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TRANSACTIONS

AND

PROCEEDINGS

OF

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THE AUTHORS OF THE SEVERAL PAPERS ARE SOLELY RESPONSIBLE FOR THE SOUNDNESS OF THE OPINIONS GIVEN AND FOR THE ACCURACY OF THE STATEMENTS MADE THEREIN.

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Royal Society of Victoria.

1882.

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Royal Society of Victoria.

ANNIVERSARY ADDRESS

OF

The President,

MR. R. L. J. ELLERY, F.R.S., F.R.A.S., Government Astronomer.

(Delivered to the Members of the Royal Society of Victoria, at their Annual Conversazione, held 26th October, 1882.)

GENTLEMEN OF THE ROYAL SOCIETY,

Somewhat more than a year has elapsed since I had last the honour and pleasure of addressing you at a similar meeting. In March last our Society entered upon its twenty-fourth session, which, so far, has been a busy one, and our meetings have all been fully occupied with interesting and important contributions. The affairs of the Society generally are in a satisfactory condition. Our member-roll is steadily increasing, our relations with kindred societies abroad are expanding year by year, the publications of our transactions are almost up to date, and our financial position, although not by any means inflated, is, on the whole, satisfactory.

As we have from time to time expended considerable sums of money in building and improvements to our house, your Council deemed it desirable to obtain the grant of the land on which it stands from the Government; for you doubtless know the land has hitherto been only permanently reserved for Royal Society purposes, and vested in trustees. Application for the grant has been duly made to the Government, and I believe its issue has been approved, and only now awaits the usual formalities.

I am sorry to say that the Council has not yet been able to arrange for a series of lectures in each session on subjects of special scientific interest, as was in contemplation, but, nevertheless, I have reason to believe that the proposition will be carried into effect in our next session, if not earlier.

In addressing you on occasions similar to the present for many years past, I have usually brought under your notice the most noteworthy facts in connection with the year's history and progress of our several science or art departments, and of kindred societies in the colony. Not desiring to depart from this time-honoured custom, and at the same time not to weary you with a long address, I refrain from any detailed reference to the affairs of the Society, the most important of which I have no doubt are familiar to you all.

Our members will be pleased to know that kindred societies in Melbourne are all flourishing, and actively engaged in contributing to the general stock of knowledge in their particular directions. The Medical Society and the Melbourne branch of the British Medical Association, which extends its functions all over the British dominions, show by the results of their meetings and their transactions, that nothing tending to progress of skill and knowledge in the sciences of medicine or surgery is neglected or overlooked by their members. The Microscopical Society continues to fulfil its functions admirably under its able and veteran president, and has done immense good in spreading a sound knowledge of the use of the microscope, and in investigating the Australian forms of minute animal and vegetable life. The good influence of the Pharmaceutical Society and its administration of the Pharmacy Bill is beginning to be felt in our community already, and the efforts of the board and the society to secure a thorough and scientific training for all who are engaged in the sale and dispensing of medicines, drugs, &c., will, I am sure, be commended on all sides.

Looking generally to the progress in our midst of those branches of knowledge which come more immediately within the province of this Society, our members must have noted a growing desire in the community to become more familiar with the sciences and with the arts. New societies and schools have sprung up, and are flourishing, not only in Melbourne, but also in the country towns. The older societies are expanding, and the working classes are evincing a genuine and earnest desire to obtain the teachings of sciences as aids to their handicrafts.

At our last meeting I spoke of the establishment of a Field Naturalists' Club in Melbourne. This continues to thrive, and offers the means, not only of acquiring knowledge in the natural history of our colony, but also of most pleasurable recreation of those members who can join in the periodic excursions in search of specimens of the animal or vegetable kingdom.

A new society has lately been started in Ballarat, under the name of "The Ballarat Field Club Science Society," which already contains about eighty members. Although this society is founded for the purpose of investigation and discussion in the natural sciences, it at present confines its attention chiefly to geological and mineralogical subjects. Lectures are delivered, papers read and discussed, and, like our Melbourne Field Naturalists' Club, excursions are periodically made to elucidate special physiographical points or for the collection of specimens. I hear also of a Philological Society having been formed in Ballarat.

Affiliated to the Sandhurst School of Mines, a "Science Society" was established some two years ago, of which our talented fellow-member, Mr. P. H. MacGillivray, M.A., is president. This society is most effectually fostering study of the natural sciences in that part of the colony by essays, papers, and discussions at the monthly meetings.

I am sure we all join in wishing success and good progress to these young societies. At the same time I may venture to warn them, from my long experience of these matters, that it is only by earnest work and persistent effort on the part of the members that they will make any real progress. Our various training institutions furnish the elementary teaching and much of the most attractive and popular incentives to a little dive into the sciences, but these societies should constitute themselves the arenas for practically applying this teaching to the general advance of science in the community.

As regards our public scientific and technical institutions, I am able to report satisfactory progress. The Government botanist, our fellow-member, Baron von Mueller, has been busily engaged in elucidating the botany of Australia and adjacent regions, involving continuous and laborious work, for the most part literary. His valuable work on the eucalypts has advanced another stage, and 120 lithographic illustrations have now been completed. A considerable amount of further information and material from the interior regions of Australia will, however, be required before this great undertaking can be completed. The Baron is now engaged on another extensive work, a complete list of the "Vascular Plants of Australia," with literary, chronological, and geographical annotations, which it is expected will be completed by the end of the year. In this work there will be enumerated about 8800 species, and it is intended to devote a second volume to the "Evasculares," containing about 4000 species. The *Fragmenta Phytographiæ Australiæ* was brought to a close last year. Baron von Mueller's work on *Select Plants for Industrial Culture* has been published in German at Cassel, and I am informed arrangements are completed for publishing it in French in Paris.

Our museums are rapidly increasing, and yearly becoming more select and valuable; not only this, but for the last few years they have contributed very largely to museums, collections, and exhibitions in other parts of the world, examples and specimens of the natural productions of Australia. The National Museum at the University continues an object of great attraction. All the collections are in excellent preservation, due largely to the freedom from dust enjoyed by the site in which the building is situated. Specimens stuffed over twenty years still appear fresh and in good preservation. There have been some important additions during the year, among which may be noted specimens illustrating the geology of New Guinea and the adjacent islands, Bleeker's famous collection of fish from the Netherlands and India coasts, and a fine group of adult orangs to compare with the superb specimens of the gorilla formerly obtained.

I am glad also to say that from our Technological and Industrial Museum at the Public Library will be furnished a large suite of specimens to aid in replacing the valuable collection lost by our neighbours in the late Garden Palace fire at Sydney. The classes and lectures at the School of Technology continue to be well attended, and taking chemistry and metallurgy, engineering, mechanical drawing, and telegraphy, we find 142 students on the rolls. As a practical example of the value of this institution, and the soundness of the training given, I may mention that many of the advanced students have been enabled to take responsible positions in factories, mines, workshops, and public offices. Besides actual technical training, a great deal of valuable experimental work is carried on at this school. One interesting item I am able, from information given me by the director of the school (Mr. Newbery) to refer to. It has been found that the steel-wire rope used for the winding gear in mines in some instances passes from a tough and safe to a brittle and unsafe stage in a few weeks—a most serious matter, considering the number of lives at stake and the great cost of the ropes. Mr. Newbery now attributes this to a physical change taking place in the steel through the action of the acidulated saline waters of the mine. The prevention Mr. Newbery suggests is to cover the ropes with a good coating of some elastic waterproof material, such as a mixture of grease and tar. Brittle ropes can be toughened by annealing, but as I believe steel rope is made with hempen core to each strand, this would necessarily be destroyed in the process, and probably render the rope less fit for use. Mr. Newbery also states from results of experiments lately carried out that wood work in buildings, such as flooring, shelving, &c., can

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be rendered practically fireproof in a very economical way by treating it with a mixture of silicate and sulphate of soda in solution.

The Botanic Gardens, under the curatorship of Mr. Guilfoyle, become more and more attractive every year, not only as a pleasurable resort, but also as a field for botanical study, where by careful and scientific arrangement the botanical student is given access to the vegetation of almost every part of the world, and in many instances under circumstances like those which surround the plants in their native habitat.

In Ballarat and Sandhurst there have been established for many years "Schools of Mines," really technical colleges, where, by lectures and regular training, students are instructed in both scientific and technical subjects. Take, for instance, the School of Mines at Sandhurst, which has lately considerably extended its functions, and made most substantial progress under the direction of its registrar, Mr. Pitman. Mathematics, surveying, engineering, mechanics, drawing, freehand drawing, chemistry, and laboratory practice, are all well taught at this school, free lectures are given in chemistry, students are drawn from all classes, and as a rule take excellent positions at the examinations in nearly all the subjects. The School of Mines, Ballarat, the oldest institution of the kind in the colony, has fulfilled most important functions in its district for many years past. It embraces in its lecture courses and practical teaching, practical and theoretical chemistry, geology, mineralogy, metallurgy, mining and mining engineering, and has also a school of telegraphy, and annual examinations are held in all the subjects. The school generally is well attended and popular, and is a most efficient institution.

Our members will note with satisfaction that through the munificent offer of the Hon. Francis Ormond, the liberal contributions of the merchants and private individuals of Melbourne, and in no less a degree to the most commendable and earnest efforts of the working men themselves, the sum of £10,000 or over has been gathered for the erection and establishing a Working Men's College on a practical and liberal basis. Mr. Ormond offered £5000 if another £5000 could be collected. The working men collected over £3000 chiefly among themselves, and the rest has been contributed by donations from others who sympathise with the object, and the Government have granted a very eligible site near the Supreme Court, facing the north side of the Public Library. Plans are now being prepared, and before very long the Working Men's College will be an accomplished fact in Melbourne.

One of the most interesting items of the year in connection with our Observatory is the apparition of three new comets, the last of which is the most remarkable that has appeared since 1843. The first appeared in September last year, and was called "Schaéberle's Comet;" the next appeared here in June this year, and is known as "Wells' Comet;" the present one, which is of unusual interest, is not yet named. It appears to have been first seen in Australia on 6th September by Captain Baker, an amateur observer at Goldsbrough, who reported its appearance to me on the 8th. It was observed at all the Australian observatories on the 9th, and subsequently. At its first apparition it was of great brilliancy, but of no very great dimensions. It was already near the sun, and visible just before sunrise. It rapidly approached the sun, and increased in brilliancy so much that on the 17th September it was visible to the naked eye at noon within 3 degs. of the sun in a clear sky; it passed its perihelion passage on the morning of the 18th, and so close to the solar surface as to be within the region beyond which the great solar volcanoes of incandescent hydrogen are often seen to extend. The velocity of this body, as it rushed half around the sun at this time, must have been stupendous beyond conception, for, according to our most recent calculation, it must have made this journey in less than six hours. It increased in grandeur after perihelion, and for the last three weeks has been a magnificent spectacle in the morning sky. As it was thought not improbable that the comet of 1812 would again return to perihelion this year, and "searching ephemerides" had actually been prepared and distributed by some French astronomers (Paris Observatory), it was at first thought possible this might be that comet, but an approximate orbit computed by our vice-president, Mr. White, from some of the earliest observations of the present comet, made any futher supposition of this kind altogether untenable. The approximate elements exhibit a remarkable likeness to the great comets of 1843 and 1880. The motions of all three are retrograde, the inclination and longitude of the node very similar, and the perihelion distance of all exceedingly small and nearly like.

The apparitions of two large comets in 1880 and 1882, with elements so very much alike that of the grand comet of 1843, have of course led to some astronomical speculation on the subject. If any celestial bodies appear successively in similar or nearly similar orbits, a supposition that they are one and the same body, or several separate bodies in the same orbit, is quite reasonable. Mr. Tebbutt, our well known astronomer, of Windsor, N.S.W., has therefore suggested it as quite possible that the comets of 1843, 1880, and 1882 are identical, returning to perihelion at rapidly diminishing periods, and that if this be so, its present excursion must be very short, barely taking it out of our sight before it turns back again towards the sun. One incentive to this suggestion was no doubt the fact that the perihelion distance of the rough orbit first computed was less than that of 1880, while that of 1880 was less than that of 1843. More recent calculations, however, show that the perihelion distance of this comet was greater than at first computed, and rather greater than that of 1880. Whether we can possibly entertain this hypothesis will soon be shown by the recession or return of the comet. If it disappear for any considerable time, then we must conclude that there are two or more comets in the same orbit. Numerous critical examinations of the physical appearances of this body have been made both with the great reflector and the 8-in. refractor at the Observatory, and a remarkable character of nucleus has been observed. On the 4th it was first seen to be of a very long oval shape, central in the head, and its long axis parallel with the general length of the tail. On the 6th October it was observed to be inclined by several degrees (5 degs. at least) from this parallelism, and to have a very bright round and distinct planet-like spot in that part of the nucleus nearest the head of the comet. On the 10th this spot had moved nearer to the centre of the elongated oval nucleus. The closeness of the dawn and subsequently strong moonlight were much against spectroscopic observation of its light until the 8th October, when I made a careful examination of the nucleus and other parts of the comet. The spectrum I found to consist of a moderately bright continuous spectrum, crossed by three broad bright bands, the approximate wave lengths of whose centres were 5605, 5070, 4720, respectively. These bands were very bright in the nucleus itself, and could be well seen anywhere near the head of the comet, and traced faintly over a part of the tail for some distance from the head. In the spectrum of Wells' comet of 1881 several observers saw the well-known D line, due to sodium—as far as I know a unique instance in the case of cometic spectra. I examined carefully for any indication of this line in the present comet, but could discover no trace.

A series of observations for the determination of the solar parallax indirectly by Dr. Gallè's method has been made with the 8-in. refractor. These observations consist in very elaborate measures of differences of declination between the small planets Victoria and Sappho and certain selected fixed stars near them, taken each night between 18th July and 18th October. Similar observations have been arranged for in Europe, America, and at the Cape. A combination of the results will furnish means for computing the parallax of both these planetoids. The periodic times of these bodies being known with great exactitude, it follows by Kepler's third law that the solar parallax can thus be indirectly determined. The observations themselves have been carried out on a very elaborate and somewhat novel plan, suggested by Mr. Gill, the astronomer at the Cape. The period of observation terminated last Wednesday. So far as Melbourne is concerned the series has not been very successful, owing to the prevalence of the cloudy weather throughout the early part of the period. Nevertheless, I think a very valuable set of measures has been secured.

The preparations for the transit of Venus, on 6th December, have lately been occupying our attention, and it is now decided that we shall have observing stations at Melbourne, at Sale (in Gippsland), and in or near Hobart. The last phases of the phenomenon occur just after the sun rises in this part of the world; we shall therefore see nothing of the earlier or intermediate phases. In Melbourne the sun will only have risen about 13 degs. above the horizon before the transit is over, and in Hobart only about 15 degs. Nevertheless, the contacts at egress, the last critical phase, should be well seen at any part of Eastern Australia. As this is the last transit of Venus that will occur for more than 120 years, of course the event is looked forward to with considerable interest. The various national observing parties are already on their road to the several observing points, and I have had the pleasure of seeing several of our English observers here within the last fortnight. One British party goes to Brisbane, another to New Zealand, and there will be an American observing party also in New Zealand.

In conjunction with the transit of Venus operations we are arranging with some of the British observers for the determination of the difference of longitude between Greenwich and the Australian cities by telegraph. To do this, Lieutenant Darwin, a member of the Brisbane observing party, will, after the transit, proceed to Singapore; at the same time Australia sends an observer with transit instruments and chronometers to Port Darwin. These gentlemen, after setting up their transit instruments and obtaining correct local time, will commence exchanging a series of time signals between the two places, and thus determine the difference of longitude. The longitude of Singapore having already been determined telegraphically, that of Port Darwin will be found, and hence the longitude of Adelaide, Melbourne, Sydney, Brisbane, &c. A similar series of observations will be made in New Zealand by either the English or American party through the cable to Sydney. We shall, therefore, have the longitudes of all these places from Greenwich ascertained by the most correct and precise method available. The observer for Port Darwin is now training for the work at our Observatory.

Our chain of intercolonial meteorology is now almost complete. Western Australia, Tasmania, and Queensland have practically joined in the work, and our daily weather telegrams now cover the coast line of Australia from Geraldtown, north of Perth, in Western Australia, to nearly Cape York; a line across Australia, from Adelaide to Port Darwin; the north and south parts of Tasmania; and New Zealand generally. The consequence is we are slowly and gradually increasing our knowledge of Australian meteorology, and of the laws which govern the movement of storms along our coast lines, and the distribution of rainfall over the various climatic regions of the continent.

The last few years have forcibly demonstrated the importance of this latter meteorological factor to Australia, and more especially to the southern and central regions. A better knowledge of the laws of deposition of rain, should such exist, would be of incalculable value, as it would show more or less precisely our "assets and liabilities" in moisture. No amount of knowledge will alter the rainfall, but it will show us how far we have to "save up," how much of the water that does fall and now runs into the sea or soaks in the ground must be saved to meet urgent wants. Whether our natural supply will be found sufficient for the purposes of irrigation except to a very limited extent in certain districts, must, in view of recent discussions on the subject at our meetings, be considered very doubtful, as must also the question of the economics of irrigation in the colony, where the cost of labour is comparatively so high as in Australia generally. A mere glance at the rainfall tables for any month shows us that the greatest precipitation takes place at our highest altitudes; our great coast range is the gathering ground of rain-producing clouds, and it is the fall on the tops of our mountains and ranges that keeps our creeks and rivers running, by slowly delivering their stored-up water through numerous and often perennial springs. Wherever destruction of the forest has occurred on the ranges, these springs have all seriously diminished, and in very many instances ceased altogether, lessening the annual flow in the chief arteries of the country. Therefore the reckless denuding of our higher forests is absolutely robbing the country of water. Should this destruction continue, a seriously-diminished flow of our rivers, dry creeks, and scarcity of water over formerly well-watered districts will become inevitable.

Time will scarcely permit of referring to numerous subjects which mark the year's progress in science generally. There are, nevertheless, one or two matters which are of somewhat more than passing interest, which may justly claim our attention for a few moments. It has been estimated that about one-seventh of the human race die of tubercular disease, or consumption as it is called, and, further, that of the deaths in middle life fully one-third are caused by this fatal disease. This dreadful scourge has gone on, and still goes on unhindered, at least to any marked extent, by any human effort, backed up by all the advanced medical science of the day. By hygienic precautions and a more profound knowledge of the disease, there is little doubt that of late years it has been in some small degree more successfully opposed; nevertheless, those who know most of it cannot but acknowledge our comparative helplessness in the face of this enemy. But knowledge is strength. Consumption is now admitted on all hands to be contagious. For the last twenty years the contagiousness or infectiousness of this disease has been suspected, and various experiments have more or less satisfactorily demonstrated its high probability. Creighton, Burdon-Sanderson, Giboux, Martin, and more recently Klebs, Cohnheim, and others, advanced still another step in the same direction, but it has remained for Professor Koch, of Breslau, now chief of the Imperial Medical Department of Berlin, to demonstrate it as a germ disease, transmissible by inoculation, and that its contagiousness is due to a form of bacillus, one of those low orders of germs which appear to be at the bottom of many diseases to which the human, as well as other animals are prone. Now, assuming this to be the case, such knowledge gives great strength, for the modes of resisting contagion offer at once a prospect of, in some degree, stemming the onward course of this destroyer. And, again, if it should be further shown, as we may reasonably hope, that being a contagious germ disease, it is not a hereditary one, then we may cheerfully anticipate that science will find effective weapons to check the spread of this fatal disease.

Speaking of this brings to my memory a *brochure* published six years ago (1876) by Mr. Wm. Thomson, of South Yarra, entitled, *Histo-Chemistry and Pathogeny of Tubercle*, which I referred to in a former address. In this pamphlet he discusses at length the pathogeny of tubercle, and gives his reasons for concluding it to be a purely germ disease. On page 27 he says—"The idea of micrococci being in any way associated with the process of tuberculosis is a recent one; and the explanation of their mode of operation is, at least as far as I am aware, now for the first time in the history of pathology attempted, with what degree of success remains to be seen." What has now been demonstrated by Koch was undoubtedly indicated as of the highest probability in Thomson's pamphlet of 1876, and reiterated at greater length, and with fuller illustrations in another pamphlet in 1879, and afterwards by Cohnheim in his work on the *Contagiousness of Tubercle*, published in 1880, who says:—"We must look forward to the day when the '*tubercle corpuscule*' shall have been discovered in the form of a minute organism."

The immense strides made in the applications of electricity to lighting and other economic purposes during the past year is a subject worthy of note and for congratulation. Not so very long ago I stated that I believed the time when electricity would supersede gas for internal illumination was far distant. I must now recant—the time is here. Electricity has replaced gas in several interiors in Melbourne, and, so far as can yet be seen, with great success. At the Opera House it is pronounced by all a great success and decided improvement; it produces less *heat* and less *headache*. Several public places in Melbourne are lit by electricity, and many establishments are about to adopt it. It has been applied to the illumination of the extensive workings of the Ellenborough Mine at Sandhurst. The Harbour Trust Commissioners have adopted it with great success for carrying on their dredging operations at night, and the trustees of the Public Library have decided to light up the library and reading-room with the incandescent electric lamps. This last instance is one in which the new mode of lighting is peculiarly well adapted, inasmuch as the reading-room in the summer months gets intolerably heated with the gas, and the products of combustion slowly but surely destroy the bindings of the books. It is the small amount of heat developed, and above all the entire absence of the deleterious products of the combustion of gas, that constitutes its great recommendation. I doubt if electric light by the incandescent lamp method will be as cheap as gas; still the advantages referred to are, I think, worth a larger difference than will probably exist. The arc light, of course, is far the most economical, but it is only well adapted for out-of-door lighting or for very large interiors.

The future of electricity as an illuminant, a transferer of mechanical power, or as an agent in metallurgical operations can scarcely be foretold, but already it is shown to be economical and eminently effective in all these directions, and is now used both in England and Germany for depositing metals from their solutions and refining copper and other metals. Dr. Siemens, in his address to the British Association in August, stated that as a transmitter of power for farm work he can, "after two years' experience, speak with confidence of its economy and efficiency." Dr. Siemens also mentions an interesting fact concerning the influence of the electric light on vegetation. He had wheat, barley, and oats planted, some of which was submitted to the influence of the electric arc light of 4000 candles placed about 20 feet above the surface of the ground. No difference was observed till mild weather set in after the end of February, when those cereals over which the electric light shone developed so rapidly that by the "end of May they stood 4 feet high and in full bloom, while the others stood 2 feet high and showed no sign of the ear."

For all the advance of electric lighting, I still believe that "gas" will remain in the ascendant, not altogether as an illuminant, but certainly as a fuel. Already it is extensively used as fuel for steam engines in town, not only for safety and cleanliness, but also for economy; and as time goes on its use in this direction will, I feel sure, greatly increase; and it is devoutly to be desired that it should do so, for not the least good practical result from its universal adoption would be having only one, or at least a few, smoke-producing centres instead of a legion. Hygiene and æsthetics should both clamour for this. Gas, moreover, is fast asserting itself as a fuel for our cooking stoves and kitchens, and although there is still a lurking prejudice against gas-cooked food in some quarters, the exhaustive trials at the Glasgow Gas Fuel Exhibition show conclusively that a properly constructed and ventilated gas stove will cook food better and freer from foreign and undesirable products than nine-tenths of the coal-cooking ranges. As an economical, easily transmitted, and safe fuel, gas has, I think, its greatest future before it.

There is another point, however, which is worthy of note. It has been shown by Dr. Tyndall that coal gas burnt with intensified currents of air, heated by passing over metal surfaces kept at a high temperature by a special and separate burner, can be so increased in illuminating power as to rival the electric arc. Therefore, though gas and electricity are destined to be rivals, the rivalry will spur on to improvement and achievement redounding to the public advantage, and, as a consequence, the prosperity of the several companies.

In conclusion, I would refer to one scientific fact of the year, of great importance—namely, the "Arctic expeditions" which have been fitted out by the various European States for concerted and extensive investigations in terrestrial magnetism, auroras, polar meteorology, natural history, and cognate physical science near both poles. There will be eleven or twelve stations surrounding the North Polar regions, one as far north as Franklin Bay, in latitude about 84 degs. north. These expeditions will be fitted out by various European Governments. In the south the Germans establish a point at South Georgia Island, the French a station at Cape Horn, and the Italians a station in Patagonia, and so on. These, in connection with our fixed meteorological station in Melbourne, it is hoped will furnish a complete and effective chain of observation over the period arranged for the work—namely, from 1st September, 1882, to 1st September, 1883. It was at first hoped by the German Polar Commission that the Australian colonies would probably cooperate by forming observing stations more southerly than Melbourne, but as the intimation of the desirability of such a step reached here too late to take action with any prospect of a practical result, the idea has been abandoned, and the cooperation of the Melbourne Observatory only in this part of the Southern Hemisphere can now possibly be given.

TRANSACTIONS.

Art. I.—*The Phanerogamia of the Mitta Mitta Source Basin and their Habitats.*

By James Stirling.

[Read 20th April, 1882.]

In my recent paper on the topography of the Australian Alps, in outlining proposed physiographical researches in the Omeo district, I intimated my intention to submit a subsequent paper on the geological structure and botany of the Mitta Mitta Source Basin (there topographically described). I regret not having been able to complete observations on the geological structure of this area sufficient to enable me to correctly delineate it, but in the meantime submit the following description of the phanerogamia, or flowering plants, together with a collection of dried specimens representing the different orders most prevalent.

A glance at the map of Victoria will show that the Mitta Mitta Source Basin is bounded by watershed lines ascending to the highest peaks and plateau in the colony. It consequently embraces hypsometrical zones of vegetation, rising from the gigantic eucalypts, prolific amid the shaded slopes of our Victorian Cordillera, through dense masses of arboreous shrubs clothing the moist head of gullies at higher elevations, and again, through undulating uplands covered with patches of heath-like plants, dwarfed arboreous shrubs, and open pasture lands to the grassy moorlands of the highest snow-clad plateaux.

In submitting the following descriptions of native flowering plants, I desire to state that they do not include the whole of the phanerogamia of this portion of our Australian Alps, but simply represent a collection made by me, according as time and circumstances permitted during the past three years. I have also restricted my remarks to species verified by our eminent botanist, Baron von Müeller, to whose kindness, indeed, I am indebted for help in the matter of systematic classification. Among numerous questions of phytological importance, there is perhaps none more interesting than that which relates to the effects of defined geological formations on the growth of plants, and more especially on the evolution of varieties. In order to contribute my quota towards a solution of the question, which may be used for comparisonal purposes by those having a larger experience and more extensive phytochemical knowledge, I have given the geological formation upon which I have found each species to be most prolific. So far as my limited observations would warrant me in forming an opinion, I would suggest meteorological conditions as exercising a more dominating influence over the growth of plants, and in the evolution of varieties, than has hitherto, so far as I am aware, been recognised. Undoubtedly, those soils decomposed from the great rock formations richest in the alkaline salts, also carbonic acid and ammoniacal compounds (from which plants derive a great part of their nourishment), greatly affect the growth of species; but whether such chemical constituents evolve varieties is, I think, quite another question. How far the phenomena of insect cross fertilisation may be assumed as a factor I cannot venture an opinion; but it is extremely probable that insect life is subordinated to climatic influences, so that altitudinal differences and hygrometric conditions are really important factors to be considered in estimating the value of geological or entomological agencies.

However, whether meteorological conditions, geological formation, or entomological considerations are paramount, or whether each are modified by the other, there can be no doubt that the subject is one of great scientific interest, and can only be settled by patient collection, comparison, and analysis. In this paper I have limited my remarks to the dicotyledonous plants only, reserving the monocotyledonæ and the cryptogamia for a subsequent paper.

Taking the area as a whole, it may be said to consist of fine open pasture lands, the more dense arboreous vegetation being confined to the Dividing Range, and the shrubs to its shaded gullies and southern slopes of prominent spurs, and the heath-like plants to open, sunny northern slopes. Out of the included 670,000 acres within the Mitta Mitta Source Basin, fully 400,000 are admirably adapted for pastoral pursuits, and there is every reason to believe that the agricultural and horticultural products of European extra-tropical countries may be successfully and profitably cultivated amid our sub-Alpine elevations; in fact, the only barrier at present existing is that of transit to a market; a good road to the seaboard, distant about sixty miles, being a desideratum.

As settlement progressed in these regions, a number of herbaceous plants were introduced; these, however, I have not included in this list. The principal rock formations within the area under consideration consist of Silurian and altered Silurian—*i.e.*, metamorphic schists, gneiss, &c., including many varieties of quartz porphyry, granite porphyry, &c., basaltic table-lands, numerous igneous dykes intersecting and intruding upon the metamorphic schists; also patches of Middle Devonian sandstone and limestone, with deposits of tertiary gravels along the courses of streams—in fact, what my friend, Mr. A. W. Howitt, has described as the "great paleozoic rock foundations of North Gippsland," intruded upon by subsequent Plutonic masses. The following arrangement is that of Baron von Müeller:—

DICOTYLEDONÆ.

CHORIPETALEÆ-HYPOGYNÆ.

Natural Order—

1. Ranunculaceæ
2. Dillenaceæ
3. Magnoliaceæ
4. Monimieæ
5. Lauraceæ
6. Violaceæ
7. Pittosporeæ
8. Droseraceæ
9. Polygaleæ
10. Rutaceæ
11. Lineæ
12. Geraniaceæ
13. Sterculeaceæ
14. Urticaceæ
15. Casuarineæ
16. Sapindaceæ
17. Stackhousieæ
18. Caryophylleæ

C. PERIGYNÆ.

Natural Order—

19. Leguminoseæ
20. Rosaceæ
21. Onagreæ
22. Halorageæ
23. Myrtaceæ
24. Rhamnaceæ
25. Araliaceæ
26. Umbellifereæ.

SYNPETALEÆ PERIGYNÆ.

Natural Order—
27. Santalaceæ
28. Proteaceæ
29. Thymeleæ
30. Rubiaceæ
31. Compositæ
32. Campanulaceæ
33. Stylideæ, or Candolleaceæ
34. Goodeniaceæ

S. HYPOGYNÆ.

Natural Order—
35. Gentianeæ
36. Scrophularinæ
37. Asperfoleiæ
38. Labiatæ
39. Epacridaceæ
40. Ericaceæ

40 natural orders, embracing 174 species.

I.—CHORIPETALEÆ-HYPOGYNÆ.

No. 1—Ranunculaceæ ( ).

Genera—Clematis and Ranunculus.

1 C. Aristata (R. Br.).—Clothing the tops of the highest trees amid our shaded sub-Alpine slopes with a canopy of snow-white blossoms; in all soils; it is apparently restricted to 4800 feet above sea-level.

2. R. Lappaceus (D. C.), "common buttercup."—Abundant on metamorphic schists around Omeo; it ascends to Alpine heights; all soils.

3. R. Gunnianus (Hask.).—On sub-Alpine slopes and terraces; all soils, up to 5000 feet.

4. R. Millani (F. v. M.).—Along source runnels of Bogong High Plains. Basaltic formation.

5. R. Muelleri (Bent.).—At head of Bundara River, near Mount Cope; 6015 feet; metamorphic soils.

6. R. anemoneus (F. v. M.).—At heads of Big River, on Silurian and granitic soils. I have not seen any species below 6000 feet.

No. 2—Dillenaceæ ( ).

Genus—Hibbertia.

1. H. diffusa (R. Br.).—Lower undulating metamorphic ranges, near Omeo; not ascending above 4000 feet.

2. H. serpillifolia (R. Br.).—On the sub-Alpine slopes, exposed rocky ridges; Silurian and altered Silurian soils; up to 5000 feet.

No. 3—Magnoliaceæ ( ).

Genus—Drimys.

1. D. aromatica (R. et G. F.), "native pepper tree."—Forms amid the shaded slopes of the Dividing Range, on Silurian soils an arboreous shrub attaining a height of 12 feet; on the higher basaltic plateau (5000 feet) it becomes fruiticose, more gregarious, and has more aromatic and pungently acrid properties; it has been used for flavouring preserves with success at Omeo.

No. 4—Monimieæ ( ).

Genera—Hedycaryi and Atherosperma.

1. H. Cunninghami (Tul.).—On the Dividing Range, at the head of Livingstone Creek; on Silurian soil; 4000 feet.
2. A. moschata, "native sassafras" (Lab.).—Forms a dense shrub along the upper courses of the Gibbo River; Silurian formation 3800 feet; frequently attains a height of 40 feet, its bark is laxative, aromatic, and is used by the splitters for flavouring tea.

No. 5—Lauraceæ ( ).

Genus—Cassytha.

1. C. melantha (R. Br.), "native scrub vine."—Parasitic; on eastern watershed of Livingstone Creek; does not ascend above 5000 feet.

No. 6—Violaceæ (De Candolle).

Genera—Viola and Hymenanthera.

1. V. hederacea (Labill).—Common during early summer on the metamorphic schists around Omeo, up to 4000 feet.
2. V. betonicifolia (S. M.).—On open pasture lands, near Omeo; 3000 feet; metamorphic soils (principally micaceous schists).

1. H. Banksii (F. v. M.).—At head of Victoria River, near Mount Phipps (Dividing Range); altered Silurian formation; 3000 feet.

No. 7—PITTOSPOREÆ (R. Br.).

Genera—Pittosporum and Bursaria.

