits. In the femur, tibia, fibula, humerus, radius, ulna, clavicle, metacarpal and metatarsal bones of man, they are present as predominating

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[5] *Idem.*

[6] *Idem.*

units in some and occur very infrequently in other individuals. In the flat bones of the cranium and in the irregular bones like those of the pelvis a few are found where it is difficult, if not impossible, to understand how they could perform any mechanical function of any value.

In the human frontal, parietal and occipital bones, a few Haversian systems may be found at right angles to each other; in the squamous portion of the temporal bone they extend vertically; in the hard palate, antero-posteriorly; in the superior and inferior maxillae, horizontally; in the spine of the scapula, horizontally; in the crest of the ilium horizontally; and in the ribs horizontally. In these different situations the mechanical functions of the Haversian systems do not seem to answer any requirement which is common to them all. Furthermore, they are not invariably found in these situations and even may not be present at all. Their presence or absence or situation within the bone is more satisfactorily explained if we assume that developmental advances in the circulation determine the types of bone.

CONCLUSIONS

A study of the circulations as they were observed in the foregoing slides leads one to the following conclusions:

1. That a cross section of bone gives no idea of the plan of circulation.

2. That there are two types of circulation, the branching and the plexiform, and these are seen only in tangential sections.

3. That the plan of circulation in bone derived from connective tissue is branching; derived from cartilage, plexiform.

4. That the circulation in a first type bone is branching, in the second and third, plexiform.

5. That the plexiform is a more advanced type of circulation than the branching and represents a later plan of vascular distribution and a more advanced degree of bone differentiation.

6. That bone is a very vascular organ.

7. That blood vessels are composed of extremely thin and finely striated connective tissue walls, without smooth muscle, occupying canals in the bone substance.

8. That vascular expansions occur in bone circulations and, by their positions, suggest equalizing blood pressures and uniformity in the circulation.

9. That developmental advances in the circulation determine types of bone.

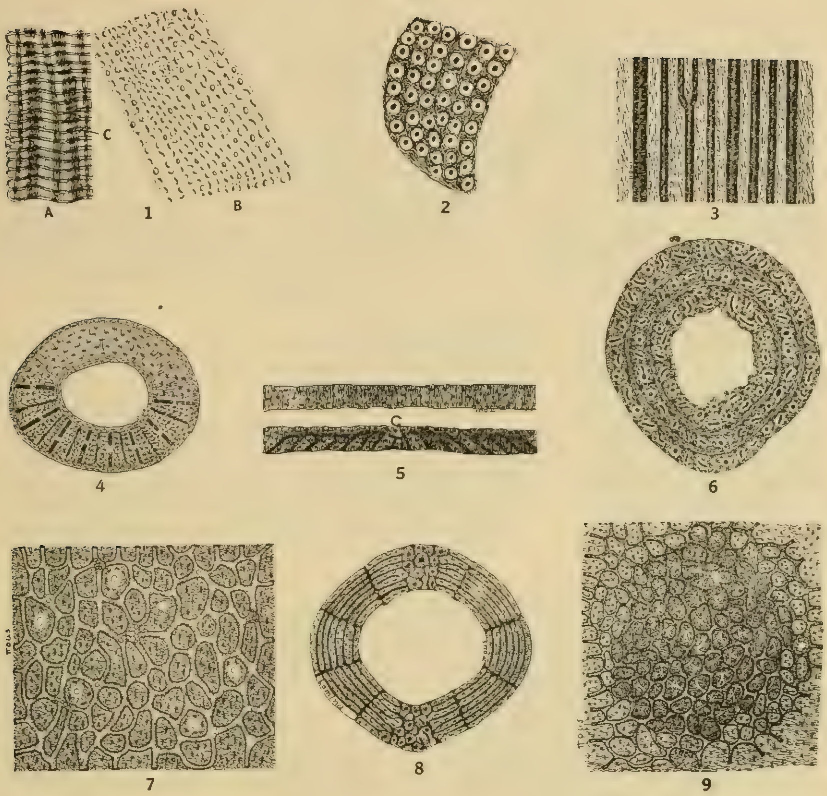

FIG. 1. A. Cross section of the bone substance of the lower jaw of a Mascalonge, Esox, showing vascular channels.
1. B. Tangential section of a cranial bone of the Mascalonge, showing parallel rows of small objects in the bone substance.
2. Cross section of the lower jaw of the Mascalonge, showing the early differentiation of Haversian systems.
3. Tangential section of the inner ridge of the lower jaw of Mascalonge, showing the circulation.
4. Cross section of the femur of a medium sized bullfrog, Rana catesbeiana, showing the structure.
5. Longitudinal section of the femur of a medium sized bullfrog, Rana catesbeiana, showing the looped vascular canals of the inner wall. C, center of the shaft.
6. Cross section of the femur of an alligator, Alligator mississippiensis, showing the structure.
7. Tangential section of the same, showing the circulation.
8. Cross section of the femur of a domestic turkey, Meleagris gallopavo, showing the structure.
9. Tangential section of the same, showing the circulation.


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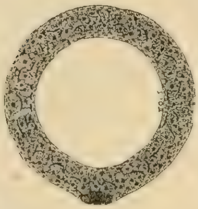
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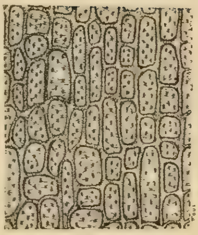
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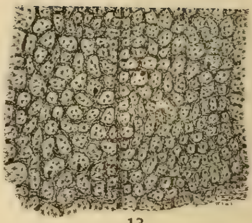
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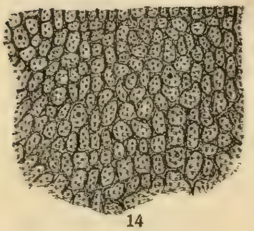
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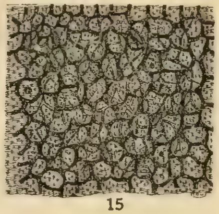
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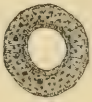
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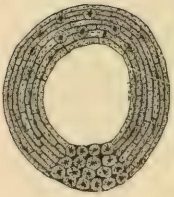
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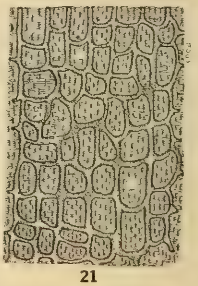
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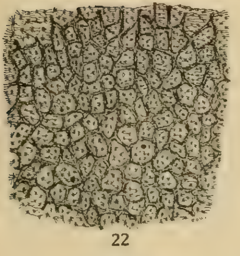
FIG. 10. Reconstruction of a second type bone with its circulation.
11. Cross section of the femur of a turkey buzzard, Cathartes aura septentrionalis, showing the structure.
12. Tangential section of the same, showing the circulation.
13. Tangential section of the femur of a domestic chicken, Gallus, showing the circulation.
14. Tangential section of the femur of a prairie chicken, Tympanuchus americanus, showing the circulation.
15. Tangential section of the femur of a domestic duck, Anas domestica, showing the circulation.
16. Cross section of the femur of a fruit bat, Pteropus (Celebes), showing the structure.
17. Tangential section of the same, showing the circulation.
18. Cross section of the femur of a lamb, Ovis, showing the structure.
19. Tangential section of the same, showing the circulation.
20. Cross section of the femur of a Mexican burro, showing the structure.
21. Tangential section of the same, showing the circulation.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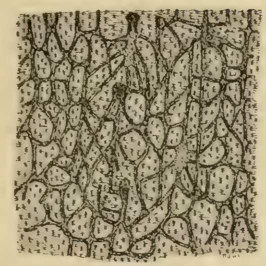
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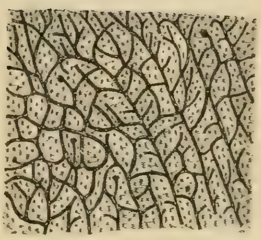
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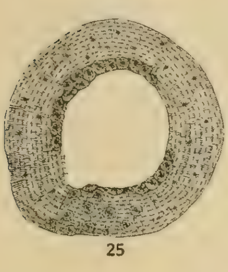
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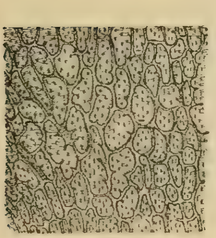
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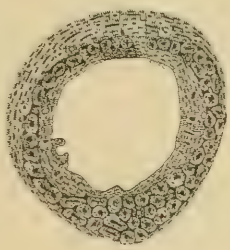
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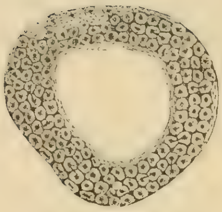
FIG. 22. Tangential section of the femur of an elk, Alces americanus, showing the circulation.
23. Tangential section of the femur of a Belgian hare, Lepus, showing the circulation.
24. Tangential section of the femur of a bulldog, showing the circulation.
25. Cross section of the femur of a monkey, Macaca rhesus, showing the structure.
26. Tangential section of the same, showing the circulation.
27. Cross section of the femur of a 9 months fetus (human), showing the structure.
28. Tangential section of the same, showing the circulation.
29. Cross section of the femur of a white child 9 years old, showing the structure.
30. Tangential section of the same, showing the circulation.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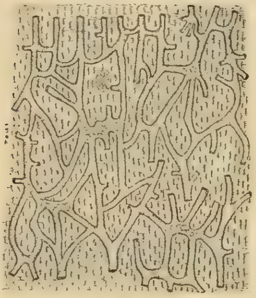
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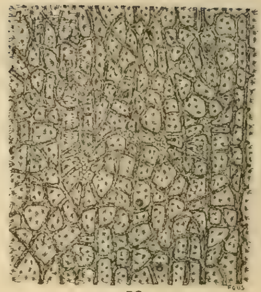
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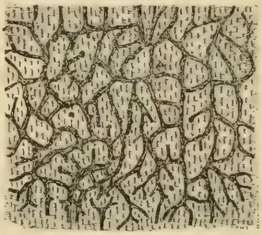
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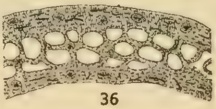
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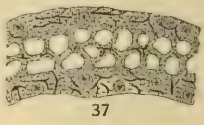
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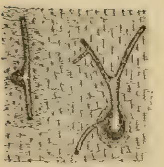
FIG. 31. Cross section of the femur of an adult white male, showing the structure.
32. Tangential section of the same, showing the circulation.
33. Tangential section of the femur of an adult white male, showing the circulation.
34. Tangential section of the femur of an adult white male, showing the circulation.
35. Tangential section of the femur of an adult white male, age 50, who died of pulmonary tuberculosis, showing the circulation.
36. Cross section of a human frontal bone, showing the structure.
37. Longitudinal section of the same, showing the structure.
38. Tangential section of the outer table of the same bone, showing the circulation.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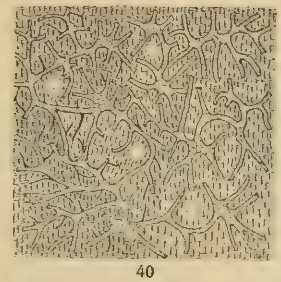
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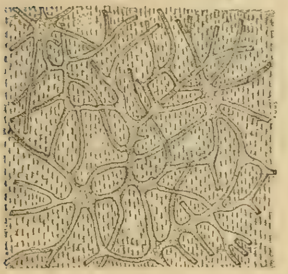
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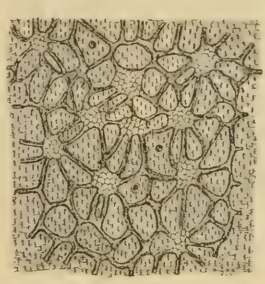
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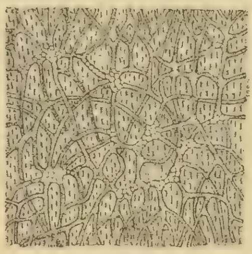
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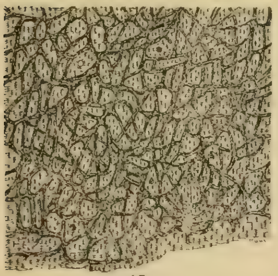
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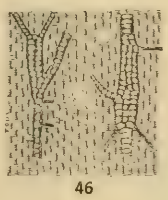
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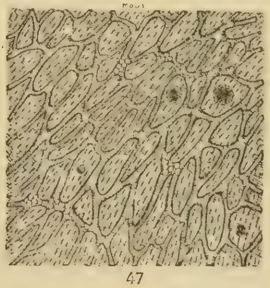
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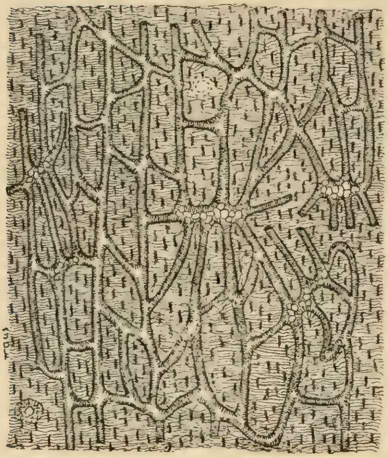
FIG. 39. Entering vascular canals of outer table of a human frontal bone.
40. Tangential section of the inner table of the same bone, showing the circulation.
41. Tangential section of the outer table of a human parietal bone, showing the circulation.
42. Tangential section of the inner table of the same bone, showing the circulation.
43. Tangential section of the squamous portion of a human temporal bone, showing the circulation.
44. Tangential section of the outer table of a human occipital bone, showing the circulation.
45. Tangential section of the inner table of the same bone, showing the circulation.
46. Vascular expansions filled with fat globules as seen in outer table of occipital bones.
47. Tangential section of human inferior maxilla in front of and just below left central incisor tooth, showing the circulation.



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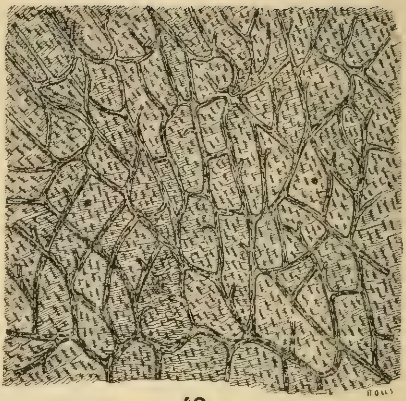

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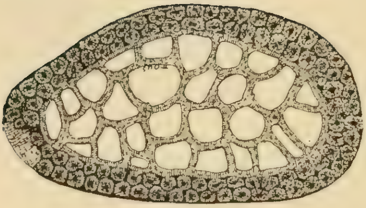

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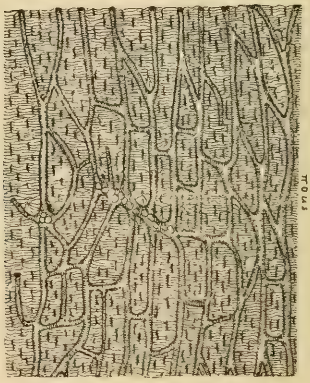

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FIG. 48. Tangential section of the infra-spinous fossa of a human scapula, showing the circulation.

49. Tangential section of the supra-spinous fossa of the same bone, showing the circulation.

50. Cross section of the 9th rib of an adult white male, showing the structure.

51. Tangential section of the same bone, inner wall, showing the circulation.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 11

THE ECHINODERMS AS ABERRANT ARTHROPODS

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(PUBLICATION 2653)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JULY 20, 1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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PREFACE

Of all the larger animal groups there is none which has been the subject of such diversified opinion regarding its affinities and systematic position as the Echinodermata. Originally assumed to be related to the cœlenterates on account of their radial symmetry, the echinoderms were later placed near the flat-worms, the annelids and the chordates. At present they are regarded as representing a very distinct and isolated group, some considering them as allied to the chordates, while others emphasize their points of similarity with the annelids; most zoologists, however, are reluctant to commit themselves regarding their probable affinities.

For many years I have been convinced that the echinoderms are by no means such anomalous creatures as they appear to be, and that, in spite of their many and extraordinary peculiarities, they are undoubtedly closely allied to the crustaceans, and especially to the barnacles. In the following pages the reasons for this belief are given.

THE DOMINANT CHARACTERISTICS OF THE ECHINODERMS

The echinoderms are very anomalous forms, and their relationships to other animals are masked not only by a highly perfected radial symmetry, but also by a unique development of all the organs of the body. Their outstanding features are the presence of a vascular, a respiratory, and a superficial skeletal system, the last composed of articulated (calcareous) elements, the absence of gill clefts, and the sharp division of the body externally into (five radial) segments. In these features they agree only with the arthropods.

THE LARVÆ OF THE ECHINODERMS

The unique larvæ of the echinoderms, which are of very varied types, vermiform, bean-shaped with five ciliated rings and a long anterior tuft of cilia, auriculariæ, bipinnariæ, brachiolariæ, plutei, etc., and differ more or less widely among themselves in the details of their development, are always at first bilaterally symmetrical, which may be accepted as an indication that the echinoderms are derived from bilaterally symmetrical ancestors.

The larvæ do not grow directly into the adults, but the latter for the most part arise from new growth within the larval body, the structures peculiar to the larvæ being absorbed; in a few cases the development is direct.

There is little in the structure or in the development of the echinoderm larvæ which is comparable to the structure or to the development of the larvæ of any other animals, and it is evident that the extraordinary features exhibited by the adult echinoderms have been projected so far forward in the ontogeny as quite to destroy the value of the larvæ as phylogenetic indices.

THE CHANGE FROM MID-SOMATIC TO INTER-SOMATIC DEVELOPMENT IN THE CRINOIDS

Perhaps the most interesting feature connected with the morphology of the crinoids, and one which it is necessary especially to emphasize in order to understand the relationships between them and the other echinoderms, is the abrupt change in the regions of bodily growth and extension which takes place beginning with the formation of the arms. It is this sudden change from interradial to radial, or from mid-somatic to inter-somatic, development which occurs at the commencement of arm formation that has always proved the chief stumbling block in the way of a correct interpretation of these animals.

In the echinoderms the primary appendages, the teeth, the water pores, and the genital openings, and in the crinoids the primary nerve cords as well, are all interradial in position. There can be no doubt, therefore, that the dividing lines between the five half somites fall in the middle of the so-called radial areas, and in the echinoids and asteroids a sharp line of division is always maintained down the middle of the radial series of plates throughout life, while no such dividing line is found in the interradial regions.

In the young crinoids each of the somatic regions is completely walled in by two large superposed plates, a dorsal basal and a "ventral" oral; beneath the basals there are usually 3-5 small infrabasals alternating with them and corresponding with the oculars of the echinoids which, since they are entirely absent in large groups, and are usually more closely associated with the column than with the calyx, are probably to be interpreted as a dissociated columnal.

The young crinoid therefore has its body protected by ten large somatic shields, five dorsal and five ventral, the latter with the primitive appendage under the median line.

The arms first appear as evaginations in the intersomatic lines at the plane of separation between the dorsal and ventral plates. The evidence is that the skeleton of the arms is double, half being derived from the somite on either side; but whatever may be the ultimate genesis of their skeleton, the arms arise as linear and almost immediately biramous appendages taking their origin from the intersomatic planes.

From this point onward the development of the animal is entirely intersomatic; the peristome and its underlying nerve ring, the water tube ring about the mouth, the blood vascular ring, the genital cord, and the cœlomic cavities all send off radial branches which increase in length as the arm grows, while along either side of the peristomial extensions (ambulacral grooves) there is formed progressively a continuous series of reduplications (ambulacral lappets) of the little flaps with their associated tentacles, the latter in communication with the radial water tube, which surrounded the mouth in the "prebrachial" stage.

THE NERVOUS SYSTEM OF THE ECHINODERMS

In the chordates the central nervous system never becomes separated by mesodermal tissues from the tract of ectoderm from which it originated in the embryo. Sedgwick remarks that this is a feature of all echinoderms in so far as the ventral nervous system is concerned, and when this nervous system is removed from the surface the removal is effected by invagination.

But the only nervous system found in the echinoderms which in its details is at all comparable to the central nervous system of the other higher invertebrates is the so-called apical nervous system of the crinoids, which first forms relatively late in life, and which appears to arise in connection with the cœlomic epithelium.

It seems to me that this nervous system of the crinoids, which is possibly (though not by any means probably) represented by the so-called mesodermal nerve plexus in the starfishes, but which is quite unrepresented in the other echinoderms, affords the best indication of the probable affinities of these animals, and at the same time its high state of development suggests that the crinoids have departed less widely from the ancestral type than have the other classes.

In the developing crinoid the ectoderm of the surface of the body becomes more or less disintegrated, and its cells to a greater or lesser extent pass inward and intermingle with the cells of the underlying mesoderm so completely that they can in no way be distinguished from them, the body wall being formed of an ectoderm-mesoderm complex in which the cells of the two types cannot be differentiated.

On the inside of this body wall, apparently in connection with the cœlomic epithelium, the apical nervous system arises; but in view of the mixed nature of the component cells of this wall it seems not illogical to assume that this apical nervous system is in reality formed from cells which, originally ectodermal, have infiltrated through the underlying mesoderm and now appear as if they belong to the cœlomic epithelium. If this hypothesis can be accepted it is obvious that the apical nervous system of the crinoids is in no way comparable to the nervous system of the chordates, and as this is the only echinodermal nervous system comparable with the nervous system of other animals it naturally follows that no affinity with the chordates can be inferred from the nervous system of the other echinoderms.

In the crinoids the larvæ become attached by the ventral side of the anterior end, and the column is a development of the preoral lobe, arising therefore from the place where in the larvæ the anterior nerve mass, just in front of the mouth, is situated. The mouth moves from the ventral surface onto the left side and then migrates upward, away from the point of attachment, until it comes to lie at the pole opposite the latter, that is, at the posterior end near the anus.

The larval nerves disappear; but some time after the torsion of the animal is completed a new nerve mass forms in exactly the place that the preceding nerve mass occupied, now become the point just above the top of the column. It is thus natural to assume that the central mass of the apical nervous system in the adult crinoid, appearing in the region previously occupied by the anterior nerve mass of the larval crinoid, corresponds to it, and therefore that it represents the anterior nerve mass in other invertebrates. But as a result of the torsion which the animal has undergone the right cœlomic sac has become extended anteriorly and, following the enteric wall, has reached over onto the left side; from its anterior end it gives off five anteriorly directed diverticula which at a later stage become cut off and give rise to the chambered organ about which the central nerve mass forms a close and almost complete investment.

The central nerve mass gives off five stout cords which immediately branch, the two branches from each being connected by one or two commissures, and then joining the similar branches from the nerve trunks on either side to form the radial nerves of the division series and arms. In each segment of the arms and pinnules, the nerve cord gives off from a ganglionic swelling four branches, two dorsolateral and two ventrolateral. In addition to these nerve cords, which may be either single or double, and are in some types represented by two widely separated parallel cords, each cirrus in its central canal contains a prolongation from the chambered organ ensheathed in nerve fibers continuous with those of the central nervous mass, and five similar prolongations from the chambered organ and the central nerve mass extend downward into the stem.

THE ECHINODERM CŒLOME

Much has been made of the fact that in the echinoderms the cœlome is enterocœlic in origin, as in the Brachiopoda, Chætognatha, Chordata, and probably the Phoronida, while in the developing molluscs, annelids and arthropods the cœlome is not enterocœlic in origin.

Sedgwick notes that in all the chordates except the tunicates the cœlome in its first state in the embryo shows more or less marked traces of three divisions, the anterior or proboscis cœlome, which in the Vertebrata and Enteropneusta is single and in *Amphioxus* double; the collar or middle cœlome, which is always double, and the trunk cœlome, which is double and which in the Vertebrata and in *Amphioxus* becomes metamerically segmented. In the echinoderms there seem to be indications, at least, of a similar tripartite division:

there is the anterior cœlome, which is sometimes single (*Asterina*) and sometimes double (*Echinus*), the hydrocœle, which is probably fundamentally double, though in some cases (holothurians and crinoids) only one hydrocœle sac is formed, and the posterior cœlome, which is always paired. But in those chordates in which the enterocœlic origin of the cœlome is clearly presented these three divisions of it always come off from the enteron separately, while in the echinoderms the enteron at most gives off only one pair of cœlomic sacs; and whereas in the chordates the middle (collar) cœlome is never more closely associated with the anterior than with the posterior, in the echinoderms it is always closely associated with the anterior cœlome, being developed from it and remaining connected with it by the stone canal throughout life.

Whatever its origin the cœlome is clearly homologous in all these types so that the manner of its development may be considered as due to special mechanical or other limitations imposed by conditions in the early stages—size, form, amount of yolk, etc.—and not to phylogenetic causes.

THE WATER VASCULAR SYSTEM

The most extraordinary structure of the echinoderm body is the water vascular system. This arises as a narrow dorsolateral outgrowth from a portion of the cœlome which unites with an ectodermic infolding on the anterior aboral surface. From this develop the stone canal and the madreporites. The ectodermic opening places the hydrocœle in communication with the exterior, so that the organ has often been compared, in whole or in part, to an annelid excretory organ or nephridium.

But Professor Patten has pointed out that it is much more like one of the typical excretory organs of the arthropods (shell gland, green gland, coxal gland) which consist of thin walled cœlomic sacs with a thick walled tubular outgrowth of varying length united to a short duct infolded from the ectoderm.

The five primary tentacles or tube feet of the echinoderm larva according to Professor Patten represent five modified thoracic appendages; an outgrowth of the underlying somite grows into each appendage in typical arthropod fashion, but instead of breaking up into separate muscles for the appendage it remains permanently in the form of a membranous diverticulum of the hydrocœle and becomes the distal end of a radiating water vascular canal. Only the distal end of the original appendage separates from the body as the primary tentacle; the remainder of the appendage, however long it may eventually become, may be regarded as lying in the surface ectoderm, developing on either side as it increases in length paired cirri which become the double row of tube feet for each arm into each of which a prolongation of the water vascular canal extends.

Primarily, then, each of the five primitive thoracic appendages, one from each of the five half metameres of which the echinoderm body is composed, contains a tube of nephridial intent leading into a canal opening to the exterior by a pore. The anterior and posterior ends of the series of half metameres join, and the excretory canal becomes a ring canal from which grow out five long radial canals giving off branches to the tentacles or tube feet as these are formed.

The excretory function of the water vascular system of the echinoderms is reduced to a minimum if, indeed, it can be said to exist at all. Its action is chiefly that of an hydraulic system whereby power originating in a great number of weak and dissociated muscle fibers scattered along and within the water tubes and their branches is unified and transmitted to the hollow tube feet, tentacles, and other appendages, while at the same time the constant inflow and outflow of water through the madreporic openings, especially when these communicate with the body cavity as they do in the gill-less crinoids, undoubtedly serve to a greater or lesser extent the purpose of respiration.

THE ECHINODERM VASCULAR SYSTEM

The vascular system, which is especially well developed in the holothurians and echinoids, is formed of a peculiarly modified connective tissue in which the fibers are sparse and which contains intercommunicating spaces without an epithelial lining. The fluid in these spaces does not appear to undergo any definite movement. Typically there is a circumoral tract with radial prolongations which lie between the radial water vessel and the radial nerve cord, an annular aboral tract in which the generative rachis is embedded and which sends off extensions to the genital organs, and in holothurians and echinoids a considerable development in the mesentery and on the gut wall.

In the barnacles no heart is ever present, and the lacunar channels in which the blood circulates are for the most part ill defined.

THE ECHINODERM SKELETON

MacBride and others have remarked that the presence of calcified skeletal tissue in the mesoderm of the body wall is a character found in the echinoderms and vertebrates only among cœlomate animals. It does not seem to me that this can be considered as any indication of affinity between these groups.

Many vertebrates have uncalcified mesodermal skeletons, and others have only partially calcified skeletons. The uncalcified skeleton of the notochord resembles in structure the parenchyma of the solid tentacles of certain cœlenterates, and is quite different from anything found in the echinoderms. Calcareous deposits of greater or lesser extent occur in the mesoderm of barnacles, brachiopods, rotifers and cestodes, as well as in the mesoglœa of sponges, and the calcareous skeletal structures of some cœlenterates are mesodermal in origin.

In certain of the early cystideans the skeleton appears to have been wholly or chiefly chitinous, and their surface exactly resembles that of the phyllopod and other crustaceans preserved in the same rocks. It is not improbable, therefore, that the calcareous exoskeleton of the echinoderms of the present seas developed from a chitinous body covering through an exoskeleton composed of chitin with an increasingly greater amount of inorganic matter such as we see today in most of the larger crustaceans.

In the developing crinoid the ectoderm of the surface of the body more or less completely disintegrates and its component cells largely pass inward and intermingle with the cells of the underlying mesoderm, so that in the crinoid the outermost layer of the body is almost as much mesodermal as it is ectodermal. This being the case, no matter what its phylogenetic relationships and tendencies are, the formation of an ectodermal skeleton has now become impossible as there is no continuous ectoderm from which to form it. A calcareous mesodermal skeleton appears, the first rudiments of which are formed in the deeper layers but soon move to a more superficial position enclosing the body in a calcareous investment formed of large and definite plates. Just before the appearance of the arms there are, in addition to the columnals, 13-15 thin cribriform films lying just below the surface and fitted edge to edge, including 3-5 infrabasals, 5 basals alternating with them, and 5 orals superposed upon the latter.

Now although this skeleton is mesodermal and calcareous, the relations between it and the enclosed body of the animal are entirely different from the relations between the vertebrate skeleton and the body organs, being on the contrary quite like the relations between the chitinous or more or less calcified skeleton of the arthropods and their enclosed body. The crinoid skeleton is a superficial (though not external) skeleton enclosing the body and giving off articulated appendages; it therefore resembles the skeleton of the arthropods more closely than it does that of any other animals. The fact that it is mesodermal and calcareous seems to me to be, in view of its development in every way like an ectodermal chitinous exoskeleton, and especially in view of the fact that it lies outside of the ventral nervous system which runs along or just within its inner surface, of purely secondary significance.

Crinoids are undoubtedly descended from animals with an articulated exoskeleton, and their articulated superficial skeleton is calcareous instead of chitinous as would be expected solely because of the disintegration of their ectoderm in the young stages.

In the arthropods we find in the sessile barnacles the beginnings of a transition from a chitinous exoskeleton to a calcareous mesodermal superficial skeleton, and from the conditions in these animals it is not difficult to supply the connection between the crustacean and the crinoid skeleton.

AUTOTOMY IN THE CRINOIDS

The crinoids with more than ten arms increase the number of their arms by breaking off the larval arms at the base, the stump forming an axillary from which two or more arms arise. This is primarily due to the inability of the brachial skeleton, a rigid calcareous investment of the dorsal and dorsolateral portions of the arm, to keep pace with the other brachial structures in development, and is therefore distantly comparable to the moulting so characteristic of the arthropods.

THE APPENDAGES OF THE CRINOIDS

The appendages in the crinoids are of two kinds. From the base, and always in connection with the chambered organ and the central nerve mass of the apical nervous system, arise uniserial jointed appendages ending in a strong hook. These are especially developed in crinoids unprovided with a stem, and serve both as tactile organs and for attachment. In their position as anterior organs and in their function as tactile and grasping organs, as well as in their uniserial structure, they recall the antennæ of the barnacles.

About the ventral surface there are five long arms typically forking at the base, thus representing biramous ventrolateral appendages and calling to mind the biramous thoracic appendages of the barnacles.

There can be no question of any direct homology between the cirri of crinoids and the antennæ of barnacles, or between the thoracic appendages of barnacles and the arms of crinoids, but both sets of organs have the same functions and the same location in each group, and are constructed on a similar plan, so that it is not impossible to regard them as parallel manifestations of the same ancestral appendicular plan, a plan not occurring in the animal kingdom outside of the arthropods and crinoids.

CHARACTERS OF A HYPOTHETICAL CRINOID WITH MID-SOMATIC DEVELOPMENT ONLY

Let us imagine a crinoid with entirely mid-somatic development and with entire instead of half somites, that is, with bilateral instead of radial symmetry. We would have a body composed of five broad somites each covered with a broad arched plate (tergum) to the edge of which is articulated a flap (oral, corresponding to a pleuron); within this would be the radial (epimeron) at the inner edge of which arises a biramous appendage. A body with five terga and five pairs of biramous appendages with their bases covered by pleura from which they are separated by epimera would certainly be considered as crustacean in character, and if it were attached by the head end, with the mouth upward, it would unhesitatingly be pronounced a barnacle, its deficiencies and anomalies of organization being ascribed to degeneration.

THE CRINOIDS AND THE BARNACLES

The crinoid develops from a highly anomalous larva, with a so-called vestibule suggesting a partial development of a bivalved covering, which attaches itself by the anterior end like the cypris larva of a barnacle and turns a half somersault bringing its mouth upward and opposite the point of attachment, also like a barnacle; so far its development equally well suggests that of a polyzoan from a cyphonautes larva; but in its further growth it develops a superficial skeleton as does an arthropod of a sort already seen in rudimentary form in the barnacles, with the chief nerve cords, which are highly developed and arthropod-like, running over or just within its internal surface as in the arthropods, and uniramous anterior (oriented from the central nerve mass) and biramous ventrolateral appendages, both sets of which have functions similar to those of the corresponding appendages in the barnacles.

Thus in spite of the utter dissimilarity in the details the broader features of the structure of the crinoids and the barnacles as well as of their development are seen to be similar, or at least comparable, or perhaps it should be said that there is less divergence between crinoids and barnacles than there is between crinoids and any other organisms.

THE CRINOIDS AND THE ABERRANT BARNACLES

The crinoids represent a derivative from a branch of the same arthropod stock that gave rise to the barnacles, but they have gone much further; half of each of the five segments of which the body is composed fails to develop so that the body is composed of five half segments joined in a circle with the central organ of the ventral nervous system at one pole and the mouth, which has moved posteriorly and come to lie near the anus, at the other; the development of the body structures after early youth suddenly becomes entirely inter-somatic instead of mid-somatic; the peristomal region becomes enormously enlarged and extended, resulting in the formation of a sort of lophophore; and the appendages have been suppressed, or at least appear in a very modified form late in life. Certain hereditary tendencies show themselves after the animal has, so to speak, recovered from the profound ontogenetic shock resulting from the loss of half its body, in the appearance of articulated uniserial tactile and grasping organs at the neural pole (the original anterior end) and of articulated biramous appendages used for food gathering or for locomotion along the ventrolateral border.

Crinoids, like barnacles, are sessile, pedunculated, attached by hook-like processes, or unattached.

The strong probability that the arthropod stock which by profound modifications gave rise to the barnacles also gave rise to the crinoids is indicated not only by the asymmetry in the Verrucidæ, in which the operculum consists of the scutum and tergum of one side only, those of the other side being fused to form one half of the wall which is completed, on the side of the movable opercular plates, by the greatly developed and displaced rostrum and carina, but also by the anomalous parasitic forms which have developed among the former in which the aberrant features are so fundamental that they have been thrust forward into the ontogeny so far as to modify profoundly the form and structure of the nauplius. These forms also show that the occurrence of complicated ramifying roots, so highly developed in some crinoids, is an inherent possibility in the barnacles.

A combination of the asymmetry of the Verrucidæ (inherent also in very many other crustaceans, and especially noticeable in the Paguridæ and Bopyridæ) carried to its logical conclusion in the complete atrophy of one side, with the modifications of the body seen in *Sphærothylacus* or *Sarcotaces* in a less extreme form, the roots of the Rhizocephala, and a skeleton formed after the manner of the plates in the shell of the Operculata, furnishes all the elements needed for recombination to form the crinoid. It may be well to call attention to the fact that outside the Cirripedia there is no group in which all the morphological peculiarities exhibited in the crinoids coëxist—indeed they are not to be found in all the rest of the animal kingdom together.

In this connection it may be worth while to review the salient features of the more important of the aberrant barnacles.

The Rhizocephala are exclusively parasitic barnacles, the most degenerate of all parasites; in the adult stage they are distinguished from normal barnacles by the entire absence of all traces of segmentation and of appendages, and at all stages they lack an alimentary canal; every trace of arthropod organization has disappeared. Nearly all of them occur on decapod crustaceans.

The body has the form of a simple sac, or may be divided into numerous similar sacs, attached by a short peduncle from which root-like processes ramify throughout the body of the host; these absorptive roots appear to be absent in the aberrant genus *Duplorbis*. The body proper is completely enveloped by the mantle which usually has a narrow aperture capable of being closed by a sphincter muscle; in *Sylon* the opening is double, and in *Thompsonia, Clistosaccus* and *Duplorbis* the mantle cavity is completely closed.

The mantle commonly is attached to the visceral mass by a narrow mesentery near which on either side are the paired (more rarely unpaired) openings of the male and female genital organs. In the different genera the external form varies considerably, and with it the position of the mesentery and of the genital apertures.

Thompsonia, the most aberrant and highly specialized of all the parasitic barnacles, consists of nothing but a diffuse system of branching and sometimes anastomozing mycelium-like roots continuous throughout the body of the host and all arising from a single original larva; the peripheral division of the root system passes out into the walking legs, abdominal swimmerets and tail fans and there gives rise to numerous (up to more than 500) small sacs consisting of a thin mantle without muscles and containing only an ovary, without generative ducts, testis or nerve ganglion. During development the visceral mass disintegrates so that at the time of hatching the mantle contains a great number of cypris larvæ ready to emerge. The escape of the larvæ is contemporaneous with, or soon followed by, a moult of the host. The empty shells of the external sacs are carried away with the cast skin, and the terminal swellings of the root system emerge as a new crop of external sacs.

In *Peltogaster* the body has an elongated sausage shape, with the mantle opening at one end, and is attached by the peduncle about the middle of its length. The mesentery is longitudinal on the proximal side (next the peduncle).

In *Sacculina* the whole body is flattened in the plane of the mesentery and has assumed a secondary and superficial bilateral symmetry about a plane at right angles to this and coinciding with the median plane of the host. In other genera, such as *Lernæodiscus* and *Triangulus,* the symmetry becomes still more complicated.

In *Clistosaccus* and in *Sylon* the genital organs are unpaired.

The peduncle perforates the integument of the host and gives off on the inside the absorption roots which, in the case of *Sacculina*, penetrate into all the organs of the host with the exception of the gills and heart, and extend to the terminal segments of the legs and into the antennules and eye stalks. In *Duplorbis,* in which the root system appears to be absent, the peduncle is hollow, its cavity communicating with the closed mantle cavity and opening at the other end into the body cavity (hæmocœle) of the host.

Apart from a single nervous ganglion (absent in *Thompsonia*) which lies close to the mesentery near the female genital openings, the only organs present are those of the generative system.

Sphærothylacus is parasitic on a simple ascidian (*Polycarpa*), living attached by ramifying roots to the inner wall of the branchial sac. The globular body is enclosed in a mantle which has a small opening. There are no appendages, but there is a complete alimentary canal with mouth and anus, the latter near the mantle opening.

The two known species of *Sarcotaces* live embedded in the muscles of fish; an alimentary canal is said to be present, and there are no roots.

In the Ascothoracica, all of which are parasitic in Zoantharia or in echinoderms, the mantle may have a bivalved form (*Synagoga* and *Petrarca*), or it may form a capacious sac (*Laura*) much larger than the body with which it is connected by a narrow neck and having only a small opening to the exterior. In *Dendrogaster* the mantle is still more developed and is produced into branched lobes. In *Laura* the mantle is covered with stellate papillæ penetrating the tissues of the host and presumably absorptive. In all cases the mantle contains ramifications of the enteric diverticula and portions of the gonads. In *Laura* the body is divided into six "thoracic" and three limbless "abdominal" somites, and ends in a caudal furca. In *Petrarca* and in *Dendrogaster* the body is unsegmented.

In these three genera a pair of preoral appendages is present and, except in *Laura*, are armed with hooked spines suggesting that they are organs of fixation. They are inserted, at least in *Laura,* at the sides of the buccal region, and are more or less enveloped by the mantle.

The cement glands appear to be absent, and the mouth parts are more or less reduced, but appear to be adapted for piercing.

The thoracic appendages are biramous and articulated only in *Synagoga*. In *Laura* they are uniramous and indistinctly segmented, and the first pair are long and slender. In *Petrarca* they are still further reduced, and in *Dendrogaster* they are represented only by some indistinct papillæ.

In all three genera the gut ends blindly, and the hepatic diverticula, which are large, extend into the mantle. The nervous system is reduced. An eye is said to be present in *Synagoga*. In *Laura* the oviducts open at the base of the first pair of cirri.

The larva of *Laura* is a nauplius lacking the frontolateral horns; in *Dendrogaster* the larva hatches as a peculiar cypris with only five pairs of biramous thoracic limbs.

In the Apoda the curious *Proteolepas bivincta* is elongated and maggot-like, with no trace of a mantle nor of appendages other than a pair of adhering antennules. The mouth parts, borne on the first "segment," seem to be adapted for piercing and sucking. The alimentary canal is greatly reduced; according to Darwin only the œsophagus is present, and there is no trace of stomach, rectum or anus.

THE CRINOIDS AND THE STARFISHES

In the crinoids during their development the mouth moves from the ventral surface onto the left side, indenting the left hydrocœle and the left posterior cœlome, and continues its migration until it comes to lie at the posterior end beside the anus. When it has reached this point the hydrocœle ring closes. As a result of this movement the right posterior cœlome has also shifted and come to lie on the aboral (originally anterior) side of the gut and the preoral lobe of the larva becomes enclosed by the rows of skeletal elements (apical plates) which are developed outside the right posterior cœlome in all echinoderms except holothurians; these plates are first laid down in a horse-shoe shaped ring which later closes, as does the hydrocœle, to form a complete ring.

In the asteroids the closure of this curved row of plates is effected far from the point of origin of the preoral lobe on the right or right dorsal side of the larval body; in the crinoids it is effected at the anterior end of the larval (posterior pole of the adult) body and encloses the preoral lobe just as the hydrocœle does in asteroids.

The larvæ of both crinoids and asteroids attach themselves by the preoral lobe; but whereas in the crinoids the preoral lobe is quite free of the circumoral vessel and arises from the apical or aboral surface of the adult, in the asteroids the preoral lobe is encircled by the water vascular ring and its withered vestige springs from the oral surface of the adult disc.

In the asteroids the mouth has shifted from the ventral surface onto the left side of the body, but has gone no further. Since the preoral lobe disappears as an appendage from the oral surface within the hydrocœle ring it is evident that the apical nervous system of the crinoids, which appears to be intimately connected with the preoral lobe, must be represented by a ventral nervous system in the asteroids.

In the crinoids the circumoral nerve ring and its extensions beneath the ciliated ambulacral grooves of the disc, arms and pinnules is associated only with the latter and with the ventral surface of the tentacles. In the asteroids the similarly situated ectodermal nervous tracts are in connection with a diffuse ectoneural plexus found throughout the ectoderm and at the mouth with an endoneural plexus which is the central portion of the so-called endodermal nervous system. The deep oral nervous system, consisting of a double cord in each radius just within the radial nerve thickening of the ectoneural system and centering in a more or less complete ring about the mouth, said to be exclusively motor in function, possibly corresponds to the deep oral system of the crinoids which consists of paired cords, one on either side of the water tube; but the latter is connected with the apical nervous system and the former is not. The apical nervous system of the asteroids, motor in function, consists of a cord in the mid-radial line of each arm and appears to develop from the dorsal peritoneum with which it remains in continuity. It differs from that of the crinoids in being radial (intersomatic) instead of interradial (mid-somatic) in position, in consisting of single cords instead of paired cords with commissures, and in lacking a well developed central organ. From its lack of any relation to the preoral lobe and its general indefiniteness of structure it is difficult to see how it can be in any way homologous with the apical nervous system of the crinoids. It is probably a special feature peculiar to asteroids.

The apical nervous system of the crinoids, from which the whole animal with the exception of the peristomal region and its extensions is innervated, is absent in the asteroids, or rather it has become merged into the circumoral structures and their derivatives.

It has been shown that the crinoids before the development of the arms are encased in plates developed over the somatic divisions, but that beginning with the appearance of the arms the development becomes wholly intersomatic or radial. In the asteroids the development is radial from the first appearance of the plates, the interradial (mid-somatic) body covering seen in the young crinoids not appearing at all.

In the crinoids there are at first no plates belonging to the ventral surface, the basals being dorsal and the orals ventrolateral, but the latter become ventral plates after the formation of the arms, which themselves are composed of a series of dorsal ossicles carrying extensions from the ventral structures on their ventral surface. In the asteroids the plates at their first appearance represent those of the crinoids after the formation of the arms as far as their bifurcation, minus the orals. There is a central plate, corresponding to the infrabasals in the crinoids; about this are five basals, corresponding to the five basals of the crinoids; beyond and alternating with these are five terminals, corresponding to the radials of the crinoids, but always single and showing no indications of a primarily paired condition as the crinoid radials do. On the opposite (ventral) surface are five pairs of plates, one pair in each radial division, corresponding to the first two post-radial plates in the crinoids, but side by side instead of tandem.

Thus whereas the extensions of the crinoid body—the arms—are just on the border between the dorsal and ventral surfaces and are composed dorsally of dorsal ossicles and ventrally of extensions of ventral structures, in the asteroids the dorsoventral edge of the body has moved dorsally so that the dividing line between the dorsal and ventral surfaces falls between the radials and the succeeding plates, and the whole ventral surface is encased in plates which are represented in the crinoids on the dorsal surface only.

