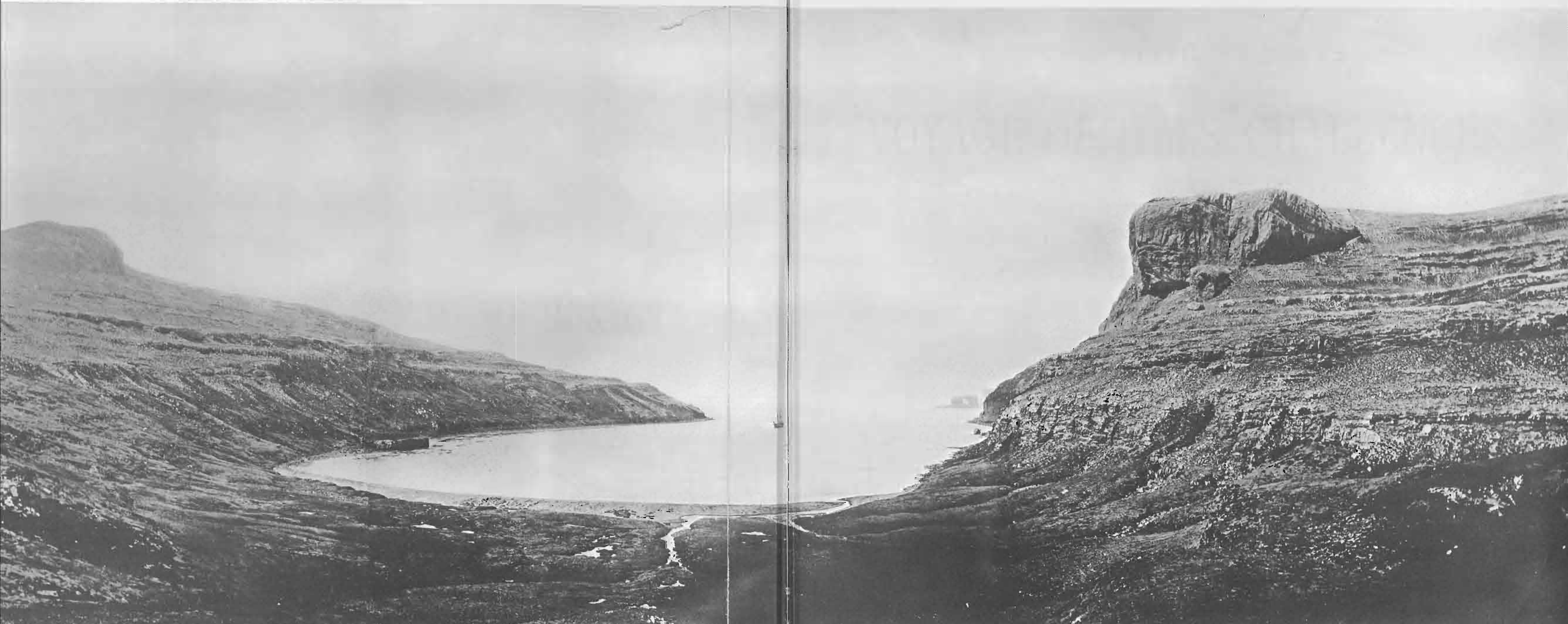
THE

VOYAGE OF H.M.S. CHALLENGER.

NARRATIVE—VOL. I.

FIRST PART.



Hoeburgh, Edinburgh. Permanent Phototype.

CHRISTMAS HARBOUR, KERGUELEN.

REPORT

ON THE

SCIENTIFIC RESULTS

OF THE

VOYAGE OF H.M.S. CHALLENGER

DURING THE YEARS 1873-76

UNDER THE COMMAND OF

CAPTAIN GEORGE S. NARES, R.N., F.R.S.

AND THE LATE

CAPTAIN FRANK TOURLE THOMSON, R.N.

PREPARED UNDER THE SUPERINTENDENCE OF

THE LATE

Sir C. WYVILLE THOMSON, Knt., F.R.S., &c.

REGIUS PROFESSOR OF NATURAL HISTORY IN THE UNIVERSITY OF EDINBURGH

DIRECTOR OF THE CIVILIAN SCIENTIFIC STAFF ON BOARD

AND NOW OF

JOHN MURRAY

ONE OF THE NATURALISTS OF THE EXPEDITION

NARRATIVE—VOL. I.

FIRST PART.

Published by Order of Her Majesty's Government

1885

JOHNSON REPRINT CORPORATION
111 Fifth Avenue, New York, N.Y. 10003

JOHNSON REPRINT COMPANY LIMITED
Berkeley Square House, London, W.1

First reprinting, 1965, Johnson Reprint Corporation
Printed in the United States of America

EDITORIAL NOTES.

The Hydrographic Part of the Narrative of the Cruise of H.M.S. Challenger would have been written by Captain Sir George S. Nares, K.C.B., had he remained in command of the ship during the whole of the voyage.

When the Expedition reached Hong Kong in December 1874, Captain Nares was recalled to take command of the last British Arctic Expedition, and he then placed his Journals in the hands of his successor in the Challenger, —the late Captain Frank Tourle Thomson.

Captain Thomson was, however, of opinion that the description of the Hydrographic Work of the Expedition should be undertaken by an officer who had been with the Challenger from the beginning, and consequently Captain Nares' Journals were, with the concurrence of the late Sir C. Wyville Thomson, handed over to Staff-Commander T. H. Tizard, the Senior Surveying Officer of the Expedition.

On the return of the Expedition to England, Staff-Commander T. H. Tizard was, on the recommendation of the Hydrographer to the Admiralty,[1] temporarily employed in the Hydrographic Office, for the purpose of preparing for publication the Charts, Diagrams, and Hydrographic Notes for the Narrative of the Cruise, and Commander J. L. P. Maclear and Lieutenant A. C. B. Bromley were also employed for a short time in preparing for publication the Magnetical Observations. The Journals of Captain G. S. Nares were freely used by the Challenger Officers, and they had throughout the assistance of the permanent Officers of the Hydrographic Department of the Admiralty. This work was commenced in 1876 and completed in 1879,

[1] Then Captain F. J. Evans, R.N., C.B., in succession (in 1874) to Rear-Admiral G. H. Richards, C.B., under whose auspices the Expedition was originally fitted out.

when the whole of the Manuscript was placed in the hands of the late Sir C. Wyville Thomson.

On the death of Sir C. Wyville Thomson in March 1882 I was entrusted by the Government with the direction of the whole of the work connected with the publication of the Official Reports on the Scientific Results of the Expedition, and as the Meteorological and Magnetical Observations had been for several years in type, these were at once issued as Volume II. of the Narrative, along with two Appendices: one on the Pressure Errors of the Challenger Thermometers, by Professor P. G. Tait, and the other on the Petrology of St. Paul's Rocks, by the Abbé A. Renard.

In his Provisional Preface to the first volume of Zoological Reports, published in 1880, Sir Wyville says:—"The first volume will contain a short narrative of the voyage, with all necessary hydrographical details; an account of the appliances and methods of observation; a running outline of the results of the different observations; and a chapter epitomising the general results of the voyage. This volume will be illustrated by a general physical chart; a series of charts of the ship's course; a series of diagrams of the vertical distribution of temperature; and some photographs of scenery. It will probably be in two parts, and is being prepared by Staff-Commander Tizard, R.N., and myself."

Although the form and scope of the present volume was thus sketched out, yet, owing to ill health and his many professional occupations, Sir Wyville was never able to make any progress with the preparation of the Manuscript for the press; he had, however, selected and caused to be printed the thirty-seven photographic plates which now accompany the text.

Under these circumstances I consulted with my former colleagues in the Challenger, Staff-Commander T. H. Tizard, Professor H. N. Moseley, and Mr. J. Y. Buchanan, as to the best course to adopt, and it was finally arranged that the first volume of the Narrative of the Cruise should be undertaken by us jointly, and should embrace as far as possible a general account of the Scientific Results of the Expedition—an arrangement which has now been carried out.

The various Abstracts indicating the nature and extent of the investigations and discoveries made by the specialists who have been engaged in the preparation of the Official Reports will be found to constitute a prominent feature of the volume; these have been prepared by the authors of the several special Reports, or have been revised by them. Great care has been taken to ensure that all statements of fact are correct, but when deductions are drawn or opinions expressed in any of the paragraphs within inverted commas, my colleagues or myself do not necessarily endorse these, the author whose name is attached to the paragraphs being responsible.

I have to acknowledge, without exception, my indebtedness to the contributors to the Official Scientific Reports, whose names appear in Appendix VII. to this volume. It would have been impossible to have compiled a general account of the Scientific Results without their cordial assistance and co-operation, at all times freely given, though often at considerable inconvenience to the authors.

As in the previously published volumes of Reports the Fahrenheit Scale of temperature has been used when not otherwise expressly stated.

The Abbé A. Renard, F.G.S., has named the rock specimens collected at the various Oceanic Islands, and he has in most instances revised the determinations of the minerals or crystalline particles found in the deposits.

Nearly all the woodcuts of scenery, and many of those of animals, are from the sketches and drawings of Dr. J. J. Wild, who accompanied the Expedition as Artist and Private Secretary to the Director of the Civilian Scientific Staff; in 1884 Dr. Wild forwarded from Australia a large number of sketches taken during the cruise, from which a selection was made.