1. P. bicolor (Banks).—A charming species, with handsome glossy sap-green foliage; bi-valved fruit; shaded gullies; along Dividing Range; Silurian soils; 4000 feet; wood useful for ornamental purposes.
1. B. spinosa (Cav.).—Sparsely distributed within this area, being confined to open rocky spurs of argillaceous schist; at junction of Livingstone Creek and Mitta Mitta River; 1700 feet. At Tongio, in valley of Tambo River; 1500 feet; it is abundant in granitic soils; and at Bindi, Middle Devonian limestone formation in same valley, it attains a height of 20 feet, with trunk 10 inches in diameter. It does not appear to ascend anywhere in the Omeo district above 4000 feet. It is locally known as kangaroo thorn. Crude potash, crude tar, and acetic acid have been obtained from its wood, according to Mr. Guilfoyle curator of the Botanic Gardens. I have also found the charcoal extremely useful for blow-pipe work.

No. 8—DROSERACEÆ (Salisb.).

Genus—Drosera.

D. Arcturi (F. v. M.).—The only species I have met with of this interesting order is confined to the High Plains, near Mount Cope, 6015 feet, on Silurian soils and basaltic detritus; the glandular hairs margining the leaf render it easily distinguishable.

No. 9—POLYGALEÆ (A. & L. de J.).

Genera—Polygala and Comesperma.

1. P. sibirica (L.).—Sparsely distributed on the flats near Hinnomunjie, Mitta Mitta River; 1700 feet; metamorphic schists and alluvium.
1. C. retusum.—Widely distributed within the area; on all paleozoic and basaltic soils up to 5000 feet.

No. 10—RUTACEÆ (A. L. de Jussieu).

Genera—Correa, Zieria, Boronia, and Eriostemon (including Croweæ).

1. C. Lawrenciana ( ).—Forms, with Leptospermun and

Callistemon, the principal shrub vegetation fringing the margin of the Cobungra, Bundara, and Big Rivers; at elevations of from 3000 to 4000 feet; on metamorphic and basaltic soils. Its strong orange odour and fuchsia-like flowers render it easily recognisable.

1. Z. Smithie (And.).—On moist heads of gullies along the Dividing Range, at an elevation of 3000 to 4000 feet, it is most abundant. Its axillary panicles of white scented flowers and trifoliate lanceolar leaves at once distinguish it amid surrounding vegetation; on Silurian soils principally.

1. B. Algida (F.v.M.).—Abundant on the rocky ridges intersecting the Bogong High Plains; 5600 feet; on basaltic formation.
2. B. polygalifolia (Sm.).—Scrubby spurs of Dividing Range, at head of Livingstone Creek and Victoria River; altered Silurian soils. Its palmately compound leaves distinguish it; the small white and light pink flowers are scented. It ascends to 4000 feet.

1. E. Crowea Saligna (F. v. M.).—Abundant on Mount Sisters, near Omeo Plains; metamorphic granite formation. Altitude, 3600 feet.
2. E. myoporoides (D. C.); 3. E. umbellatus (Turc).—Both to be met with on Dividing Range, margining Omeo Plains; on quartz porphyry formation; 3000 to 4000 feet.

No. 11—LINEÆ (De Candolle).

Genus—Linum.

1. L. marginale ( ).—Abundant on all soils (paleozoic and igneous) during January; ascends to 5000 feet. It has a tenacious bark, useful for paper manufacture.

No. 12—GERANIACEÆ (A. L. de J.).

Genera—Geranium and Pelargonium.

1. G. dissectum (L.).—On Dividing Range, margining Omeo Plains; quartz porphyry formation, and near Omeo on metamorphic schist soils; between 2000 and 4000 feet.

1. P. Australe (Wild.).—East of Omeo Plains, near Mount Sisters; quartz porphyry and metamorphic granite formations; 3000 to 4000 feet.

No. 13—Sterculiaceæ (Vent.).

Genus—Lasiopetalum.

1. L. dasyphyllum (Sieb.).—On the outskirts of other shrubs; Dividing Range, at head of Livingstone Creek; 3600 feet; Silurian soils. Its flowers are peculiar, and hermaphrodite.

No. 14—Urticeæ (Ventenat).

Genus—Urtica.

1. U. incisa (Poir), "common nettle."—On cultivated ground around Omeo, and densely distributed through moist heads of gullies along Dividing Range; humid soils; up to 5000 feet.

No. 15—Casuarineæ (Mirbel).

Genus—Casuarina.

1. C. suberosa (Link).—Limited within the area to the lower undulating ranges margining Omeo Plains, on south side; mica schist formation; 3000 feet.
2. C. distyla (F. v. M.).—Forms dense scrub clothing steep ranges at Tongio (along valley of Tambo River); 1000 to 2000 feet; on granitic and argillaceous schist formation; rare in Mitta Mitta source basin.

No. 16—Sapindaceæ (A. L. de J.).

Genus—Dodonæa.

1. D. viscosa.—On Dividing Range, at head of Livingstone Creek and Wentworth River; Silurian formation; ascends to 4500 feet.

No. 17—Stackhousiaeæ (R. Br.).

Genus—Stackhousia.

1. S. linarifolia.—Abundant on metamorphic schists around Omeo; up to 4000 feet.

No. 18—Caryophylleæ (Scop.).

Genera—Stellaria, Colobanthus, and Scleranthus.

1. S. pungeus (Brogn.).—Is seen to advantage during the dry season, beginning of March, when the grasses are parched; around Omeo; 2300 feet; metamorphic schists.
1. C. subulatus ( ).—This moss-like plant is abundant on the basaltic plateaux of Bogong High Plains and on the lower shelves of altered Silurian rocks; from 4000 to 6000 feet.
1. Scleranthus biflorus (Hook).—Is abundant on the dry, sunny slopes of the eastern watershed of the Livingstone Creek; mica schist formation, it is frequently mistaken for tufts of moss, so similar is its appearance.

II.—CHORIPETALEÆ-PERIGYNÆ.

No. 19—Leguminoseæ (Haller).

Sub-order No 1—Papilionaceæ.

Genera—Oxylobium (And.), Mirbelia (Smith), Gompholobium (Smith), Daviesia (Smith), Pultenea (Smith), Dillwynia (Smith), Platylobium (Smith), Bossieæ (Vent.), Hovea (R. Br.) Goodia (Sals.), Lotus (Towns), Acacia (Towns).

1. O. procumbeus ( ).—At head of Livingstone Creek granitic soils and metamorphic schists; also High Plains; basaltic formation; 5000 feet.
1. M. Oxylobium( ).—Open, sunny, northern slopes of Mount Livingstone, near Omeo; gneissose schists; 3500 feet; blooms in January.
1. C. Heuglii (Bentham).—On Dividing Range, margining Omeo Plains; quartz porphyries; 3900 feet. It has large yellow flowers.
1. D. latifolia (R. Br.).—On Silurian soils along Dividing Range, particularly along the margin of Wentworth River; it forms dense scrub, attaining a height of 20 feet; altitude, 3900 feet.
2. D. ulicina (Sm.).—On heathy ranges near Omeo; 3000 feet; metamorphic schists; eastern watershed of Livingstone Creek ("native hop").
3. D. Buxifolia (Bent.).—On Dividing Range, at head of

Victoria River, and along Wentworth eastern watershed; on Silurian formation and quartz conglomerates; altitude, 3500 feet.

1. P. fasiculata (Bent.).—Restricted to the higher tablelands; basaltic and lower Silurian formations; 5000 feet. This is a charming rose-coloured species.

2. P. juniperina (Lat.)—A charming species, abundant at head of Livingstone Creek; orange-coloured flowers.

1. D. ericefolia (Sm.).—On coarse conglomerates, sandy soils; along Dividing Range, at heads of Livingstone Creek. This pretty species flourishes at elevations of 3000 to 4000 feet. It is more abundant on Wentworth River source basin.

1. P. obtusangulum.—Covering the shaded hill sides; up to 5000 feet; all over the area, particularly on the western watershed of the Livingstone Creek. On metamorphic schists this species is abundant.

1. B. riparia (A. C.).—On felsitic rock masses near Omeo this species is most abundant; altitude, 2500 feet. The young plants are edible; stock, especially horses, are fond of it.

2. B. bracteosa (F. v. M.).—Forming a dense underscrub on the higher plateaux; basaltic and Silurian formation; at 4500 feet; 3 to 5 feet high.

3. B. foliosa (Cunng.).—This is the most elegant of the papilionaceous shrubs to be met with in this district. Its spreading, flattened branches take almost the form of fern fronds. It is abundant on the sunny slopes of Mount Livingstone, 3000 feet, and on tertiary gravels *in situ*.

1. H. heterophylla (R. Br.).—Is met with along the banks of the Livingstone Creek; 2200 feet; mica schist formation. Its blue flowers distinguish it.

1. G. lotifolia (Salsb.).—The soft trifoliate leaves and racemes of golden yellow flowers render it easily known. It is sparsely distributed within the area at Tongio Gap, 4000 feet, on altered Silurian soils; south of Dividing Range, on Wentworth River, it is more gregarious and luxuriant.

1. L. corniculatus (L.).—On moist situations along the affluents of Livingstone Creek; up to 3000 feet.

2. L. Australis (And.).—In similar situations with L. corniculatus; ascending to 5000 feet; on metamorphic, Silurian, and basaltic soils; principally along moist margins of watercourses.

Sub-order No. 2—Mimoseæ.

Genus—Acacia.

1. A. myrtifolia (Willd).—Flourishes on the northern slopes of Mount Livingstone, in the neighbourhood of granite dykes; along western or southern watershed of Dry Gully; auriferous country; 3000 feet.
2. A. melanoxylon (R. Br.), locally called "lightwood."—Is dispersed among eucalyptus in eastern watershed of Livingstone Creek; ascends to 4000 feet; on metamorphic soils.
3. A. discolor (Willd).—On Dividing Range, at head of Livingstone Creek; 4000 feet; granitic soils; it is sparsely distributed. On Wentworth River it is more gregarious, forming dense underscrub on Silurian soils.
4. A. decurrens (Willd).—Is moderately abundant within the area along the upper flat courses of gullies; metamorphic soils; south of Dividing Range it is abundant.
5. A. pycantha, "golden wattle."—Only occasionally to be met with in the area, on Silurian soils; it is prolific on ranges south of Dividing Range; its gum is very transparent.
6. A. vomeriformis.—This peculiar shrub is abundant on the coarse sandy soils disintegrated from quartz conglomerate in upper courses of Wentworth River at elevations of 3000 feet. On Dry Gully watershed, near Omeo, it is also to be met with on gneissose schists. Another species, similar in appearance to A. vomeriformis, is also to be met with in same habitat.
7. A. silicuformis (A. C.).—Is abundant on the gravels along bed of Livingstone Creek; 2000 feet.
8. A. alpini (F. v. M.).—Is met with on all elevations above 3000 feet up to 5000 feet, principally on altered Silurian soils.
9. A. verticillata (Willd).—In similar habitats to A. vomerformis, particularly in Wentworth River watershed, at elevations of 3000 feet.

No. 20—Rosaceæ (A. L. de J.).

Genera—Rubus and Alchemilla.

1. R. parvifolius (L.), "native raspberry."—Is abundant on all river margins on rocky bluffs within the area.

1. A. vulgaris, "common lady's mantle."—Is met with on Paw Paw Plains, at head of the Victoria River; 4000 feet; basaltic soils.

No. 21—Onagreæ (Adanson).

Genus—Epilobium.

1. E. tetragonium (L.).—On moist, boggy situations along upper courses of Livingstone Creek; 3500 feet, and on higher plateaux up to 5000 feet.

No. 22—Salicarieæ (Adanson).

Genus—Lythrum.

1. Salicaria (L.).—Is found growing on the alluvium of principal streams, particularly south of Dividing Range, on Tambo and Dargo Rivers, at elevations of 1000 to 2000 feet.

No. 23—Halorageæ (R. Br.).

Genus—Haloragis.

1. H. tetragyna (R. Br.).—A small, herbaceous species; is abundant on the metamorphic schists around Omeo.

No. 24—Myrtaceæ (Adanson).

Genera—Bæckea, Leptospermum Kunzea, Callistemon, Eucalyptus.

1. B. gunniana (F. v. M.).—Is abundant on the basaltic tablelands along source runnels, at elevations of 5000 feet.
2. B. Diffusa (Lieb.).—Along upper courses of Benambra Creek, on boggy soils; Silurian formation; altitude, 3700 feet.

1. Leptospermem scoparium (Forst.).—Along margin of Livingstone Creek and Cobungra River; mica schist formation; altitude, 3000 feet.
2. L. lanigerum (Sm.).—In similar habitats to L. scoparium; metamorphic schists.

1. K. parvifolia (Scha.).—Mount Sisters, Dividing Range margin of Omeo Plains; metamorphic granite; on dry slopes.

1. C. salignus, var. Siebierii (D. C.).—On the Paw and Precipice Plains; 4000 feet; basaltic formation; more abundant along source runnels; intersecting the higher plateaux of Dargo High Plains, south of Dividing Range; 5000 feet.

EUCALYPTUS.

1. Genus E. amygdalina, "white gum," is the most prevalent species; distributed all over the area up to 5000 fect, where it gives place to C. alpini —our Alpine species, locally called snow gums.
2. E. obliqua "stringy bark."—Sparsely distributed on granitic and coarse argillaceous schist formation, on the northern sunny slopes of the lower ridges and along the crest of the main Dividing Range.
3. F. melliodora, "honey eucalypt, or box."—Is hardly represented north of the Dividing Range; along the valley of the Tambo it is the principal species, remarkable for its ash-grey foliage, the durability and hardness of its timber, and its excellent qualities as fuel. It flourishes in hard granitic and gneissic soils in this watershed.
4. E. globulus, "blue gum."—Attains a great height amid the moist southern slopes along the Dividing Range, although not abundant within the area. I have noted trees in the moist gullies, starting from the Tambo Gully, 320 feet high, with leaves lanceolar falcate, fully 2 feet long.
5. E. fissilis, "messmate," is moderately distributed along with
6. E. coriacea, on lower heathy spurs, near the Dividing Range.
7. E. viminalis, "manna gum," is confined to the flats along the Livingstone Creek.
8. E. stuartina, is common towards the Omeo Plains, while close to Omeo a rough-barked, black-stemmed, thick-foliaged species, known as "Black Sally," gives character to the landscape.
9. E. rostrata, "red gum," and 10, C. sideroxylun, "iron bark," are absent from this source basin, unless on the eastern affluents, at lower elevations, as along the Gibbo River.
11. E. pauciflora and 12, E. gunnii, are shrubby Alpine species, which Baron Müeller has been good enough

to inform me are found amid our Alpine regions, although I have not yet identified them; these are probably locally known as snow-gums, ascending to the edge of the highest plateaux at 6000 feet.

13. E. stellulata.—Also a sub-Alpine species. Abundant round Omeo Plains; 3000 feet.

No. 25—Rhamneæ.

Genera—Pomaderris and Cryptandra, including Spyridium and Colletia, including Discaria.

1. P. apetala (Labill).—Abundant in heads of gullies with other arboreous shrubs, on south of Dividing Range; all formations; ascends to 4000 feet; its straight stem is said to be used for hop poles in Gippsland.

2. P. phylicifolia (Lod.).—Along margin of Livingstone Creek, near Omeo; 2000 feet; metamorphic schists, sparsely distributed; shrubby.

1. C. omara (Sir S. Small).—At head of Livingstone Creek, on sandy soils; 3800 feet. More abundant on quartz conglomerate in Wentworth River watershed; 3000 feet.

1. S. parirfolium (F.v.M.).—Along margin of Livingstone Creek; on quartzitic schists, near Omeo; 2200 feet. I have not noted any higher than this.

1. D. Australis (Hook.).—Also found growing on metamorphic schists, particularly mica schist, near Omeo; 2000 to 3000 feet. This is a spiney species, easily distinguishable.

No. 26—Araliaceæ (Vent.).

Genus—Panax.

1. P. sambucifolias (Lieb.).—This handsome shrub, with its straight, unbranched stem, and tuft of dark, sap-green foliage, is found in shaded rocky sidelings along Livingstone Creek; 2200 feet. At higher elevations, along the Dividing Range, the leaves become thicker and more succulent; ascends to 4000 feet, principally on metamorphosed Silurian soils.

No. 27—UMBELLIFEREÆ (Morison).

Genera—Hydroctyle, Didiscus, and Trachymene.

1. H. laxiflora (Towns).—Is common on pasture lands around Omeo; metamorphic soils; 2000 to 3000 feet.
1. D. homilis (D. C.).—On the detritus of coarse gneissose soils along Victoria River, at altitude of 3500 feet.
1. T. billierdierii (F. v. M.).—On sandy soils at head of Livingstone Creek; 3700 feet; but more abundant on conglomerate detritus along the valley of Wentworth River; 3000 feet.

III.—SYNPETALEÆ-PERIGYNÆ.

No. 28—SANTALACEÆ (R. Br.).

Genera—Leptomoria, Omphacomeria, Exocarpus.

1. L. aphylla (R. Br.).—Common on the open northern slopes of Mount Livingstone; 3000 feet; the fruit is succulent and acrid.
2. O. acerba (A. de C.).—Confined to the Dividing Range, near Mount Sisters; quartz porphyry formation; at elevations of 3000 to 4000 feet.
1. E. cupressiformis (Labill), "cherry-tree."—Is sparsely distributed on undulating ranges near Omeo Plains; more abundant south of Dividing Range.
2. E. stricta (R. Br.).—Common all round Omeo, along eastern slopes of Livingstone Creek, up to 3800 feet; metamorphosed Silurian soils.
3. E. humifusa (R. Br.).—A prostrate bush, abundant at the higher elevations margining Bogong High Plains; granitic and Silurian formation; also on the basaltic plateaux, up to 6000 feet.
4. E. nana (Hook.).—Prostrate shrub, at head of Benambra Creek, and at Mt. Cobberas; 6015 feet, trap form.

No. 29—PROTEACEÆ (A. L. de J.).

Sub-order No. 1—NUMENTACEÆ.

1. Persoonia juniperina.—Is abundant along the valley of the Livingstone Creek, on mica schist formation; up to 4000 feet.

2. P. conteriflora (Bent.).—Similar habitats to P. juniperina.

Sub-order No. 2—TOLLICULARES.

1. Grevillea miquelania (F. v. M.).—On Dividing Range, near Mount Tambo; quartz porphyry formation; on rocky ridges; 3500 feet.
2. G. alpini (L.).—On undulating ranges (metamorphic soils), all round Omeo, and most abundant on south-eastern watershed of Victoria River; ascends to 4000 feet.
3. C. parviflora (R. Br.).—Along the courses of the Livingstone Creek and all eastern afluents of the Mitta Mitta; on altered Silurian soils; up to 4500 feet.

1. Hakea microcarpa (R. Br.).—On margin of Livingstone Creek; ascends to 3600 feet.
2. H. acicularis (R. Br.).—On the shelves of the higher plateaux; basaltic formation; especially on Dargo High Plains, near Mayford; 4800 feet.

1. Lomatia longifolia (R. Br.).—In shaded positions all over ranges near Omeo, both on metamorphic and Silurian soils; ascends to 4000 feet.
2. L. ilicifolia (R. Br.).—On shaded gullies and slopes along Dividing Range, principally on Silurian tracts; altitude, 2000 to 4000 feet.

1. Banksia marginata (Cav.).—Only sparsely distributed, amid junction of streams; a few at junction of Dry Gully and Livingstone Creek; more abundant at lower elevations on rocky ledges of gneissic schists.

No. 30—THYMELEÆ (A. L. de J.).

Genus—Pimelea.

1. P. glauca (R. Br.).—Is abundant all over the open ranges on eastern watershed of Livingstone Creek; blooms during February; metamorphic schists.
2. P. alpina (F.v. M.).—Is also abundant on elevations up to 6000 feet; principally on basaltic soils; Paw Paw and Precipice Plains.
3. P. curviflora ( ).—Similar habitats to P. glauca.
4. P. ligustrina (Lab.).—Is here confined to the lower

source runnels of the higher plateaux; 4000 to 6000 feet; basaltic formation. It is said to contain sudorific and alterative medicinal properties.

5. P. axiflora (F. v. M.).—Along shaded slopes, western watershed of Livingstone Creek. Its bark is said to produce a tenacious bast for paper manufacture.
6. P. pauciflora (R. Br.).—Sparsely distributed along with P. axiflora, but its bark produces a fine brown dye; more abundant along Dividing Range.

No. 31—Rubiaceæ (A. L. de J.).

Genera—Asperula, Galium, Coprosma.

1. Coprosma hirtella (Lab.).—Along western margin of Livingstone Creek, and on Dividing Range; ascends to 5000 feet; all soils.
2. C. microphylla (F. v. M.).—Confined to Dividing Range, Silurian soils, near Tongro Gap; 3600 to 4000 feet; its small leaves and berries distinguish it.
3. C. pumilla (Hook.)—Bogong Plains, at an elevation of 5000 feet, on basaltic formation.
1. Asperula oleaganta (T. H.).—This small herbaceous plant is abundant on the humid mica schists around Omeo, and ascends to 5000 feet.
1. Galium Australe (D. C.).—Also abundant in moist places near Omeo.

No. 32—Compositeæ (Vall.).

Genera—Aster, Vittadinea Erigeron, Brachycome, Gnaphalium, Leptorynchus, Helichrysum, Helipterum, Cassina, Cotula, Senecio.

1. Brachycome nivalis (F. v. M.).—During spring this species is abundant all over our sub-Alpine and Alpine elevations.
2. B. ciliaris (Lers.).—Is also abundant, particularly at the heads of the Cobungra and Bundara Rivers; Silurian and basaltic soils.
3. B. radicans (F. v. M.).—In damp situations along Livingstone Creek.

(*Aster* includes Olearia and Celmisia.)

1. A. argophylla ( ), "native musk."—Most abundant on Silurian tracts along Dividing Range, where it frequently forms dense scrubs; does not ascend higher than 5000 feet within this basin.
2. A. myrsinoides (A. Cun.).—At the lower elevations is a robust shrub; on the higher plateaux almost herbaceous and more gregarious.
3. A lepidophylla (Bent.).—Confined to Livingstone Creek near Omeo; 2000 feet; not forming dense underscrub as along the coast-line on sandy soils.

1. Vittadina Australis (A. Rich.).—Abundant on dry slopes of Livingstone Creek near Omeo; 2000 to 3000 feet; quartzitic and gneissose schists.

1. Erigeron pappochromus (Labil).—On the slopes of Mount Cope 6015 feet, and also Mount Hotham 6108 feet. This species when at its greatest luxuriance presents a faded appearance.

1. Gnaphalium alpigenum (F. v. M).—On slopes of Mount Cope this woolly-foliaged plant is abundant.

1. Leptorynchus squammatis (Tess.).—Everywhere abundant during early summer; on all elevations, among open pasture lands; ascends to 5000 feet.

Helichrysum ("everlastings").

14. H. lucidum (Henckel), syn. with H. bracteatum.—Represented by a narrow-leaved variety around Omeo, and by an Alpine variety at elevations of 5000 to 6000 feet, covering those highlands with fields of bright golden-yellow flowers, giving character to the landscape; basaltic formation.
2. H. apiculatum (D. C.).—More abundant on the open ridges near Omeo; up to 3000 feet; mica schists.
3. H. semipapposum (D. C.).—All open northern slopes near Omeo; ascends to 5000 feet; principally on metamorphic soils.
4. H. baccharoides (F. v. M.).—Restricted to the source runnels intersecting the higher plateaux; basaltic soils; covering acres with a dense undergrowth; altitude 5000 to 6300 feet.

1. Helipterum incarum (D. C.).—A variety auriceps; is common on metamorphic schists near Omeo, at elevations of 2000 to 3000 feet, while a white flowered species is restricted to the higher basaltic plateaux, between 5000 and 6000 feet, covering

portion of the open mossy flats with snowy mantle of beautiful blossoms, giving a distinctively Alpine aspect to the localities, and harmonising with the fields of golden Helichrysum lucidum.

2. H. anthemoides (D. C.).—Is more abundant at lower elevations, between 3000 and 6000 feet; on all open grassy flats and hill sides.

1. Cassina aculeata (R. Br.).—Forms an arboreous shrub along the Livingstone Creek near Omeo; 2000 feet; restricted to this habitat apparently—*i.e.*, within the area under consideration.

1. Cotula alpini, "native daisies."—Abundant on the Alpine slopes and terraces; all soils up to 6500 feet; not seen below 2000 feet within this area.

1. Senecio Australis (Wild.); 2. S. vagus (F. v. M.).—Both abundant along southern slopes of Dividing Range in moist gullies; on Silurian formation; sparsely distributed within the area at elevations of 3000 to 4000 feet.

3. S. pertinatus (Towns).—Is to be met with on the higher plateaux.

4. S. bedfordia (Towns), "native flannel plant."—This arboreous shrub is thickly distributed amid our sub-Alpine and Alpine slopes, particularly along the Dividing Range. The leaves have been used by packers and others for fodder for horses during the snowy season. After having been cut for a day, horses will eat them readily. It ascends to 5000 feet; on all soils.

No. 33—CAMPANULACEÆ (A. L. de J.).

Genus—Wahlenbergia.

Wahlenbergia gracilis (A. de C.).—This pretty species is everywhere abundant all over the area. The flowers are purplish blue on the higher plateaux, and the plant more dwarfed.

No. 34—CANDOLLACEÆ (F. v. M.).

Genus—Stylidium.

Stylidium graminifolium (Scharuy).—Equally abundant on the metamorphic schists near Omeo and the higher plateaux. Attains its greatest luxuriance at 4000 feet in basaltic soils.

No. 35—Goodeniaceæ (R. Br.).

1. Goodenia ovta (Sm.).—This species so common along the coast in Gippsland is here restricted to sub-Alpine heights of 3000 feet, on Silurian soils.
1. Velleia paradoxa (R. Br.).—Common both on the metamorphic schists around Omeo, and on the tablelands up to 6000 feet.

IV.—SYNPETALÆ-HYPOGYNÆ.

No. 36—Gentianeæ (   ).

Genera—Erythræa and Gentiana.

1. E. Australis (R. Br.).—Is abundant on ranges around Omeo, and ascends to the basaltic plateaux Bogong High Plains. Its pink flowers arranged in corymbrose panicles render it easily known.
1. G. Saxosa (   ).—More abundant on the higher Alpine slopes and terraces. It differs from Erythræa in not leaving the calyx divided at the base, and the anthers not becoming spirally twisted as they wither.

No. 37—Schropularinæ (Mistel).

Genera—Gratiola, Veronica, Euphrasia.

1. G. peruviana (L.).—This small succulent plant is found growing along the moist margins of the principal streams, up to 4000 feet, on alluvium principally. It posseses purgative properties.
1. V. gracilis (R. Br.).—On the open sunny slopes near Omeo this blue-flowered species is prevalent; principally on mica schist formation.
2. V. Derwentii (And.).—Abundant on all shaded situations, where moisture aids their growth; ascending to Alpine elevations of 5000 feet.
3. V. perfoliata (R. Br.).—Most abundant on Dividing Range between Mount Sisters and Mount Tambo east of Omeo Plains, particularly on quartz porphyry

formation, where it is found growing from crevices of the rock. Its sessille, opposite, cordate, smooth and entire margined leaves at once distinguish it.

4. V. serpilifolia (L.).—Is to be met with at higher elevations on the western affluence of the Mitta, near Mounts Cope and Wills; 5000 to 6000 feet.
1. E. speciosa (R. Br.).—During spring the fields around Omeo are covered with this pretty puce-flowered species. It ascends to 4000 feet on all soils.
2. E. scabra (R. Br.)—Alike abundant on all soils; between 3000 and 6000 feet. Its yellow flowers distinguish it.
3. E. Brownii (R. Br.).—Is most abundant at the highest elevations near Mount Fainter and Mount Bogong; 5000 to 6500 feet; all soils.

No. 38—Asperfoliæ ( ).

Genera—Mysotes and Cynoglossum.

1. M. sauvcolens (R. Br.).—Along the banks of the Livingstone Creek near Omeo, its scorpoid racemes of yellow flowers render it easily distinguishable. It is most prolific on the detritus of felsitic rocks.
1. C. sauvcolens (R. Br.).—On metamorphic soils along the lower valley of Livingstone Creek. The nuts of this species are muricated and depressed externally.

No. 38—Labiateæ (Adam.).

Genera—Mentha, Prostanthera, Azuga.

1. M. Australis (R. Br.), "native mint."—Distributed in moderate patches along the margins of the principal streams; all soils; up to 4000 feet.
1. P. lasianthos (Labill).—Is here confined to the Dividing Range at heads of gullies; on Silurian soils; principally at an elevation of 3800 feet.
2. P. phylicifolia (F. v. M.).—Along the margin of the Cobungra River on gneissose schists; 3500 feet.
3. P. rodundifolia (R. Br.).—On alluvial river flats between 2000 and 3000 feet within the area.

1. A. Australis (R. Br.).—This succulent, herbaceous species, is abundant all over the area on all soils up to 4000 feet. It becomes dwarfed and procumbent at the higher elevations.

No. 39—EPACRIDACEÆ (R. Br.).

Genus—Styphelia (Epacris).

(In arranging the species of this important order, I have adopted Baron von Müeller's generic system, as given in his recently published and valuable work on *Census of the Genera of Plants Hitherto Known as Indigenous to Australia,* 1881.)

1. Styphelia humifusa (Labill).—On metamorphic soils on the undulating ranges east of Omeo; 2200 feet; rather procumbent.
2. S. lanceolatus (R. Br.).—Dividing Range at head of Livingstone Creek on Silurian soils; 4000 feet, and at lower elevations.
3. S. virgatus (R. Br.).—Similar habitats to Lanceolatus; grows, also, on metamorphic soils near Omeo.
4. Styphelia serrulata.—Is equally abundant on the heathy ridges and the lower, more open, and rolling pasture hills; it gives relief to the parched appearance of the latter during the end of summer, giving a variegated verdant aspect to the browned surface. Its principal habitats are the watersheds of the Livingstone Creek and Victoria River, ascending to 4000 feet in all soils.
5. S. scoparia.—This bushy species is met with along the Dividing Range. Most abundant at elevations of 3000 to 4000 feet.
6. S. Frazeri (R. Br.).—On the lower rounded ranges near junction of Livingstone Creek and Mitta Mitta River; on argillaceous mica schists principally.
7. S. montana (R. Br.).—On Dividing Range at head of Livingstone Creek, at contact of granitic and Silurian rock masses.

1. E. impressa (Lab.).—This charming heath-like species with its varying tints of crimson, pink, and white, is here most prolific on sandy soils south of the Dividing Range; within the Mitta Mitta Source Basin it is but sparsely distributed.

E. microphylla (R. Br.).—Is abundant at the heads of the Livingstone Creek, granitic formation, and along the upper courses of Benambra Creek; at elevations of 3000 to 4000 feet; on alluvial flats, Silurian formation.

No. 40—Ericaceæ.

The order to which the true heaths belong is represented by the genus Gaultheria hispida, a stiff branching Alpine shrub, luxuriant amid the basaltic soils on the higher plateaux, blooming during December and January.

QUANTITY OF WATER CONSUMED IN IRRIGATION.

By W. W. CULCHETH, M. Inst. C.E.

Art. II.—*Quantity of Water Consumed in Irrigation.*

By W. W. Culcheth, M. Inst. C. E.

[Read 20th April, 1882.]

I.—Introductory Remarks.

1. In a country like Australia, where so little in the way of irrigation has been accomplished, the experience of other countries must be depended on. The author at first intended giving the results of his own experience and observations (extending over a period of more than twenty years) on irrigation generally in India, thinking the information would be useful to many at the present time; but the limits prescribed for this paper would not permit of much more than one branch of the subject—the quantity of water required for irrigation—being treated in sufficient detail to be really of any practical use.

2. The quantity of water required for irrigation is a most important point in connection with the probable success of any proposed scheme; nevertheless, opinions of engineers are much divided on the subject. Numerous experiments and measurements of water actually consumed have been made, often giving under various forms widely differing results. In many cases, however, the differences are more apparent than real, being in the conditions of the cases rather than in the results themselves. Shortly before leaving India, the author made several notes from the official report (the latest he has seen) on the irrigation of the North-western Provinces (India) for the year 1875-76. At the time, the author had not arrived at the conclusions about to be noticed, hence there will appear an incompleteness of information on certain points, which cannot at present be remedied. From these and other notes, some useful results may be deduced, which the author will endeavour to give in a convenient form for use in Australia.

3. It is sometimes assumed that because a given supply of water has been made to irrigate so many acres, or, expressed in the usual way, because a "duty" of so many acres per cubic foot per second of canal discharge has been

obtained in one locality, the same duty may be estimated for elsewhere, notwithstanding differences of climate, of soil, in the quantity of water available, in the length of canal the water has to traverse before reaching the fields, in the mode of using the water, in the crops grown, in the number of waterings they require, and in several other respects. The number of acres irrigated per cubic foot per second of discharge may be sufficient information to base calculations on when one country only is concerned, and there are certain points of resemblance in the schemes, though not always even then; but when the information is required for application in another country, and under wholly different conditions, it is too vague to be of much use. The following instances of the actual duty obtained on certain canals in various countries may be taken in illustration of this:—

Countries and Canals.	Acres irrigated per cubic foot per second of supply.		Authorities.
	Extremes.	Average.	
India { Eastern Jumna Canal..	184 to 291	216	Official Report* — Results of ten years, 1866 to 1876.
India { Ganges Canal	154 to 239	190	
Spain—Canals from River Turia	38 to 114	78	Major Scott Moncrieff, R.E.†
Italy { Canals in Lombardy ..	62 to 104	70	Col. Baird Smith, R.E.‡
Italy { ,, Piedmont ..	43 to 106	55	

Even in one canal there are differences; thus in one division of the Ganges Canal a duty of 97 acres only was obtained in 1875-76, while in another the duty was 290 acres; in the cold season only, one division gave 41 acres and another 204 acres (see par. 6).