The asteroids therefore differ from the crinoids in the temporary attachment of the larvæ; in the relatively slight alteration in the position of the mouth; in lacking the apical nervous system, which has either completely disappeared or has become transformed into a ventral nervous system centering in a ring or rings about the mouth; in omitting the early mid-somatic development, the development of the body being inter-somatic from the first; and in having moved the border between the ventral and dorsal surfaces dorsally so that all the post-radial plates now lie on the ventral surface, the arms being formed by an extension of the body in the plane dividing the crinoid radials from the plates succeeding.

THE SEA-URCHINS AND THE BRITTLE-STARS

The echinoids and ophiurans differ still more widely from the crinoid type. Their larvæ, except in special cases, are extraordinarily developed plutei which have no attached stage at all, and are characterized by the small size of the preoral lobe, by the great development of the post-anal portion of the body, and by the possession of a special larval skeleton supporting the arms which is later resorbed.

Whereas the asteroids differ from the crinoids in transferring the post-radial plates from the dorsal to the ventral surface and thereby forming a ventral skeleton of primarily dorsal elements, the echinoids have gone further and have eliminated the dorsal surface altogether except for a ring of plates about the periproctal region and the small area within it, the globular body being composed of plates representing the ventral plates of the asteroids. The perfection of an entirely new type of compact radially symmetrical body from the crinoid through the asteroid, simulating the compact radially symmetrical cœlenterate body, has furnished a starting point for new development, and bilateral symmetry, superposed upon the perfected radial symmetry, has reappeared and in some cases (as in *Pourtalesia*) has been carried to an extreme.

The ophiurans are phylogenetically parallel to the echinoids, but their line of specialization is entirely different. In them the relation of the dorsal to the ventral surface has remained as in the asteroids, but the radial (intersomatic) extensions of the body have become narrowed and consolidated into highly efficient jointed appendages from which all non-essential structures have been eliminated.

THE FEEDING HABITS OF THE ECHINODERMS AND THE CRUSTACEANS

Corresponding with the progressive specialization in their structure it is interesting to note a progressive specialization in the feeding habits of the echinoderms. The crinoids are plankton feeders, like the barnacles. The starfishes are largely carnivorous, feeding especially upon molluscs, but some swallow mud out of which they digest the organic matter. The echinoids feed upon vegetable matter or upon organic detritus, and many are mud or sand swallowers. The ophiurans feed largely upon detritus or swallow mud, but many are ectoparasitic upon cœlenterates and crinoids from which they steal the food in or on its way to the stomach.

Thus along with the widening of the gap between the structure of the true barnacles and that of the echinoderms there is a similar divergence in their feeding habits; from plankton feeders they become simply scavengers and parasites.

The recent crustaceans as a whole show exactly the same line of specialization from the phyllopod, which feeds on minute organisms, to the decapod, which feeds largely on carrion or detritus, or is ectoparasitic on cœlenterates or on crinoids, and this development of the feeding habit, with the emphasis on the scavenging activities, is characteristic of these two groups alone.

PROFESSOR PATTEN'S INTERPRETATION OF THE AFFINITIES OF THE ECHINODERMS

Although I arrived at the conclusion that the echinoderms and the arthropods are in reality closely related more than ten years ago and in a short paper published in April, 1910, that conclusion is readily to be inferred, Professor William Patten was the first to attempt to explain the relationships of the echinoderms to the arthropods in detail. His reasoning is so entirely different from mine that it is worth while to repeat his arguments here.

He says: "The echinoderms are notable for their contrasts and contradictions. Their outward appearance and their pronounced radial structure distinguish them from all other animals, and at first sight suggest a very primitive organization similar to that of the cœlenterates. On the other hand they display a high degree of histological and anatomical specialization that is in marked contrast with their low grade of organic efficiency. They begin their early embryonic development with a bilaterally symmetrical body and with clear indications of metamerism, only to change it in the later stages for one that is radially symmetrical and in which all outward traces of metamerism have disappeared. After a short free-swimming larval existence they attach themselves, neural side down, by means of larval appendages and a cephalic outgrowth; they then turn neural side up and remain so attached for life; or in some cases they give up their sessile existence and again become free, moving slowly about, neural side down. There are, therefore, three chief characteristics of the echinoderms that demand our first consideration: (1) The early bilateral symmetry and metamerism; (2) the sessile life and mode of attachment by cephalic outgrowths; and (3) the asymmetry. There appears to be but one explanation for these remarkable conditions, which is as follows: The early development of bilateral symmetry and metamerism in the echinoderms, and the presence of a telocele and telopore in place of the more primitive gastrula and blastopore, clearly indicate that they had their origin in bilaterally symmetrical animals of the acraniate type that had already acquired a considerable degree of complexity. These ancestral forms probably belonged to the cirriped group, for before the latent asymmetry becomes effective the young echinoderm larva resembles a cirriped in its form, mode of attachment, and subsequent metamorphosis more than it does any other animal. The radiate structure of the later stages was due to a persistent local defect, or to the absence of a definite part of the embryonic formative material, which in turn created a condition of unstable equilibrium, the result of which is that the whole side, following the path of least resistence, bends toward the defective area, forming an arch that increases in curvature until an approximate equilibrium is again attained by the union of the two ends to form a circle. The original half metameres and segmental organs are then arranged in radiating lines, thus creating a new radiate type and a new set of internal conditions that dominate the future growth of the organism. If we assume that a strongly marked asymmetry, such as that which occurs so frequently as an abnormality in *Xiphosura,* or even as a normal character in the Bopyridæ and Paguridæ, was a fixed feature of the hypothetical ancestral cirripeds and was capable of a successful organic adjustment, we shall have a perfectly simple and natural explanation of the origin and structure of the echinoderms.

"The young asteroid larva is said to attach itself voluntarily at first, and for a short time only; later it becomes permanently attached, head first and neural side down, in the same remarkable manner as a young cirriped, both the cephalic appendages (which are thick walled and muscular, with a long basal portion and a short terminal knob studded with small adhesive papillæ, greatly resembling the minute adhesive antennæ of the cirripeds and parasitic crustaceans) and the adhesive disc taking part in the process. The young crinoid larva attaches itself wholly by means of the cephalic disc, as the adhesive appendages appear to be absent. Its first position is with the neural or oral surface down, as in the cypris stage of the cirriped. The disc then elongates, forming a slender cephalic stalk or peduncle, and the larva turns a somersault, bringing its neural side uppermost. Meanwhile the vestibule, or peribranchial chamber, which at first is small and temporarily closed, enlarges, then ruptures, and the five appendages project from the cup-like head in typical cirriped fashion. In certain of the representatives of the recent echinoderms, such as the asteroids, the fixed stage is temporary, while in certain others, such as the echinoids and holothurians, it appears to be omitted altogether and the young echinoderm, after its metamorphosis, again acquires a limited power of locomotion. But in most primitive echinoderms, such as the stalked crinoids, blastoids and cystideans, a permanent attachment by an elongated cephalic stalk, in typical cirriped fashion, was the almost invariable rule, and no doubt represented the primitive condition for the whole class. When an echinoderm does become free it acquires only a very limited power of locomotion and of coordinated movement. Its characteristic lack of efficiency in this respect is due not so much to its simple structure as to the fact that its freedom was gained at a late period in the phylogeny of a very ancient group in which sessile inaction was the prevailing condition. It is often assumed that a sessile or parasitic mode of life is the initial cause of degeneration. The various anatomical peculiarities common to the copepods, cirripeds and acraniates do not bear out this conclusion. The fact that in these diverse subphyla we see the same shifting of cephalic appendages to the hæmal side, the same cephalic outgrowths, and the same degeneration of the neuro-muscular organs, indicates that there are certain initial defects or peculiarities of germinal material common to the whole group, and that these are the underlying cause of defective organization, the defective organization being in every case of such a nature that a sessile or parasitic or vegetative mode of life is the only one possible."

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 12

A STUDY OF THE BODY TEMPERATURE OF BIRDS

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(Publication 2658)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
DECEMBER 30, 1921

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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INTRODUCTION

The subject of the body temperatures of the many and varied species that compose the great vertebrate class of birds is one that in the past has been rather slightly treated by those interested in avian physiology. Statements to the effect that the bodily temperatures of birds are higher than in others in the group of classes composing the Vertebrata, are current in many zoologies and text books, but on the whole, literature gives few definite statements of fact on the subject, and observations have been restricted to a comparatively small number of species. In the course of other work many hundreds of birds have been handled in the flesh by the present writer, and after some thought methods were devised for the taking and recording of body temperatures in as accurate a manner as possible. This was a little known field of endeavor and at first no guides as to method were available, so that mistakes were made, and early records had to be abandoned. Continued experimentation led to definite methods that promised accuracy, and it is upon these that the following account is based. The results of studies covering the period from January, 1912, to October, 1919, are included herewith, giving a total of 1,558 records covering observations on 327 species of birds distributed among 50 families. If the number of observations seems small compared to the length of time involved it must be considered that the taking of temperatures was not always feasible as the difficulties attending the task were manifold and varied.

The results of this work are embodied in a series of tables which form the foundation upon which this report is based. In addition to the 327 species of birds on which observations regarding body temperature have been made by the writer personally, a supplementary compilation has been given (in table 5) embodying published records on this subject for other species, in order to render this account of the body temperatures of birds as complete as practicable. In this final table records are given for 89 forms, so that in the following pages may be found definite statements regarding the temperatures of 416 species of birds. It is hoped that the work of securing such records may be continued until a much greater amount of information covering many more species is available.

It was the original intention to incorporate in this paper a table giving in detail the individual records upon which the work has been based. Such a course was desirable as it would have furnished a mass of data far greater than any hitherto available for those who may be interested in using such information in lines of research other than that in which it has been utilized here. In addition it would have given opportunity to check up more carefully the deductions that I have made. Cost of printing of tabular matter has proved so high at the time of publication that it has been necessary to omit such a detailed statement and to supply the records only in a condensed form. The table itself is, however, deposited in the files of the Smithsonian Institution and may be consulted by those interested in using it.

From his studies in the subject of avian body temperatures the writer has ventured to come to certain conclusions and deductions, some in accordance and some at variance with modern ideas as previously accepted. If these seem sufficiently substantiated to meet the approval of others, then may the time and labor required in the compilation of these data be deemed justified. The following pages are respectfully submitted for attention, with the hope that part if not all of this labor may gain the stamp of approval from those who may be interested in such lines of research.

In carrying on these investigations the writer has been indebted to the Smithsonian Institution for a grant of seventy-five dollars from the Hodgkins Fund, for the purchase of specially constructed thermometers required, and for certain other minor expenses incurred.

METHOD OF SECURING AVIAN BODY TEMPERATURES

In recording the body temperatures of birds it was necessary to work with thermometers that permitted a considerable range in registration as it was found that the degree of bodily heat was high or low according to the species in hand. All records were made in the Fahrenheit scale by means of clinical thermometers similar in form to those used by physicians. For the present investigation it was necessary to have these instruments specially made to give accurate registration ranging from 95°+ to 115°+. Ordinary clinical thermometers do not register above 110°+ so that they could not be utilized, for certain passeriform species frequently have temperatures ranging above that figure.

While engaged in field work these special thermometers were carried constantly in suitable carrying cases. When a bird was shot a temperature reading was taken when the specimen could be reached immediately. If there was delay in retrieving for any reason, an accurate temperature record could not be made, so that it was possible to secure records in less than one-half of the birds that were collected. In taking temperatures of specimens of small or medium size the thermometer was placed in the opened mouth of the bird, and worked down until the lower end was entirely within the cavity of the thorax, usually until it reached the proventriculus. With birds of larger size the reading was taken through the anus, with the thermometer thrust in through the cloaca well into the canal of the large intestine. In either case it was necessary to penetrate the body cavity to secure a correct reading. The peripheral circulation of birds is poor, so that often there may be a difference of two to five degrees between the temperature of the upper part of the oesophagus and that of the body cavity proper. A similar variation was noted between the temperature of the cloaca and the large intestine above it.

The thermometers used were self-registering, and were so constructed that they reacted immediately to any increase in heat. The highest point of a reading was reached in a very few seconds, but to insure accuracy the instrument was held in position for a period ranging from half a minute to a minute. After each reading the thermometer was shaken down to be ready for instant use when needed again.

Temperatures were read to tenths of a degree, and were transcribed at once in a note book opposite the name of the bird, together with the date and other needed information. In each case the time of day was noted to the nearest quarter hour. Thus a temperature taken at five minutes past ten in the morning was recorded as 10.00 a. m. and one at ten minutes past ten as 10.15 a. m. Further refinement in recording the time of day was considered useless, as save on certain meridians there is always slight variation between the actual time as shown by the height of the sun, and the time adopted for universal local use as a matter of convenience. The time of observations recorded during the continuance of the so-called "daylight saving" regulations of 1918 and 1919 has been corrected in each instance to normal.

In order to be prepared at all times to secure temperature records of birds it was necessary to have thermometers constantly at hand while in the field. The physical labor involved in field work at times is arduous, so that though carrying cases of an improved type were used many instruments were destroyed in spite of every precaution. Some were broken through accident, others were crushed by birds while records were being secured, and a few were lost. In all a considerable number were used in securing the records given.

The records of temperatures of birds secured have been taken throughout the year, but the localities where this work has been carried on have all been in the limits of the United States in temperate regions where extreme cold in winter has not been encountered. As a matter of fact very few of the observations have been made at a time when the temperature of the air was below +25° Fahr. For this reason it has not been necessary to adopt means for warming the thermometers, or for keeping them warm, immediately previous to their use. During the early course of the observations recorded herein experiments were made in heating thermometers by holding them in the mouth of the observer when it seemed probably that they were to be used in a short time. In this way the temperature of the bulb and the glass for a short distance above was warmed to +98°, more or less (depending upon the condition of the mouth). It was soon found however that the results gained with warm and cold thermometers were so nearly identical that it was impossible to distinguish between them. Where observations on the body temperatures of birds are to be made at times when the air is at zero Fahrenheit, or even lower, it would seem probable that it would be necessary to take some steps to use thermometers that had been previously heated at least to a slight degree. This fact may be readily determined by observation. It is probable that save in the most extreme cold weather error from using unwarmed instruments would not amount to more than a few tenths of a degree.

The observations recorded in the tables at the close of this paper are to be regarded at best as approximations to the actual temperature of the birds handled. In treating data of this nature taken by force from the lower animals we can only assume that we are correct in our observations. Through experience we may establish what we consider as the normal limit of variation, but in many cases it is difficult to be assured that we are absolutely correct. Through long experience the writer believes that the records presented are a portrayal of the conditions as nearly correct as may be with the instruments used.

DIURNAL RHYTHM IN TEMPERATURE

The question of the diurnal rise and fall of temperature in a few species of birds and animals has been carefully investigated by Simpson and Galbraith.[1] These authors, on two different occasions, secured records of the body temperature of living gulls, starlings, sparrowhawks, a kestrel, thrushes, several owls, and domestic fowls, ducks and pigeons, at three-hour intervals for period of a week. The results obtained when tabulated gave curves that agree essentially with similar curves taken for man and other mammals. (Variation in the time

TABLE I.—*Time of maximum and minimum temperatures in birds*
(Taken from Simpson and Galbraith)

Species	Time of average maximum temp.	Time of average minimum temp.	Species	Time of average maximum temp.	Time of average minimum temp.
Domestic fowl ♂ . .	3.00 p.m.	3.00 a.m.	"Hawk"	4.00 p.m.	1.00 a.m.
Domestic fowl ♀ . .	3.00 p.m.	3.00 a.m.	"Hawk"	4.00 p.m.	1.00 a.m.
Bantam fowl ♂ . . .	6.00 p.m.	12.00 a.m.	Thrush	12.00 p.m.	12.00 a.m.
Bantam fowl ♀ . . .	6.00 p.m.	3.00 a.m.	Thrush	1.00 p.m.	1.00 a.m.
Domestic duck ♂ . .	9.00 a.m.	3.00 a.m.	Starling	3.00 p.m.	12.00 a.m.
Domestic duck ♀ . .	12.00 p.m.	3.00 a.m.	Starling	6.00 p.m.	3.00 a.m.
Domestic pigeon ♂	6.00 p.m.	12.00 a.m.	Starling	3.00 p.m.	3.00 a.m.
Domestic pigeon ♀	12.00 p.m.	12.00 a.m.	Owl	3.00 a.m.	9.00 a.m.
"Seagull"	3.00 p.m.	12.00 a.m.	Owl	4.00 a.m.	10.00 a.m.
"Seagull"	12.00 p.m.	3.00 a.m.	Owl	4.00 a.m.	7.00 p.m.
Jackdaw ♂	1.00 p.m.	1.00 a.m.	Owl	4.00 a.m.	1.00 p.m.
Jackdaw ♀	1.00 p.m.	1.00 a.m.			

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[1] Journ. of Phys., Vol. XXXIII, 1905, pp. 225-238.

of high and low temperature in individuals belonging to the same species, as shown in the table on page 5, are probably to be explained on the grounds of individual temperament in the birds under experiment. Thus a bird that soon became accustomed to handling would give a slightly different series of readings from one that remained wild and that struggled violently whenever approached.)

In the case of those species normally active during the hours of daylight a constant diurnal rhythm was indicated, with a gradual rise until late in the afternoon and then a corresponding decrease until early in the morning. In owls, species of nocturnal habit, the temperature curves were reversed, the highest point being observed late at night and the lowest during the day. It was found on the whole that the temperature curves of daylight-loving species were similar to those of diurnal mammals save that the point of highest temperature in the birds came earlier in the afternoon and that of low temperature earlier in the morning.

Hildén and Stenbäck[1] record a series of experiments in which birds were confined in a dark room and their activities regulated by means of artificial light. Light was turned on from 6 p. m. to 6 a. m., with a more brilliant illumination from 9 p. m. to 3 a. m. to correspond to the brighter portion of the middle of the normal day. After the second day the diurnal birds studied in general adapted themselves to this change in condition in such a way that the temperature rhythm was reversed, the highest point in the record for each twenty-four hours coming after midnight instead of afternoon. When the experiments were terminated and the birds again led a normal life in relation to daylight the temperature curves at once adjusted to the normal rhythm.

In studies made by the present writer the range of diurnal temperature is well shown by records for certain of the owls. Thus a male barn owl (*Aluco pratincola*) killed at 3.00 p. m., as it flew from a perch in a cottonwood tree had a temperature of 101.9°. The day was bright and clear and the bird had in all probability been at rest since early morning. Another male, shot at 8.30 p. m., while quartering back and forth across a level flat near the Gila River in Arizona, showed a body heat of 105.0°. This bird was seen coursing about for several minutes and had evidently been hunting for food for some time. The variation in the screech owls (*Otus asio*) also is instructive in connection with the same points. A male and a female taken by hand at 3.30 p. m., from a low pine at the edge of a swamp in

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[1] Skandinavisches Arch. für Phys. Bd. 34, 1916, pp. 382-413.

western Florida, gave temperatures of 101.8° and 102.7° respectively. A second male shot an hour later registered 100.7°. These birds had been resting quietly for the entire day. In direct contrast is the condition found in a male killed by moonlight at 8.15 p. m. in the Chiricahua Mountains in southeastern Arizona. On this evening screech owls had been actively calling for over an hour before this one was secured. The bird taken had a temperature of 105.4°. A female secured in the Dragoon Mountains, Arizona, at 8.45 a. m., not long after it had retired for the day, registered a body heat of 105.3°. In the case of those species active during the hours of daylight the difference is less marked, due in large part to the fact that the majority of birds examined had been killed during the period of their normal activity when little or no temperature range was evident that could be correlated directly with time. However, it is possible to cite a few cases showing this regular variation.

The series of mourning doves (*Zenaidura macroura*) obtained may be discussed as pertinent in the matter of diurnal variation in birds of diurnal habit. In four males secured between 5.00 a. m. and 5.45 a. m., the range in temperature is from 108.0° to 109.8°, the four records giving a mean of 108.9°. Five other birds shot between 5.00 p. m. and 6.00 p. m. under similar conditions give a variation of from 109.3° to 110.4° with a mean of 109.6°. An average difference of .7° is thus shown. All of these birds were feeding but in the first set killed early in morning the body heat was still comparatively low.

As stated above, most of the records were secured at hours when the temperature was naturally high so that little time variation is shown. However, the following may be quoted in addition to the above. An ash-throated flycatcher (*Myiarchus cinerascens*) taken at 7.30 a. m. had a temperature of 108.6°. Another taken at 10.00 a. m. registered 110.0° and a third shot at 11.00 a. m. showed a body temperature of 111.8°. All of these birds were males. A male Canadian warbler (*Wilsonia canadensis*) shot at 7.30 a. m. registered 106.7° and another taken at 9.45 a. m. gave a temperature of 107.6°. Females of the same species taken at 7.30 and 9.00 on the same morning had a bodily heat of 107.7° and 107.0° while a third bird of the latter sex killed at 12.00 p. m. showed 108.3°.

The daily increase in bodily temperature in our smaller birds may be exemplified also by the following: On September 12, 1919, at Plummers Island, Maryland, the writer spent the day in observing small birds, many of which were in their southward migration. There had been a heavy rain the previous evening, and later high wind had come up with a considerable fall in temperature. The early morning was damp and cold so that insectivorous birds were more or less inactive until the sun was well up in the sky. As the air became warmer the birds, correspondingly, became more sprightly. A female magnolia warbler (*Dendroica magnolia*) secured at 8.30 a. m., had a bodily temperature of 107.0°. At this time birds of similar habit were just commencing to move about and feed. A male of the same species shot at 9.30 a. m. had a temperature of 108.2° and a second male taken at 10.15 a. m. had a temperature of 108.3°. Other warblers taken between 9.00 a. m. and 10.30 a. m. gave records similar to the last. Thus a female bay-breasted warbler (*Dendroica castanea*) shot at 9.15 a. m. registered 108.8° and a male killed at 10.00 a. m. registered 108.7°. A male black and white warbler (*Mniotilta varia*) secured at 9.15 registered 108.5°. In the observations of this forenoon it was noted that the red-eyed vireo (*Vireosylva olivacea*) was astir much earlier in the day than the warblers. This activity apparently was reflected in the body temperature as a female taken at 9.15 gave a record of 109.7°, a reading distinctly higher than that of the warblers taken at the same time, although average temperatures for the two groups on the whole are about the same.

In perusal of the data used in preparing this paper many cases are found of range in temperature not correlated with time. These, however, cannot be taken as destroying the value of those instances where early and late readings were available that show a distinct rhythm or increase from early to late. As stated above, the bulk of the records are made during the period of high activity when the bodily temperature approaches a maximum. Range in temperature then is to be attributed to other causes. Had records made early in the morning been available in all of these cases there can be no question but that an increase in body heat correlated with time would have been shown.

The daily variation in temperature is much more in birds of small size than in those of greater bulk. Thus Simpson and Galbraith[1] found the daily range in the "thrush" (*Turdus merula?*) to be from 6.8° to 7.5°, in starlings (*Sturnus vulgaris*) from 5.2° to 7.2°, while in the domestic fowl it amounted to 1.9° and in the domesticated duck from 1.6° to 1.8°. The marked difference in these cases is noticeable.

The diurnal variation in temperature that has been noted may be attributed directly to the metabolism of the individual as reflected by its activities. With movement and the digestion of food heat is generated. Although a part of this is dissipated through the usual

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[1] Journ. of Phys., Vol. XXXIII, 1905, p. 237.

channels there is a gradual accumulation that warms the tissues and thus is held. This accumulation reaches its height near the close of the day's activities. At night the body is inactive so that at once the production of heat is lessened. The stored up heat energy of the day therefore is slowly dissipated and is replaced only in part, so that there is a steady lessening of the body temperature until the beginning of a new period of activity. With this there is a sudden jump again in the production of heat and a corresponding increase in body temperature. In the case of our small birds that migrate by night the increased activity induced must of necessity make a decided break in the daily temperature rhythm. No data on this point is available, but it must be supposed that the prolonged flights that are made tend to bring the temperature above the normal for individuals at rest. A part of the accumulated heat secured during the day may be attributed to the continual ingestion and digestion of food, as the nutriment thus secured would be provocative of renewed energy. As digestion is rapid the stomach is soon empty when no food is being taken in so that the temperature of night-flying migrants may be held down to some extent by a decrease without constant renewal in the stored nutriment in the tissues.

Although in birds there seems at present no indication of a marked seasonal variation in degree of temperature yet we may suppose that the total amount of heat produced by the body may be slightly more in summer than in winter. As the period of daily activity is one of high temperature (considered on the basis of diurnal species) it will be readily seen that that period of activity is much longer, in species living north or south of the tropics, during a day in June than during a corresponding period in December. There is therefore a contrast in many birds in the total amount of heat produced in the seasons of summer and winter even though no birds are known to hibernate. Although it may be supposed that the increased activity in summer among our small birds may be offset in part by brief siestas taken in the heat of the day, still it would not seem that the difference between the two seasons would be anywhere near compensated. The quantity of body heat produced during the summer period may therefore be considered greater than for the winter.

VARIATION IN TEMPERATURE IN RELATION TO SEX

Variation in body temperature correlated with sex has been well established in mammals, where the temperature of the female is stated to average slightly higher than in the male. Thus Roger[1] records a

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[1] Richet's Dict. de Phys., Vol. III, 1898, p. 96.

slightly higher temperature in girls than in boys, although the subjects of experiment were too young to exhibit striking sexual differences. Martins[1] notes a higher temperature in females than in males of the domestic duck, and Simpson and Galbraith[2] make similar observations with regard to other birds in those cases in which the sex of the individuals in hand was known at the time of experiment or was determined later by dissection. A few observations made by Hildén and Stenbäck[3] do not bear this out, as they cite higher temperatures in males than in females. Apparently these authors misunderstood Simpson and Galbraith as they state that these observers also record higher temperatures in males than in females although the reverse is true.

In my own observations there is found in some species a convincing agreement with the findings of Simpson and Galbraith, Martins and Roger in this matter, as where a sufficient amount of data is available the average temperature of the female is usually slightly higher than that in the male. Certain exceptions to this rule will be noted later. The difference in favor of the female where present is rather slight, being usually only a part of a degree. Thus in the green-winged teal (*Nettion carolinense*) the temperature of the male (19 records) averaged 106.1°, of the female (8 records) 106.6°, a difference of .5° in favor of the female. In Traill's flycatcher (*Empidonax trailli*) males (6 records) averaged 108.0° and females (4 records) 108.6° a difference of .6°. Numerous other instances will be noted in table 3 but need not be cited here as the two given will serve to exemplify the statement made above.

The present work, however, has emphasized the fact that in certain groups the temperature of the male on the average is distinctly higher than in the female. Apparently this is true in the herons (*Ardeidae*) as in three species in that group we have the following averages: Great blue heron (*Ardea herodias*) male (2) 104.8°, female (2) 103.7°; snowy heron (*Egretta candidissima*) male (5) 104.8°, female (8) 104.0°; and black-crowned night heron (*Nycticorax naevius*) male (3) 103.5° and female (2) 102.6°. A similar difference is best shown perhaps in certain of the shore-birds, as the phalaropes, where it is indeed striking. In the northern phalarope (*Lobipes lobatus*) males (9 records) averaged 107.6° and females (17) only 106.6°. Males (10) of the Wilson's phalarope (*Steganopus tricolor*) gave 106.3°, and females (18) only 105.7°. The same

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[1] Journ. de Phys., 1858, p. 19.

[2] Journ. of Phys., 1905, p. 237.

[3] Skandinavisches Arch. für Phys., Bd. 34, 1916, pp. 382-413.

holds true of the avocet (*Recurvirostra americana*) where 14 males averaged 106.6° and 12 females only 104.9°. A good series of readings for the black-necked stilt (*Himantopus mexicanus*) showed the same average (105.8°) for both males and females. Through the family Scolopacidae the general average on the whole showed a balance in favor of the males save in a few instances. Among the Charadriidae two species, the black-bellied plover (*Squatarola squatarola*) and the killdeer (*Oxyechus vociferus*) show a balance in favor of the female, while in the snowy plover (*AEgialitis nivosa*) and the mountain plover (*Podasocys montanus*) the reverse is true. In some passerines the two sexes average about the same in degree of bodily heat. Thus in the yellow-headed blackbird (*Xanthocephalus xanthocephalus*) males (29 records) averaged 108.3° and females (18 records) 108.2°. Similarly in the house finch (*Corpodacus mexicanus*) males (20 records) averaged 108.9° and females (7 records) 108.8°. In these species we have, therefore practically an agreement in both sexes as the difference noted, amounting to only one-tenth of one degree may well result from accident in securing the records.

It appears therefore that in many species of birds temperatures of females are higher than those of males. In a considerable number, however, the two sexes average about the same, though with more information it may be found that there is a slight difference in favor of the females. In a few cases there is found a higher temperature in males than in females. This last is true in the Ardeidae, the Phalaropodidae, the Scolopacidae and in part in the Charadriidae.

In the average run of species of homoiothermal animals the difference in temperature between male and female may be ascribed to the needs of sexual activity and reproduction. At least this higher temperature seems correlated with certain phases of reproduction. In many birds the care of the young devolves upon the female and she has the higher body temperature. In the Phalaropodidae, on the contrary, it has long been known that the duties of incubation and the rearing of the young fall to the lot of the male, so that in connection with this it would appear that he has developed a higher body temperature than the female. In the case of the Scolopacidae the writer is prepared to state from his own observations that incubation and brooding of the young may fall largely upon the male in the willet (*Catoptrophorus inornatus*) and it is suspected (though not yet proven) that this may be true of the majority of the species in this family. Males of this group examined in breeding season often exhibit areas upon the lower surface of the body bare of feathers where the skin is thickened and vascular as in birds that have been incubating. This is true also in the Recurvirostridae. In the case of the herons definite knowledge is lacking so that I venture no statement in regard to their sexual aberration in body temperature.

Admitting that the incubation of eggs and the brooding of young necessitate a higher temperature in the parent, it appears that in those species where this duty falls upon the female she has a higher average temperature than the male. Where the male performs these duties the reverse is true. As in many cases, in particular among the passerines, these cares are shared about equally by both parents, we may expect in such species a close approximation in body temperature in the two sexes, a supposition that is well borne out by the data given in table 3. On the basis of this reasoning it may be permissible to theorize further with regard to the shore birds. In many species here the cares of the family are undoubtedly shared by both parents though as has been said, in a good many forms this duty falls on the males alone. However, in those that have been investigated, the greater part show a higher temperature in males than in females. In this group then, where the male is the home drudge taking over all the family cares and leaving the female in freedom after the deposition of the eggs the condition may be assumed to be a primitive one. Males of other species have become emancipated in part from this domestic yoke so that the task of rearing offspring is shared in part by their spouses, though this has occurred so recently that adjustment is not complete and the body of the male still develops a higher average temperature. Such statements however must be taken with reserve and cannot be considered as applying to other groups of birds.

EXTERNAL TEMPERATURE IN RELATION TO BODILY HEAT

In the cold-blooded vertebrates heat generation within the body is slow, while the processes that act in controlling radiation are imperfectly active. In consequence the animal chills or is warmed in close harmony with fluctuations in heat of its surrounding element. Such creatures of necessity are sluggish when they encounter low temperatures and become more active when well warmed. When cooled below a certain point they become torpid and dormant. It would seem that animals of such habit have the means utilized in equalizing or resisting high temperatures better developed than those that might assist them in overcoming cold. Otherwise turtles, frogs, or lizards would be killed when basking in the intense heat of a midsummer sun. This equalization of heat must be accomplished largely by the lungs in Reptilia, as skin glands that might serve this purpose are absent. The amphibians, with their poorly developed lungs, gain the same end by evaporation and radiation through their moist glandular skins. There is a definite limit, however, to the degree of heat that these cold-blooded animals may endure. In Arizona I have seen a Gila monster (*Heloderma suspectum*) fresh from the desert perish when the sack in which it was confined was inadvertently left exposed in the noonday sun for a period of fifteen or twenty minutes.

Although in these cold-blooded animals there is a direct reaction to external cold, with birds the case is entirely different. Some investigators in making studies of avian body temperatures have been careful to record the temperature of the atmosphere and to cite this data in connection with their other records. After due consideration I have not done this as I do not consider that there is any constant relation between the normal temperature of the surrounding medium and that of the body cavity in birds. After making careful records of avian body temperatures at all seasons of the year, I am, in light of the records available at present, unable to recognize any constant difference between body temperatures made in the same species at seasons of marked heat or marked cold. Where the individual is in normal health and is sufficiently supplied with food, the agencies of temperature control will tend to maintain an even body heat. Any variation that may occur, other than that incident to the daily rhythmic rise and fall of body heat, may be attributed to some other condition that under normal conditions would disappear within a comparatively short period through a readjustment of the bodily functions. Any bird may, through inclement exposure, become thoroughly chilled and so have a greatly reduced temperature but such a condition cannot be considered normal. Thus an immature white-faced glossy ibis (*Plegadis guarauna*) exposed for half an hour to a severe rain and hail storm became so chilled that it could scarcely stand and shook violently with cold. When warmed with hot towels and dried out once more it was restored to its normal condition and soon was running about on the floor of the laboratory so far recovered that it mischievously began to torment other smaller birds confined with it.

Birds, however, may be divided roughly into two classes with regard to their ability to adjust to external temperature. The first category includes those able to withstand any reasonable degree of cold, while in the second are included those species that migrate to regions where cold in any degree is not encountered at the approach of inclement weather. Broadly speaking, the question of difference between these two groups is not so much one of change in external temperature as it is of food supply. Thus species that feed on flying or crawling insects, or on fresh fruits, must leave before a supply of this food fails. Others that search out insects in hibernation, dried berries, or live on seeds, pay little attention to the approach of chilling weather. The question seems on the whole one of adequate food supply, that the organism may receive its life-giving elements constantly. However, forms that habitually experience cold weather during a part of the year must have a greater development of reaction for temperature regulation than do those of the other groups. Some species from the category of those accustomed only to a hot climate may experience severe cold without harm if supplied with proper food. Others succumb under these unusual conditions. Thus, Mr. N. Hollister, Superintendent of the National Zoological Park, informs me that red, blue and yellow macaws (*Ara macao*) confined in large flight cages, remain outdoors at Washington, D. C., during the winter in perfect health. An allied species however, the blue and yellow macaw (*Ara ararauna*), was unable to withstand the cold and perished, though it throve during warmer weather. From information available it seems that both of these macaws in their normal range inhabit the tropical zone, and are subjected to the same general conditions of life.

There is a marked decrease in body temperature where food is not obtained in suitable amount while the bird is subjected to cold. This may be seen readily among our smaller insectivorous birds where they are caught by a sudden return of cold weather during their northward migration in spring. Decrease in bodily temperature from this cause may be illustrated by the following:

During the latter part of May, 1916, I was stationed at a small field laboratory in Utah near the point where Bear River enters Great Salt Lake. For several days preceding the evening of May 23 the weather had been mild, and small migrant birds that nested in the mountains had left the middle of the valley for the uplands. On the night in question a cold wind with a driving rain came on and continued until ten the following morning, and there was little rise in temperature of the air until late afternoon. A few Audubon's, pileolated and yellow warblers and an occasional small flycatcher appeared in the willows, and until noon there was a steady flight of swallows down the river toward some haven on the flats below. To escape the driving wind, the latter flew low over the river or beat along behind shelter of the willows that fringed the stream. Hundreds passed, travelling in little flocks so that for a time there seemed to be no end of the constant procession of passing birds. These small birds were not obtaining food as no insects were to be had and in consequence many were suffering from a lowered vitality. This was reflected in the body temperatures of individuals that I collected. Thus, two male violet-green swallows (*Tachycineta thalassina lepida*) registered 103.8° and 106.8°, respectively, a female black-throated gray warbler (*Dendroica nigrescens*) 105.4°, a female Audubon's warbler (*Dendroica auduboni*) 105.6° and two purple martins (*Progne subis*) 104.8° and 105.0°. Such abnormal records, due manifestly to lack of sufficient food, were not included in the register giving the normal average and range of temperature. That they were abnormal may be ascertained by referring to other records given for these species.

Birds that remain in regions where they are exposed to cold, become more heavily feathered before the winter season so that there is less radiation of heat externally. Correspondingly, in summer the feathered covering is thinner, and the feathers themselves often become more worn so they are less burdensome. With increased cold there is apparently some readjustment to maintain the bodily heat at its normal point. Were this not so the individual would become affected so unfavorably that with prolonged exposure it would perish. We must suppose a more rapid metabolism and a conservation of the resultant energy in order to overcome this. Such a condition is not difficult to imagine in hawks, crows, and other birds of large size, but is wonderful when such feathered mites as the kinglets, creepers and chickadees are considered.

The part that the feet and tarsi of birds play in equalizing the body temperature is difficult to state. In the majority of birds the space from the lower end of the tibio-tarsus to the tips of the toes is covered with skin in which are developed more or less perfect horny scutes (the whole forming one of the most evident reptilian features visible in the living bird.) The blood supply is of fair quantity clear to the tips of the toes, as blood trickles from slight wounds in the foot. There is no evidence of a forced circulation yet in many cases warm blood must be conveyed constantly to these parts to avoid frost-bite. Many ducks, grebes and other aquatic birds remain during winter just south of the line of ice. Swans, phalaropes and loons appear in the Arctic regions with the first breaking up of ice. I have seen auklets, puffins, and murrelets swimming and diving for hours in Bering Sea with no apparent discomfort at a time when the temperature of the water registered +39° Fahrenheit. Mallards and other wild ducks frequently clamber out of the water and stand about on ice for considerable periods without visible hardship. How these birds overcome or avoid the effect of cold upon their feet is a mystery as yet. Although supplied with a certain amount of blood, as has been stated, the feet and tarsi of birds are more often cold or cool to the touch than otherwise in spite of the high body heat. In fact they are seldom warm save in the hottest weather. Frozen feet and toes are not uncommon among domestic fowls but are seldom encountered in wild birds. The skin of the feet and tarsi is smooth and oily, so that in the case of aquatic species water does not adhere when the extremities are exposed to the air, thus preventing danger through the formation of ice. Aquatic birds at rest frequently draw up the feet one at a time beneath the long feathers covering the flanks, and ducks often rest on frozen ground with both feet drawn up in this manner, so that relief is available when needed.

In some groups of birds the tarsi and at times the toes are well protected by a covering of feathers that prevent the radiation of heat. Such a development is found in ptarmigan and certain other grouse, in our owls of northern habitat, and in the sand grouse and rough-legged hawks. A similar covering, though less dense and heavy, is found, however, in other birds that never encounter severe cold. Thus the tarsus is feathered in whole or in part in some trogons, in whippoorwills, in certain species of edible-nest swiftlets (*Collocalia*) and many others. The entire tarsi and upper surfaces of the toes are feathered in the Old World martin (*Delichon urbica*). Although this covering is present in *Delichon,* in the bank swallow (*Riparia riparia*) a species that also breeds regularly far north in Arctic regions, the feathering is restricted to a small tuft on the posterior face of the tarsus near its lower end. Where this covering of the legs and feet is found in species that at present do not seem to require it for protection it may be supposed that it has persisted after an ancient need causing the growth has disappeared, or that it has developed as a correlated structure, perhaps ornamental in nature. Thus in tropical owls the feathering of tarsi and toes is greatly reduced, although in northern species it is very heavy.

On the whole it would appear that radiation of heat through the lower extremities is comparatively slight.

DIVERSE MISCELLANEOUS FACTORS IN THEIR RELATION TO BODY TEMPERATURE

Previous sections have covered various phases of variations in temperature due to sex, daily temperature rhythm and other conditions. It remains to consider a few miscellaneous factors that affect this matter. Some of these are normal and some abnormal.

The ingestion of large masses of food will frequently cause a sudden decrease in body temperature in a bird of small size. The matter swallowed if cold will absorb warmth until it has acquired a degree of heat equivalent to that of the tissues inclosing it. In this way a distinct lowering of internal heat may be occasioned. On Sept. 12, 1919, while watching two yellow-throated viroes (*Lanivirco flavirons*) that were feeding in company I saw one after much effort swallow a very large caterpillar. Both of these birds were collected and were found to be immature females. The bird that had eaten the caterpillar five minutes before it was killed registered a body temperature of 107.2°, while the other gave a reading of 108.1°. This difference of .9° was attributed to heat absorbed by the large mass of recently ingested food. This may be considered a normal variation.

In small birds bathing may also occasion a slight decrease in body temperature where the plumage becomes thoroughly wet. The heat taken up during evaporation incident to drying the feathers may occasion an appreciable drop in body heat. As an example of this, a verdin (*Auriparus flaviceps*) that had just bathed, taken June 16, 1919, near Arlington, Arizona, gave a temperature of only 106.0°, while others of this species ranged from 106.5° to 107.6°. Variation from this cause is slight, however, and would not be appreciable save in species of very small size.

Many persons with whom the writer has discussed the question of the taking and recording of the body temperatures of birds have expressed the belief that the shock produced in the bird when it is shot is sufficient to increase the bodily temperature to a marked degree. Such statements have come in particular from physicians and others of similar training. Experiment and observation have shown, however, that this is not true. On various occasions by accident or intention birds have been killed in such a way that they were instantly riddled by shot, so that all functions of the body, nervous as well as circulatory must have ceased instantly when the bird was struck, and this on occasions when the individual in question had no reason to suspect danger. Temperatures of such specimens show no variation from those of birds taken in a more normal way. As a matter of fact it has transpired that the shock of wound in birds serves rapidly to reduce their body heat after a period of from thirty to sixty seconds. Thus a wing-tipped bird, with an injury that is comparatively slight, will be found usually to have a temperature below normal after a period of two minutes has elapsed from the time that it was injured. With more serious injuries the fall in body heat may be so great that a record made on a living bird four or five minutes after it was shot is so low that it must often be considered as abnormal. As an example of this I may cite the case of a cinnamon teal (*Querquedula cyanoptera*) that was struck in such a way that the sight of both eyes was destroyed though other injury was not present. This bird rested quietly on the water, while I went for a boat in order to retrieve it. On reaching the spot fifteen minutes later the body temperature of the duck was found to register only 102.0°, a reading considerably below normal. Many other examples of a similar sort in the case of birds bearing only slight wounds have come under observation. The rapid reduction in body heat is due perhaps to an abnormal exchange and radiation through the air-sacs.

TEMPERATURE OF YOUNG

During the course of this investigation occasional opportunities were presented for securing temperatures on nestling birds or on young of species that leave the nest as soon as hatched. These have not been used in securing the average temperatures for each species given in table 3 or for the family records in table 4, as they showed some variations from readings for adults. The results obtained are, however, of considerable interest and are presented in tabular form herewith in order that they may be discussed briefly. In this table the few species included are grouped under family headings. In the second column is given the temperature and under remarks is included a statement of the approximate age of the individual and the manner in which the temperature was taken. In certain passerine species, where axillar temperatures were taken, the end of the thermometer was held closely in the hollow between the folded wing and the body. Birds utilized from the same nest or brood are grouped in brackets.

Of the species listed those belonging to the families Colymbidae, Laridae, Anatidae, Rallidae and Recurvirostridae are precocial while those listed under Columbidae, Tyrannidae, Hirundinidae, Mniotiltidae, Mimidae, Paridae, and Turdidae are altricial. A difference in the temperature records in the two groups is readily apparent upon examining the table. In the group of precocial birds there is on the whole less variation and the temperatures given closely approximate those of adults of the same species. The only wide divergence in this group is in the case of the three-day old young of the black-necked stilt (*Himantopus mexicanus*). It so happened, however, that the temperatures of these three birds were taken upon a cold raw day, when the young were very evidently affected by the external cold, perhaps through lack of sufficient food.

In the case of the altricial species considerable variation is present and these birds show a much lower average temperature than adults.