I have had in my possession for reference the Official Journals of Dr. Wild and the late Dr. Rudolf von Willemoes-Suhm. Captain Pelham Aldrich, Lieutenant Herbert Swire, Lieutenant Arthur Channer, Fleet-Surgeon George Maclean, and Mr. R. R. A. Richards placed journals or sketch-books in my hands for reference; a few of the sketches have been reproduced in this volume as woodcuts, and two of the coloured plates of natives are from the sketches of Lieutenant Swire. I take this opportunity of acknowledging the friendly assistance which has been extended to me by all the Naval Officers of the Expedition whenever information was desired in connection with the Editorial Work. A similar acknowledgment must be extended to Captain Sir Frederick J. Evans, K.C.B., till lately the Hydrographer, and the Officers of the Hydrographic Department of the Admiralty, to Sir Joseph D. Hooker, K.C.S.I., and the Botanists at the Royal Herbarium, Kew, and to Professor Archibald Geikie, the Director-General of the Geological Survey, as also to T. Digby Pigott, Esq., the Controller, and Gentlemen in the various departments of Her Majesty's Stationery Office.

To Dr. A. Günther and the Naturalists in the British Museum I return my thanks for the trouble they have at all times taken in determining or assisting in the determination of specimens, and in furnishing me with short Reports on the Incidental Terrestrial Collections from the Oceanic Islands. To the Rev. O. P. Cambridge and many other Naturalists and Scientific Men at home and abroad I am also indebted for like information and services.

In the Editorial Work connected with the passing of the Official Reports through the press, I have for more than two years had the able assistance of Mr. W. E. Hoyle, M.A., M.R.C.S., and for a shorter period of Mr. Frank E. Beddard, M.A. In the general scientific and other work of this Office valuable assistance has also been rendered by Mr. James Chumley, Mr. Frederick Pearcey, and Mr. James Monteith. In various ways while engaged in the preparation of the Narrative of the Cruise I have been assisted by Mr. Hugh Robert Mill, B.Sc., Mr. J. Rattray, M.A., B.Sc., Mr. J. T. Cunningham, B.A., and Mr. H. Roscoe Dunville, B.A.

To the Artists, Engravers, Lithographers, and Printers who have been engaged in the work my thanks are also due.

John Murray.

Challenger Office, 32 Queen Street,
Edinburgh, *6th March* 1885.

NARRATIVE

OF THE

CRUISE OF H.M.S. CHALLENGER

WITH A

GENERAL ACCOUNT OF THE SCIENTIFIC RESULTS OF THE EXPEDITION

BY

STAFF-COMMANDER T. H. TIZARD, R.N.; PROFESSOR H. N. MOSELEY, F.R.S.;
MR. J. Y. BUCHANAN, M.A.; AND MR. JOHN MURRAY, PH.D.;
MEMBERS OF THE EXPEDITION.

Partly Illustrated by Dr. J. J. WILD, Artist to the Expedition.

PREFACE.

Had the responsibility of the production of the Narrative of the Cruise rested with the same members of the Expedition from the commencement, a somewhat different method would probably have been followed in the preparation of this volume. The arrangement of the matter and the style have been largely determined by the circumstances arising out of the change of Captains during the Cruise, the unexpected death of Sir C. Wyville Thomson in 1882, and the necessity for publication before the completion of many of the special Reports.

It is hoped, however, that the volume will be found to contain a faithful record of the Work of the Expedition, and as complete an account of the scientific results as is possible in the present state of the investigations.

A considerable part of Professor Moseley's contribution to the Narrative is in the form of revised and modified extracts from his Journal, published in 1877.[1]

With respect to the depths assigned to the Zoological specimens, it may be well to state that the Naturalists of the Expedition have simply recorded the greatest depth to which the dredge or trawl was believed to have descended at each Station. It will be evident that the instrument may have been occasionally dragged into slightly deeper or shallower water than was recorded by the sounding line, and what is of greater consequence, the trawl or dredge may have caught animals while sinking through the water or being hauled up again. In the great majority of cases there is little

[1] Notes by a Naturalist on the Challenger, London, 1877.

difficulty in deciding which animals were dredged from the bottom and which were caught by the instruments in the surface or subsurface waters. With some Fish, Crustaceans, Medusæ, and other groups, however, there is considerable difficulty; in these cases the organisation is often a guide, and the specialist who has made a careful study of the group to which the species belongs, is best able to form an opinion as to the depth at which the specimens were probably captured. These circumstances should therefore always be borne in mind when the depths at which animals have lived are being discussed, and only after careful consideration should it be inferred that they were procured at the depths ascribed to them in the lists.

We desire on our own behalf, and on that of the members of the Expedition generally, to offer most grateful thanks for the liberal hospitality and ready assistance we received in all parts of the world, not only in the British Colonies but also in Foreign Countries. It has not been possible to refer in every instance to those who extended a friendly welcome to members of the Expedition and added so much to the pleasure of the Cruise, but the remembrances of many incidents and friendly acts appear, to the members of the Naval and Civilian Staffs who survive, to grow brighter rather than more dim with the lapse of time.

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ERRATA.

Page 199, in explanation of woodcut (fig. 83), for "*wyvilii*" read "*wyvillii.*"
Page 436, line 7, for "*Chætoceras*" read "*Chætoceros.*"
Pages 470 and 471, brackets round *Taonius* instead of *Procalistes* in the explanation of woodcuts.
Page 487, line 9 from bottom, *for* "fig. 141" *read* "fig. 176."
Page 496, line 15 from bottom, *for* "Vitu" *read* "Viti.'
Page 521, line 15, for "*Aphynonus*" read "*Aphyonus.*"
Page 541, line 7, for "*strata*" read "*strota.*"

INTRODUCTION.

Knowledge possessed by the Ancients concerning the Ocean, its Saltness and its Inhabitants—Researches during the Middle Ages, the Fifteenth, Sixteenth, and Seventeenth Centuries—The Expeditions of the Eighteenth Century, and the Arctic and Antarctic Expeditions of the early part of the Nineteenth Century—The "Lightning" and "Porcupine" Expeditions—Correspondence between the Royal Society and the Admiralty with reference to the investigation of the Great Ocean Basins.

A BRIEF review of the efforts made to acquire a knowledge of the Ocean, and a general account of the opinions held prior to the year 1872 as to the physical and biological conditions of the great ocean basins, may form an appropriate Introduction to the Narrative of the Voyage of H.M.S. Challenger. The objects which the promoters had in view when they urged Her Majesty's Government to fit out and despatch an Expedition on a special scientific investigation of the depths of the sea will thus be indicated.

The sea and the life in its waters were little studied by the learned men of the ancient civilisations, which were clustered round the nearly tideless Mediterranean. Their sea-lore consisted in great part of wildly exaggerated descriptions of the more striking marine phenomena woven into a vague mythology. The sea was an object of terror, for navigation was uncertain in the extreme; what lay beyond the Pillars of Hercules was veiled in mystery, and what lay beneath the surface of the waters crossed by the ancient navies was equally unknown.

The sea was not, so far as is known, made the subject of close attention until Aristotle (384–322 B.C.) brought his mind to bear on it in common with the other departments of natural history. Aristotle studied the physical conditions of the sea as far as a man without apparatus could study them. He thought that in the ocean the water was warmer and salter at the surface than at the bottom; he considered that as the sun's heat was always evaporating the water the sea would ultimately be dried up.[1] Aristotle's opinions regarding ocean physics must be viewed as mere speculations, but his researches on marine animals were of distinct scientific value. He named and described more or less minutely one hundred and sixteen species of fishes, about twenty-four species of Crustaceans and Annelids, and some forty Molluscs and Radiates,[2] making a total of one hundred and eighty species inhabiting the Ægean Sea; and the student is still reminded of his study of the anatomy of *Echinus* by the significant name "Aristotle's Lantern" applied to its masticatory apparatus.

After Aristotle no original inquirer into these matters appeared for many centuries.

Pliny the elder (23-79 A.D.), in his gossipy "Natural History," presents Aristotle's discoveries modified by much subsequent superstition and tradition. He concisely catalogues marine animals into one hundred and seventy-six species, being four less than the number recorded by Aristotle in the Ægean Sea alone. Pleased with this enumeration, he then exclaims:—"Surely then everyone must allow that it is quite impossible to comprise every species of terrestrial animal in one general view for the information of mankind. And yet, by Hercules! in the sea and in the Ocean, vast as it is, there exists nothing that is unknown to us, and, a truly marvellous fact, it is with those things which Nature has concealed in the deep that we are the best acquainted!"

Pliny had to confess himself unable to give a detailed account of the depth of the ocean, some parts he stated to be 15 stadia (over 1500 fathoms) deep, others "immensely deep, no bottom having been found;"[3] but he makes up for this in a way by explaining very clearly "why the sea is salt." He says:—"Hence it is that the widely diffused sea is impregnated with the flavour of salt, in consequence of what is sweet and mild being evaporated from it, which the force of fire easily accomplishes; while all the more acrid and thick matter is left behind, on which account the water of the sea is less salt at some depth than at the surface."[4]

In this explanation Pliny followed Aristotle, and helped to open up a magnificent arena for the hair-splitting scholastics of the Middle Ages to dispute in. Bishop Watson[5] says:—"There are few questions respecting the natural history of the globe which have been discussed with more attention, or decided with less satisfaction, than that concerning the primary cause of the saltness of the sea. The solution of it had perplexed the philosophers before the time of Aristotle; it surpassed his own great genius, and those of his followers who have attempted to support his arguments have been betrayed into very ill grounded conclusions concerning it. Father Kircher,[6] after having consulted three and thirty authors upon the subject, could not help remarking, that the fluctuations of the ocean itself were scarcely more various than the opinions of

[1] Meteorolog., lib. ii. cap. iii.
[2] De Animal. Hist., lib. iv. cap. i.-vii.; Eng. transl. by Ogle, pp. 97-115, London, 1882.
[3] Hist. Nat., lib. ii. cap. cii.
[4] *Ibid.*, lib. ii. cap. c.
[5] Chemical Essays, vol. ii. pp. 93, 94, 2nd ed., 1782.
[6] Mundus Subterraneus, Liber iii. chap. iii.

men concerning the origin of its saline impregnation." It was not until the time of Boyle that the theory at present held regarding the origin of salt in the sea was propounded.