4. The volume of any stream, which is to be turned wholly into a canal for irrigation, will be consumed as follows:—

(1) By loss at the head itself.

(2) By loss from escapes provided at convenient places to insure the safety of the works.

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* Irrigation Revenue Report of the North-western Provinces (India) for the year 1875-76, page 13, par. 23.

† Irrigation in Southern Europe (1868), page 168.

‡ Italian Irrigation (1855), Vol. I., pages 116 to 298.

(3) By loss from evaporation and percolation—
(*a*) In the canal itself.
(*b*) In the distributaries, called in Northern India *rájbahas*.
(*c*) In the village watercourses, called *gúls*.
(*d*) In the small field channels, for the supply of one field only at a time.
(*N.B.*—*c* and *d* might be noticed under one head, but a division is convenient for the purpose of this paper.)

(4) Lost by accidental breaches of banks and by carelessness of cultivators.

(5) Utilised in irrigating the fields.

5. The consumption under these several heads may be more fully explained as follows :—Head (1) represents the difference between the volume of water flowing down the stream and that entering the canal. Head (2) explains the difference between the supply entering the canal and that available for irrigation. The consumption under these two heads may be neglected in this paper, since the results adopted are based on the net supply of water available. The loss under (3) is an item of the greatest uncertainty; it is affected by the lengths of the several portions of the works along which the water has to travel, and by the nature of the soil. A village watercourse is here supposed to be one for the supply of a whole village or a large portion of a village, situated at a distance from a distributary; on the average such may be a mile in length, or, perhaps, a little more. The field channels—for the supply of one field only at a time—may be on the average, perhaps, 200 yards in length. Head (4) is an uncertain quantity; the best way of providing for the loss of water by breaching of banks is, perhaps, to consider it as part of the loss (under 3*b*, 3*c*) from the distributaries, &c., breached, and for the rest (waste by cultivators) to increase the allowance per acre irrigated. By this arrangement this item of loss need not be further considered separately. Head (5) represents the useful employment of the water; every effort should evidently be made to increase the proportion of water under this head by reducing that under the other heads. For practical purposes, the quantity of water consumed may be divided into two parts—(1) that usefully employed in the field, and (2) that lost in the canal and watercourses, large and small.

II.—Results Obtained in India.

6. In 1875-76 the Ganges canal had been in operation over twenty years, but irrigation was not considered to be fully developed. The " duty" obtained from the water, or the area irrigated per cubic foot per second, passing down four of the divisions of the canal (there were altogether seven divisions), and the average duty of the whole canal, in 1875-6 (an average year), were* :—

Divisions of the Ganges Canal.	During the monsoon.	During the cold season.	For the whole year. †	
	Acres.	Acres.	Acres.	
Northern ..	60	41	97	Least duty during the cold season.
Anupshahr ..	46	72	117	" " " monsoon.
Cawnpore ..	70	149	220	
Etawah ..	83	204	290	Highest duty each harvest.
Average for the whole canal	65	129	192	

There are two harvests in the year, each ordinary crop being on the ground and requiring water from three to five months. Sugar-cane and garden-produce are exceptional, belonging to both harvests. Cold season crops are chiefly wheat, barley, and other grains (except maize, which is a monsoon crop). Grasses and fodder are seldom irrigated to any great extent in India, particularly during the cold season.

7. It is not quite clear from the author's notes whether the duty of each division refers to the water entering the distributaries of the division, or whether it includes the loss in the canal as well. The author believes the former view is correct, as he is not aware that the canal discharge is gauged elsewhere than near the head and at escapes. Moreover, the duty for the year given in the official report, when comparing several years and the results of two canals together, is 187 acres‡; but when comparing the results obtained in the various divisions, and for the two seasons,

*Irrigation Revenue Report of the North-western Provinces (India) for the year 1875-76, page 9A, table IX.

†The duty for the year is not the sum of the areas for the two harvests, the yearly duty being separately calculated.

‡ Irrigation Revenue Report of the North-western Provinces (India) for the year 1875-76, page 13, par. 23.

separately, the duty is given at 192 acres.* The former would apparently include the loss in the canal, and the latter exclude it; though to avoid error the author has made calculations on each supposition (see App. B).

8. The small duty obtained in the two first divisions in the cold season is explained in the report to be due to the smallness of the area of cold weather crops irrigated, while the high duty in the Etawah division is said to be due to a large area having received only one watering late in the season. So far as the author's notes go, he fails to find any notice taken of the great difference of soil in the various divisions, though it is too important a factor to have been entirely overlooked. The author's notes are, doubtless, incomplete on this point. The low duty year after year in the upper part of the canal, where the soil is light and sandy, and the high duty also year after year in the lower parts of the canal, where much of the soil is heavy and clayey, coupled with other facts to be presently noticed, lead the author to look to the soil as the chief cause of this constant difference. But, in order to allow due weight to the difference in the watering of crops, the author proposes to take (instead of the extreme results shown above) the Anupshahr division as the type of a light soil, and the Cawnpore division as the type of a soil partly sand and partly clay. Fortunately, these are the two divisions with which the author is best acquainted.

9. Taking these two divisions as types of the two soils, and confining further attention to results obtained during the cold season only, since the crops then grown in India more nearly correspond with those grown in the southern portions, at least, of Australia, while the monsoon as a season has no counterpart here, the following figures are obtained :—

——	Area irrigated per cubic foot per second.	Quantity of water used per acre.	Depth of water over area irrigated.	——
	acres.	cubic feet.	feet.	
Light sandy soil ..	72	183,000	4·19	See Appendix D.
Mixed sand and clay soil	149	88,000	2·02	See Appendix D.
Average for the whole canal	129	102,000	2·34	See *a* and *q*, Appendix B.

* Irrigation Revenue Report of the North-western Provinces (India) for the year 1875-76, page 17, par. 38

The figures, as regards the soils, can only be considered as approximations. The average for the whole canal also does not represent the average consumption in fully irrigated fields, since some fields are said to have received only one watering.

10. Results obtained in two other cases may be here briefly noted, leaving till later (see pars. 25 to 27) remarks on their connection with this paper. In 1868-69, a year of great scarcity in the North-western Provinces of India, when the irrigation from the Ganges and Eastern Jumna canals was greater than in any previous year and for several years afterwards, the area irrigated by the Ganges canal, with an average supply of 4668 cubic feet of water per second during the cold season, was 794,794 acres, the duty obtained being 170 acres per cubic foot per second.* In the second case, the author found by measurements of discharge and irrigation from a reservoir in Rajputana during two years, that in five months of the cold season (November to March) an average of 65,000 cubic feet of water was consumed per acre (a depth of nearly 18 inches) in three waterings of about 6 inches each in depth. With a supply of 12 cubic feet per second, gauged at the tank sluices, running for ten hours, an average area of 20 acres was watered daily.

III.—Consumption of Water in the Fields.

11. The author, a few years ago, carefully measured the quantity of water actually used in irrigating cold weather crops from certain wells. It was found in one case that 29,579 cubic feet per acre (a depth of 8·15 inches) had been used, and in another 36,357 cubic feet per acre (a depth of 10·02 inches).† The soil was a light loam, of considerable depth, corresponding, perhaps, with the average land irrigated from the Ganges canal. But since well irrigation is more economical than that from canals, an increase must be made before applying these results to canal irrigation. The author is of opinion that, including the waste of cultivators, an increase of about one-third on the average of the above

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*Professional Papers on Indian Engineering, Vol. VII. (Roorkee, 1870), page 306.

† Professional Papers on Indian Engineering, Vol. II., new series (Roorkee, 1873), page 150.

two quantities would suffice, making the depth, say, 12 inches, and the quantity of water per acre about 44,000 cubic feet, given in four waterings, averaging 3 inches each in depth. This represents the consumption under heads 3*d*, 5, and a portion of 4 (see pars. 4 and 5), and is in the main supported by some results obtained a few years ago on the Bari Doab canal, in the Punjab.* Colonel Baird Smith, R.E., mentions that the result of several experiments made in Italy, in the irrigation of meadows, gave a depth of 3¼ inches for each watering; other experiments gave as much as 6 inches, but some of the water was available for other land at a lower level.† Major Scott Moncrieff, R.E., records that 2·36 inches (·06 metre) was found by experiment to be an ample depth for watering in Castile.‡ Many other instances could by given, more or less in support of the author's figures, and some showing higher results; but since it is seldom stated at what distances the fields were from the point of measurement, what was the nature of the soil, and other important particulars, it is fair to conclude that the higher results include considerable loss in the channels leading to the fields; this loss the author is endeavouring to arrive at separately.

12. In a light sandy soil more water would be consumed; but the author is decidedly of opinion that most of the increased consumption above shown to occur in certain divisions of the Ganges canal, is in the canal and distributaries, where they pass through light soil, rather than in the fields. If beds be similarly formed in two different soils, the extra consumption in the lighter soil is an increase of the quantity absorbed during the time each bed takes to fill.§ Thus, supposing a depth of 2 inches of water required in the bed, and that 1 inch is absorbed in average soil before this depth is attained, making 3 inches consumed; then the increase in a light sandy soil would be on the 1 inch, which might become, say, 2 inches, making the consumption in the light soil 4 inches. These figures represent, in the opinion of the author, the depths of the waterings respec-

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* Professional Papers on Indian Engineering, Vol. I., new series (Roorkee, 1872), page 368.

† Italian Irrigation (1855), Vol. II., pages 84, 85.

‡ Irrigation in Southern Europe (1868), page 105.

§ There are 400 or 500 beds to an acre in well irrigation, but fewer in canal irrigation. Evaporation may be neglected for the short time (some three to five minutes only) each of these takes to fill.

tively necessary in the two soils mentioned. In a similar way the author estimates the depth absorbed in a mixed sand and clay soil at half an inch, making the depth of each watering 2½ inches.

13. To make, however, every reasonable allowance for wasteful consumption on the Ganges canal, let a further increase be made to the above estimated depths of waterings. The average consumption per acre being 102,000 cubic feet (see *q*, Appendix B), suppose half be taken as having been used in the fields in four waterings; this would make the depth of each watering in average soil 3½ inches, or one-sixth more than above stated to be necessary; the extra half-inch may be considered as avoidable waste. For very light soil, a depth of 5 inches may be taken (one inch of which is avoidable waste), making the consumpton for the season 20 inches, or, say, 72,000 cubic feet per acre. For a mixed sand and clay soil a depth of 3 inches may be allowed for a watering, and 12 inches for the season, or say 44,000 cubic feet per acre. These quantities are at best approximations, but it is necessary to make some estimate of the kind before the results obtained in India can be put in a form applicable to any other country. The allowance for single waterings will, in the opinion of the author, be found generally applicable to other countries, under a system similar to that adopted in India, whereby water is flowing on to any plot of land for a short time only. Unless in very light soil, or in exceptional circumstances, a depth of 3 to 4 inches seems to be sufficient in European countries as well as in India.

14. The year 1875-76 has been taken as an average year; the duty of the water (either 192 acres or 187 acres—see par. 7) at least corresponds sufficiently with the average duty (190 acres—see par. 3) of the ten years 1866-76 to make it appear such. The quantities of water given in the last paragraph, based on the returns of that year, will, the author believes, be found ample to cover the average consumption in the fields. It must not be overlooked by any one wishing to verify the figures by further experiments that, besides the consumption in the fields, it includes only the loss in the small field-channels, or those for the supply of one field only at a time; loss in village water-courses, or such as are intended to supply several fields at one time, is not included. Probably it would seldom be convenient to gauge the discharge so as to include field-channels only. To allow, therefore, of results obtained in different places

being compared, the points suggested further on (see par. 32) should be noted in every case. And, further, when the field-channels are unusually long, it would be better to consider them separately.

IV.—Loss by Evaporation and Percolation.

15. The remainder of the consumption (averaging, in the case of the Ganges canal for the year 1875-76, 51,000 cubic feet per acre) represents loss by evaporation and percolation in the various channels from the point where the discharge was gauged to the point where the water was issued for individual fields. The total quantity lost daily over the various channels included on this occasion was 192 million cubic feet (see App. B), which will probably be found a near approximation to the loss each year on this canal. The author particularly wishes to urge that this loss, instead of being referred to as so much per cent. of the supply or so many cubic feet per second per mile, as usual hitherto, should be expressed by the depth spread over the whole wetted area of the bed and slopes of the various watercourses. In this form, results obtained on one canal could be applied, as the author will endeavour to show, to other canals, not only in the same country, but also to canals in other countries. The chief points for consideration are noted further on (see pars. 29 and 33).

16. The author has calculated that the loss daily by percolation from the Ganges canal and its distributaries in the cold season of 1875-76 was from $4\frac{1}{3}$ inches to $7\frac{1}{4}$ inches in depth over the whole wetted surface (see App. B). The lesser depth supposes the loss from the canal itself to be included in the 102,000 cubic feet of water consumed per acre; the greater depth supposes the measurements of discharge to have been made at the distributary heads, thus taking no account of the loss in the canal itself. The latter supposition appears to the author more likely to be correct than the former (see par. 7). Assuming, then, the greater depth as correct, and that the loss in the canal was equal in *depth* to that in the distributaries and minor watercourses, the total loss during the season would suffice to fill a trench having a width equal to that of the wetted perimeter and an average depth of over 90 feet, extending the whole length of canal and dis-

tributaries. Further calculations by the author, to ascertain the loss in various soils (see App. D), show that a depth of 1½ feet would probably be lost daily in very sandy soil; in which case the loss in one part of the canal (the Northern division) during this season would be sufficient to fill a trench nearly 170 feet in width by over 200 feet in depth, for the whole length of the division (about 50 miles). In the first fifteen miles or so, the loss might be double this, or even more (see App. D).

17. The quantity of water lost, when expressed in this form, may appear enormous; but further considerations will perhaps convince those acquainted with the facts to be presently noticed, that it is not more than there is good reason for believing actually takes place. The above quantity, large as it may appear, is, however, small compared with the average volume of water carried by the canal; and special measures to prevent the loss are not worth undertaking. The average loss in the Northern division of the canal was, in fact, only 15·58 cubic feet per second per lineal mile, out of a mean discharge in the season of 4447 cubic feet per second —about one-third (·35) per cent. only. In this form the loss appears insignificant. Where, however, the canal is smaller, and particularly in the distributaries, the proportion lost is much greater. In a small watercourse the loss in a mile may be one-fourth of the discharge at its head (see instance given in next paragraph); here the advantage of puddle in sandy soil is apparent.

18. A Ganges canal officer (Mr. Beresford) some time since gave instances of the loss of water in portions of his (the Anupshahr) division,* which the author, from his recollection of it, would consider not uncommon in that division. Mr. Beresford mentioned a loss of 1·25 cubic feet per second in the first mile of a distributary, having a discharge at the head of 50 cubic feet per second; allowing a wetted perimeter of 16 feet, the depth percolating in 24 hours would be 1·28 feet. In the case of a small watercourse having a head discharge of one cubic foot per second, the loss was ·03 cubic foot in a furlong (·24 cubic foot in a mile); with a wetted perimeter of 4 feet, the depth lost would be ·98 foot per diem; with 3 feet wetted perimeter, the loss would be 1·31 feet in depth. Mr. Login, who was some years ago in

*Professional Papers on Indian Engineering, Vol. V., new series (Roorkee, 1876), page 416.

charge of the Northern division of the canal, has recorded the results of some measurements of the volume of water passing down it in December, 1860, from which the author has calculated that the average daily loss in the first 15 miles was 2·66 feet in depth, and in 31 miles a little further down it was probably 1½ feet (see App. C).

19. The following are some results calculated by the author from data given by Colonel Baird Smith, R.E., for three canals in Italy :—*

	Total discharge per second.	Loss in whole length per second.	Length of canal.	Mean wetted perimeter, estimated by the author.	Average loss. Per mile of canal per second.	Average loss. Depth over wetted surface in 24 hours.
	c. ft.	c. ft.	miles.	feet.	c. ft.	feet.
Naviglio Grande ..	1851	158	31	100	5	·835
Canal Muzza ..	2652	477	35	150	13½	1·487
,, Martesana..	843	105	28	60	3¾	1·023

These results are merely approximations, as the data are incomplete; but even allowing a considerable margin for errors, the results support the views of the author regarding the excessive loss in certain soils. Some experiments made by the author some years ago, to ascertain what proportion of rainfall might be expected to flow off the ground, showed that about a quarter-inch per hour (6 inches a day) was absorbed. The soil was a light sandy one, in which, by the way, a very fair garden was formed, and the subsoil to a depth of 3 or 4 feet was very similar in appearance to the surface soil. More water would doubtless have been absorbed had a constant head been maintained; all that was done in the experiment was to prevent the ground drying up.

20. In the disposal of sewage there is a system called "intermittent downward filtration," in which sewage is poured in large quantities on land, with a view to its being purified in its passage through the soil. The land must be thoroughly underdrained. At Kendal, England, on one occasion, sewage was flowing on to the land "at the rate of 2,000,000 gallons per diem, equivalent to a depth of 19 inches. . . . The average quantity of sewage flowing out of the land was at least 1,000,000 gallons per diem, equivalent

*Italian Irrigation, Second Edition, Vol. I., pages 219-225, 250-254, and 270-276.

to a depth of 9½ inches over the filtration area. So that, after allowing for the 35 days in each year when the sewage was applied to other land, the enormous depth of 261 feet per annum was purified by the filtration areas, and had been so purified for the last three years."* Such an instance is perhaps exceptional for sewage filtration, but it shows what certain soil can do when the subsoil is thoroughly drained. In the filtration of water for the supply of towns, a very large quantity of water is passed through layers of sand and other material. In London, a depth of from 4½ feet to 18 feet is filtered in 24 hours. The filters are usually formed of 2 feet or 3 feet of sand over 3 feet to 5 feet of gravel and other porous material. This shows what sand, over a porous substratum, can carry off.

21. The canal officer before mentioned, Mr. Beresford, stated that he had seen water just reach an outlet or a field, and no more, and "there are places where a fairly large *kulába*" (outlet) "in a whole week only irrigates two or three fields."† The author recollects that some years ago, when one distributary in the Anupshahr (then called the Fatehgarh branch) division of the Ganges canal was first opened, and for months afterwards, a discharge of something like 80 cubic feet per second in the upper part, was with difficulty able to supply a fourth of this quantity 20 or 25 miles further down; all outlets between had to be closed in order to obtain enough water in the lower part of the distributary to irrigate from it. The author has known several small tanks, where the subsoil was non-retentive, to fill after a heavy fall of rain, and in a couple of days or so, a depth of 6 or 7 feet to soak away. The great facility for the percolation of water offered by very sandy soil, with a porous substratum, is shown by certain rivers in many parts of the world, which are lost in sandy plains—in some cases during the drier portions of the year only, in other cases all the year round. Instances are to be found in parts of Australia.

22. In nearly all these cases a portion of the loss was unquestionably due to evaporation. In canals, evaporation would take place not only from the surface of the water, but also from the moist part of the banks, where water is absorbed and rises above the water-line in the canal. This addition to

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*Proceedings of the Institution of Civil Engineers, Vol. XLVIII., page 207.

†Professional Papers on Indian Engineering, Vol. V., new series (Roorkee, 1876), page 416.

the loss may be unimportant in a large canal, but it may add very materially to the loss from a small watercourse, where it would in similar soil be as much as in the canal, and, consequently, bear a larger proportion to the water surface. Till more is known on the point, it will be convenient to take the wetted perimeter for both evaporation and percolation. The author is of opinion that a quarter-inch per diem may be taken as the average loss from a canal and its distributaries. This might be too much to allow from a large area of deep water, except, perhaps, on very hot, dry, and windy days but it is not too much to allow in hot and dry weather, when irrigation is most needed, as an average for streams, some a few feet deep, and others a few inches only. In a moist and cool climate, and in damp weather also, evaporation would generally be much less than a quarter-inch a day, but under such conditions, irrigation would scarcely be a necessity, unless for what would in India be monsoon crops, which are not considered in this paper, with the exception of rice. In Appendix A, less loss by evaporation has been allowed for rice cultivation, owing to the conditions attending it. Whether evaporation be estimated at a quarter-inch or a little more, since the loss from percolation has been shown to be very great, that by evaporation from water flowing in channels may generally be neglected, except in very clayey soils, where percolation is comparatively little.

23. The depth of water in the canal has not been taken into consideration in the foregoing remarks, because the author's observations on the loss of water from tanks has led him to the conclusion that where the variations of water level are regular, the loss is practically independent of the depth of water in the tank. Doubtless the comparatively great thickness of soil through which the water usually has to pass, is one reason why the effect of a varying depth of water in a tank on percolation is not perceptible. The author sees no reasons for supposing that percolation from any channel, in which water is constantly flowing, would be materially different from percolation from a tank. The author's contention is, that in any given case (tank or canal) the loss in depth would, under ordinary conditions, be practically the same, whatever the depth of water. If the depth of water is one factor, the thickness of soil through which percolation takes place is another factor.

24. The fact of water being often stored in open and unlined reservoirs, formed on the surface of the ground or in

slight excavation, might at first sight be taken as opposed to the foregoing deductions regarding the extent of percolation; but the conditions under which tanks can be successfully formed are essentially different from those pertaining to an ordinary canal. It will suffice here to remark that generally those conditions which are favourable to the construction of a tank restrict the escape of subsoil water, while those favourable to a canal facilitate its escape; and on the free escape or otherwise of the subsoil water, it depends whether percolation is much or little.

V.—Application of Results to other Countries than India.

25. Before showing how to apply the foregoing deductions to canals in other countries than India, it will be well to examine the two cases briefly noticed above (see par. 10) and their bearing on the conclusions drawn by the author. In the first instance, with a larger supply in the Ganges canal in the cold season of 1868-69 by 5 per cent. than that in the cold season of 1875-76, the area irrigated was 39 per cent. larger. It is clear that either there was less waste or the crops received less water in 1868-69—probably both. That the crops received less than the usual quantity of water in 1868-69 is evident from the remark by the Superintending Engineer (Colonel Brownlow, R.E.)—"I have no hesitation in saying that, but for the timely and providential fall of rain in the end of January, there would have been failure of crops, and consequent bitter distress over considerable areas."* There was an unusually large supply of water (6000 cubic feet per second in October, 1868) at the commencement of the season, allowing a larger area than in any previous year being watered; but when, in January, 1870, the supply fell to 4200 cubic feet per second, the canal could not have supplied the wants of the irrigators had not rain fallen. It is thus clear that the crops received less than their normal supply of water—probably an average of three waterings was given instead of four, the usual number.

26. Taking the number of days in the season for convenience of comparison, the same as in 1875-76 (there may

* Professional Papers on Indian Engineering, Vol. VII. (Roorkee, 1870), page 303.

have been more, but this will not be found materially to affect the result), and using the same symbols as in Appendix B, the following results are obtained :—

$$\left.\begin{array}{l} D = 4668 \text{ c. ft. per second} \\ A = 794{,}794 \text{ acres} \end{array}\right\} a = \frac{794{,}794}{4668} = 170 \text{ acres}$$

$$Q = 4668 \times 86{,}400 = 403 \text{ million c. ft.}$$

$$q = 152\ Q \div A = 77{,}132 \text{ c. ft. per acre.}$$

The area of wetted surface (M) over which the loss took place may have been less in 1868-69 than in 1875-76, since there was a less length (by nearly 300 miles) of distributaries in the former year; but probably the larger area irrigated necessitated more village watercourses being in operation, while many of these, doubtless, having been quickly and carelessly formed on an emergency, and used for the first time, the loss in them would be greater than in ordinary years. On the whole, then, perhaps it will be safe to estimate the loss (Q_a) as in both years the same, that is, 192 million cubic feet daily. Then $q_a = 152\ Q_a \div A = 36{,}740$ cubic feet per acre, leaving $q_c = 40{,}392$ cubic feet per acre, which would represent a depth of about 11 inches. Allowing $3\frac{1}{2}$ inches per watering (see par. 13), it would appear that a little over three waterings, on the average, were given, which is probably correct. Taking a greater number of days (than 152) for the season would increase the values of q and q_c; but, if irrigation went on for a longer period, it would be only fair to assume that more waterings would be given to some of the fields; this would increase the average number of waterings as well as the consumption of water per acre without altering the "duty." It is evident from Colonel Brownlow's remarks that fewer waterings were given at the ordinary time; the above calculation gives corresponding results, and so far supports the author's previous deductions.

27. In the second instance the result—65,000 cubic feet per acre (q)—may be distributed in the following manner: —D = 12 cubic feet per second = 432,000 cubic feet in 10 hours, the consumption daily. Mean distance of the fields from the tank was two miles; though as much as two miles of distributary and ten village watercourses, each say half a mile long, would be running at one time to irrigate 20 acres daily, on the average. Then the area over which loss has to be distributed was :—

			π	Sq. feet.	Total.
Distributary ...	2 ×	5280 ×	7 =	73,920	153,120 sq. ft.
Village channels	10 ×	2640 ×	3 =	79,200	

Then, taking for one trial a depth of 4 inches for a watering, and in another $4\frac{1}{2}$ inches (supposing half the land to be excessively sandy, as much of it was), the depth lost in channels would be 11 inches in the first case and $8\frac{1}{4}$ inches in the second, thus :—

——	First Supposition.		Second Supposition.	
	Depth.	Quantity.	Depth.	Quantity.
	inches.	cubic feet.	inches.	cubic feet.
Utilised in 20 acres	4	290,400	$4\frac{1}{2}$	326,700
Lost over 153,000 sq. ft. ..	11	141,600	$8\frac{1}{4}$	105,300
Total consumption	—	432,000	—	432,000

28. For the application of the foregoing results to Australia or to other countries than India, certain local information is necessary. First, in order to estimate the quantity of water required for actual irrigation (excluding loss by percolation) it is necessary to ascertain, besides the nature of the soil, what crops are to be irrigated, the number of waterings to be given to each, the intervals between the waterings and at what season water will be required. The author would then allow for each watering a depth of from 3 to 5 inches, according to the soil, as shown in Appendix A. If excess of water is to be used to save labour without any compensation in other ways, a larger supply would have to be allowed, according to the extra time the water would be flowing on any plot of ground (see column 7 of Appendix A). The result arrived at by multiplying the quantity consumed per acre each time by the number of waterings and by the area, will give the total quantity of water required for irrigation, including only loss in the field-channels up to a length, say, of 150 yards. More water might be used for the first watering of a crop (called in N. India *paleo*), but less would generally suffice afterwards, unless the ground were continually stirred up, or the upper crust repeatedly broken by hoeing. For the first few years the consumption of water might, and probably would, be in excess of this estimate, but good management should bring it down.

29. To estimate the loss by percolation from a canal and distributaries, the nature of the soil passed through

by the various channels, the approximate depth of soil and the nature of the subsoil, must be ascertained. Then, take the mean wetted perimeter of the canal and each distributary and multiply it by the respective length of each and by the number of days water would be flowing during the irrigating season. Allow a loss according to the scale given in Appendix A (cols. 2 and 3) over the whole wetted surface of bed and slopes of all channels.* If the soil or subsoil in which the canal is carried is an open or loose gravel or is much fissured and of considerable depth, a much larger loss than given by the scale may be expected; such places should be avoided if possible. In a narrow valley, or where an impervious substratum lies a little below the canal bed, or at a greater depth but rising on both sides so as to confine the subterranean current, or where the subsoil is less pervious than the surface soil, the loss would probably be less. Where, however, canals of any size are likely to be made, the country would be more or less open and the underground current practically unrestricted. After a few years the loss might be expected to decrease, owing to the pores of the subsoil becoming clogged.

VI.—Concluding Remarks.

30. The author has for several years watched carefully the working of various irrigation projects, and made inquiry into the causes of failure in certain cases. As a contribution to a subject on which but little is accurately known, loose generalisations being usually accepted, he thinks it right to make public the results of his observations, imperfect as they are; others can then make use of them or not as they please. Much difference of opinion may be expressed regarding the real value of the data accepted by the author, and the conclusions he has arrived at—(he will be glad to see these fully criticised), but he would urge on those having better knowledge of the subject, that the results of their observations should at the same time be given in a form suitable for the object of this paper—to serve as a guide for engineers in other countries than their own, epsecially in countries like Australia, where irrigation is in its infancy. Appendix A

* Where experiments on the absorbing power of the soil can be made in the manner described a little further on (see par. 33), it would perhaps be more satisfactory to base calculations of loss on the results so obtained.

should be considered as merely tentative—to be replaced by a better scale when fuller information is available.

31. However vague and imperfect the results given in this paper may be considered, it should not be forgotten that the same points have been hitherto not less vaguely dealt with (see par. 3), and that, moreover, irrigation is not singular in this respect. In many engineering calculations there is often very great latitude allowed in the shape of co-efficients, the value of which depends on the judgment of the one using them; as, for instance, in calculating discharges of an irregular channel, of a channel when partially obstructed and, generally, whenever the conditions are complicated, as in practice they often are. Many other points, especially in hydraulic engineering, might be mentioned, such as the proportion of rainfall flowing off the surface of the ground for the supply of a reservoir, the volume of sewage it is necessary to provide for in any case, and others which will readily occur to an engineer.

32. Further investigation being very desirable, or rather essentially necessary, a few remarks on the point may be useful. When measuring the quantity of water used in irrigation, in order that results obtained in different localities may be compared, the author would suggest that the following particulars be noted:—Volume of water supplied, length of channel from the point of gauging the discharge to the field, mean wetted perimeter of channel, whether the channel is old or newly formed, and whether puddled in any way or not, average size of the beds in the fields, or the approximate number per acre, how long one bed takes to fill, how many previous waterings have been given to the same crop, at what intervals and how long since the last, whether or not the watercourse has been used just before for another field or otherwise, if the field has been hoed or the surface of the ground disturbed since the last watering, height of the crop or the extent to which it shelters the ground, nature of the soil, state of the weather at and just before the time of watering, date of measurement, and such other information as the observer may deem likely to affect the result. For want of full particulars, results hitherto obtained in different places are often not comparable. If, moreover, the observer would endeavour to apportion the total consumption between the fields and the watercourses in each case, somewhat after the example given above (see par. 27), it is probable that correct information would be obtained

quickly, since errors would be detected at once, and unusual results would lead to further inquiry.

33. The author's experiments on absorption before alluded to (see par. 19) were conducted as follows:—Several beds, formed by little ridges of clay, and measuring inside 4·8 feet square, were kept supplied with water; five gallons were poured on at a time, each gallon over the area enclosed giving a depth of one-twelfth inch. The object was to ascertain how long it would take for the soil to absorb given quantities of water. A somewhat similar arrangement might be adopted to ascertain the absorbing powers of any soil; but a measurable depth of water should be maintained, say not less than one inch; in the author's experiments this was not done. It would be well to note the quantities poured on in given periods, in order that it might be seen when, the absorption having assumed its normal rate, the experiment might be discontinued. At first, absorption would be very rapid, but it would soon decrease. Evaporation during the day, especially in hot weather, would be found to affect the result. In these experiments the following points should be noted:—Nature of soil, nature and depth of subsoil, and the general formation of the substratum in the neighbourhood, with any other points affecting the escape or retention of subsoil water; a natural drainage channel or other depression in the ground close by would be likely to assist very materially the escape of subsoil water. The results of these observations would, as a rule, apply only to the case of a canal, and not to a site likely to be selected as suitable for a tank (see pars. 24 and 29).

33. In conclusion, the author will offer a few remarks on the importance of the results brought to notice in this paper with reference to contemplated irrigation works in Australia. A canal may of course be constructed, and water supplied for irrigation, notwithstanding very erroneous notions as to the quantity of water required for various crops, the area likely to be irrigated, and on other similar points; but as all such works partake more or less of a commercial nature—a fair return for the outlay being in some form or other expected—it is important that a trustworthy estimate should be formed, or disappointment is likely to result. It is very unpleasant to find, after constructing a long canal, that water will not reach the end of it, that the supply is sufficient for only one-half or one-third of the area it was hoped to irrigate, and that in consequence of

various mistakes, instead of a profit of 5 or 10 per cent, only ½ per cent. is realised, or, perhaps, the working expenses not even covered. These things have happened in India and elsewhere. It is not much consolation to be told that in 20 years' time the estimate may be fulfilled; and yet it is on results given by old canals, without proper correction, that estimates for new ones are often based, forgetting that usually it takes several years for irrigation to become fully developed.