TABLE 2.—*Table of temperatures of young or nestling birds*

Species	Temperature	Remarks
COLYMBIDAE		
Podilymbus podiceps	104.5	Newly hatched (interthoracic).
“ “	100.4	
“ “	101.4	From one brood.
“ “	100.3	
LARIDAE		
Sterna forsteri	107.3	Ten days old (rectal).
“ “	106.8	“ “ “ “
“ “	105.6	Seven “ “ “
“ “	101.5	Two “ “ “
“ “	104.5	Six “ “ “
Hydrochelidon nigra	105.4	Seven “ “ “
ANATIDAE		
Anas platyrhynchos	105.8	One-third grown “
Chaulelasmus streperus	104.5	One day old “
“ “	106.1	“ “ “ “
“ “	107.3	“ “ “ “
“ “	107.8	“ “ “ “
“ “	107.8	“ “ “ “
Querquedula cyanoptera	107.7	“ “ “ “
“ “	106.5	“ “ “ “
“ “	105.6	“ “ “ “
“ “	106.3	“ “ “ “
Spatula clypeata	102.7	One-half grown “
“ “	104.0	“ “ “ “
Marila americana	102.9	Two hours old “
“ “	102.7	“ “ “ “
“ “	105.6	Five days old “
“ “	106.8	“ “ “ “
“ “	106.0	“ “ “ “
“ “	107.5	“ “ “ “
“ “	106.0	“ “ “ “
“ “	104.0	Ten “ “ “
“ “	106.0	Two weeks “ “
Erismatura jamaicensis	104.2	Ten days “ “
RALLIDAE		
Fulica americana	108.6	One-third grown “
“ “	109.0	One-half “ “
“ “	106.6	“ “ “ “
“ “	104.5	“ “ “ “
RECURVIROSTRIDAE		
Recurvirostra americana	103.9	One week old “
“ “	104.3	“ “ “ “
“ “	104.5	“ “ “ “
“ “	103.6	“ “ “ “
“ “	104.4	Newly hatched.
Himantopus mexicanus	95.8	One day old “
“ “	95.3	“ “ “ “
“ “	97.8	“ “ “ “
“ “	105.7	One-half grown “
COLUMBIDAE		
Zenaidura macroura	106.5	Two weeks old “
TYRANNIDAE		
Myiarchus crinitus	103.3	Nestling, 12 days old (axillar).
“ “	103.8	“ “ “ “ “
“ “	103.2	“ “ “ “ “
“ “	103.8	“ “ “ “ “
“ “	103.7	“ “ “ “ (interthoracic)

TABLE 2.—*Continued*

Species	Temperature	Remarks
HIRUNDINIDAE		
Petrochelidon lunifrons	103.4	Nestling, 2 weeks old (interthoracic).
“ “	102.8	“ “ “ “ “
MNIOTILTIDAE		
Geothlypis trichas	100.2	Nestling, 7 days old (axillar).
“ “	101.8	“ “ “ “ “
“ “	102.5	“ “ “ “ “
“ “	102.8	“ “ “ “ “
MIMIDAE		
Dumetella carolinensis	105.0	Nestling (axillar). One brood.
“ “	105.2	
“ “	105.7	
“ “	97.7	Nestling, 8 days old (axillar) One brood.
“ “	98.8	
“ “	97.9	
PARIDAE		
Penthestes gambeli	101.4	Nestling nearly grown (interthoracic). One brood.
“ “	97.0	
TURDIDAE		
Sialia currucoides	97.6	Nestling, week old (interthoracic). One brood.
“ “	96.7	

These helpless young are evidently as dependent upon brooding by a parent to maintain their bodily heat as are eggs before hatching. Apparently the body temperature may be considerably reduced, however, without permanent injury so that the body heat may sink as low as 97° without death resulting. Even where nestling birds have developed contour feathers the temperature still remains considerably below the average for the adult. When the bird leaves the nest at once there is agreement between the degree of bodily heat that it develops and that present in the adult.

The single observation recorded for a young mourning dove is apparently anomalous as it averages higher than those given for other altricial birds. This is of interest as the doves have distinct affinities with groups having precocial young but in the Columbidae the immature birds, though covered with down at birth, are confined to the nest until able to fly. Further study of young doves and of other down-covered young that do not leave the nest when first hatched, as young hawks, owls, turacos and others, will be of interest.

From this discussion it may be stated with apparent certainty that in birds with precocial young the mechanism of temperature control is well organized at birth, while in species with altricial offspring this power is so feebly developed that these birds are largely dependent upon the parents for heat. The ability of perfect temperature control is not fully matured until the young leave the nest. The early development of this faculty in precocial young is in line with their advanced stage as regards securing food, general activity, and ability to care for themselves. According to Pembrey,[1] similar statements regarding young birds have been made by Edwards.[2]

METHOD OF TEMPERATURE CONTROL IN BIRDS

Bodily heat in all animals is caused by tissue changes during active work performed by various organs or parts. Mills[3] states that bodily heat, though arising in great part from actual oxidations that take place in the system, is in its entire amount best defined as the outcome of all chemical processes that take place in the organism. In so-called cold-blooded vertebrates the combined energy or rate of these chemical changes is slow, so that heat is given off by the body almost as rapidly as it is generated. In the groups that we class as warm-blooded, Aves and Mammalia, these changes are more rapid and intense so that heat generation may be in excess of heat radiation. In the warm-blooded group there is also a more or less perfect control of heat radiation when the body is normal in health. In homoiothermal animals there is, therefore, an approximation to the maintenance of a fairly uniform internal temperature, and the animal remains independent of the ordinary rise and fall of the degree of heat of its external medium.

Bayliss[4] considers control of heat production (probably in muscles) as the primitive method of temperature control. Among homoiothermal animals, the Monotremes (both *Echidna* and *Ornithorhynchus*) have the lowest body temperatures, as the average for these species is only 85.6° Fahr. In the case of *Echidna* all regulation of temperature appears to be through change in heat production as this animal possesses no sudoriferous glands and shows no apparent change in respiration at high temperatures. In cold weather it hibernates and maintains a temperature only slightly above that of the air. The duck-bill (*Ornithorhynchus*) has the power of regulating both heat loss and heat production so that its temperature is maintained at a more even level. The marsupials are intermediate in this respect between monotremes and higher mammals.

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[1] Schäfer, E. A., Text-book of Phys., London, Vol. I, 1898, p. 804.

[2] " De l'influence des agens physiques sur la vie, Paris, 1824. (Not seen by the present writer.)

[3] Animal Physiology, p. 461.

[4] Principles of General Physiology, 1915, pp. 458-459.

It has been estimated by Helmholtz[1] that in the human body heat lost through transpired air amounts to 5.2%, through the water of respiration to 14.7% and through the skin to 77.5%. The remaining amount disseminated is given off in egesta or is consumed in warming ingesta. The part played by the skin glands in regulating temperature in the mammal is readily seen. The distribution of skin glands varies in different groups, though such glands are known in all save Cetaceans, elephants, Echidna, and some others. It is claimed, for example, that in the dog skin glands are present only in the legs or feet but in this case the open mouth and protruding tongue act as organs for reducing excess body heat. The presence of skin glands in the horse is readily observed in an animal that is hard driven in warm weather.

Amphibians agree with mammals in the presence of many integumentary glands, though in this group the use of these structures is in some ways different in purpose. In reptiles and in birds, the two classes joined in the supergroup Sauropsida, skin-glands are practically wanting and no case is known in which glands similar to those in mammals are found. In birds the development of feathers with their filamentous barbs and barbules, as a body covering, would not have been possible had sudoriferous glands been present in the skin. Excretion of fluid through such glands inevitably would have soiled such delicate structures as feathers and ultimately have destroyed them. The diffusion of heat through the skin in birds is confined to the amount, notably small in quantity, that is, given off by direct radiation. It is a fact easy of verification that the skin in birds is deficient in blood supply when compared with mammals. Only a comparatively small amount of blood, therefore, can be cooled to any extensive degree through the agency of the skin.

As a matter of fact the feathers that form a loose covering over the bodies of birds are not adapted to the radiation of heat but on the contrary tend to conserve it and hold it within. Though the contour feathers lie smoothly one upon the other yet they are permeated and separated by innumerable air-spaces varying in size from the tiny interstices between barbs, barbules, and barbicels in individual feathers, to the broader areas separating one feather from another. These all go to make up series of more or less closed air cells that act efficiently as non-conductors and serve to retain the bodily heat within. The use of so-called "dead" air-spaces between walls as a protection against conduction of heat and cold is too well known to make further explanation of this factor necessary.

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[1] Smith, R. M., Physiology of Domestic Animals, 1889, p. 696.

This lack of heat regulation by means of the skin would throw the vital work of temperature control directly upon the respiratory system. In this fact then we have a ready explanation for the presence of the great series of pulmonary air-sacs that are developed throughout the avian class as a whole. Birds in order to maintain a high rate of metabolism, necessary to continued activity without reference to shifts and changes in the temperature of their surrounding media, have been forced to develop an auxiliary to the small amount of heat that may be thrown off through the lungs. This has led to the evolution of the air-sacs that, while connected by ostia directly with the lungs, radiate throughout the coelom and penetrate the bones to serve as an agency of temperature control. In other words, safety to the organism demanded that if activity be great and continued, there be some safe release for the excess heat developed during rapid muscular movement.

The proper function of the air-sacs has been a moot point for many years and has given rise to considerable discussion. Some have considered that these sacs acted as reservoirs to replenish air in the lungs, as containers that, balloon like, raised the weight of the bird in flight, or that the presence of these open spaces reduced the relative specific gravity of the body. While the idea of the true use of the air-sacs in birds as organs of temperature control was arrived at independently by the present writer, subsequently an admirable exposition of the same fact has been found in an account by J.-M. Soum.[1] This author in turn believed that the discovery of this fact originated in an hypothesis first advanced by De Vescovi.[2] W. P. Pycraft[3] also has adopted this view as he states that "the air stored in these reservoirs serves not only for respiratory purposes, but also as regulators of temperature, thereby compensating for the lack of sweat glands." With this comment, however, he goes no further, as he gives no details to support this statement.[4] M. Soum, however, made an admirable exposition of his hypothesis. He pointed out that all birds possess air-sacs, have a covering of feathers, and lack skin glands, and all have a high temperature. To correlate these facts he believed it necessary to consider the air-sacs as a means of temperature control. The additional facts that I am able to bring forth leave no doubt as to the correctness of this belief.

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[1] Soc. Linn. de Lyon, Vol. XLII, 1895, pp. 153-157.

[2] Res Zoologicae, Ann. 1, No. 1, Rome. (This publication I have not seen.)

[3] History of Birds, London, 1910, p. 17.

[4] With regard to statements by other authors consult also Headley, Structure and Life of Birds, pp. 100-103.

To continue, as the statement given in the preceding paragraphs becomes more clear, it seems evident that the bird owes its high development, when compared with the reptile, to the growth of these air-sacs as well as to a complete double circulation of the blood. The truth of this statement is apparent when it is considered that the Crocodilia among reptiles possess a double circulation so nearly perfect that only a comparatively small amount of venous blood finds its way into the purified stream of the trunk arteries. Yet these creatures are "cold-blooded" and become dormant when subjected to cold. In other words, their body processes function so slowly that when they encounter an outside temperature below a certain point heat is given off by the body more rapidly than it can be produced. It follows then that the bodily activities ebb lower and lower until finally they are practically at a standstill.

With animals as active as are birds means of relief from overheating must be well organized; the extension of the air-sacs through the body cavity is excellent for this purpose. The walls of the sacs are very poorly supplied with blood so that heat is not radiated directly by means of special circulatory vessels. The thin walls of the sacs, however, are brought into intimate contact with the trunks bearing the blood stream and their principal branches while in addition the sacs closely invest the glands and organs that generate heat. It is claimed that the liver produces more heat than any other organ so that the blood from the hepatic drainage is warmer than any other in the body. The liver itself is partly enclosed by air-sacs, while the venous trunks coming from it adjoin sacs that give excellent opportunity for the casting off of excess heat. Ramifications of air-sacs in the bones of the body are not uniform in distribution and appear to follow no set plan. Some species have the osseous system highly pneumatic throughout while in others this pneumaticity is greatly reduced. When air-sacs are present in bones invested by considerable muscle masses they may be considered as developments that tend to further the proper radiation of excess heat. Thus air cells in the keel of the sternum and the coracoids would aid in controlling heat generated in the pectoral muscles and supplement the work of those divisions of the sacs that underlie the body of the sternum and penetrate from the thorax into the cervical region.

Evolution of the air-sacs beyond their normal development of five main pairs that fill the body cavity and the cervical region apparently has been partly beyond control. The presence of numerous cells between the skin and muscles in brown pelicans may be supposed to break the impact of the water as the birds dive for food. The presence of these same air-pads in the white pelican and, possibly, in the man-o'-war bird may be explained by considering that they were developed as a protection while diving from a height and that they have persisted now that these birds have altered their mode of securing food. Similar air-pads in the screamers, however, cannot be explained by the same argument. Similarly there seems no adequate explanation on the basis of use for pneumaticity in the pedal phalanges of the Bucerotidae or in the pygostyle of the Picidae.

Many physiologists have supposed that air-sacs have been developed by birds to impart lightness to the body, especially to the bones. Anatomists, however, have pointed out that while the main air-sacs are more or less uniform in growth, in many cases the bones are highly pneumatic in species not especially noted for strong or prolonged flight. The hornbills, already cited as having the osseous system more extensively permeated with ramifications of air cells than any other group, are not known to be especially active on the wing.

In the most recently published extensive account of avian air-sacs Bruno Müller[1] considers that air-sacs serve no special physiological function but that they give bulk to the bird body without adding to its weight. This author continues with the statement that the connection of the air-sacs with the lungs comes from their manner of development, and that this connection serves merely to "assist in renewing the air in the trachea." Reflection and study of the facts of avian anatomy show, however, that this line of reasoning is untenable. Bats among mammals fly with the utmost ease and yet possess no such system of air cells as permeates the body in birds. Some of our most ancient birds from the standpoint of phylogeny are flightless, have been in this condition for millions of years, and yet have as perfect a system of air-sacs as are found in forms noted for their powers of flight. Fossil remains of an ostrich have been found in the Pliocene deposits in the Siwalik Hills in India, an indication of the ancient ancestry of our present-day struthious birds. To those who would adhere to the theory of Müller as propounded above the highly emphysematous condition prevailing in the screamers (*Anhima* and *Chauna*) and others may seem of importance but the condition, as has been said, may be ascribed more to an exaggerated development, unchecked because it had no particular significance to the organism as a whole. Otherwise we must expect a similar condition in other species, as the Old World vultures and American buzzards

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[1] Air-sacs of the Pigeon, Smithsonian Misc. Coll. (Quart. Iss.) Vol. 50, pt. 3, Jan. 16, 1908, pp. 403-404.

(*Cathartidae*) that like the screamers spend hours in soaring high in air.

The action of the air-sacs in controlling the body temperature may be demonstrated clearly by the following. A house sparrow (*Passer domesticus*) was caught across the neck in a spring mouse trap of the "Out o' Sight" type. The bird struggled and fluttered violently for approximately 60 seconds while at the same time ingress or egress of air to or from the lungs was prevented by compression of the trachea against the edge of the trap platform by the spring of the trap. I reached this bird as it became quiet and found that the body temperature (interthoracic) registered 114° Fahr. The violent, sustained muscular exertion had produced a considerable amount of heat that could not be given off as the accustomed outlet was blocked. The temperature, therefore, rose several degrees above the usual maximum for this species. These same factors operate occasionally when the trachea of a wounded bird is clogged with blood that prevents the passage of air. The air current must be cut off quickly, however, as the temperature falls rapidly in a wounded bird even when it is struggling.

During hot weather it is common to see birds breathing rapidly with the mouth held open. This facilitates the rapid inspiration and expiration of air from the lungs. Cooling of the mucous membranes of the posterior portion of the mouth may also be of slight aid in reducing the excess internal heat. In the case of some young birds, as, for example, young herons, there is in connection with this habit of breathing with open mouth another development to aid in regulating the internal temperature of the body. When overheated these birds open the mouth widely so as to expand the capacious mouth cavity and pharynx while at the same time the skin on the sides of the upper throat is vibrated with great rapidity. The inner walls of the pharynx and upper throat in the birds in question are highly vascular so that the currents of air set in motion aid in cooling the blood exposed in the radiating blood vessels found near the surface in the moist mucous lining. Conversely it may well transpire that the checking of the rapidity of interchange of air between the branches of the bronchi and the air-sacs during extremely cold weather may bring about a storage or an increase in internal heat. In other words the heat of the body cavity may be held at a higher level by the cessation of inhalation of constant supplies of cold air into the air-sacs. We may imagine a delicate adjustment here that will vary expiration of heated air at need. With the air-sacs acting thus as heat reservoirs the ability of some species of birds to withstand bitter cold winter weather may be better understood.

Temperature control among birds is less perfect in juvenile than in adult individuals so that the action described in the case of young herons in the preceding paragraph is of great aid to control of heat through the air-sacs. As temperature is poorly regulated in young individuals parent birds often find it highly necessary to shelter their offspring when these are reared in exposed nests. On hot cloudless days, therefore, one bird of each pair remains constantly at the nest during the warmer part of the day, and intervenes its body and partly spread wings between the young in the nest and the burning rays of the sun. I have seen many young herons and ibises perish when the adults were driven from their nests on hot days, and during field work in rookeries of these birds have made it a point to visit them during the cooler portions of morning or afternoon, or to come on days when the sky was overcast by clouds in order to prevent such mortality. As another evidence of poorer temperature control in young birds I may add that in several cases I have seen immature coots (*Fulica americana*) die, apparently of sunstroke, when unduly excited while exposed to the burning rays of a western sun. Adult birds seem able to react against these circumstances in such a way that they do not succumb but often exhibit evident signs of severe suffering. It is probable that the more perfect development of the feathered covering in adult birds is of as great advantage in this as the increased efficiency of the heat regulatory organization in the body.

On a few occasions I have observed a further development of the function of temperature control by air-sacs in certain forms of birds while in the fledgling state. Those who have had occasion to work in summer in marshes densely grown with rushes will agree that at times the heat encountered is almost overpowering. In a few instances in such situations I have observed young yellow-headed blackbirds recently from the nest, resting quietly with the cervical air-sacs immensely swollen so that the lower part of the neck was greatly enlarged. The whole gave the appearance of some unwholesome tumorous growth and at first I was under the impression that the birds were diseased. On handling them, however, the sacs rapidly subsided and the birds seemed normal in every respect. The same phenomenon has been observed in young savanna sparrows and in young red-winged blackbirds. In these cases I was forced to conclude that the distended air-sacs form an insulation or protection against heat from without. In other words, that the enlarged cavity of the sac acted as a dead air space protecting the blood stream in the larger vessels from becoming overheated. The importance of the enlarged cervical sacs in preventing excessive heating of the carotid artery carrying blood to the head may readily be seen.

SIGNIFICANCE OF TEMPERATURE CONTROL

In common parlance animals are divided in two groups distinguished as those with " warm blood " or " cold blood," according to their condition as regards body heat. Though two classes may be recognized without difficulty, the criterion implied in these two terms is not exact as a " cold-blooded " animal temporarily may have its body temperature raised to a high degree. The distinction between the two, in fact, is not one of actual degree of heat, but rather one of maintenance of a more or less uniform temperature in the group defined as possessing " warm blood," and of fluctuation in bodily temperature in those distinguished as " cold-blooded." To express this idea with exactness, the first group of animals is said to be homoiothermal, and the second poikilothermal, terms proposed by Bergman[1] in 1847.

It will be admitted without question that the possession and maintenance of warm blood is of advantage to any animal. We may suppose, therefore, with what amounts to some certainty that this faculty when once gained, would not be lost. On the basis of this assumption it may be concluded further that the first vertebrates were cold-blooded, an hypothesis in line with facts of evolution as they are understood and accepted at the present time. Whether these types developed in regions of equable temperatures or in areas with moderate seasonable changes is a matter of no moment in the present discussion. In either case these early vertebrates as they extended their ranges, encountered barriers erected by cold during a part of the year. Groups successful in coping with this condition developed an ability to undergo certain periods, longer or shorter in length, in the state of suspended animation that we term hibernation, and then to revive and carry on their activities as before with return of a period of increased warmth. In meeting these conditions of cold it was of advantage to develop increased resistance to the torpor induced. In other words, it was an advantage to the organism to maintain its activity at lower and lower temperatures. In order to accomplish this it was necessary to evolve a mechanism for temperature control in the body, and for regulation of the rate of production of heat from ingested food elements. When once begun, such control would prove

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[1] Göttinger Studien, Vol. I, 1847, p. 593.

of value not only in overcoming cold but in enabling the organism to withstand excessive heat.

It seems probable that in our living fishes there is little actual temperature control. In Amphibia, this regulation is developed to some extent, and it has progressed somewhat farther in modern reptiles. In the bird, however, the regulation of body temperature has reached its highest point, though birds stand second to mammals from an evolutionary standpoint. Proof of this is found in the fact that birds have the highest body temperatures known, and that none of them hibernate (in spite of ancient beliefs to the contrary). Where conditions become too unfavorable, birds, through their power of flight, pass readily to regions where the environment is more clement. They are enabled, therefore, to foster their powers of temperature control and keep them at the highest pitch. Small mammals, on the contrary, are more or less sedentary and in many cases must still undergo hibernation in order to maintain themselves in regions with cold winters. As they must always hibernate in order to survive there is, in their case, less incentive to develop temperature and temperature control beyond a certain point.

Thermogenic centers or areas in the central nervous system developed for temperature control have been studied in mammals and have been fixed tentatively by some in or near the corpus striatum. Others would recognize a cortical heat center. Seemingly this matter has received little attention in birds and it would be unwise in the absence of definite data to decide that this function is vested in the same areas in this group when the wide separation between birds and mammals is considered. It may be assumed as certain that heat production and heat control are under nervous direction and that these two functions are directly concerned in whatever mechanism has developed for temperature control.

The origin of the warm-blooded animal may be attributed to natural selection in which certain individuals showed a slight reaction against temperature conditions producing hibernation in their fellows. In other words, these favored ones were able to remain active in a temperature a few degrees colder than others of their kind. With this tendency as a basis and with strains developing in which this tendency was perpetuated it followed that there were evolved groups of species with a more independent metabolism in regard to the degree or the lack of heat of the surrounding medium. " Warm blood " therefore arose in a struggle against enforced hibernation. During evolution of the vertebrates it may be that among living groups of today, warm blood arose first among the birds.[1] We may suppose, however, that primitive pro-avian creatures (on the borderline between small-brained reptile and large-brained bird) were cold-blooded and that they were subject to hibernation as is any reptile today. However, it seems probable that *Archaeopteryx,* the most primitive of known birds, was warm-blooded, as impressions of feathers are shown distinctly in the slabs of stone containing the remains of these creatures. These marks made by feathers indicate the development of a body covering designed to retain heat, a circumstance unknown in any cold-blooded vertebrate. How far back we may safely trace this supposed warm-blooded ancestral bird creature is problematical but in this connection attention may be called to the supposition that there are grounds for believing that Pterosaurs, among ancient reptiles, possessed warm blood. As warm blood permitted greater mental and physical activity it was natural that the mammal should also develop this faculty, though it seems probable that this function arose independently in the Reptilian-Avian and Mammalian groups.

DISCUSSION OF DIFFERENCES IN AVERAGE TEMPERATURES

Attention has been called to the general statement that the body temperatures of birds vary as a rule from low to high as the species change from those considered low in the scale of development to those farther advanced. Agreement with this theory is shown in part in the data summarized in table 4. Thus grebes, the totipalmate groups (Anhingidae, Phalacrocoracidae and Pelecanidae) and herons are in general low in average body temperature, while gulls, shorebirds, pigeons and cuckoos are high. Many apparent discrepancies to this broad statement may be noted. These must be left for the present without attempt at explanation save to note that knowledge of the actual evolution of groups in birds is slight, while new facts constantly demand a revision of the status of many forms. Whether the variations in body temperature here noted may have significance time alone can tell. It is probable that temperature level is of value as a criterion only between the most primitive and the most highly developed groups and that the great mass of intermediate orders and families may in some cases in themselves develop high or low temperature according to their actual needs.

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[1] According to Osborn (Origin and Evolution of Life, 1918, p. 236) primitive mammals arose during the Jurassic period. The earliest known birds are found in deposits of this same age but are so highly specialized that it is evident that they were preceded by a long line of pro-aves of more ancient origin than the early mammals.

When ranged by families the highest temperatures noted are to be found in pigeons, cuckoos, woodpeckers and in the great passerine order beginning (in table 4) with the Tyrannidae and ending with the Turdidae. It must be noted too that the range of body temperature among ducks is in general comparatively high. Gulls and shorebirds show a general agreement, compatible with their close relationship as now commonly accepted. The quails (Odontophoridae) seem to have a temperature high for birds that have been considered comparatively low in development. The observations recorded for the owls probably do not represent a true average as many of the readings upon which the mean is based were taken during the day when temperature in these birds normally is at low ebb. The low average given for the kingfishers is based upon a small number of observations and may be incorrect. Humming-birds, with their tiny bodies seem to have a considerable range in temperature, but as a whole fall low in body warmth. This apparent lack of heat may be due in part to the small bulk of their bodies in comparison with the size of the thermometers used. Part of their heat may have been absorbed and dissipated by the glass of the inserted instrument.

Observations upon the greater part of the species of woodpeckers found in the United States reveal an almost uniform high level of body temperature. The general range and the limits of variation from high to low are similar to those of passerine families. As in other families individuals large in body show a general lower temperature and a smaller limit of variation than do some others of smaller bulk. The records on the whole are so uniform that further comment regarding them is superfluous.

An examination of the species and families of passerine birds reveals much of interest. Of the twenty-two families for which records are given eleven or exactly one-half, have a mean temperature averaging below 108°. It will be noticed that most of these families are those having only a small number of species represented in the records. In several instances observations were available on one species alone and only in the crows, swallows, vireos, wrens and nuthatches is the number of species available comparatively large. The Hirundinidae (seven species) with an average temperature of 106.7° is the only family in the order falling below 107°. Seven families, the Tyrannidae, Alaudidae, Fringillidae, Tangaridae, Bombycillidae, Mimidae and Turdidae, have mean temperatures higher than 108.5°. These seven families include 86 of the 203 species of passeriform birds represented, or approximately 42 per cent. The Alaudidae show a mean temperature of 109.4°, which is higher than for any other group, but is not comparable, as this family is represented by only one species, the horned lark (*Otocoris alpestris*). A number of species included in other families have a higher average temperature than this so that this must be discarded. Among the others the Bombycillidae, Mimidae, and Turdidae each show an average of 108.9° while the three families remaining in the category under discussion vary only two- or three-tenths of a degree below this. From 108.6° to 108.9° would seem therefore to be the maximum for families of perching birds where records are available for a number of species.

A comparative examination of some of the species of perching birds brings out still other facts of interest. It has already been stated that the swallows as a group possess the lowest average body temperature. In the seven species examined in this family only one, the rough-winged swallow (*Stelgidopteryx serripennis*), showed an average body heat above 107.5°. Turning to the higher temperatures it is found that in the Tyrannidae there are five species in which the mean temperature for the male or female is 110° or more. The Fringillidae include three species in this category and the Corvidae, Icteridae, Mniotiltidae and Turdidae each possess one. In other words there are records for twelve species in all in which this is true. The highest average temperature for both sexes is that of the western wood pewee (*Myiochanes richardsoni*) with a mean of 110.2°. The highest single reading believed to be valid was found in this species in an individual killed in the Graham Mountains, Arizona, at two o'clock in the afternoon on June 25, 1919. This bird, shot dead as it rested quietly in the shade of a cottonwood fell to the ground without a struggle. When the temperature was taken the extraordinary reading of 112.7° was secured. From the data at hand it is indicated that the highest average body temperatures for a number of related species may be found in the Tyrannidae. This statement is made only tentatively as further observation may show that other groups are equal in this respect. It is not unusual for individual birds in several other groups of perching birds to register 110° or more as shown by the column of maximum temperatures in table 3, and accident of association of such high records might give a high average. Only by recording many extended observations can error from this cause be reduced to a minimum.

EXPLANATION OF TABLES

The data secured during this investigation into the body temperature of birds are summarized in two tables that are given in the pages that follow. The table giving in detail the individual records, which it was found necessary to omit from this paper owing to the excessive cost of publishing tabular matter, is deposited in the files of the Smithsonian Institution and may be consulted by those who wish to use the data contained in it.

The order of arrangement and the nomenclature, followed is that of the third edition of the American Ornithologist's Union Check-list of Birds, published in 1910.[1] By referring to this check-list physiologists and others interested in these tables, who may not have made detailed studies of birds, will have no difficulty in ascertaining the application of the names that are used, and the relationship of the various forms that are treated. At one time the writer intended, in publishing this information, to use names of birds in accordance with the most modern findings in nomenclature, and to arrange them in a sequence of families that would express his own ideas in classification. The latter idea was commendable as it tended to place the species into what may be considered a somewhat more natural sequence that showed a tendency (not universal, however) for a gradual increase in degree of bodily temperature from forms low in the scale to those conceded to be higher in development. With regard to the names to be employed it was soon seen that changes were so rapid that they tended to bewilder even those more or less adept in such matters, while to workers in other fields, they would be wholly unintelligible without great expenditure of time in looking up and verifying the various authorities. As the present contribution is not one of research into systematic ornithology but rather a treatise designed to throw light upon the physiological and more general aspects of our science, this scheme of using such a classification was abandoned and another plan was adopted.

In table 3 is given a synopsis of the information of all of the records secured with the average, minimum and maximum temperatures summarized for males and females of the species treated so far as this data is available. In this table attempt is made to arrange the matter in order of convenience for reference. The name and sex of the bird are followed by the mean temperature. After this are given the minimum and maximum range, the number of records available, and a symbol that indicates the manner in which they were taken, the abbreviation R. meaning rectal and I. interthoracic. In this table subspecific names are ignored entirely and all information is grouped under

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[1] Check-list of North American Birds, prepared by a Committee of the American Ornithologists' Union, Third Edition (Revised), New York, 1910, pp. 1-430, 2 maps.

specific names. The mean temperature for each sex is given where information for both males and females is available.

In grouping this information a departure has been made from a method that has been utilized by many authors that gives the minimum temperature, then the maximum, and then the mean. In the present connection the mean temperature for each species is considered the most important fact and is therefore placed first, nearest the name of the bird concerned. Records showing the minimum and maximum range follow immediately where they are readily available in case this information is desired.

In table 4 is given another summary in which mean temperatures for each of the families of birds represented is tabulated. The name of the family is followed by the number of species represented in the present studies. Following this are mean, minimum and maximum temperatures with the mean as the most important fact given first. The data in these three columns are taken from the column of mean temperatures in table 3. In other words, this is a summary based upon the mean temperatures alone of the various species.

The laborious work of securing the averages in these various tables was performed with the aid of a computing machine. This not only greatly lessened the labor and expedited the work in hand but also made the results less liable to error than would have been the case had it been necessary to perform so many computations mentally.

In a final table (table 5), is given a compilation of temperature records for species of birds that I have not been able to examine personally in the flesh. This table has been taken from available literature and includes only those records for which it has been possible to assign specific names with certainty. Where a record is listed simply as "gull," "hawk," etc., it has been discarded. No attempt has been made to cite all records available for each species but simply to give enough to indicate the body temperature in relation to other forms. Many published notes have been discarded for lack of certain identification, while in utilizing other records I have simply quoted what I have found with no assumption as to accuracy of statement. Records are given for 89 species of birds in addition to those found in table 3. The table has been made as complete as practicable but no claim is made that it includes all records that have been published.

The system of nomenclature to be used in recording the data in table 5 has given considerable trouble. The records cited cover birds from all parts of the world. This material is listed according to the arrangement found in Sharpe's Handlist [1] and the names used are given in accordance with this list in most cases. In a few instances relating to North American birds, to avoid confusion with the system of names found in the previous tables, the names given are those of the A. O. U. Checklist for 1910 as in tables 3 and 4. Such deviations from the general rule are indicated by reference to a suitable footnote. This has eliminated confusion in generic names that might otherwise arise, as for example in the case of the two closely related scaup ducks, where the lesser scaup is given in table 3 as *Marila affinis,* while following Sharpe in table 5 the greater scaup would appear as *Fuligula marila.* By using the name in the A. O. U. Checklist this is changed to *Marila marila* thus dispelling any uncertainty as to the relationship of the two birds in the minds of those not familiar with the changes that have occurred in the application of generic names to these birds.

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[1] Sharpe, R. B., Handlist of the Genera and Species of Birds, 5 vols., 1899-1909.