The rage for geographical exploration which set in after the discovery of America naturally brought the phenomena of the sea into greater prominence. Sir John Hawkins' story, as told by Boyle, while almost poetical enough to suggest Coleridge's well-known lines,[1] has yet a flavour of scientific observation about it:—

"Were it not for the Moving of the Sea, by the Force of Winds, Tides and Currents, it would corrupt all the World. The Experience of which I saw *Anno* 1590, lying with a Fleet about the Islands of *Azores*, almost Six Months, the greatest Part of the time we were becalmed, with which all the Sea became so replenished with several sorts of Gellies and Forms of Serpents, Adders and Snakes, as seem'd Wonderful; some green, some black, some yellow, some white, some of divers Colours, and many of them had Life, and some there were a Yard and a half, and some two Yards long; which had I not seen, I could hardly have believed; and hereof are Witnesses all the Company of the Ships, which were then present, so that hardly a Man could draw a Bucket of Water clear of some Corruption."[2]

The Science of the Sea may be said to date from the seventeenth century. The methods used were crude, but they sometimes contained the germs of great ideas; the results arrived at were often erroneous, but they were steps in the right direction; and the researches were animated by the true scientific spirit, the spirit of observation and experiment.

In his paper, Of the Saltness of the Sea,[3] Boyle detailed a great number of experiments. He personally made a series of observations on the water of the English Channel, collecting it from various depths, and observing its specific gravity. The samples from beneath the surface were probably procured by means of Hooke's water-bottle, an extremely ingenious valved box, which is fully described and figured in one of the early numbers of the Philosophical Transactions.[4] Boyle investigated the saltness of the water by a number of processes: he tried the estimation of total solids by direct evaporation and ignition, but not being satisfied with the result he ultimately took the density as an index of the saltness, and determined this either by means of a glass hydrometer, by weighing in a phial which was afterwards weighed when full of distilled water, or by weighing a piece of sulphur in distilled water and sea water consecutively.

"As for the different degrees of the saltness of the sea," says Boyle, "I shall deliver what I have been informed of as briefly as I can. And first, it hath been observed, by one

[1] "The very deep did rot: O Christ!
That ever this should be!
Yea, slimy things did crawl with legs
Upon the slimy sea."

[2] Boyle's Works, epitomized by Boulton, vol. i. p. 281, London, 1699.

[3] *Ibid.*, p. 274.

[4] *Phil. Trans.*, vol. ii. p. 442, 1667. (The figure is reproduced in the tailpiece to this Introduction.)

to whom I gave a glass conveniently shaped to try the specific gravity of the water, that it grew heavier and heavier as he came nearer the line, till within about 30° latitude; from whence to Jamaica he observed no alteration in the specific gravity in the least. And in confirmation of this I am likewise informed, by one, who for his own satisfaction weighed the water, both under the Aequinoctial and at Cape of Good Hope, and found that the weight of both was the same. To which may be added that it is commonly observed at Mozambique, one of the hottest places in the world, that the sea is so salt there, that it bears up the ships a considerable height out of the water, more than in other places; and that the water may be much salter in one place than another, by having more salt dissolved in it, does not only appear from what hath been said, but also from what is frequently observed in the different strengths of brine-pits."[1]

About this time Hooke invented a machine for ascertaining the depth of the sea without a line.[2] It consisted of a sphere of light wood carefully pitched and varnished, which was sunk by means of a leaden sphere attached to it by a spring hook. When it reached the bottom the catch was released by the impact, the lead ball remained, and the float rose to the surface. The depth was calculated, by means of a certain formula, from the time which elapsed between letting it go and again seeing the float; and the machine answered well in shallow and still water. Hooke himself pointed out that in a current it would not show the true depth, but that the arrangement would be extremely valuable as a means of detecting under currents, and measuring their direction and velocity. The idea of self-detaching weights was not revived for two hundred years, when Brooke's sounding machine was invented.

The early volumes of the Philosophical Transactions abound in records of work done on subjects connected with the sea. In 1680 a "Person of Honour who was becalmed off of Pantalara near Sicily" amused himself by calculating the pressure at great depths by sinking a bottle "stopp'd with an excellent, good, tender cork" fixed in by various devices; he obtained some interesting results.[3]

These researches are now only of interest as showing how active a part was taken in marine physics in the early days of the Royal Society.

The phosphorescence of the sea attracted much attention about the beginning of the eighteenth century. The beautiful display seen on moving an oar through the water on a calm dark autumn night, the milky way of powdery light starred here and there with globes of soft brilliance, and the grand effect of a swell breaking on a rocky beach in showers of luminous spray, were examined by several investigators, and reasons the most various were assigned for the appearance. Newton suggested that the light was produced by the continual agitation of the water,[4] some observers thought it a phosphorescence of

[1] Boulton's Boyle, vol. i. p. 282.
[2] Lowthorp's Abridgment, *Phil. Trans.*, vol. ii. p. 257. (Figured in tailpiece to this Introduction.)
[3] *Phil. Trans.*, vol. i. p. 504.
[4] Optics, Bk. iii. p. 314, 1730.

decomposition like that of rotten wood, others held it to be a bituminous substance endowed with a self-shining power,[1] and others considered that it was produced in some unknown manner by living creatures.

The specialization of research in the modern sense was unknown to the philosophers of the seventeenth century, and when in the eighteenth the observational and experimental sciences began to separate out and develop, each in its own direction, marine research was, for a time, practically neglected. The chemist was busy investigating the riches of the earth and fighting over theories; the natural philosopher was studying light, heat, sound, electricity, and motion; the geologist was at work on the rocks and in the mines; the naturalist studied the terrestrial animals and plants of his own and distant countries, those living in the sea or on the seashore receiving less attention. The attention of navigators was fully taken up with the perfecting of their science, the development of nautical astronomy, the study of the forces which control the magnetic needle, the discovery of the longitude, the search for new lands and new routes.

Deep soundings in several parts of the ocean were recorded about the middle of the eighteenth century, but considerable caution must be used in discussing these, as the methods in use at that time were not such as to make any depth exceeding a few hundred fathoms a matter of certainty. In 1749 Ellis sounded in 891 fathoms off the northwest coast of Africa, and observed the temperature at that depth. Before the invention of the self-registering thermometer, the temperature below the surface was ascertained by taking a sample of water from the required depth in a bottle or valved box made of as imperfect heat-conductors as possible, and noting the temperature when brought on deck; this, at the best, was unsatisfactory.

In 1558 appeared the fourth book of Gesner's work on the History of Animals,[2] which is devoted to the nature of fishes and marine animals, and John Jonston,[3] who studied at St. Andrews in 1619, published in 1649 a treatise on aquatic animals, while other authors of less note contributed to the slowly increasing knowledge of littoral and pelagic animals and plants during the fifteenth, sixteenth, and seventeenth centuries.

The honour of first employing the dredge as a means of scientific investigation is claimed for two Italian naturalists—Marsili and Donati—who about 1750 used an ordinary oyster dredge for obtaining specimens in shallow water. In 1779 Otho F. Müller, a Danish zoologist, invented a special naturalists' dredge, a net attached to a square iron frame, and with this arrangement he studied the marine fauna of the coast of Denmark to a depth of 30 fathoms. The rich variety of form and colour, the enormous abundance of living creatures of all kinds, seemed like the revelation of a new world. It may be imagined how those old explorers felt who first caught sight of the wonders hidden by

[1] Encyclopédie Méthodique, art. Mer, t. ii. p. 744, 1786.
[2] Historiæ Animalium, Liber iv., Tiguri, 1558.
[3] Historiæ naturalis de Piscibus et Cetis Libri V.; de Exanguibus aquaticis Libri IV., Francf., 1649, Amst., 1657.

the waves on reading Edward Forbes' enthusiastic description of his first deep-water dredging:—

"Beneath the waves there are many dominions yet to be visited and kingdoms to be discovered, and he who venturously brings up from the abyss enough of their inhabitants to display the physiognomy of the country, will taste that cup of delight, the sweetness of whose draught those only who have made a discovery know. Well do I remember the first day when I saw the dredge hauled up after it had been dragging along the sea bottom, at a depth of more than 100 fathoms. Fishing lines had now and then entangled creatures at as great, and greater depths, but these were few and far between, and only served to whet our curiosity, without affording the information we thirsted for. They were like the few stray bodies of strange red men which tradition reports to have been washed on the shores of the Old World, before the discovery of the New, and which served to indicate the existence of unexplored realms inhabited by unknown races, but not to supply information about their character, habits, and extent. But when a whole dredgeful of living creatures from the unexplored depth appeared, it was as if we had lighted upon a city of the unknown people, and were able, through the numbers and varieties taken, to understand what manner of beings they were. Well do I remember anxiously separating every trace of organic life from the enveloping mud, and gazing with delighted eye on creatures hitherto unknown, or on groups of living shapes, the true habitats of which had never been ascertained before, nor had their aspect, when in the full vigour and beauty of life, ever before delighted the eye of a naturalist. And when, at close of day, our active labours over, we counted the bodies of the slain, or curiously watched the proceedings of those whom we had selected as prisoners, and confined in crystal vases, filled with a limited allowance of their native element, our feelings of exultation were as vivid, and surely as pardonable, as the triumphant satisfaction of some old Spanish 'Conquisatador,' musing over his siege of a wondrous Astlan[1] city, and reckoning the number of painted Indians he had brought to the ground by the prowess of his stalwart arm."[2]

Dredging in shallow water was found to be so easy, and its results so interesting, and often so unexpected, that it soon became popular among naturalists, and assisted in turning their attention more particularly to marine life.