APPENDIX A—*Empirical Scale for estimating the depths and quantities of water lost by percolation, and consumed in the irrigation of fields, in certain specified soils, where better information is not available.**

Class and nature of soil.	Loss by absorption or percolation daily.†		Loss by evaporation (see par. 22).	Consumption of water in the irrigation of fields.‡					Remarks.
				When flowing for a few minutes only into each separate division of field (see pars. 12 and 13).		Extra quantity per acre, when flowing for a considerable time, including evaporation.			
							For a continuous flow.		
	Depth (see par. 16).	Quantity per mile for each foot in width of wetted perimeter.		Depth of watering.	Quantity per acre each time.	For each hour *after* ground is saturated.	First 24 hours.	Each succeeding 24 hours.	
	Inches.	Cubic feet.		Inches.	Cubic feet.	Cubic feet.	Cubic feet.	Cubic feet.	
1—Pure sand. Nothing grows on it, except where a little soil may have collected on the surface, or just below it	36	15,840 or, say, 16,000	This may ordinarily be estimated at about ¼-inch, or, say, 100 c. ft. per mile for each foot in width, daily. The wetted perimeter of channels, as for percolation, should be taken. In rice irrigation the loss would probably be less than ¼-inch daily.	—	—	—	—	—	No cultivation possible unless other materials be mixed with it, when the soil would become that classed as 2.
2—Excessively sandy soil. Very poor; in its natural state, a long coarse grass or some sort of scrub may be found on it; when manured and cultivated, light crops may be produced. This is known as *bhoor* land in N. India	18	8,000		5	18,150	2,760	84,398	66,248	On these soils a continuous flow of water should be avoided, if possible, owing to great percolation.
3—Light sandy soil. No mixture of clay perceptible; when cultivated, fair crops may be grown	9	4,000		4	14,520	1,399	48,098	33,578	
4—Soils containing a mixture of sand and clay—									
a—Sand largely predominating, forming, with manure, a light loam, and producing very good crops	4½	2,000		3	10,890	719	28,132	17,242	
b—Sand and clay in about equal parts, forming, with manure, a rich loam—perhaps the best for general farming	2¼	1,000		3	10,890	378	19,965	9,075	These soils, with the next (5), crack when dry, allowing water to run to waste; hence extra allowance made for irrigation.
c—Clay largely predominating, forming under cultivation a heavy loam	1⅛	500		4	14,520	208	19,511	4,991	
5—Almost pure clay. Found in low, marshy localities, and unsuited, as a rule, for any culture but that of rice§	½	220		5	18,150	100	20,550	2,400	Loss by evaporation assumed to be less than for other crops (see par. 22).

* See par. 30 and App. D. † See pars. 29 and 33. ‡ See pars. 28 and 32.

§ After this ground has been flooded for rice, a depth of ·66 inch daily flowing on to it has been allowed to keep up the supply, giving a "duty" of 36 acres per cubic foot per second; Col. Baird Smith estimated that a depth of ·62 to ·68 inch was consumed. See *Italian Irrigation*, Vol. II., pages 101 and 106.

APPENDIX B.

Calculation of the Average Loss of Water by Percolation from the Ganges Canal during the Cold Season of 1875-76.

Let D = mean discharge flowing during the season (152 days) = 4447 c. ft. per second. This may have been gauged in the main canal, thus including loss in the canal itself (case A), or more probably (case B), the gauging may have taken place at the distributary heads, thus excluding loss in the canal (see par. 7).

A = area irrigated during the season = 571,907 acres.

a = „ „ per c. ft. per sec. of discharge = A ÷ D = 128·6 acres.

Q = average quantity of water consumed daily on the whole canal = 4447 × 86,400 = 384 million c. ft.

q = quantity consumed per acre = 152 Q ÷ A = 102,000 c. ft.

q_c = quantity used in the fields per acre (51,000 c. ft.—see par 13) = $q \div 2$.

q_a = quantity per acre lost before reaching the fields (51,000 c. ft. —see par. 15) = $q \div 2$.

Q_a = quantity lost daily on the canal, bearing the same proportion to Q that q_a does to q ∴ $Q_a = Q \div 2$ = 192 million c. ft.

Q_c = quantity used daily in the fields = $Q - Q_a$ = 192 million c. ft.

l = average length in miles of channels (large and small) traversed by the water from the point where it is gauged to the fields, after allowing for closures (*tátíls*) during the season.

π = wetted perimeter of various channels in feet.

M = miles of wetted surface of channels one foot in width = $l \times \pi$.

w = wetted surface in sq. feet = 5280 M.

d = depth in feet lost by percolation daily.

Then—

——	Total lengths in operation.	l	π	$M = l \times \pi$.	
				Case A.	Case B.
	miles.	miles.	feet.		
Canal	579	400	100	40,000	..
Distributaries ..	3386	2500	12	30,000	30,000
Village watercourses.	(See	below.)		30,000	30,000
Totals				100,000	60,000

The length of village watercourses has been assumed at 3 or 4 miles per mile of distributary, and π = 3 or 4 feet; then, area is about the same as that of distributaries. Field-channels (see 3*d*, par. 4) are not included.

From the foregoing the following average depths are obtained:—

——	Q_a	M.	Loss per M per diem = $Q_a \div$ M.	Depth lost per diem (d) = $Q_a \div$ 5280 M.
	mill. c. ft.		c ft.	feet. inches.
Case A	192	100,000	1921	·3638 = 4·366
Case B	192	60,000	3202	·6064 = 7·277

These are the average depths over the whole wetted surface in cases A and B respectively, lost by percolation (see par. 16).

APPENDIX C.

Calculation of the Loss of Water by Percolation in the first part of the Ganges Canal.

(*For Symbols, see Appendix B.*)

The volume of water (D) passing down the canal in December, 1860 (see "Pro. Inst. Civil Engineers," vol. 27, p. 509), was found to be —— at the head, Hardwar, 6710 c. ft. per second, and at Roorkee, 6283 c. ft. per second, giving a loss of 427 c. ft. per second in this length of about 18 miles. The loss really took place in 15 miles, or probably less, where beds of sand and boulders are crossed. The depth of water in the canal was from $8\frac{1}{4}$ ft. to 9 ft., making $\pi = 175$ ft. Then $w = 15 \times 5280 \times 175 = 13{\cdot}86$ mill. sq. ft., and $Q_a = 427 \times 86{,}400 = 37$ mill. c. ft. $\therefore d = Q_a \div w = 37 \div 13{\cdot}86 = 2{\cdot}66$ ft. At the Ratmu river it must have been much more—probably over 3 feet.

At the same time, 31 miles below Roorkee, D = 5279 c. ft. per second, showing a further loss of 1004 c. ft. per second. A portion of this was used for irrigation, though probably not more than 400, or, say, 500 c. ft. per second. The larger quantity would leave 500 c. ft. per second as the loss by percolation in the 31 miles, giving an average depth (d) of a little over $1\frac{1}{2}$ ft. daily; though, owing to the consumption for irrigation being uncertain, this result is open to question. Between the 30th and 40th miles, where a sandy tract of country is crossed, the depth would be in excess of the average, and doubtless fully $1\frac{1}{2}$ ft.

APPENDIX D.

Calculation of the Probable Depths of Water Lost by Percolation in Various Soils.

Taking the figures given in App. B, the average depth lost over the whole wetted surface of canal, distributaries and watercourses (case A) was ·3638 ft.—or, more probably, the canal not being included (case B), ·6064 ft.—over wetted surface of distributaries and watercourses only.

In light sandy soil the duty obtained from the water (see par. 9) was 72 acres, making the consumption per acre $= aq \div 72 = 183,000$ c. ft. Since the quantity used in the fields in sandy soil has been taken at 72,000 c. ft. per acre (see par. 13), that lost by percolation would be $183,000 - 72,000 = 111,000$ c. ft. per acre. It may be assumed that the depth percolating through a light sandy soil would bear the same ratio to the average depth lost in the canal as the loss per acre in the light soil (111,000 c. ft.) bears to the average loss per acre (51,000 c. ft.—see q_a, App. B). Then—

	c. ft.		c. ft.		
As	51,000	:	111,000	: :	·3638 ft. : ·792 ft.—case A.
					·6064 ft. : 1·320 ft.—case B.

Now, since the loss per acre in light soil is based on the results obtained in the Anupshahr division of the Ganges canal, in which sandy soil largely predominates, though there is also some clayey soil, it is fair to assume that, had the soil been entirely sandy, the loss would have been greater. Assuming case B as the correct one (see par. 7), it will probably not be thought too much, after reading the instances of loss mentioned in the paper (pars. 18 to 21) and in Appendix C, to take the loss, in what in App. A (class 2) is termed an excessively sandy soil, at $1\frac{1}{2}$ feet per diem. This result may be considered as of general application in India or elsewhere.

The loss in clayey soil is not so easily estimated. The Cawnpore division of the Ganges canal, as a type of a mixed sand and clay soil, shows a duty of 149 acres per c. ft. per second (see par. 9), making the consumption per acre $= aq \div 149 = 88,000$ c. ft. Calculating as above (in the case of a sandy soil), the depth would be ·523 ft. in case B; but, as far as present information goes, this is too vague to be of much use. The loss in pure clay is practically nil; but a slight admixture of clay reduces materially the percolation through a sandy soil. On the whole, perhaps, the empirical scale given in App. A is as near an approach to a correct estimate as is possible at present (see par. 30). It will at any rate be better than taking one depth for any mixture of sand and clay, irrespective of the proportions. If further inquiries are carried on as recommended in the paper (par. 33), more definite results may be obtained in time.

Art. III.—*Australian Mosses, enumerated by*

William Mitten, Esq.

[Contributed 20th April, 1882.]

Less than two years ago the great bryologist, Dr. Edward Hampe, then at the venerable age of eighty-five years, responded most kindly to a wish of mine, to place together systematically the names of all mosses of continental Australia, which had become known to him either from large material out of my own collections for nearly thirty years, or from any other bryologic sources accessible to him. Death soon subsequently closed the researches of this Nestor in botanic science, and the list above referred to was therefore his last contribution to that branch of knowledge, which he had leadingly advanced since more than half a century. Dr. Hampe's record having been published in the eleventh volume of the *Fragmenta Phytographicæ Australiæ*, along with enumerations of different Australian evascular Acotyledoneæ by other masterly specialists, I was eager to supplement the bryologic index also with those Tasmanian species, which are not known to occur in continental Australia, and also with any other mosses, which would be additional to those of Dr. Hampe's record. A request made for this purpose to the foremost of bryologists in Britain, William Mitten, Esq., who already twenty years ago had aided much in the elaboration of the mosses for Sir Joseph Hooker's *Flora Tasmaniæ*, met with a most ready response. Accordingly, he has now enumerated all the Australian species known to him, either from literary works or from collections accessible in Britain. Meanwhile, to close the eleventh volume of the *Fragmenta* in 1881, a supplement to Hampe's list, compiled by myself, had passed through the press; and it devolves therefore on me to see otherwise early publication given to Mr. Mitten's fuller writings, particularly as the manuscripts were placed by him unreservedly at my disposal. I beg therefore, to submit these pages to the Royal Society of Victoria, the mosses of our own colony being dealt with in these writings also, and some additional notes of localities given by myself. I may still add, that Mr. Mitten has evolved a special and very excellent system of bryology from his most extensive study of mosses, obtained from all parts of the globe, which systematic arrangement of his own he has applied already to a most ample descriptive elaboration of the moss-flora of South America.

FERD. VON MUELLER.

I. DICRANEÆ.

Bruchia, Schwaegrichen.—(Sporledera, Hampe).

B. exigua, Hook. & Wils. in Hook. icon. pl. rar. 737 A. (Phascum); C. Muell. in Bot. Zeit., 1847 (Bruchia); Krauseana, Hampe, C. Muell., Syn. I. 16.
Swan River, Drummond; St. Vincent Gulf, Dr. Behr.

B. minuta, Mitt. in J. Hook., Fl. Tasm. II., 165, t. 171.
Tasmania, Archer.

Pleuridium, Bridel.

P. gracilentum, Mitt. in J. Hook. Fl. Tasm. II., 164.
King George's Sound, Menzies; Tasmania, Archer.

P. curvulum, Tayl.; P. nervosum, Mitt. in Kew Journ. Bot. VIII., 257 (Phascum); pulchellum, Hook. and Wils. (Eccremidium).
Swan River, Drummond; Gippsland, F. v. Mueller.

P. tenuissimum, Tayl. in Lond. Journ. of Bot., 1846 (Bryum); arcuatum, Hook. and Wils. in Hook. icon. pl. rar. 738 A. (Eccremidium).
Swan River, Drummond.

P. tenellum, Mitt. in J. Hook. Fl. Tasm. II., 164.
Tasmania, Archer.

Ditrichium, Timm.—(Leptotrichum, Hampe).

D. Muelleri, Hampe in Linnæa, 1855, 206.
Grampians, F. v. M.

D. scabrifolium, Mitt.
Tasmania, Archer.

D. Oldfieldi, Mitt. in J. Hook. Fl. Tasm. II., 177 (Leptotrichum).
Tasmania, Oldfield.

D. laxifolium, J. Hook. & Wils. in Fl. Tasm. II., 177; D. flexifolium, Mitt. in Kew Journ. Bot. VIII., 257.
Victoria, F. v. M.; Tasmania, J. Hooker, Oldfield.

D. australe, Mitt. in J. Hook. Fl. Tasm. II., 177.
Tasmania, Archer.

D. affine, C. Muell.
Victoria, F. v. M.

D. cylindrocarpum, C. Muell. in Bot. Zeit., 1851, 351.
Tasmania, Mossman.

D. elongatum, J. Hook. & Wils. in Fl. Tasm. II., 176.
Tasmania, Fraser, J. Hooker, Archer.

Dicranella, C. Mueller.

D. rufo-aurea, Hampe in Linnæa, 1859, 60 (Angstrœmia).
Australian Alps, F. v. M.

D. Dietrichiæ, C. Muell. in Linnæa XXXV., 617.
Queensland, A. Dietrich.

D. trichodontoidea, C. Muell. in Revue Bryol., 1876, 3.
Near Sydney, Kayser.

D. tricruris, C. Muell. (Angstrœmia, Diobelon) in Linnæa XXXV., 616.

Anisothecium, Mitten.

A. ferrugineum, Mitt. in J. Hook. Fl. Tasm. II., 171 (Leptotrichum); brachycarpum, Hampe in Linnæa, 1872.
Blue Mountains, Rev. Dr. Woolls; Tasmania, Archer.

Trematodon, Cl. Richard.

T. longescens, C. Mueller in Rev. Bryol., 1876, 3.
Near Sydney, Kayser.

T. flexipes, Mitt. in J. Hook. Fl. Tasm. II., 173, t. 172.
Tasmania, Archer.

Rhabdoweisia, Bruch & Schimper.

R. cyathocarpa, Mont. (Zygodon).
Tasmania, Archer, Oldfield.

Leptodontium, Hampe.

L. papillatum, J. Hook. & Wils. in Fl. N. Zeal., t. 85; Leskea rubicaulis, Tayl.; Zygodon Preissianus, Hampe in Linnæa, 1860, 633.
West. Austr., Preiss; Victoria, Adamson; Tasmania, J. Hooker, Archer, Oldfield.

Blindia, Bruch & Schimper.

B. robusta, Hampe in Linnæa, 1860, 627; F. v. M., Austr. Mosses, pl. VII.
Australian Alps, F. v. M.

B. arcuata, Mitten.
Tasmania, Archer.

Holomitrium, Bridel.

H. Dietrichiæ, C. Muell. in Linnæa, 1871, 147.
Brisbane River, Dietrich; Severn River, Hartmann.

H. Muelleri, Hampe & C. Muell. in Linnæa, 1870, 513.
Victoria, F. v. M.

H. perichætiale, Brid. Bryol. univ. I, 227.
Sealers' Cove, F. v. M.; Tasmania, Gunn.

H. Novæ Valesiæ, C. Muell. in Rev. Bryol., 1876, 3.
Near Sydney, Kayser.

Mesotus, Mitten.

M. acutus, Mitten, M. alato similis, sed foliis densius areolatis margine magis serrulatis distinguendus.
Australia, inter Sphærophoron, from Borrer's Collect.

Dicranum, Hedwig.

1. * Isocarpus.

D. microcarpum, J. Hook. & Wils. in Fl. Tasm. II., 166; D. cirrhatum (Holomitrium), Mitt. in Kew Journ. of Bot. VIII., 257.
Tasmania, Archer.

2. ** Hemicampylus.

D. Menziesii, Taylor; D. brachypelma, C. Mueller.
Tarwin, Grampians, F. v. M.

D. chlorocladum, C. Muell. in Rev. Bryol., 1876, 3.
Near Sydney, Kayser.

D. subviride, C. Muell. in Linnæa, 1872, 515.
Near Sydney, Sieber.

D. dicarpum, Hornschuch; D. leucolomoides, C. Mueller in Bot. Zeit., 1851, 54.
Near Sydney, Sieber; Maitland, Vicary; Gippsland, F. v. M.; Brisbane-River, Bailey; Tasmania, Archer.

D. polychaetum, Hampe in Linnæa, 1859 p. 60.
Yarra and Grampians, F. v. M.

D. suberectum, Hampe in Linnæa, 1860, 629.
Tarwin, F. v. M.
D. Walteri, Hampe.
Victoria, C. Walter.
D. angustinervis, Mitten.
Victoria, F. v. M.; Tasmania, Archer.
D. diaphanoneuron, Hampe & C. Muell. in Linnæa, 1870, 515.
Stirling's Range, F. v. M.
D. Billardieri, Schwaegrichen suppl. II, 70, t. 121.
Victoria, F. v. M.; Tasmania, Gunn.
D. pungens, J. Hook. & Wils. in Flora Antarct., 17, t. 59; subpungens, Hampe in Linnæa, 1860, 629.
Grampians, F. v. M.; Tasmania, Archer.
D. punctulatum, Hampe in Linnæa, 1860, 628.
Australian Alps, F. v. M.

3. *** Eudicranum.

D. austrinum, Mitten; D. Sphagni varietas, J. Hook., Fl. Tasm. II., 171.
King George's Sound, Cunningham; interior of sub-tropical Australia, Sir Thomas Mitchell; Tasmania.
D. argutum, Hampe in Linnæa, 1870, 516.
New South Wales, Hooker's Collection.

Eucamptodon, Montagne.

E. Muelleri, Hampe & C. Muell. in Linnæa XXXVI., 513.
Victoria, F. v. M.

Dicnemon, Bridel.

D. rugosum, Hooker (Leucodon).
Australia, Dickson.
D. calycinum, Hooker (Leucodon).
Australia, Dickson.
D. enerve, C. Mueller in Revue Bryol., 1876, 3.
Near Sydney, Kayser.

Ceratodon, Bridel.

C. purpureus, Bridel; convolutus, Reichardt.
Snowy River, Tarwin, Gippsland, F. v. M.; King George's Sound, Cunningham; Ash Island, Hunter River and Newcastle, Mrs. Forde.

C. stenocarpus, Montagne.
Tasmania, Oldfield.

Tridontium, J. Hooker.

T. Tasmanicum, J. Hook. in Hook. Icon. Plant. rar. 248.
Tasmania, Gunn.

Pœcilophyllum, Mitten.

P. Leichhardti, Hampe & C. Muell. (Leucoloma) in Linnæa, 1870, 514.
New South Wales, Leichhardt; Victoria, F. v. M.; Brisbane River, Bailey.

Sclerodontium, Schwægrichen.—(Dicnemonella, Hampe and C. Mueller).

S. pallidum, Hook., Musci exot., 172 (Leucodon); Dicranum Sieberianum, Schw.
Victoria, F. v. M.; Port Jackson, Gaudichaud; Tasmania, Gunn.

S. Fraseri, Mitten, S. pallido simillimum, sed foliis nervo lato crassiore, cellulis lævioribus, limbo marginis nullo.
New South Wales, Fraser; Parramatta, Woolls.

Campylopus, Bridel.

C. introflexus, Hedw. (Dicranum); leptocephalum, C. Muell. in Linnæa, 1855, 206 (Dicranum).
Sealers' Cove, Gippsland; Goulbourne Ranges and Mt. Gambier, F. v. M.; King George's Sound, Cunningham; near Port Jackson, Sieber; Maitland, Vicary; Ash Island, Hunter River, Mrs. Forde.

C. pudicus, Hornschuch.
Near Port Jackson, Sieber.

C. bicolor, Hornschuch.
King George's Sound, Cunningham; Swan River, Drummond; Tasmania, Gunn.

C. clavatus, R. Brown in Schwgr. Suppl., 255.
Tasmania, R. Brown, Oldfield; near Sydney, Jupp.

C. appressifolius, Mitt. in J. Hook. Handb. Fl. N. Zeal., 414.
New South Wales, Cunningham.

C. torquatus, Mitt. in J. Hook. Fl. Tasm. II., 173; flexuosus, Hampe in Linnæa, 1855, 206; pallidus, J. Hook. & Wils. in Fl. N. Zeal. II., 68, t. 84.

Tarwin, Victoria, F. v. M.; Richmond River, Camara; Tasmania, Archer; Bellenden Ker Range, Karsten.

C. nudus, Hampe in Linnæa, 1860, 630.
Tarwin, F. v. M.

C. capillatus, J. Hook. & Wils. in Fl. Tasm. II., 172.
Tasmania, Oldfield, Stuart.

C. insidiosus, J. Hook. & Wils. in Fl. Tasm. II., 172.
Tasmania, Oldfield, Stuart.

C. densifolius, Angstr., Oefvers, 1872, 4, 18.
Wollongong, Professor Andersson.

C. Australiensis, Duby in Mem. de la Soc. de Phys. et d'Hist. Nat. de Genève, 1869.
Locality unrecorded.

C. Erythropoma, Duby in Mem. Soc. Phys. Hist. Nat., 1869.
Victoria, F. v. M.

C. subtorquatus, C. Muell. in Rev. Bryol., 1876, 3.
Sydney, Kayser.

II. GRIMMIEÆ.

Grimmia, Ehrhart.

1. * Schistidium.

G. apocarpa, Hedwig.
Australian Alps, F. v. M.; Tasmania, Archer.

G. mutica, Hampe in Linnæa, 1860, 631; apocarpa var. foliis muticis, in J. Hook. Fl. Tasm. II., 180.
Mount Wellington, Sealers' Cove, F. v. M.; Parramatta, Woolls.

G. cyathocarpa, Hampe in Linnæa, 1872, 516.
Gippsland, F. v. M.; Blue Mountains, Mrs. Calvert.

G. flexifolia, Hampe in Linnæa, 1860, 632.
Snowy River, F. v. M.

2. ** Eugrimmia.

G. trichophylla, Greville.
Tasmania, Hooker; Oldfield, Archer.

G. crispata, C. Muell. & Hampe in Linnæa, 1853, 498.
Flinders Range.

G. funalis, B. & S.; J. Hook. Fl. Tasm. II., 180.
Tasmania, Gunn.

G. pulvinata, Hook. & Taylor, var. obtusa; G. cygnicolla, Tayl.
Swan River, Drummond; Australian Alps, Gippsland, F. v. M.; Tasmania, J. Hooker, Oldfield, Archer.

3. *** Guembelia.

Mitten, Musci Austr. Americ, 101.

G. leucophæa, Grev.; G. leiocarpa, Taylor.
Swan River, Drummond; Brisbane River, Bailey; Tasmania, Hooker, Archer.

G. callosa, C. Muell. & Hampe in Linnæa, 1853, 498.
Barossa Range and Brown's Hill, F. v. M.

G. procumbens, Mitten; dioica, humilis, gracilis; folia patentia, lanceolata, nervo carinata, cellulis superioribus rotundis minutis inferioribus oblongis prædita; perichætialia longiora, erecta, dimidio inferiore amplexante pallidiore, dimidio superiore angusta, apice pilo brevi denticulato terminata; theca ovalis, lævis, in pedunculo ea duplo longiore exserta, operculum acuminatum; peristomii dentes perforati; annulus compositus.
Gippsland, Snowy River, F. v. M.

G. montanæ similis.

4. **** Dryptodon.

G. chlorocarpa, Mitten.
Tasmania, Archer.

G. symphyodon, C. Mueller; G. emersa ejusd. in Bot. Zeit., 1851, 562.
Tasmania, Hooker, Archer, Mossmann.

G. crispula, J. Hook. & Wils. in Fl. Antarct, 124.
Tasmania, Gunn, J. Hooker, Archer.

5. ***** Rhacomitrium.

G. lanuginosa (Dill.), C. Mueller, Synops. I., 806.
Australian Alps, F. v. M.

Var. pruinosa, in J. Hook. Fl. Tasm. II., 182.
Tasmania.

G. Sundaica, C. Mueller.
Queensland.

G. pseudo-patens, C. Mueller in Rev. Bryol, 1878, 3.
Near Sydney, Kayser.

G. heterosticha, Hedwig, J. Hook. Fl. Tasm. II., 182.
Tasmania.

Glyphomitrium, Bridel.

G. Muelleri, Mitt. in Journ. of Proceed. Linn. Soc., 1859; Brachystelium Howeanum, Hampe.
Glasshouse Mountains, Moreton Bay, F. v. M.; Lord Howe's Island, Milne.

G. Adamsoni, Mitt. in Journ. Linn. Soc., 1859.
Near Melbourne, Adamson.

G. acutifolium, J. Hook. & Wils. in Fl. Tasm. II., 180.
South Australia, Prentice; Tasmania, J. Hooker, Archer.

G. Australe, Hampe in Linnæa, 1855, 208.
Buchan River, F. v. M.

G. Mittenii, Jæger; G. serratum, Mitt. in J. Hook. Fl. Tasm. II., 181.
Tasmania, Archer.

III. LEUCOBRYEÆ.

Octoblepharum, Hedwig.

O. albidum (L.), Hedwig.
Locality unrecorded.

Leucobryum, Hampe—(Sect. Pegophyllum, Mitt.).

L. brachyphyllum, Hampe.
Newcastle, Mrs. Forde; Parramatta, Woolls.; Sealers' Cove, F. v. M.; Moreton Bay, Bailey; Richmond River, Camara; Bellenden Ker Ranges, Karsten.

L. subchlorophyllosum, Hampe in Linnæa, 1876, 304.
Mount Warning, Guilfoyle.

L. spirostichum, C. Muell.; L. Teysmanni, fidè Hampe.
Near Sydney, Kayser.

L. candidum, Schwægr, t. 187 (Dicranum).
Tasmania, Archer.

IV. SYRRHOPODONTEÆ.

Syrrhopodon, Schwægrichen.

S. platycerii, Mitten.
Lord Howe's Island, Milne, also M'Gillivray.

S. Novæ Valesiæ, C. Muell. in Revue Bryol., 1876, 3.
Near Sydney, Kayser.

S. fimbriatum, C. Mueller in Linnæa, 1872, 151.
Brisbane River, A. Dietrich.

Thyridium, Mitten.

T. fasciculatum, Hook. & Grev. (Syrrhopodon); clavatus Schw.
N. S. Wales, G. Sieber.

Calymperes, Bridel.

C. latifolium, Hampe in Pl. Preiss, 1846, 116.
Perth, Preiss; N. S. Wales.
C. Kennedyanum, Hampe in Linnæa, 1876, 303.
Rockingham Bay, Kennedy; Goode Island, Queensland, Powell.

V. TORTULEÆ.

Acaulon, C. Mueller.

A. Brisbanicum, C. Muell. in Linnæa, 1871, 144.
Brisbane River, Dietrich.
A. integrifolium, C. Muell. in Bot. Zeit., 1855, 745.
Yarra River, F. v. M.
A. turgidum, Mitt. in J. Hook. Fl. Tasm.
Tasmania, Archer.

Phascum, Linné.

P. perpusillum, C. Muell. in Linnæa, 1871, 145.
Brisbane River, Dietrich.
P. Drummondii, Wilson in Lond. Journ. Bot.,.1848, 26, t. 1.
Melbourne, Adamson.
P. cylindricum, Tayl. in Lond. Journ. Bot., 1846, 42.
Swan River, Drummond.

Pottia, Ehrhart.

P. cæspitulosa, C. Muell. & Hampe (Anacalypta) in Linnæa, 1853, 491.
Near Mt. Lofty, also Yarra River, F. v. M.
P. brevicaulis, Tayl. (Gymnostomum).
Swan River, Drummond.
P. brachyodus, Hampe in Linnæa, 1860, 624.
Yarra River, F. v. M.

Weisia, Hedwig.

W. inflexa, Tayl. (Gymnostomum).
Swan River, Drummond.

W. nuda, Mitt.; humilis; folia a basi erectiora, subquadrata, pellucide areolata, patentia, oblongo-ligulata, acuta apiculatave, canaliculata planiusculave, nervo obscure flavo excurrente prædita, integerrima, cellulis rotundis densis obscuris areolata; perichætialia conformia; theca in pedunculo pallido ovalis, gymnostoma; operculum subulatum, theca brevius.

Trichostomo mutabili similis.

Moreton Bay, F. v. M.

W. bicolor, Hampe (Gymnostomum) in J. Hook. Fl. Tasm. II., 165.

Tasmania.

W. nudiflora, C. Muell. & Hampe in Linnæa, 1853, 496.

Bugle Range, F. v. M.; Yarra and Mount Abrupt, F. v. M.

W. riparia, Hampe in Linnæa 1860, 626.

Gawler River, F. v. M.

W. flavipes, J. Hook. & Wils. in Fl. N. Zeal., 57,

Gippsland, F. v. M.; Tasmania, Gunn, Archer, Oldfield.

W. controversa, Hedwig.

Tasmania, Archer.

Trichostomum, Hedwig.

T. cirrhatum, Hampe, Icones, 28.

Swan River, Preiss.

T. leptotheca, C. Muell. in Linnæa XXXV., 625.

Gippsland, F. v. M.

Tortula, Hedwig.

1. * Trichostomum.

T. Knightii, Mitt. in J. Hook. Fl. Tasm. II., 174.

Tasmania, Mossman.

2. ** Helicopogon.

T. pseudopilifera, Hampe in Linnæa, 1853, 493; T. luteola, Mitt. in Kew Journ. Bot. VIII., 258; T. pungens, J. Hook. & Wils. in Fl. Tasm. II., 175.

Darebin Creek and Gippsland, F. v. M.; Tasmania, Oldfield, Archer, Gunn.

3. *** Pachynoma.

T. torquata, Taylor in Lond. Journ. Bot., 1846, 50.

Swan River, Drummond; New South Wales, Woolls; Tasmania, Oldfield, Archer.

T. adusta, Mitt. in Kew Journ. Bot. VIII., 258 (Desmatodon).
Gippsland, F. v. M.

T. calcicola, Hampe, Icones, 29.
Fremantle, Preiss.

T. Australasica, Hook. & Grev.; T. rufiseta, Tayl.; T. fuscescens, J. Hook & Wils. (Trichostomum).
Swan River, Drummond.

T. rubiginosa, C. Muell. in Linnæa XXXV., 625 (Eutrichostomum).
Yarra River, F. v. M.

4. **** Leptopogon.

T. calycina, Schw. (Barbula).
Swan River, Drummond; King George's Sound, Cunningham; Queensland, Miss Gore; Arthur's Seat, F. v M.; Tasmania, Hummock Island, Bass' Straits, Milne.

Var. brevicaulis, Hampe; Sealers' Cove, F. v. M.

T. subcalycina, C. Muell. in Linnæa XXXV., 617.
Brisbane River.

T. subtorquata, C. Muell. & Hampe in Linnæa, 1853, 492.
Mount Gambier, F. v. M.; Australian Mosses, pl. III.

T. Tasmanica, Hampe in Linnæa, 1852.
Tasmania, Stuart.

T. brachyphylla, Hampe in Linnæa, 1860, 625.
Victoria, F. v. M.

T. Parramattana, Mitten; caulis humilis, innovans; folia sparsa, a basi erecta, subquadrata, pellucide areolata, oblongo-ligulata, patentia, canaliculata, nervo flavo obscuro in mucronem brevissimum excurrente prædita, integerrima, cellulis minutis densis obscuris areolata; perichætialia longiora, arcte convoluta, apice obtusa, pellucide areolata; theca in pedunculo longo flavo elliptica, erecta subarcuatave, operculo subulato subæquilonga; peristomium rubrum, elongatum; annulus compositus.
Parramatta, Woolls.

Caulis 2 to 3 mm. altus. Folia obscure viridia, parte patente 1 mm. longa, sicca incurva. Pedunculus 2 cm. longus. Statura T. convolutæ, foliis autem T. calycinæ.

5. ***** Desmatodon.

T. nervosa, Bridel.
Avon River, F. v. M.; Melbourne, Adamson; Tasmania.

T. recurvata, Hooker.
Tasmania, Oldfield.
T. crassinervia, Taylor. (Desmatodon); reflexidens, Hampe (Trichostomum) in Linnæa, 1860, 625.
Swan River, Drummond; Yarra and Avon Rivers, F. v. M.

6. ****** Syntrichia.

T. fleximarginata, C. Muell. & Hampe in Linnæa, 1853, 493.
Victoria, F. v. M.; Australian Mosses, pl. VI.
T. rubra, Mitten; T. serrulata, Mitt. in Kew Journ. Bot. VIII., 258.
Australian Alps, F. v. M.
T. papillosa, Wilson.
Sealers' Cove, F. v. M.
T. breviseta, C. Muell. & Hampe in Linnæa, 1853, 492.
Mt. Gambier, F. v. M.; Australian Mosses, pl. IV.
T. princeps (Syntrichia), De Notaris; T. antarctica, Hampe in J. Hook. Fl. Tasm. II., 175; T. cuspidata et rubella, J. Hook. & Wils., l. c.; T. panduræfolia, C. Muell. & Hampe in Linnæa, 1853, 493.
Victoria, F. v. M.; Australian Mosses, pl. V.
T. Latrobeana, C. Muell. & Hampe in Bot. Zeit., 1864, 358.
Latrobe and Axe-River, F. v. M.; Tasmania, Archer.

Streptopogon, Wilson.

S. mnioides, Schw., t. 310 (Barbula); crispata, Hampe in Linnæa, 1876, 304.
Mount Macedon; Tasmania, Archer, Mossman.

Encalypta, Schreber.

E. Tasmanica, Hampe & C. Muell. in Linnæa, 1853, 491; australis, Mitt. et. vulgaris, var. in J. Hook. Fl. Tasm. II., 182; ciliata, Hedw. Mitt. in Kew Journ. Bot. VIII., 259.
Tasmania, Archer.

Pyramitrium, Hampe.