Table 3.—*Summary of records of body temperature in birds*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
Colymbidae						
Aechmophorus occidentalis	M.	101.3	....	....	1	R.
Colymbus auritus	M.	103.7	....	....	1	“
“ “	F.	104.9	....	....	1	“
Colymbus nigricollis	M.	104.2	103.0	104.6	4	“
“ “	F.	104.9	104.7	105.2	2	“
Podilymbus podiceps	F.	102.7	....	....	1	“
Laridae						
Larus californicus	M.	106.7	106.2	107.2	3	R.
“ “	F.	106.3	....	....	1	“
Larus delawarensis	F.	106.3	....	....	1	“
Larus atricilla	M.	105.9	....	....	1	“
Larus franklini	M.	105.1	104.5	106.0	3	“
“ “	F.	105.9	105.0	106.6	4	“
Larus philadelphia	M.	106.5	....	....	1	“
Sterna caspia	M.	105.3	103.7	106.8	2	“
“ “	F.	107.0	....	....	1	“
Sterna maxima	M.	105.6	....	....	1	“
“ “	F.	106.8	....	....	1	“
Sterna sandvichensis	M.	106.9	....	....	1	“
Sterna forsteri	M.	106.3	105.6	107.0	4	“
“ “	F.	106.8	105.7	107.3	4	“
Hydrochelidon nigra	M.	106.9	106.0	107.3	4	“
“ “	F.	107.0	106.5	107.6	6	“
Rynchopidae						
Rynchops nigra	M.	105.0	104.5	105.9	2	R.
Anhingidae						
Anhinga anhinga	M.	105.7	....	....	1	R.
Phalacrocoracidae						
Phalacrocorax auritus	M.	106.1	101.4	107.0	4	R.
“ “	F.	106.3	106.2	106.3	2	“
Pelecanidae						
Pelecanus erythrorhynchos	M.	103.5	103.0	104.0	2	R.
“ “	F.	103.8	....	....	1	“
Pelecanus occidentalis	M.	104.6	104.2	105.0	2	“
“ “	F.	104.5	103.4	106.3	4	“
Anatidae						
Mergus serrator	M.	107.5	....	....	1	R.
“ “	F.	107.5	106.3	108.6	2	“
Anas platyrhynchos	M.	106.4	105.1	108.0	4	“
“ “	F.	106.1	105.4	109.0	7	“
Chaulelasmus streperus	M.	107.5	....	....	1	“
Mareca americana	M.	105.8	....	....	1	“
Nettion carolinense	M.	106.1	104.2	108.0	19	“
“ “	F.	106.6	104.4	109.8	8	“
Querquedula discors	M.	108.6	107.7	109.4	2	“
“ “	F.	107.3	....	....	1	“
Querquedula cyanoptera	M.	106.5	105.0	108.2	7	“
“ “	F.	108.0	105.8	109.1	5	“
Spatula clypeata	M.	105.8	104.6	107.7	3	“
“ “	F.	107.3	106.3	100.0	3	“
Dafila acuta	M.	106.1	104.4	108.0	9	“
“ “	F.	107.5	106.9	108.0	2	“
Marila americana	M.	106.3	104.0	108.1	4	“
“ “	F.	109.9	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
ANATIDAE—*Continued*						
Marila affinis	M.	106.5	105.8	107.0	3	R.
“ “	F.	106.4	104.4	108.0	7	“
Erismatura jamaicensis	M.	106.2	103.9	108.2	2	“
“ “	F.	108.0	105.4	109.7	3	“
Chen hyperboreus	F.	107.7	....	....	1	“
Branta canadensis	M.	106.9	....	....	1	“
“ “	F.	105.8	104.6	107.0	2	“
IBIDIDAE						
Guara alba	F.	108.0	....	....	1	R.
Plegadis guarauna	F.	105.1	104.4	105.6	5	“
ARDEIDAE						
Botaurus lentiginosus	M.	104.0	....	....	1	R.
Ardea herodias	M.	104.8	104.5	105.0	2	“
“ “	F.	103.7	103.4	103.9	2	“
Egretta candidissima	M.	104.8	104.0	105.2	5	“
“ “	F.	104.0	102.2	106.2	8	“
Hydranassa tricolor	F.	105.5	105.5	105.5	2	“
Butorides virescens	F.	105.8	....	....	1	“
Nycticorax nycticorax	M.	103.5	102.4	105.4	3	“
“ “	F.	102.6	101.6	103.7	2	“
ARAMIDAE						
Aramus vociferus	M.	104.5	104.3	104.6	2	R.
RALLIDAE						
Rallus virginianus	M.	105.5	....	....	1	I.
“ “	F.	105.6	....	....	1	“
Fulica americana	?	106.7	105.9	109.0	12	R.
PHALAROPODIDAE						
Lobipes lobatus	M.	107.6	105.6	109.9	9	I.
“ “	F.	106.6	103.2	108.7	17	“
Steganopus tricolor	M.	106.3	104.8	108.6	10	“
“ “	F.	105.7	103.9	107.4	18	“
RECURVIROSTRIDAE						
Recurvirostra americana	M.	106.6	104.7	108.9	14	R.
“ “	F.	104.9	104.1	106.4	12	“
Himantopus mexicanus	M.	105.8	104.6	106.9	10	“
“ “	F.	105.8	103.8	108.4	9	“
SCOLOPACIDAE						
Gallinago delicata	M.	106.3	....	....	1	R.
“ “	F.	105.3	....	....	1	“
Macrorhamphus griseus	M.	106.1	103.4	108.0	9	“
“ “	F.	105.2	102.4	108.4	10	“
Pisobia maculata	F.	107.0	107.0	107.0	2	I.
Pisobia bairdi	M.	107.9	106.5	108.6	4	“
“ “	F.	107.2	....	....	1	“
Pisobia minutilla	M.	106.1	106.1	106.2	2	“
“ “	F.	106.6	105.9	107.8	6	“
Pelidna alpina	F.	106.8	....	....	1	“
Ereunetes mauri	M.	107.4	106.4	108.2	4	“
“ “	F.	107.3	106.0	108.4	21	“
Calidris leucophaea	M.	107.2	....	....	1	“
“ “	F.	107.1	106.3	108.8	7	“
Limosa fedoa	M.	105.9	104.6	106.5	4	R.
“ “	F.	105.1	102.3	107.3	27	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
SCOLOPACIDAE—*Continued*						
Totanus melanoleucus	M.	107.0	106.5	107.6	4	R.
“ “	F.	106.4	105.4	108.0	6	“
Totanus flavipes	M.	106.2	105.8	106.6	2	“
“ “	F.	106.9	105.4	108.2	4	“
Helodromas solitarius	M.	109.1	....	....	1	“
Catoptrophorus semipalmatus ..	M.	106.7	105.3	108.9	7	“
“ “ ..	F.	106.6	104.6	108.3	10	“
Actitis macularia	M.	108.4	....	....	1	I.
Numenius americanus	M.	105.6	104.3	106.4	4	R.
CHARADRIIDAE						
Squatarola squatarola	M.	106.1	105.3	107.9	4	R.
“ “	F.	106.3	....	....	1	“
Oxyechus vociferus	M.	107.0	106.3	108.3	5	I.
“ “	F.	107.1	106.1	108.9	5	“
AEgialitis semipalmata	F.	109.0	....	....	1	“
AEgialitis nivosa	M.	106.8	106.4	107.3	2	“
“ “	F.	105.1	104.2	106.6	3	“
Ochthodromus wilsonius	F.	108.0	....	....	1	“
Podasocys montanus	M.	105.1	104.3	105.8	2	“
“ “	F.	106.7	106.6	106.8	2	“
ODONTOPHORIDAE						
Colinus virginianus	M.	106.8	....	....	1	R.
“ “	F.	107.4	....	....	1	“
Oreortyx picta	M.	107.4	106.8	108.2	3	“
“ “	F.	107.8	....	....	1	“
Lophortyx californica	M.	108.0	107.4	108.7	4	“
“ “	F.	107.9	107.0	108.7	3	“
COLUMBIDAE						
Columba fasciata	M	108.0	....	....	1	R.
Zenaidura macroura	M.	109.0	107.3	111.8	11	“
“ “	F.	107.7	107.4	109.7	2	“
Melopelia asiatica	M.	108.5	107.3	111.8	7	“
“ “	F.	108.9	107.4	109.7	8	“
Chaemepelia passerina	M.	107.2	106.6	107.8	2	I.
CATHARTIDAE						
Cathartes aura	M.	103.8	....	....	1	R.
BUTEONIDAE						
Circus hudsonius	F.	105.5	....	....	1	R.
Accipiter velox	F.	109.0	108.0	110.0	2	“
Buteo borealis	M.	105.0	104.2	105.8	2	R.
Buteo swainsoni	M.	105.1	104.9	105.3	2	“
“ “	F.	105.5	....	....	1	“
FALCONIDAE						
Falco peregrinus	F.	105.2	104.2	107.3	4	R.
Falco sparverius	M.	106.8	....	....	1	“
ALUCONIDAE						
Aluco pratincola	M.	103.5	101.9	105.0	2	R.
STRIGIDAE						
Asio wilsonianus	M.	104.2	....	....	1	R.
Asio flammeus	M.	102.2	....	....	1	“
Otus asio	M.	102.6	100.7	105.4	3	I.
“ “	F.	104.0	102.7	105.3	2	“
Otus flammeolus	M.	102.5	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
STRIGIDAE—*Continued*						
Bubo virginianus	F.	103.8	102.0	105.8	3	R.
Speotyto cunicularia	F.	106.6	....	....	1	“
CUCULIDAE						
Coccyzus americanus	F.	108.1	106.9	109.3	3	I.
Coccyzus erythropthalmus	M.	109.6	....	....	1	“
“ “	F.	108.3	108.2	108.5	2	“
ALCEDINIDAE						
Ceryle alcyon	M.	104.0	102.6	105.3	2	R.
PICIDAE						
Dryobates villosus	M.	108.2	108.0	108.4	2	I.
“ “	F.	108.7	108.3	109.0	2	“
Dryobates pubescens	M.	107.2	106.2	108.2	7	“
“ “	F.	108.3	107.9	108.7	2	“
Dryobates borealis	M.	108.2	....	....	1	“
“ “	F.	108.5	108.2	108.8	2	“
Dryobates scalaris	M.	107.3	106.8	107.9	4	“
“ “	F.	109.8	....	....	1	“
Dryobates nuttalli	M.	108.0	108.0	108.0	3	“
“ “	F.	108.4	108.1	108.7	2	“
Dryobates arizonae	M.	108.2	108.0	108.4	2	“
Picoides arcticus	M.	108.1	....	....	1	“
Picoides americanus	M.	107.0	106.5	107.4	2	“
“ “	F.	107.4	....	....	1	“
Sphyrapicus varius	M.	109.4	....	....	1	“
“ “	F.	107.8	106.8	109.0	3	“
Sphyrapicus ruber	M.	107.0	....	....	1	“
“ “	F.	108.5	....	....	1	“
Sphyrapicus thyroideus	M.	107.1	....	....	1	“
“ “	F.	106.3	105.2	107.3	2	“
Phloeotomus pileatus	M.	107.0	106.9	107.2	3	R.
Melanerpes erythrocephalus	M.	108.0	....	....	1	I.
“ “	F.	108.6	....	....	1	“
Melanerpes formicivorus	M.	108.6	108.0	109.2	3	“
“ “	F.	108.2	107.5	108.8	2	“
Asyndesmus lewisi	M.	108.6	....	....	1	“
“ “	F.	107.3	....	....	1	“
Centurus carolinus	M.	109.4	109.4	109.4	3	“
Centurus uropygialis	M.	108.7	....	....	1	“
“ “	F.	107.0	....	....	1	“
Colaptes auratus	M.	109.1	108.3	110.0	2	“
Colaptes cafer	M.	107.2	....	....	1	“
“ “	F.	108.9	....	....	1	“
Colaptes chrysoides	M.	105.8	....	....	1	“
“ “	F.	108.6	....	....	1	“
CAPRIMULGIDAE						
Antrostomus vociferus	M.	108.4	....	....	1	I.
Phalaenoptilus nuttalli	M.	107.2	....	....	1	“
Chordeiles virginianus	M.	106.2	....	....	1	“
“ “	F.	105.7	105.0	106.4	2	“
Chordeiles acutipennis	M.	107.8	107.7	107.9	2	“
“ “	F.	107.4	....	....	1	“
MICROPODIDAE						
Chaetura pelagica	F.	107.2	....	....	1	I.
Aëronautes melanoleucus	M.	106.0	105.7	106.3	4	“
“ “	F.	105.3	105.2	105.3	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
TROCHILIDAE						
Archilochus colubris	M.	106.0	....	....	1	I.
“ “	F.	101.4	100.8	102.0	2	“
Archilochus alexandri	M.	103.0	102.7	103.6	3	“
“ “	F.	102.7	101.4	104.3	3	“
Selasphorus platycercus	F.	101.5	....	....	1	“
Selasphorus rufus	M.	102.2	101.8	102.6	2	“
Cynanthus latirostris	M.	105.9	105.1	106.5	3	“
TYRANNIDAE						
Tyrannus tyrannus	F.	107.8	....	....	1	I.
Tyrannus verticalis	M.	108.5	108.3	108.6	2	“
Tyrannus vociferans	M.	107.0	....	....	1	“
“ “	F.	108.2	....	....	1	“
Myiarchus cinerascens	M.	109.8	108.6	111.8	4	“
“ “	F.	110.1	109.2	111.0	2	“
Myiarchus lawrencei	M.	109.5	109.2	109.8	2	“
“ “	F.	110.2	....	....	1	“
Sayornis phoebe	M.	109.9	....	....	1	“
Sayornis nigricans	M.	109.1	108.6	109.7	3	“
“ “	F.	110.0	....	....	1	“
Nuttallornis borealis	M.	109.0	108.0	110.0	2	“
“ “	F.	108.4	....	....	1	“
Myiochanes pertinax	F.	110.3	108.7	111.6	5	“
Myiochanes virens	M.	108.9	....	....	1	“
Myiochanes richardsoni	M.	110.0	108.6	112.7	4	“
“ “	F.	110.4	....	....	1	“
Empidonax flaviventris	M.	108.0	107.4	109.0	6	“
“ “	F.	108.2	107.6	108.7	4	“
Empidonax difficilis	M.	108.2	107.0	109.8	3	“
Empidonax virescens	M.	108.8	108.4	109.2	2	“
“ “	F.	108.6	....	....	1	“
Empidonax trailli	M.	108.0	107.5	108.7	6	“
“ “	F.	108.6	107.2	109.6	4	“
Empidonax minimus	M.	107.5	....	....	1	“
“ “	F.	108.3	107.6	109.0	2	“
Empidonax hammondi	M.	106.2	....	....	1	“
“ “	F.	107.9	107.3	108.7	3	“
Empidonax wrighti	M.	108.3	107.7	108.7	3	“
Pyrocephalus rubinus	M.	108.6	108.2	109.0	2	“
ALAUDIDAE						
Otocoris alpestris	M.	109.4	108.6	110.4	3	I.
“ “	F.	109.4	108.6	110.3	6	“
CORVIDAE						
Pica pica	M.	107.3	106.4	108.6	9	I.
“ “	F.	107.1	106.2	108.8	9	“
Pica nuttalli	M.	108.1	....	....	1	“
“ “	F.	107.7	107.6	107.8	2	“
Cyanocitta cristata	M.	108.4	108.0	108.8	2	“
“ “	F.	109.3	....	....	1	“
Cyanocitta stelleri	M.	107.4	....	....	1	“
“ “	F.	107.8	107.3	108.3	2	“
Aphelocoma cyanea	M.	108.2	107.7	108.5	5	“
“ “	F.	107.9	107.1	108.6	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
CORVIDAE—*Continued*						
Aphelocoma woodhousei	M.	108.6	108.4	108.7	2	I.
“ “	F.	110.3	....	....	1	“
Aphelocoma californica	M.	107.5	107.3	107.6	2	“
“ “	F.	108.7	....	....	1	“
Aphelocoma sieberi	M.	108.5	108.2	108.7	2	“
“ “	F.	108.4	108.2	108.6	2	“
Perisoreus obscurus	M.	108.2	107.8	108.6	2	“
“ “	F.	107.3	....	....	1	“
Corvus corax	M.	107.4	....	....	1	R.
“ “	F.	108.6	107.6	109.6	2	“
Corvus cryptoleucus	M.	107.6	107.6	107.7	2	“
“ “	F.	106.8	....	....	1	“
Corvus brachyrhynchos	M.	107.9	107.6	108.4	4	“
Nucifraga columbiana	M.	106.6	....	....	1	“
“ “	F.	107.1	106.8	107.4	2	“
Cyanocephalus cyanocephalus	M.	106.6	....	....	1	I.
“ “	F.	108.3	....	....	1	“
ICTERIDAE						
Dolichonyx oryzivorus	M.	107.0	....	....	1	I.
Molothrus ater	M.	108.1	107.3	108.5	4	“
“ “	F.	108.2	108.0	108.3	2	“
Xanthocephalus xanthocephalus	M.	108.3	107.0	110.0	29	“
“ “	F.	108.2	106.6	110.3	18	“
Agelaius phoeniceus	M.	108.3	106.5	110.3	10	“
“ “	F.	108.1	106.7	108.7	6	“
Agelaius tricolor	M.	108.5	....	....	1	“
“ “	F.	108.6	108.0	109.0	4	“
Sturnella neglecta	M.	107.6	....	....	1	“
“ “	F.	108.4	107.8	109.0	2	“
Icterus parisorum	M.	107.9	107.2	108.4	4	I.
“ “	F.	108.1	107.8	108.3	2	“
Icterus cucullatus	M.	109.3	108.3	110.4	2	“
“ “	F.	107.6	....	....	1	“
Icterus spurius	M.	108.1	....	....	1	“
Icterus galbula	M.	109.1	109.1	109.2	2	“
Icterus bullocki	F.	108.0	107.8	108.2	3	“
Euphagus carolinus	M.	110.3	110.0	110.6	2	“
“ “	F.	109.7	109.6	110.0	3	“
Euphagus cyanocephalus	M.	108.7	108.6	108.8	2	“
“ “	F.	107.1	106.1	108.1	2	“
Quiscalus quiscula	F.	109.6	....	....	1	“
Megaquiscalus major	M.	109.4	109.3	109.6	2	“
“ “	F.	108.6	....	....	1	R.
FRINGILLIDAE						
Hesperiphona vespertina	M.	109.5	....	....	1	I.
“ “	F.	108.0	....	....	1	“
Carpodacus purpureus	M.	108.3	106.7	109.5	6	“
“ “	F.	108.3	....	....	1	“
Carpodacus mexicanus	M.	108.9	108.0	110.0	20	“
“ “	F.	108.8	108.6	109.2	7	“
Loxia curvirostra	M.	108.2	107.9	108.6	3	“
Loxia leucoptera	F.	109.4	108.9	109.9	2	“
Passer domesticus	M.	107.6	106.8	108.6	7	“
“ “	F.	107.9	107.0	108.8	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
FRINGILLIDAE—*Continued*						
Astragalinus tristis	M.	107.7	106.0	109.9	4	I.
“ “	F.	108.1	106.6	109.7	2	“
Spinus pinus	M.	108.3	107.4	108.8	3	“
“ “	F.	107.3	106.7	107.6	3	“
Calcarius lapponicus	F.	107.0	....	....	1	“
Passerculus sandwichensis	M.	108.3	106.6	110.0	5	“
“ “	F.	109.2	108.4	110.0	3	“
Ammodramus savannarum	M.	108.6	....	....	1	“
Passerherbulus henslowi	M.	106.2	....	....	1	“
Chondestes grammacus	F.	109.2	108.3	110.2	2	“
Zonotrichia querula	M.	108.2	107.5	109.6	3	“
“ “	F.	108.8	....	....	1	“
Zonotrichia leucophrys	M.	109.0	106.8	110.2	4	“
“ “	F.	108.9	108.8	109.1	2	“
Zonotrichia coronata	M.	108.5	....	....	1	“
“ “	F.	109.5	109.4	109.6	2	“
Zonotrichia albicollis	M.	110.2	109.4	110.8	5	“
Spizella monticola	M.	108.0	....	....	1	“
“ “	F.	108.6	107.3	109.5	8	“
Spizella passerina	M.	109.6	....	....	1	“
“ “	F.	106.9	....	....	1	“
Spizella pallida	M.	108.0	107.5	108.4	3	“
Spizella breweri	M.	108.1	107.7	108.5	2	I.
“ “	F.	108.7	108.0	109.4	2	“
Spizella pusilla	M.	107.4	106.2	108.7	5	“
“ “	F.	108.2	....	....	1	“
Junco hyemalis	M.	108.6	106.8	110.0	8	“
“ “	F.	108.8	107.1	110.3	3	“
Junco oreganus	M.	109.2	108.5	110.6	7	I.
“ “	F.	108.5	108.6	109.0	2	“
Junco phaeonotus	M.	108.3	108.0	108.9	4	“
“ “	F.	108.8	107.9	109.7	6	“
Amphispiza bilineata	M.	108.0	107.9	108.0	3	“
“ “	F.	110.0	....	....	1	“
Amphispiza nevadensis	F.	109.4	108.6	110.0	3	“
Peucaea aestivalis	M.	107.8	....	....	1	“
Aimophila ruficeps	M.	109.8	109.4	110.2	2	“
Melospiza melodia	M.	109.1	108.0	109.8	11	“
“ “	F.	109.1	108.3	110.2	4	“
Melospiza lincolni	M.	107.8	107.2	108.5	2	“
Melospiza georgiana	M.	108.8	107.9	109.8	3	“
“ “	F.	109.0	....	....	1	“
Passerella iliaca	M.	109.3	108.5	110.0	3	“
“ “	F.	109.3	108.6	109.9	2	“
Pipilo erythrophthalmus	M.	110.0	109.6	110.3	3	“
Pipilo maculatus	F.	109.1	108.4	110.3	3	“
Pipilo fuscus	M.	107.9	107.6	108.0	3	“
Pipilo crissalis	M.	108.5	108.0	109.6	3	“
“ “	F.	107.8	....	....	1	“
Pipilo aberti	M.	109.4	....	....	1	“
“ “	F.	110.4	....	....	1	“
Cardinalis cardinalis	M.	109.3	107.6	110.8	7	“
“ “	F.	109.3	108.6	110.0	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
FRINGILLIDAE—*Continued*						
Zamelodia ludoviciana	M.	107.8	107.3	108.2	2	I.
“ “	F.	108.8	....	....	1	“
Zamelodia melanocephala	M.	108.5	108.2	109.0	5	“
“ “	F.	108.5	108.0	109.5	4	“
Guiraca caerulea	M.	108.0	107.0	108.6	3	“
Passerina cyanea	M.	107.6	107.5	107.6	2	“
“ “	F.	109.8	....	....	1	“
Passerina amoena	M.	108.9	....	....	1	“
“ “	F.	108.2	....	....	1	“
Spiza americana	M.	108.3	107.9	108.9	7	“
Calamospiza melanocorys	M.	108.3	108.2	108.4	2	“
TANGARIDAE						
Piranga ludoviciana	M.	108.4	108.1	108.7	4	I.
“ “	F.	107.3	....	....	1	“
Piranga erythromelas	M.	107.8	106.8	109.5	4	“
“ “	F.	107.3	....	....	1	“
Piranga hepatica	M.	108.6	107.2	109.4	5	“
“ “	F.	110.2	110.0	110.4	2	“
Piranga rubra	M.	109.9	....	....	1	“
“ “	F.	109.3	109.1	109.5	3	“
HIRUNDINIDAE						
Progne subis	M.	107.4	107.0	107.7	4	“
“ “	F.	106.8	....	....	1	“
Petrochelidon lunifrons	M.	106.3	105.0	107.3	4	“
Hirundo erythrogastra	M.	106.5	....	....	1	“
Iridiprocne bicolor	M.	106.8	106.8	106.8	2	“
“ “	F.	107.0	106.0	107.9	2	“
Tachycincta thalassina	M.	105.7	104.6	106.8	2	“
“ “	F.	105.5	....	....	1	“
Riparia riparia	M.	105.7	105.4	106.2	4	“
Stelgidopteryx serripennis	M.	108.8	108.7	109.0	2	“
BOMBYCILLIDAE						
Bombycilla cedrorum	M.	108.2	107.2	109.2	3	I.
“ “	F.	109.7	109.0	110.7	3	“
PTILOGONATIDAE						
Phainopepla nitens	F.	107.4	107.4	107.4	2	I.
LANIIDAE						
Lanius ludovicianus	M.	107.5	....	....	1	I.
“ “	F.	108.0	107.3	109.3	3	“
VIREONIDAE						
Vireosylva olivacea	M.	108.5	107.9	109.2	2	I.
“ “	F.	109.7	....	....	1	“
Vireosylva philadelphica	M.	107.3	106.8	107.8	2	“
Vireosylva gilva	M.	107.5	107.0	107.9	3	“
“ “	F.	107.6	107.6	107.7	2	“
Lanivireo flavifrons	M.	108.0	....	....	1	“
“ “	F.	107.7	107.2	108.1	2	“
Lanivireo solitarius	M.	108.0	107.8	108.3	2	“
“ “	F.	107.3	107.3	107.4	2	“
Vireo griseus	F.	107.4	....	....	1	“
Vireo huttoni	F.	107.9	....	....	1	“
Vireo belli	M.	107.5	106.5	108.3	3	“
“ “	F.	106.3	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
MNIOTILTIDAE						
Mniotilta varia	M.	108.0	107.0	109.0	5	I.
“ “	F.	108.0	....	....	1	“
Helmitherus vermivorus	M.	107.4	107.2	107.5	2	“
“ “	F.	108.8	....	....	1	“
Vermivora pinus	M.	106.9	....	....	1	“
Vermivora chrysoptera	M.	109.4	....	....	1	“
“ “	F.	108.2	....	....	1	“
Vermivora luciae	M.	108.7	108.6	108.9	2	“
“ “	F.	108.8	108.0	109.5	2	“
Vermivora virginiae	M.	108.0	107.8	108.3	2	“
“ “	F.	108.2	108.0	108.5	2	“
Vermivora celata	M.	107.7	106.3	109.1	2	“
“ “	F.	107.3	107.2	107.4	2	“
Vermivora peregrina	M.	107.9	107.5	108.0	4	“
“ “	F.	108.3	....	....	1	“
Compsothlypis americana	M.	107.2	106.7	107.8	3	“
“ “	F.	108.4	....	....	1	“
Peucedramus olivaceus	M.	107.5	....	....	1	I.
Dendroica tigrina	M.	108.8	107.6	109.9	2	“
Dendroica aestiva	M.	108.6	107.9	109.8	3	“
Dendroica caerulescens	M.	108.0	107.5	108.5	6	“
“ “	F.	108.6	106.8	108.4	2	“
Dendroica coronata	F.	108.5	107.6	109.0	4	“
Dendroica auduboni	M.	107.7	106.9	108.4	3	“
“ “	F.	108.0	....	....	1	“
Dendroica magnolia	M.	108.0	106.6	109.3	5	“
“ “	F.	107.7	107.0	108.2	4	“
Dendroica cerulea	M.	109.0	....	....	1	“
Dendroica pennsylvanica	M.	108.6	107.2	109.4	6	“
“ “	F.	108.4	108.0	108.7	2	“
Dendroica castanea	M.	107.9	107.2	108.7	7	“
“ “	F.	108.8	108.7	108.9	3	“
Dendroica striata	M.	107.8	107.2	108.5	3	“
“ “	F.	107.4	107.0	107.8	2	“
Dendroica fusca	M.	107.8	107.8	107.8	3	“
“ “	F.	108.2	107.8	108.6	2	“
Dendroica dominica	M.	108.3	108.0	108.6	2	“
Dendroica graciae	M.	108.0	107.2	109.5	4	“
Dendroica nigrescens	F.	108.2	....	....	1	“
Dendroica virens	M.	108.0	107.6	108.5	9	I.
Dendroica vigorsi	M.	108.3	108.0	108.6	2	“
“ “	F.	109.2	....	....	1	“
Dendroica palmarum	M.	108.9	108.0	109.5	3	“
“ “	F.	108.3	107.8	109.2	4	“
Dendroica discolor	M.	108.0	107.6	108.4	2	“
Seiurus aurocapillus	M.	107.4	107.1	108.0	3	“
Seiurus noveboracensis	M.	108.5	106.2	109.7	4	“
“ “	F.	109.0	....	....	1	“
Seiurus motacilla	M.	109.4	....	....	1	“
Oporornis formosus	M.	107.8	....	....	1	“
Oporornis philadelphia	M.	107.7	107.3	108.0	3	“
Oporornis tolmiei	M.	108.2	107.0	109.4	2	“
“ “	F.	107.0	....	....	1	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
Mniotiltidae—*Continued*						
Geothlypis trichas	M.	108.0	....	....	1	I.
“ “	F.	108.1	106.6	109.0	3	“
Icteria virens	M.	109.2	108.0	110.4	2	“
“ “	F.	107.9	....	....	1	“
Wilsonia citrina	M.	109.6	....	....	1	“
Wilsonia pusilla	M.	107.7	106.8	108.6	6	“
“ “	F.	106.6	....	....	1	“
Wilsonia canadensis	M.	107.2	106.7	107.6	2	“
“ “	F.	107.6	107.0	108.3	3	“
Setophaga ruticilla	M.	106.8	....	....	1	“
“ “	F.	109.0	....	....	1	“
Setophaga picta	M.	108.5	108.0	109.0	3	“
“ “	F.	111.0	....	....	1	“
Motacillidae						
Anthus rubescens	M.	107.9	107.6	108.1	2	I.
“ “	F.	109.1	108.4	109.8	2	“
Anthus spraguei	M.	108.6	108.6	108.6	2	“
Cinclidae						
Cinclus mexicanus	M.	107.3	....	....	1	I.
Mimidae						
Oreoscoptes montanus	M.	109.0	....	....	1	I.
“ “	F.	109.2	....	....	1	“
Mimus polyglottos	M.	109.2	108.1	110.4	4	“
“ “	F.	109.0	108.4	109.6	2	“
Dumetella carolinensis	M.	108.6	....	....	1	“
“ “	F.	108.7	108.6	108.8	2	“
Toxostoma curvirostre	M.	108.0	....	....	1	“
“ “	F.	109.7	....	....	1	“
Toxostoma crissale	M.	108.5	....	....	1	“
“ “	F.	109.5	....	....	1	“
Troglodytidae						
Heleodytes brunneicapillus	F.	108.5	....	....	1	I.
Catherpes mexicanus	F.	107.9	....	....	1	“
Thryothorus ludovicianus	M.	108.9	108.4	109.7	3	“
“ “	F.	108.4	108.2	108.7	4	“
Thryomanes bewicki	M.	107.9	107.4	108.2	3	“
“ “	F.	107.5	107.5	107.6	2	“
Troglodytes aëdon	M.	106.2	....	....	1	“
Nannus hiemalis	M.	107.3	106.6	107.9	5	“
Telmatodytes palustris	M.	107.4	106.2	109.2	7	“
“ “	F.	105.7	105.2	106.6	3	“
Certhiidae						
Certhia familiaris	M.	107.7	107.1	108.5	4	I.
“ “	F.	107.4	....	....	1	“
Sittidae						
Sitta carolinensis	M.	107.7	106.8	108.3	3	I.
“ “	F.	107.7	106.0	108.8	3	“
Sitta canadensis	M.	107.9	107.5	108.2	5	“
“ “	F.	107.9	107.8	107.9	3	“
Sitta pusilla	M.	106.2	....	....	1	“
Sitta pygmaea	F.	107.8	107.8	107.9	2	“

TABLE 3.—*Continued*

Species	Sex	Temperature			No. of records	
		Mean	Minimum	Maximum		
PARIDAE						
Baeolophus bicolor	M.	108.8	108.6	109.0	3	I.
" "	F.	109.4	109.2	109.6	2	"
Baeolophus inornatus	M.	108.7	107.7	110.0	4	"
" "	F.	108.6	....	....	1	"
Baeolophus wollweberi	M.	107.6	....	....	1	"
" "	F.	108.5	108.3	108.7	2	"
Penthestes atricapillus	M.	107.9	....	....	1	"
" "	F.	108.7	108.2	109.6	3	"
Penthestes carolinensis	M.	108.0	106.6	109.4	4	"
" "	F.	108.3	107.5	109.3	8	"
Penthestes sclateri	M.	107.3	106.3	108.4	2	"
" "	F.	107.8	....	....	1	"
Penthestes gambeli	M.	109.0	....	....	1	"
" "	F.	108.3	107.9	108.6	2	"
Psaltriparus minimus	M.	106.0	106.0	106.0	2	"
" "	F.	105.3	....	....	1	"
Psaltriparus plumbeus	M.	108.2	....	....	1	"
" "	F.	107.4	....	....	1	"
Auriparus flaviceps	M.	106.2	106.0	106.5	2	"
" "	F.	107.5	107.5	107.6	2	"
CHAMAEIDAE						
Chamaea fasciata	M.	106.8	....	....	1	I.
" "	F.	108.0	108.0	108.1	2	"
SYLVIIDAE						
Regulus satrapa	M.	106.9	106.3	107.3	4	I.
" "	F.	107.7	....	....	1	"
Regulus calendula	M.	106.0	106.0	106.1	2	"
" "	F.	107.7	107.3	108.3	3	"
Polioptila caerulea	M.	107.7	106.0	108.7	5	"
" "	F.	107.6	....	....	1	"
Polioptila plumbea	M.	107.8	107.5	108.0	2	"
TURDIDAE						
Myadestes townsendi	F.	109.3	108.6	110.0	2	I.
Hylocichla mustelina	M.	109.0	....	....	1	"
Hylocichla fuscescens	M.	109.0	108.6	109.4	2	"
Hylocichla aliciae	M.	109.6	....	....	1	"
" "	F.	108.3	108.0	108.6	2	"
Hylocichla ustulata	M.	108.3	107.2	109.5	2	"
" "	F.	110.4	110.1	110.8	2	"
Hylocichla guttata	M.	109.3	108.4	109.8	6	"
" "	F.	107.6	....	....	1	"
Planesticus migratorius	M.	109.8	107.6	111.6	8	"
" "	F.	109.7	....	....	1	"
Sialia sialis	M.	108.1	108.0	108.2	2	"
" "	F.	108.0	....	....	1	"
Sialia mexicana	M.	109.6	....	....	1	"
Sialia currucoides	M.	108.0	....	....	1	"

TABLE 4.—*Average temperatures of families of birds, summarized from Table 3*

Family	No. of species	Temperature			No. of records
		Mean	Minimum	Maximum	
Colymbidae	4	103.6	101.3	104.9	10
Laridae	10	106.3	105.1	107.0	38
Rynchopidae	1	105.0	.....	.....	2
Anhingidae	1	105.7	.....	.....	1
Phalacrocoracidae	1	106.2	106.1	106.3	7
Pelecanidae	2	103.6	103.5	103.8	9
Anatidae	14	107.0	105.8	109.9	98
Ibididae	2	106.5	105.1	108.0	6
Ardeidae	6	104.3	102.6	105.8	26
Aramidae	1	104.5	.....	.....	2
Rallidae	2	105.9	105.5	106.7	14
Phalaropodidae	2	106.6	105.7	107.6	54
Recurvirostridae	2	105.7	104.9	106.6	45
Scolopacidae	15	106.7	105.1	109.1	140
Charadriidae	6	106.7	105.1	109.0	26
Odontophoridae	3	107.6	106.8	108.0	13
Columbidae	4	108.2	107.2	109.0	39
Cathartidae	1	103.8	.....	.....	1
Buteonidae	4	106.0	105.0	109.0	8
Falconidae	2	106.0	105.2	106.8	5
Aluconidae	1	103.5	.....	.....	2
Strigidae	6	103.7	102.2	106.6	12
Cuculidae	2	108.7	108.1	109.6	6
Alcedinidae	1	104.0	.....	.....	2
Picidae	20	108.0	105.8	109.8	64
Caprimulgidae	4	107.1	105.7	108.4	8
Micropodidae	2	106.2	105.3	107.2	7
Trochilidae	5	103.2	101.4	106.0	15
Tyrannidae	19	108.7	106.2	110.4	71
Alaudidae	1	109.4	.....	.....	9
Corvidae	14	107.9	106.6	110.3	62
Icteridae	15	108.4	107.0	110.3	106
Fringillidae	46	108.6	106.2	110.4	236
Tangaridae	4	108.6	107.3	110.2	21
Hirundinidae	7	106.7	105.5	108.8	23
Bombycillidae	1	108.9	108.2	109.7	6
Ptilogonatidae	1	107.4	.....	.....	2
Laniidae	1	107.8	107.5	108.0	4
Vireonidae	8	107.7	106.3	109.7	23
Mniotiltidae	41	108.2	106.6	111.0	163
Motacillidae	2	108.5	107.9	109.1	6
Cinclidae	1	107.3	.....	.....	1
Mimidae	5	108.9	108.0	109.7	15
Troglodytidae	7	107.6	105.7	108.9	30
Certhiidae	1	107.5	107.4	107.7	5
Sittidae	4	107.5	106.2	107.9	17
Paridae	10	107.9	105.3	109.4	44
Chamaeidae	1	108.0	108.0	108.1	3
Sylviidae	4	107.3	106.0	107.8	18
Turdidae	10	108.9	107.6	110.4	33

TABLE 5.—*Temperatures of species of birds not included in Table 3, taken from available literature*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
STRUTHIONIDAE						
Struthio camelus	M.	104.0	.....	.....	1	Bergtold, 1917, p. 52.
" "	F.	101.0	100.0	102.0	2	Bergtold, 1917, p. 52.
DROMAEIDAE						
Dromaeus novaehollandiae.	?	102.2	.....	.....	?	Sutherland, 1899, p. 789.
CASUARIIDAE						
Casuarius intensus ...	?	101.8	.....	.....	?	Sutherland, 1899, p. 789.
Casuarius beccarii ...	?	102.5	.....	.....	?	Sutherland, 1899, p. 789.
APTERYGIDAE						
Apteryx mantelli	M.	100.0	99.3	100.7	2	Sutherland, 1899, p. 789.
Apteryx haasti	M.	100.5	.....	.....	1	Sutherland, 1899, p. 789.
TINAMIDAE						
Rhynchotus rufescens.	?	105.4	.....	.....	?	Sutherland, 1899, p. 789.
Nothura maculosa ...	?	104.9	102.5	108.3	3	Sutherland, 1899, p. 789.
CRACIDAE						
Crax globicera	M.	106.4	.....	.....	3	Bergtold, 1917, p. 53.
" "	F.	106.4	.....	.....	4	Bergtold, 1917, p. 53.
PHASIANIDAE						
Francolinus natalensis.	?	107.9	.....	.....	?	Bergtold, 1917, p. 53.
Phasianus torquatus..	M.	107.5	.....	.....	2	Bergtold, 1917, p. 53.
" " ..	F.	106.0	.....	.....	1	Bergtold, 1917, p. 53.
Gallus gallus	M.	106.5	105.6	107.5	52	Simpson and Galbraith, 1905, p. 237.
" "	F.	106.7	105.5	107.4	52	Simpson and Galbraith, 1905, p. 237.
" " (Bantam).	M.	106.4	105.2	107.3	52	Simpson and Galbraith, 1905, p. 237.
" " " .	F.	106.9	105.6	107.8	52	Simpson and Galbraith, 1905, p. 237.
Pavo cristatus	?	107.1	104.9	109.4	2	Milne-Edwards, H., 1863, p. 17.
Numida meleagris ...	?	110.0	.....	.....	?	Pembery, 1898, p. 791.
Meleagris gallopavo..	?	109.0	.....	.....	?	Pembery, 1898, p. 791.
COLUMBIDAE						
Columba livia (domestic).	M.	105.6	103.9	105.6	51	Simpson and Galbraith, 1905, p. 237.
Columba livia (domestic).	F.	106.4	105.1	107.5	52	Simpson and Galbraith, 1905, p. 237.
Columba phaeonota...	?	110.0	.....	.....	1	Bergtold, 1917, p. 55.
Geotrygon montana...	?	110.0	.....	.....	1	Bergtold, 1917, p. 55.
RALLIDAE						
Rallus crepitans[1].....	?	104.2	.....	.....	...	Weber, 1918, p. 31.
Fulica atra	?	104.9	.....	.....	1	Milne-Edwards, H., 1863, p. 18.
SPHENISCIDAE						
Eudyptula minor	?	102.1	100.0	104 2	?	White, 1916, p. 56.
PROCELLARIIDAE						
Procellaria pelagica...	?	103.6	.....	.....	1	Simpson, 1912a, p. 31.
PUFFINIDAE						
Puffinus tenuirostris[1].	?	101.6	100.0	103.2	?	White, 1916, p. 46.
" " .	yg.	100.2	99.4	101.0	?	White, 1916, p. 46.
Fulmarus glacialis....	?	101.8	100.5	103.3	5	Martins, 1858, p. 32.
Daption capensis	?	103.6	102.8	104.3	4	Brown-Sequard, 1858, p. 44.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
DIOMEDEIDAE						
Diomedea exulans ...	?	105.2	103.2	107.4	7	Brown-Sequard, 1858, p. 43.
Thalassogeron chlororhynchus	?	105.8	105.2	106.3	2	Brown-Sequard, 1858, p. 43.
ALCIDAE						
Alca torda	M.	103.8	.....	.....	1	Simpson, 1912a, p. 32.
“ “	F.	105.9	.....	.....	1	Simpson, 1912a, p. 32.
Uria troille	M.	104.3	102.3	106.1	2	Simpson, 1912a, pp. 27-32.
“ “	F.	104 5	103.6	105.4	3	Simpson, 1912a, pp. 27-32.
Uria lomvia	?	104.9	103.5	106.7	8	Martins, 1858, p. 32.
Cepphus grylle	M.	105.1	104.1	105.8	6	Simpson, 1912a, pp. 27-32.
“ “	F.	105.6	104.3	106.7	7	Simpson, 1912a, pp. 27-32.
Fratercula arctica	?	105.3	105.2	105.5	2	Martins, 1858, p. 32.
LARIDAE						
Larus ridibundus	?	1 6.5	.....	.....	1	Martins, 1858, p. 32.
Larus argentatus	?	108.2	106.9	109.4	10	Martins, 1858, p. 32.
Larus fuscus	?	107.0	106 3	107.7	3	Simpson, 1912a, p. 31.
Larus canus	?	107.1	105.9	107.7	8	Simpson, 1912a, p. 31.
Larus glaucus	?	105.3	103.6	107.0	12	Martins, 1858, p. 33.
Pagophila eburnea ...	?	104.8	103.9	106.2	3	Martins, 1858, pp. 32-33.
Rissa tridactyla	?	106.6	103.8	108.3	16	Simpson, 1912a, p. 31.
Megalestris catarrhactes.	?	104.2	103.2	105.4	6	Brown-Sequard, 1858, p. 44.
STERCORARIIDAE						
Stercorarius parasiticus.	?	106.2	.....	.....	1	White, 1916, p. 46.
CHIONIDIDAE						
Chionis minor	?	104.0	.....	.....	?	Eydoux and Souleyet, 1838, p. 458.
EURYPYGIDAE						
Eurypyga helias	?	102.4	.....	.....	1	Bergtold, 1917, p. 54.
ANATIDAE						
Cygnus olor	M.	105.9	105.7	106.3	3	Martins, 1858, p. 33.
“ “	F.	105.9	105.6	106.3	4	Martins, 1858, p. 33.
Cairina moschata	?	107.7	105.5	108.2	16	Martins, 1858, p. 37.
Aix sponsa[1]	?	107.6	.....	.....	1	Simpson, 1912a, p. 31.
Anser (domestic goose).	?	106.4	104.4	107.6	96	Martins, 1858, pp. 34-36.
Anser albifrons	?	109.1	.....	.....	1	Martins, 1858, p. 36.
Cygnopsis cygnoides..	?	109.1	108.3	109.9	4	Martins, 1858, p. 33.
Branta bernicla	?	108.9	.....	.....	1	Martins, 1858, p. 36.
Tadorna tadorna	?	108.8	108.3	109.2	3	Martins, 1858, p. 36.
Anas platyrhynchos[1] (domestic).	M.	106.4	105.6	107.2	42	Simpson and Galbraith, 1905, p. 237.
Anas platyrhynchos[1] (domestic).	F.	107.0	105.9	107.7	41	Simpson and Galbraith, 1905, p. 237.
Anas rubripes[1]	?	105.8	105.2	106.7	3	Simpson, 1912a, p. 31.
Mareca penelope	?	108.5	106.6	109.5	18	Martins, 1858, p. 40.
Marila marila[1]	?	108.8	107.9	109.9	7	Martins, 1858, p. 36.
Clangula clangula ...	?	104.7	.....	.....	1	Simpson, 1912a, p. 31.
Oidemia nigra	?	106.3	105.6	107.0	2	Simpson, 1912a, p. 31.
Somateria mollissima.	?	108.4	104.1	109.8	9	Martins, 1858, p. 36.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
PHALACROCORACIDAE						
Phalacrocorax carbo	?	103.6	102.0	104.5	12	Simpson, 1912a, p. 31.
Phalacrocorax graculus.	M.	104.7	102.9	105.6	7	Simpson, 1912a, pp. 27-32.
Phalacrocorax graculus.	F.	104.8	103.2	106.1	12	Simpson, 1912a, pp. 27-32.
SULIDAE						
Sula bassana	?	107.0	104.5	108.1	7	Simpson, 1912a, p. 31.
FALCONIDAE						
Astur palumbarius	?	107.2	106.8	107.4	?	Hildén and Stenbäck, 1916, pp. 382-413.
Gypaëtus barbatus	?	105.8	.....	.....	?	Milne-Edwards, H., 1863, p. 17.
Archibuteo lagopus	M.	105.8	.....	.....	1	Bergtold, 1917, p. 53.
Falco mexicanus	M.	106.6	.....	.....	1	Bergtold, 1917, p. 53.
BUBONIDAE						
Strix varia[1]	?	102.6	102.6	102.6	?	Weber, 1918, p. 31.
MOMOTIDAE						
Momotus paraensis	?	104.1	.....	.....	1	Bergtold, 1917, p. 55.
MICROPODIDAE[1]						
Micropus apus	?	111.2	.....	.....	?	Pembery, 1898, p. 791.
MUSOPHAGIDAE						
Turacus corythaix	?	104.2	.....	.....	1	Bergtold, 1917, p. 55.
CUCULIDAE						
Geococcyx californianus.	M.	107.4	.....	.....	1	Bergtold, 1917, p. 55.
MIMIDAE						
Toxostoma rufum	?	109.6	.....	.....	1	Weber, 1918, p. 29.
TURDIDAE						
Turdus pilaris	?	110.6	.....	.....	?	Pembery, 1898, p. 791.
Hylocichla iliaca	?	109.9	.....	.....	?	Pembery, 1898, p. 791.
Hylocichla musica	?	105.6	101.2	108.7	29	Simpson and Galbraith, 1905, p. 237.
“ “	?	106.0	101.5	108.3	21	Simpson and Galbraith, 1905, p. 237.
BOMBYCILLIDAE[1]						
Bombycilla garrula[1]	M.	108.0	.....	.....	1	Bergtold, 1917, p. 56.
“ “[1]	F.	107.1	106.2	107.8	3	Bergtold, 1917, p. 56.
PARIDAE						
Parus major	?	111.2	.....	.....	?	Pembery, 1898, p. 791.
MNIOTILTIDAE						
Oporornis agilis	?	108.6	.....	.....	1	Weber, 1918, p. 29.
FRINGILLIDAE						
Ligurinus chloris	?	106.8	106.1	107.9	?	Hildén and Stenbäck, 1916, pp. 382-413.
Pyrrhula pyrrhula	?	107.9	.....	.....	1	Milne-Edwards, H., 1863, p. 17.
Emberiza citrinella	?	109.8	.....	.....	?	Pembery, 1898, p. 791.
Plectrophenax nivalis.	?	109.6	109.2	110.1	2	Milne-Edwards, H., 1863, p. 17.
Calcarius ornatus	M.	109.6	.....	.....	1	Bergtold, 1917, p. 57.
Passerherbulus caudacutus[1].	?	109.2	....	.....	1	Weber, 1918. p. 30.
Peucaea cassini[1]	M.	108.0	.....	.....	1	Bergtold, 1917, p. 57.

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[1] A. O. U. Checklist, 1910.

TABLE 5.—*Continued*

Species	Sex	Temperature			Number of records	Reference
		Mean	Minimum	Maximum		
STURNIDAE						
Sturnus vulgaris	?	106.7	101.9	109.1	17	Simpson and Galbraith, 1905, p. 237.
" "	?	107.8	104.3	110.2	55	Simpson and Galbraith, 1905, p. 237.
" "	?	106.5	103.5	108.7	55	Simpson and Galbraith, 1905, p. 237.
" "	?	106.6	103.3	109.2	56	Simpson and Galbraith, 1905, p. 237.
PARADISEIDAE						
Paradisea apoda	?	106.7	.....	.....	1	Bergtold, 1917, p. 55.
CORVIDAE						
Coloeus monedula ...	M.	107.0	105.2	108.4	56	Simpson and Galbraith, 1905, p. 237.
" " ...	F.	107.7	106.2	108.8	57	Simpson and Galbraith, 1905, p. 237.
Psilorhinus morio ...	?	110.0	.....	.....	1	Bergtold, 1917, p. 57.
Pyrrhocorax alpinus..	?	107.7	.....	.....	1	Milne-Edwards, H., 1863, p. 17.

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SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 13

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BY

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(PUBLICATION 2662)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 25, 1922

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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By L. B. ALDRICH

INTRODUCTION

The instrument about to be described is the outgrowth of the experience of Dr. Abbot and myself in the use of the pyranometer, and was planned in many discussions between us, as we walked together to and from the office. The pyranometer (described in Smithsonian Miscellaneous Collections, Vol. 66, Nos. 7 and 11, and Vol. 69, No. 9) has proved of great value in a wide range of radiation measurements. We have long felt the desirability and need, however, of a radiation measuring instrument of equal sensitiveness which would be perfectly absorbing and radiating for all wave-lengths by virtue of its form. Existing types of instruments, such as the pyranometer, bolometer, Ångström's pyrgeometer, compensation pyrheliometer, etc., all use a blackened flat surface upon which the radiation falls and is mostly absorbed. For the usual range of wave-lengths, for which the percentage absorption of the blackened surface is well known, these instruments are highly satisfactory. But in measuring radiations from bodies at comparatively low temperatures, grave doubt arises [with these instruments] because of the uncertainty of the absorptive power of a blackened flat surface for rays of long wave-length.

In the new instrument we have tried to produce one embodying an approximately "black-body" absorber, and still to retain as far as possible the advantages of the simple pyranometer. The melikeron is not as sensitive nor as quick-acting as the pyranometer, yet we have been very well pleased with its behavior. A detailed description of the instrument follows.

DESCRIPTION OF THE MELIKERON

The name of the instrument, first suggested by Dr. Abbot, is the Greek word μελικήρογ, honeycomb. That portion of the instrument which absorbs the radiation to be measured is somewhat like a honeycomb in shape.

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Sheet therlo,[1] an alloy having a low temperature coefficient of resistance, was rolled out into a strip about a meter long and as thin as possible. (In the first instrument made, this strip was about 0.05 mm. in thickness. This was about the limit of thinness obtainable by rolling between cold rollers. For the second instrument, a strip of one-half this thickness was produced by rolling between hot rollers. This was done by the mechanician of the University of Wisconsin Physics Department, through the kindness of Dr. C. E. Mendenhall.) With a straight edge, the strip was cut to one-half inch in width, and then pressed out in a specially prepared die, to assume the alternately flat and zigzag shape shown in figure 3. When this long strip was held together in a square frame, there were formed 200 small triangular tubes with walls in common, each tube one-half inch in depth and about 2.5 mm. on a side. The open end of this honeycomb of triangular tubes forms the absorbing area of the instrument.

The advantage gained by the large number of cells is that the outer ones protect the inner ones from loss of heat, so that notwithstanding the very large area of the walls of the cells compared to their open ends, the central cells, losing only at front and rear, change temperature about as much as flat strips presenting equal areas would do for the same intensity of radiation. We invoke, in other words, the guard-ring principle.

Before the long, crinkled strip was pressed into this square shape, each apex was coated with thin shellac, the whole baked in an oven for some hours, and this process repeated several times. Thus the whole strip, when formed into its final shape, was insulated, each part from every other that could come in contact with it, and a current of electricity could be sent through its whole length.

On the walls of the central cluster of tubes formed by the bending of the strip were fastened four thermo-electric elements, of fine copper and nickel wire. The junctions were symmetrically placed 2.5, 5.0, 7.5 and 10.0 mm. respectively along the length of the tube and insulated from it by thin tissue paper. These wires were brought out on the lower end of the tubes and connected in series. The constant temperature junctions were buried in wax on the under side of the glass plates *f*, *f* (fig. 2) and the outer leads were soldered to the binding posts *a*, *a*, (fig. 1). The two ends of the therlo strip were connected by copper wires to binding posts *a′*, *a′* (fig. 1).

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[1] Obtained from the Driver-Harris Wire Co.

Referring to figures 1 and 2, we may see how the honeycomb is mounted. Figure 1 is a view looking vertically down upon the instrument with shutter (*c*) wide open. Figure 2 is a vertical cross-section. Two nickeled copper plates (*i, h*), each with square holes 3 cm. on a side are placed one about 6 mm. above the other. The plates are held

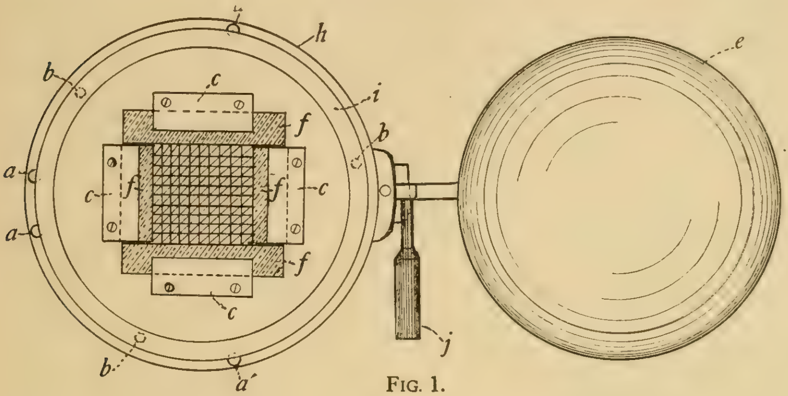

FIG. 1.

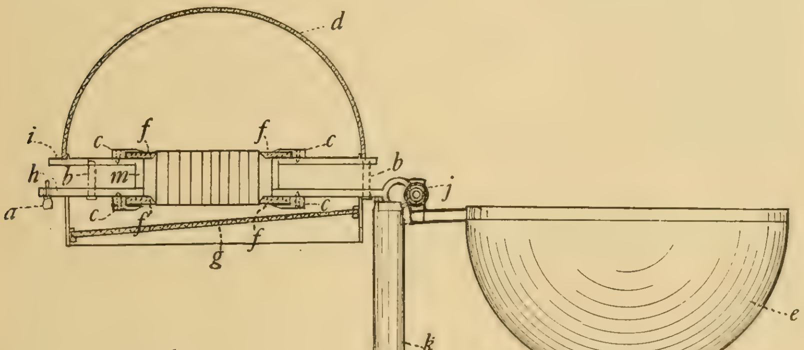

FIG. 2.

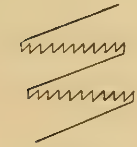

FIG. 3.

together by the three posts (*b*) and the space between the plates around the square hole enclosed with a copper box (*m*) attached to the upper plate. The wires leading to the four binding posts (*a, a, a′, a′*) pass through holes in this copper box. Four nickeled copper clips (*c*) are screwed to the top of the upper plate, and four more to the bottom of the lower plate. Each of these eight clips holds in place a silvered glass plate (*f*), each of which glass plates is beveled along its inner edge. These beveled glass edges serve to support the therlo strip in its square form, four around the upper edge of the honeycomb and four around the lower edge. The upper four also serve to determine the area which absorbs radiation. The silvered glass mirror (*g*), below the honeycomb, is placed, as shown, at a small angle to the face of the honeycomb and serves both to protect from the wind and to reflect radiation escaping from the lower face of the honeycomb back upon the sides of the tubes. The rod (*k*) screws into the plate (*h*) and affords a means of mounting the instrument in any desired position. The hemispherical shutter, (*e*), nickeled on the outside and blackened inside, operates from the handle (*j*), just as in the pyranometer. The optically figured ultra-violet crown glass hemisphere (*d*) serves the same purpose as in the pyranometer and may be used or not, according to whether or not it is desired to cut off the exchange of long waves between the instrument and the object to which it is exposed.

The melikeron is similar to the pyranometer in principle. In place of a small flat absorbing surface we substitute a large absorbing area consisting of the above described honeycomb of triangular tubes. Radiation falling normally passes through and is reflected back upon the walls by the rear mirror. Radiation not falling normally strikes the walls of the tubes and after one or more reflections is absorbed. For the purpose of somewhat increasing the blackness of the honeycomb, only the lower two-thirds of each tube is painted with lampblack, the upper one-third remaining a metallic reflector. Thus the number of regular reflections before final absorption is increased and the loss by diffuse reflection near the upper end reduced, because the diffusely reflecting and radiating lampblack lies so far below the aperture that the latter subtends only a small angular area as viewed from the blackened surface.

METHOD OF USE

For nocturnal radiation, or for the measurement of radiation exchange between the instrument and an object at lower temperature, the melikeron is used like the pyranometer. That is, an electric current is passed into the therlo strip producing heat sufficient to exactly compensate for the loss of heat by radiation. Knowing the current used, the resistance of the strip, and the other constants of the instrument, the amount of heat radiated is computed as with the pyranometer.

For measurements on the sun, daylight sky, or any radiation from bodies at higher temperature than the instrument, the simple "first-swing" pyranometer method is not applicable, since the slow-acting melikeron prevents a definite first-swing of the galvanometer and requires several minutes to complete the galvanometer deflection. An almost equally simple and satisfactory method applicable to constant sources of radiation was suggested by Dr. Abbot, however, namely: To open the shutter and expose to the radiation to be measured until the galvanometer deflection is constant, then close the shutter and instantly introduce sufficient current to keep the galvanometer at the same reading.

CONSTANTS OF INSTRUMENTS AND TESTS MADE

As mentioned above, two copies of the melikeron have been made. The second instrument embodies several improvements, notably a thinner therlo strip, and the tipping of the rear mirror at a slight angle to the honeycomb face. The constant of each instrument and tests made with each are given below.

Melikeron No. 1.—The constant of the instrument may be obtained in two ways:

(1) By computation from the dimensions and properties of the instrument;

(2) By direct comparisons on the sun with a silver disk pyrheliometer or other standardized instrument.

Only the first of these methods was used for the constant of Melikeron No. 1. As compared with the second method, this method is difficult and inaccurate, because of the uncertainty of such corrections as the amount reflected from the end surfaces of the thin metal composing the tubes, the amount lost by reflection and radiation from the upper portion of the tubes, the decrease in total aperture due to the unavoidable indentations around the edge, etc. A rough determination was made of the computed constant of Melikeron No. 1, as follows:

Area of aperture formed by beveled glass edges = 5.83 cm.^{2}
Estimated decrease in area of unused portions = .30 "

Corrected area = 5.53 "

Resistance of therlo strip = 0.945 ohms.

Then $\frac{.945 \times 60}{4.183 \times 5.53} = 2.45$ = constant Melikeron No. 1, applicable to reduce C^2 readings to calories per $\left(\frac{\text{cm.}^2}{\text{min.}}\right)$.