The increased interest in the biological conditions was accompanied by a more careful study of the physical and chemical problems presented by sea water. A great many analyses were made towards the end of last century, but the methods then employed were too imperfect to yield results of much scientific value, and the principle on which they were conducted was erroneous. It was assumed that a proximate analysis of the salts in sea water could be made by weighing the amount of each particular salt that could

[1] Astlan was the country from which, according to native tradition, the Aztecs came.

[2] Natural History of European Seas, p. 11, 1859.

be separated from the water, and thus these analyses gave long and very conflicting lists, all claiming to present the precise quantity of sulphate and muriate of soda, of sulphate and muriate of magnesia, and of sulphate and muriate of lime, in the water. It was not until 1818 that the different proportions in which these salts were procured were conclusively shown to be due, not, necessarily, to any difference in the sea water, but to differences in the methods of analysing it. In that year Dr. John Murray of Edinburgh published an extremely valuable research on the water of the Firth of Forth;[1] he showed that by treating portions of the same sample of water in different ways, widely different quantities of the various salts might be obtained, and that the only satisfactory method of proceeding was to determine each base and each acid separately. The attempt to discover whether the composition of sea water differed at different places was frequently made, but the conditions of observation were unsatisfactory. The samples could not be relied upon as properly collected or preserved, and much uncertainty remained on the subject.

Péron, a French naturalist who went round the world in the year XII. of the Republic (1805), made a number of observations on the temperature of the ocean at different depths. He was strongly impressed by the importance of oceanic research, and wrote :—" Of all the experiments in Natural Philosophy there are few the results of which are more interesting or more curious than those which form the subject of this memoir. The meteorologist must derive from them valuable data in regard to atmospheric observations in the middle of the ocean ; they may furnish to the naturalist knowledge indispensably necessary in regard to the habitation of the different tribes of marine animals ; and the geologue and philosopher will find in them the most certain facts in regard to the propagation of heat in the middle of the seas, and of the physical state of the interior parts of the globe, the deepest excavations of which can scarcely go beyond the surface. In a word, there is no science which may not derive benefit from the results of experiments of this kind. How much then ought we to be surprised that they have hitherto excited so little attention ! "[2]

Péron's results were very erroneous ; he imagined that the bed of the ocean was covered with eternal ice, and that, as a consequence, life was impossible there. From the state of deep-sea research at the time this theory was quite plausible and required to be refuted before it was rejected. Sir John Ross's great Arctic voyage in 1818 furnished complete and most satisfactory evidence that Péron's deductions were wrong. Apart from the exploring work and the very valuable magnetic observations of Ross's expedition, it stands out in history as the first in which satisfactory soundings were made and samples of the bottom obtained. Ross had invented an arrangement, which he called the " Deep-sea Clamm," for gripping a portion of the bottom and

[1] *Trans. Roy. Soc. Edin.*, vol. xiii. p. 205, 1818.
[2] *Journal de Physique*, t. lix. p. 361, an. xiii. ; *Phil. Mag.*, ser. 1, vol. xxi. p. 129, 1805.

bringing it up safely.[1] He attached this to the line on a number of occasions, and succeeded in bringing up as much as 6 lbs. of mud from the great depth of 1050 fathoms in Baffin Bay; and on September 1st, 1819, in Possession Bay, "soundings were obtained correctly in 1000 fathoms, consisting of soft mud, in which there were worms, and entangled on the sounding-line, at the depth of 800 fathoms, a beautiful *Caput-Medusæ*,"[2] thus proving that there was animal life on the bed of the ocean notwithstanding the darkness, stillness, silence, and enormous pressure produced by more than a mile of superincumbent water. Starfishes were frequently found attached to the line at depths of over 800 fathoms from the surface, but these discoveries were strangely lost sight of for many years. The zoological collections made on this voyage must have been of great scientific value, and it is much to be regretted that, on their arrival in this country, a large number of the specimens were in a state unfit for identification. The scientific work of the cruise had been entrusted to Sir Edward Sabine, who, while anxious to do justice to the whole circle of the sciences, naturally devoted himself most to his own department of physical and magnetic observations. Sir John Ross keenly felt the want of a naturalist. He writes:—

"An endless variety of the class Acalephæ were brought home, and sent to the Museum, but in a state so much contracted by the spirit as to render it impossible for Dr. Leach to make out their genera. Observations on these animals whilst living accompanied by accurate drawings, are quite necessary to render the preserved specimens of any degree of use; and it is to be regretted that no Naturalist capable of performing these indispensable parts of his duties accompanied the Expedition."[3]

Considerable attention was also paid to meteorology and ocean physics, and the record of the voyage includes a number of tables of continuous meteorological observations. the density of the surface water was observed daily, and occasionally that at a depth of 80 fathoms.[4] Deep-sea temperatures were taken at short intervals of time and of depth by means of a self-registering thermometer with a protected bulb, resembling that devised by Sir William Thomson[5] and Professor W. A. Miller half a century later.[6]

In his second Arctic voyage, from 1829 to 1833, Sir John Ross continued his scientific observations, and frequently dredged in shallow water, his limit of depth being 70 fathoms.[7] The large zoological collections were unfortunately lost to science, as they had to be abandoned with the "Victory," and since there was no naturalist on the expedition the loss was complete.

The researches of Mr. Darwin during the voyage of H.M.S. "Beagle" (1831–36), remarkable in so many respects, are to be noted in this connection chiefly for his obser-

[1] Voyage of Discovery in His Majesty's Ships "Isabella" and "Alexander," Appendix, p. cxxxv, London, 1819.
[2] *Ibid.*, p. 178.
[3] *Ibid.*, Appendix, pp. lxiii, lxiv.
[4] *Ibid.*, Appendix, three large plates.
[5] Depths of the Sea, p. 293, 1874; *Proc. Roy. Soc. Edin.*, vol. ii. pp. 267–271, 1851.
[6] Depths of the Sea, p. 290.
[7] Narrative of a Second Voyage in Search of a Northwest Passage, Appendix, p. lxxxi, London, 1835.

vations on the bathymetrical limit of reef-forming corals, and on the structure and origin of coral reefs and islands.

About this time appeared Sir John Dalyell's interesting investigations on Scottish zoophytes and the first microscopic researches of Ehrenberg upon living and fossil marine organisms. The microgeologic studies of the latter, pointing out the relation between modern marine deposits and geological formations, added a new interest to the investigation of marine life. In 1837 Mr Alan Stevenson applied the method still in use for ascertaining the direction and velocity of marine under-currents.[1]

The next great advance in marine zoology was the invention of Ball's dredge in 1838. The special features of this dredge were such as to give it at once the first place as a naturalist's appliance, and after the lapse of nearly half a century it remains practically unexcelled.

The great importance of dredging as a means of zoological research was recognised in 1839 by the British Association, which appointed a committee "for researches with the dredge, with a view to the investigation of the marine zoology of Great Britain, the illustration of the geographical distribution of marine animals, and the more accurate determination of the fossils of the Pliocene period under the superintendence of Mr. Gray, Mr. Forbes, Mr. Goodsir, Mr. Patterson, Mr. Thompson of Belfast, Mr. Ball of Dublin, Dr. George Johnston, Mr. Smith of Jordan Hill, and Mr. A. Strickland."[2]

From the number of eminent men on this committee valuable reports were looked for, and not in vain. One alone, Professor Edward Forbes, did more than any of his contemporaries to advance marine zoology. He conducted long and patient investigations into the bathymetrical distribution of life in various seas; and by the fascination of his literary style he invested his reports with an interest that carried the knowledge of his work far beyond the limits usually set to the labours of specialists. Forbes' ideas on many points are no longer entertained; had he lived longer he himself would doubtless have been the first to discover and proclaim the falsity of many of them. "To Forbes is due the credit of having been the first to treat these questions in a broad philosophical sense, and to point out that the only means of acquiring a true knowledge of the *rationale* of the distribution of our present fauna, is to make ourselves acquainted with its history, to connect the present with the past. This is the direction which must be taken by future inquiry. Forbes, as a pioneer in this line of research, was scarcely in a position to appreciate the full value of his work. Every year adds enormously to our stock of data, and every new fact indicates more clearly the brilliant results which are to be obtained by following his methods, and by emulating his enthusiasm and his indefatigable industry."[3]

[1] The Principles and Practice of Canal and River Engineering, by David Stevenson, F.R.S.E., p. 116, 2nd ed. Edinburgh, 1872.

[2] *Brit. Assoc. Report*, p. 127, 1839; Memoir of Edward Forbes, F.R.S., by Wilson and Geikie, p. 246, 1861.

[3] Depths of the Sea, p. 6, 1874.

Forbes believed with all the intensity of the old school of naturalists in the immutability of species, and in specific centres of distribution; he based his beliefs on facts of his own observation, and if these now appear insufficient and unsatisfactory, it must be remembered that he worked before Darwin's Origin of Species gave to naturalists the modern ideas of natural selection and evolution.