P. cristatum, Hampe in Linnæa, 1872, 513.
Blue Mountains, Mrs. Calvert.
P. Novæ Valesiæ, Hampe in Linnæa, 1872, 513.
Blue Mountains, Mrs. Calvert.

VI. ORTHOTRICHEÆ.

Orthotrichum, Hedwig.

O. laterale, Hampe in Linnæa, 1876, 309.
Hume River, F. v. M.

O. Tasmanicum, J. Hook. & Wils. in Lond. Journ. Bot. VII., 27, t. 1.
Tasmania, Gunn, Oldfield, Archer, Mossman.

O. Lawrencei, Mitt. in J. Hook. Fl. Tasm. II., 188.
Tasmania, Lawrence.

Ulota, Mohr.

U. lutea, Mitt. in J. Hook. Fl. Tasm. II., 184; crispa var., l. c.; crocea, Hampe (Orthotrichum).
Tasmania; Gunn, Hooker, Archer.

Macromitrium, Bridel.

1. * Macrocoma.

M. Eucalyptorum, C. Muell. & Hampe in Linnæa, 1853, 500; microphyllum, Hooker & Greville.
Victoria, F. v. M.; Toowoomba, Hartmann; Tasmania, Archer.

M. Novæ Valesiæ, C. Mueller in Rev. Bryol., 1876, 3.
Near Sydney, Kayser.

M. Dæmelii, C. Mueller in Rev. Bryol., 1877, 43.
Queensland, Daemel; Toowoomba, Hartmann.

M. Geheebii, C. Mueller; Hampe in Linnæa, 1876, 308.
Illawarra, Johnson.

2. ** Goniostoma.

M. pusillum, Mitten; J. Hook., Fl. Tasm. II., 183.
Tasmania, Archer.

M. microstomum, Hook. & Grev.
Sealers' Cove, F. v. M.; Brisbane River, Bailey; Toowoomba, Hartmann.

M. Scottiæ, C. Muell. in Linnæa XXXV.
Ash Island, Hunter River, Miss Scott; Tasmania, Gunn.

M. asperulum, Mitt. in J. Hook. Fl. Tasm. II., 376.
Tasmania, Lawrence.

M. Muelleri, Hampe (Macromitrium).
Sealers' Cove, F. v. M.

M. Archeri, Mitt. in J. Hook. Fl. Tasm. II., 183; M. linearifolium, C. Mueller.
Maitland, Vicary; Tasmania, Archer, Oldfield.

M. hemitrichodes, Schwægrichen, spec. musc. t. 136; G. amœnum et Sieberi, Hornschuch.
Botany Bay, Dickson, Sieber; Ranges between the Burnett and Brisbane Rivers, F. v. M.; Ash Island, Mrs. Forde.

M. intermedium, Mitt.; rami humiles; folia humiditate patenti-incurva, siccitate compacte contorta, sublanceolato-linearia, acuta, nervo carinata; cellulæ eorum ubique rotundatæ, parvæ, carnosulæ, distinctæ, fere læves; folia perichætialia breviora, lanceolata, acuta, erecta; theca in pedunculo 2-3 lineari ovalis; operculum subulatum; calyptra infra thecam descendens, multifida, appresse ramentosa.
Brisbane River, Bailey.

Very similar to G. hemitrichodes, but areolation different.

M. diaphanum, C. Mueller in Linnæa, 1871, 151.
Brisbane River, Dietrich, Bailey.

M. Baileyi, Mitten; rami breves; folia humiditate erecto-patentia, siccitate convoluta, oblongo-ligulata, nervo carinata, inferne cellulis oblongis pellucidis superne densis rotundatis obscuris formata; perichætialia breviora, erecta, ovata, acuta; calyptra ramentis paucis appressis pilosa.
Brisbane River, Bailey.

M. aurescens, Hampe in Linnæa, 1860, 633.
Dawson River, F. v. M.

M. spirale, Hampe.
Locality unrecorded.

M. Reinwardtii, Schw., t. 173; J. Hook. Fl. Tasm. II., 183.
Tasmania, Gunn.

M. lingulare, Mitt. in Journ. Linn. Soc. IV., 78; G. weissioides, C. Muell. in Linnæa, 1871.
Ranges between the Burnett and Brisbane Rivers, F. v. M.; Brisbane, Bailey.

M. prorepens, Hook., Musci exot. 120.
Norfolk Island, Bauer.

3. *** Leiostoma.

M. involutifolium, Hook.
Ranges between the Rivers Burnett and Brisbane, F. v. M.; Toowoomba, Hartmann.

M. carinatum, Mitten; M. involutifolio simillimum sed paululum majus; folia magis carinata, basi cellulis paucis elongatis prædita, apice magis subcucullato-incurva; perichætialia conformia; theca infra os plicata, in pedunculo brevi exserta.

In M. involutifolium the capsule is smooth, the perichætial leaves are shorter than the cauline leaves and more acuminated.

M. viridissimum, Mitten; M. involutifolio simile, sed elatius et ob folia longiora crassius; folia perichætialia superne angustiora, apicibus basin thecæ oblongo-cylindraceæ basi plicatæ fere attingentia; calyptra ramentis appressis obtecta.

Ranges between the Burnett and Brisbane Rivers, F. v. M.; Toowoomba, Hartmann.

M. subulatum, Mitten; longe repens; rami curvati, ascendentes; folia humiditate patentia, arcuato-incurva, siccitate torta crispataque, rigidula, subnitentia, a basi elongate lanceolata, sensim longe subulato-angustata, acuta, nervo percurrente carinata, basi cellulis angustis elongatis inde ad apicem rotundatis prædita; perichætialia ovata, longius angustata; theca in pedunculo 2-3 lineari parva, ovalis, plicata; peristomii dentes lati pallidi.

Bass' Straits, Milne.

Habitus M. cirrhosi et a reliquis speciebus Australibus diversissimum.

M. sordido-virens, C. Muell. in Linnæa, 1871, 153.

Brisbane River, Dietrich.

M. Tongense, Sullivant in American Expl. Exped., t. 5.

Lord Howe's Island, Fullagar and Lind.

M. adstrictum, Angstroem, Œfvers, 1872, 4, 19; M. Owhaiense, C. Mueller, fide Jæger.

Wollongong, Prof. Andersson.

M. brevisetaceum, Hampe in Linnæa XXXVIII., 633.

Lord Howe's Island, Fullagar and Lind.

Powellia, Mitten.

P. involutifolia, Mitt. in the Journ. Linn. Soc. X., 187; Australis, Hampe in Linnæa, 1870, 524 (Helicophyllum).

Rockinghan Bay, Dallachy.

Zygodon, Hooker and Taylor.

Z. intermedius, Bruch and Shimper.

Tasmania, Archer, Mossman.

Z. brachypodus, Hampe & C. Muell. in Linnæa, 1855, 210.
Sealers' Cove, F. v. M.

Z. Brownii, Schw., t. 317.
Sealers' Cove, F. v. M.; Tasmania, Archer,

Z. Hookeri, Hampe in Linnæa, 1859, 60.
Grampians, F. v. M.

Z. minutus, C. Muell. & Hampe in Linnæa, 1855, 209.
Sealers' Cove, F. v. M.

Z. anomalus, Dozy & Molkenbœr; Z. Reinwardtii, Mitt. in J. Hook., Fl. Tasm. II., 185.
Tasmania, Oldfield.

Z. Menziesii, Schw., t. 137 (Codonoblepharum); Drummondii, Taylor.
Swan River, Drummond; Melbourne, Adamson; Port Albert and Tarwin, F. v. M.; Tasmania Gunn, Archer, Oldfield.

Gymnocybe, R. Brown.

G. palustris, Mitten; Aulacomnion, Schwægrichen, J. Hook., Fl. Tasm. II., 192.
Tasmania, Gunn.

Apalodium, Mitten.

A. lanceolatum, Mitt. in Kew Journ. Bot. VIII., 761 (Orthodontium).
Mount Wellington, Gippsland, F. v. M.; Tasmania, Archer.

A. lineare, Taylor (Zygodon), Weissia pallens, Wilson.
Swan River, Drummond.

A. australe, J. Hook. et Wils. in Fl. Antarct., t. 153.
Tasmania, J. Hooker, Archer, Oldfield.

A. sulcatum, Hook. & Wils.
Grampians, F. v. M.

VII. SPLACHNEÆ.

Tayloria, Hooker.

T. calophylla, C. Muell. in Bot. Zeit., 1851, 564 (Dissodon); robusta (Eremodon), J. Hook. et Wils.
Tasmania, Mossman.

T. octoblepharis, Hooker; cuspidata (Dissodon), C. Mueller.
Tarwin, Sealers' Cove, F. v. M.; Tasmania, Archer, Oldfield.

Splachnum, Linné.

S. Gunnii, J. Hook. & Wils. in London Journ. of Bot. VII., 26, t. 1; Tetraplodon Tasmanicus, Hampe in Linnæa, 1876, 302.
Tasmania, Gunn, Schuster.

VIII. FUNARIEÆ.

Ephemerum, Hampe.

E. cristatum, Hook. & Wils. in Hook. Icon. pl. rar., t. 737 A.
Tasmania, Archer.

E. fimbriatum, C. Muell. in Linnæa, 1871, 145.
Brisbane River, Dietrich.

Pleurophascum, Lindberg.

P. grandiglobum, Lindberg, in Journ. of Bot., 1875.
Alps of Tasmania, Picton River, R. Johnston.

Leptangium, Montagne.

L. repens, Hook., Musci. exot., 106 (Anictangium).
Tasmania, Archer.

L. tumidum, Mitt.; folia oblongo-ovalia, cochleariformi-concava, margine late recurva, apice acuta vel apiculo brevi angusto terminata, enervia, cellulis oblongis carnosulis areolata.
Tasmania, Archer.

Caules 2 centim. alti, fusci. Folia 3 mm. longa, flavo-fusca. Quoad genus, fructu absente, dubium.

Physcomitrium, Bridel.

P. firmum, Mitt. in Kew Journ. Bot. VIII., 259.
Delatite, F. v. M.

P. Brisbanicum, C. Muell. in Linnæa, 1871, 146.
Brisbane River, Dietrich.

P. subserratum, C. Muell. in Linnæa, 1860, 623.
Dargo River, F. v. M.

P. minutulum, C. Muell. in Linnæa, 1871, 147.
Brisbane River, A. Dietrich.

P. conicum, Mitt. in J. Hook. Fl. Tasm. II., 197.
Tasmania, Archer.

P. nodulifolium, Mitten; monoicum; caulis semiuncialis uncialisve; folia sparsa, erecto-patentia appressaque, comalia patentia, oblongo-obovata, breviter apiculata, margine a medio ad apicem serrulata; nervus in apiculo evanescens; cellulæ oblongæ, limitibus nodulosæ; theca in pedunculo circiter 3 lineari erecta; theca subglobosa, collo æquilonga, ore paululum coarctata, satis magna sed non dilatata.

Near Moreton Bay, F. v. M. (1856).

Primo adspectu P. firmo simile, sed foliis serrulatis et areolatione diversissimum.

P. flaccidum, Mitten; caulis gracilis; folia patentia, flaccida, obovata, acuta, margine superne serrulata, nervo sub apice evanido prædita, cellulis teneris areolata; pedunculus gracilis; theca globosa, collo æquilongo attenuata, demum cyathiformis.

Ash Island, Hunter River, Newcastle, Mrs. E. Forde.

Caulis 1 centim. altus. Folia 1 mm. longa. Pedunculus 5 mm. metiens.

P. integrifolium, Hampe & C. Mueller in Linnæa, 1853, 490.

Delatite, F. v. M.

Goniomitrium, Hooker and Wilson.

G. acuminatum, Hook. & Wils. in Lond. Journ. Bot., 1846, t. 3 B.

Swan River, Drummond; Clermont, Queensland, Miss Gore.

G. enerve, Hook. & Wils. in Lond. Journ. Bot., 1846.

Swan River, Drummond.

Entosthodon, Schwægrichen.

E. clavæformis, C. Muell. & Hampe in Linnæa, 1853, 490.

Torrens River, F. v. M.

E. laxus, J. Hook. & Wils. in Fl. Antarct., t. 151 (Physcomitrium).

Australian Alps, F. v. M.; Tasmania, Archer, Oldfield.

E. apophysatus, Tayl. in Lond. Journ. Bot., 1846, 42; E. Taylori, C. Muell., Syn. I., 122.

Swan River, Drummond; Queensland, Miss Gore; Yarra River and Gippsland, F. v. M.; Tasmania, Archer.

E. productus, Mitten in J. Hook. Fl. Tasm. II., 197.

Tasmania, Archer.

E. varius, Mitten; caulis brevissimus; folia in comam congesta, ovali-rotundata, breviter apiculata, immar-

ginata, integerrima, nervo infra apicem evanido prædita; theca in pedunculo subunciali clavata, subinæqualis; operculum fere planum, gymnostomum.
Victoria, Adamson.

Species ambigua, foliis Funariæ hygrometricæ, thecis Entosthodonti apophysato similior.

Funaria, Schreber.

1. * Plagiodus.

F. subnuda, Tayl. in Lond. Journ. Bot., 1846, 57.
Swan River, Drummond.

F. glabra, Tayl. in Lond. Journ. Bot., 1846, 57.; F. acaulis, Hampe in Linnæa, 1860, 624; F. radians, Mitt., in Kew Journ. Bot. VIII., 259.
Swan River, Drummond; Gippsland, F. v. M.; Tasmania, Archer.

F. Tasmanica, C. Muell. & Hampe in Linnæa, 1853, 490; F. v. M., Austr. Mosses, pl. 1.
Tasmania, Stuart.

F. crispula, J. Hook. & Wils. in Fl. Tasm. II., 198.
Tasmania, Oldfield, Archer.

2. ** Eufunaria.

F. hygrometrica, Linné.
Maitland, Vicary; Brisbane River, Bailey; Ash Island, Hunter River, Mrs. E. Forde; Bellenden Ker Range, Karsten.

F. papillata, Hampe in Linnæa, 1876, 302.
Brisbane River, Slater.

IX. BARTRAMIEÆ.

Bartramidula, Bruch & Schimper.

B. pusilla, J. Hook. & Wils. in Lond. Journ. Bot., 1844, 545 (Glyphocarpa).
Tasmania, Lyall, Archer, Oldfield.

B. Hampei, Mitt.; Bartramia erecta, Hampe in Linnæa, 1876, 305.
Mount William, Sullivan.

Philonotis, Bridel.

P. appressa, J. Hook. & Wils.
Australian Alps, F. v. M.; Tasmania, Archer, Oldfield.

P. uncinatula, C. Muell. in Revue Bryol., 1876, 4.
Near Sydney, Kayser.
P. atro-lutea, C. Muell. in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.
P. Slateri, Hampe in Linnæa, 1876, 306.
Brisbane River, Slater.
P. pallida, Hampe in Linnæa, 1876, 307.
Sub-tropical East Australia, Eaves.
P. pseudo-mollis, C. Muell. in Linnæa, 1871, 150.
Brisbane River, Dietrich.
P. tenuis, Tayl. in J. Hook. Fl. Tasm. II., 193.
Tasmania, Oldfield.
P. fertilis, Mitt. in Kew Journ. Bot. VIII., 260.
Mount Hotham, Australian Alps, F. v. M.

Breutelia, Schimper.

B. Sieberi, Hornschuch (Bartramia).
Near Port Jackson, Sieber 13; Mount Tomah, Cunningham; Tasmania, Archer, Oldfield.
B. pendula, Hook., Musci exot. 21 (Bartramia).
Near Port Jackson, Sieber 15; Tasmania, J. Hooker, Oldfield.
B. elongata, J. Hook. and Wils. (Bartramia).
Tasmania, Archer.
B. comosa, Mitt. in J. Hook. Fl. Tasm. II., 195 (Bartramia).
Mt. Dromedary, N.S.W., Reader; Tasmania, Archer, Mossman.
B. crassa, J. Hook. & Wils. in Fl. Tasm. II., 194 (Bartramia).
Tasmania, Mossman, Archer.
B. affinis, Hook., Musci exot. 176 (Bartramia).
Victoria, Robertson; Snowy River and Buffalo Range, F. v. M.; Tasmania, Mossman, Archer, Oldfield.
B. divaricata, Mitt. in J. Hook. Fl. Tasm. II., 195 (Bartramia).
Tasmania, Archer.
B. commutata, Hampe in Linnæa, 1876, 307 (Bartramia).
Grampians, F. v. M.; Tasmania,
B. luteola, C. Muell. in Rev. Bryol., 1876, 4.
Sydney, Kayser.

Conostomum, Swartz.

C. Australe, Swartz in Schrad., Neu. Journ. für Bot., 134.
Tasmania, Archer.
C. curvirostre, Mitt. in Kew Journ. Bot. VIII., 260 (Bartramidula).
Munyang Mounts., Australian Alps, F. v. M.

C. pusillum, J. Hook. & Wils. in Fl. Antarct., t. 86; C. parvulum, Hampe in Linnæa, 1855, 207.
Grampians, Victoria, F. v. M.; Tasmania, Archer, Oldfield.

Bartramia, Hedwig.

B. papillata, J. Hook. & Wils. in Fl. N. Zeal., t. 86; B. acerosa, Hampe in Linnæa, 1855, 207.
Snowy River, F. v. M.; Mount Dromedary, Reader; Tasmania, Archer.

B. fragilis, Mitt. in J. Hook. Fl. Tasm. II., 196.
Tasmania, Archer.

B. strictifolia, Tayl. in Lond. Journ. Bot. V., 451 (1846).
Swan River, Drummond.

B. Halleriana, Hedwig; B. Mossmaniana, C. Muell. in Bot. Zeit., 1851, 552.
Tasmania, Archer.

Meesia, Hedwig.

M. Muelleri, C. Muell. & Hampe in Linnæa, 1865, 208.; M. macrantha, Mitten.
Cobberas Mountains, Australian Alps, F. v. M.

X. BRYEÆ.

Bryum, Linné.

1. * Dicranobryum.

B. Preissianum, Hampe, Icones, 25.
Swan River, Drummond, Preiss.; Victoria, F. v. M.

2. ** Webera.

B. nutans, Schreber; B. longifolium, Hampe in Linnæa, 1855, 205.
Grampians, Cobberas and Snowy River, F. v. M.; Tasmania, Archer, Oldfield, Gunn.

B. nudiflorum, C. Muell. & Hampe in Linnæa, 1855, 205.
Yarra River, F. v. M.

B. clavæforme, Hampe & C. Muell. (Pohlia) in Linnæa, 1870, 519.
Mount Disappointment, F. v. M., Taylor.

B. erythrocaule, Hampe in Linnæa, 1872, 516.
Blue Mountains, Mrs. Calvert.

B. albicans, Wahlenberg.
Locality not recorded.

3. *** Leptobryum.

B. pyriforme, Hedwig.
Maitland, Vicary.

B. sericeum, Hampe in Linnæa, 1853, 494.
Tasmania, Stuart.

**** Brachymenium.

B. lanceolatum, J. Hook. & Wils. in Fl. Tasm. II., t. 173.
Tasmania, Gunn.

***** Eccremothecium.

B. dichotomum, Hedwig; B. balanoides, Tayl.; B. pachytheca, C. Muell.
Swan River, Drummond; Yarra River, F. v. M.; Tasmania, Gunn, Oldfield.

B. Gambierense, C. Muell. in Linnæa, 1871, 148.
Mount Gambier, also in Victoria, F. v. M.

B. cupulatum, C. Muell. in Linnæa, 1871, 149.
Victoria, also Brown's Hill Creek on St. Vincent's Gulf, F. v. M.

B. pachypomatoides, Hampe.
Locality unrecorded.

B. brevicaule, Hampe et C. Muell. in Linnæa XXXVI., 518.
Locality unrecorded.

B. suberythrocarpum, C. Muell. in Bot. Zeit., 1856, 417.
Rottnest, West Australia, Preiss.

B. subæneum, C. Muell. & Hampe in Linnæa, 1853, 494.
Victoria, F. v. M.

B. macropelma, C. Muell. in Linnæa, 1871, 149.
South-West Australia, Preiss; Porongerup, F. v. M.

B. erythrocarpoides, C. Muell. & Hampe in Linnæa, 1853, 495.
Mt. Lofty Range, F. v. M.

B. subpachypoma, Hampe & C. Muell. in Linnæa, 1870, 518.
Rockingham Bay, Dallachy.

B. pyrothecium, Hampe in Linnæa, 1855, 205.
Sealers' Cove, Thomson River, Avon; Glenelg River, F. v. M.

B. inæquale, Tayl. in Lond. Journ. Bot., 1848, 53.
Swan River, Drummond.

B. multicaule, Tayl. in Lond. Journ. Bot., 1848, 53.
Swan River, Drummond.

B. creberrimum, Tayl. in Lond. Journ. Bot., 1848, 53.
Swan River, Drummond.

B. argenteum, Linné, var. nivea.
Victoria, F. v. M.; Tasmania, Gunn.
B. subrotundifolium, Hampe in Linnæa, 1876, 512.
Mt. Ararat, Sullivan.
B. subatropurpureum, C. Muell. in Linnæa, 1871, 147.
Brisbane River, Dietrich.
B. chrysoneuron, C. Muell. in Bot. Zeit., 1851, 549; B. duriusculum, J. Hook. & Wils.
Cobberas Mts., Austral. Alps, F. v. M., Tasmania.
B. curvicollum, Mitten; B. clavatum, J. Hook. & Wils., Fl. N. Zeal. 84, t. 85.
Tasmania, Archer, Gunn.
B. viridulum, C. Muell. in Rev. Bryol., 1876, 3.
Australia.
B. torquescens, Bruch & Schimper.
Australia, F. v. M.
B. intermedium, W. & M.; J. Hook. Fl. Tasm. II., 189.
Tasmania, J. Hooker.
B. pseudo-pallescens, Hampe & C. Muell.
Locality unrecorded.
B. camptothecium, Taylor.
Swan River, Drummond; Mount William, F. v. M.
B. Australe, Hampe, Icones 26.
Swan River, Preiss.
Var. minor; Victoria, F. v. M.
B. rubiginosum, J. Hook. & Wils. in Fl. Tasm. II., 190.
Tasmania, Gunn.
B. crassum, J. Hook. & Wils. in Fl. N. Zeal., t. 86.
Mount Hotham, Australian Alps, F. v. M.; Tasmania, Archer, Gunn.
B. crassinerve, J. Hook. & Wils.
Munyang Mountains, F. v. M.
B. blandum, J. Hook. & Wils. in Fl. Antarct., t. 60; var. luridum.
Tasmania, Gunn.
B. Tasmanicum, Hampe in Linnæa, 1852.
Tasmania, R. Brown, Archer, Mossman.
B. bimum, Schreber; J. Hook. Fl. Tasm. II., 190.
Tasmania, Archer.
B. lævigatum, J. Hook. & Wils. in Fl. Antarct., t. 154.
Tasmania, Lawrence, Archer, Gunn.
B. capillare, Hedwig.
Tasmania, Gunn.
B. obconicum, Hornschuch.
Tasmania, Gunn.

B. cæspiticium, L. var. crinitum, J. Hook., Fl. Tasm. II., 191.
Tasmania, Gunn, Archer.
B. leucacanthum, Hampe.
Lord Howe's Island, Fullagar.
B. subtomentosum, Hampe & C. Muell. in Linnæa, 1870, 516.
Victoria, F. v. M.; near Melbourne, Adamson; Richmond River, Camara; Brisbane River, Bailey.
B. brachyaris, C. Mueller.
Locality unrecorded.
B. albo-limbatum, Hampe & C. Muell. in Linnæa, 1870, 517.
Porongerup, West Australia, F. v. M.
B. robustum, Hampe in Linnæa, 1860, 627.
Tarwin River, F. v. M.; Mt. Dromedary, Reader.
B. crispatum, Hampe in Linnæa, 1876, 310.
Between Cape Otway and Cape Patton, Walter.
B. olivaceum, Hampe in Linnæa, 1876, 311.
Sub-tropical East Australia, Eaves.
B. leptothecium, Taylor; B. truncorum, Wilson in J. Hook. Fl. Tasm. II., 192.
Sealers' Cove, Gippsland, F. v. M.; Tasmania, Archer, Gunn, Mossman.
B. Billardieri, Schwægrichen.
Australian Alps, F. v. M.; Tomah, Cunningham; Tasmania, Archer, J. Hooker; Lord Howe's Island, Milne.
B. breviramulosum, Hampe in Linnæa, 1876, 311.
Mount Ararat, Sullivan.
B. subfasciculatum, Hampe in Linnæa, 1876, 312.
Sub-tropical East Australia, Eaves.
B. rufescens, J. Hook. & Wilson in Fl. Tasm. II., 192.
Victoria, F. v. M.; Tasmania, Hooker, Gunn.
B. roseodens, C. Muell., Rev. Bryol., 1876, 3.
Near Sydney, Kayser.
B. Commersonii, Bridel, mant. musc., 119.
Logan River, Scortechini; Lord Howe's Island, Milne.

Mielichhoferia, Hornschuch.

1. * Leptochlæna.

M. microdonta, Mitten.
Gippsland, F. v. M.; Tasmania, Archer, Oldfield

2. ** Haplodontium.

M. Eckloni, Hornschuch; J. Hook. Fl. Tasm. II., 189.
Tasmania, Gunn, Archer.

M. Australis, Hampe in Linnæa, 1855, 204, et 1860, 626.
Gippsland and Grampians, F. v. M.

Leptostomum, R. Brown.

L. macrocarpum, R. Br. in Transact. Linn. Soc. X., 322.
Norfolk Island, Cunningham.

L. inclinans, R. Br., l. c. 320, t. 23; L. flexipile, C. Mueller.
Sealers' Cove and Grampians, F. v. M.; Mount Wellington, Tasm., R. Brown; Western Mountains, Archer.

Var. longiseta, Hampe in Linnæa, 1855, 206.
Sealers' Cove, F. v. M.

Leptotheca, Schwægrichen.

L. Gaudichaudi, Schw., t. 186.
Grampians and Avon River, F. v. M.; Tasmania, J. Hooker, Oldfield, Archer.

Mnium, Dillenius.

M. rostratum, Schwægrichen; M. Novæ Valesiæ, C. Muell. in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.

Mittenia, Lindberg.

M. plumula, Lindberg; Mitten in J. Hook. Fl. Tasm. II., 187, t. 173 (Mniopsis).
Tasmania, Archer.

Hymenodon, J. Hooker et Wilson.

H. piliferum, J. Hook. & Wils. in Fl. N. Zeal., t. 92.
Victoria, F. v. M.; Tasmania, Sir J. Hooker, Archer.

Rhizogonium, Bridel.

1. * Pyrrhobryum.

R. spiniforme, Bruch in Regensb. flora, 1846, p. 134.
Australian Alps, F. v. M.; Tasmania, Archer, Mossman; Bellenden Ker Range, Karsten; Ash Island, Mrs. Forde.

R. Parramattense, C. Muell., Synops. II., 255.
Parramatta (herb. Kunze).

R. Hookeri, C. Mueller; R. mnioides, Wils. var. contortum et var. lutescens, J. Hook. Fl. Tasm. II., 216; Mossmanianum, C. Muell. in Bot. Zeit., 1851, 547.
Mt. William and Sealers' Cove, F. v. M.; Tasmania, Mossman, Archer.

2 ** Eurhizogonium.

R. distichum, Bridel, Bryol. univ. II., 665.
Victoria, F. v. M.; Tasmania, Archer, Mossman.
R. Geheebii, C. Muell. in Rev. Bryol., 1876, 3.
Sydney, Kayser.
R. Novæ Hollandiæ, Bridel, Bryol. univ. II., 664.
Victoria, F. v. M.; Tasmania, Archer.
R. aristatum, Hampe in Linnæa, 1876, 714.
Tasmania, Schuster.
R. gracillimum, Hampe in Linnæa, 1876, 314.
Buchan River, F. v. M.; between Cape Otway and Cape Patten, Walter.
R. Muelleri, Hampe in Linnæa, 1855, 211.
Mt. William and Sealers' Cove, F. v. M.
R. bifarium, Schimper in der Bot. Zeitung, 1844, p. 125.
Tasmania, Oldfield.
R. undulatum, Lindberg, Œfvers af F. Vet. Soc. Foerh., 1869.
Parramatta, Woolls; Sydney, F. v. M.; Twofold Bay, Mossman; Ash Island, Hunter River, Mrs. Forde; Brisbane River, Bailey.
R. taxiforme, Hampe in Linnæa, 1876, 313.
Johnston River, Fitzalan.

3. *** Goniobryum.

Lindberg in der Hedwigia, 1863, p. 21—Photinophyllum, Mitten.
R. pellucidum, Mitten; reticulatum, Hampe in Linnæa, 1860.
Apollo Bay, F. v. M.; Tasmania, Archer.
R. subbasilare, Hook., Musci. exot. 10 (Hypnum).
Tasmania, Gunn, Archer.

XI. HYPOPTERYGIEÆ.

Cyathophorum, Beauvois.

C. pteridioides, Beauvois; C. pennatum, Bridel.
Victoria, F. v. M.; Tasmania, Archer, Gunn, Oldfield.

Hypopterygium, Bridel.

1. * Lopidium.

H. concinnum, Hooker.
Sealers' Cove, F. v. M.

H. nematosum, C. Muell. in Journ. Mus. Godefr. Heft. VI., 30.
Mount Elliot, Kayser.

H. pallens, J. Hook. & Wils. in Fl. N. Zeal., 119.
Victoria, F. v. M.; Tasmania, R. Brown, Gunn, Oldfield, Archer, Stuart.

H. planatum, Hampe in Linnæa, 1874, 672.
Mount Elliot, Kayser.

2. ** Catharomnion.

H. ciliatum, Hedw. (Pterygynandrium).
Tasmania, Gunn.

3. *** Euhypopterygium.

H. Muelleri; Hampe in Linnæa, 1855, 215.
Buchan River, F. v. M.; Brisbane River, Bailey.

H. discolor, Mitten; H. Scottiæ, C. Muell. in Linnæa XXXV., 619.
Parramatta, Woolls; Ash. Isl., Hunter River, Mrs. Forde; Moreton Bay and Mt. Gambier, F. v. M.

H. Novæ Zealandiæ, C. Mueller in Bot. Zeit., 1851, 367; H. Smithianum, J. Hook. & Wils. in Fl. N. Zeal. II., 118.
Sealers' Cove, F. v. M.; Tasmania, Hooker, Archer, Oldfield.

H. glaucum, Sullivant in Amer. Expl. Exp., 26; H. Smithianum var., J. Hook. & Wils. in Fl. N. Zeal. II., 118.
Tasmania, Archer.

H. viridulum, Mitt. in J. Hook. Handb. Fl. N. Zeal. II., 487.
Ash Island and Hunter River, Mrs. Forde; Brisbane River, Bailey.

H. oceanicum, Mitt. in J. Hook. Handb. Fl. N. Zeal. II., 487; H. Norfolkianum, C. Muell.
Norfolk Island, Cunningham, Thompson, Milne.

XII. RHACOPILEÆ.

Rhacopilum, Bridel.

R. strumiferum, C. Mueller in Bot. Zeitung, 1851, 563; R australe, J. Hook. and Wils. in Fl. N. Zeal., 121.
Tasmania, Archer.

R. crinitum, Hampe & C. Muell. in Linnæa, 1870, 526.
Porongerup, West Australia, F. v. M.

R. convolutaceum, C. Mueller, Synops. II., 13; R. cristatum, J. Hook. & Wils. in Fl. N. Zeal., 121.
Ranges between the Burnett and Brisbane Rivers, F. v. M.; Richmond River, Camara; Norfolk Island, Thompson; Ash Island, Mrs. Forde.

R. purpurascens, Hampe in Linnæa, 1876, 326.
Near Melbourne and on Mt. Elephant, F. v. M.

R. æruginosum, C. Mueller in Rev. Bryol., 1877, 43.
Toowoomba, Hartmann.

XIII. HOOKERIEÆ.

Daltonia; Hooker and Taylor.

D. pusilla, J. Hook. and Wils. in Fl. Tasm. II., 221.
Tasmania, Oldfield.

Distichophyllum, Dozy & Molkenboer.

1. * Mniadelphus.

D. apiculatum, J. Hook. & Wils. in Fl. N. Zeal., t. 93 (Hookeria).
Tasmania, Gunn.

D. complanatum, Hampe in Linnæa, 1876, 320.
Johanna River, near Cape Otway, F. v. M.

D. subrotundum, Hampe in Linnæa, 1876, 320.
Mt. Disappointment, F. v. M.

D. microcarpum, Hedw. (Hypnum).
Tasmania, Archer, Gunn.

D. sinuosum, J. Hook. & Wils. in Fl. Tasm. II., 219.
Tasmania, Gunn, Oldfield.

2. ** Discophyllum.

D. pulchellum, J. Hook. & Wils. in Fl. Antarct., t. 62.
Tasmania, Gunn, Archer.

D. crispulum, J. Hook. & Wils. in Fl. N. Zeal.; t. 93.
Tasmania, Archer.

D. amblyphyllum, J. Hook. & Wils. in Fl. N. Zeal., t. 93.
Tasmania, Gunn.

D. Zetterstedtii, C. Muell. in Linnæa, 1871, 158.
Victoria, F. v. M.

Hookeria, Smith.

(Cyclodictyon, Mitten.)