This is the constant without the glass hemisphere. *With* glass hemisphere, allowing for the reflection loss at two glass surfaces, the constant becomes 2.66 for the rays of short wave-length for which glass is highly transmissible.

Test experiments of three kinds were made with Melikeron No. 1:

(1) Using an incandescent lamp source, comparisons were made by interchanging Melikeron No. 1 and Pyranometer A. P. O. No. 5.

TABLE I

Date, 1920	Conditions	Calories (by melikeron No. 1)	Calories (by pyranometer No. 5)	Ratio melikeron/pyranometer
Feb. 11..	Carbon lamp, 60 cm directly above..	.0538	.0648	.830
Feb. 12..	Same, except angle 25° from zenith.	.0522	.0537	.972
Feb. 13..	Mazda "Daylight" lamp, 30 cm. above, 13° from zenith.	.0558	.0562	.995
Feb. 13..	Same source, 8 cm. above and 25 cm. east, 72° from zenith.	.0245	.0237	1.033
Feb. 14..	Same source, 30 cm. above, 7½° from zenith.	.0502	.0517	.972
Feb. 14..	Same source, 30 cm. above, 4½° from zenith.	.0435	.0512	.850

Both instruments were leveled, and the source placed at varying angles and distances. To insure constancy of the source, storage batteries were used. The results are summarized in table I.

As would be expected, since in Melikeron No. 1 the rear mirror is perpendicular to the honeycomb tubes, the instrument does not measure the full amount of radiation falling *normally* or nearly so, for this passes through the tubes to the rear mirror and is reflected by it directly back without being absorbed. For incidence greater than

TABLE II

(February 18, 1920)

	(Current)^2 by melikeron No. 1	(Current)^2 by pyrgeometer No. 22	Calories by melikeron	Constant of pyrgeometer No. 22
With R. S. plate	.01334	.00304	.0327	10.85
No “ “	.01756	.00350	.0430	12.28
With “ “	.01284	.00286	.0314	10.97
With “ “	.01246	.00282	.0305	10.81
No “ “	.01483	.00313	.0364	11.61
No “ “	.01573	.00314	.0385	12.26
With “ “	.01096	.00259	.0269	10.40
No “ “	.01309	.00256	.0321	12.55

Mean constant No. 22 with R. S. = 10.78.
Mean constant No. 22 no R. S. = 12.18.

5 degrees from normal, however, good agreement is shown between the pyranometer and the melikeron.

(2) Comparisons were made between Melikeron No. 1 and Ångström Pyrgeometer No. 22, with and without the interposition of a rock salt plate. A flat copper vessel (fig. 4) 90 x 86 cm., blackened on the front surface by painting with lampblack-alcohol-shellac paint and filled with ice-cooled water, formed the source, the instruments being at room temperature. A double shutter (*s*), sliding horizontally close to the copper vessel, exposed or screened the source. The instruments could be quickly exchanged, each mounted with absorbing surface vertical, facing the copper vessel, and 65 cm. from it. Alternate comparisons were made with and without a 1 cm. rock salt plate (*r*), figure 4, interposed directly in front of the instrument aperture. Using the above computed constant of the melikeron, values of the constant of Pyrgeometer No. 22 were determined (table II).

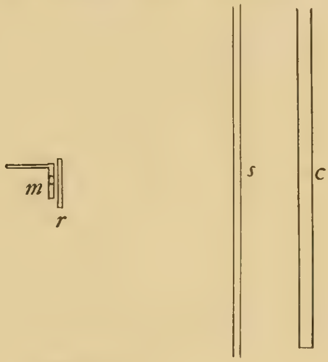

FIG. 4.

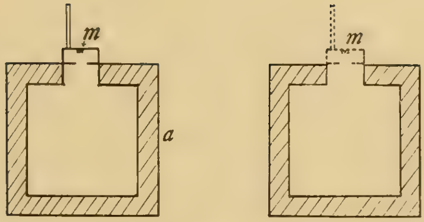

FIG. 5.

The absolute value of these results is of little weight, but the markedly lower value of the constant of Pyrgeometer No. 22 for the case where waves longer than 20μ are excluded, seems to indicate the greater "blackness" of the melikeron as compared with the other instrument for rays of very great wave-length.

(3) A rough determination of the constant σ of Stefan's formula was made. A wooden case and water jacket were fitted around Melikeron No. 1 to protect it from temperature fluctuations of the surroundings. This jacket extended over the face of the instrument, leaving an aperture 3.64 cm. in diameter at 7.03 cm. from the honeycomb face. Two hollow-chamber black bodies were made of double walled galvanized iron vessels (*a* and *b*, fig. 5) filled between the walls with stirred water, one at room temperature, the other containing a mixture of ice and water. The melikeron and surrounding jacket just filled the aperture of either of these black bodies, and could be quickly moved from one to the other aperture. The results are summarized. Details and necessary corrections which have been introduced in these results here will be found in the forthcoming Vol. IV, Annals of the Astrophysical Observatory.

Temperature of		(Current)^2	Observed calories $\left(\frac{\text{cm.}^2}{\text{min.}}\right)$	σ (calories per cm.^{2} per min.)
B. B. "a"	B. B. "b"			
°	°			
19.63	0.44	.003807	.00954	8.45×10^{-11} (Mean of 7)
28.30	0.40	.005852	.01434	8.53×10^{-11} (Mean of 7)

Value usually accepted (Smith. Phys. Tables, 7, p. 247) 8.26×10^{-11}.

These values are not given as new determinations of sigma. They have little weight for this purpose. They are given to show that not only does the melikeron agree with the standardized pyranometer for short-wave radiation observations but it also agrees well with the best work for long-wave rays.

Melikeron No. 2.—The constant of this instrument was determined with more care, and by both methods above mentioned.

(1) Computed constant.

Area of aperture formed by beveled glass edges $= 2.42 \times 2.42 = 5.86$ cm.^{2}

Therlo strip = 80 cm. long and .003 thick, making an end cross-sectional area of 0.24 cm.^{2}

Assume 40 per cent loss by reflection from this edge and this correction becomes .096 cm.^{2}

Area of incomplete triangles along edge of aperture = 0.36 cm.^{2}

Radiation entering $\frac{1}{2}$ this area is lost = 0.18 cm.^{2}

Assume direct absorption for solar rays[1] of therlo strip = 70 per cent, then of the other 18 cm.^{2} 30 per cent is lost = .054 cm.^{2} Hence, the total correction for incomplete triangles is .054 + .18 = .234 cm.^{2}

Area of irregular indentations that can lose energy by direct radiation = .06 cm.^{2}

Of this, $\frac{1}{2}$ is lost = .03 cm.^{2} (because radiation from one side of perpendicular is lost, other side is absorbed).

Total losses of all kinds = .096 + .234 + .03 = .36 cm.^{2}

Corrected area = 5.86 − .36 = 5.50 cm.^{2}

Resistance of strip = 1.555 ohms.

Computed constant (without glass hemisphere) =

$$\frac{1.555 \times 60}{4.183 \times 5.50} = 4.05$$

(2) Observed Constant.

The constant determined by comparison with pyrheliometers may be given more weight. The melikeron was mounted equatorially and a hood placed around it, similar to that supplied with the pyranometer, exposing the instrument only to the sun and a small area of sky around it. A double, ventilated shutter, blackened below, served to cut off the radiation at intervals. The first comparison was made on Mount Wilson, California, August 29 and 30, 1920, using secondary pyrheliometer No. IV. All the following values are *without* glass hemisphere.

First determination—Melikeron mounted so that sun rays fall normally on the instrument.

Calories by Pyr. No. IV $\left(\text{per}\ \frac{\text{cm.}^2}{\text{min.}}\right)$ = 1.468 (mean of 3).

(Current)^2 of Melikeron = .348 (mean of 3).

$$\frac{1.468}{.348} = 4.22 = \text{constant Melikeron No. 2.}$$

Second determination—Melikeron mounted so that sun rays strike the instrument at an angle of 8°.5 (cos. = .989).

Calories by Pyr. No. IV = 1.437 (mean of 3).

(Current)^2 of Melikeron = .360 (mean of 3).

$$\frac{1.437 \times .989}{.360} = 3.95 = \text{constant of Melikeron No. 2.}$$

From the ratio of these two results it appears that 6.8 per cent of the *normal* beam is absorbed and scattered, probably largely by

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[1] For rays of great wave-length the absorption is much less, so that this part of the loss would be increased. The difference cannot be serious, however, because this correction is after all very small.

the silvered surface of the rear mirror. Thus 3.95 is regarded as more nearly correct for ordinary work with beams which (unlike direct run-rays) subtend large angles.

The second comparison was made at Mount Harqua Hala, Arizona, by Dr. Abbot, November 10, 1920, using secondary pyrheliometers S. I. No. 32 and A. P. O. No. 9.

First determination—Melikeron normal to sun's rays.

Calories by Pyr. No. 32 and No. 9 = 1.531 (mean value).
(Current)^2 of Melikeron = .347 (mean value).

$$\frac{1.531}{.347} = 4.41 = \text{constant of Melikeron No. 2.}$$

Second determination—Melikeron at 7° angle to sun's rays (cos. 7° = .992).

Calories by Pyr. No. 32 and No. 9 = 1.538 (mean value).
(Current)^2 of Melikeron = .378

$$\frac{1.538 \times .992}{.378} = 4.04 = \text{constant of Melikeron No. 2.}$$

This result shows for *normally* incident rays a considerably greater absorption and scattering by the rear mirror than was the case in the comparison of August 30. From the deteriorated appearance of the silvered mirror on November 10 this was quite to be expected for sun rays, but the deterioration was probably quite negligible for earth rays. The best constant, then, of Melikeron No. 2 without glass hemisphere is the mean of 3.95 and 4.04, or 4.00 which is now the adopted value, applicable for all rays not at strictly *normal* incidence.

At Mount Wilson and Mount Harqua Hala numerous comparisons on the night sky were made between Melikeron No. 2 and Pyrgeometer No. 22. The two instruments, leveled, were mounted at the same height and within less than 6 inches of each other. Exactly similar bright tin-box shutters were used on both instruments. Using the above adopted constant of Melikeron No. 2, a value of the constant of Pyrgeometer No. 22 was obtained each time. The results are summarized in table III.

The mean of all, under these varying conditions of air temperature and water-vapor content is 9.72. There is perhaps some evidence in these values that the constant of Pyrgeometer No. 22 is a function of both air temperature and water-vapor content. But further comparisons under a wider range of air conditions are needed to confirm it.

To illustrate this indication, values are given in the table computed by the formula:

$$\text{Constant} = 11.50 - 3.12p - 1.47\ (t - 60°)^{1/3}.$$

They fit the observations much closer than the mean. This would be expected. To increase either the humidity or the temperature is to diminish the proportion of the extreme long-wave rays. The insertion of the salt plate in the above reported experiments with Melikeron No. 1 had a similar tendency. Hence, in view of the earlier observations, from the analogy, we should expect by increasing humidity or temperature to reduce the observed pyrgeometer constant. The observations are in harmony with this view.

TABLE III

Date, 1920	Wet and dry (t) readings, F.		Pressure aqueous vapor (p)	Constant of pyrgeometer No. 22	Δ from mean	Computed value	o−c
Mt. Wilson	Wet °	Dry °	mm.				
August 25	45.0 45.7	48.6 48.4	7.1 7.3	9.36	−0.36	9.59	−0.23
August 27	50.1 49.5	58.3 57.3	7.3 7.2	10.00	+0.28	9.43	+0.57
August 28	52.0	58.2	8.5	9.29	−0.43	9.03	+0.26
August 28	48.3 46.0	58.0 58.0	6.4 5.1	9.78	+0.06	9.90	−0.12
August 28	45.5 45.0	58.2 57.3	4.8 4.8	10.33	+0.61	10.19	+0.14
Mt. Harqua Hala							
September 29...	53.0 53.0	70.5 70.2	6.2 6.3	9.40	−0.32	9.23	+0.17
September 30...	47.6 48.7	69.0 67.0	3.3 4.5	9.70	−0.02	9.99	−0.29
October 1.......	50.0 50.0	64.3 64.3	5.9 5.9	9.36	−0.36	9.42	−0.06
October 2.......	45.9 45.9	63.5 62.3	3.8 4.1	10.02	+0.30	10.06	−0.04
October 3.......	49.5 49.2	66.0 65.5	5.1 5.1	9.95	+0.23	9.65	+0.30

It is hoped many further experiments with the melikeron may soon be made with a view to a better knowledge of the behavior of long wave-length radiation in our atmosphere and as emitted by bodies at low temperatures.

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 14

A NEW SAUROPOD DINOSAUR FROM THE OJO ALAMO FORMATION OF NEW MEXICO

(With Two Plates)

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(Publication 2663)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
JANUARY 31, 1922

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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(With Two Plates)

INTRODUCTION

In a brief note[1] I have recently announced the discovery by Mr. John B. Reeside, Jr., geologist of the United States Geological Survey, of Sauropodous dinosaur remains in the Upper Cretaceous of New Mexico, and it is now proposed to give a more detailed account of the specimens and of their exact geological occurrence than was possible in the preliminary notice.

The remains so far recovered consist of a left scapula and a right ischium, both in a good state of preservation. The great importance of these particular bones lies in the fact that the remains of Sauropodous dinosaurs have not previously been known to occur above the Lower Cretaceous in North America, so that the extension of their geological range into the Upper Cretaceous is of the greatest paleontologic and geologic interest.

It is particularly fortunate that this discovery should have been made by a trained geologist of Mr. Reeside's attainments, and in a section so well established as to preclude the possibility of question as to their late position in the geological column.

That these bones pertain to a member of the Sauropoda is indicated by their immense size and also by their close general resemblance to homologous elements of the typical Sauropoda from the Morrison formation. Marked differences in details, however, more especially in the ischium, in conjunction with the very late geological occurrence, makes it necessary to establish a new genus and species for their reception, for which the name *Alamosaurus sanjuanensis* is proposed.

DESCRIPTION

ALAMOSAURUS, new genus

The characters of this genus are included in the following description of the type species:

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[1] Science (N. S.), vol. LIV, 1921, p. 274.

ALAMOSAURUS SANJUANENSIS, new species

Plates 1, 2

Type.—Cat. No. 10,486, U. S. N. M., consists of the nearly complete left scapula.

Paratype.—Cat. No. 10,487, U. S. N. M., consists of the nearly complete right ischium.

Type locality.—Barrel Spring Arroyo, one mile south of Ojo Alamo, San Juan County, New Mexico.

Horizon.—Ojo Alamo formation, Upper Cretaceous.

Collector.—J. B. Reeside, Jr., June, 1921.

The scapula and ischium designated as the type and paratype, respectively, were found in the same geological horizon, but some 200 feet distant from one another. While it is quite possible that both may pertain to the same individual, it is thought best to regard them as distinct until their closer relationship can be more positively established.

Scapula.—The scapula is in a good state of preservation except for the loss of a portion of the proximal or articular end (see pl. 1) where it projected above the ground and was weathered away. The suprascapular end is also incomplete, though apparently only the border is missing. In size this bone rivals the largest of the *Camarasaurus* scapulae described by Messrs. Osborn and Mook,[1] since as preserved its greatest length is 155 cm. (60 inches), and it is conservatively estimated that the total length of the complete bone would have been at least 170 cm. (68 inches).

In outline, as shown in plate 1, the blade of the scapula differs from any described form in that there is a gradual widening of the shaft from below upward to the superior end, there being no especial expansion of the anterior border as found in *Camarasaurus,* nor rapid superior expansion of both borders as found in *Diplodocus* and *Haplocanthosaurus.* While this portion of the bone is heavy it is not so massive as in *Camarasaurus,* being much thinner. The superior end is flattened out, though the external surface becomes convex transversely as the middle of the bone is approached. From end to end the bone is curved as in other members of the Sauropoda. Both anterior and posterior borders thin out to sharp edges, this condition continuing downward half its total length. Immediately above the point where the anterior border begins to turn upward to form the prescapular expansion of the lower end the border becomes thick-

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[1] Memoirs Amer. Mus. Nat. Hist., new ser., vol. 3, pt. 3, 1921, p. 341, fig. 74.

ened and rounded. The posterior border, however, continues downward as a fairly sharp edge to the downward swing of this border to form the glenoid socket where the bone rapidly thickens transversely.

The spine or ridge on the lower external surface extends from the base of the shaft in an anterior direction to the anterior-superior border, and at right angles to the longitudinal axis of the bone. This ridge is not greatly elevated except that on the side toward the coracoidal border the bone is rapidly and deeply excavated, forming a muscle fossa of great extent. On the upper side of this ridge the surface of the bone slopes off gradually to the border, there being no excavation or superior fossa such as is found in so many Sauropod scapulae.

MEASUREMENTS

	Centimeters
Greatest length of scapula (as preserved)	155
" " " " (estimated)	170
Greatest breadth of superior end	45
Least breadth of shaft	29
Greatest breadth inferior (oblique)	82
Thickness of shaft at center	29

Ischium.—A large bone found in the same horizon but some 200 feet distant from the scapula described above is identified as the right ischium of a Sauropod dinosaur. This bone differs so from other Sauropod ischia that its true nature was determined with difficulty. That it pertains to a member of the Sauropoda is indicated by its large size and also by its general resemblance, though differing markedly from any described form. It is characterized by its extreme shortness, and especially by the lack of the long, slender posterior extension so characteristic of other Sauropod ischia.

The proximal portion is nearly complete, lacking only a small portion of the sharp inner edge of the acetabular border. The distal end, though not perfect, apparently lacks but little of being complete. Likewise the thin inner border below the articulation for the pubis is slightly imperfect. Except for the missing portions mentioned, the bone is in a remarkably fine state of preservation.

The expanded proximal end is unusual, not so much because of its great antero-posterior extent, but on account of the great dorso-ventral diameter, and especially the great length of the pubic articulation which extends distalward more than one-half the total length of the bone. Below the pubic articulation the inner border presents a thin, sharp edge, and the flattened distal portion gradually diminishes in width to the distal end. This end is apparently without distal expansion, though the incomplete surfaces makes this point slightly uncertain. Neither can it be definitely determined whether the ischia met on the median line, though I am inclined to think they did. The rounded and somewhat thickened posterior border is deeply concave from end to end. The sweep downward from the iliac articulation is especially pronounced. On the posterior external surface at the mid-length of the bone is a raised ridge with roughened surface marking the point of insertion for a strong muscle.

The form and principal features of this bone are well shown in plate 2.

Measurements	Centimeters
Greatest length	81
Greatest width of proximal end	44.5
Greatest width at lower end of pubic articulation	32
Greatest length of pubic articular surface	37.5
Greatest transverse diameter of articular end for ilium	10.5

RELATIONSHIPS

The scapula cannot be closely correlated with any of those of described genera, and the ischium differs so much in its details from those with which it has been compared as to indicate an animal with a considerably different pelvic structure than any of the Sauropoda with which we are acquainted to-day. That both of these bones pertain to the same individual cannot be proven, but that both are Sauropod in aspect seems certain.

In size the scapula approaches *Camarasaurus*, but it differs by the non-expansion of the upper anterior border and the very much thinner blade; from *Diplodocus* it is to be distinguished by its larger size and the direction of the spine in relation to the longitudinal axis. In the present specimen this angle is approximately 90°, whereas in *Diplodocus* and *Amphicoelus* it is acute. The scapulae of *Apatosaurus, Amphicoelus,* and *Brachiosaurus* are more slender and with a much more constricted shaft at their narrowest width. *Haplocanthosaurus* is very much smaller and has a very different outline.

GEOLOGICAL OCCURRENCE

At my request Mr. Reeside prepared the following note on the stratigraphy:

NOTE ON THE STRATIGRAPHY OF SAN JUAN COUNTY, NEW MEXICO, WITH ESPECIAL REFERENCE TO THE OCCURRENCE OF DINOSAURS

The oldest rocks exposed in San Juan County, New Mexico, have been assigned to the McElmo formation of Jurassic or Lower Cretaceous age. The overlying rocks, of Upper Cretaceous and Tertiary age, have been divided into a number of units named in ascending order as follows: Dakota sandstone, Mancos shale, Point Lookout sandstone, Menefee formation, Cliff House standstone, Lewis shale, Pictured Cliffs sandstone, Fruitland formation, Kirtland shale with included Farmington sandstone member, Ojo Alamo sandstone, Puerco formation, Torrejon formation, and Wasatch formation. The Point Lookout sandstone, Menefee formation, and Cliff House sandstone comprise the Mesaverde formation of the older literature and the Pictured Cliffs sandstone, Fruitland formation, and Kirtland shale, the Laramie formation. The Dakota sandstone contains coal beds and other plant remains and grades into the overlying Mancos shale. The formations from the Mancos shale to the Pictured Cliffs sandstone, inclusive, are marine except parts of the Menefee formation which are brackish and fresh water deposits with coal beds. The lower part of the Fruitland formation contains a transition series of brackish water beds and the upper part and all of the overlying formations are fluviatile deposits. The Mancos shale represents in large part the Benton shale and Niobrara formation of the region east of the Rocky Mountains. Its extreme upper part, however, is the equivalent of the basal part of the Pierre shale. The Mesaverde group, Lewis shale, and Pictured Cliffs sandstone contain invertebrates of Montana age, and the Fruitland and Kirtland formations, plants, invertebrates, and reptiles of Montana age. These beds definitely assignable to the Upper Cretaceous, *i. e.*, from Dakota sandstone to Kirtland shale, inclusive, are a comformable series 5,500 feet thick, of which about 4,000 feet are of Montana age. The age of the Ojo Alamo sandstone is in dispute. It has been assigned by some writers on the basis of its dinosaur fauna to the Montana group and correlated with the Judith River beds. It is separated from the Kirtland shale by a widespread unconformity and has been correlated on that ground by other writers with the Denver and Raton formations of post-Montana age. The Puerco and Torrejon formations contain large mammalian faunas and are usually placed in the Tertiary, though some writers would place them in the Cretaceous. The Wasatch formation is universally accepted as Tertiary.

Dinosaur remains have been found in the Fruitland formation, throughout the Kirtland shale, and in the Ojo Alamo sandstone. The sauropod bones found in June, 1921, came from the lower part of the Ojo Alamo sandstone on Barrel Spring Arroyo, one mile south of Ojo Alamo. A detailed section at this locality is as follows:[1]

Ojo Alamo sandstone:	Feet
Sandstone, conglomeratic; top eroded	15+
Shale, dark greenish gray	7
Sandstone, soft, nearly white, crossbedded; contains gray argillaceous streaks and brown concretions	21
Shale, wine red, with local gray sandstone lenses	5
Sandstone, soft, white, crossbedded; contains brown concretions in the lower part	10
Sandstone, brown, platy, ferruginous	1
Shale, dark bluish gray to purple, sandy	4

---

[1] See Bauer, C. M., Stratigraphy of a part of the Chaco River Valley. U. S. Geol. Survey Prof. Paper 98, pl. 69 and pl. 70, 1916. This locality is shown as locality 67 on plate 69 and the stratigraphic section as section R on plate 70.

Ojo Alamo sandstone:—Continued.	Feet
Sandstone, soft white, conglomeratic; contains brown concretions; horizon of the sauropod and other bones	6
Sandstone, yellow to brown, conglomeratic; contains an abundance of siliceous pebbles as large as 3 inches in diameter	5
Unconformity.	
Kirtland shale:	
Shale, gray to drab, with several wine red layers; scattered dinosaur bones	30
Sandstone with lenses of grit, fine conglomerate, and many clay pellets	10
Shale, gray	20±
Farmington sandstone member: brown indurated sandstone and gray shale	80±
Shale, gray to drab, and sandstone, soft, gray-white	1000±
Fruitland formation:	
Sandstone, shale, and coal.	

Directly associated with the bones of *Alamosaurus* are many other fragmentary and undeterminable dinosaur bones, teeth of carnivorous and Ceratopsian dinosaurs, dermal plates of an armored form, turtle fragments, and crocodile bones. At nearly the same horizon in adjacent localities on Barrel Spring Arroyo there were obtained part of the frill of an undetermined Ceratopsian[1] different from known forms, dermal plates of an armored dinosaur,[2] incomplete vertebrae of a carnivorous dinosaur as large as *Tyrannosaurus*,[3] fragments of a Ceratopsian frill marked with radiating vasicular grooves like those of *Triceratops*, but indeterminable.[4] This horizon is also the source of the maxillary and fragments of a skull collected by Sinclair and Granger and identified by Brown as *Kritosaurus navajovius*.[5]

From the uppermost part of the Kirtland shale near this locality have been collected specimens that are closely related to species known to be of Montana age: *Kritosaurus navajovius* Brown, skull and

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[1] Gilmore, C. W., Reptilian faunas of the Torrejon, Puerco, and underlying Upper Cretaceous formations of San Juan County, New Mexico: U. S. Geol. Survey Prof. Paper 119, p. 65, 1919.

[2] Idem, p. 65, pl. 26, fig. 2.

[3] Idem, p. 67.

[4] Gilmore, Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations: U. S. Geol. Survey Prof. Paper 98, p. 287, 1916.

[5] Sinclair, W. J., and Granger, Walter, Paleocene deposits of the San Juan Basin, New Mexico: Am. Mus. Nat. Hist. Bull., vol. 33, p. 303, 1914.

other bones[1]; *Monoclonius* sp., horn core and fragments of frill[2]; armored dinosaur suggesting a Belly River genus,[3] humerus; a carnivorous form suggesting *Dryptosaurus* or *Dynamosaurus,* dentary[4]; undeterminable fragments of other trachodont, ceratopsian, and carnivorous dinosaurs; turtle and crocodile bones.

In 1910 the late Dr. S. W. Williston[5] reported the discovery of a Sauropod coracoid in the Trinity Sand of Oklahoma, Lower Cretaceous in age, which, in so far as western North America is concerned, represented the latest occurrence of Sauropod dinosaurs, up to the time of the present discovery. In the eastern United States, Sauropod dinosaurs (*Astrodon, Pleurocoelus*) have been known as occurring in the Arundel (Potomac) formation since Marsh first described them in 1888, but for a long time the Arundel was correlated with the Morrison formation (Atlantosaurus beds) of the west, but more recently, largely on paleobotanical evidence, it has been referred to the Lower Cretaceous. A recent restudy of the Arundel vertebrates[6] appears to indicate a higher position in the Lower Cretaceous than has previously been given them. It is also of interest that the Maryland Sauropoda are found associated with the remains of other dinosaurs having undoubted Upper Cretaceous affinities, as is the case with the bones now under discussion.

It thus appears that these specimens, found under conditions which allow no question of doubt to be raised, furnish the first indisputable evidence of the occurrence of Sauropodous dinosaurs in the Upper Cretaceous of North America.

REPORTED DISCOVERIES OF SAUROPOD REMAINS IN UPPER CRETACEOUS DEPOSITS

There have been a considerable number of reported occurrences of Sauropod dinosaur remains in Upper Cretaceous deposits in various parts of the world. Those recorded are from India, southern France, South America, Madagascar, German East Africa, and Egypt. These

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[1] Brown, Barnum, The Cretaceous Ojo Alamo beds of New Mexico, with description of the new dinosaur genus Kritosaurus: Am. Mus. Nat. Hist. Bull., vol. 28, p. 269, 1910.

Gilmore, C. W., Vertebrate faunas of the Ojo Alamo, Kirtland, and Fruitland formations, U. S. Geol. Surv. Prof. Paper No. 98, pp. 283-284, fig. 28; p. 285, 1916.

[2] Brown, Barnum, idem, p. 278.

[3] Gilmore, C. W., idem, p. 287.

[4] Gilmore, C. W., idem, p. 288, pl. 73, fig. 1.

[5] See Larkin, Pierce, Journ. Geol., vol. 18, No. 1, 1910, p. 93.

[6] Gilmore, C. W., Proc. U. S. Nat. Mus., vol. 59, 1921, pp. 581-594, pls. 110-114.

finds, however, have been called into question for one cause or another, so that as the evidence stands to-day, their exact status is very unsatisfactory.

Below I shall briefly review these various discoveries, although no attempt will be made to critically re-examine the evidence, however desirable that may be. I feel that in this problem I should defer to those having a wider knowledge of geological structures, and especially to those who have available extensive collections of Sauropodous dinosaur materials with which to make the necessary comparisons.

Taken in chronological order these reported finds are as follows:

1. Apparently the first Sauropod remains to be described from the Middle Cretaceous or above were those found in the Lamenta beds, probably Cenomanian, near Jabalpur, India. These specimens were described by Falconer[1] in 1862, without name, and it was 1877 before their Sauropod nature was recognized by Lydekker,[2] who redescribed them under the name *Titanosaurus indicus,* the type being a postmedian caudal vertebra.

2. In 1893, Lydekker[3] described various dinosaur bones from the Guaranitic beds of Patagonia, referring them to the Sauropod genera *Titanosaurus* and *Argyrosaurus.* These identifications were based upon numerous vertebral centra, limb and foot bones, fragmentary parts of the sacrum, pelvis, etc. The limb bones appear to have been in a splendid state of preservation and are certainly sauropod in aspect, though this assignment is seriously questioned by Nopcsa as I shall show later. Hatcher[4] observes that the Guaranitic beds " are referred to the Upper Cretaceous both upon stratigraphic and paleontologic evidences. Just where they should be placed in that series cannot be determined until we know more of the Dinosaurs contained in them. At present it seems not improbable that they will prove to be the equivalent of the Laramie of North America, as they have long been considered by Dr. Ameghino and others."

3. In 1899 Depéret[5] recognized the Sauropod genus *Titanosaurus* as occurring in the Danian of the Montague Noire of southern France. This determination was based upon a femur, an identification to which, as in the former case, Nopcsa makes serious objection as to its validity. He says:[6] " I wish briefly to draw attention to the fact that the Upper Cretaceous *Titanosaurus,* as known from the

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[1] Paleontological Memoirs, vol. 1, 1868, p. 418, pl. 34, figs. 3, 4, 5.

[2] Rec. Geol. Surv. India, vol. 10, 1877, pp. 38-41.

[3] Anales Museo de La Plata, vol. 2, pt. 1, 1893, pp. 1-12, pls. 1-5.

[4] Amer. Journ. Sci., vol. 9, 4th ser., 1900, pp. 94, 95.

[5] Bull. Soc. Geol. France, 3d ser., vol. 27, 1899, p. 692.

[6] Geol. Mag., n. s., Dec. 5, 1910, p. 261.

Montague Noire in France and from the Cretaceous formation of Argentina, and perhaps also from East Africa, has nothing to do with the Sauropoda, but belongs to the Trachodontid Orthopoda, as proved by the abundant Transylvanian material at my disposal." He then goes on to point out that these dinosaurs referred to *Titanosaurus* are generically identical with *Telmatosaurus,* a heavily built Trachodontid animal from Transylvania, of which the structure is largely known from undescribed material, the name *Titanosaurus* being applicable only to the English Wealden Sauropod described in 1887.[1]

4. In 1907, Thevenin[2] described certain fossils from Madagascar that were referred to the Sauropod genera *Bothriospondylus* and *Titanosaurus.* These are Cenomanian in age.

5. In 1907, Dr. E. Frass made the interesting discovery of Sauropod dinosaurs in southern German East Africa. These were at first thought to be of Upper Cretaceous origin, but since it now appears to be universally recognized that these animals are from the Lower Cretaceous and Upper Jurassic, they may be dismissed from further consideration in the present connection.[3]

6. Dr. W. D. Matthew, in a recent letter, informs me that Strömer has some fine Sauropod material as yet undescribed, "with that extraordinary *Spinosaurus*[4] from the Upper Cretaceous of Baharich Oasis, Egypt." According to Strömer these are Cenomanian-Albian in age.

From this brief review of the reported finds of Sauropod remains of Cenomanian age or above, it will be seen that much doubt exists either as to their proper identification or to their exact geological position. In the light of this more recent discovery, under conditions that permit hardly a question of doubt to be raised as to either identity or stratigraphic position, it would appear very probable that a critical re-examination of the evidence would show the original determination of some of these finds to be valid in all respects. That Sauropod dinosaurs continued to exist until after the Cenomanian, and even into the Danian, there is every reason to believe.

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[1] In this Nopcsa is mistaken for the name would certainly be applicable to the genotype which is the specimen from India described by Lydekker in 1877 and again reviewed in the Quarterly Journal of the Geological Society of London, p. 156, in connection with the Wealden Sauropod cited by Nopcsa. It is also of interest to note that Seeley, in the same article, p. 160, regarded the specimens from India as being insufficient for purposes of identification, or to enable the relations of the animal to be determined.

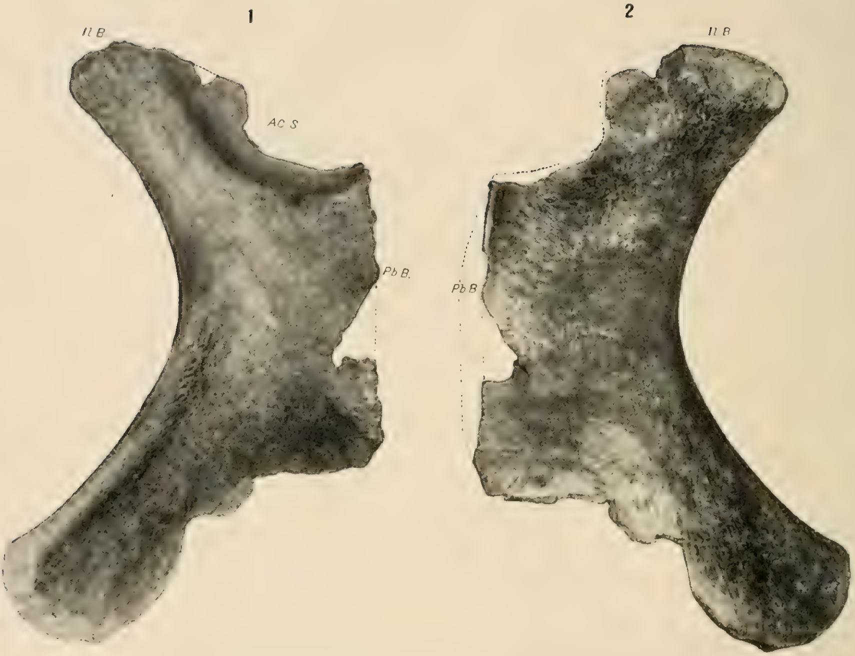
[2] Annales de Paleontologie, 1907.

[3] See Schuchert, Bull. Geol. Soc. America, vol. 29, No. 2, 1918, p. 264, for citations of articles and discussion of the age of the Tendagura series.

[4] Abh. Bayer. Akad. Wiss., Nov., 1915.

LEFT SCAPULA OF ALAMOSAURUS SANJUANENSIS

Type. About one-tenth natural size



RIGHT ISCHIUM OF ALAMOSAURUS SANJUANENSIS

Paratype. About one-tenth natural size. 1. External view. 2. Internal view

SMITHSONIAN MISCELLANEOUS COLLECTIONS
VOLUME 72, NUMBER 15

EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1921

(Publication 2669)

CITY OF WASHINGTON
PUBLISHED BY THE SMITHSONIAN INSTITUTION
1922

The Lord Baltimore Press
BALTIMORE, MD., U. S. A.

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EXPLORATIONS AND FIELD-WORK OF THE SMITHSONIAN INSTITUTION IN 1921

INTRODUCTION

The exploration and field-work conducted by the Smithsonian Institution is one of the means employed for the "increase and diffusion of knowledge," the purpose of the Institution as stipulated in the will of James Smithson, its founder. Attention is directed whenever possible to regions which have previously been imperfectly explored from a scientific point of view, and during the seventy-five years of its existence, the Institution's field parties have been able to make notable additions to existing knowledge as well as to provide vast collections of biological, zoological, and anthropological material for the exhibition and study series of the United States National Museum, a branch of the Institution.

During the past year, the effectiveness of the Institution's limited funds for this work has been so reduced by the prevailing high costs that it was not possible to take part in as many expeditions as is customary. The more important of those which did take the field are briefly described in the present pamphlet, which serves as an announcement of the results obtained, many of the expeditions being later treated more fully in the various series of publications under the direction of the Institution. The photographs here reproduced were for the most part taken by the field-workers themselves.

GEOLOGICAL EXPLORATIONS IN THE CANADIAN ROCKIES

The geological work by Secretary Charles D. Walcott in the Canadian Rockies was in continuation of that of the field seasons of 1919, 1920, for the purpose of securing data on the pre-Devonian strata of the Sawback range in Ranger Brook Canyon, and a reconnaissance of the pre-Devonian formations to the northwest as far as the headwaters of the North Fork of the Saskatchewan River, Alberta.

The season was an unusually cold and stormy one. The party started with a pack train from Banff, June 30, and returned September 30. During this period there were 35 stormy days, 28 cloudy and cold days (20° to 45°) and more or less snow fell on 20 days in August and

SMITHSONIAN MISCELLANEOUS COLLECTIONS, VOL. 72, NO. 15

FIG. 1.—Panoramic view from south side of Saskatchewan River looking west up the river toward Mounts Outram (10,670′) and Forbes (12,102′); Glacier Lake canyon, and on right across the North Fork, Survey Peak and unnamed mountains to the north.
Locality: The view is from a point about 47 miles (75.2 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (C. D. Walcott, 1921.)

FIG. 2.—Looking south down Baker Creek with upturned Upper Cambrian limestones of the Sawback Range on the left (east); the Ten Peaks in distance across Bow Valley, and Baker Mountain on the right.

Locality: The camera was on a low ridge directly east of Baker Lake 8.5 miles (13.6 km.) in an air line northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

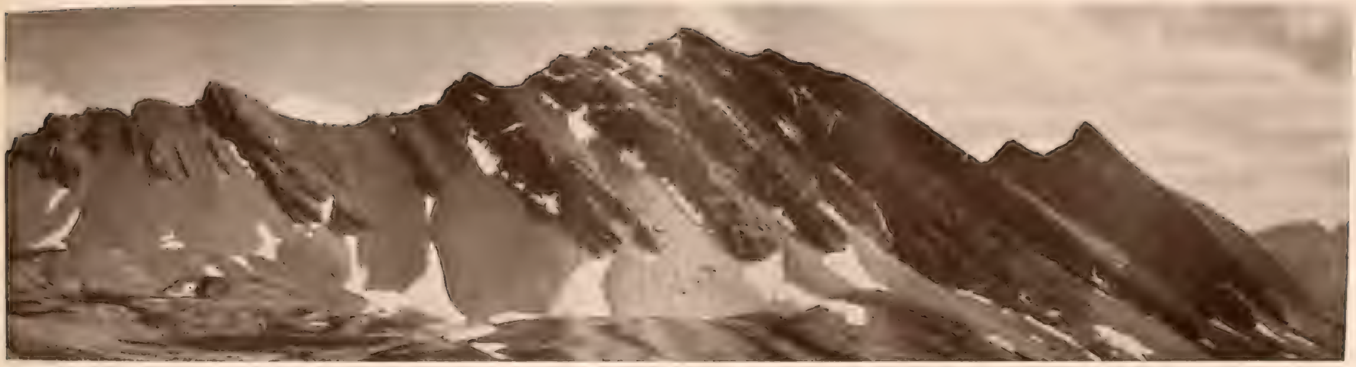

FIG. 3.—Upturned Devonian, Ordovician, and Cambrian strata southwest of Badger Pass, at head of Cascade Creek and northeast of canyon of Johnson Creek. *Locality:* Southeast side of canyon leading up from Johnson Creek to Badger Pass in Sawback Range. Position of camera about ten miles in air line east of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (C. D. Walcott, 1921.)

FIG. 4.—Thompson Pass on Continental Divide. Mountain on south [illegible] *Locality:* Thompson Pass about 63 miles (101.3 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta [illegible]

FIG. 5.—Mt. Douglass (11,015′) from the north, with Black Douglass on the left and White Douglass on the right. Devonian limestones form upper cliffs, with Ordovician and Cambrian limestones on lower eastern slopes. *Locality:* View taken from the north side of the head of Red Deer River about 10.5 miles (16.8 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

Fig. 6.—Thrust fault on north end of Oyster Mountain along which a thick bed of Upper Cambrian limestone has been forced from the southwest (right hand) against a mass of thin bedded and shaly limestones of Devonian or Ordovician age so as to crumple and distort the latter.

Locality: View taken from the north side of the head of Red Deer River about 10.5 miles (16.8 km.) northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

FIG. 7.—Panoramic view looking west over Baker Lake. On the left Baker Mountain (7,230′) and on right Fossil Mountain (9,655′). Back of Fossil Mountain, Ptarmigan Peak (10,060′) and across from it (left) Fort Mountain (9,510′). *Locality:* The camera was on a low ridge directly east of Baker Lake 8.5 miles (13.6 km.) in an air line northeast of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (C. D. Walcott, 1921.)

September. While on the trail 30 camps were made, but owing to weather conditions and to the fact that the snow remained on the slopes and cliffs above timber line, a relatively small amount of productive work was accomplished.

The section studied near the head of Ranger Brook Canyon of the Sawback Range about 12 miles (19.3 km.) northwest of Banff, was from the base of the Devonian limestones down through the post-Cambrian (Ozarkian) Mons formation and the subjacent Lyell and Sullivan[1] formations of the Upper Cambrian.

Fig. 8.—Camp on the lower eastern slope of Fossil Mountain looking north toward the head of Red Deer River.

The character of the formations is indicated by figures 2 and 3, which show the southwesterly slope of the highly inclined beds (45° to 70°) and the saw-tooth-like effect caused by the unequal rate of erosion of the massive bands of limestone and the softer, more friable sandy and clay shales. Towards the northwest end of the Sawback range at the Red Deer River the Black and White Douglass mountains stand high above the surrounding ridges. (Fig. 5.) Oyster Mountain

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[1] See Exploration pamphlet for 1919, Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.

Fig. 9.—Looking north from below Baker Lake to the headwaters of Red Deer River. Mrs. Walcott is pointing to an eagle soaring high above the valley.

(fig. 6) has been cut out by erosion from the limestones between Douglass and Fossil mountains, and figure 6 illustrates the crumpling of shaly limestones by thrusting of a series of massive limestone strata against them during the period of displacement of the great series of formations of this part of the Cordilleran ranges.

Fossil Mountain, named from the presence of Devonian corals, is about 9 miles (14.4 km.) northeast of Lake Louise Station and faces Baker Creek Pass on the east. It has a good section of Devonian and pre-Devonian rocks on its eastern slope. There is a fine outlook from camp at the east foot of the mountain.

FIG. 10.—Wild flower camp on northwest side of Johnson Creek Pass. (Mrs. Mary V. Walcott, 1921.)

The broad U-shaped valley (fig. 9) between Fossil and Oyster mountains has been eroded in the shale and thin bedded limestones that pass beneath Fossil Mountain; this formation is one of those in the Sawback Range that is readily worn away, with the result that the agencies of erosion followed by the glaciers have made a valley altogether disproportionate to the present erosion agencies, water, frost and snow.

At a camp in the heart of the Sawback Range on a tributary of Baker Creek leading up to Johnson Pass there was a wonderful exhibit of wild flowers in bloom. Mrs. Walcott counted 82 species within a short distance of the tents. A spring-fed pond supplied camp water; dead pines and spruce, firewood; and a grass covered snowslide slope, abundant feed for the horses.

The moss pink (fig. 11) and the beautiful *Dryas octopetala* were very abundant, but heavy frosts in August killed nearly all the plants and few of the flowers went to seed.

On our way north we crossed over Pipestone Pass and down the Siffleur River. Clearwater River heads in glacial gravels on the east side of the Siffleur about two miles north of Pipestone Pass. Figure 13 is a view looking west through the Clearwater Pass and across to the high cliffs on the western side of Siffleur Canyon.

Twenty-five miles further to the northwest at the point where the south branch (Mistaya Creek), the middle branch (Howse River), and the north branch unite to form the Saskatchewan River, there are some beautiful and instructive views of the surrounding mountains. Figure 1 (frontispiece) is a fine view of the head of the river, with Howse River in the left background and the North Fork beyond the island on the right. The Mount Forbes massif on the left is a superb mountain mass and in the distant center is Division Mountain at the head of Glacier Lake Canyon which we visited in 1919; on the right Survey Peak and beyond two unnamed points. The Glacier Lake section of the pre-Devonian and Upper Cambrian formations was studied on the northern slopes of the Mount Forbes massif as illustrated by figure 1 (frontispiece) of the Smithsonian exploration pamphlet for 1919,[1] and the rugged cliffs and peak of Mount Forbes are shown by text figure 14 of the present number.

Twelve miles northeast of Mount Forbes the cliffs of Mount Murchison (fig. 15) rise high above the dark forested slopes and present a view of the Devonian and pre-Devonian formations that is unequalled in all this region of peaks, cliffs and broad canyon valleys.

Opposite Mount Murchison on the north side of the Saskatchewan, Mount Wilson (fig. 16) presents another section of the pre-Devonian formations, the upper end of which is a massive white quartzite formed of the sands of the beaches over which the Devonian Sea deposited thick layers of calcareous sediments abounding in the remains of corals and various invertebrates of the time. On the west, Mount Wilson rises directly above the North Fork of the Saskatchewan which here flows through a narrow picturesque inner canyon (fig. 17).

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[1] Smithsonian Misc. Coll., Vol. 72, No. 1.

FIG. 11.—Moss pink in Johnson Creek Pass.

FIG. 12.—*Dryas octopetala* below Johnson Creek Pass.