Forbes' name is inseparably associated with the bathymetrical distribution of marine life, and his clearly defined zones—the Littoral, Laminarian, Coralline, and the Region of the Deep-sea Corals—enormously facilitated the work of descriptive naturalists. The region of deep-sea corals extended from 50 fathoms to an unknown depth, and Forbes points out that vegetable life is entirely absent from it, and "as we descend deeper and deeper in this region, the inhabitants become more and more modified, and fewer and fewer, indicating our approach towards an abyss where life is either extinguished, or exhibits but a few sparks to mark its lingering presence. Its confines are yet undetermined, and it is in the exploration of this vast deep-sea region that the finest field for submarine discovery yet remains."[1] In another place he indicates the plateau between Shetland and the Færöe Islands, on which the depth nowhere exceeds 700 fathoms, as the place on which dredging is most likely to settle the question of the existence of a zero of life, and he points out that while the life-zero is probably about the 300 fathom line in the Mediterranean, the researches of Arctic voyagers have shown it to be much deeper in Polar regions. The disciples of all great men tend to assert dogmatically what their master suggested hypothetically, and it was so with the followers of Edward Forbes. They viewed the life-zero, not as a probability, but as a certainty, building their belief more on the *à priori* absurdity of creatures being able to live in the absence of light and air, and under the great pressure which must prevail in the depths of the sea, than on any direct evidence.

The United States Government sent out their first purely scientific expedition in 1838 under the command of Captain Wilkes. This expedition returned in 1842; its work was chiefly geographical and astronomical, but during the first year a few dredgings were made in shallow water, and a number of deep soundings were obtained at intervals during the voyage. The sounding line employed was a copper wire, a great improve menton previous methods. The great American naturalist Dana, who accompanied this expedition, added much to the knowledge of several groups of shallow water and pelagic animals.

A British Antarctic Expedition under Sir James Clark Ross sailed in the "Erebus" and "Terror" in 1839, and returned safely in 1843. Like Sir John Ross in the Arctic voyages, his nephew was determined to make the most of his opportunities in all directions, and was seconded in his efforts by the able co-operation of Sir Joseph Dalton Hooker, who accompanied the expedition as assistant surgeon. Without neglecting

[1] Natural History of European Seas, p. 26, 1859. This classification was given as early as 1839. See Memoir of Edward Forbes, p. 255.

his main purpose—the exploration of the ice-bound coasts of the southern hemisphere and the search for the South Magnetic Pole—Ross carried on astronomical, physical, and zoological work, and achieved results so important and hitherto so overlooked as to justify a somewhat detailed notice.

Sir Joseph Hooker first made known some of the results of Ross's deep-sea dredgings and investigations in 1845,[1] and fuller details were given by Ross himself in the account of the voyage published in 1847.

A number of unsuccessful attempts were made to ascertain the depth of the water in mid-ocean, the failure being due to the want of a proper line. Sir James Ross accordingly had one made on board, 3600 fathoms long, fitted here and there with swivels to prevent it unlaying in its descent, and made strong enough to support a weight of 76 lbs.

On the 3rd January 1840, when in lat. 27° 26′ S. and long. 17° 29′ W., the first abysmal sounding was satisfactorily made with the new line, the depth marked being 2425 fathoms.[2] Such great depths could only be attempted in dead calm weather, and the line was allowed to run out from an enormous reel in one of the ship's boats, the time each 100 fathom mark left the reel being noted in the usual way.

On the 3rd March 1840, a sounding of 2677 fathoms was made in lat. 33° 21′ S. and long. 9° E., 450 miles west of the Cape of Good Hope. Water of equal depth was frequently sounded during the cruise, and on two occasions at least no bottom could be found with over 4000 fathoms of line.

The temperature of the water was observed very frequently at all depths down to 2000 fathoms, and its density at the surface and at various depths was determined almost daily. These observations were very valuable at the time, as giving the first real clue to the distribution of temperature at the bottom of the sea; but both in this expedition and in those of Wilkes and D'Urville, the thermometers were not properly protected against pressure, and consequently it came to be generally believed that in all open seas the water below a certain depth maintained a uniform temperature of 39° F. right down to the bottom.

Ross lays special emphasis on the fact mentioned by earlier observers that the surface temperature of the water falls rapidly as the depth of the sea diminishes; he cites one instance when in a single day the temperature at the surface fell from 70° F. where the depth was 400 fathoms, to 51°·5 where it was only 48 fathoms,[3] a fact now known to be of local but not of universal occurrence.

The dredgings, which were taken occasionally, turned out to be one of the most valuable parts of the scientific work of the expedition. On the 21st April 1840, a haul of the dredge was taken in 95 fathoms of water, and it came up full of coral. On the 18th January 1841, when in lat. 72° 57′ S. and long. 176° 6′ E., a Pycnogonid

[1] *Ann. and Mag. Nat. Hist.*, ser. 1, vol. xvi. p. 238, 1845.

[2] Antarctic Voyage, vol. i. p. 26, 1847.

[3] *Ibid.*, vol. i. p. 34.

(*Nymphon gracile*) was found attached to the lead, after a sounding in 230 fathoms. Next day, when the depth was 270 fathoms, a dredge was put over, and when hauled up was found to be nearly full; it contained a block of granite, a number of small stones, some beautiful specimens of living corals, and, to quote Captain Ross's own words:—

"Corallines,[1] Flustræ, and a variety of marine invertebrate animals, also came up in the net, showing an abundance and great variety of animal life. Amongst them I detected two species of *Pycnogonum*, *Idotea baffini*, hitherto considered peculiar to the Arctic Seas, a Chiton, seven or eight bivalves and univalves, an unknown species of *Gammarus*, and two kinds of *Serpula* adhering to the pebbles and shells."[2]

On January 20th, 1841, the deep-sea clamm brought up stiff green mud containing corals and fragments of Starfish from a depth of 320 fathoms. Two days later the dredge was put over and allowed to trail along the bottom for two or three hours in 300 fathoms, and its contents included "many animals, some Corallines, and a quantity of sand, mud, and small stones."[3]

Ross's deepest dredging was made at 10 A.M. on the 11th August 1841, in lat. 33° 32′ S., long. 167° 40′ E., when the dredge was let go in 400 fathoms; after being dragged along the ground for half an hour, it was hauled on deck, and found to contain "some beautiful specimens of Coral, Corallines, Flustræ, and a few Crustaceous animals." The reflections of the accomplished leader of the expedition are extremely significant. So completely had Ross's researches faded from memory, that twenty years after they were made, the fact of living creatures being found under 400 fathoms of water was hailed as a great discovery. Yet Ross, referring to his dredgings in 1841, says:—

"It was interesting amongst these creatures to recognise several that I had been in the habit of taking in equally high northern latitudes; and although contrary to the general belief of naturalists, I have no doubt that from however great a depth we may be able to bring up the mud and stones of the bed of the ocean, we shall find them teeming with animal life; the extreme pressure at the greatest depth does not appear to affect these creatures; hitherto we have not been able to determine this point beyond a thousand fathoms, but from that depth several shellfish have been brought up with the mud."[4]

From the fact that the same species were to be found at both poles, and that these animals are very sensitive to a change of temperature, he suggested that it would be possible for them to pass from one frigid zone to another, provided the temperature of the intervening sea bottom had a range not exceeding 5° F. Ross's observations confirmed his idea that the temperature at the bottom of the open sea was uniform in all latitudes, and subsequent investigations prove it, generally speaking, to be correct.

Sir James Ross was an indefatigable zoological collector, but it is to be regretted that his large collections of deep-sea animals, which he retained in his own possession

[1] Most probably Polyzoa are here referred to.—J.M.

[2] Antarctic Voyage, vol. i. p. 202.

[3] *Ibid.*, p. 207.

[4] *Ibid.*, pp. 202, 203.

after the return of the expedition, were found to be totally destroyed at the time of his death. Had these been carefully described during the cruise or on the return of the expedition to England, the gain to science would have been immense, for not only would many new species and genera have been discovered, but the facts would have been recorded in the journals usually consulted by zoologists, instead of being lost sight of as was the case. A large number of zoological drawings made by Sir Joseph Hooker during the Antarctic cruise were recently handed to the various naturalists engaged in working up the Challenger collections, and these show that some of the Challenger discoveries had been anticipated by Ross. Sir Joseph Hooker, whose botanical researches are so well known, recorded the existence of immense numbers of Diatoms on the surface of the Antarctic Ocean, and pointed out that the mud at the bottom, as obtained in Ross's dredgings, consisted of their dead remains.[1]

When Sir John Franklin's ill-fated Polar expedition set out in 1845, Mr. Harry Goodsir, a young zoologist of great promise, sailed on board the "Erebus" as assistant surgeon and naturalist. The expedition never returned, and only fragmentary records are preserved of the valuable work which Goodsir had already accomplished. "On the 28th June a dredge was sunk to the enormous depth of 300 fathoms, and produced many highly interesting species of Mollusca, Crustacea, Asteriadæ, Spatangi, and Corallines; such as *Fusus*, *Turritella*, *Venus*, *Dentalium*, &c., and also some large forms of Isopoda. As bearing upon the geographical distribution of species, Mr. Goodsir considers the occurrence of *Brissus lyrifer* (Forbes) and *Alauna rostrata* (Goodsir) as of the greatest interest, both of them being natives of the Scottish seas. The remarkable depth also appears to us to give peculiar interest to these researches, as we believe that the deepest dredgings ever previously obtained were those of Professor E. Forbes in the Levant, the deepest of which was 230 fathoms, itself far beyond any made by other naturalists."[2]

Up to this time all the deep dredgings had been made during Polar expeditions, though not necessarily in Polar regions; the reason being that the time and trouble of working a dredge in deep water were too great to make it feasible except on scientific expeditions, and the only scientific expeditions of those days were despatched toward the poles. In 1846, however, Captain Spratt, R.N., dredged in 310 fathoms, 40 miles to the east of Malta, and found abundance of animal life, including eight distinct species of Mollusca.[3]

During this period of rapid advance in marine zoology, the problems of ocean physics and meteorology were not lost sight of. Rennel had been collecting particulars of the currents, prevailing winds, and general meteorology of the ocean from 1810 to 1830, and his Investigation of Currents, &c., is still a valuable book of reference. Maury also collected facts of all kinds bearing on these matters between the years 1848 and

[1] Flora Antarctica, vol. ii. p. 503, London, 1847.
[2] *Ann. and Mag. Nat. Hist.*, ser. 1, vol. xvi. p. 163, 1845.
[3] Spratt, On the Influence of Temperature upon the Distribution of the Fauna in the Ægean Sea, *Brit. Assoc. Report*, Communications, p. 81, 1848.