H. lepida, Mitten; folia lateralia obovata ovaliave obtusa, apiculo brevi terminata; intermedia late ovalia, acuta; omnia binervia, limbo angusto integerrimo marginata, cellulis hexagonis limpidis areolata.
Bellenden Ker's Range, Karsten.
Folia pallide viridia, 1 mm. longa; Fructus ignotus, genus igitur dubium.

Sauloma, J. Hooker & Wilson.

S. tenellum, J. Hook. & Wils. in Fl. N. Zeal., t. 92 (Hookeria).
Bunyip Creek, F. v. M.; Tasmania, Hooker, Archer, Gunn, Oldfield.

Pterygophyllum, Bridel.

P. Hookeri, Jæger II., 247; Pt. obscurum, Mitt. in J. Hook. Fl. Tasm. II., 220, t. 177.
Tasmania, Archer.

P. denticulatum, J. Hook. & Wils.
Tasmania, Gunn.

P. nigellum, J. Hook. & Wils. in Fl. N. Zeal., t. 93 (Hookeria); H. hepaticifolia, C. Muell. & Hampe in Linnæa, 1853, 503.
Tasmania, Sir J. Hooker; Dandenong Ranges, Steep Bank River, Bunyip Creek, and many other places in ferntree-gullies, F. v. M.

XIV. ERPODIEÆ.

Erpodium, Bridel.

E. Hodgkinsonianum, Hampe & C. Mueller.
Richmond River, Mrs. Hodgkinson.

XV. NECKEREÆ.

Hedwigia, Ehrhart.

1. * Euhedwigia.

H. ciliata, Ehrhart in Hannov. Magaz., 1781, p. 109; H. microcyathea, C. Muell. in Bot. Zeit., 1851, 564 et forsan H. Jaratzkæ, C. Muell., Rev. Bryol., 1876, 3.

Ingogobbi, Australian Alps, F. v. M.; near Sydney, Kayser; Tasmania, Hooker, Mossman.

2. ** Hedwigidium.

H. imberbis, Sm. (Gymnostomum); H. Drummondi, Tayl. (Schistidium); J. Hook. Fl. Tasm. II., 179 et forsan H. emersa, Hampe & C. Mueller.
Swan River, Drummond; Tasmania, Archer.

Rhacocarpus, Lindberg.

R. Humboldti, J. Hook. & Wils. in Fl. Tasm. II., 179 (Hedwigia); H. Australis, Hampe in Linnæa, 1860, 636.
Swan River, Drummond; Grampians, F. v. M.; Tasmania, Archer, Hooker, Gunn.

Lasia, Bridel.

L. subproducta, C. Muell. in Rev. Bryol., 1877, 43.
Parramatta, Woolls; Toowoomba, Hartmann.
L. Australis, C. Muell. in Linnæa, 620.
Ash Island, Hunter River, Mrs. E. Forde; Toowoomba, Hartmann; Brisbane River, F. v. M.

Cryphæa, Bridel.

1. * Eucryphæa.

C. brevidens, C. Muell. in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.
C. tenella, Hornschuch.
New South Wales, Sieber.
C. crenulata, Mitt. in Journ. Linn. Soc., 1859.
Tarwin, Gippsland, F. v. M.; Tasmania, Archer.

2. ** Philudora.

C. ovalifolia, C. Muell. in Bot. Zeit., 1851.
Twofold Bay, Mossman; Parramatta, Woolls; Brisbane River, Bailey.
C. squarrulosa, Hampe in Linnæa, 1860, 636.
Gippsland, Tarwin, F. v. M., Australian Mosses, pl. XI.
C. Muelleri, Hampe in Linnæa, 1851, 212 (Dendropogon); C. dilatata, Mitt. in Kew Journ. Bot. VIII., 263.
Buchan River and Moreton Bay, F. v. M.
C. Tasmanica, Mitt. in J. Hook. Fl. Tasm. II., 204.
Tasmania, Archer.

C. imbricata, J. Hook. & Wils. in Fl. Tasm. II., 202 (Leskea).
Tasmania, Oldfield.

Bescherellia, Duby.

B. brevifolia, Hampe in Linnæa, 1876, 317.
Toowoomba, Slater; Brisbane, Bailey; Riverina, Dangar.
B. cyrtopus, F. v. Mueller; Cyrtopus bescherellioides, C. Mueller in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.

Spiridens, Nees ab Esenbeck.

S. Muelleri, Hampe in Rev. Bryol. 1875, 118; perhaps S. capilliferus, Mitten.
Mt. Lidgbird, Lord Howe's Island, C. Moore.

Lepyrodon, Hampe.

L. Lagurus, Hook., Musci. exot., t. 126 (Leucodon).
Mt. Latrobe, Australian Alps; Tasmania, Hooker, Archer, Oldfield.

Garovaglia, Endlicher.

1. * Euptychium.

G. cuspidata, Mitt. in Kew Journ. Bot. VIII., 263 (Esenbeckia); Euptychium Neo-Caledonicum, Schimper.
Moreton Bay, F. v. M.; Brisbane River, A. Dietrich.
G. mucronata, Hampe in Linnæa, 1874, 666.
Lord Howe's Island, Fullagar and Lind.
G. robusta, Hampe in Linnæa, 1874, 667.
Lord Howe's Island, Fullagar and Lind.
G. Muelleri, Hampe in Linnæa, 1876, 318 (Endotrichum).
Tropical East Australia, Eaves.

2. ** Endotrichella.

G. lepida, C. Muell. in Linnæa, 1871, 157.
Herbert's River, Dallachy.
G. Dietrichiæ, C. Muell. in Linnæa, 1871, 155.
Brisbane River, A. Dietrich.

3. *** Cladomnion, (J. Hooker & Wilson; Ptychothecium, Hampe; stereodon, Mitten).

G. sciuroides, Hook., Musci. exot. 175 (Leskea); G. glyphotheca, C. Muell. in Linnæa, 1855, 212 (Neckera); G.

Muelleriana, Hampe in Linnæa, 1860, 637 (Glyphothecium).
Tasmania, Sir J. Hooker; Tarwin, Gippsland, F. v. M.

Ptychomnion, J. Hook. and Wils.

P. aciculare, Labill (Hypnum), Brid.
New South Wales, Capt. Cartwright; Victoria, F. v. M.; Tasmania, Lyall, Gunn, Archer, Oldfield.

Pterobryum, Hornschuch.

1. * Calyptothecium.

P. Australinum, Mitten; rami pinnati, frondiformes, stipitati; folia (e medio frondis) complanata, patentia; media ovata, apice late acuta; lateralia complicata, infra apicem parum excavata, omnia nervo tenui ultra medium evanido prædita, margine, integerrima, cellulis oblongis pellucidis areolata.
Islands of Moreton Bay, F. v. M.
Fronds 3 inches high, about 2 millimetres wide, where the foliage is most fully developed. In colour pale-green, scarcely shining.

P. humile, Mitt.; P. Australino simillimum, sed folia (e medio frondis) oblonga, obtusa; lateralia complicata; omnia nervo tenui, supra medium evanido prædita, margine apicem versus subserrulata, cellulis oblongis areolata.
Richmond River, Henderson.

P. acutum, Mitt.; folia (e medio frondis) ovata, apice obtuse acuminata, lateralia breviter acutata et complicata, omnia basi cordato-auriculata, nervo tenui supra medium evanido instructa, apice serrulata, cellulis elongatis areolata.
Richmond River, Henderson.

P. duplicato similior.

2. ** Trachyloma.

P. planifolium, Hook. (Neckera).
Parramatta, Woolls; Tasmania, Mossman.

P. Muelleri, Hampe.
Apollo Bay, F. v. M.

P. diversinerve, Hampe.
Yarra River, F. v. M.

3. *** Braithwaitea (Lindberg; Dendro-Leskea, Hampe).

P. sulcatum, Hook. Musc. exot., t. 164 (Leskea); Pt. nematosum, C. Muell. in Linnæa XXXV., 615 (Pilotrichum).
Near Port Jackson, R. Brown; Ranges between the Burnett and Brisbane Rivers, F. v. M.; Brisbane River, Bailey.

Meteorium, Bridel.

M. Kermadecensis, C. Muell. in Bot. Zeit., 1857, 779; M. Hornschuchii, Mitt. (Trachypus); M. cuspidiferum, Taylor in J. Hook., Fl. Tasm. II., 203.
Tasmania, Hooker, Gunn, Oldfield, Archer.

M. Eavesianum, Hampe in Linnæa, 1876, 219 (Neckera, Pilotrichella).
Sub-tropical East Australia, Eaves.

M. limbatum, C. Muell. & Hampe in Linnæa, 1853, p. 502; M. cerinum, J. Hook. et Wils. in Fl. Tasm. II., 203.
Victoria, F. v. M.; Ash Island, Hunter River, Mrs. E. Forde; Maitland, Vicary; Tasmania, Archer.

M. filipendulum, J. Hook. et Wils. in Fl. Tasm. II., 203; Neckera Scottiæ, C. Muell. in Linnæa XXXV., 621 (Papillaria).
Ash Island, Hunter River, Mrs. E. Forde; Brisbane, Bailey; Tasmania, Gunn.

M. amblyacis, C. Muell. in Linnæa XXXVI., 521.
New South Wales, Leichhardt; Brisbane River, Bailey.

M. flexicaule, Tayl. in J. Hook. Fl. N. Zeal., 101.; M. squamatum, C. Muell. & Hampe in adnot. ad M. amblyacem, in Linnæa XXXVI., 522, probably also.
Australia, Tasmania, Archer.

M. Reginæ, Hampe in Linnæa, 1876, 319 (Neckera, Pilotrichella).
Toowoomba, Hartmann.

M. dimorphum, C. Muell. in Linnæa, 1873, 516.
Blue Mountains, New South Wales, Mrs. Calvert.

M. fulvum, Mitt. in Journ. Linn. Soc., 1859.
Tarwin, F. v. M.

M. molle, Hedwig (Leskea).
Tarwin, F. v. M.

M. Billardieri, Hampe.
Gippsland, F. v. M.

M. trichophoroides, Hampe in Linnæa, 1874, 668.
Lord Howe's Island, Fullagar and Lind.

M. compressum, Mitten; rami elongati, flexuosi, ramulis irregularibus remotis pinnati, saepe attenuati: folia appressa, a basi amplexante subcordata oblongo-lanceolata, in ramulis longius et tenuissime flexuoso-angustata, remote denticulata, inferne crenulata, cellulis angustis unipapillatis areolata, enervia.
Brisbane River, Bailey.

Neckera, Hedwig.

N. aurescens, Hampe in Linnæa, 1855, 212; N. leptotheca, Mitt. in Hook. Kew Journ. VIII., 263.
Tarwin and Brodribb Rivers, F. v. M.

N. hymenodonta, C. Muell. in Bot. Zeit., 1851, 564; N. pennata, var. Tasmanica, Hampe in Linnæa, 1852; N. pennata, Wilson in J. Hook. Fl. Tasm. II., 204.
Tasmania, Mossman, Archer.

N. Leichhardti, Hampe & C. Muell. in Linnæa, 1870, 520.
New South Wales, Leichhardt.

Homalia, Bridel.

H. falcifolia, J. Hook. et Wils. in Fl. N. Zeal., t. 92.
Tasmania, Gunn.

Porotrichum, Bridel.

(Camptochæte, Reichardt; Lembophyllum, Lindberg; Cœlidium et Isothecium, J. Hook. et Wils.; Thamniella, Bescherelle.)

P. arbusculum, Hook. (Neckera).
Tasmania, Archer, Gunn, Oldfield.

P. fruticosum, Mitten; P. arbusculo simillimum, sed foliis ovalibus acutioribus et theca in pedunculo elongato pendula dignoscendum.
Tasmania, Gunn.

P. divulsum, J. Hook. and Wils. in Fl. N. Zeal., t. 90.
Tarwin, F. v. M.; Tasmania, Lawrence, Gunn, Archer, Oldfield.

P. deflexum, Mitten in Muscis Stephensonii; Dendro-Hypnum Leichhardti, Hampe in Linnæa, 1876, 523 (probably).
Sealers' Cove, F. v. M.; New South Wales, Leichhardt.

P. vagum, Hornsch. (Hypnum); P. assimile, Hampe; P. Schlosseri, Sendtner.
Richmond River, Henderson; Parramatta, Woolls; Brisbane River, Bailey; Tasmania, Archer.

P. ramulosum, Mitt. in Kew Journ. of Bot. VIII., 253; P. chlorocladium, C. Muell. in Linnæa XXXV., 622.
Steep Bank and Tarwin River, Apollo Bay, F. v. M.; Brisbane River, Bailey; Bellenden Ker's Range, Karsten.

P. clandestinum, J. Hook. et Wils. in Fl. N. Zeal., t. 90.
Sealers' Cove, F. v. M.

P. cochlearifolium, Schw., t. 88 (Hypnum).
Tasmania, Archer, J. Hooker.

P. gracile, J. Hook. et Wils. in Fl. Antarct., t. 61.
Tasmania, Archer.

P. decurvatum, Hampe.
Locality unrecorded.

P. pseudo-pilaceum, Hampe.
Locality unrecorded.

P. orbiculare, Hampe.
Locality unrecorded.

P. Novæ Cambriæ, Hampe.
Locality unrecorded.

Thamnium, Schimper.

T. pandum, J. Hook. et Wils.
Parramatta, Woolls.

T. flagellare, Angstrœm in der Hedwigia, 1875, p. 66.
Australia.

T. eflagellare, Angstrœm in der Hedwigia, 1875, p. 66.
Sydney.

T. pumilum, J. Hook. et Wils. in Fl. Tasm. II., 206 (Isothecium); T. rivale, Mitten.
Tasmania, Archer.

T. perpusillum, C. Mueller.
Australia.

XVI. SEMATOPHYLLEÆ.

Rhaphidorrhynchum, Schimper.

R. Joliffii, Mitt. in J. Hook. Fl. Tasm. II., 213.
Tasmania, Archer.

P. homomallum, Hampe, Icon., 6; Leskea Drummondii, Taylor.
Swan River, Drummond, Preiss; King George's Sound, Cunningham; St. Vincent's Gulf and Sealers' Cove, F. v. M.; Tasmania, Gunn, Oldfield, Hooker.

R. contiguum, J. Hook. et Wils. in Fl. Tasm. II., 213; R. subhomomallum, C. Muell. in Bot. Zeit., 1857, 781.
New South Wales, R. Brown; Brisbane River, Bailey; Lord Howe's Island, M'Gillivray.

R. cerviculatum, J. Hook. et Wils. in Fl. N. Zeal., t. 91.
Tasmania, Archer, Gunn.

R. limatum, J. Hook et Wils. in Fl. Tasm. II., 213.
Tasmania, Lyall, Archer, Oldfield; Gippsland, F. v. M.

R. calidioides, C. Muell. in Linnæa, 1856, 213.
Sealers' Cove, F. v. M., Australian Mosses, pl. XIV.

R. tenuirostre, Hook., Musci exot. 111 (Hypnum).
Tasmania, Gunn, Oldfield.

R. splendidula, Hampe (Leskea).
Locality unrecorded.

Acanthocladium, Mitten.

(Acanthodium, Mitten olim.)

A. extenuatum, Bridel (Hypnum); H. crinitum, J. Hook. et Wils.; Leskea amblyocarpa, Hampe in Linnæa, 1860 (probably).
Bunyip Creek, F. v. M.; Macquarie River, Ball; Tasmania, Archer, Gunn.

XVII. STEREODONTEÆ.

Entodon, C. Mueller.

E. pallidus, Mitt. in Seem. Fl. Vit., 398.
Brisbane River, Bailey; Queensland, Miss Gore.

E. Tasmanicus, Mitten; robustus; caulis quadriuncialis; folia compressa, ovata, acuta, apice serrulata.
Hobarton.

E. Hartmanni, C. Muell. in Rev. Bryol., 1877, p. 4.
Toowoomba, Queensland, Hartmann.

E. Novæ Valesiæ, Hampe.
New South Wales.

E. Myosurella, C. Muell. in Rev. Bryol., 1876, p. 4.
Near Sydney, Kayser.

E. Mackayensis, C. Muell. in Linnæa XXXVII., 155.
Port Mackay, A. Dietrich.

E. Dæmelii, C. Mueller.
Gayndah, Queensland, Dæmel.

Plagiothecium, Bruch & Schimper.

P. denticulatum, Linn. (Hypnum).
Tarwin River and Australian Alps, F. v. M.; Tasmania, Oldfield.

P. lamprostachys, Hampe in Linnæa, 1859, 60 (Platyhypnum).

P. Howeanum, C. Mueller (Hypnum).
Lord Howe's Island, Fullagar and Lind.

Acroceratium, Mitten.

A. auriculatum, Montagne; Hypnum chlamydophyllum, J. Hook. et Wils. in Fl. Antarct., t. 61.
Tarwin River, F. v. M.; Tasmania, Archer.

A. politum, J. Hook. et Wils. in Fl. Antarct., t. 154 (Hypnum); callichroum, Mont. (Phyllogonium); elegans, Hampe (Phyllogonium) in Linnæa, 1855, 212; Mitt. in Kew Journ. Bot. VIII.; Hampeanum, C. Muell. in Linnæa, 1869, 29 (Orthorhynchium).
Sealers' Cove, F. v. M.; Tasmania, Gunn, Mossman, Oldfield.

Isopterygium, Mitten.

I. molliculum, Sullivant in U. S. Explor. Exp., t. 11; C. Muell. in Linnæa, 1871, 160; Hypnum Norfolkianum; H. nitidulum, Hampe et C. Muell. in Linnæa, 1870, 524 (Platyhypnum).
Norfolk Island, Thompson; Lord Howe's Island, M'Gillivray.

I. umbilicatulum, C. Muell. in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.

I. candidum, C. Muell. in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.

I. Walterianum, Hampe in Linnæa, 1876, 322.
Mt. Macedon, Walter.

I. austro-pusillum, C. Mueller in Linnæa, 1872, 159 (Platyhypnum, Hampe).
Brisbane River, A. Dietrich.

Amblystegium, Schimper.

A. riparium, Linné (Hypnum); H. Muelleri, C. Muell. & Hampe in Linnæa, 1853, 504.
Latrobe River and Lake Wellington, F. v. M.

A. uncinatum, Hedwig; Hypnum pseudo-uncinatum, Hampe in Linnæa, 1860, 639.
King George's Sound, Cunningham.

A. decussatum, J. Hook. et Wils. in Fl. N. Zeal., t. 90. (Hypnum).
Tasmania, Gunn.

A. oblongifolium, Hampe in Linnæa, 1860, 641.
South Esk River, Tasmania, F. v. M.

A. fluitans, L. (Hypnum); Hypnum pseudo-fluitans, Hampe.
Tasmania, Gunn.

A. convolutifolium, Hampe in Linnæa, 1859, 641 (Serpenti-Hypnum).
Dargo, F. v. M.

A. fontinaloides, Hampe in Linnæa XXXVII., 518.
Blue Mountains, Mrs. Calvert.

Stereodon, Bridel.

S. chrysogaster, C. Mueller; Hypnum patale, J. Hook. and Wils. in Fl. N. Zeal., t. 90.
Tasmania, Archer.

S. cupressiforme, L. var. minor, J. Hook., Fl. Tasm. II., 212; H. Mossmanianum, C. Muell. in Bot. Zeit., 1851, 565.
Sealers' Cove, F. v. M.; Tasmania, Archer, Gunn.

S. leucochlorum, Hampe in Linnæa XXXVIII., 669.
Lord Howe's Island, Fullagar and Lind.

S. Walterianum, Hampe.
Victoria, Walter.

Ectropothecium, Mitten.

E. Slateri, Hampe in Linnæa, 1876, 321 (Hypnum).
Brisbane River, Slater.

E. Hillianum, Hampe in Linnæa, 1876, 322 (Hypnum).
Queensland, W. Hill.

E. cygnisetum, C. Mueller.
Locality unrecorded.

XVIII. HYPNEÆ.

Fabronia, Raddi.

F. Hampeana, Sonder; Hampe, Icon., 13; F. incana, Taylor.
Swan River, Drummond, Preiss.

F. Australis, Hook., Musc. Exot., 160.
King George's Sound, Menzies.

F. Scottiæ, C. Muell. in Linnæa XXXV., 620.
Ash Island, Hunter River, Mrs. E. Forde.
F. Tayloriana, Hampe in Linnæa, 1870, 522.
Mt. Disappointment, Taylor; M'Arthur's Creek, on Casuarina, F. v. M.

Stereophyllum, Mitten.

S. lepturum, Tayl. (Hypnum).
Swan River, Drummond; King George's Sound, Cunningham.

Rhynchostegium, Schimper.

R. tenuifolium, Hedwig; Hypnum collatum, J. Hook. and Wils. in Fl. Tasm. II., 209; H. Megapolitanum, Hampe in Linnæa, 1855, 213.
Sealers' Cove, F. v. M.
R. subclavatum, Hampe.
Sealers' Cove.
R. antipodum, Hampe.
Locality unrecorded.
R. dentiferum, Hampe in Linnæa, 1859, 60.
Gippsland, F. v. M.
R. patulum, Hampe in Linnæa, 1872, 162.
Gippsland, Walter.
R. laevisetum, Geheeb in Rev. Bryol., 1876, p. 4.
Sydney, Kayser.
R. obtusum, Geheeb in Rev. Bryol., 1876, p. 4.
Sydney, Kayser.
R. latifolium, Geheeb in Rev. Bryol., 1876, 4.
Sydney, Kayser.
R. distractum, Hampe in Linnæa, 1860, 642.
Sealers' Cove, F. v. M.
R. luxatum, Mitt. in Kew Journ. Bot. VIII., 264.
Gippsland, F. v. M.
R. pseudo-stramineum, Hampe in Linnæa, 1872, 518.
Blue Mountains, Mrs. Calvert.
R. cucullatum, Mitt. in Kew Journ. Bot. VIII., 265.
Dargo River, F. v. M.
R. incurvum, Hampe in F. v. M. fragm. XI., suppl. 51 (Hypnum).
Locality unrecorded.
R. Parramattense, Hampe & C. Mueller (Hypnum).
New South Wales.

R. erythropodium, Hampe in Linnæa XXXVII., 161 (Hypnum).
Rockingham's Bay, Dallachy.
R. strumiferum, Hampe in F. v. M., fragm. XI., suppl. 51.
Locality unrecorded.
R. congruens, Hampe in Linnæa, 1858, 643; F. v. M., Austr. Mosses, pl. XIII.
Victoria Ranges, Steep-bank River, F. v. M.
R. glauco-viride, Hampe in Linnæa, 1876, 325.
Rockingham Bay, Dallachy.
R. austro-montanum, Hampe in F. v. M. fragm. XI., suppl. 51 (Hypnum).
Locality unrecorded.
R. pseudo-murale, Hampe in Linnæa, 1859-60 (Hypnum).
Gippsland, Moe Swamp, F. v. M.
R. Pseudo-Teesdalii, Hampe in Linnæa, 1859-60 (Rhyncho-Hypnum).
Gippsland, Broadrib River, F. v. M.
R. muriculatum, J. Hook. et Wils.
Tasmania, J. Hooker, Gunn.
R. trachychaetum, F. v. Mueller, Australian Mosses, pl. XV.,
Victoria, F. v. M.
R. subpungens, Hampe et C. Mueller.
Locality unrecorded.
R. glaucescens, Hornschuch.
Locality unrecorded.

Brachythecium, Schimper.

B. aristatum, J. Hook. et Wils. in Fl. Tasm. II., 210 (Hypnum)
Tasmania, Archer, Gunn.
B. Kayseri, Geheeb in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.
B. Novæ Valesiæ, Geheeb in Rev. Bryol., 1876, 4.
Near Sydney, Kayser.
B. paradoxum, J. Hook. et Wils. in Fl. Antarct., t. 155 (Hypnum).
Gippsland, F. v. M.; Tasmania, Archer.
B. salebrosum, Mitten; B. campestre, Mitten in J. Hook., Fl. Tasm, II., 210, non Bruch.
Tasmania, Archer.
P. rutabulum, L. (Hypnum).
Tasmania, Archer, Gunn, Oldfield.

B. austro-alpinum, Hampe in Linnæa, 1859-60 (Sciuro-Hypnum).
Australian Alps, F. v. M.

Sciaromium, Mitten.

S. glauco-virens, Mitt. in Seem. Fl. Vit., 400.
Norfolk Island.

Hypnodendron, C. Mueller.

(Mniodendron, Lindberg).

H. comosum, Labillardière (Hypnum).
Tasmania, Labillardière; Gippsland, F. v. M.
H. Sieberi, C. Muell., Syn. II., 504.
New South Wales, Sieber; Tasmania, J. Hooker, Gunn, Archer.
H. Colensoi, J. Hook. et Wils. in Fl. Tasm. II., t. 176.
Tasmania, Gunn.
H. Archeri, Mitt. in J. Hook. Fl. Tasm. II., 206.
Tasmania, Archer.
H. arcuatum, Hedwig; H. spininervium, Hook., Musci exot. 29.
Victoria, F. v. M.; Bellenden Ker Range, Karsten.
H. prænitens, Hampe in Linnæa, 1874, 671.
Lord Howe's Island.

Thuidium, Schimper.

T. furfurosum, J. Hook. & Wils. in Fl. N. Zeal. 107 (Hypnum); H. unguiculatum, J. Hook. and Wils. in Fl. Tasm. II., t. 176; H. hastatum, C. Muell.; H. Stuartii, C. Muell. in Linnæa, 1856, 459; H. amblystegioides, C. Muell. in Rev. Bryol. 1876, 4.
Tasmania, Archer; Ash Island, Mrs. Forde; Victoria, F. v. M.
T. sparsum, J. Hook and Wils.
Bellenden Ker Range, Karsten; Logan River, Scortechini; perhaps var. of the preceding.
T. ramentosum, Mitten.
Toowoomba, Hartmann; Brisbane River, Bailey, Logan River, Scortechini; Parramatta, Woolls; Norfolk Island, Thompson; Bellenden Ker Range, Karsten.
T. læviusculum, Mitt. in J. Hook. Fl. Tasm. II., 207.
Parramatta, Woolls.

T. nano-delicatulum, Hampe in Linnæa, 1876, 324.
Illawarra, Johnson; sub-tropical East Australia, Eaves.

T. erectum, Hampe.
Locality unrecorded.

T. suberectum, Hampe in Linnæa, 1860, 638; F. v. M., Austr. Mosses, pl. XII.
Tarwin River, F. v. M.

T. rubens, Hampe & C. Muell.
Locality unrecorded.

T. plumuliforme, Hampe, in Linnæa, 1876, 324.
Illawarra, Johnson.

XIX. SKITOPHYLLEÆ.

Fissidens, Bridel.

F. Muelleri, Hampe in Linnæa 1855, 214 (Conomitrium), et 1860, 644; F. Dillenii, Mitt. in Kew Journ. Bot. VIII., 262.
Murray River, F. v. M.

F. rigidulus, J. Hook. & Wils. in Fl. N. Zeal., t. 83.
Australian Alps, F. v. M., Tasmania, Archer, Gunn, Oldfield.

F. pungens, C. Muell. & Hampe in Linnæa, 1853, 502; F. v. Mosses Austr. M. pl. XVII.; incurvus var., Wilson, in J. Hook. Fl. Tasm. II., 167.
Barossa Range, F. v. M.

F. vittatus, J. Hook. & Wils. in Fl. Tasm. II., 167.
Swan River, Drummond; Tasmania, Gunn; Gippsland, F. v. M.

F. maceratus, Mitten; humilis, flaccidus; folia laxe inserta, ligulato-lanceolata, acuta, integerrima, nervo tenui supra medium laminæ apicalis evanescente prædita; lamina vera æqualis; cellulæ ovali-hexagonæ, pellucidæ; margo limbi angustissimus, fere obsoletus; theca in pedunculo elongato erecta, obovata.
Brisbane River, Bailey.

Caulis 2 mm. altus; folia 2 mm. longa; pedunculus 4 mm. altus.

F. incurvus, Schwægrichen, J. Hook. Fl. Tasm. II., 167.
Tasmania, Gunn, Oldfield.

F. Taylori, C. Mueller; F. pygmæus, Tayl. in Lond. Journ. of Bot. 1846, 66.
Swan River, Drummond; Tasmania, Archer.

F. pacificus, Angstrœm in Œfvers of Kongl. Vetens. Fœrh., 1872-3.
New South Wales, Prof. Anderson.

F. delicatulus, Angstr., Œfvers of Kongl. Vetens. Fœrh. 1872-3.
New South Wales, Prof. Anderson.

F. linearis, Brid., Syn. I., 71.
Australia.

F. semilimbatus, C. Muell. & Hampe in Linnæa 1853, 501.
Yarra; Gippsland, F. v. M., Australian Mosses, pl. XVIII.

F. oblongifolius, J. Hook. & Wils. in Fl. N. Zeal., t. 83.
Tarwin, F. v. M.; Tasmania, Archer.

F. strictus, J. Hook. & Wils. in Fl. Tasm. II., 167.
Tasmania, Oldfield

F. integerrimus, Mitt. in J. Hook. Fl. Tasm. II., t. 171.
Tasmania, Archer.

F. hyophilus, Mitten; monoicus; caulis decumbens, ramosus; folia linealia, obtuseacutata; lamina vera apice subæqualis, immarginata; nervus pellucidus, ante apicem evanidus; cellulæ minutæ, rotundæ, obscuriusculæ, marginales minutissime prominulæ; theca in pedunculo folii longitudinis parva, ovalis, subæqualis; operculum rostratum.
Ranges between the Burnett and Brisbane Rivers, F. v. M. Caulis 5-10 mm. longus; folia, 2 mm. longa; pedunculus 2 mm.; color luteo-viridis.

F. pallidus, J. Hook. & Wils. in Fl. N. Zeal., t. 83.
Tasmania, Gunn.

F. tenellus, J. Hook. & Wils. in Fl. N. Zeal. II., t. 83.
Sealers' Cove, F. v. M.; Tasmania, Archer.

F. perpusillus, C. Muell. & Hampe in Linnæa, 1855, 214 (Conomitrium).
Sealers' Cove, F. v. M., Australian Mosses, pl. XVI.

F. basilaris, C. Muell. & Hampe in Linnæa, 1853, 501.
Barossa Range, F. v. M.

F. macrodus, Hampe in Linnæa, 1860, 645; F. v. M., Austr. Mosses, pl. XIX.
Yarra River, F. v. M.

F. elamellosus, C. Muell. & Hampe in Linnæa, 1855, 214; F. v. M., Austr. Mosses, pl. XX.
Yarra River, F. v. M.

F. Victorialis, Mitten; caulis gracilis, elongatus; folia integerrima, parva, oblongo-lanceolata, acuta; lamina vera apice inæqualis; nervus intus apicem evanidus, obscure fusco-flavus; cellulæ minutæ, rotundæ, limitibus latiusculæ, pellucidæ.

Victoria River, F. v. M.

Caulis 1 centm. altus, cum foliis 1½ mm. latus.

One of the only three mosses seen by me in North-west Australia in 1855 and 1856—F. v. M.

F. Dietrichiæ, C. Muell. in Linnæa, 1871, 146.
Brisbane River, Dietrich.

F. dealbatus, J. Hooker & Wilson.
Tasmania, Archer.

F. Archeri, F. v. M.

F. adiantoides, Wilson in J. Hook. Fl. Tasm. II., 168 non Hedwig.
Tasmania, Gunn, Archer.

XX. POLYTRICHEÆ.

Buxbaumia, Haller.

B. Tasmanica, Mitt. in J. Hook. Fl. Tasm. II., 199.
Tasmania, Archer.

Atrichum, Beauvois.

A. Muelleri, C. Muell. & Hampe in Linnæa, 1855, 211 (Catharinea); A. ligulatum, Mitt. in J. Hook. Fl. Tasm. II., 200.
Dandenong, Apollo Bay, Tarwin River and other places in Gippsland, F. v. M.; Parramatta, Woolls; Tasmania, Archer.

Psilopilum, Bridel.

P. crispulum, J. Hook. & Wils. in Fl. N. Zeal., t. 87.
Tasmania, Archer.

P. Australe, J. Hook. & Wils. in Fl. N. Zeal., t. 87.
Tasmania, J. Hooker, Archer.

P. pyriforme, Hampe in Linnæa XXXVII., 517 (Catharinea).
Blue Mountains, Mrs. Calvert.

Polytrichadelphus, C. Mueller.

P. Magellanicus, Hedw., Sp. Musc., t. 20, f. 1. (Polytrichum, L.); P. innovans, C. Muell. in Bot. Zeit., 1851, 548.
Tasmania, Oldfield, Archer, Mossman.

P. Australasiæ, Hampe in Linnæa, 1876, 315.
Sub-tropical East Australia, Eaves; Richmond River, Capt. Stackhouse.

P. Arnoldi, Hampe.
Mount Arnold, Upper Yarra, and Goulbourne River, F. v. M.

Pogonatum, Bridel.

P. alpinum, L. (Polytrichum); P. austro-alpinum, F. v. M.; P. pseudo-alpinum, C. Muell. in Bot. Zeit., 1853, 750.
Cobberas Mts., Australian Alps, F. v. M.; Tasmania, Archer.

P. Gulliveri, Hampe in Linnæa, 1876, 315.
Mt. Wellington, Tasmania, Gulliver.

Polytrichum, Dillenius.

P. commune, Linne, sp. pl. 1109.
Victoria, F. v. M.; Tasmania, Gunn, Archer.
Var. perigoniale.
Cobberas Mts., F. v. M.

P. Novæ Hollandiæ, Jæger, I., 732; P. densifolium, Hampe in Linnæa, 1860, 635.
Mount Wellington, F. v. M.

P. juniperinum, Hedwig, Spec. Musc., 89.
Victoria, up to the highest Alps, F. v. M.; near Melbourne, Adamson; Mt. Wellington, Tasmania, Mossman, Archer.