FIG. 13.—Looking westward up through the head of Clearwater River Canyon across Siffleur River Canyon to the high cliffs of Middle Cambrian rocks, which are about 2 miles (3.2 km.) north of Pipestone Pass.
Locality: The divide at the head of Clearwater River Canyon is about 21 miles (33.6 km.) in an air line north 12° west of the Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (C. D. Walcott, 1920.)

Fig. 14.—Mount Forbes as seen from the north, looking across the lower end of Glacier Lake Canyon Valley. The locality is from the upper slope of Survey Peak above Glacier Lake, about 48 miles (76.8 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1919.)

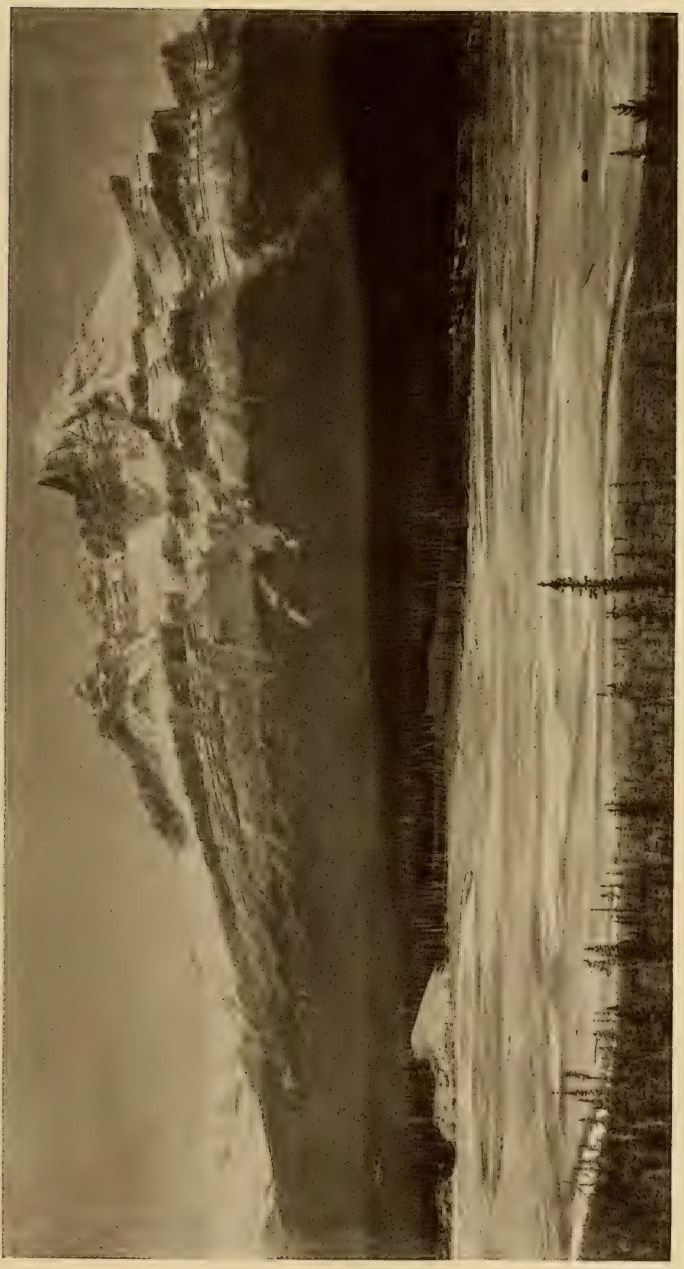

FIG. 15.—Mount Murchison (11,500′) from the north side of the Saskatchewan River.

Locality: The view is from a point about 47 miles (75.2 km.) northwest from Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

FIG. 16.—Mount Wilson from the south. The summit cliffs on the right are formed of the Mount Wilson quartzite capped by dark Devonian limestone.

Fig. 17.—Falls of the North Fork of the Saskatchewan River about one mile (1.6 km.) above where the North Fork unites with the Middle Fork (Howse River). The rocks are Upper Cambrian shaly limestones dipping east toward Mount Wilson.

Locality: About 48.5 miles (78 km.) northwest from Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

FIG. 18.—Quartzite cliffs at the summit of the north ridge of Mount Wilson. The cliffs are capped by dark Devonian limestones very much as are those of the southeast side of the mountain, as shown by fig. 16.

Locality: View taken from the river flats of the North Fork about 7 miles (11.2 km.) north of the Saskatchewan River and 55 miles (88.4 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada.

The trail up the North Fork follows the bed of the river most of the way to its head beneath Wilcox Pass. The same is true of the trail up the west branch called Alexandra River, and its northwest extension named Castleguard River, by the Interprovincial survey of the boundary between Alberta and British Columbia. Near the union of Castleguard and Alexandra Rivers there is a fine view of the peaks along the Continental Divide and Alexandra glacier. On one of the misting days of early September a photograph of Alexandra glacier, Queens Peak, and Mount Alexandra was taken from the river bed and is reproduced as figure 20.

FIG. 19.—Mount Wilson and glacier from the southeast, with the eastern section of the broad syncline, of which Mount Wilson is the western section, on the right.

Locality: View taken from south shore of Saskatchewan River about two miles (3.2 km.) east of Mistaya Creek and 47 miles (75.2 km.) northwest from Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mrs. Mary V. Walcott, 1921.)

Castleguard River heads in a deep, rather broad canyon at the foot of the Castleguard glacier. Thompson Pass is on the southwest and high barrier ridges on the northeast. On the summit of the latter great terraced buttes occur with narrow side facing the line of drainage (fig. 21). These outlying buttes are formed of the alternating hard

Fig. 20.—View of Alexandra glacier with Mount Alexandra (11,215′) in distance on the north (right), Queens Peak (10,990′) immediately to right of glacier, Mount Douai (10,230′) on left of glacier; all on Continental Divide. The gravelly bed of the flood plain of Alexandra River in the foreground.

Locality: Near head of Alexandra River, a tributary of the North Fork of the Saskatchewan River. Mount Alexandra is about 59 miles (94.8 km.) in an air line northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (Mr. and Mrs. C. D. Walcott, 1921.)

FIG. 21.—Terraced buttes back from the northeastern branch of the Castleguard River. They all have one or more small glaciers on their lower slopes, which are at about 8,000 feet (2,438 m.) elevation.

Locality: Near head of Castleguard River, 5 miles (8.04 km.) northeast of Thompson Pass, which is about 63 miles (101.3 km.) northwest of Lake Louise Station on the Canadian Pacific Railway, Alberta, Canada. (C. D. Walcott, 1921.)

FIG. 22.—Waiting for the pack horses to be brought up to receive camera boxes, dunnage bags, blanket rolls, tent, and small impedimenta.

FIG. 23.—Horses foraging through the snow.

and soft bands of limestone and shale of the Sullivan[1] formation, and they form a somewhat unique topographic feature, and are the top of the world at this point.

Thompson Pass is one of the scenic features of the Continental Divide when viewed from the high Alpine valley on the northeast side of Castleguard Canyon. The Pass is low (6,511′ or 1,984 m.), and bold high ridges lead up to mountain summits on either side (fig. 4). A view taken on a misting day shows Watchman Lake (6,050′ or 1,844 m.) and above it Cinema Lake (6,400′ or 1,950 m.) on the northeast slope of the Pass. On the south Watchman Peak (8,674′ or 2,634 m.) which lies in front of Mount Rice (10,745′ or 3,275 m.) and on the right Mount Bryce (11,000′ or 3,352 m.) and Bryce glacier, which is at the head of the middle branch of Castleguard River. The Castleguard glaciers flow down from Mount Castleguard (10,090′ or 3,075 m.), which is a fine peak a few miles northeast of Mount Bryce. Figure 4 is a fine illustration of a misting day along the Continental Divide. We were camped for a week on the south side of the Alpine

FIG. 24.—A snowy morning on upper Pipestone River.

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[1] Smithsonian Misc. Coll., Vol. 72, No. 1, 1920, p. 15.

upland in the foreground, and on each day numerous squalls of fine snow or frozen mist would sweep over from Thompson Pass or Bryce glacier.

I do not know the origin of the names of Rice and Bryce, but it is probable that the mountains were named in honor of Sir Cecil Arthur Spring-Rice and Lord James Bryce.

As the result of unfavorable weather not more than one-third of the work planned was completed when the late September snow drove us back to the railroad. The morning we broke camp to go to Lake Louise Station the horses were pawing away the snow to get at the grass beneath (fig. 23), and the snow was very beautiful on the trees and along the stream below camp (fig. 24). The trail was obscured by it and to make matters more complicated, snow driven by a strong east wind beat into our faces during the seven hours march. The next day the sun came out and the storms were forgotten except for the wonderful snow scenes along the trail down the Pipestone River.

The Commissioner of the Canadian National Parks, Hon. J. B. Harkin, and the members of the Parks Service in the field, from Superintendent to Park Warden, were most helpful, and the same is true of the officials and employees of the Canadian Pacific Railway.

PALEONTOLOGICAL FIELD-WORK IN THE UNITED STATES

Field-work by the Department of Geology of the U. S. National Museum during 1921 was carried on by three members of the Division of Invertebrate and Vertebrate Paleontology.

Dr. R. S. Bassler, Curator of the Division of Paleontology, in cooperation with the Geological Survey of Tennessee spent the month of July in field-work in the Central Basin of that State, where he was occupied in collecting geologic material and in mapping and studying the economic resources of the Franklin quadrangle in Williamson County, south of Nashville. This area of about 250 square miles is of economic interest, on account of phosphate and oil shale possibilities. It is also classic ground for the paleontologist because of the numerous outcrops of Ordovician and later Paleozoic formations which afford a wealth of fossils. During the course of the mapping, Dr. Bassler was able to collect a considerable number of these fossils needed in the museum study series and was also fortunate in securing several large exhibits illustrating various geological phenomena. Among the latter is a large mass of limestone composed entirely of the dismembered calices and columns of a large species of crinoid or sea lily in which the individual fragments are perfectly

FIG. 25.—Contorted and cross bedded phosphate rock, Franklin, Tenn. (Photograph by Bassler.)

FIG. 26.—Massive limestone with an intercalated coral reef, near Franklin, Tenn. (Photograph by Bassler.)

preserved and admirably illustrate the formation of a limestone through the accumulation of this type of animal remains. Material was also secured, both for the exhibition and study series, illustrating the origin of the phosphate beds of the locality through the removal from a phosphatic limestone of the easily soluble calcium carbonate by the leaching power of surface waters. Such material is represented in figure 25 showing a rock outcrop where a porous limestone is overlaid by the contorted and crossbedded rock which upon such leaching gives rise to the phosphate.

Among the interesting stratigraphic results secured was one showing the efficacy of coral reefs of the Ordovician in rock formation. The massive limestone about fifteen feet thick shown in figure 26 represents a middle Ordovician formation here containing but a single reef but within a distance of ten miles the number of intercalated coral reefs has so increased that the formation attains a thickness of over 250 feet.

An ancient Indian village near Brentwood, Tennessee, was visited during this trip in the interest of the Bureau of Ethnology. The object of the visit, namely the determination of the length of time since the village was deserted, proved to be, however, outside of the domain of geology.

Upon the completion of this work Dr. Bassler proceeded to Springfield, Illinois, where with the permission of Dr. A. R. Crook, Chief of the Museum, he prepared casts of the type specimens of invertebrate fossils contained in the Illinois State Museum collections. The aim in this work is to make the national collections of invertebrate fossils as complete as possible in its representation of type specimens, a work which was further advanced in the early part of January by a visit to the Walker Museum of the University of Chicago, where the casting of all the Paleozoic species which had remained unfinished on the occasion of a former trip was completed.

Through the courtesy of Mr. E. J. Armstrong, of Erie, Pennsylvania, Dr. Bassler was enabled to visit all the classical Silurian and Devonian localities in northwestern Pennsylvania and western New York during the latter half of September. The object of this trip was to obtain a field knowledge of the detailed geology and to collect carefully selected sets of fossils illustrating the numerous formations of this region. This work was successful and the many large collections of Devonian fossils in the museum hitherto lacking exact stratigraphic data can now be determined and arranged in the detail necessary to-day.

In April, Mr. C. W. Gilmore, the Associate Curator of Vertebrate Paleontology was authorized to undertake a trip into New Mexico, "for the purpose of making collections of geological material for the National Museum and determining the advisability of preserving certain lands in northern New Mexico for national monumental purposes." Mr. Gilmore was obliged to report that:

> Since the many square miles of "bad lands" surrounding the reserved area are equally fossiliferous and in places present much more favorable territory for the recovery of fossil remains than any observed within the boundaries of the monument, and also since the greater part of these surrounding areas lie within Pueblo Grants over which federal control has been relinquished, there would be no advantage in retaining governmental control of so small a part of the area as is represented in the proposed monument.

Mr. Gilmore did, however, find a contiguous fossiliferous area in the Santa Clara Pueblo Grant and secured for the museum a well-preserved skull and other bones of a small rhinoceros, and in an adjoining Pojoaque Pueblo area remains of an extinct camel. The most promising area for collecting would appear to lie within land grants over which the government has at present no control.

In January, this same year, Mr. J. W. Gidley, Assistant Curator in this Division, was authorized in cooperation with the United States Geological Survey to conduct field explorations in the San Pedro and Sulphur Springs Valleys of southern Arizona and on the completion of this work to visit the La Brea asphalt deposits of southern California and from there go to Agate, in Nebraska, for the purpose of securing other exhibition material. The work in Arizona was eminently successful, Mr. Gidley shipping some 24 boxes having an aggregate weight of 5,000 pounds. The bulk of this collection, he reports represents "a practically new Pliocene fauna containing about 60 vertebrate species, most of which are mammalian."

In detail Mr. Gidley reports essentially as follows:

"The geological structure of the San Pedro Valley will be published in detail by Doctor Bryan of the United States Geological Survey. It, however, may be noted here that this beautiful desert valley, now drained by the Rio San Pedro (which, rising near the Mexican border, runs nearly north-northwest, emptying into the Gila River, more than a hundred miles away), narrows and deepens as it runs northward from Benson leaving relatively small and scattered areas of sedimentary deposits which may contain fossil vertebrate remains. Most of our work, therefore, was confined to the upper valley, which forms a rather wide basin bounded on the east by the Dragoon mountains, on the west by the Whetstone Range, and on the south by the Tombstone mountains, and extends northward a few miles below the town of Benson.

" Erosional exposures in this general region are quite extensive, but time and funds being limited the work done on this expedition was confined entirely to two promising localities of relatively small area, previously located by Doctor Bryan. One of these is situated on the west side of the valley, about two or three miles due south of Benson, the other on the east side, at the head of a large 'wash' three miles east of the Curtis ranch which is situated on the state road about 14 miles south-southeast of Benson and an equal distance northwest of Tombstone. The latter locality occupied the greater part of my time and yielded by far the greater amount of material, although the number of species later collected in the Benson locality, slightly exceeded those found here.

FIG. 27.—General view of fossil bearing exposure at Curtis Ranch locality, looking across the San Pedro Valley. Partly excavated bones of Glyptodon in foreground. (Photograph by Gidley.)

" Among the larger, and, from the museum standpoint, more important specimens secured at this locality are included parts of two skeletons of a new species of mastodon, and parts of three skeletons of a large armored edentate, *Glyptotherium,* which when restored should make a striking exhibition piece.

" Other material obtained here consists of remains representing a wide variety of species which include a large and a smaller species of camel, the latter apparently closely related to the South American guanaco; two or three species of horses, a species of deer; a small extinct antelope of the *Merycodus* type; a carnivore related to the dog-wolf group but more primitive in some respects than any of the living forms; several new species of the rodent group, but all belonging to modern genera; two species of land turtles, and a species of bird not yet determined.

FIG. 28.—Portion of the carapace or bony skin covering of a Glyptodon, partially excavated. Curtis Ranch locality. (Photograph by Gidley.)

" At the close of this work, which had nearly exhausted the original allotment for field expenses, an additional sum was granted, whereby it was possible to proceed with a desired investigation planned for earlier, in the Sulphur Springs Valley near Willcox.

" I arrived at Willcox on the 15th of March. As found on a previous visit the conditions were not such as would inspire enthusiasm over the prospects of a good collecting-field. The surrounding country stretched away for miles in every direction almost as level as a floor, with no erosional exposures; and had not recent fossil remains already been discovered through the digging of a shallow well in the vicinity no one would have suspected their presence here. Several years earlier fossil bones had also been found at nearly the same depth (about 9 feet) in another well, now filled in, which had been dug at a distance of about 250 feet from the present open one. It was thus assumed that the fossil-bearing gravel deposit was of rather wide extent, and that by making a long stripping with plow and scrapers, a considerable area of " pay gravel " might be uncovered and worked at comparatively small expense. The spot chosen as being most promising was naturally that between the two wells.

" At Willcox, the services were procured of a reliable man with teams, plow and scrapers and this work was put into execution. Thanks are here due Mr. Harris, a local real estate agent, who lent valuable aid in this connection. I was also indebted to this gentleman for permission to put through the project, for the locality worked was on deeded land which he had in charge.

" As the stripping progressed, it became evident that the strata, or layers, of deposits passed through did not conform to the section exposed in the abandoned well. Hence, on reaching the 7-foot level three prospect holes, about 15 feet apart, were put down to a depth of about 6 feet, or 4 feet lower than the top of the gravel deposit in the well. In none of these holes was there any sand or gravel encountered thus proving that the gravel exposed in the well was part of an ancient stream channel of limited lateral extent. This discovery of course caused a complete abandonment of the trench excavation work, and the remainder of our time was spent in ' mining ' the gravel from the sides of the well as far as was considered safe to do so. In this way several good fossil horse teeth were procured.

" From Willcox, I went by way of Tucson to Feldman, arriving there about noon of the 29th of March, where I was joined by Dr. Bryan. Feldman is a ranch and post office in the lower valley of the San Pedro, about 90 miles north-northwest of Benson and about 10 miles above the junction of the San Pedro with the Gila. The valley here is very much narrowed and deepened, the river bed being nearly 2,000 feet lower than at the Curtis ranch. The gradient of the streams and ' washes ' emptying into the San Pedro in this vicinity is very steep and benches and divides rise quite abruptly on either side. Erosional exposures one might expect to find here under these conditions are very much reduced by a heavy covering of gravel of relatively recent age. But paleontological evidence for confirming the age of this part of the valley was so much desired, a special effort

FIG. 29.—Base of skull of mastodon with tusks in position, partially excavated. Curtis Ranch locality. (Photograph by Gidley.)

FIG. 30.—Searching for small mammal jaws in excavation made in collecting one of the mastodon skeletons. Curtis Ranch locality. (Photograph by Gidley.)

to procure it was considered worth while. However, the few days spent here met with little success, and owing to the great inconvenience of continuing it further without more complete field equipment, the project was abandoned. On the morning of April 2, we left Feldman, returning to Benson via Tucson, and the next morning began a systematic search for fossils at a locality about two to three miles south of the town. During our earlier stay at the Curtis ranch we had made one short visit to this locality, the material obtained then suggesting a slight difference in age, or phase, between these deposits and those of the Curtis locality. The material obtained at this place is fragmentary and abounds mostly in remains of mammals of small size, intermixed with which were bones of birds of several species sufficiently well preserved for their determination, and a new species of box turtle. Here remains of thirty-four species of vertebrates were recovered. This collection, together with the material obtained at the Curtis ranch locality, in which 26 species are represented, makes up a very considerable fauna which should not only do much toward definitely determining the age of the beds of the San Pedro Valley, but will also throw valuable added light on the at present very little-known animal life of the upper Pliocene of America."

From Arizona, Mr. Gidley proceeded to Los Angeles, California, where he passed a week studying the museum of the southern branch of the University of California and in examining the well-known asphalt bone deposits of the Rancho la Brea. From Los Angeles, he proceeded on the 16th of April to Agate, Nebraska, prepared to carry out a second detail of field-work mentioned above. He was unfortunate here in encountering bad weather, but succeeded in securing for the museum a block of the bone-bearing sandstone some 3½ by 5½ feet and 14 inches in thickness. This was shipped to the museum and preparation for exhibition is now under way.

ASTROPHYSICAL FIELD-WORK IN ARIZONA AND IN CHILE

As stated in last year's Exploration pamphlet,[1] the solar radiation work of the Smithsonian Astrophysical Observatory was removed from Mount Wilson, California, to Mount Harqua Hala, Arizona, in September, 1920, in order to observe under better sky conditions, and in a more favorable place for continuing the observing the whole year round. Under the charge of Dr. C. G. Abbot the work was

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[1] Smithsonian Misc. Coll., Vol. 72, No. 6.

established and continued at Mount Harqua Hala until January 20, 1921, when it was taken in charge by Mr. L. B. Aldrich. He remained until May 20, 1921, when he was relieved by Mr. A. F. Moore, formerly director of the Smithsonian private observing station at Calama and Montezuma, Chile. Under Mr. Moore's charge, the work has been continued steadily at Mount Harqua Hala, with the assistance of Mr. F. A. Greeley.

The Smithsonian Institution maintains from the income of the Hodgkins fund a similar station at Mount Montezuma, near Calama, Chile, under the direction of Mr. L. H. Abbot assisted by Mr. P. E. Greeley. From this Chilean station daily telegrams are forwarded to Buenos Aires, Argentina, giving the observed value of the solar constant of radiation for the day. These data are employed regularly by the Argentine Weather Bureau for weather-forecasting purposes.

While the Smithsonian Institution is not yet in position to champion the use of statistics of solar variation for meteorological forecasts, the great interest which its studies of solar variability have aroused here and abroad seems clearly to warrant the continued maintenance of the Arizona and Chile solar stations under the best possible observing conditions for several years, until a satisfactory basis for a test of the solar variability as a weather-forecasting element has been laid.

The present year has unluckily proved unfortunate at both stations. At Mount Harqua Hala the spring months were very hazy, the summer and autumn months unusually cloudy, with almost unprecedentedly heavy rainfall. At Montezuma the cloudiness of the earlier months was quite unprecedented. During August and September a disarrangement of the apparatus caused apparently by earthquake, combined with illness of the director, led to the loss of many observing days.

In October, Dr. Abbot began an inspection trip to Montezuma, arriving at the station on November 15, and remaining until December 14. During this interval of 30 days, the observers fortunately were able to determine the solar radiation on 26 days, and generally with three or four closely agreeing determinations per day. All of the apparatus was readjusted and improved to the most perfect state of fitness. Many of the results in these conditions proved of a higher grade than ever before observed. In fact it would be hard to conceive of anything which could add now to the excellence of the Montezuma station and outfit.

The accompanying illustrations show the desolate, rainless character of the region; figure 31 shows the mountain top with the observ-

FIG. 31.—Summit of Mount Montezuma. Observing cave near the top.

FIG. 32.—Garage, Shop and Dwelling, Mount Montezuma.

ing cave; figure 32, the group of buildings comprising the observer's quarters, the shop and the garage; and figure 33 the entrance to the observing cave with such observing apparatus as is employed outside during observations of the solar constant.

It is possible to drive the automobile on high gear clear to the observer's quarters which are situated at the head of a cañon sheltered on the west by a rise of several hundred feet from the strong west winds of afternoon. There is almost invariably practically complete absence of wind for several hours after sunrise, a thing highly favorable to morning work.

FIG. 33.—Pyranometer, coelostat, pyrheliometers and theodolite with L. H. Abbot, Director at Mount Montezuma.

The observing cave near the top of the mountain is less than 10 minutes walk from the observer's quarters. It is only necessary to go up twice a day, once to observe, and again at 8.30 P. M. to signal the observed value to Calama, whence it is telegraphed to Buenos Aires.

BOTANICAL EXPEDITION TO THE ORIENT

During the summer and fall, 1921, Dr. A. S. Hitchcock, systematic agrostologist of the Department of Agriculture and custodian of the section of grasses of the Division of Plants in the U. S. National

Museum, visited the Orient for the purpose of collecting and studying the grasses, especially the bamboos. He left Washington April 25 and returned December 23, visiting the Philippines, Japan, China, and Indo China. Six days were spent at Honolulu on the way over. Collections were made at the following places: *Philippines,* Manila, Los Baños, Baguio; *Japan,* Keelung (Formosa), Yokohama, Tokio, Nikko, Lake Hakone, Mount Fuji, Kyoto, Nagasaki; *China,* Shanghai, Nanking, Kuling, Hongkong, Canton, Wampoa, Yingtak, Shiuchow, Lohfau Mountain, Macao, Island of Hainan, Pakhoi; *Indo-China,* Haiphong, Hanoi, Vinh, Hue, Tourane.

Fig. 34.—A peasant's hut near Gotemba, Japan. The roofs of the building are thatched with coarse grass. The bundles are for firewood.

The countries were visited in the order named so that collections might be made at the most favorable season for grasses.

Collecting in the vicinity of Manila is not very satisfactory as the native flora has been largely replaced by introduced species. From Los Baños, the seat of the Agricultural College, a trip was made to the summit of Mount Makeling about 3,500 feet high. This mountain is of especial interest to botanists as it is the most accessible region for the virgin forest, most of which has disappeared from the vicinity of Manila. On this mountain was met one of the worst pests of the eastern tropics, the leeches. At upper altitudes in the rain forest these vile worms are found in countless numbers. They attach themselves to the skin and suck the blood with great avidity and constant vigilance is necessary to prevent serious damage.

Japan is not very favorable for the collecting of grasses as it is mostly a forested region and there is comparatively little open country. The bamboos were of interest as there are many species. In the Lake Hakone region the hills were covered for miles with a single species of bamboo (*Arundinaria chino*), 4 to 8 feet high, often to the exclusion of everything else.

FIG. 35.—Hills near Lake Hakone, Japan. The vegetation on the distant slopes is almost exclusively a single species of bamboo (*Arundinaria chino*), 4 to 8 feet high.

China on the other hand was very rich in grasses. One of the surprises of the trip was to find so much open grass land in a country that is said to be very thickly populated. The cities of China are very much crowded and the valley lands are intensively cultivated, but the hills are unoccupied and almost unused. This is in striking contrast to our own western regions where, except in National Forests and other protected areas, the grass lands are extensively grazed. The basic reason for this condition in China appears to be the risk from bandits. The valley lands can be protected but the hills are open to the attack of robbers.

China was entered at Shanghai, a large comparatively modern city, much under the influence of foreigners. Here is the only American post office outside of the United States or its possessions. Mail can be sent from here under frank or with United States postage stamps. The two other places visited in central China were Nanking and Kuling. At the former city is the University of Nanking, a flourishing missionary institution, which extended many courtesies to Doctor Hitchcock. Nanking is a thoroughly Chinese city showing little foreign influence. Like most Chinese cities it is surrounded by a high wall, this one being 32 miles in length and 30 to 50 feet high. Kuling is a resort on a mountain south of the treaty port Kiu Kiang, where the missionaries and other foreigners of central China congregate during the summer.

Fig. 36.—A street scene in Shanghai.

During the visit of Doctor Hitchcock the Yangtse River was in flood and the rice fields of the valley were covered with water. The unfortunate peasants were in the water up to their waists or even to their shoulders cutting the rice and placing it in small circular

FIG. 37.—A typical valley at Nanking, China, showing intensive cultivation. There is a fish pond in the left foreground. The hills on each side of the valley are covered with grass, much of which will be cut and used for fuel.

FIG. 38.—A ricksha party just after passing out through one of the main gates of Nanking China. The city wall is about 50 feet high.

Fig. 39.—The Yangtse Valley above Nanking in flood. View from a river steamer.

Fig. 40.—Slender pieces of split bamboo drying in the sun. From these joss sticks are to be made.

boats. The bundles were supported on the ends of crossed poles on the dikes to hold them out of the water to dry.

FIG. 41.—A clump of bamboo, Canton, China. A common ornamental plant.

The gateway to south China is Hongkong, a very mountainous island owned by the British, the peak being 1,800 feet high. There is here a botanic garden and a herbarium. Canton lies up the river west of Hongkong about 80 miles. Opposite Canton on the island of Honam is the Canton Christian College, where Doctor Hitchcock made his headquarters. Excursions were made to Yingtak and Shiuchow on the North River north of Canton, to Lohfau Mountain east of Canton and north of Sheklung, to Wampoa 10 miles east of Canton, where the Wilkes Expedition made collections, and to Macao, a Portuguese possession 40 miles from Hongkong and the oldest foreign settlement in this region.

A more extended trip was made in company with Mr. McClure of the Canton Christian College, to Indo-China and the Island of Hainan. Going from Hongkong to Haiphong, a stop was made at Pakhoi on the southern coast of Kwantung Province. Here forty-six species of grasses were obtained in a few hours on the sandy areas and rocky hills. Haiphong is the port of Tongking. Indo-China is a French Colony (officially French Indo-China), consisting of five divisions, Tongking, Annam, Cambodia, Cochin-China, and Laos. The objective in Indo-China was Hue, the capital of Annam. Loureiro, a Portuguese botanist, resided here and published in 1790 a flora of Cochin-China and it was to determine the identity of many of

FIG. 42.—A street scene in Yingtak, on the North River, about 80 miles north of Canton. The bundles of stalks are to be used for firewood.

his grasses that this interesting city was visited. To reach Hue one goes by rail to Hanoi and then south to Vinh, the present terminus of the railroad that is to be built to Hue and ultimately to Saigon. Beyond Vinh one goes by auto-bus over good roads about 175 miles. A trip was made to Tourane on the coast, connected with Hue by railroad.

On the return trip from Haiphong to Honkkong, a stop was made in Hainan, landing at Hoihow on the north coast. Hainan is a seldom-visited island about 180 miles long, belonging to China.

Fig. 43.—A wayside shrine at Yingtak, China. These shrines are common but, like the present one, often suffer from neglect.

Through the kindness of Doctor McCandliss, a missionary in charge of a hospital at Hoihow, we were able to penetrate to the interior of the island as far as Kachek where there is a branch missionary station. The journey was made by boat on the river the first day and on foot the second and third days. From Kachek a trip was made up the river into the foothills of the Five-finger Mountains. Traveling in Hainan as in many other parts of China is chiefly by chair carried by two coolies.

Traveling in China is mostly by rather primitive methods. Modern steamers ply along the coast and on the larger rivers and there are a few railroads. The sampan, a small partly covered boat propelled by oars, is common in the harbors. In the cities where the roads are wide enough the ricksha (jinrikisha) is used. This is a two-wheeled cart, mostly now with pneumatic tires, drawn by a coolie, and holding one person. In the narrow streets of the cities where there is not room for rickshas, and on the country trails or paths, chairs are commonly used. These are covered seats supported by two poles and carried by two coolies. Long journeys in them are far from com-

FIG. 44.—A sampan at Shiuchow. This is the common type of small boat used on the rivers of south China. The bamboo pole is used to push the boat in shallow water. Oars are used in deeper water.

fortable. In the part of China visited animals are little used for transportation of any kind. Freight is carried on land by man-power, one man with a pole supporting two weights, two men with a pole supporting one weight, heavy loads on rude wheelbarrows, in the cities heavy loads, as much as a ton, on carts pulled and pushed by several men.

FIG. 45.—A specimen of the traveler's tree, growing in the botanical garden at Huê, the capital of Annam, French Indo-China. The plant is a native of Madagascar.

One of the curious sights to one visiting China for the first time is the enormous number of graves distributed at random over the country. Thousands of little mounds are to be seen on every hand, some hemispherical and grass-covered, some more elaborate, with stones or masonry.

The agriculture of China is intensive and in some ways much in advance of ours. The rice fields show usually a perfect even stand, and the amount per acre is the maximum. It represents a large amount of labor as every stalk is set out and harvested by hand.

The botanical results of the trip were very satisfactory, a large and valuable collection of grasses having been made.

BIOLOGICAL EXPLORATION IN THE DOMINICAN REPUBLIC

In November, 1920, Dr. W. L. Abbott revisited the Dominican Republic, working in both the Samaná Peninsula and the region lying between Sánchez (at the head of Samaná Bay) and Puerto Plata, on the north coast. Already familiar with much of this territory, he was able to investigate a number of new and very interesting localities. Two weeks was spent at Sánchez; three weeks in the vicinity of Samaná, a town on the south coast of the Samaná Peninsula about 20 miles east of Sánchez, and on the mountain known as Pilón d'Azúcar; seven weeks at several stations along the railroad connecting Sánchez and Puerto Plata, among which were Villa Riva, Pimentel, Cotuy, Mao, and Navarrete; two weeks in the easternmost portion of the peninsula, in visiting Las Cacaos, Rojo Cabo, and Cape Samaná; one week on the south coast of Samaná Bay in the vicinity of San Gabriel; and one week in the region of Old Heart River, in the north-central part of the peninsula.

Contrasting with the remaining part of Hispaniola, the population of the Samaná Peninsula is chiefly English-speaking, due to the fact that Samaná was settled by a colony of Philadelphia negroes under President Boyer of Haiti in 1820-22. The region is well watered and has a luxuriant vegetation, and provisions are plentiful and relatively cheap. The hills extending north to the coast from Pilón d'Azúcar are covered with unbroken forests.

The Yuna River forms a vast swamp, which occupies the entire region at the head of Samaná Bay and extends along the railroad for a distance of 12 miles. West of this swamp region, in the vicinity of Villa Riva, Pimentel, and Cotuy, are vast stretches of grassy savannah. The soil is fertile, and the inhabitants are industrious and prosperous. Beyond this region the land, except along the streams, becomes arid and the towns, such as Guaybin, Navarrete, and Mao, are small, poorly provisioned, and lacking in enterprise.

FIG. 46.—View down Río Mao from schist outcrop near Bulla; cliffs of conglomerate in the distance.

FIG. 47.—View along the Río Mao, near Cercado de Mao.

Numerous caves provide an interesting feature on the south coast of Samaná Bay, one of them comprising nearly the whole interior of San Gabriel Isle. A cave at the mouth of Naranjita River contained a quantity of Indian bones and pottery.

A collection of about 4,000 plants was procured, representing 1,460 numbers. Of these about 20 per cent are ferns, one being an interesting new species of *Anemia*.

The birds obtained by Doctor Abbott on this visit totaled thirty-one skins, with a few skeletons and eggs, chiefly representing species not previously collected by him. Of particular interest is a whip-poor-will (*Antrostomus*), closely related to a species found in Cuba, but not hitherto recorded from Santo Domingo. On the natural grassy plains on the north side of the island he secured several specimens each of the local form of the grasshopper sparrow (*Ammodramus savannarum intricatus*), and of the stone-plover or thick-knee (*Oedicnemus dominicensis*), both new to the museum collections. The thick-knee belongs to a family of birds resembling overgrown plovers, and is related to them. It occurs in the West Indies only in Santo Domingo, but allied forms are found in suitable localities in Central and South America. The family is chiefly an Old World one, and for the most part tropical in distribution. The Santo Domingo species is well-known to the natives, under the name " boukera," and tame individuals

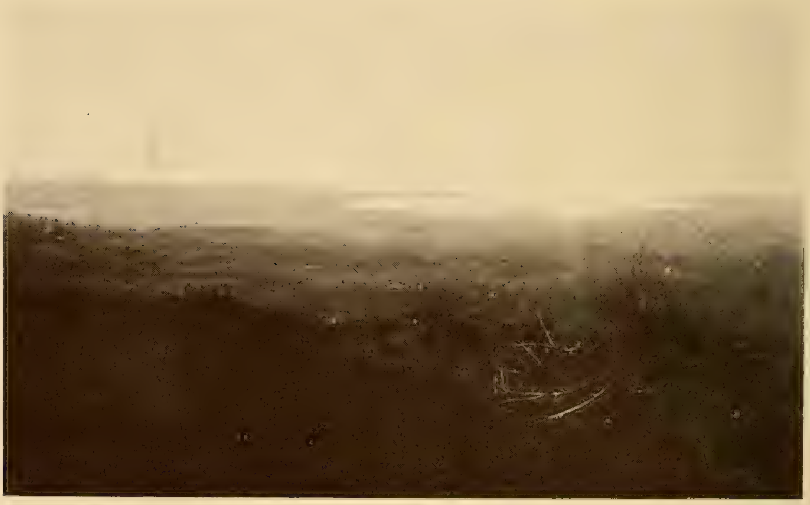

FIG. 48.—Harbor of Puerto Plata, looking north from Monte Isabel de Torres.

are often kept about the houses for the purpose of ridding the premises of insects and spiders.

In addition many land shells and a considerable quantity of ethnological material were secured. Doctor Abbott left New York about the middle of December, 1921, on another expedition to the island, but thus far no information or material has been received from him.

EXPERIMENTS IN HEREDITY

Progress in the experiments in heredity conducted under the joint auspices of the Smithsonian and Carnegie Institutions by the writer, Dr. Paul Bartsch of the U. S. National Museum, have from time to time been published in this pamphlet and in the Year Book of the Carnegie Institution. A summary of the results attained up to 1920 was published as " Experiments in the Breeding of Cerions " in 1920, volume 14 of the Department of Marine Biology of the Carnegie Institution, pp. 3-55, pls. 1-59.

The reported loss of the Cerion colonies introduced into the Tortugas which were said to have been wiped out by the hurricane of September, 1919, made it necessary to revisit the Bahamas to secure additional breeding material for the heredity experiments. Accordingly, passage was secured at Miami on the power schooner " Tecoma " for Nassau, New Providence, on May 18, and there the services of the power boat " Standard J " were secured for a trip to Andros.

The desired adolescent specimens of *Cerion viaregis* were obtained along King's Road, Bastian Point, South Bight, Andros, with considerable difficulty because the agricultural efforts on the part of the local population have shifted to the ground that was occupied by the Cerion colonies during our 1912 visit.

The colony of *Cerion casablancae* has met with even greater misfortune, for sheep and pigs have been introduced into the region occupied by this species, and the larger vegetation has been cut down in order to furnish more opportune habitat for grass culture. These new environmental conditions promise well to exterminate this colony. The necessary material for the experiments was secured with great difficulty.

A trip was next made through South Bight to the western end of Andros and then back to the eastern shore through Middle Bight. On this journey many stops were made and Cerions were gathered in large numbers. The localities from which they were taken were carefully listed so that it will be possible to go back to the same spot in the future and gather material for comparison with that now resting in the National Museum.

There were several points of interest as far as the physical features of the locality visited were concerned. In 1912 the waters of the western end of South Bight were of a creamy consistency and the land areas adjacent low flats, mud cracked, with flakes of oolitic rock. On the present visit South Bight was found to be a perfectly clear stretch of water with well-packed bottom with an abundant growth of aquatic plants, while the land adjacent gave the impression of moss covered flats. The green element, however, was due to blue-green algae, which appear to serve as a binding factor.

The trip was enlivened by an iguana hunt, which resulted in the securing of several of these large lizards which are now in the collection of our Zoological Park.

Returning to Nassau, five days were spent exploring the cays off the northwestern shore of New Providence and the adjacent mainland. Here large collections of Cerions were made, the location of each colony being carefully noted, so that these likewise may serve as a check series for comparison with future generations produced in place.

On June 3 Dr. Bartsch returned to Miami and on the following day set sail for the Tortugas, stopping to examine the various plantings along the Florida keys.

It was a pleasure to find that the hybrid colony on Newfound Harbor Key, around which the greatest interest centers just now, had escaped being wiped out by the hurricane. Evidently the rain preceding the hurricane had caused the Cerions to take to the ground, as they are wont to do for foraging purposes under such circumstances, and the dense mats of grass here had kept them from being swept away by the floods that had passed over them, a most fortunate state of affairs. A large number of dead specimens were nevertheless found, which have been placed in the National Museum for record.

Incidentally, it may be stated that another almost fledged young great white heron was discovered on White Heron Key, the island that furnished the specimen that was shipped to the Zoological Park two years ago. The present specimen, which is probably a younger brother or sister of the former sending, was also transmitted by parcel post to the Zoo, where it arrived in good condition.

In "Experiments in the Breeding of Cerions," there are given on page 46 detailed measurements of 100 specimens representing the check series of *Cerion crassilabris* from Balena Point, near Guanico

Bay, Porto Rico, which were planted on Loggerhead Key in 1915. These were figured on plates 48 to 50. On page 47 measurements were given and on plate 51 figures of 36 adult shells of the first Florida grown generation which were gathered in January, 1919. This year a much larger series of first generation material was found, and 200 of such specimens were measured.

The summaries of these measurements show that no appreciable changes in measurements have taken place in the first generation of Florida grown *Cerion crassilabris*. The measurements in size all fall within the limits of variation, as denoted in the check series, excepting one, *i. e.*, a single specimen which was found among the 200 of the first Florida grown generation that had a diameter 0.2 mm. less than any in the check series. There is no doubt that one could find an individual giving such a measurement among the specimens on the native heath of this species, for the check series was not a selected one, but a hundred specimens taken at random.

COMPARISON OF MEASUREMENTS OF FIRST FLORIDA GROWN CERION CRASSILABRIS WITH THE CHECK SERIES

		No. whorls	Altitude	Greatest diameter
Average	Check series	9.55	22.13	12.41
	First generation	9.13	22.36	11.89
Greatest diameter	Check series	10.5	27.5	13.9
	First generation	10.4	25.7	13.2
Least diameter	Check series	8.5	19.0	10.6
	First generation	8.6	19.6	10.4

It is interesting, therefore, to note that so far as the first generation of this Porto Rican Cerion is concerned, it is in complete agreement with the facts adduced from the two Bahaman species.

The hurricane of 1919 destroyed the cages in which had been placed a specimen of each of two species, in order to determine their ability to hybridize, and to note the results of such crosses as might be observed from such selected individuals.

A new set of cages was therefore prepared. Eleven groups of these cages consist of four compartments, each a cubic yard in size. The septa between compartments are double wire walls to prevent possible mating through the meshes of the fine Monel metal wire screen. In each of these cages there were placed a Hymenocallis plant, some grass and dead wood rubbish, in other words, habitat conditions which were found to be favored by Cerions at the Tortugas. Then two half-grown specimens, one of *Cerion viaregis* and one of *Cerion incanum* from Key West, were placed in each of the forty-four compartments. These cages are securely anchored, and every precaution has been taken to make sure that the mollusks will be confined within them, and that no extraneous individuals can find entrance. The cages are arranged as shown in the following diagram, and a better idea of them may be formed from the photograph (fig. 50).

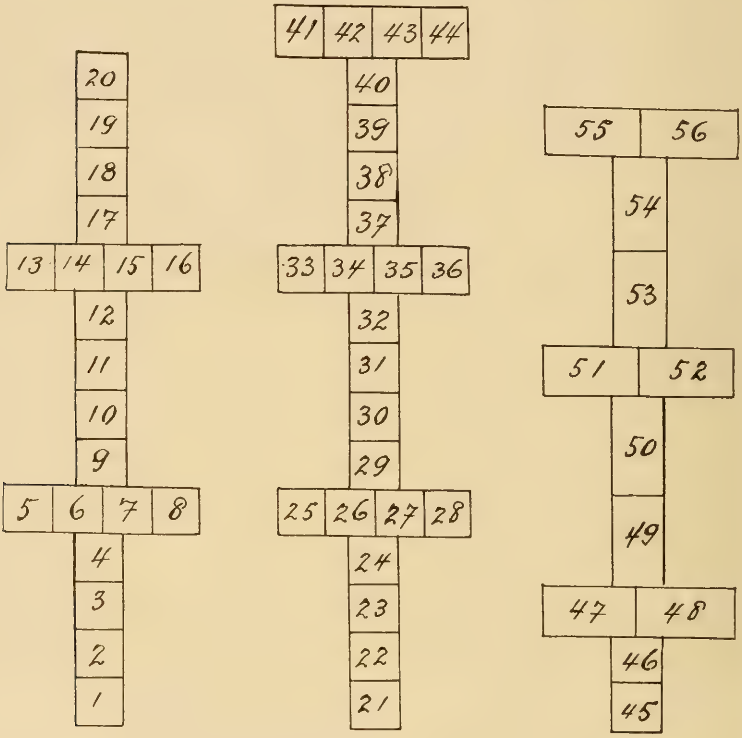

Fig. 49.—Diagram showing arrangement of cages.

Cages No. 45 and No. 46 are of the same size as those last mentioned. In cage 45 were placed 183 young of *Cerion incanum* from Key West, in order to determine what percentage of these will reach maturity. In cage 46 was placed an abnormal specimen of *Cerion viaregis*. This had a spiral keel, which may be the result of an injury, although Doctor Bartsch was unable to discover any sign of it. With it was also placed a normal specimen of *Cerion viaregis* in order to determine if this character might be transmitted to offspring.

In addition to these, five groups of cages were made which have the same size as the four unit cages, but they have only one partition in the middle, thus making them 3 by 6 feet, and 3 feet high. In these there were placed the following combinations:

No. 47, 25 each of *Cerion incanum* and *Cerion viaregis.*

No. 48, 25 each of *Cerion incanum* and *Cerion casablancae.*

No. 49, 25 each of *Cerion incanum* and *Cerion uva.*

No. 50, 25 each of *Cerion incanum* and *Cerion crassilabris.*

FIG. 50.—A portion of the monel metal wire cages used in Cerion breeding experiments.

No. 51, 25 each of *Cerion viaregis* and *Cerion uva.*

No. 52, 25 each of *Cerion viaregis* and *Cerion crassilabris.*

No. 53, 25 each of *Cerion casablancae* and *Cerion uva.*

No. 54, 25 each of *Cerion casablancae* and *Cerion crassilabris.*

No. 55, 25 each of *Cerion uva* and *Cerion crassilabris.*

In cage 56 there were placed 203 young of various sizes of the huge new form collected in Middle Bight, Andros, which Doctor Bartsch has called *Cerion mayori.*

Two additional species were introduced this year on Loggerhead Key, one *Cerion mayori,* as above stated, and the second, *Cerion incanum,* as also stated above, but of this species a large colony was also placed about the water tower at the northern end of the island, in order to have additional material if it should be needed for breeding purposes in the future.