1858, and published his famous Sailing Directions embodying these statistics. One important result of Maury's exertions was the maritime conference held in Brussels in 1853, which resulted in international observations being taken on many naval and mercantile ships, thus obtaining several of the advantages of scientific expeditions at very little expense.

Before 1850 the attention of the Norwegian naturalist, Michael Sars, had been directed to the bathymetrical distribution of life on his native coasts, and he published in the following year a list of thirteen species which lived at a depth of about 300 fathoms.[1] His son, G. O. Sars, afterwards assisted him in the work of deep-water dredging, and the result was, in 1864, a list of ninety-two species, which lived between the depths of 200 and 300 fathoms.[2] A few years later these untiring investigators found abundance of life at the bottom under 450 fathoms of water.[3]

A great impulse was given to deep-sea soundings when Brooke, an officer in the United States Navy, invented his sounding machine in 1854. Its principle was that described by Hooke two centuries before; the sinker was detached when the weight struck the bottom, but it differed in that the sounding tube could be drawn up by the line, bringing with it a small sample of the deposit on which it struck. Bailey's description of the micro-organisms found in these deposits, as well as others obtained by the U.S. Coast Survey, excited great interest among scientific men.[4] A few years later the instrument was modified and improved by Commander Dayman, who employed it for his soundings across the Atlantic, when investigating the depths through which the Atlantic telegraph cable would require to pass.[5] The necessity for ascertaining the form and conditions of the sea bed for telegraph purposes was the occasion of considerable increase in the scientific knowledge of great depths.

The samples of "Atlantic ooze" procured from the greatest depths of that ocean by the sounding rods of the telegraph ships were eagerly examined by the leading European and American naturalists. The ooze was found to consist largely, in some cases almost wholly, of the shells of Foraminifera and the siliceous skeletons of Radiolarians and Diatoms. The question soon came to be whether all the Foraminifera naturally lived on the bottom, or whether it was only their dead shells that collected there, the animals living and dying on the surface, or at some intermediate depth. This question was exceedingly difficult to settle from the data possessed by the disputants prior to the Challenger and other exploring expeditions.

[1] Beretning om en i Sommeren 1849 foretagen zoologisk Reise i Lofoten og Finmarken, *Nyt Mag. f. Naturvid.*, Bd. vi. p. 133, 1851.

[2] Bemærkninger over det dyriske Livs Udbredning i Havets Dybder, *Forhandl. Vidensk. Selsk.*, Christiania, p. 54 (1864), 1865.

[3] *Forhandl. Vidensk. Selsk.*, Christiania, p. 248 (1868), 1869; translation, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. iii. p. 425, 1869.

[4] *Amer. Journ. Sci. and Arts*, vol. lxxi., 1856.

[5] Depths of the Sea, p. 214.

In the preserved samples of the ooze it was believed that there was evidence of the existence of sheets of living protoplasm—a shell-less Rhizopod named *Bathybius*[1]—covering the bottom of the ocean everywhere. The Naturalists of the Challenger failed to detect *Bathybius* in freshly procured samples of the ooze, and have shown that the protoplasmic appearance arose from the great excess of alcohol used in the preservation of the samples of the ooze, producing a gelatinous-like precipitate of calcium sulphate.

The voyage of the "Bulldog" in 1860, under Sir Leopold M'Clintock, is especially noteworthy amongst the cruises of surveying ships. The "Bulldog," which was sent to examine a proposed northern cable route, took soundings from Færöe to Iceland and thence to Greenland and Labrador. Though bad weather prevailed for a great part of the cruise, a large number of soundings and many samples of mud were taken; as the expedition had the good fortune to be accompanied by Dr. G. C. Wallich as naturalist, these were carefully examined as they were brought up. The invention of the "Bulldog" sounding machine—a combination of Ross's deep-sea clamm with Brooke's detaching weight—made it possible to obtain larger samples of the bottom than had been usual before.

On one occasion a depth of 1260 fathoms was indicated. "That single sounding," says Dr. Wallich, "I may be permitted to say compensated for every disappointment that weather and accident may have previously engendered. At the eleventh hour, and under circumstances the most unfavourable for searching out its secrets, the deep has sent forth the long-coveted message."[2] That message was conveyed by thirteen Starfishes which had attached themselves to a portion of the sounding line that had been allowed to lie on the bottom for some time. This haul raised a storm of controversy. Dr. Wallich was firmly convinced that it was proof beyond question of the existence of highly organised animal life at great depths, but many eminent zoologists argued that it was quite probable that the Starfishes had "convulsively embraced" the line somewhere on its way up. The idea of a life-zero was far too firmly fixed in the zoological mind of that period to be readily displaced.

In the same year, 1860, a telegraph cable which was being raised for repair in the Mediterranean under the direction of Mr. Fleeming Jenkin, now Professor of Engineering in the University of Edinburgh, was the means of definitely deciding the fact of highly organised creatures living at great depths.[3] Parts of the cable which had been lying under 1200 fathoms of water for many years were found covered with animals that had fixed themselves at a very early stage of development and had grown to maturity there. Some of these were examined and described by Professor Allman of Edinburgh, others by M. Milne-Edwards of Paris.

[1] Huxley, *Quart. Journ. Micr. Sci.*, N. S., vol. viii. p. 210, 1868; Haeckel, Studien über Moneren und andere Protisten, p. 86, Leipzig, 1870.

[2] North-Atlantic Sea-bed, p. 68, London, 1862.

[3] Depths of the Sea, p. 26, 1874.

During Otto Torell's expedition to Spitzbergen in 1864, a great number of creatures were taken at a depth of 1000 to 1400 fathoms in the "Maclean nets." They included Rhizopoda, Bryozoa, Sponges, Annelids, Crustacea, and other forms. In subsequent expeditions to Spitzbergen, creatures were frequently secured from a similar depth.[1]

In 1865 a paper by Professor Forchhammer of Copenhagen on the Composition of Sea-Water in different parts of the Ocean was published in the Philosophical Transactions,[2] recording the result of twenty years of patient work, and its publication made an era in the history of ocean chemistry. Forchhammer worked under great disadvantages; his samples of water were brought home by seafaring men from different parts of the world in corked bottles, and they were necessarily all taken from the surface or immediately beneath it. Forchhammer did not attempt to determine quantitatively all the elements that occur in sea water, but confined himself to the very accurate estimation of the principal components, viz., chlorine, sulphuric acid, magnesia, lime, potash, and (by difference) soda. Although his methods have since been improved on, all the analyses were models of care and accuracy, and all his results have been confirmed and extended by Professor Dittmar's elaborate research, carried on under conditions so immensely more favourable on the water samples carefully collected on board the Challenger. Forchhammer's grand conclusion is that although the salinity of sea water may and does vary within certain limits, yet if samples be taken in all parts of the open sea, avoiding the vicinity of land and the mouths of large rivers, the proportion of each constituent to the total salts will be found to be the same everywhere. The differences in surface sea water then are merely differences due to dilution and concentration.

In 1867 Count L. F. de Pourtalès commenced, in connection with the United States Coast Survey, a series of deep dredgings on the margin of the Gulf Stream. Working in the U.S. Coast Survey steamer "Corwin," he dredged down to a depth of 350 fathoms; and in the following year he resumed the work in the same place in the U.S. Coast Survey steamer "Bibb," and dredged successfully in 510 fathoms, finding animal life exceedingly abundant. Although a great part of the collections made by Pourtalès were lost in the great fire of Chicago, many new species have been described and brought under the notice of zoologists, and the wide bearing of the new facts obtained were comprehensively discussed by Professor Louis Agassiz, who took part in these explorations with Pourtalès.[3]

It has always been supposed that costly appliances and a large crew are absolutely necessary for successful dredging in water of any great depth. G. O. Sars indeed had worked down to 300 fathoms in a small boat manned by three men, off the Lofoten

[1] *Zeitschr. f. wiss. Zool.*, Bd. xx. p. 457, 1870.
[2] *Phil. Trans.*, vol. clv. pp. 203–262, 1865.
[3] *Bull. Mus. Comp. Zoöl.*, Cambridge, U.S.A., 1868 and 1869.