P. Sullivani, Hampe in Linnæa, 1876, 316.
Between Mt. Ararat and Mt. William, Sullivan.

Dawsonia, R. Brown.

D. superba, Greville in Ann. and Mag. of Nat. Hist., 1847, 226, pl. 12.
N. S. Wales; Dandenong, Upper Yarra, Sealers' Cove and many other places in Gippsland, F. v. M.; Tasmania, Archer.

D. polytrichoides, R. Brown.
Near Port Jackson, R. Brown; Parramatta, Woolls.; Brisbane River, Bailey; Ash Island, Mrs. Forde.

D. longiseta, Hampe in Linnæa, 1860, 634; F. v. M., Austr. Mosses, pl. IX.
Parramatta, Woolls; Brisbane River, Bailey.

D. appressa, Hampe in Linnæa, 1858, p. 635; F. v. M.; Australian Mosses, pl. X.
Onkaparinga Valley, St. Vincent's Gulf, F. v. M.

XXI. SPHAGNEÆ.

Sphagnum, Dillenius.

S. confertum, Mitt. in J. Hook. Fl. Tasm. II., 163.
Tasmania, Archer.

S. Australe, Mitt. in J. Hook. Fl. Tasm. II., 163.
Tasmania, Archer.

S. cymbophyllum, F. v. M., second gen. rep., 1854, p. 17; S. cymbifolioides, C. Muell. in Bot. Zeit., 1851, 546 (nomen vix servandum) et forsan S. contortum, Wilson in J. Hook. Fl. Tasm. II., 162.
Australian Alps, F. v. M.; Tasmania, Gunn, Archer. Oldfield.

S. molliculum Mitt. in J. Hook. Fl. Tasm. II., 163.
Tasmania, Archer.

S. Novæ Zealandiæ, Mitt. in J. Hook. Fl. Tasm. II., 163.
Tasmania, Archer.

S. cristatum, Hampe.
Australian Alps, F. v. M.

S. compactum, Bridel.
Tasmania, Oldfield.

S. subcontortum, Hampe in Linnæa, 1876, 301.
Mount Warning, Guilfoyle.

S. cymbifolium, Dillenius.
Gippsland, F. v. M.; Brisbane River, Bailey; Tasmania, Gunn, Archer, Oldfield.

XXII. ANDREÆÆ.

Andreæa, Ehrhart.

A. subulata, Harvey in Hook. Icon. pl. rar. II., 201.; A. pseudo-subulata, C. Muell. in Bot. Zeit., 1864.
Tasmania, Archer.

A. Australis, F. v. M.; Mitten in Kew Journ. Bot. VIII., 257.
Munyang Mountains, Mt. Wellington and other places high in the Australian Alps, F. v. M.

A. montana, Mitt. in J. Hook. Fl. Tasm. II., 161.
Tasmania, Archer.

A. nitida, J. Hook. & Wils. in Fl. Antarct., t. 53.
Tasmania, Archer.

A. asperula, Mitt. in Journ. Linn. Soc., 1859; A. Muelleri, Sonder.
Australian Alps, F. v. M.

A. petrophila, Ehrhart Beitr. I., 192.
Tasmania, Archer, Gunn.

A. acuminata, Mitt. in Journ. Linn. Soc., 1859.
Tasmania, Archer.

ART. IV.—*Electric Lighting.*

BY R. E. JOSEPH.

[Read 11th May, 1882.]

A FEW months back, in a paper read before you, I briefly reviewed the progress and improvements that had taken place in electric lighting, and then promised to lay before you, at a future time, further information on the subject. In my former paper I gave you an account of the principal machines used in generating currents, of the lamps in use, and the adaptation of different systems for various requirements. Since then certain changes that have taken place, not so much in the construction of the apparatus as in the methods of using them, have necessitated a slight alteration in my views on the matter. Commencing with generators of the current, the battery appears to have remained in exactly the same position as before, and I am not aware of any improvements having been made in any of the numerous forms, to render it a useful agent for electric lighting. In dynamo-machines the principle of construction remains the same; very little, if anything, has been done to render the machines more efficient. As a proof of this, the Siemens, Gramme, and Brush, which were spoken of as giving the best results, still hold the foremost position amongst the now numerous descriptions of machines. The original Siemens machine gives now, as before, a very high per centage of useful work per horse-power, followed, however, very closely by the Gramme. Since my former paper some twenty or thirty new descriptions of dynamo-machines have been introduced, but a very slight examination shows that they are all constructed on either the Siemens or Gramme principle, and that if they possess any advantage over them, it is, in most cases, in mechanical details, such as simplifying their manufacture, reducing the tendency to over-heating, and arrangements of certain parts to facilitate cleaning, &c. There are, however, one or two exceptions in which a very high amount of efficiency has been obtained, with the use of less wire on the revolving coils than usual; this extra efficiency being gained by the methods of arranging the coils, and also by placing nearly the whole of the wire in the magnetic field. Amongst the most prominent and successful of these modifications are the Weston, Burgin, and Schukert machines. The Weston has a Siemens armature, but contains half the number of coils on its circumference, the place of the wire being taken by soft iron, and the wire itself laying in a channel surrounded by soft iron, has its inductive effects considerably augmented. The Burgin is a combination of the Siemens and Gramme. The revolving bobbin is long,like the Siemens, but it is built up of a series of rings, wound something like the Gramme, and connected together. The Schukert is a Gramme ring, but exposes nearly the whole of the wire in the magnetic field. Dynamo-machines are now required, giving two different kinds of current—low tension for single, and high tension for multiple arc lights. The low tension is of course easily attainable, large wire and low speed, giving a very large current of very low tension. The most remarkable description of machine of this kind is Edison's, the armature being built up of bars of copper, having practically no resistance whatever, driven at a speed of 350 revolutions per minute, it is stated it will supply sufficient current to maintain 1000 incandescent lamps of about seven candle-power each, all joined up of course in parallel circuit.

To obtain currents of high tension is not so easy. With the present system of generating currents, it is attained by either decreasing the size of the wire on the bobbins and increasing the number of convolutions, or by increasing the speed of rotation. In the first instance the trouble of heating and destroying the coils makes its appearance, and in the second the difficulties of mechanical construction—that of making the revolving bobbin in such a form as to be perfectly secure, and to prevent the wire flying off when revolved at very high speeds. Consequently, up to the present time, the highest tension current machine made is that of Brush, capable of supporting forty arc lights on one circuit.

The armature is a modification of the Gramme ring, and contains a very large quantity of wire wound in spaces cut out of the iron ring. Special precautions are taken to prevent cross-currents being generated, and for keeping the armature cool. The wire coils pass very close to the pole-pieces of the field-magnets, the very excellent workmanship shown in the construction of the machine enabling this to be done with safety. The commutator is so arranged as to supply a current to excite the field magnets without passing into the outside circuit, whilst it also cuts out all coils that are not used in generating a current, thus reducing the resistance of the machine. In other machines the same end is obtained by using a separate machine to excite the field-magnets of the generator; this, whilst keeping the field-magnets in perfectly uniform condition, lowers the resistance and increases the electro-motive force to a considerable extent. The question, however, arises as to the advisability of using machines of high tension. Looking at electric lighting as a thoroughly practical means for illumination, it appears certain that it will be necessary to maintain a considerable number of lights on one circuit. I refer now to arc lights. The difficulties I mention do not apply to the same extent to the incandescent lamp. In the earlier days of electric lighting, where instalations were used in certain buildings only, lights fed from single machines were found convenient, and unquestionably the most economical for very powerful lights. When, however, the method of lighting from a central station and supplying a very great number of lights distributed at various distances from the generator had to be determined, it became evident that it would be impossible to carry it out by the same system. The immense number of conductors required would alone be sufficient to condemn it, apart from the cost of attendance to the number of machines that would be in use. Therefore, systems capable of supporting a number of lights from one machine rapidly gained public favour, and the system that could support the greatest number of lamps in the same circuit has commercially been the greatest success. But has this advantage been gained in a right direction? and if the present system be adhered to, does it not amount to either a limit to the number of lights to be used or the introduction of machines which for safety to human life are hardly to be desired. The original dynamo-machines constructed to generate low tension currents are perfectly harmless, the current may be conducted by imperfectly insulated conductors, as in the instance of the Berlin electric railway, where the iron rails laid on wooden sleepers are the only conductors used, and they answer perfectly even in

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wet weather. A person coming in contact with the wires or any portion of the apparatus might, and probably would, detect the presence of a current, but that is all; so that for safety and facility for conducting the current, the low tension was all that could be desired. But then it became clear that if a considerable distance intervened between the lamp and the machine, a very large conductor became necessary, whilst if more than one light was required on one circuit, the low tension current failed to support them. Consequently the tension of the current was increased in proportion to the number of lights required to be maintained, or for the distance the current had to pass between the machine and lamp, and attended with the usual characteristics of currents of this nature.

The insulation of everything in connection with the circuit has to be most carefully attended to; and such insulation requires to be of a very high nature, or failures must occur. The recent failures of the Brush system in London, Edinburgh, and elsewhere, have all been traced to imperfect insulation of the circuit, and if it has been found difficult and expensive to provide a perfect insulation for a current supporting from 30 to 40 lights, those who are familiar with the behaviour of high tension currents will at once realise the state of affairs, if machines were made to support, say, even 100; and with the difficulties of insulation comes the dangers from fire, and loss of human life. With a badly insulated conductor from such machines, fires have occurred undoubtedly; whilst there have also been several instances recorded of fatal accidents occurring through the same cause, and although, by taking careful precautions, the risks of mishaps may be reduced to a minimum, they are always liable to occur, and with any increase in the tension of the current, probably would constantly occur. It would therefore appear that machines capable of supporting, say, from ten to fifteen powerful arc lights, are the largest that should be used, both for safety and certainty in working, as long as high-tension currents are required for such purpose. This would therefore point to the conclusion, that, for successful and commercial electric lighting, we should look in another direction, even if we have to re-arrange the whole of our present system of working.

Since writing this I have come across a paper read by Mr. Swan, before the Royal Institution, and printed in *Engineering* for March, and in which the following paragraph appears :—" Can electricity be distributed as widely and cheaply as gas ? On one condition, which I hope can be complied with, this may be answered in the affirmative. The condition is that it be found practicable and safe to distribute electricity of comparatively high tension."

It will thus be seen that Mr. Swan assumes that a high-tension current is absolutely necessary for an extended and economic distribution of the current, and with our present method of working, there is very little doubt that his views are correct. I am, however, of opinion that, instead of endeavouring to perfect any system which requires for its success the employment of such currents, we should turn our attention to obtain the required results by the safe and easily worked low-tension current.

Respecting arc lamps, I have little to add to my former remarks. Their construction has been considerably simplified, and by this means several difficulties formerly experienced in their working have been removed.

The specimens before you this evening are the "Siemen" pendulum and differential lamp, fitted with Dr. Siemen's abutment pole, for burning from fourteen to nineteen hours; the "Brush," double rod, burning sixteen hours; and the "Weston" lamp, slightly modified and manufactured in the colony. The last two lamps contain no wheel work or delicate mechanism to feed the carbons, the regulation being effected solely by electro-magnets so arranged that the proper length of arc is maintained by means of a shunt of fine wire placed in circuit between the two carbons, and acting in an opposite direction to the main wire coils. The arc light remains as before the most economical means of illumination for large spaces, a light of about 3000 candle-power being maintained by an efficient dynamo-machine, and driven by a gas-engine consuming about sixty feet of gas per hour, or as much as would suffice for the support of from twelve to fifteen gas-jets for the same period, and when it is borne in mind that gas costs three times as much as coal for an equivalent amount of power, the economy of the arc light becomes at once apparent. The Jablochkoff candles still maintain a prominent position in electric lighting on the Continent; but beyond lighting part of the Thames embankment, London, the system does not appear to have made much progress in England. Semi-incandescent lamps also do not make very much headway. One that has been prominently before the public for some time is the Joel incandescent lamp, and consists of a slender pencil of carbon, the point of which impinges on a copper button. The success it has met with is not due to the principle, which is old, but to the thought and care bestowed in carrying out mechanical details of construction in rendering the lamp certain and automatic in its action.

The use of powerful currents demands a special system of testing. The ordinary methods adopted for battery-testing cannot always be conveniently used, although of course they are the most reliable; but as all of them would involve the use of shunts and a very delicate apparatus, special galvanometers or dynamometers have been introduced, which give fairly approximate measurements. Siemen's dynamometer consists of a coil of wire through which the powerful current is sent, and passes by means of mercurial contacts through a rectangular frame of stout copper wire, suspended by a spiral steel spring at right angles to the wire coil. The instrument being set at zero, the current will deflect the wire-frame, the opposing force being the torsion of the spiral spring. The angle of torsion through which the spring has to be moved in order to bring the wire frame to its zero point, can be read off on the dial, and its value having been previously determined by experiment and a table prepared, the amount of current in ampères flowing through the instrument can at once be ascertained. The accuracy of this instrument depends entirely on the stability of the spiral spring; and in order to render it as stable as possible, it is made of finely tempered steel wire and then gilded.

The absence of permanent magnets in this instrument renders it of use for measuring alternate currents, for which purpose another coil of thinner wire is provided. Another form of galvanometer, lately introduced by Professors Perry and Ayrton, is a modification of the Desprès galvanometer, in which a very small compound magnet needle is placed in the field of a powerful permanent horse-shoe magnet. The needle is also in the centre of a small wire coil, constructed of a strand of ten wires, and so connected with a commutator that the current can be either sent in parallel circuit —that is, with the wires joined together at each end, and representing a short and thick wire—or in series, which would be the wire joined in continuous circuit, of one-tenth the size, but ten times as long as in the former case.

The action of this galvanometer renders the needle perfectly dead beat, returning to zero quickly, whilst the proportions of the instrument are so arranged that the amount of current passing can be read off in ampères without the aid of tables, and by the double arrangement of the wire-coil the galvanometer is ten times more sensitive when joined up in series than in parallel circuit, thus rendering the instrument available for the measurements of small currents. Perry and Aryton's galvanometer has the advantage of being portable, and is sufficiently accurate for ordinary testing or ascertaining the amount of current passing through an electric light circuit. It is particularly valuable in incandescent systems, because it becomes absolutely necessary to keep the current constant and steady, and with such a galvanometer in circuit, any alteration in the current strength can at once be seen. For a temporary instalation of the electric light, and where an engine not specially adapted for driving dynamo-machines is used, the galvanometer, if placed near the engine-driver, serves the purpose of an auxiliary governor. The engine-driver watches the galvanometer needle, and having been directed to keep it at a certain position, increases or diminishes the speed of the engine according to any alteration in the galvanometer. This method answered perfectly well recently at a lecture given at home, the steady working of the Swan lamps shown there being entirely governed by the above arrangement.

In my former paper I spoke with great distrust of Edison's attempts at incandescent lamps. I felt justified in the remarks then made, because really nothing but failures had been recorded against him. Since then he has unquestionably achieved a success, and produced an incandescent lamp, which is stated to be quite equal to that of Swan. The specimens of lamps before you are the "Original" and "New Swan," the "British," and the "Maxim." These lamps are similar in construction—a fine carbon loop in an exhausted and hermetically sealed glass bulb. The Swan carbon is prepared from ordinary crotchet cotton, treated with sulphuric acid and carbonised. The Maxim is made out of cardboard. Edison's is constructed from bamboo fibre, so that they may all be classed as the same—all being converted into carbon. But whilst their construction is apparently the same, their behaviour and endurance differs slightly. Thus the old Swan lamp should not be pressed beyond fifteen to twenty candle-power, when it will last about 600 hours. The new form has lasted over 1000 hours. The Edison lamps must not be pressed beyond seven candle-power, whilst the Maxim ranges from twenty-five to eighty candle-power, absorbing, of course, a larger, but not proportionately larger, amount of current. The incandescent lamp, whilst not being nearly so economical as the arc light, possesses advantages that would more than compensate for this deficiency. It may be accepted, I think, as a fair average that about 200 candle-power per horse-power can be obtained from incandescent lamps, everything being in its highest state of efficiency; but it probably will be found with respect to endurance that from 120 to 150 would produce the most economical results. Probably one of the most peculiar features about the carbon loop is the alteration in its resistance when heated. It is of course well known that increase of temperature in metals increases their resistance; with the carbon loop it is different, increase of temperature reducing the resistance to a remarkable degree, in some cases as much as 60 per cent. A Swan lamp with a resistance of 65 ohms when cold, will only have a resistance of about 37 when heated to incandescence. The current necessary to maintain a Swan lamp of about fifteen candle-power is 1·25 ampères, with an electro-motive force of forty volts. It will thus be seen that certain arrangements have to be made in placing a number of incandescent lamps in circuit. They are arranged usually as parallel, compound parallel, and in parallel series circuit, according to the resistance of the lamps and the machine supplying the current. No difficulty need therefore be experienced in working any number of incandescent lamps from very large dynamo-machines of low tension.

For purposes of regulation, two or three methods present themselves as being efficient—by interposing a high resistance in the leading circuit, by alteration of the position of the brushes on the commutator of the machine, or by interposing a resistance in the circuit of the field-magnets when a separate exciter is used. By this means less power is absorbed, and, consequently, it is the most economical.

Incandescent lamps can be supported by either continuous or alternate currents, by either high or low tension, so that almost any kind of machine can be adapted to them.

That the successful introduction of incandescent lighting will cause a revolution in ordinary systems of illumination is now, I think, quite evident. Even in its present stage incandescent lighting has commenced to play an important part, and is being rapidly introduced for lighting places of amusement, churches, and large establishments, whilst nearly every modern steamship has been, or is being, fitted up with one of the systems.

With respect to the economy of the incandescent lamp, I think it can be shown that even at the present time the cost of producing an equal amount of illumination will not exceed that of gas.

A ton of coal will, I believe, produce 10,000 cubic feet of gas—enough to supply 2000 good gas burners for one hour. A ton of coal burnt in the steam-engine will produce 748 horse-power and will support 7460 incandescent lamps of the same power as the gas burner for the same period of time. I have only estimated the horse-power at 3 lbs. of coal per hour, but in an extensive system of lighting to take the place of gas the amount of coal used per horse-power would not be so much. I think on board some of the large steamers from 1½ to 2 lbs. of coal per horse power per hour is all that is used; but, as in the manufacture of gas the residue of the coal yields products of great value. I have quoted the larger amount as a set off.

The cost of manufacture, wear and tear, &c., should not be more in the one case than the other; whilst the distribution would be in favour of the electric lamp; whilst the cost of renewals would not amount to anything like the difference shown to exist between the two systems.

Taking another example. Twenty-five cubic feet of gas will produce one horse-power in a gas-engine for one hour, and thus support ten incandescent lamps; whilst the same amount of gas burnt would only suffice for five burners of equal illuminating power. I have not in this paper treated on the subject of secondary batteries or accumulators, neither having spare time to make any experiments in this direction, nor information of a reliable nature to show that their use in electric lighting has been extended beyond the lecture-room or for experimental work.

ART. V.—*Experiments upon the Hardwoods of Australia.*

A compilation by F. A. CAMPBELL, C.E.

[Contributed 11th May, 1882.]

THE strength, durability, and other properties of the colonial hardwoods is a subject involved in considerable obscurity. This arises from the small number, and the fragmentary nature of the experiments yet made, the incompleteness of the records, the great diversity of results where uniformity was to be expected, and the want of exactness in the designation of the various timbers tested.

Notwithstanding that the experiments are few in number, and many of these incomplete, it might, I think, be a work of some interest and service, a work, moreover, which as far as I know, has not yet been attempted, to collect and compare the records of those experiments which have been made up to the present time, to note the conditions under which they were carried out, and to place in a convenient form for reference mean results derived from the whole of the observations.

Such a work would establish an index and starting-point for those who might wish to follow up the subject, and would furnish engineers, architects, and others with at least approximate values for many of the properties of the various timbers tested. To accomplish this in a concise form, and as far as the data which I have been able to collect will permit, has been my aim and desire in writing this paper.

The useful hardwoods of Australia belong almost entirely to the Eucalypt family, and to this fact is due much of the difficulty in affixing the true names to the timbers procured for the purpose of experiment; for not only do many of the varieties greatly resemble one another, and bear in consequence the same popular name, but the same variety is frequently so altered by the influence of locality, that it goes by many different names.

This of course causes much confusion, and detracts greatly from the value of those experiments, where the true botanical names have not been supplied. There is now, however, being issued from the press a work which should do much to rectify this. The *Atlas of the Eucalypts,* by Baron F. von Mueller, supplies a want long felt, and supplies it in a manner eminently worthy of the genius and learning of the author.

I will now proceed to notice the different series of experiments which have been made upon colonial timbers up to the present time, and to which I have had access.

Fowkes.—These were experiments made by Colonel Fowkes upon timbers sent to the International Exhibition of 1862. A great variety of woods from the different colonies came under his notice. The experiments upon them are numerous and very fully recorded. Specific gravity, crushing weights along and across the fibre, elasticity, and transverse strength were tested. The scantlings were 12 inches between bearings and 2 inches square, 1-inch cubes being used for crushing weights.

This is the most extensive series of experiments yet made upon colonial timbers, but its value is considerably diminished, from the fact that the botanical names of the trees furnishing the specimens have not been given.

Sydney Mint, 1858.—These are taken from May's *Australian Builders' Price-book.* They were carried out by the Commissioner of Railways, four experiments being made upon each of four different kinds of woods. The scantlings were 4 feet between the bearings and 1¾ inches square. Transverse strength only was tested, and no botanical names are furnished.

Sydney Mint, 1861.—This series was carried out by Colonel Ward, and a very full report furnished to the Parliament of New South Wales. A wide variety of the timbers of New South Wales and Queensland are noticed, information being appended as to the locality, size of tree, and uses to which the timber is put. The botanical name is also given in many instances. The scantlings were 4 feet between bearings and 2 inches square. Specific gravity, elasticity, and transverse strength were tested, and a valuable series of experiments is the result.

Victorian Railway Department, 1865.—These were carried out at Sandhurst, Victoria, and are entirely devoted to red-gum timber. Altogether, nine experiments were made upon scantlings of unusual size—viz., 14 feet 8 inches between bearings—the breadth and depth ranging from $10\frac{1}{4}$ inches by 7 inches to $11\frac{1}{2}$ inches by $8\frac{1}{2}$ inches. The specific gravity, elasticity, and transverse strength were tested, very full particulars as to the deflection being given. These experiments are of great value, on account of the large size of the pieces tested.

Tredgold.—These are taken from Tredgold's *Carpentry*, edition of 1875. The information is stated to have been furnished by Mr. Josiah Atwool, at one time resident in New South Wales. The information refers to the specific gravity and transverse strength of three timbers only, no particulars being given as to how the experiments were carried out.

Laslett.—Mr. Laslett is the author of a work termed *Timber and Timber Trees*, and, when this was written, was timber inspector to the Admiralty. This work is one of the most valuable treatises devoted to timber yet published. In it the author discusses a very great variety of British and foreign woods, and gives details of numerous experiments which he has carried out. Many of the colonial timbers come under his notice, and he applies to them in most cases their true designation. Four to six experiments were made on each variety, the scantlings being 6 feet between bearings and 2 inches square for transverse, 2 inches square for tensile, and various-sized cubes for crushing tests. The specific gravity, elasticity, tensile, transverse, and crushing strengths were tested. Where comparison can be made, the results arrived at by Mr. Laslett are very generally in accord with those of other experimenters, tensile strengths excepted, for which he gives much lower values. The length of the pieces tested for transverse strength is stated to have been 7 feet, but only 6 feet between bearings. Now, in calculating the values of E. and S., Mr. Laslett has unfortunately taken the length as 7 feet, thereby arriving at incorrect conclusions. This is to be regretted, as the error is embodied in the tables, to which one naturally turns for information of the kind. Observing this discrepancy, I have calculated afresh the values of E. and S. for all cases to which I have found it necessary to refer.

Mueller.—These experiments are taken from the *Eucalyptographia.* They were carried out by Baron von Mueller and Mr. Luehmann. The scantlings were 2 feet long and 2 inches square. The specific gravity, elasticity, and transverse strength were tested for twelve different species.

Of course, the various timbers are properly designated; and it is to be hoped that these gentlemen will be able to extend their labours in this direction, as their work derives so much value from the perfect identification of the timbers in hand.

Mitchell.—These experiments were made upon blue-gum timber only; the records being taken from Mueller's *Eucalyptographia.* The scantlings were 7 feet long and 2 inches square. The specific gravity, elasticity, transverse and tensile strength were tested, and the period of seasoning which each piece had undergone is noted.

Campbell.—These were tensile tests only, made by the writer upon nine of the colonial woods, a report of which was read to this Society in May, 1879. The sectional area was from one-sixteenth to one-eighth of an inch. The results obtained are much higher than those of Mr. Laslett, but correspond closely enough with those of Mr. Mitchell, and the quotations in Rankin and Molesworth.

Hurst, Rankin, and Molesworth also give values for different properties of some of the woods, but as these have in all probability been derived from some of the experiments already noticed, I have not made use of them.

In recent numbers of the *Australian Engineering and Building News*, to which I have contributed some papers on the subject, will be found details of the experiments which have here been mentioned. I will in this paper only give in a condensed tabular form, the mean results of the whole, noting opposite to each the names of the experimenters, and by means of the figures under each name, indicating the particular work done by them. The table is arranged in order of the transverse strength of the timbers mentioned.

Species of Timber.	1 Specific gravity.	2 Crushing weight per square inch.		3 E. from forml. $E=\frac{l^3 w}{16 ad^3 \delta}$	4 Modulus of Rupture.	5 Tensile strength per sq. inch.	Authority.
		Longl.	Transverse.				
1. IRONBARK—(*E. Leucoxylon and E. Siderophyloia*)	1·117	10,166	4,100	488,066	18,258	15,950	S. Mint. 1-3-4. Tredgold. 1-4. Fowkes. 1-2-3-4. Campbell. 5. Laslett. 1-2-3-4-5.
2. TUART—(*Eucalyptus Gomphocephala*)	1·169	9,340	..	447,700	13,890	10,284	Laslett. 1-2-3-4-5.
3. BLACKBUTT—(*E. Pilularis*)	·990	8,449	8,064	313,600	13,529	..	S. Mint. 1-3-4. Fowkes. 1-2-3-4.
4. BLUEGUM—(*E. Globulus*)	1·017	7,730	6,600	509,750	13,140	20,100	Mitchell. 1-3-4-5. Laslett. 1-2-3-4-5. Mueller. 1-3-4. Tredgold. 1-4 Fowkes. 1-2-3-4. Campbell. 5.
5. YELLOW BOX—(*E. Melliodora*)	1·017	..	..	472,605	12,312	..	S. Mint. 1-3-4. Mueller. 1-3-4.
6. BLOODWOOD—(*E. Corymbosa*)	·918	..	..	399,450	11,970	..	S. Mint. 1-3-4.
7. SPOTTED GUM—(*E. Goniocalyx*)	·981	9,072	7,308	322,900	11,943	..	S. Mint. 1-3-4. Mueller. 1-3-4. Fowkes. 1-2-3-4.
8. STRINGYBARK—(*E. Macrorrhyncha*) ..	·995	7,744	6,650	231,850	11,656	22,000	S. Mint. 1-3-4. Mueller. 1-3-4 Fowkes. 1-2-3-4. Campbell. 5.
9. KARI—(*E. Diversicolor*)	·980	12,513	..	568,620	11,640	7,070	Laslett. 1-2-3-4-5.
10. WOOLYBUTT—(*E. Longifolia*)	1·054	7,297	2,968	285,995	11,524	..	S. Mint. 1-3-4. Fowkes. 1-2-3-4.
11. REDGUM—(*E. Rostrata*)	·990	..	..	433,000	10,250	16,400	Vict. Ry. Depart. 1-3-4. Mueller. 1-3-4. Campbell. 5.
12. JARRAH—(*E. Marginata*)	1·007	7,166	..	177,690	9,250	2,940	Laslett. 1-2-3-4-5.

I have also compiled a table in which is given what might be termed safe practical moduli of rupture for six of the principal hardwoods of the group. This I have made up from the different series of experiments, giving them values in accordance with their comprehensiveness and completeness, and then making certain deductions to ensure being upon the safe side. I have confidence that the results present fair average values for the transverse strength of the timbers named; that they err, if at all, in being below the mark; and that they are sufficiently sure data for all calculations for purposes of construction.

Timber.	Moduli of Rupture.
1. Ironbark	16,000 lbs.
2. Bluegum	11,000
3. Yellow box	10,000
4. Spotted gum	10,000
5. Stringy-bark	9,000
6. Redgum	8,000

Tamworth, N.S.W., October 31st, 1881.

Art. VI.—*Floods on the River Barwon.*

By W. C. Kernot, M.A., C.E.

[Read 8th June, 1882.]

Having been prevented by circumstances of a very painful and urgent nature from taking part in the discussion upon Mr. W. W. Culcheth's paper upon the above subject, I venture at this comparatively late period to submit my views upon a question which all will admit to possess the highest practical importance.

The due proportioning of the waterway of bridges is a question of vital moment to the railway, road, or hydraulic engineer. If the waterways are made needlessly large, the waste of money may be most serious; if they are unduly small, as I maintain them to have been at Geelong, disasters of unparalleled magnitude may be the result. The problem that has been presented at Geelong will recur from time to time as our railways and roads extend, and the damage to property, in the event of insufficient waterway being provided, will increase indefinitely as population becomes denser, and the margins of our rivers become fringed with mills and factories and dwellings. Hence it is of the highest importance that a proper scientific system of dealing with the question should be adopted generally by the profession.

The enquiry before us is this, was the department's design for the Barwon Bridge right or wrong, sufficient or insufficient, and was the flooding of the Woollen Mills independent or not of the presence of the railway works? The former view was strenuously maintained by the Government witnesses at the trial, including amongst their number the gentleman at present occupying the honourable and important position of Engineer in Chief of Victorian Railways. The latter is Mr. Culcheth's opinion and my own.

Without going into the arithmetical details, I would say at the outset, that my own calculations, made prior to the publication of Mr. Culcheth's results, agree very closely with his conclusions as to the discharge of the river, and the extent to which the water rose in the mills above what would have been its level had the railway works not been in existence. This latter amount is given by him as 3.70 feet, and by me as 3.50 feet.

In order to verify this result as far as possible by direct experiment, a model was made representing, to scale, the bed and valley of the river for a distance of about a mile and a half above and below the railway works, and corresponding in this respect with Mr. Culcheth's lithographed section. Water was caused to flow over this model until a flood was produced, corresponding with the actual flood marks of 1880. The railway works made in a separate piece were then removed, and the water fell through a height of 4 feet, according to the scale of the model. On replacing the wooden representative of the railway bank, the water rose again to its original position. The experiment was repeated a considerable number of times with identical results, and taken in conjunction with the calculations, establishes most conclusively the truth of the proposition, that had the railway bank not been in existence, the water in the factories would have been from three to four feet lower than it actually was. An inspection of the water as it flowed over the model threw important light on some points of difficulty. For example, the comparatively high water level at Haworth's Tannery, which is on the downstream side of the bridge, had been a source of a little perplexity, but on the model the true constriction and most rapid fall of the water was seen to be *not under the bridge itself, but on a line drawn from the south end of the bridge to the south-west angle of the tannery.* The width of the stream at this point is *less than half* the length of the bridge. Another point of interest that presented itself was the marked effect of the piles of the bridge in breaking up the stream and retarding the flow.

I propose to criticise in detail the departmental mode of dealing with the problem, and also various statements made at the trial by the departmental witnesses, and which I conceive to be erroneous and unscientific.

The first noteworthy point is the serious error that occurred in determining the high flood level of 1852. This was at the time of constructing the works fixed at 16.53 feet above datum, but on the trial commencing, the old value was abandoned and 19.85 substituted. The ease with which evidence was obtained for this latter value, leads to the conclusion that but little care was taken at the earlier date to obtain a reliable height. Further, it is to be noted that the flood mark of 1852 was well known at Collins' Mill, 1½ miles higher up the river, and that a calculation based upon this and the 16.53 flood mark, leads to a discharge of enormous magnitude, many times greater than the part of the valley lower down could possibly carry away without the water rising to a level far higher than 16.53. In view of the accessible and highly reliable flood mark at Collins' Mill, the 16.53 flood level is physically impossible. Had the above-mentioned calculation been made when the works were being first laid out, a most serious error would have been detected.

Next it was reiterated that, however the case might be with a 19.85 feet flood, that the railway works provided ample waterway for a 16.53 feet one. Now I would most emphatically endorse Mr. Culcheth's opinion, that it is impossible to determine waterway by reference to high flood mark alone. It is absolutely necessary that discharge should be also determined, and this it seems was never ascertained by the officers of the department. Calculating the discharge from the Collins' Mill flood mark and the 16.53 level at the railway, the result is found to be no less than 180,000 cubic feet per second. But the openings provided at the railway have an effective area up to a level of 16.53 of less than 5000 square feet. Dividing 180,000 by 5000 we find that to discharge the flood the water must pass through the openings at the incredible velocity of *36 feet per second,* or more than 20 miles per hour. To produce this velocity a heading up of *20 feet in height* would be needed. Had the railway engineers made this simple calculation when designing the bridge, one of two results must have happened—either they would have enlarged the waterway at least four-fold, or they would have rejected the data upon which the computation was based, and sought further information.