While at the Tortugas a careful bird census was made, as usual. By the use of a blind, a series of photographs of the beautiful roseate tern, nesting here abundantly, was secured. The accompanying illustration shows one of these birds together with an unhatched egg and a babe.

FIG. 51.—Roseate tern, young, and egg. Bush Key, Tortugas, Fla.

ENTOMOLOGICAL EXPEDITION TO ALASKA

In May, 1921, Dr. J. M. Aldrich, Associate Curator of Insects, U. S National Museum, was detailed to collect insects in Alaska, especially in the interior. The museum had very little material from Alaska, except from the coast region. The government railroad, extending from the southern coast north to Fairbanks, was nearing completion, and offered opportunity for travel not heretofore existing. It appeared also that the completion of the railroad would probably lead to an increase of population which would create greater interest in the insects of the region.

Doctor Aldrich left Seattle May 30. The steamship made some stops for unloading freight, enabling him to collect one day at Skagway and one day at Valdez. The coast region is fairly familiar to tourists, with its innumerable islands, steep shore-line, snow-capped mountains and numerous glaciers (figs. 52-56). Seward was reached on June 9. The government railroad begins at this point and close connections were made with a waiting train. The railroad passes over rugged mountains in the Kenai peninsula close to several large glaciers; it then descends to sea-level at Turnagain Arm, keeping near the shore line to Anchorage. This was the first collecting point which might be considered to represent the fauna of the interior. Although it is on tide-water it is behind the coast range and has the dry climate characteristic of the interior. The town is on a level glacial plain, several miles wide, covered with a light forest and having a thin soil upon quite recently deposited gravel. The forest is composed of spruce, aspen, birch, alder and willow. After several days collecting here the journey northward was resumed. Steel had been laid as far as Hurricane, 285 miles from Seward. On arriving here Doctor Aldrich was furnished a horse by the Alaskan Engineering Commission and rode along the right-of-way for 85 miles across Broad Pass and down the Nenana River to Healy, which was at the time the terminus of the rails laid southward from Nenana on the Tanana River. Only casual collecting was done until Healy was reached, but here it was necessary to wait several days for baggage to be brought from Hurricane by wagon. This proved to be a very good collecting

FIG. 52.—Cannery near Juneau, Alaska.

point as it is at the mouth of the canyon on the edge of the Yukon Valley, thus combining to some extent the mountain and plain fauna. After five days here, Doctor Aldrich went north on the railroad to Nenana, collected there for only part of a day and continued the following day on the narrow gauge line, recently acquired by the government, to Fairbanks, his destination. It had been intended to spend most of the collecting time in the vicinity of Fairbanks, but the trip had taken much longer than expected, so he stayed only a week at this point.

Fig. 53—North side Lynn Canal near Skagway, Alaska.

Fig. 54.—Glacier on Lynn Canal, Alaska.

The Tanana Valley at Fairbanks is typical of the Yukon Valley in general, as far as the species of insects are concerned. Although it is within about 100 miles of the Arctic Circle, it has a fairly hot summer on account of the extremely long period of sunshine in the day. Some farms are developed and the government experiment station has been demonstrating for many years that the usual garden vegetables of the northern states as well as some cereals can be grown. The aspect of the light forest is much like parts of northern Minnesota and the regions about Lake Superior generally: the insects collected were mostly species occurring in the region named and eastward to the Adirondacks and New England.

FIG. 55.—Port Althorp, Alaska (merely a cannery).

FIG. 56.—Looking north from Tannel Station, Alaska. Valley filled with glacial gravel in part very recent.

A return trip was made along the same route, with stops at Healy and at some of the construction camps on the unfinished part of the

Fig. 57.—A good insect collecting ground on Ship Creek, near Anchorage, Alaska.

Fig. 58.—Homesteader's cabin near Anchorage, Alaska.

FIG. 59.—Outskirts of Anchorage. Log houses make up almost the whole town, and are the usual thing in Alaska.

FIG. 60.—Outskirts of Anchorage, Alaska. Half-cleared land.

road. The bad condition of the wagon road along the right-of-way south of Healy had reduced wagon travel to a very low stage. The only wagons using the road were those of the Alaskan Engineering

FIG. 61.—Spruce forest on Chulitna River near Mount McKinley.

FIG. 62.—Hurricane, a construction camp on the government railroad 285 miles north from Seward, Alaska.

Commission, carrying supplies to the camps. As each wagon turned back on unloading, and only a few were in use at the time, considerable delay was encountered in getting baggage moved from Healy to

Hurricane. This delay could have been used to good advantage for collecting except for the fact that the weather became cloudy and windy and very unfavorable. Doctor Aldrich, after several days delay, went on to Anchorage and spent a few more days collecting there while awaiting his baggage. Here the weather was again favorable so that the result was very good. Resuming his journey Doctor Aldrich went to Seward with the intention of spending at least ten days in getting a collection of the insects of the humid coast region. The weather, however, gradually became more rainy, greatly limiting the result and finally making it expedient to take the boat from Seward about a week after arrival.

FIG. 63.—Middle fork of Chulitna, a little south of Broad Pass. Corduroy bridge of the Alaskan Engineering Commission.

The expedition resulted in the accession of about 10,000 specimens of Alaska insects, nearly all from the interior region. As far as they have been studied up to the present time they indicate three somewhat distinct faunal regions in the territory covered.

First, the maritime fauna consisting of the insects living upon the seashore and depending upon the ocean for necessary conditions of existence. Insects of this group extend down the coast, in many cases as far as the State of Washington and some even so far as San Francisco; while it is presumed that they would also be found more or less in the Asiatic side of Bering Sea.

The second element is that of the humid mountain region along the coast; a considerable part of this fauna extends to Puget Sound,

FIG. 64.—Contractors' cabins on the line of the government railroad near Broad Pass, Alaska.

FIG. 65.—Looking northward down the Nenana, Alaska. Unfinished government railroad in foreground and down left side.

Mount Rainier, and in less degree, to other mountains of the Pacific northwest. The relation of this element to the Asiatic fauna is very little known.

The third element of the Alaska fauna, as far as observed, is that of the dry interior and especially of the Yukon Valley, which has many elements in common with Northern Minnesota, Wisconsin and Michigan, Ontario, the Adirondack Mountains of New York and the White Mountains of New Hampshire. Many of the insects of this group also occur in the Rocky Mountains of Colorado and no doubt further exploration will show that they occur in other mountains of the western United States. Those which represent a more northern range also reappear in Labrador collections, and presumably extend across North America although we have no collections from intermediate points. This element contains many species known from Finland and the Scandinavian Peninsula in Europe, presumably extending in their distribution across Russia and Siberia.


FIG. 66.—Town of Healy in the lignite belt on the Nenana River, Alaska.

In most orders of insects Alaska has a comparatively large fauna. There are very numerous species of the two-winged flies, or Diptera; and from Doctor Aldrich's long experience with this group he naturally paid especial attention to collecting in this order. Bumble bees and wasps are conspicuous insects everywhere on flowers; and in the absence of darkness bumble bees were observed to work as late as 10.30 at night in Fairbanks. Grasshoppers were strikingly scarce, only two species being found and in all but half a dozen specimens.

Mosquitoes in the interior are exceedingly abundant, as is well known. Especial attention was given to them in collecting, and two species previously undescribed were among the material brought back. It appears, however, that the most troublesome species are the same ones which occur in somewhat less numbers in the Pacific northwest in occasional favorable localities. Horse flies are very numerous in the region at Fairbanks where they are commonly called moose flies since the moose is more common than the horse.

FIG. 67.—Construction camp at Nenana Bridge, north of Healy, Alaska.

The common house fly was not found at any point in Alaska. Continuous attention was given to this matter, and collections were made at the garbage dumps in Anchorage and Seward; while at Ketchican, the southernmost town in Alaska, grocery stores, restaurants and a cannery were carefully examined early in August without finding any of the flies. Other garbage-feeding flies were studied at every possible point and one new species of blow-fly was collected. The absence of several scavenger flies which are common in the United States was noted.

The exploration of Alaska, especially the interior, from an entomological point of view is important in itself and also forms a link in the study of a much broader problem—that of the entire Holarctic fauna which extends almost continuously around the globe in the vicinity of the Arctic Circle. It is a matter of great scientific interest to determine how much of this northern fauna is the same in the new world as in the old, and also to determine how much of the fauna further south, as for instance in the United States, has been derived from this northern region. It is hoped that opportunity will arise to carry this exploration much farther not only in Alaska, where as yet merely a beginning has been made, but also in other northern regions as for instance Labrador, Greenland and Siberia.

FIG. 68.—Fairbanks, Alaska, and adjacent country from top of a building.

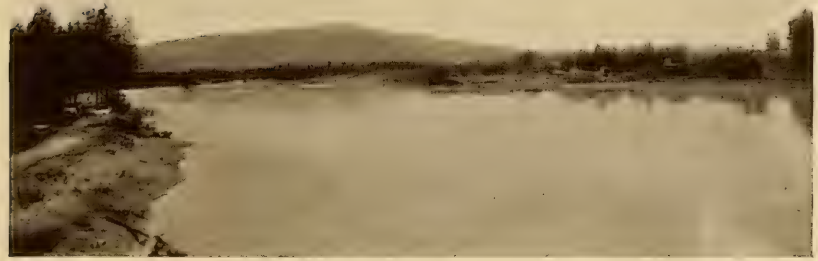

FIG. 69.—Looking up the Cheva River eastward from Fairbanks, Alaska. Some farms cleared and cultivated on the slopes of the distant hill.

ARCHEOLOGICAL FIELD-WORK ON THE MESA VERDE NATIONAL PARK

During May and June, 1921, Dr. J. Walter Fewkes, Chief of the Bureau of American Ethnology, continued his archeological work of former years on the Mesa Verde National Park, Colorado, the brief season's field-work being financed with a small allotment from the Bureau of American Ethnology.

The site chosen for field operations was the Mummy Lake cluster of mounds, a typical prehistoric southwestern village situated 4¼ miles north of Spruce-tree Camp. One of the mounds in this village, excavated in 1916, is now known as Far View House. The surface contours of the remaining mounds differ somewhat, indicating that the buildings hidden in them have different forms, but excavations are necessary to determine the use of these buildings. It has long been known that some of the prehistoric pueblos of our southwest had rooms called kivas for religious purposes, but only within the last year has it been recognized that there was sometimes added to these kivas a complex of rooms, also for ceremonial purposes. Several of these specialized religious structures have already been described, but there remain many other mysterious mounds beckoning the archeologist for excavation and accurate identification. How many different types of buildings designed solely for ceremonials there are in our southwest, time will reveal.

The word house (*ki,* Hopi) is applied in prehistoric cliff-dwellers' nomenclature to a compact collection of inhabited rooms, secular and religious (fig. 70). A pueblo is such a communal dwelling; but a group of uninhabited rooms, each and all constructed for ceremonial purposes, should bear another name. The discovery of Sun Temple introduced archeologists to a type of southwestern buildings not intended for habitations, but for a specific communal purpose supposed to be religious. Fire Temple, on the Mesa Verde, is also regarded as such a specialized building and is likewise believed to have had a religious use. Similarly, Cedar-tree Tower and Far View Tower were not habitations but communal buildings with a religious function. The "Lower House" at Yucca House National Monument, the "Great Kiva" at Aztec, and similar great kivas situated in the Chaco Canyon and elsewhere on tributaries of the San Juan River morphologically belong to this type. All these may be called temples. There are many large buildings never inhabited but now in ruins scattered over the southwest, the use of which is doubtful. Among these are

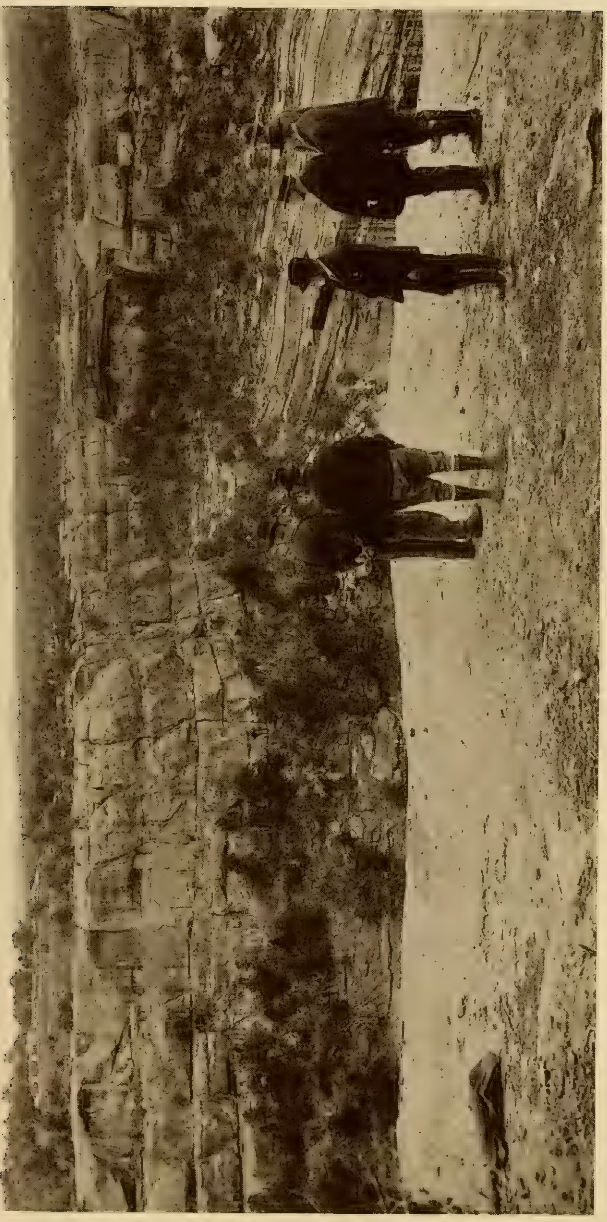

Fig. 70.—Sun Temple and Cliff Palace: from Sun Point, Mesa Verde National Park. (Photograph by Geo. L. Beam. Courtesy Denver and Rio Grande Railroad.)

the so-called fire houses or "houses" of the Hopi fire people and the twin mounds conspicuous on the mesa top above Sikyatki, which may on excavation be found to have been devoted solely to religious purposes.

FIG. 71.—Far View Tower and Kiva, partially excavated. Mesa Verde National Park. (Photograph by Fewkes.)

This specialization in the San Juan Valley of buildings showing functional differentiation in structure is indicative of a high cultural development. It is instructive to find that it is confined to prehistoric stages of development and is most abundant in areas where sedentary inhabitants had disappeared before the advent of Europeans.

The plan of the work of the Bureau on the Mesa Verde National Park in 1921 was to investigate a conspicuous and centrally placed mound not far from Far View House. The indications are that this was an ancient necropolis of the Mummy Lake Village, combining subterranean rooms or kivas with a large cemetery situated on the southern side of a high tower. Unfortunately, this cemetery had been rifled several years ago by vandals; but the many fragments of pottery found on the surface betray features important in cultural comparisons.

Far View Tower was relatively an ancient building; its architectural form is characteristic and its pottery decidedly archaic as compared with that of the golden epoch of geometric decoration from Cliff Palace or Spruce-tree House. We may never know in what century this tower was built, but its construction can be referred to an older epoch than the great cliff dwellings of the park, which were probably inhabited as late as 1300 A. D. The refuse heaps of cliff houses have so little depth that a stratification or superposition of pottery shards is too small to afford satisfactory evidence of long occupancy. In historic refuse heaps of pueblos now inhabited they are thicker and the stratification method has proved advantageous; but nothing that was not already known has been added to our knowledge of the sequence of prehistoric pottery of cliff houses by this method of study. No Mesa Verde refuse mound has yet shown any difference in the character of pottery found on its surface and at its base. The pottery fragments of mounds containing relics of earth lodges are as a rule cruder than others. The pottery from the cemetery or necropolis of Far View Tower is rudely decorated ware, while that from Far View House is finer, but not as well made as that from Spruce-tree House. It is probably older than the pottery from Far View House, but both are more ancient than the pottery from Spruce-tree House.

Far View Tower (fig. 71), like Cedar-tree Tower, has one and possibly more subterranean rooms or kivas on the south side, but the latter lacks the large cemetery. The use to which Far View Tower was put and the significance of the relation of the accompanying kivas to it were probably not very different from those at Cedar-tree Tower, discovered last year (1920). Evidently the complex was devoted to some archaic cult, like fire worship.

In addition to the work above mentioned, Doctor Fewkes also excavated Painted Kiva House, a small prehistoric cliff dwelling situated on the Mesa Verde a short distance north of Cedar-tree Tower, under the rim of the west side of Soda Canyon. This ruin was excavated and described by Baron Nordenskiöld, who called it Ruin 9. It contains remains of two well-made kivas of the regular circular Mesa Verde type and of several granaries and living rooms. The approaches to it from the mesa rim are very precipitous and it was necessary to construct four ladders and otherwise improve the trail to enable visitors to see it.

On the walls of one of its two kivas there survives a very good example of decorated plastering. As shown in the accompanying illustration (fig. 72) there is a dado or lower part of the kiva wall which is painted red, and on its upper edge there are arranged at intervals clusters of triangular symbols (three in number) around which extends a row of dots. The Hopi identify these triangles as symbols of butterflies. They are of common occurrence on the walls of several kivas and survive in certain secular rooms of the cliff dwellers. These triangles with surrounding dots occur constantly on the oldest cliff-dweller pottery, as shown in the accompanying figures. The ventilator shaft is represented in the painted kiva by a tortuous passage, extending under walls and opening some distance from the room. It is spacious enough to serve as an entrance into the ceremonial chamber. Although Baron Nordenskiöld made extensive excavations in Painted Kiva House and devoted several pages of his memoir to a description of it and the specimens he found there, many objects (fig. 73) remained in rear chambers which were found in 1921.

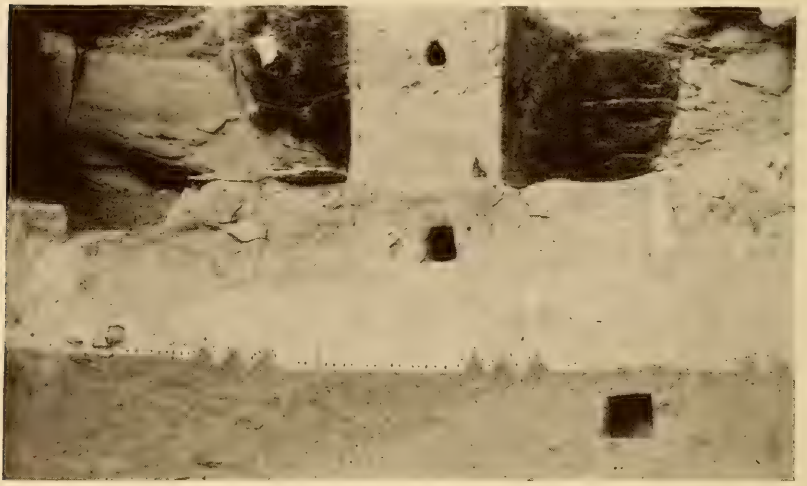

Fig. 72.—Interior of kiva, showing mural decoration, niches, and pilaster. Painted Kiva House, Mesa Verde National Park. (Photograph by Fewkes.)

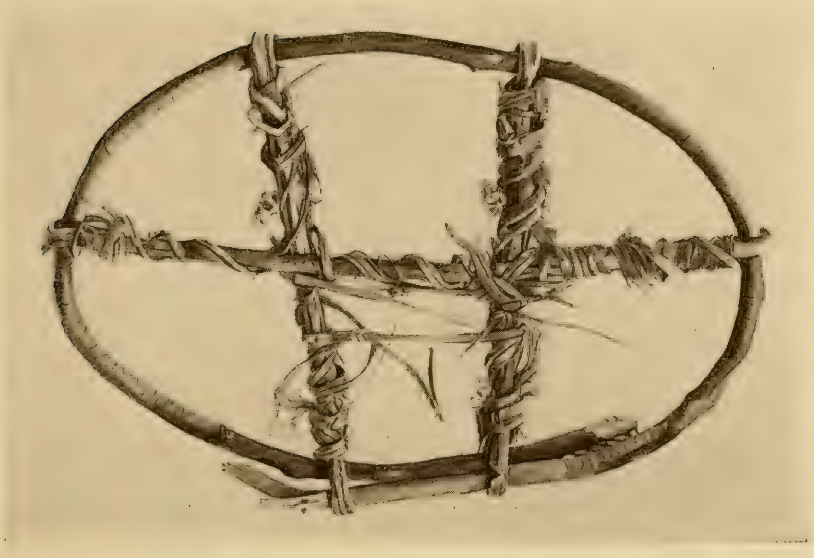

FIG. 73.—Snowshoe frame. Painted Kiva House, Mesa Verde National Park. Size: 14½ inches by 9½ inches. (Drawn by Mrs. George Mullett.)

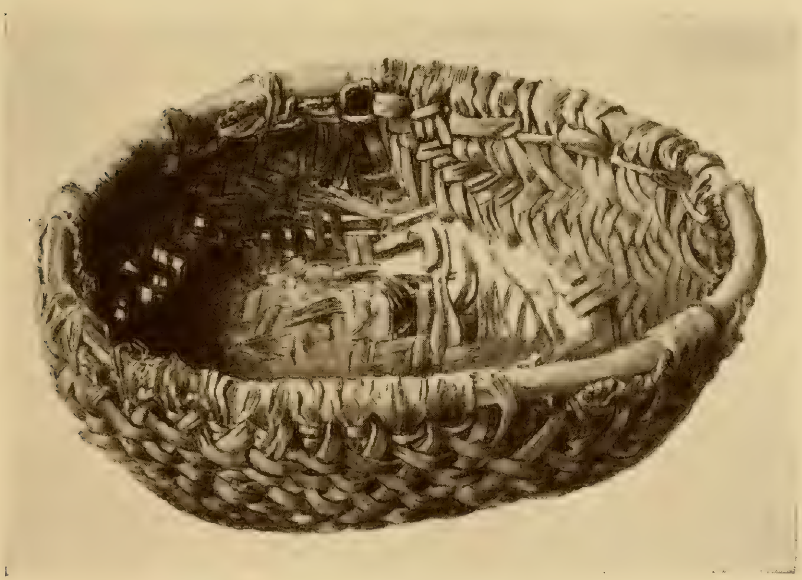

FIG. 74.—Rim basket. Painted Kiva House, Mesa Verde National Park. Size: 15¼ inches. (Drawn by Mrs. George Mullett.)

Among the instructive specimens collected in Painted Kiva House should be mentioned a rim basket (fig. 74) and a woven headstrap of yucca fiber. The unique object shown in figure 75 reminds one of Navaho "*bugaboos*," sometimes found farther down the San Juan but not yet recorded from Mesa Verde. In a rear room which gave every evidence of having been a granary or bin for storage there were found numerous ears of corn with kernels entire, beans, and squash seeds. The belief is widespread that cliff-dweller seed corn when

FIG. 75.—Unidentified object. Painted Kiva House, Mesa Verde National Park. Size: 5¾ inches long. (Photograph by De Lancey Gill.)

planted will germinate, but all experiments in that direction have failed. There is no hope that any greater success will reward experiments made with corn from this granary. In the centuries that have elapsed since the mesa was deserted, corn seed left behind has lost its vitality.

The walls of a ruin called Mummy House, situated almost directly under Sun Temple, are among the most carefully constructed on the park. This ruin has one kiva which was cleaned out but not repaired. A mummy (now in the Mesa Verde Park Museum) was found in this ruin several years ago. Above it is Willow-tree House, practically inaccessible. Ladders were put in place connecting the trail up the canyon with Mummy House. A typical form of cliff house called Oak-tree House, before and after repair, is shown in figures 76 and 77.

One of the important ruins on the Mesa Verde, called Step House by Nordenskiöld, is situated in a cave 5 miles west of Spruce-tree Camp. It presents to the archeologist one of the most instructive problems on the Mesa, and should be put in shape for visitors. In the floor of this cave, which has been considerably dug over by Nordenskiöld and others, there was material bearing on a most interesting chronological problem, viz., the age of the cliff houses; for the artifacts in this place represent two different epochs in the cultural history of the pure pueblo-cliff-dwelling type. Out of the floor of the cave there projects the edges of upright slabs of stone showing the existence of cists like those in Earth Lodge A. These suggest the slab-house culture; but at the other end is a building in the highest form of horizontal masonry. The probability is that the former is the older construction or that it was built by the most ancient people of the park, who lived and were buried in that end of the cave, designated by Nordenskiöld a cemetery. Here we have evidences, both architectural and ceramic, of former earth lodges or fragile walled buildings of the prepuebloan or archaic culture. The original dwelling built by people when they moved into Step House Cave was an earth lodge, and the dwelling with horizontal masonry and kivas, at the other end of the cavern, was a later development. The pottery of the former is more archaic than that of the latter. Figure 78 illustrates the most highly developed Mesa Verde pottery. We have, in other words, indications of two distinct stages of development in Step House Cave—one the earth lodge and the other the pure pueblo or kiva style; the former or earth construction situated at one end of the cave, the latter stage at the other. This evidence of two stages of

Fig. 76.—Oak-tree House, before repair. (Photograph by Geo. L. Beam. Courtesy Denver and Rio Grande Railroad.)

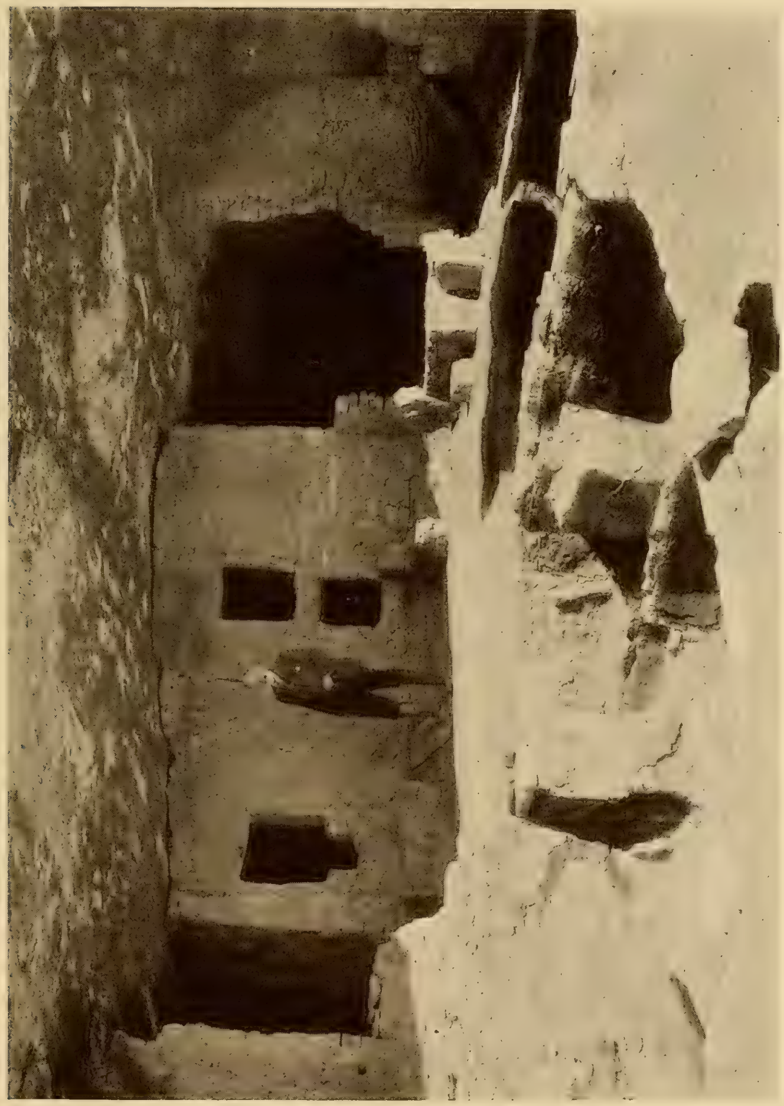

FIG. 77.—Middle room of Oak-tree House, repaired. (Photograph by Geo. L. Beam. Courtesy Denver and Rio Grande Railroad.)

development in the same cave is derived from both ceramic and architectural studies. The indications are that after the earth-lodge condition was outgrown the floor of the cave where the evidence occurs was used as a cemetery, and the survivors constructed their new homes at the other end of the cave in the form of cliff houses. Although no satisfactory scheme of the chronological sequence of different types of Mesa Verde pottery has been worked out, it is most important to pay some attention to its bearing on the age of the above-mentioned buildings.

The mortuary pottery (fig. 79) from the Far View Tower cemetery belongs to a primitive type quite unlike any yet recorded from Mesa Verde cliff dwellings. The most exceptional features are the numerous varieties of coiled, corrugated, undecorated ware. Figure 80, restored from a fragment, and figure 81 show one of these exceptional bowls. A similar bowl with a blackened inner surface occurs elsewhere in the southwest, as on the Little Colorado, but has never been described from the Mesa Verde. A comparison of ceramic objects from the cemetery of Far View Tower (fig. 82) indicates it belongs to an ancient type related to Earth Lodge A, described in the explorations pamphlet for 1919.[1] Attempts have been made to show an architectural evolution from an earth lodge with roof and walls of logs and mud into buildings constructed of well-laid horizontal stone masonry. There is a chronological development in technique, form and decoration of pottery from the simple to the complex, but those who have studied cliff-house pottery have not yet succeeded in arranging the different kinds in chronological sequence.

Each ceramic area in our southwest has its distinct facies. Mesa Verde pottery excels all others in its geometrical decoration. Conventionalized designs and life figures on it are few in number and crude in execution, but linear designs are abundant and varied. In the prehistoric Hopi pottery, where there are few life figures and the majority of designs are geometric or highly conventionalized, there is nothing showing successive steps in the development of designs. In those ruins where geometric figures (fig. 83) predominate there is little to show their evolution. The pottery from the Mimbres Valley, New Mexico, decorated with both fine geometric and realistic figures, gives us no clue to evolution of different typical naturalistic designs. Apparently the three types, geometric, conventional, and realistic, are distinct from their very origin and it is difficult to prove that one type

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[1] Smithsonian Misc. Coll., Vol. 72, No. 1.

FIG. 78.—Mug; black on white ware. Fire Temple House, Mesa Verde National Park. Size: 4 by 4 inches. (Photograph by De Lancey Gill.)

FIG. 79.—Archaic black on white ware; coarse decoration, Far View House Village. Necropolis, Mesa Verde National Park. Size: 5¼ inches.

FIG. 80.—Bowl; indented corrugated ware with black interior, Far View House Village. Necropolis, Mesa Verde National Park. Size: 4½ by 2⅛ inches. (Repaired by W. H. Egberts.)

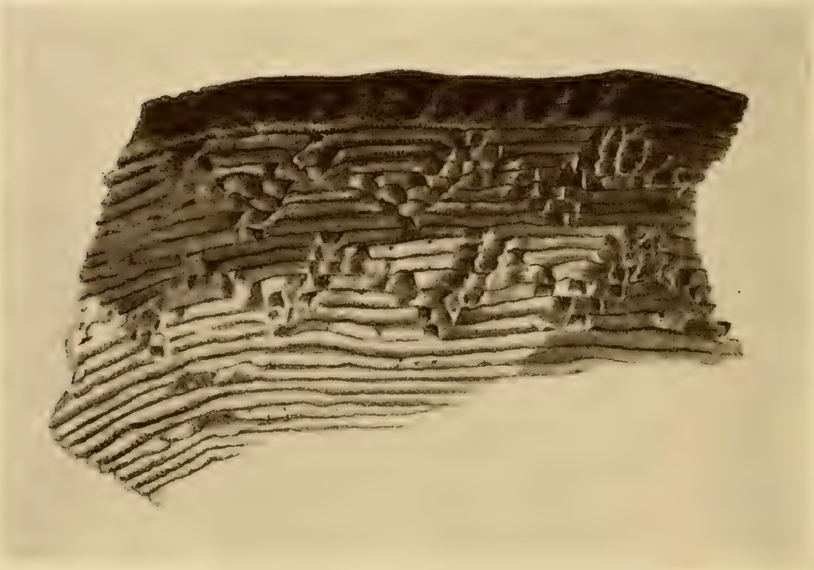
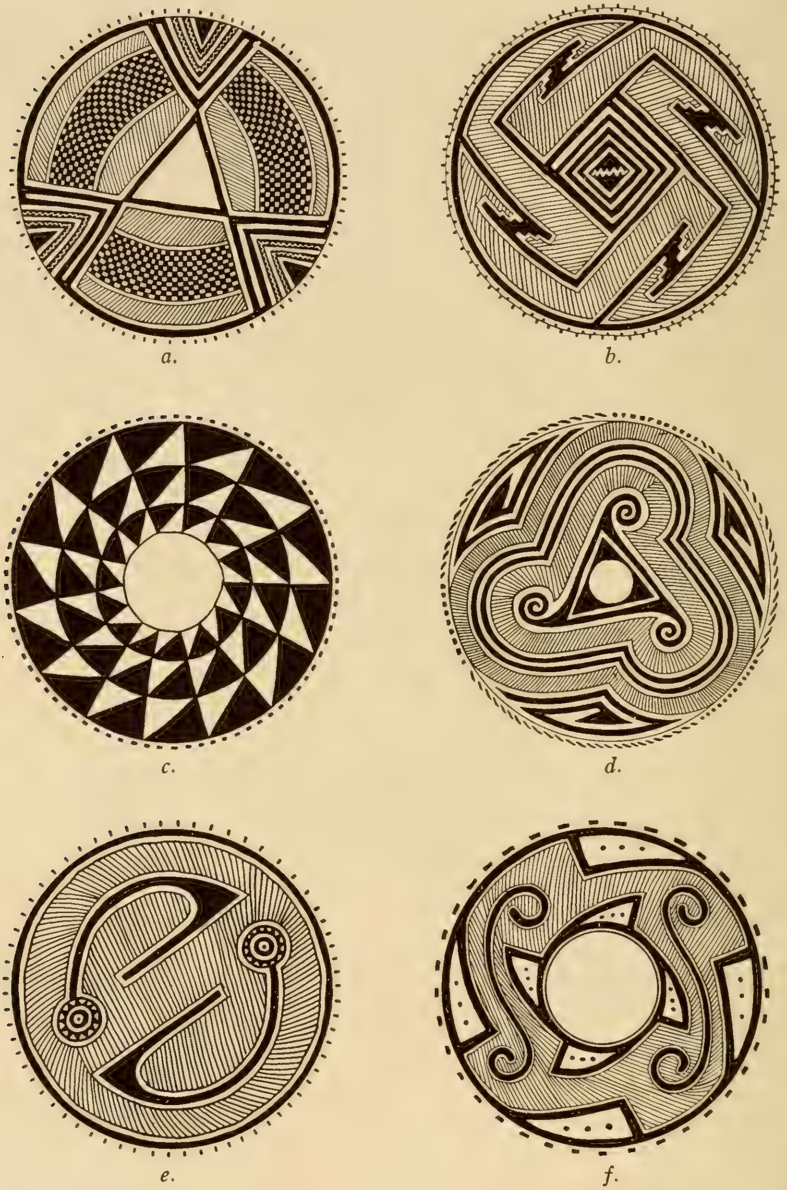


FIG. 81.—Detail of indented corrugated bowl, figure 80, Far View House Village. Necropolis, Mesa Verde National Park. (Drawn by Mrs. George Mullett.)

preceded another in evolution. For the present, then, our knowledge of sequence of types of pottery is largely derived from descriptions and not generalizations. But our archeological method permits us to determine the main features of a stage of culture among the Indians of which little is historically known. For instance, previous to the year 1915 we were ignorant of the manners and customs of the people who inhabited the Mimbres Valley, New Mexico. Documentary history is silent about them. Through archeological studies data are being brought to light year by year by which our knowledge of these Indians is greatly advanced. Pictures on ancient pottery often impart more information than written descriptions and are most important in the study of lost races. During the last few years Mr. E. D. Osborn, of Deming, New Mexico, has from time to time sent to the bureau many unique photographs of mortuary bowls (figs. 84-86), some of

FIG. 82.—Archaic black and white ware, coarse decoration, Far View House Village. Necropolis, Mesa Verde National Park. Size: 3½ by 3 inches. (Photograph by De Lancey Gill.)



a. *b.* *c.* *d.* *e.* *f.*

FIG. 83.—Decorated pottery from Mesa Verde National Park. *a,* triangular geometric design; *b,* hatched and terraced line; *c,* black triangles in concentric series; *d,* central triangle with curved lines at angles; *e,* unknown geometric design; *f,* S-shaped design. (Drawn from photograph, by Mrs George Mullett.)

FIG. 84.—Decorated pottery from Mimbres Valley, New Mexico, Osborn Collection. *a,* bird trap; *b,* gambling game; *c,* emergence of man from lower world; *d,* white outline on black ground; *e,* two fishes; *f,* two negative pictures of fishes. (Drawn from photograph, by Mrs. George Mullett.)

a. *b.* *c.* *d.* *e.* *f.*

FIG. 85.—Decorated pottery from Mimbres Valley, New Mexico, Osborn Collection. *a,* unknown bird, from back, with outstretched wings; *b,* feathers used in geometric decoration; *c,* three-headed turkey; *d,* parrot, head often repeated as club-shaped design on Casas Grandes pottery; *e,* humming birds and flowers; *f,* unidentified flowers. (Drawn from photograph, by Mrs. George Mullett.)

a. *b.* *c.* *d.* *e.* *f.*

FIG. 86.—Decorated pottery from Mimbres Valley, New Mexico, Osborn Collection. *a*, unknown fish with feathered horn; *b*, animal heads like swastika; *c*, sun with four tail feathers; *d*, geometric ornaments; *e*, geometric ornaments; *f*, geometric ornaments. (Drawn from photograph, by Mrs. George Mullett.)

which are decorated with well-made pictures showing hitherto unknown features of prehistoric life in that valley. Similar pictures have been reproduced in former reports, but several specimens lately discovered are the most instructive yet found. References to a few of these close this account.

The food bowl (fig. 84*a*) apparently represents a hunter snaring birds. He carries three nooses in his hand and in three of the snares that are set are birds, while a fourth is empty. On the opposite side of the bowl there are two other birds that possibly have been captured earlier.

Figure 84*b* represents a prehistoric game of " stick dice." In this design three of the " canes " or dice are represented in a rectangular enclosure around which are seated the players. The stakes are arrows shown in a receptacle deposited above the picture.

Two fishes shown in figure 84*e* call to mind the unusual method of representing certain life figures, men, birds, and other animals, on other pieces of pottery. The background of the two fishes of figure 84*f* is black, the bodies white; a negative picture common on ware from Casas Grandes, Mexico, and peculiar to the inland basin in which the Mimbres lies. The upper beak and eye of the head of the well-drawn parrot is shown in figure 85*d*. This conventionalized head often occurs without the body of a bird or any realistic likeness to a parrot in the decoration of pottery from Casas Grandes and it is interesting to note in this connection that Mr. Osborn claims to have found a mound a few miles from Deming, New Mexico, in which the pottery is practically the same as the well-known Casas Grandes ware.

The body of the animal represented in figure 86*a* is serpentine, but the shape of the head and the possession of fins suggest a water monster. The horn with a cluster of feathers occurs in a similar painting without fins, and may be a representation of the Horned or Plumed Serpent.

As is true of decorations on prehistoric Hopi ware, the feather is sometimes used as a decorative element. The identification of the use of this motive was made by a comparison of the undoubted bird with outstretched wings and well-marked symbolic wing feathers shown in figure 85*a*, and the existence of four clusters of a like design in figure 85*b*. A study of over a hundred decorations, realistic, conventional and geometrical, taken from Mimbres pottery indicates that this lost people of southern New Mexico had reached a very high stage of ceramic decoration. There is evidence that this art was somewhat influenced from outside but mainly developed where it was found. It is one of several localized culture areas related to but not necessarily belonging to the pueblo with which it has affinity. It is most closely affiliated with that of Casas Grandes and the southern part of the plateau in which it lies. The environment of this plateau is Mexican, climatically speaking, and the culture will probably be found to correspond. While superior to the Casas Grandes and all other prehistoric Indian pottery in variety and the accuracy with which human and animal figures are drawn, it shares enough with it to hold a place in the same group.

ARCHEOLOGICAL COLLECTING IN THE DOMINICAN REPUBLIC

While engaged in a biological exploration of this republic in 1921 and previous years, Dr. W. L. Abbott of Philadelphia incidentally made a collection of aboriginal Indian antiquities on the north coast, especially around Samaná Bay and the region between it and Puerto Plata, as well as in other parts of the island. No systematic excavations were attempted; the majority of the specimens were either purchased or otherwise obtained. The localities where individual specimens were said to have been found are mentioned in the legends under the illustrations. This accession contains many specimens, one or two of which merit special notice, even if it anticipates a final report.

There is in this collection an exceptionally good water jar of unique form upon the neck of which are incised rude figures of animal or human heads. The body of this jar (fig. 87), instead of being round is roughly four-sided, its base flat, neck constructed bottle shaped. Another bowl (fig. 88), spherical in form, is also unique and the incised figure covers much of the upper surface.

In the collections of every West Indian archeologist there are specimens of burnt clay heads called "zemis" (idols) by the natives. These objects are not idols but broken handles of bowls, portions of which sometimes adhere to them. As broken specimens they teach very little, but if the jar from which they were broken be restored they become instructive. The results of Mr. Egbert's clever reconstruction of the bowls to which three of the handles belong are shown in figure 89, *a*, *b*, and *c*.

The decoration of Santo Domingo pottery, like that from prehistoric Porto Rico, as a rule is limited to handles or lugs of bowls and vases. These heads are attached to the rims of jars or bowls and give us a means of classification. They fall naturally into three distinct types: First, and most common (fig. 89*a*), those where the handles are opposite each other, the handle represented as looking into the bowl;

second, a less common type, those with handle faces looking outward; and third (fig. 89*c*), rarest of all, those with human or animal heads attached to the rim by the back of the head or lying along the rim of the bowl with their axis parallel to it. Santo Domingo pottery as a rule is a coarse biscuit ware, its surface waterworn but smooth, apparently sometimes formerly covered with a red slip, showing, however, no evidence of a glaze. Although in bolder relief than that made by the prehistoric potters who preceded the Carib in the Lesser

FIG. 87.—Unique vase. Cueva de Roma, Dominican Republic. Size: 8¾ inches. U. S. Nat. Mus. No. 316445.

Antilles, the ceramics of the aborigines of the Greater Antilles are more closely related to the work of the Huaxtecs of Mexico than to that of the aborigines of South America.

There are in the Abbott collection representatives of all types of those Antillean idols characterized as three-pointed stones: one (figs. 90 and 91) with head on the anterior point; another (fig. 92), a second type characterized by a head on the side of the cone; a third type has the cone modified into a head; and lastly one smooth, undecorated specimen, referred to a fourth type. The specimen represented in figure 93 belongs to the first type and has on each side of the base of the cone two shallow circular pits; each of these pits represents a joint of the fore and hind limbs, both of which are cut in relief on the side. Although similar pairs of pits are known on several specimens and accompanying forelegs or arms sometimes appear in relief, no specimen with two pits both having relief representations of limbs has been recorded.

FIG. 88.—Globular bowl of thin ware. Locality, Yaqui del Norte, Dominican Republic. Size: 5¾ inches. U. S. Nat. Mus. No. 293016.

Fig. 89.—Restored pottery from shards collected in the Dominican Republic, by Dr. W. L. Abbott. Restoration by W. H. Egberts. *a,* food bowl with effigies on rim, facing inward; *b,* effigy bowl with handles in form of heads, facing upward; *c,* food bowl, handles in form of heads transversely placed on rim. Size: *a,* 9½ inches; *b,* 6¼ inches; *c,* 16¾ inches. U. S. Nat. Mus. No. 316454.

FIG. 90.—Three-pointed stone of first type, from side. Constanza, Dominican Republic. Size, 5¾ inches x 2½ inches. U. S. Nat. Mus. No. 309536.

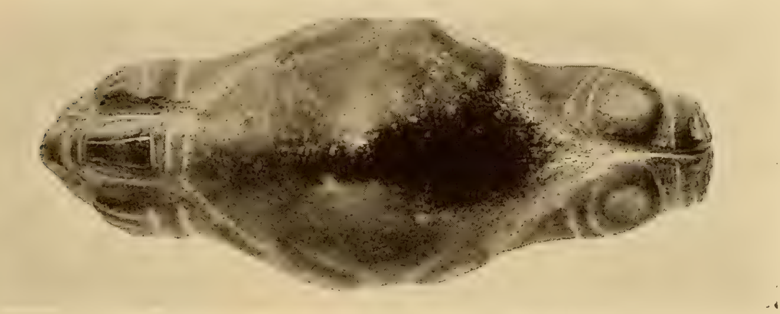


FIG. 91.—Same three-pointed stone from above.

FIG. 92.—Three-pointed stone of second type, from side. Constanza, Dominican Republic. Size: 2½ inches x 1½ inches. U. S. Nat. Mus. No. 309537.

a.

b.

Fig. 93.—Front and rear views of three-pointed stone of first type, whose side and top are shown in figs. 90 and 91.
a, front; *b*, rear.