Islands, but his example was not much followed. In 1868 Professor Perceval Wright[1] proceeded to Setubal in Portugal, in order to investigate the occurrence of *Hyalonema*, which was reported to be frequently taken on the lines of the shark-fishers who had long pursued their calling, at the great depth of 500 fathoms. He succeeded in getting abundance of specimens of *Hyalonema*, although six men were required to work the dredge, and the depth of the water was 480 fathoms. "This dredging," says Professor Wyville Thomson, "is of special interest, for it shows that although difficult and laborious, and attended with a certain amount of risk, it is not impossible in an open boat, and with a crew of alien fishermen, to test the nature of the bottom, and the character of the fauna, even to the great depth of 500 fathoms."[2] But although possible, such dredging is too laborious and dangerous to be frequently resorted to, and for any systematic study of the depths of the sea more elaborate arrangements must be made.

The subject of deep-sea dredging was not being neglected in Great Britain. In the spring of 1868 Professor Wyville Thomson, in a letter to Dr. W. B. Carpenter, urged the employment of a Government vessel in a dredging expedition off the coast of Scotland, and in consequence of this the Royal Society laid before the Admiralty a statement of the advantages to science likely to result from a short dredging cruise in the North Atlantic. The Admiralty responded by placing the surveying ship "Lightning," Captain May, at the disposal of Drs. Thomson and Carpenter in the autumn of the same year. The conditions of work in the "Lightning" were very unfortunate both as regards the vessel and the weather which prevailed during the six weeks that the cruise lasted. In spite of all the difficulties in the way, dredging was carried on to a depth of 650 fathoms, and temperature observations of the greatest interest were obtained, which ultimately led to the discovery of the Wyville Thomson Ridge in the Færöe Channel in 1880.[3] Professor Wyville Thomson thus sums up the results of the "Lightning" expedition :—

"It had been shown beyond question that animal life is varied and abundant, represented by all the invertebrate groups, at depths in the ocean down to 650 fathoms at least, notwithstanding the extraordinary conditions to which animals are there exposed.

"It had been determined that, instead of the water in the sea beyond a certain depth varying according to latitude having a uniform temperature of 4° C., an indraught of Arctic water may have at any depth beyond the influence of the direct rays of the sun a temperature so low as $-2°$ C.; or on the other hand, a warm current may have at any moderate depth a temperature of 6°·5 C., and it had been shown that great masses of

[1] See Notes on Deep-Sea Dredging, *Ann. and Mag. Nat. Hist.*, ser. 4, vol. ii, pp. 423–427, 1868.
[2] Depths of the Sea, p. 277, 1874.
[3] Exploration of the Færöe Channel, *Proc. Roy. Soc. Edin.*, vol. xi. pp. 638–717, 1882.

water at different temperatures are moving about, each in its particular course; maintaining a remarkable system of oceanic circulation, and yet keeping so distinct from one another that an hour's sail may be sufficient to pass from the extreme of heat to the extreme of cold.

"Finally, it had been shown that a large proportion of the forms living at great depths in the sea belong to species hitherto unknown, and that thus a new field of boundless extent and great interest is open to the naturalist. It had been further shown that many of these deep-sea animals are specifically identical with tertiary fossils hitherto believed to be extinct, while others associate themselves with and illustrate extinct groups of the fauna of more remote periods; as, for example, the vitreous sponges illustrate and unriddle the ventriculites of the chalk." [1]

In consideration of the value and novelty of these results, the Royal Society urged the Admiralty to provide means of extending the observations. In 1869 the surveying ship "Porcupine," Captain Calver, was appointed to this service. In addition to the temperature observations, which had turned out so interesting in the "Lightning," it was decided to make a number of chemical observations on the water. For this purpose the chartroom was fitted up as a laboratory, and a chemist was invited to join the biologists on the cruise. A number of arrangements were also made for facilitating dredging and the subsequent observations. The "Porcupine" was a first-rate vessel for the purpose, and between May and September 1869 she made three distinct trips. The first of these was under the scientific direction of the late Mr. Gwyn Jeffreys, and it was chiefly devoted to dredging off the west coast of Ireland and in the channel between Scotland and Rockall. The deepest dredging made was in 1470 fathoms, and no lack of life was found at that depth. It was accordingly resolved that, during the second trip, under the direction of Professor Wyville Thomson, an attempt should be made to dredge in the deepest water within reach, so that a definite answer to the general question of the existence of life at great depths could be arrived at. The "Porcupine" was steered for the Bay of Biscay, and at a point about 250 miles west of Ushant two highly successful hauls of the dredge were taken in water over 2000 fathoms deep, and in both animal forms from the Protozoa to the Mollusca were abundant.[2] It was on this cruise that Captain Calver suggested the employment of hempen tangles attached to the dredge frame, an idea which Professor Thomson says inaugurated a new era in dredging.[3]

The third cruise of 1869, during which Dr. Carpenter was the naturalist in charge, was intended to be a repetition of that of the "Lightning" in the previous autumn. The observations of the earlier expedition were confirmed and extended in various directions.

In 1870 Mr. Gwyn Jeffreys and Dr. Carpenter continued the work in the

[1] Depths of the Sea, pp. 79, 80, 1874. [2] *Ibid.*, pp. 96, 97. [3] *Ibid.*, p. 256.

"Porcupine" by a highly interesting series of soundings and dredgings in the Mediterranean and current observations in the Strait of Gibraltar. Dr. Carpenter resumed the study of this region in the following year in the "Shearwater," commanded by Captain G. S. Nares, afterwards Captain of the Challenger, and this expedition was no less interesting or important than those that went before.

The chemical and physical work of the "Porcupine" expeditions was not so satisfactory as might have been expected. Marine chemistry was so entirely new, that a great deal of preliminary work had to be done in order to gain the experience necessary for further more accurate experiments; and it was in the way of suggesting improvements for future use that the chemical work of the "Porcupine" was most valuable.

In December 1871 and early in 1872 the U.S. Coast Survey steamer "Hassler," under the scientific direction of Professor Louis Agassiz, dredged in considerable depths off the coast of South America.

About this period appeared an important work by Delesse on the lithology and distribution of marine deposits,[1] in which the littoral formations of the coast of France are described in detail, and our knowledge of the deeper deposits of the North Atlantic are reviewed.

This introductory chapter is not intended as a history of marine scientific research; its purpose is merely to trace the gradual growth of knowledge of the physical and biological conditions of the ocean up to 1872, and to recall some of the more important of the earlier researches which have been allowed to fade from the attention of the scientific public. More emphasis is laid on the beginning of the various enterprises than on their subsequent development, and prominence has been given throughout to the work carried on by British investigators. It is not on account of any notion that the expeditions despatched by other countries were less important at the time, or productive of less permanent results, that the older cruises of the "Astrolabe," of the "Venus," and the "Bonite," and the more modern ones of the "Eugenie," the "Novara," the "Magenta," and other vessels have not been dwelt upon. It is because the line of researches which had a direct bearing on the despatch of the Challenger could be indicated sufficiently clearly without entering into greater detail.

The cruises of the "Porcupine" proved that there was life at vast depths in the sea, and that, with a little care, this life could be investigated by ordinary and well known means. The results, taken in conjunction with the conclusions of the contemporary German North Sea Expedition, also showed the great importance of a careful study of the physical, and especially the chemical, as well as the biological, conditions of the sea.

[1] A. Delesse, Lithologie du Fond des Mers, Paris, 1871.

The vast ocean lay scientifically unexplored. All the efforts of the previous decade had been directed to the strips of water round the coast and to enclosed or partially enclosed seas; great things had certainly been done there, but as certainly far greater things remained to be done beyond. This consideration led to the conception of the idea of a great exploring expedition which should circumnavigate the globe, find out the most profound abysses of the ocean, and extract from them some sign of what went on at the greatest depths.

The following correspondence extracted from the Minutes of Council of the Royal Society giving expression to this idea, and tracing the progress of its realisation, will best show how all the difficulties in the way of inaugurating an undertaking of such magnitude and novelty were successfully surmounted; and their perusal will be a fitting introduction to the chapters containing the Narrative of the Cruise, the study of which cannot fail to convince the reader that, high as were the hopes entertained by the promoters of the Expedition, the performance was even greater than had been anticipated.

"*June 29th*, 1871.

"Read the following Letter from Dr. Carpenter:—

"'UNIVERSITY OF LONDON, BURLINGTON GARDENS, W.
"'*June* 15, 1871.

"'DEAR PROF. STOKES,—The information we have lately received as to the activity with which other nations are now entering upon the Physical and Biological Exploration of the Deep Sea, makes it appear to my colleagues and myself that the time is now come for bringing before our own Government the importance of initiating a more complete and systematic course of research than we have yet had the means of prosecuting.

"'The accompanying slip from last week's 'Nature' will make known to the Council what is going on elsewhere, and the feeling entertained on the subjects alike in the scientific world and (as I have good reason to believe) by the public generally.[1]

"'For adequately carrying out any extensive plan of research, it would be requisite that special provision should be made; and as the Estimates for next year will have to be framed before the end of the present year, no time ought now to be lost, if the matter is to be taken up at all.

"'In order that the various departments of Science to which these researches are related should be adequately represented,—so that any Application made to Government should be on the broadest basis possible, —I should suggest that the Council of the Royal Society, as the promoters of all that has been already done in the matter, should take the initiative; and should appoint a Committee to consider a Scheme, in conjunction with the President of the British Association, and the Presidents of the Chemical, Geographical, Geological, Linnean, and Zoological Societies. Such a Committee might meet before the Recess, and decide upon some general plan; and this would be then considered as to its details by the Members representing different departments

[1] *Nature*, vol. iv. p. 107, 1871. The paragraph states that the Governments of Germany, Sweden, and the United States were preparing to despatch ships to various parts of the ocean expressly fitted for deep-sea exploration.

of Scientific Enquiry, so that they might be able to report to the Council, and enable it to lay that Scheme (if approved) before the Government by the end of November.

"'Believe me, dear Prof. Stokes,

"'Yours faithfully,

"'WILLIAM B. CARPENTER.'

"'*Prof. Stokes.*'

"Resolved,—That the subject of Dr. Carpenter's Letter be taken into consideration at an early Meeting of the Council after the Recess.

"*October 26th*, 1871.

"In reference to the subject of Dr. Carpenter's Letter of the 15th June, read at the last Meeting of Council, the Secretary stated that he had received a subsequent Letter from him, dated Malta, 29th Sept., which was now read. In this Letter Dr. Carpenter urges the expediency of making arrangements for the proposed circumnavigating Expedition without delay, and communicates a correspondence with the First Lord of the Admiralty, from which it appears that H.M. Government will be prepared to give the requisite aid in furtherance of such an Expedition on receipt of a formal Application from the Royal Society; and in consequence of this information, Dr. Carpenter now suggests a modification in the composition of the Committee to which, in his former Letter, he had proposed that the matter should be referred.

"Resolved,—That a Committee be appointed to consider the plan of operations it would be advisable to follow in the proposed Expedition, the staff of scientific superintendents and assistants to be employed, and the different provisions and arrangements to be made, with an estimate of the probable expense, and to submit to the Council for approval a scheme which might be laid before H.M. Government, if the Council see fit, at as early a period as may be convenient. The Committee to consist of the President and Officers of the Royal Society, Dr. Carpenter, Dr. Frankland, Dr. Hooker, Professor Huxley, the Hydrographer of the Admiralty, Mr. Gwyn Jeffreys, Mr. Siemens, Sir William Thomson, Dr. Wyville Thomson, and Dr. Williamson, with power to add to their number.

"*November 30th*, 1871.

"The following Report of the Committee on the proposed voyage of circumnavigation was read:—

"'*Report of the Committee appointed at the Meeting of the Council held October 26th, to consider the Scheme of a Circumnavigation Expedition.*

"'The Committee having before them the correspondence which has already taken place between the First Lord of the Admiralty and Dr. Carpenter, are of opinion that it is advisable that the Council should make immediate Application to Her Majesty's Government for the means of carrying out the objects therein referred to; but that it would not be expedient that such Application should include more than a *general specification* of those objects,—which may be stated as follows:—

"'1. To investigate the *Physical Conditions* of the *Deep Sea*, in the great Ocean-basins,—the North and South Atlantic, the North and South Pacific, and the Southern Ocean (as far as the neighbourhood of the great ice-barrier); in regard to Depth, Temperature, Circulation, Specific Gravity, and Penetration of Light; the observations and experiments upon all these points being made at various ranges of depth from the surface to the bottom.

"'2. To determine the *Chemical Composition* of *Sea Water*, not merely at the surface and bottom, but at various intermediate depths; such determinations to include the Saline Constituents, the Gases, and the Organic Matter in *solution*, and the nature of any particles found in *suspension*.

"'3. To acertain the *Physical* and *Chemical* characters of the *Deposits* everywhere in progress on the Sea-bottom; and to trace, so far as may be possible, the sources of those deposits.

"'4. To examine the Distribution of *Organic Life* throughout the areas traversed, especially in the *deep* Ocean-bottoms and at different depths; with especial reference to the Physical and Chemical conditions already referred to, and to the connection of the present with the past condition of the Globe.

"'It is suggested that the Expedition should leave this country in the latter half of the year 1872; and as its perfect organization will require much time and labour, it is desirable that suitable preparations should be commenced forthwith.

"'For effectively carrying out the objects just specified, there will be required:—

"'1. A Ship of sufficient size to furnish ample accommodation and storage-room for sea-voyages of considerable length and for a probable absence of four years.

"'2. A Staff of Scientific Men, qualified to take charge of the several branches of investigation above enumerated.

"'3. An ample supply of all that will be required for the Collection of the objects of research; for the prosecution of Physical and Chemical investigations; and for the study and preservation of the various forms of Organic Life which will be obtained.

"'The Committee would propose that in making this Application to the Admiralty, the President and Council should offer their services in suggesting the Route which may appear to be most desirable for the Expedition to pursue; and also in framing Instructions for the Officers charged with the several branches of Scientific Research; with a view to facilitate the preparation by their Lordships of their general Instructions for the conduct of the Voyage to the Naval Officers commanding.

"'With this object they would propose that a Committee should be appointed by the Council, which should include persons thoroughly versed in the various branches of Science to be represented in the Expedition, who should give their advice and assistance previous to and during the progress of the Expedition.

"'The President and Council should also express their readiness to select and recommend to their Lordships persons qualified to be entrusted with the various branches of Scientific investigation to be represented, naming the Salaries which may appear to them commensurate with the duties to be fulfilled.

"'The President and Council should also, in the opinion of this Committee, recommend that in accordance with former precedents in regard to Expeditions of a similar character undertaken by this and other Governments, a full and complete publication of the results of the Voyage with adequate illustrations should form a part of the general plan; and that the work should be brought out as soon after the return of the Expedition as may be convenient.

"'It may be well to point out to the Admiralty, that the operations of the Expedition now proposed should not dispense with such researches of a less laborious character as their Lordships might be disposed to make from time to time from either the home or the foreign stations of the British Navy.'

"Resolved,—That this Report be received, and be taken into consideration at the next Meeting of Council.

"*December 7th*, 1871.

"The Report of the Committee on the subject of a Scientific Circumnavigation Voyage, received at the last Meeting, having been taken into consideration, it was

"Resolved,—That application be made to Her Majesty's Government, as recommended by the Committee, and that the following Draft of a Letter to be addressed by the Secretary to the Secretary of the Admiralty be approved:—

"'*To the Secretary of the Admiralty.*

"'THE ROYAL SOCIETY, BURLINGTON HOUSE,
"'*December 8th*, 1871.

"'SIR,—I am directed by the President and Council of the Royal Society to request that you will represent to the Lords Commissioners of the Admiralty that the experience of the recent scientific investigations of the deep sea, carried on in European waters by the Admiralty at the instance of the Royal Society (Reports of which will be found in their 'Proceedings' herewith enclosed), has led them to the conviction that advantages of great importance to Science and to Navigation would accrue from the extension of such investigations to the great oceanic regions of the Globe. The President and Council therefore venture to submit to their Lordships' favourable consideration a proposal for fitting out an Expedition commensurate to the objects in view; which objects are briefly as follows:—

"'(1) The Physical conditions of the deep sea throughout all the great Ocean-basins.

"'(2) The chemical constitution of the water at various depths from the surface to the bottom.

"'(3) The physical and chemical characters of the deposits.

"'(4) The distribution of organic life throughout the areas explored.

"'For effectively carrying out these researches there would, in the opinion of the President and Council, be required—

"'(1) A ship of sufficient size to afford accommodation and storage-room for sea-voyages of considerable length and for a probable absence of four years.

"'(2) A staff of scientific men qualified to take charge of the several branches of investigation.

"'(3) A supply of everything necessary for the collection of the objects of research, for the prosecution of the physical and chemical investigations, and for the study and preservation of the specimens of organic life.

"'The President and Council hope that, in the event of their recommendation being adopted, it may be possible for the Expedition to leave England some time in the year 1872; and they would suggest that as its organization will require much time and labour, no time should be lost in the commencement of preparations.

"'The President and Council desire to take this opportunity of expressing their readiness to render every assistance in their power to such an undertaking; to advise upon (1) the route which might be followed by the Expedition, (2) the scientific equipment, (3) the composition of the scientific staff, (4) the instructions for that staff; as well as upon any matter connected with the Expedition upon which their Lordships might desire their opinion.

"'The President and Council have abstained from any allusion to geographical discovery or hydrographical investigations, for which the proposed Expedition will doubtless afford abundant opportunity, because their Lordships will doubtless be better judges of what may be conveniently undertaken in these respects, without departing materially from the primary objects of the voyage; and they would only add their hope that in accordance with the precedents followed by this and other countries under somewhat similar circumstances, a full account of the voyage and its scientific results may be published under the auspices of the Government as soon after its return as convenient, the necessary expense being defrayed by a grant from the Treasury.

"'The President and Council desire, in conclusion, to express their willingness to assist in the preparation for such publication of the scientific results.

"'I remain, &c.'"[1]

It is unnecessary to describe the cruises of the United States ship "Tuscarora," of the German ship "Gazelle," or the yearly expeditions of the Norwegian Government in the North Atlantic, for these belong to the same period as that of the Challenger. Nor is it necessary to do more than refer to the still more recent cruises of the "Knight

[1] For continuation of this correspondence, see Appendix A. to Chapter I.

Errant" and "Triton," to the explorations of Alexander Agassiz in the U.S. Coast Survey steamer "Blake," to the work of the Italians in the ship "Washington," to the French expeditions in the "Travailleur" and "Talisman," or to the systematic researches of the United States Fish Commission.

The work done by all of these was of the same general character; they were in many respects supplementary, and, as a result, the science of abysmal research has been founded and carried on to a prosperous state of development. This science cannot, from its nature, advance slowly and gradually; it must proceed by strides, which will probably be as far apart in point of time as they are important with respect to discovery.