There are only seven known specimens of three-pointed stones of the second group, and the U. S. National Museum now has five of these, one of which we owe to Doctor Abbott.

He has also added to the museum collection the three especially fine Antillean amulets shown in figure 94. The form of one—that figured in the middle—is unique. These objects are supposed to have been used as fetishes and to have been tied to the foreheads of warriors when they went into battle, as described by Gomara and other early writers.

FIG. 94.—Three marble amulets. Locality, Guayubin, Yaqui River, Dominican Republic. *a*, 2⅞ inches, U. S. Nat. Mus. No. 316448; *b*, 4¼ inches, No. 316446; *c*, 2$\frac{5}{16}$ inches, No. 316447.

The cylindrical object of clay with incised figure shown in figure 95 belongs to a type concerning the use of which there has been considerable discussion. These specimens have been identified as rollers for stamping pottery with the design incised on their surfaces; but if

Fig. 95.—Cylindrical stamp for imprinting pigment markings. Constanza. Size: 2¾ inches. U. S. Nat. Mus. No. 309559.

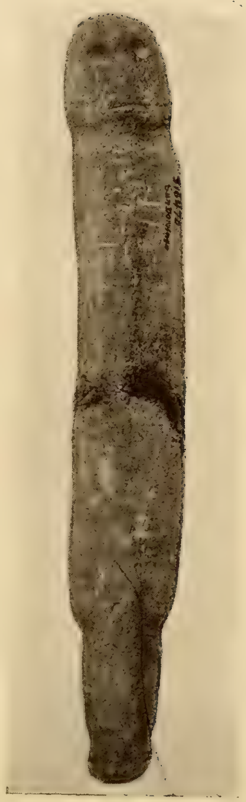


Fig. 96.—Stone baton. Collected by Col. G. C. Thorpe. Size: 16⅜ inches. U. S. Nat. Mus. No. 316475.

Fig. 97.—Stamp made of pottery, for marking fabrics or imprinting design on the body. Dominican Republic. Size: 2½ inches. U. S. Nat. Mus. No. 309567.

we judge from the similar objects of aborigines of Venezuela they were more probably used for stamping fabrics or even for printing certain totemistic or other designs on the face or body.

There is in the Abbott collection an artificially worked stone (fig. 96), about a foot in length, which appears to have been used as a baton, possibly a badge of office. One end bears incised designs representing eyes and mouth suggesting a human head.

FIG. 98.—Stone Cassava grinder. Yaqui del Norte, Jarabacoa. Size: 12¾ inches x 19½ inches. U. S. Nat. Mus. No. 292998.

Figure 97 resembles outwardly a pestle, but a closer examination shows that it is made of clay, a material impossible for an effective grinding implement. It has many pits on the under surface (shown in the figure) which suggests that it was functionally like the cylinder above mentioned used for imprinting paint patterns on the human body or woven fabrics.

One of several flat stone objects collected by Doctor Abbott having extensions, two " handles " on the rim, is shown in figure 98. In shape and especially in the form and position of the handles these stone implements resemble graters—generally of wood—specimens of which are still in use in Haiti. Stone graters are novelties and those collected by Doctor Abbott are the first of this material added to the museum. It is probable that the surface of this stone was formerly covered with some kind of matrix in which were set sharp stones arranged in an ornamental design that has now completely disappeared, leaving no trace of its former presence.

All the above-mentioned specimens are referred to the Tainan or most advanced neolithic culture of the West Indies, that originated and flourished in the Haiti-Santo Domingo and Porto Rico areas in prehistoric times. The three-pointed idols, stone collars, elbow stones, and characteristic pottery separate the Porto Rico Tainan from that of Jamaica, eastern Cuba, and the Bahamas, which belong to another closely related culture that may be called Cuban Tainan.

The pottery of the aborigines of the Lesser Antilles belongs to an allied prehistoric Tainan culture that was submerged by the Caribs, who inhabited these islands when discovered by Europeans, at the close of the 15th century. The fine addition that Doctor Abbott has made to our West Indian collection all belongs to the true Tainan culture which reached its highest development in Española and Porto Rico.

The archeological specimens from the West Indies presented to the museum by Doctor Abbott are very valuable and as time goes on will be more and more appreciated by students of the history of man in the Antilles.

ARCHEOLOGICAL RECONNAISSANCE OF THE CAHOKIA AND RELATED MOUND GROUPS

David I. Bushnell, Jr., collaborator of the Bureau of American Ethnology, conducted during 1921 a reconnaissance of the remarkable mound groups in the vicinity of the great Cahokia Mound. The information secured at this time, added to notes made during frequent visits in the past, has been used in preparing the following sketch of the interesting region.

It is quite evident that long before Père Marquette discovered and passed the mouth of the Missouri, during his journey down the Mississippi early in the summer of 1673, the region immediately below the confluence of the two great streams had been an important center, a gathering place, of the native inhabitants of the valley. Mound groups, village sites, and burial places remain to indicate the presence of a numerous people before the coming of Europeans, and the innumerable objects of native origin encountered in the region bear evidence of their skill in working the available materials.

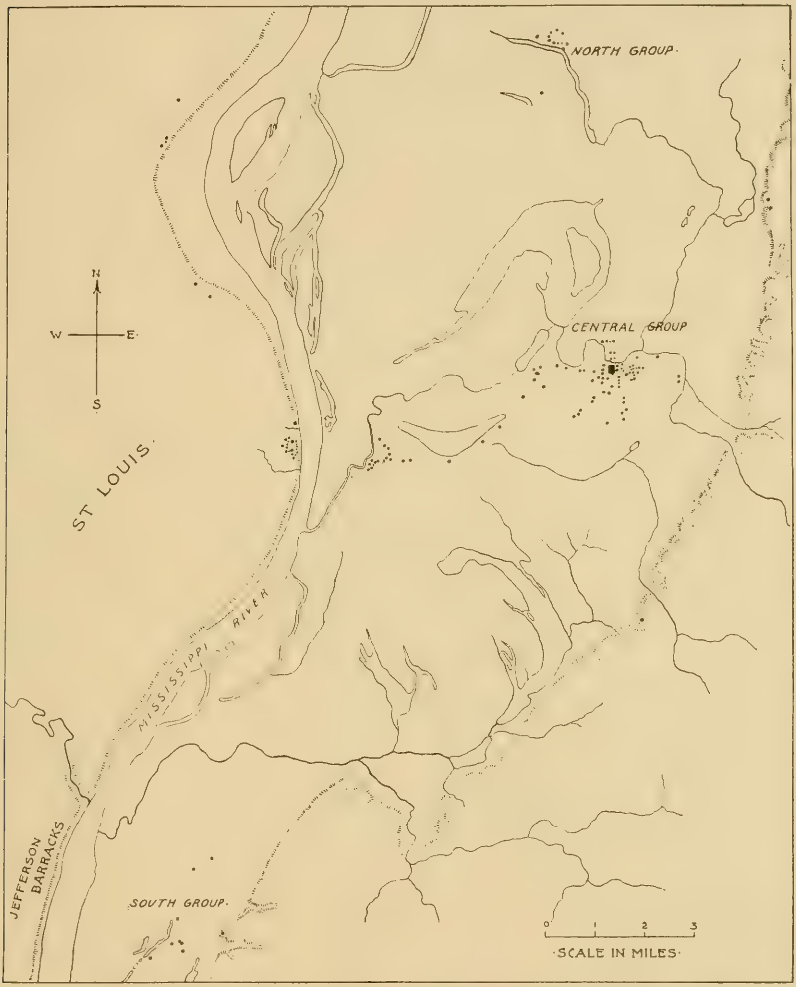


Fig. 99.—Map showing location of mound groups.

Immediately below the mouth of the Missouri, on the left or Illinois bank of the Mississippi, the river bluffs become more distant from the stream and consequently the lowlands are in some places 6 or 8 miles in width from east to west. Shallow lakes covered much of the surface and some parts were heavily timbered. As indicated on the accompanying map, figure 99, four mound groups stood in the lowlands east of the Mississippi and a fifth was on the opposite bank, land now covered by the city of St. Louis. And as is shown on the map the five groups were placed with a certain degree of order to one another, with the great mound, Cahokia, rising near the center of the area.

But who were the builders of the mounds, the most important groups in the Mississippi Valley? The question may never be definitely answered although it is more than probable they should be attributed to a tribe or tribes known in historic times but who may have become greatly reduced in numbers and relative importance before the coming of the French. Evidently the historic Algonquian tribes did not reach the eastern bank of the Mississippi until about the beginning of the seventeenth century, and it is doubtful if others of this linguistic family had preceded them. Siouan tribes when moving from the eastward may have traversed the region, but there is no reason whatsoever to attribute the great mound groups which form the subject of this sketch to either the Algonquian or Siouan tribes. The works were probably raised by a southern tribe, a southern people who at some time before the arrival of the Algonquian tribes, or the migration of the Siouan tribes from the eastward, occupied the region, later to move elsewhere, possibly to return southward. These may have been the ancient Natchez, the Chickasaw, or some other Muskhogean tribe of whom we possess no historic record; however, a careful examination of the mode of construction and the contents of one or more of the mounds may enable us to arrive at some conclusions regarding their origin.

The great Cahokia Mound which rises from the level alluvial plain near the center of the area, is somewhat less than 6 miles east of the Mississippi and 10 miles east of south of the mouth of the Missouri. It is a truncated pyramid, of rectangular form, with a broad terrace extending from the south side which continues in a graded way or approach. The sides of the work face the cardinal points, as do those of the lesser rectangular mounds of the group. Its maximum elevation is about 100 feet. Its extreme length including the approach is 1,080 feet, and its width from east to west is 710 feet. The base covers an area of approximately 16 acres. Viewed from the east, as in figure 100, it appears quite regular in outline and is clearly defined from base to summit. A small conical mound formerly stood on the

FIG. 100.—Cahokia. The eastern side, with the graded approach on the south.

upper plateau near the southeastern corner but it was removed many years ago. The northwestern portion of the great mound is deeply gullied and very irregular in contour; it is a question whether this part of the structure was ever completed.

Cahokia is the largest earthwork in the United States and one of the most remarkable monuments left by the native tribes. Fortunately it remains in its original condition, practically untouched since the coming of Europeans, and in this condition it should be preserved. With each succeeding generation, as the lesser mounds and other earthworks disappear by reason of the cultivation of the soil or the requirement of the land for other purposes, this great terraced work is destined to become of greater popular interest and immediate steps should be taken to make certain its preservation.

The several groups, as indicated on the map, may now be described in detail.

NORTH GROUP

Eleven mounds constitute this group which stands on the north side of Long Lake, near the station of Mitchell. They are about three and one-half miles east of the Mississippi, nearly midway across the lowlands and some seven miles west of north of Cahokia. When the group was surveyed March 13, 1900, it was not possible to determine the original shape of several of the mounds. The land had been cultivated for many years and this, with the constant washing and wearing away of the surface, had caused the works to assume an entirely different appearance from their original condition.

The largest mound of this group stood apart and to the west of the main cluster. It was practically destroyed years ago at the time of the construction of two railroads which pass through it, but parts of the work may now be traced between and on either side of the tracks. Many remarkable objects of stone and copper were recovered during the destruction of the structure.

As is shown on the map the large mound stood to the west. The mound nearest it on the east, as determined by the survey of 1900, was 1,200 feet distant and at that time had a maximum elevation of 9.3 feet above the plain, and was of circular form with a diameter of approximately 237 feet. Eastward from this mound are other units of the group. The highest mound of the group at that time measured 10.4 feet, but undoubtedly the large work to the west was originally much higher than any now standing.

South of the lake, away from the main group, is a single, isolated mound. Others may have stood within the area, all traces of which have disappeared.

CENTRAL OR CAHOKIA GROUP

Surrounding the great Cahokia Mound, which has already been briefly described, were many lesser works, about seventy in number, some of which were more than 40 feet in height. Some were rectangular, others were circular and although at first glance they appear to have been placed without definite order, nevertheless it is quite evident that in several instances they were so arranged as to create inclosed areas, thus conforming with the position of the mounds of the three lesser groups to the north, west, and south of the central cluster.

Unfortunately the large majority of the mounds east and west of the great central structure have been much reduced and modified by the plow, while several have been practically destroyed and a slight rise is all that remains to indicate their position. The inclosure formed of the smaller mounds on the east is clearly defined and gives the impression of having been intentionally planned and arranged, but for what purpose may never be determined. And although many of the lesser mounds have thus lost their original form and appearance, Cahokia remains the most important and impressive native work in the Valley of the Mississippi. As the great mound now stands it should be preserved: to permit its destruction would be a calamity, an irreparable loss to future generations.

The rectangular work immediately southwest of Cahokia was occupied from 1810 until 1813 by a small body of Trappist monks, during which time their garden was on the southern terrace of the great mound. According to the survey of 1875-1876 from which all measurements now given are derived, this lesser mound was 25 feet in height, its base line from north to south was 180 feet and from east to west 200 feet. Just south of this is a small circular work. A short distance east of south of the latter stands a conical mound which rises 44 feet above the plain, having a diameter at base of 150 feet. Immediately east of this is a rather irregular mound 46 feet in height, and possibly other units of this remarkable cluster were even higher and more extensive than these. A rectangular mound southeast of the preceding was, according to the survey mentioned, 40 feet in height, with its base extending 300 feet from north to south and 250 feet from east to west. This reference to several of the lesser works

FIG. 101.—Airplane photograph showing Cahokia in upper right center. Mounds to the south and southwest are also defined, likewise the country northward. Camera pointed west of north.

FIG. 102.—Airplane photograph showing Cahokia in the upper left corner. The rectangular mound in the center of the picture, just south of Cahokia, rises 46 feet above the original surface. A light snow covers the ground.

FIG. 103.—Airplane photograph showing mound north of Cahokia, partly removed. Camera pointed west.

FIG. 104.—Airplane photograph showing mound about 1½ miles west of Cahokia. One of the most perfect of the group, and probably quite similar in appearance to the large mound of the St. Louis group which was removed in 1869. Camera pointed northeast.

will serve to convey an idea of the magnitude of the group as a whole; the most important prehistoric site in the entire valley.

It is of interest to be able to reproduce at this time four aerial pictures of units of the Cahokia group, and these are believed to be the first photographs of American mounds or earthworks to be taken from the air. The negatives, with others, were made during the winter of 1921 and 1922 by Lieut. Harold R. Wells and Lieut. Ashley C. McKinley, stationed at Scott Field, Belleville, Illinois, under instructions of Major Frank M. Kennedy.

Unfortunately, weather conditions during the winter were not favorable for aerial photography, and although many attempts were made ground haze and smoke interfered greatly with the work. As Major Kennedy wrote in part February 6, 1922, after mentioning the mines and factories in the vicinity of the mounds: "These activities produce a large amount of smoke which seems to settle near the ground and form a blanket two or three hundred feet thick." Nevertheless the four pictures are shown to record the first attempt to photograph mounds from an airplane.

On the summit of the bluffs northeast of Cahokia, as indicated on the map, are two mounds of great interest which command a wide view of the lowlands extending to the Mississippi, and beyond. Both are of conical form and rise 30 feet or more above the original surface. One, as it appears from the foot of the bluff, is shown in figure 105.

A view of the bluffs, with the beginning of the lowlands which slope westward to the bank of the Mississippi, is reproduced in figure 106. This is looking northward from a point southeast of Cahokia.

Extending from the main group which surrounded the great mound, in a direction south of west and following a slight ridge, is a chain of works which terminated in an irregular group of smaller mounds near the bank of the Mississippi. It is to be regretted that all units of this group have now disappeared.

WEST OR ST. LOUIS GROUP

There formerly stood on the right, or west bank of the Mississippi, on the summit of the high bluff within the limits of the present city of St. Louis, an interesting group of mounds, twenty-seven or more in number. All have now disappeared but fortunately their positions were indicated on early maps of the city.

One of the earliest as well as most detailed descriptions of the mounds was that prepared by members of the Long Expedition, more than a century ago. At that time they stood north of the settled

FIG. 105.—Conical mound on summit of the bluff northeast of Cahokia.

FIG. 106.—Looking northward from near the road leading to Belleville, showing the eastern border of the lowlands which extend westward to the Mississippi.

Fig. 107.—St. Louis from the Illinois bank of the Mississippi, 1840. Showing the large mound in the northern part of the city.

portion of the town and were in their primitive condition, but soon the settlement was to extend northward and the mounds were destined to be leveled. A view of St. Louis from the east, taken from the Illinois bank of the Mississippi during the year 1840, is reproduced in figure 107. Far to the north of the principal structures of the town, on the extreme right of the picture, stands the large detached mound. The main group was below, probably near the middle of the picture.

The large isolated work was more than 1,400 feet north of the main cluster which formed an inclosure, thus conforming with the arrangement of the mounds on the opposite side of the river. This most important work was of oval form, with the maximum diameter of its base, from north to south, 319 feet, and from east to west 158 feet. The dimensions of the summit plateau were 139 feet and 11 feet. Height 34 feet. On the eastern side, facing the river, was a terrace resembling that on the south side of Cahokia, which was 79 feet from east to west and probably extended the entire length of the structure.

At the time of the destruction of the great mound in the year 1869 a most remarkable cavity was discovered within it. This was a burial chamber which could be traced for a distance of 70 feet and part had previously been removed. It had probably been constructed of logs over which the mass of earth had been deposited and shaped. Within were encountered human remains in the last stages of decay, and associated with these were vast quantities of shell beads and other objects. This was truly a remarkable structure and one which should have been preserved, but unfortunately it shared the fate of the lesser mounds of the group, all traces of which have now disappeared.

SOUTH GROUP

The southern part of the American Bottom—a name long applied to the lowlands occupied by the ancient works mentioned in this sketch—across the Mississippi from Jefferson Barracks, becomes quite narrow, the bluffs approach the river and are, in some places, a scant mile from the low marshy ground which was formerly covered with water the greater part of the year. But the land extending along the foot of the bluffs at this point was evidently at one time occupied by a village of some importance which stood in the midst of a group of mounds. This may be designated the south group and in some respects resembles the north or Mitchell group, already described.

The site was visited by the writer during the latter part of October, 1921, at which time a plan of the group was made, this now being included on the general map. As is indicated there are now seven mounds standing on the lowland and one, a large conical structure, on the bluff to the east. It is said that until a few years ago, at the time of the construction of several railroad embankments, five mounds extended in a row southward from the one now remaining nearest the bluffs, consequently these, together with the five now remaining, formed an inclosure quite similar to the north group. Northward from the main cluster or inclosure, are two detached mounds, both large and prominent. The group as a whole and as it originally stood, must have been as interesting and imposing as either the north or west groups as already described, and all were probably of equal importance to their builders.

Fig. 108.—Village site and mounds at Bixby, with bluffs beyond.

Unfortunately, the majority of the remaining units of the group have been greatly reduced and modified by the plow and consequently it is not possible to determine their original size or form. However, it is evident the second mound from the south, on the west near the Mississippi, was rectangular and quite large. It appears to have been oriented with its sides facing the cardinal points, as were the units of the other groups, including the great mound. At the present time it is worn down by long-continued cultivation and now measures about 12 feet in height, with a diameter of 200 feet. A photograph looking eastward from the summit of this work is reproduced in figure 108.

This is a view over the plain once occupied by a native village and shows the bluffs in the distance. Fragmentary pottery and objects of stone are now found scattered over the intervening ground.

As has been mentioned, and as is shown on the map, a conical mound stands on the bluff just east of the main group. It is not on the highest point, not on the summit, but on a commanding spot visible from miles away, north and south, and from far westward across the Mississippi. It is on the bluff in the exact middle of figure 108, and a closer view, taken from the south, is shown in figure 109. This resembles the two mounds on the bluffs northeast of Cahokia and is of equal interest.

Fig. 109.—Conical mound on bluff east of Bixby.

No other area of equal size in the entire valley of the Mississippi appears to have been of so great importance to the native tribes as that mentioned in this sketch. Here they reared their greatest monument, Cahokia, and surrounded it with many lesser works. The several distinct clusters should be considered units of a greater group, in which the massive terraced work stood as the central structure. This was the gathering place of a numerous people, but when or whence they came can never be known. Now, two and one-half centuries after the region was first entered by the French, at which time Illinois tribes were occupying small villages near the banks of the Mississippi, the majority of the ancient mounds have disappeared, but Cahokia remains and it should ever stand. It must be saved as have the pyramids of Egypt; a monument of another race whose origin is shrouded in mystery.

ARCHEOLOGICAL INVESTIGATIONS AT PUEBLO BONITO, NEW MEXICO

Mr. Neil M. Judd, curator of American archeology, U. S. National Museum, began work during the year on a five-year archeological project undertaken by the National Geographic Society, mentioned in the Smithsonian Exploration Pamphlet for 1920,[1] centering about Pueblo Bonito, one of the largest and most important prehistoric ruins in the United States. Mr. Judd left Washington for New Mexico on May 1 and shortly thereafter began operations in the great ruin; his staff consisted of seven assistants with Navaho and Zuñi Indians employed for the actual work of excavation.

FIG. 110.—Pueblo Bonito, from the northwest, showing the vast accumulations of fallen wall material and wind-blown sand which cover the ruin. The present height of the north wall is indicated by the three figures in the left center. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

The first few weeks were largely devoted to development of a water supply sufficient for the expedition camp, to transporting equipment and provisions from the railroad, 62 miles distant, and to removal of several hundred tons of fallen wall material and wind-blown sand which had accumulated in that section of the ruin selected for the season's explorations. Following these preliminaries attention was

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[1] Smithsonian Misc. Coll., Vol. 72, No. 6.

directed, respectively, to the central and southeastern portions of the pueblo. The central wing was considered of prime importance since it included the Great Kiva, the civil and religious heart of Pueblo Bonito; the southeastern quarter was chosen because its masonry, apparently the most recent of all in the village, suggested that antiquities found in this area would illustrate the very apex of cultural advancement by the ancient Bonitians, thus forming an index for subsequent discoveries.

FIG. 111.—Zuñi workmen pointing out features of the masonry in Pueblo Bonito, which is far superior to that in their own village. The skill exhibited by the ancient artisans was a source of constant admiration to these modern Pueblos. (Photograph by Neil M. Judd. Courtesy of the National Geographic Society.)

Altogether, fifty secular rooms and five kivas were excavated during the summer. In addition, a number of dwellings previously opened were cleared of their individual accumulations of wind-deposited sand and other débris. An outstanding result of this work was identification of three distinct types of masonry, each illustrating the dominant construction method at a given period during occupancy of the village. It is, of course, still too early to designate the factors which brought about these various styles in building, just as any present effort to trace the ground area formerly occupied by each of the three types

FIG. 112.—Central portion of Pueblo Bonito, from the south, showing the north cliffs of Chaco Canyon towering above the ruin. Some of the rooms were so large that the initial work of excavation could be done directly with teams. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

FIG. 113.—An excavated kiva in Pueblo Bonito, showing the low encircling bench and, above this, the roofing timbers which overlap above the pilasters. At the left will be seen the decayed fragments of upright hewn planks which stood between the dome-shaped roof and the circular wall of the chamber. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

Fig. 114.—Excavating the Great Kiva. The block of masonry in the middle is the fireplace; that in the lower right, an inter-pillar compartment. The piles of stone at the top consist of blocks retained for repair of the ancient walls. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

Fig. 115.—The Great Kiva and its surrounding rooms, as seen from the cliffs north of Pueblo Bonito. This remarkable structure is 52 feet in diameter; it was the largest and most important ceremonial room in the village. A trench for stratigraphical examination of the west refuse mound will be noted at the upper left center. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

would be premature. Dwellings were razed and replaced by other structures as Pueblo Bonito grew in size and population.

Those walls which appear to have formed the nucleus of the village are crude and irregular; the rooms they inclose are relatively small and low of ceiling. In contrast to these, walls of the second type exhibit an infinite amount of patience and attention to detail. They consist of rather large uniform blocks of friable sandstone, dressed on the face only, laid in adobe mud and chinked with innumerable small, thin chips. Equally marked in its variation from that in the oldest houses is the masonry of the third type mentioned. In this, uniformly thin tablets of laminate sandstone were utilized with a minimum of adobe and little or no chinking. Larger blocks were frequently laid in bands both for the decorative effect produced and as bonds to hold the masonry veneer to the earthy core of the wall. Beneath the floors of a large number of the rooms excavated during 1921 were found the razed walls of older structures in which a different style of construction prevailed.

These principal variations in masonry may represent merely local developments—the will of ascendant influences in Pueblo Bonito—but it seems more reasonable to believe that each came in upon a wave of immigration from other regions. Among the collections made during the summer are specimens of pottery characteristic of the Mesa Verde cliff-dwellings in Colorado, of the prehistoric ruins in the Kayenta and Gila River districts of Arizona and of the Rio San Francisco, New Mexico. The very number of these objects would indicate not that they had been introduced through intertribal commerce but rather that their makers had come to dwell at Pueblo Bonito, bringing with them their own distinctive arts and industries. On the other hand, it is manifest that the prehistoric Bonitians maintained an active trade with other primitive folk at a great distance from their terraced village in Chaco Canyon. The quantity of Pacific coast shell—used for beads, pendants and other ornaments—copper bells from central Mexico and especially skeletons of the great macaw (*Ara macao*), furnish abundant proof that adventurers from Pueblo Bonito or friendly traders from distant valleys braved the rigors of open desert travel long before the Spanish conquistadores introduced the horse and other beasts of burden.

The circular kivas in Pueblo Bonito, as elsewhere, were both council chambers where clan representatives met for consultation and religious sanctuaries in which secret ceremonies were enacted and preparations made for public rituals to be held in the open courts of the

FIG. 116.—Repairing third-story walls in Pueblo Bonito. Some of these high walls had been so weakened by vandalism and the elements that their repair was necessary before excavation could safely be undertaken beneath. The work will serve, also, to preserve the present height of the walls for many years to come. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

Fig. 117.—Repaired walls of the third type of masonry, showing occasional bands of thicker blocks inserted for strength and decorative effect. Corner doorways are not uncommon in Pueblo Bonito; they provided a direct means of communication between neighboring dwellings occupied by members of the same family or clan. (Photograph by Neil M. Judd. Courtesy of the National Geographic Society.)

FIG. 118.—A Zuñi Indian in an ancient Bonitian doorway. The excellence of the masonry and the trueness of the corners are well illustrated in this picture; a typical lintel of pine poles will be noted at the top. (Photograph by Neil M. Judd. Courtesy of the National Geographic Society.)

FIG. 119.—A trench 20 feet deep was cut in the west refuse mound in order to obtain chronological data. Potsherds deposited during the early occupancy of Pueblo Bonito were quite different from those found near the surface of the mound. (Photograph by O. C. Havens. Courtesy of the National Geographic Society.)

village. These important structures were constructed both below the level of the plazas and among the living rooms, in which latter case the surrounding walls were so arranged as to simulate the required subterranean position. In certain features of construction and equipment, however, Bonitian kivas—judging from the five already excavated—differ from those heretofore examined in other sections of the Southwest. The ventilator shaft is connected with a manhole in the room through a hidden tunnel; sub-floor chambers are sometimes, but not always, present; the primary roof supports or pilasters have been so specialized as to lose their original stability and to take on a new function, that of depositories for ceremonial offerings.

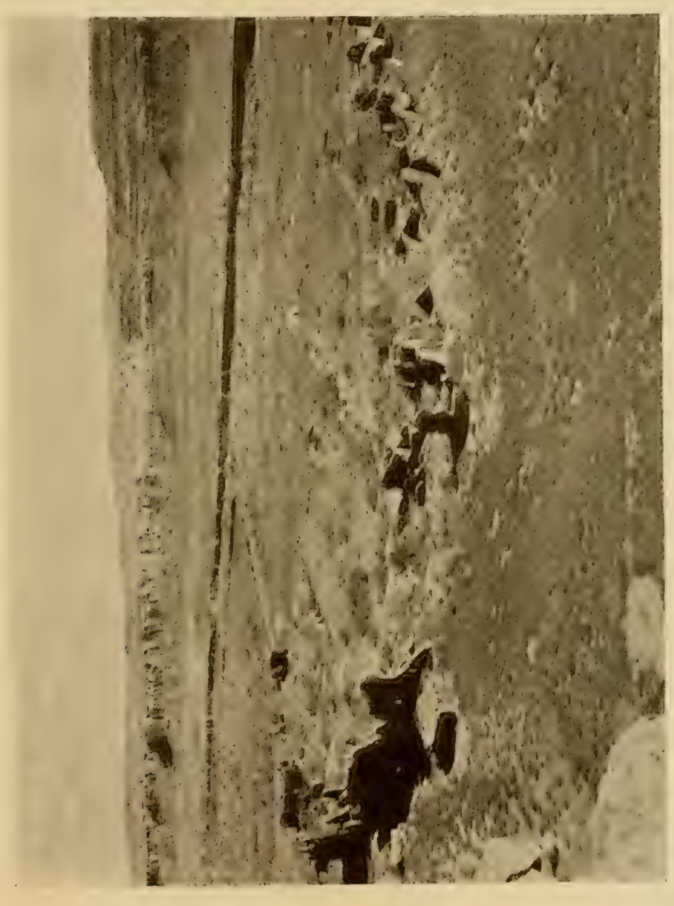

FIG. 120.—Pueblo Bonito as seen from the north wall of Chaco Canyon. The ruin is semicircular in shape and covers more than three acres of ground. Its dwellings were terraced upward from two inner courts; its outer wall was unbroken except for small, elevated ventilators. Excavations thus far have disclosed but one entrance, that from the south. (Photograph by Charles Martin. Courtesy of the National Geographic Society.)

The Great Kiva possesses several noteworthy features not found in the lesser structures of its kind. It is a room of exceptional size, being 52 feet (15.85 m.) in diameter with a ceiling formerly 11 feet (3.35 m.) high. The central portion of its flat roof was supported by four masonry pillars each of which had a separate foundation of low grade, soft coal. On the east and west sides of the chamber, between the pillars, were built-in receptacles, probably for containing ceremonial paraphernalia. A fire box with protective screen stood at the south side and, opposite this, a flight of narrow steps led to an elevated room in which a central block of masonry represented the "altar."

FIG. 121.—A naïve example of Bonitian engineering. In an obvious attempt to hold up a huge section of cliff which threatened to topple upon their village, the ancients placed pine props under the weathered section and covered these with a great terraced mass of masonry. The north wall of Pueblo Bonito stands at the left. (Photograph by Charles Martin. Courtesy of the National Geographic Society.)

Excavation of the kivas and secular rooms in Pueblo Bonito is contributing in large measure to our knowledge of the prehistoric sedentary peoples of the Southwest. Chronological data from the vast accumulations which comprise the adjacent refuse mounds is expected to illustrate not only the character and extent of local cultural development but to serve also as a medium of correlation between the ancient Bonitians and other aboriginal peoples of the southwestern United States. Through such data it is hoped ultimately to arrive at the approximate age of this famous center of pre-Columbian civilization.

The National Geographic Society proposes, as an essential feature of its Pueblo Bonito Expedition, to conduct dependent researches which will seek to determine the ancient source of water supply; the agricultural possibilities of Chaco Canyon in prehistoric times; the rapidity of subsequent sedimentation; the age and probable source of the large timbers used in roofing the dwellings of Pueblo Bonito, and the geophysical changes, if any, brought about since abandonment of the great ruin. These are lines of investigation which may result in information of far-reaching significance and yet they have been generally neglected, heretofore, in connection with archeological explorations.

ARCHEOLOGICAL FIELD-WORK IN SOUTH DAKOTA AND MISSOURI

In the fall of 1921 Mr. W. E. Myer, a voluntary collaborator of the Bureau of American Ethnology, investigated sites in South Dakota and western Missouri, known to have been occupied by the Omahas and Osages in early historic times, after they had come in contact with the whites but before they had been changed thereby to any considerable extent.

Especial attention was paid to any resemblance to the ancient cultures found in the valleys of the Ohio, Cumberland, and Tennessee rivers. This line of research was suggested by certain traditions of both the Omahas and Osages, as well as some of the other branches of the great Siouan linguistic family, that they had at one time lived east of the Mississippi River, on the Ohio, and elsewhere, and after many wanderings, stopping here and there for years, finally reached their present sites in South Dakota and western Missouri.

THE OMAHA SITES

Mr. Francis La Flesche reported that the traditions of his people, the Omahas, stated that they had occupied two important villages on what the Omahas call " The Big Bend of the Xe," at some time in the seventeenth or eighteenth century. These traditions also told of many important events while the Omahas dwelt on these two sites.

Aided by these traditions, Mr. Myer was enabled to locate these two ancient villages. He found one of these on the Big Sioux River, at its junction with Split Rock River, designated Split Rock site in this report.

He found the other site where the Rock Island Railroad now crosses the Big Sioux River, about 10 miles southeast of Sioux Falls. It is designated here the Rock Island site.

ROCK ISLAND SITE

Sometime in the seventeenth century the Omaha and Poncas removed from the Pipestone regions in Minnesota and finally, after some further wanderings, built a fortified town on the Big Sioux River at the Rock Island site. While living in this fortified Rock Island site they were attacked and defeated by an enemy, most probably the Dakotas, and finally forced to leave the region. Before leaving, they buried their dead from this fight in a mound on this site. This burial tradition was confirmed by excavations made by Mr. A. G. Risty and Mr. F. W. Pettigrew, who report finding a considerable amount of human bones in one of the mounds. Some glass beads and small copper bells of white man's make were also found in one of the mounds on this site. There is evidence that this site was occupied somewhere between 1700 and 1725.

SPLIT ROCK SITE

After leaving the Rock Island site, the Omahas and Poncas roved without long permanent settlements for several years, but finally returned to their beloved Xe and built a permanent village at Split Rock site on "The Big Bend" at the junction of the Big Sioux and Split Rock rivers.

The month of October, 1921, was spent exploring this Split Rock site. Many interesting relics of the Omahas were here unearthed, which throw new light on the life of these people before they had been very much changed by contact with the whites.

There is a group of 30 mounds on the ridge between the two rivers marking the site of that portion of the old town occupied by the Omahas. On a hill one-half mile to the east was a group of ten more mounds, occupied by the Poncas before they split away from the Omahas at this old town.

On the tall ridge 1½ miles to the west, by following the clues furnished by the traditions, three low mounds were discovered. These were said by the traditions to have been on the site of the lookouts for the main village. These lookout mounds command a view, ranging from 6 to 15 miles, on all sides. The mounds on this Split Rock site appear to have nearly all been used for burial.

The exploration of mound No. 1 showed that the Indians had selected for its site the summit of a beautiful little knoll on the edge of the steep bluff-like bank of Split Rock River. In the soil of this summit they dug a shallow pit, about 12 feet by 6 feet, and 2 feet deep. In this shallow pit bones belonging to five bodies had been placed. Several of these bodies appeared to have been buried after decay of the flesh. One body appeared to have been buried in the flesh, closely flexed, and this human bundle placed in the pit. The position of the skeleton of a horse with a crushed frontal bone showed that when this body-bundle had been placed in the pit, a large horse, about seven years of age, had been led to the knoll and there killed, on the edge of the pit, by the side of this body-bundle. Then, over all these, a low, round-topped mound, 60 feet across base and 5½ feet in height, had been raised.

FIG. 122.—A portion of the layer of human bones on floor of charnel pit.

Mound No. 2, the largest mound of the group, was near the center of the village. It was round-topped, 110 feet across base, and 10 feet high. This mound proved to be of considerable importance. In beginning its construction, a rectangular charnel pit, 12 feet by 14 feet, and 2 feet deep, had been dug in the surface of the soil near the center of the town. This empty pit was then thoroughly coated with a white layer, about ⅛ inch in thickness. This white coating was made from calcined bones.

The bottom and sides of this white pit were then probably covered with soft furs. This is indicated by a thin black layer of animal matter next to the white coating.

On the floor of this fur-lined pit, bones representing about 50 human beings had been laid. These bones had been brought from elsewhere after the decay of flesh. The bones presented the appearance of belonging to bodies which had either been left unburied, as on some battle field, or of belonging to scaffold burials. This solid layer of compressed broken and decayed human bones entirely covered the floor of the charnel pit to a depth of from 2 inches to 6 inches.

FIG. 123.—Bone flesher.

Portions of this layer of human bones, before it had been disturbed, are shown in figure 122.

On top of this solid mass of human bones traces of the thin fur layer were also found. Over this soft, warm fur covering a layer of bark was laid, and over this bark earth had been spread to a depth of from 3 to 6 inches. This layer of earth was then smoothed and pressed down, and on this surface a white coating, similar to that on the bottom and sides, had been spread. Thus, these human bones, enclosed in their layer of warm furs, were completely incased by this white layer, very much as the filling of a pie is enclosed by the crust. Only one small, cylindrical copper bead was found with all this mass of bones.

On the exterior of this communal charnel pit, on all four sides, the separate burials of several adults and two small children were found. With these outer burials were found several objects. Amongst these was the bone flesher shown in figure 123. With a compact bundle of bones belonging to two adults was a small pile of 30 circular ornaments of shell like those shown in figure 124. These ornaments had probably been attached to some garment in the original temporary burial and removed from the decayed garment when placed with the bones in this new burial.

FIG. 124.—Shell ornaments.

No object of white man's manufacture was found on this site. There is evidence that this site was occupied by the Omahas somewhere between 1725 and 1775.

The Omahas and their kindred, the Poncas, lived together at this Split Rock site. It was here that some of the most important events in the history of the Omahas and Poncas took place. While living here the long hostilities between the still united Omahas and Poncas and their old enemies, the Cheyennes and Arikaras, were ended by a peace which was concluded with great ceremony at this Omaha-Ponca town. At the urgent request of the Arikara the sacred chant and dance of the calumet was used to cement this great peace pact. In this manner the Omahas and Poncas for the first time came into contact with this the most profoundly binding and sacred ceremony known to savage man.

At this site the age-long association between the kindred Omahas and Poncas was broken. The tradition does not give the cause of their separation; but for some reason the Poncas, after having lived with the Omahas through their long slow wanderings in the regions east of the Mississippi and through the lower and middle reaches of the Missouri Valley, left their kindred and formed a separate tribe.

It was at this site that the Omahas first came to possess the white man's horse, which was to play such an important part in the later Omaha life. The tradition tells that neither the Poncas nor the Omahas had possessed horses until after their separation at this site. The finding of the skeleton of a horse in a mound on this site is one of the many evidences which confirm this tradition that the Omahas remained at this site after the Poncas split away, and shows the Omahas were still living here when they first obtained horses.

OSAGE SITES

In Vernon and Bates counties, western Missouri, near the junction of the Osage and Marmiton rivers, Mr. Myer found several sites known to have been occupied by the Osage Indians in early historic times, shortly after they had come in contact with the whites.

Two of these early historic Osage sites, the village of the Grand Osage and the Little Osage village, were probably located. These were visited by Zebulon Pike in his journey of exploration in 1806.

The site of the village of the Grand Osage was at the junction of the Marmiton and Little Osage rivers, in Vernon County.

The probable site of the Little Osage village of Pike was at the Perry and MacMahan coal mine, about 2 miles northwest of the village of the Grand Osage. Old settlers stated that decayed lodge poles were still standing and many other signs of Indian occupancy were to be seen at this Little Osage site as late as 1840. The present appearance of this site is shown in figure 125.

A considerable collection of surface finds from this site shows no objects of white man's manufacture; but local tradition says fragments of brass kettles, old gun barrels, early bullets, and other objects of white man's manufacture have been found here.

FIG. 125.—Site of Pike's Little Osage Village.

FIG. 126.—Halley's Bluff.

FIG. 127.—Site of cache pits at base of Halley's Bluff.

Two of these surface finds throw light on the extent of aboriginal barter. One of these is a broken obsidian implement. The nearest source of this material is probably in the Rocky Mountains, some 1,000 miles to the west. Another is a shard of Mesa Verde pottery, the nearest source of which is in the Mesa Verde culture region around the southwestern corner of Colorado, about 800 miles to the west.

The largest Osage village in Vernon County is at what is still known as Old Town, on Old Town creek, about 3½ miles south of Pike's village of the Grand Osage. This site covers about 40 acres and is the best known of any of the Osage sites. It has yielded a large amount of iron axes, gun barrels, gun locks, fragments of brass kettles, glass beads, and other articles of early white manufacture. Along with these large quantities of shell beads, flint arrow heads, broken pipes, and other objects of purely aboriginal origin were found. Old Town culture furnishes an excellent example of Indian culture in the days of early contact with the whites.

The most picturesque Indian site in this Osage region is Halley's Bluff on the Osage River, about 1½ miles down stream from where the Marmiton and Marais des Cygnes unite to form the Osage River. A photograph of a portion of this bluff is shown in figure 126. There is evidence showing occupancy of this bluff by Indians long before the coming of the white man and probably before the coming of the Osages.

The long summit of the bluff shows many small, low heaps of stones and other Indian signs. The sheltered spaces at the foot of the overhanging cliffs were out of reach of the highest waters and were sheltered in large degree from the winds and rains. Here, in these dry, sheltered spaces, these ancient people lived and worked. They dug about 20 cache pits at present about 5 feet in depth, in the moderately soft red sandstone.

FIELD-WORK ON THE KIOWA, PUEBLO, AND CALIFORNIA INDIANS

At the end of July Mr. J. P. Harrington, ethnologist, proceeded to California to continue his studies of the Indians of the Chumashan area of that state. Place-names, material culture, and sociology, all these branches being closely related to language, were especially investigated and all obtainable data recorded. By rare good fortune several dozen old ceremonial songs were obtained on the phonograph, with full notes and translation where possible, these songs having not been in use since the middle of the past century. The songs were accompanied by the beating of the split-stick, and the rendition, while not what might be desired, will doubtless be adequate for transcription. They belong to several distinct cycles. Interesting comparisons were drawn between the California Indian culture and that of the southwest. The sweathouse is certainly the same as the kiva. The California phratries correspond to the dual division of the Pueblos. The dancers who represent demons are the Pueblo katcinas. These resemblances also extend to many minor features.

Fig. 128.—Aged Mission Indian informant. (Photograph by Harrington.)

Nor was the linguistic side of the work neglected, ethnology and linguistics, and in fact archeology, of necessity going hand in hand in this difficult field. This linguistic work is of the greatest importance since it furnishes material for comparison with all the related languages.

Mr. Harrington's field studies reveal the fact that the language of the Kiowa, who are now settled in Oklahoma but formerly had eastern Montana as their habitat, is closely and genetically related to that of the Taos and other Tanoan tribes of New Mexico, which have typical Pueblo culture. Thus, the interesting fact is established that the Taos speak a dialect of Kiowa just as the Hopi, farther west, speak a divergent Shoshonean. These studies also make it clear that Keres and Zuñi are related to each other genetically, and furthermore to Tano-Kiowan and Shoshonean, the languages all having a common origin.

ARCHEOLOGICAL FIELD-WORK ON THE SUSQUEHANNA RIVER, PENNSYLVANIA

In July, 1921, Mr. John L. Baer, Acting Curator of American Archeology of the United States National Museum, examined for the Bureau of American Ethnology a number of instructive pictographs at Bald Friars and Miles Island in the Susquehanna River.

FIG. 129.—Petroglyphs, Bald Friars, Md.

FIG. 130.—Petroglyphs on Miles Island, Susquehanna River, Pa., near Mason-Dixon Line.

These occur about one-fourth the distance between Bald Friars Station and Conowingo Station, on the Columbia and Port Deposit Railroad.

All the rocks upon which petroglyphs are found seem to have been polished before the petroglyphs were cut in them. The top surfaces of most of the rocks bearing petroglyphs were marked with cups and circular grooves, some of which were concentric. Some of the rocks were fractured destroying the continuity of pictures that originally existed. Upon one large rock broken from its original position possibly by ice are carved two slender fishes headed up-stream. The rock upon which they were found suggests a good stand for shad fishing with a net.

On a group of low rocks to the northwest of Miles Island is a peculiar arrangement of figures. On one side of a tectiform rock are two concentric circles with radiating spokes, a cup, and two semicircular concentric grooves, while on the ridge and extending down on the opposite side of the roof-like rock is a figure that might represent an animal.

During the same trip, Mr. Baer spent several days on Mount Johnson Island, Susquehanna River, and on the near-by flats below Peach Bottom, Lancaster Co., Pa., seeking further evidences of the bannerstone workshop in which he has been interested for a number of years. He brought back with him a number of broken and unfinished slate bannerstones, flint pecking stones, polishing stones and other utensils showing evidences of a considerable sized workshop on the island. A synoptic series from this workshop showing the different stages in the manufacture of the bannerstone has been placed on exhibit in the Pennsylvania case in the American Archeological collection of the National Museum.

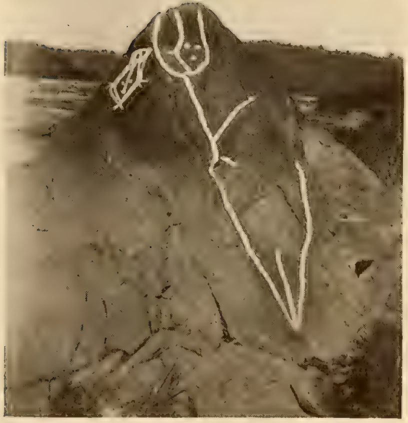

FIG. 131.—Petroglyphs on Miles Island, Susquehanna River, Pa., near Mason-Dixon Line.

FIG. 132.—Petroglyphs, Bald Friars, Md.