If we abandon the Collins' Mill flood mark, and take the 16.53 flood level at the railway as the only datum, it is not possible to make any calculation at all, as no velocity can be ascertained. However, an experiment upon the model before-mentioned showed that when the water stood at 16.53, at the Breakwater it was about level with the flow of the Victoria Mill, 17.30, and that if the railway bank were then inserted the water rose to 20 at the mill, flooding it to a depth of 2.70 feet. In view of this experiment and the preceding calculation, I must dissent most emphatically from the statement of the railway engineers, that the bridge was correctly designed in view of the data supplied by the field officer.

In the evidence given on the side of the department, it was repeatedly asserted that the railway works gave about double the waterway of the large road bridge in the vicinity, and the waterway was stated to be 735 and 390 lineal feet in the two cases respectively. Upon this comparison the opinion of the railway engineers as to the sufficiency of their works appears to have been based. But the comparison is altogether erroneous. In the first place it is tacitly assumed that the road bridge was large enough, whereas experience proves that it is not, a portion of the flood escaping over a low part of the approaches. Next the 735 feet includes the Waurn Ponds Creek Bridge 135 feet long, and as this creek is a totally distinct stream from the Barwon, it is manifestly quite unfair to include it. Thirdly, the bridge over the main stream, though really 600 feet long, is placed in so peculiar a position as to leave only 290 feet between its south end and Haworth's Tannery, through which the whole stream has to pass, and this 290 feet is so surrounded by obstructions in the way of piles, iron rods, walings, braces, stanchions, and chains, also a great bed of reeds, and several dead trees, that I fail to see that it is equal in discharging power to more than one half of the clear unobstructed opening of 390 feet at the road bride. Thus the railway bridge *instead of double, affords only half the effective waterway of the road bridge,* which itself has proved not quite large enough. In the experiments with the model, it was observed that the heading up of the water at the road bridge was always less than half that which occurred at the railway, and that in this latter case the great fall in the surface of the water took place, not under the bridge, but between the south end of the bridge and the south-west corner of Haworth's Tannery, and just below the point where the true constriction exists.

In conclusion, I feel bound to raise my most earnest and emphatic protest against the way in which the gentlemen on the defence set aside scientific laws and formulæ as "mere theory," and insisted on practice being the only guide. Now, Sir, what is this theory but the practical experience of the best and wisest men that have ever given their attention to the subject, systematised, verified, and adapted to cases of ordinary professional work? And what is practice but simply one's own way of doing one's work, differing in every individual case, which may be right or wrong, scientific or crude, economical or extravagant, according to the mental constitution, and amount of education possessed by the engineer? The popular idea that science is mere theory, and unreliable when brought to the test—while practice, ignorant, inconsistent, and unintelligible, as it too often is, is the only guide to be followed, is a delusion leading to the most deplorable results.

ART. VII.—*Influence of Light on the Development of Bacteria.*

By J. JAMIESON, M.D.

[Read 8th June, 1882.]

It is a common opinion, and probably a correct one, that abundance of light is favourable to the preservation and restoration of health. In how far the evil effects, resulting from the occupation of badly lighted dwellings, are due to the want of light in itself or to other insanitary conditions, damp, bad drainage, dirt, &c., which are often associated with it, is not easy to prove with certainty. It has been supposed, further, that the spread of epidemic and other contagious diseases is favoured by conditions, which prevent the access of the sun's rays to the walls and to the interior of ordinary dwellings, and still more of hospitals, This unfavourable result of shutting off direct sunlight has even been ascribed to the effect of that light in destroying disease germs. Very much of all this is simply matter of opinion, the supposed destructive action of sunlight on germs being, perhaps, assumed from the common observation, that the various species of mould grow and multiply most freely in close, dark, damp places. Even here, however, I am not aware of exact observations or experiments having been made to test the share that darkness, by itself, without the other conditions, may have in favouring mouldy growths.

Confirmation of the common opinion about the destructive action of sunlight on those low forms of life, with which the germs of some diseases are probably closely allied, seemed to be supplied by the investigations of Messrs. Downes and Blunt, reported in detail in the "Proceedings of the Royal Society of London," for 1877 (vol. xxvi., p. 488). The general conclusions to which they had come were summarised in a short communication in *Nature*, for July 12th, 1877, to the following effect:—Light is inimical to the development of bacteria, and may either prevent or only retard their development; but that, for the attainment of the full effect, direct insolation is necessary. The germs originally present are destroyed by direct insolation, while the fitness of the solution in which they were contained, to serve as a nidus, is not affected. They used Pasteur's solution, inoculated with bacterial germs, and then exposed to direct sunlight in test tubes. The experiments described seemed to bear out their contention, though the results were not of a uniform character. They found an exposure of 3½ hours suffice for sterilization in one case, while in another it was not produced after 11 hours. They could suggest no other explanation than "that external conditions—notably temperature—may retard or counteract the preservative quality of the solar rays." Remarkably enough, they found that in weak solutions, diluted to one-tenth, they failed to accomplish sterilization. Professor Tyndall read a communication before the Royal Society on the same subject (Proceedings, vol. xxviii., p. 212), in which he stated that when flasks, containing infusions of cucumber and turnip, were inoculated and exposed to the sun, they were not completely sterilized, as they showed abundant formation of bacteria after they were removed to a warm room. In view of the anomalies which had been met with by Messrs. Downes and Blunt, and the different conclusions he had arrived at, he suggested the necessity for repeating the experiments. In the same volume of the Proceedings (xxviii., p. 199), there appeared another paper by these gentlemen, extending and confirming their conclusions. Finally, at the meeting of the British Association in 1881, Professor Tyndall read a paper (*Nature*, Sept. 15th, 1881), in which he gave the results of another series of experiments. He found the statements of Messrs. Downes and Blunt correct, in so far as the suspension of development was concerned, but he never succeeded in producing perfect sterilization, all the flasks exposed to sunlight becoming turbid when removed to a shady place. He expressed the definite opinion that the difference between flasks exposed to the sun, and those kept in the shade, after inoculation, was not owing to difference of temperature. It seems to have been tacitly assumed, both by him and by the other investigators, that any elevation of temperature, to which their tubes and flasks were liable in the course of their exposure, could only be favourable to bacterial growth; and merely noting this fact, I go on to relate my own experiments, which have brought me to different conclusions.

I was led to make them by the discussions going on as to the sanitary condition of the Melbourne Hospital, and the injurious effects supposed to have been produced by the comparative exclusion of the sun's rays from parts of the buildings. Though my investigations have not led me to conclude that light is inimical to the development of bacteria, I by no means wish to derive therefrom the further conclusion, that it is a matter of indifference whether or not hospital wards, or other human habitations, are well lighted. I do think it probable, however, that insufficient lighting does not act, by allowing the free growth of disease germs, and so favouring the origination or spread of erysipelas and allied diseases.

In the experiments, now to be described, I used Cohn's solution, as in a series of investigations on the action of disinfectants, already communicated to this Society (11th October, 1877). This fluid, admirably adapted for the cultivation of the *Bacterium termo,* the active organism in the production of putrefaction, has the following composition:—

Tartrate of Ammonia ...	2
Sulphate of Magnesia ...	1
Acid Phosphate of Potash	1
Chloride of Calcium ...	$\frac{1}{10}$
Distilled Water ...	200

My ordinary procedure was to put about two fluid drams of this solution into ordinary one-ounce phials, and, after inoculation, plug them with cotton wadding. Free access of air was thus allowed, while solid particles were excluded. A considerable series of experiments, sixteen in number, were made to determine—(1) Whether ordinary diffused light interferes in any way with the development of bacteria in Cohn's solution; (2) whether direct insolation has that effect; and (3) whether direct insolation quickly causes the destruction of bacteria in the dried state. They were begun in February last, and continued as other occupations permitted.

Exp. I. On February 21st three phials, inoculated each with three drops of putrid meat juice swarming with bacteria, were placed outside, on the sill of a window on which the rays of the sun fell nearly all day. The weather was very hot. On the 23rd all were still quite transparent, and one was removed and put in a shady place. On the 26th this showed three specks of mould, but no opalescence from bacteria. On the 28th the others left in the sun were still perfectly transparent, and showed no mould formation.

Exp. II. On 28th February, at 11.40 a.m., an ounce of solution was inoculated with twenty drops of putrid meat juice, and distributed in four bottles. Two were exposed to the sun, and the others, wrapped in brown paper, were placed alongside of them. The weather was bright but cool. On 3rd March both of the covered bottles began to show cloudiness, and soon became quite opalescent. Next day (4th), at 2.30 p.m., both of the exposed bottles were quite transparent. One of them was then wrapped in paper, and both left in the same place, but on the 6th they were still transparent.

So far these results seemed fully to confirm the conclusions of Downes and Blunt. Direct insolation had not only checked the growth of the bacteria, but had actually sterilized the solutions so far as they were concerned. The survival of mould spores, after the destruction of bacteria, also agreed with what these observers had found.

I proceeded next to try what the effect of diffused light would be.

Exp. III. On 11th March, at 2.30 p.m., I inoculated six drams of solution, with five drops of opalescent fluid from one of the bottles left from a previous experiment, and distributed it equally in four bottles. Two were wrapped in brown paper, and the others left uncovered, and all placed in a bright light on an inner window sill, but guarded from the direct rays of the sun. On the 13th, at 9 a.m., they were all nearly opaque, no difference being perceived. It was evident from this, that bright diffused sunlight is not inimical to the development of bacteria. This experiment, conclusive enough in itself, was confirmed by the next.

Exp. IV. An ounce of solution, inoculated with four drops of opalescent fluid from previous experiment, was put into four bottles. Two were exposed to the sun; one in the same situation but wrapped in brown paper, and the fourth left exposed to the light inside, at 2.30 p.m. on 15th March. The temperature in the sun was noted at 110° F., and next day at 112° F. On the 17th, at 9 a.m., the wrapped bottle and the one in diffused light were already cloudy, the latter most distinctly. The two exposed bottles were perfectly transparent, and both remained so till the 19th, at noon, though one of them had been taken out of the sun.

Having apparently established the fact that the bacteria in Cohn's solution may be not only retarded in their development, but even killed by exposure to the sun's rays, I tried next to discover the time needed for their destruction.

Exp. V. On 27th March, at 11.30 a.m., four bottles charged with solution, inoculated as in Exp. IV., were taken; one of them left in ordinary diffused light for a test, and the other three placed in the sun, and left for 1½, 2½, and 5 hours respectively, and then put beside the test bottle, the thermometer marking 116°, 124°, and 108° F. at different times in the course of exposure. On the 30th, at 9 a.m., the test solution was found to be milky and crusted; those exposed for 1½ and 2½ hours showed traces of opalescence, while that which had been exposed for five hours was quite transparent, remaining so till the morning of 1st April, when it began to show slight opalescence; the others, before that time, having become almost opaque. With the conditions under which I experimented, therefore, five hours proved almost sufficient for the sterilization of the inoculated solution.

I began now to ask myself in how far the effect, so clearly produced by insolation, might not be due to the solution being raised, by standing on a hot window sill, to a temperature sufficient to paralyse and even kill bacteria, and that independently of any chemical or other action of the sun's rays. The utter want of any such destructive influence in diffused light made this not improbable, and I altered my procedure in the next two experiments.

Exp. VI. On 6th April, at 2 p.m., the weather being bright but cool, three bottles, containing each two drams of inoculated solution, were suspended outside of a window, in front of the glass, with the same exposure. The 7th was cloudy, the 8th bright and cool, and on the 9th, which was bright and warm, all were still found transparent; and at 9 a.m. one was brought inside out of the sun. On the 10th, which was also bright, another was taken in at 9 a.m., the one which was left out then showing faint signs of cloudiness. A thermometer hung up beside it marked a temperature of 98° F. Next day (the 11th), at 9 a.m., the exposed bottle was quite milky, the others just beginning to show traces of opalescence, the one removed on the 9th being least advanced. Here then the solution which had been longest and continuously exposed to insolation became first altered by bacterial development. There was scarcely any explanation conceivable, but that, in all, the development had been retarded by the coolness of the weather at first; and that the warmth (98° F.) outside, on the 10th and 11th, favoured that development in the bottle exposed to it; the others, inside of the house, being at a lower temperature. Long and continuous insolation had here certainly been little, if at all, inimical to the growth of bacteria.

Exp. VII. On 14th April, at 12.30 p.m., I inoculated six drams of solution with two drops of bacterialised fluid, and divided it equally over three bottles. They were all suspended in the sun, one of them having been first wrapped in brown paper. The weather was cloudy and almost cold on the following days, the 19th and 20th, however, being bright all day; and only on the 21st were the exposed bottles found to be opalescent. The solution in the covered bottle was quite milky. My interpretation of these conditions was, that the coldness of the weather had checked the multiplication of the bacteria in the first days, growth only beginning actively in the brighter and warmer weather of the 19th and 20th. The more advanced development in the covered bottle was most naturally to be ascribed, I think, to the wrapping keeping it at a more uniform temperature, and especially preventing that from sinking so low during the night.

The result of these two experiments was clearly to show that insolation, associated with moderate or low temperature, has no destructive influence on bacteria, not even apparently retarding their growth. I was, therefore, driven to conclusions directly contradictory to those both of Professor Tyndall and of Messrs. Downes and Blunt. The doubt, of course, which at once suggested itself was, whether the sun's rays, even in summer in England, would raise a solution exposed to them to a temperature sufficient of itself to destroy bacteria. To settle this point it was necessary, first of all, to ascertain the lowest temperature at which the *Bacterium termo* is paralysed or killed. This information has been provided by the careful experiments of Dr. Eduard Eidam, reported in Cohn's "Beiträge Zur Biologie der Pflanzen" (heft. III., p. 208). He found that while very low temperatures check indefinitely the growth of this organism, growth becomes more active with gradual elevation up to 35° C. (95° F.). Temperatures above this are again less favourable, and between 40° and 45° C. (104°-113° F.), the bacteria remain in a torpid condition, a kind of heat rigidity (Wärmestarre), but are not killed. An exposure for seven days to a temperature of 45° C. was sufficent to cause their destruction; while fourteen hours of exposure at 47° C. (116.3° F.), three to four hours at 50°-52° C. (122°-125.6° F.), and one hour at 60° C. (140° F.) sufficed to produce the same effect. Under a hot Australian sun there is no difficulty about getting a temperature of 140° F. or over, 125° F. being quite common, and so the destruction of bacteria by insolation is easily accounted for. Whether a high enough temperature for that purpose is readily attained in England may be doubtful, and the fact that Professor Tyndall never succeeded in sterilizing his solutions, meets its explanation in this way. It is possible that, in June or July, when Messrs. Downes and Blunt carried on most of their investigations, a heat of 125° F. may be occasionally reached for three or four hours continuously, and this would suffice. An anomaly, to them apparently unaccountable, viz., that solution in very small test tubes was more easily sterilized than when contained in larger ones, may be explained by the circumstance that a small body of fluid would more speedily and certainly be raised to the required temperature than a larger one. The fact that Professor Tyndall, in his experiments, used flasks, which I presume were of considerable size, would on the same principle account for his failure to get complete destruction of germs—the attainment of temporary torpidity, by a temperature slightly exceeding 104° F., being comparatively easy.

While, therefore, it might be going beyond my competence to deny to direct sunlight any influence inimical to the development of bacteria, I have no hesitation in expressing the opinion that such inimical influence of light *per se* is not established, either by my own experiments, or by those which I have ventured to criticise, and to interpret in a different sense from their authors. I can explain their error only by supposing that it had not occurred to them as possible, that bacteria might be paralysed, or even killed, by continuous exposure to ordinary summer heat. An expression, contained in one of Messrs. Downes and Blunt's Memoirs, already quoted, to the effect "that temperature may retard or counteract the preservative quality of the solar rays," seems to show clearly that it was actually their opinion, that any elevation of temperature, to which their solutions were exposed, could act only by hastening the development to such an extent as to overcome the destructive power of light as light. Professor Tyndall says, "On many occasions the temperature of the exposed flasks was far more favourable to the development of life than that of the shaded ones."

When it is considered how much greater is the difficulty of destroying bacteria or their germs in the dry than in the moist state, either by heat or disinfectants, it might almost with safety be concluded that insolation, which fails to destroy the *bacterium termo* in solutions, is not likely to injure it when dried.

As reported in my previous communication to this Society, I found dried bacteria resist a temperature of about 212° F. for fifteen minutes, and, therefore, no solar heat could be expected to kill them. But as desiccation, when sufficiently complete, has that effect, it might readily happen that exposure to the sun's rays in hot weather might act destructively, in virtue of its drying effect. To test the influence of insolation on the dry bacteria, I soaked blotting-paper with bacterialised solution, obtained from a bottle used in one of the previous experiments, and exposed it to the sun freely suspended by a piece of thread. Similar pieces of paper were hung up in a shady but well-aired passage, and in a well-lighted room. This was done twice; and, to test the condition of the bacteria in the pores of the paper, the following precautions were taken:—Bottles, as before, after receiving about two drams of pure solution, were plugged with cotton wadding, and then kept for some time in boiling water to secure complete sterilization. After time was allowed for cooling, the plug was taken out, a little square of the blotting-paper dropped quickly in, contact only with scissors being allowed, and the plug replaced. In the first series of experiments, carried on in hot weather, it was found that, after two days, the bacteria had not been killed in any of the papers; that, after four days, they had been killed in that exposed to the sun, and that hung in a current of air, but in the shade; and not killed in that which had been suspended in bright, diffused light. After seven days, the last also failed to bring about milkiness in the solution. I conclude, therefore, that it was simply a question of desiccation with all of them, the time needed to produce destruction in that way varying with temperature and exposure to currents of air. In the other series, a similar result was reached. The growth of bacteria in the bottle containing the sun-dried paper was later in occurring than in the others, but was not completely prevented even after five days of exposure. The interest of these experiments consists in the proof supplied, that, under conditions very favourable to rapid and complete desiccation, such as free exposure to air and sun, bacteria may be destroyed in a comparatively short time, not less, however, than from two to four days being needed even in this climate in summer, and even longer, unless the weather be actually hot.

Since writing this paper I find from a passage in a letter contained in *Nature* (vol. III., p. 247), that Dr. Bastian had been led to ascribe to the actinic rays of the sun an important influence in promoting the spontaneous generation of organisms in organic infusions. Though that notion may be considered as fairly set aside by Professor Tyndall's experiments, recorded in the *Philosophical Transactions* (part I., 1877), and again in his *Essays on the Floating Matter of the Air* (p. 231), the interesting fact remains that, at different times, both a favouring and an inimical action on the development of these minute organisms should have been ascribed to the sun's rays, when in reality they appear to have little, if any, appreciable direct influence in either direction.

ART. VIII.—*Remarks on Railway and Marine Signals, and on the Necessity of Accurate Testing of the Sight of Signal and Look-out Men by Land and Sea.*

BY JAMES T. RUDALL, F.R.C.S.

[Read 8th June, 1882.]

THE great increase of travelling in recent years, the large numbers of ocean-going and other steamships, the frequency of railway trains running over the same lines, and the numerous intersections of these, have become attended by dangers of which some cannot be wholly eliminated; and others, though avoidable, are only now beginning to receive attention.

If one remembers that between New York and Liverpool nearly thirty large steamship companies have their vessels constantly running over almost the same track of ocean at a speed often of sixteen or eighteen knots an hour; or if one observes the succession of trains at a large railway station like the Victoria, in London, one is likely not to underrate the necessity of increasing vigilance and perfect physical capability on the part of the signallers and look-out men and the drivers of trains. Very little reflection suggests the necessity of using a code of signals suited as regards size and colour to the optical capacities of the normal eye, as these have been determined by scientific examination. Of course this has already been partly attended to long ago in a rough way, but by no means with the accuracy which the subject now both permits and demands. Almost equally apparent is it that the signals should be, at least in the case of ocean steamers and railway lines of coterminous countries, not national but international.

Another at least equally important condition requisite to ensure safety in travelling is visual competency on the part of all those who are engaged in signalling or in looking out for signals.

The essential requirements therefore are:—

1. A series of signals for sea, to be agreed upon and accepted by all maritime nations; and, further, an uniformity as to size, colour, and signification of land (railway) signals.

2. That these signals should be in relation with the visual acuity and colour perception of the normal human eye.

3. That no signallers or observers should be employed who do not come up to a certain fixed standard of visual acuity, refraction, and colour sense.

In regard to the first of these requirements, the necessity of a commission of delegates from the principal maritime Governments was strongly urged by the International Medical Congress of 1881, in order to secure uniformity in size, colour, and disposition of signal lights. Such a commission would at the same time ensure the conditions required under the second heading. But there should be no delay in carrying out the third requirement. This is absolutely essential to the safety of life of the travelling population.

It might be thought that nothing can be easier than to decide, with but little trouble or method, whether a person has good sight and good perception of colours. In a very small percentage of those who would present themselves for examination this question might, perhaps, be at once decided in the negative; but in a relatively large proportion the incapacity would be detected only by a detailed and systematic examination.

It is, of course, well known that one condition essential to distinct vision is that an image of the object looked at should be formed on the retina.

As regards refraction, it is now generally accepted that the dioptric media in the normal eye accurately focus parallel rays on the percipient layer of the retina; consequently neither divergent nor convergent rays can be brought to a focus on that percipient layer without some alteration.

For divergent rays this alteration is effected by an increased convexity of the crystalline lens, produced through the agency of the ciliary muscle.

Hooke* investigated the angular distance required to observe two fixed stars separately, and he found that among a hundred persons scarcely one was in a position to distinguish the two stars when the apparent distance is less than 60″. The correctness of this observation of Hooke has been confirmed in different ways by modern investigators. Professor Snellen, of Utrecht, some years ago devised a series of black letters on a white ground, which are easily read in good light by the normal eye at such a distance that the whole letter is seen under an angle of 5′, but the openings in the letters under an angle of 1′. These test types have come into general use by those concerned in the management of optical defects of the eye. It is necessary that the results of an examination by the types should be further supplemented by determination of the refraction, because it is possible for a myopic,† or short-sighted person, sometimes to read No. 20 Sneller at 20 feet by partly closing the eyelids, so as to diminish the circles of dispersion on the retina (and, perhaps, by, at the same time, slightly flattening the eye), and, on the other hand, a hypermetropic‡ person, with good accommodation, may also read the same letters—viz., No. 20 at 20 feet.

There is yet another anomaly of refraction—viz., astigmatism, in which, owing to the curvatures of the dioptric system being unequal in the different meridians, no true

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* *Posthumous Works* (1705), quoted by Professor Donders.

† In whom parallel rays are brought to a focus in front of the retina.

‡ In whom parallel rays, if continued, would come to a focus only behind the retina.

focus is formed. If the vertical meridian has a shorter radius of curvature than the horizontal, a point of light in the focus of the latter will not be seen as a point, but as approaching the form of a horizontal line, and *vice versa*. An eye may be normal or hypermetropic in one meridian and myopic in another. So, besides deciphering the test types, the eye must also be proved emmetropic—*i.e.*, to possess normal refraction.

Of course if any of these anomalies of refraction were present in a high degree, the individual would not be able to read the large test types at the required distance, yet a dangerous amount of ametropia might remain concealed if special attention were not also directed to the state of the refraction. The visual field must also be complete; there are cases in which, with great contraction of the field, the sharpness of sight remains good in the central parts.

We now come to the colour perception, which has of late years attracted so much attention. Absolute colour-blindness is a very rare condition; but in the male sex of the white races, diminished colour sense would appear to be of quite unexpected frequency. Thus, according to Mr. George Lawson, Professor Donders, of Utrecht, found amongst 2300 railroad *employés* that 152, or 6·60 per cent., were colour-blind. Professor Holmgren, of Sweden, found amongst 32,165 males that 1019, or 3·25 per cent., were colour-blind. Dr. Cohn found amongst 2429 schoolboys of Breslau 95, or 4 per cent., colour-blind. Dr. Magnus found amongst 3273 school boys of Breslau 3·5 per cent. colour-blind. Dr. Joy Jeffries, of Boston, found amongst 10,387 that 431, or 4·149 per cent., were colour-blind. In the female sex colour-blindness seems rare. It is known that for ordinary vision that part of the retina including the macula lutea and its immediate neighbourhood is the most sensitive, and that in proportion as images are formed on the more peripheral parts the impression conveyed to the sensorium is less exact and intense. From careful examinations it has been found that blue is distinguished over a larger portion of the visual field than red, and red over a larger part than green. It appears that within the limit of the visual field in the normal eye there is a zone of about 10° in which pigment colours are not recognised. What seems at first surprising is that many colour-blind persons (I use the term in the sense before ascribed to it) do recognise and name correctly the principal colours. "Thus," says Professor Pole, "a soldier's red coat or a stick of red sealing-wax conveys to me a very positive sensation of colour, by which I am able to identify in a great number of instances bodies of this hue. If, therefore, the investigation of any experiences ended here, there would be no reason to consider me blind to red. But when I examine more closely what I do see, I am obliged to come to the conclusion that the sensation I perceive is not one that I can identify separately, but is simply a modification of one of my other sensations. It is, in fact, a yellow shaded with black or gray, a darkened yellow, or what I may call yellow-brown. I find that all the most common hues of red correspond to this description; and in proportion as they are more scarlet or more tending towards orange, the yellow I see is more vivid. The explanation, I suppose, is that none of such reds are pure—they are combinations of red with yellow, so that I see the yellow element of the combination, while the true red element of the combination is invisible to me as a colour, and acts only as a darkening shade."

Dr. Wolfe, referring to colour-blindness, says:—"It may well be asked, how is it possible for a colour-blind engine-driver, for instance, to perform his duty for any length of time without exposing his deficiency? But the explanation given by Holmgren is simple when we come to remember that a colour-blind person may come to distinguish between red, green, and white lanterns or flags, and even learn to call them by their right names, whilst all the time it is not colour which he sees; he only differentiates by the degree of intensity of light." "In short, the colour-blind person supplements his defective vision of colour by all secondary aids. He trains himself to notice differences which escape most other eyes; these differences serve him in lieu of colour. That is the reason why collisions do not daily occur on railways and at sea from mistakes made by colour-blind officials."

When the conditions are unfavourable for the colour-blind person supplementing his deficiency of sight by other means, as in rain, mist, and some other states of the atmosphere, the danger of making mistakes in the colours of signals becomes very great.

From the statistics quoted above, we cannot escape the conclusion that there are on board of our steamships and on our railways numerous instances of persons whose visual deficiencies disqualify them for their important responsibilities in regard to human life, for the tests hitherto employed are nearly useless, perhaps even mischievous as leading to a false sense of security.

Without contending that all the requirements are thoroughly worked out, I am convinced that the systematic testing recommended by the International Medical Congress of last year (and copies of the "resolutions" have no doubt before now been widely distributed over the civilised world) would, if carried out as directed, at once reduce to a small fraction the dangers to travellers through mistakes from visual defects of officials on steamships and railways.

ART. IX.—*Descriptions of New, or Little Known, Polyzoa.*

PART II.

BY P. H. MACGILLIVRAY, M.A., M.R.C.S., F.L.S.

(WITH THREE PLATES.)

[Read 13th July, 1882.]

Membraniporella distans, n. sp. Fig. 5.

CELLS remote, glistening; costæ, about eight or ten on a side, expanded and perforated at their inner ends; a narrow, slightly raised line down the middle of the cell; mouth straight below, arched above, with several (2—5) blunt spines round the upper margin; ovicell small, rounded, smooth, with an elevated ridge across the front.

Port Phillip Heads.

This species is closely allied to *M. nitida*, of which it may eventually prove to be only a variety. In the only specimen I have seen, the cells are irregularly scattered over a small fragment of Retepora; some are contiguous, although most are widely separated and arranged in no definite order. The retepore is very dirty and rotten, and it is impossible to make out the nature of the connection between the remote cells. The ribs are generally expanded towards the mesial extremity, and frequently there perforated. This is caused by the ribs, in growing, dividing dichotomously towards the inner part, and these divisions by again uniting, or by their union with those of the opposite side, leaving the round or oval openings. The ovicell is smaller and shallower than in *M. nitida*, and has a slight ridge separating an area from the smooth, round, superior part.

Microporella renipuncta, n. sp. Fig. 1.

Cells broadly ovate; surface smooth, or faintly granular, or areolated; a large, reniform, punctate plate below the mouth, toward the middle of the cell; mouth straight below, arched above, with four or five spines on the upper margin; a transverse avicularium, with an acute mandible, between the lower lip and the reniform pore; ovicell large, prominent, the front with a semicircular area, smooth, or marked with radiating lines, the circumference being thickened, and nearly smooth or granular.

Port Phillip Heads.

This beautiful species is at once distinguished by the large, reniform, perforated plate and the transverse avicularium. The avicularium is absent in some of the cells, but seems to be present in all those supporting ovicells. The reniform plate is distinctly raised, and has the appearance of a thin membrane bulging forwards and pierced by numerous punctures. In old, calcified specimens, the surface is markedly areolated.

Microporella stellata, Smitt.* Fig. 4.

Cells broadly oval or rhomboidal, slightly convex; surface thickly covered with rounded eminences, each of which is pierced by a stellate pore; mouth wide, shallow, slightly arched above and slightly projecting forwards below, margin thickened; at the summit of the cell and at each lower angle of the mouth is a rounded eminence, on which is situated an avicularium with the triangular mandible directed towards the mouth, the superior vertically downwards, the lateral obliquely upwards and inwards.

Port Phillip Heads, a single specimen, Mr. J. B. Wilson.

Microporella Malusii, var. *personata*. Fig. 8.

Cells pyriform, smooth; mouth arched above straight below, with slightly thickened edges; no spines; a transverse, lunate, dentate pore below the mouth with the sides elevated, especially inferiorly, into a mound-like prominence; ovicell large, granular, the lower angles produced across the front of the cell to form a large collar.

Port Phillip Heads, a single specimen, Mr. J. B. Wilson.

This differs so much from the normal form of *M. Malusii*, that it may be doubtful whether it ought not to be characterised as a new species. There are no lateral pores, the margin of the ovicell is not sculptured in the usual way, and the lower angles are produced across the front of the

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* *Porina stellata*, Floridan Bryozoa, Part II., p. 26, Pl. V. Figs. 130—133.

cell to form, by their junction, a large collar, obscuring the lower part of the mouth. Busk's *L. thyreophora*, already shown by Hincks to be an unimportant variety of *M. Malusii*, also occurs at the Heads.

Lagenipora tuberculata, n. sp. Fig. 15.

Cells large, flask-shaped, erect or semi-erect; mouth rounded or oval, with a thickened projecting peristome; surface studded with large, hollow, pointed tubercles, which occasionally, owing to attrition, form raised pores.

Port Phillip Heads.

Schizoporella lata, n. sp. Fig. 7.

Cells quadrate or oval, arranged in linear series; front slightly convex, granulo-punctured; mouth large, with a rather wide, shallow-pointed sinus below; below the mouth is a small elevation bearing a minute avicularium; ovicell large, rounded, thickly punctate.

Port Phillip Heads.

S. triangula (Hincks), which also accurs here, differs in the cells being much flatter, the mouth wider, and the suboral avicularium larger and more distinct.

Schizoporella insignis, n. sp. Fig. 11.

Cells large, quincuncial, indistinct; surface deeply areolated; mouth semicircular, or rather higher than wide, nearly straight below, and with a deep rounded sinus; four or five spines above; avicularia very large, situated below and outside the mouth, on one or both sides, and with the mandible extending obliquely upwards and outwards to nearly opposite the centre of the upper margin of the mouth of the cell in the adjacent series; ovicell mitriform, deeply imbeded in the cell above, divided into two parts by a thick ridge parallel to the outer edge, the inner part nearly smooth but areolated at the edges, the outer sloping and also deeply areolated.

Dredged off Port Phillip Heads by Mr. Wilson and myself, always in the Hemeschara form.

The mandible of the avicularium is sometimes much narrower and more pointed, and also situated lower down, than in the specimen figured.

Schizoporella punctigera, n. sp. Fig. 13.

Cells ovate, arranged in linear, radiating series, smooth or nearly so; mouth rounded above, nearly straight below, with a narrow deep sinus; four spines on the upper margin; a minute transverse avicularium on an elevated umbo immediately below the mouth; ovicell rounded, thickly punctate, and with a smooth rim.

Port Phillip Heads, dredged by Mr. Wilson and myself.

Closely allied to *S. lata*, but I think distinct. The mouth is narrower, the sinus is much narrower and sharper, and the ovicell is more prominent.

Lepralia setigera, Smitt. Figs. 2 and 3.

Cells pyriform or ovate, convex, smooth; a series of long, slender, rigid spines attached to the circumference of the cells except at the base; mouth higher than broad, arched above, straight or rather rounded upwards and forwards below, constricted at the junction of the middle and lower thirds by a projecting, pointed process, the edges bevelled inwards, especially on the upper border; a long, very slender vibraculum on either side, opposite the lower part of the mouth, extending downwards nearly the whole length of the cell: ovicell rounded, with a thickened rim.

Port Phillip Heads, dredged by Mr. Wilson and myself.

I have no doubt that this species is the *Escharella setigera* of Smitt* and the *Lepralia Kirchenpaueri*, var. *teres*, of Hincks.† Heller's *L. Kirchenpaueri* is, probably, a different species. The chief peculiarity is the remarkable series of stiff, slender spines fringing the circumference of the cells which is found in perfect specimens; in older ones, however, they are not present, and their absence, as well as that of the delicate vibracula, with the more strongly calcified and shorter cells, gives it a very different appearance. The surface of the ovicell is divided into two parts, the circumference being thickened; sometimes the inner edge of this thickened part forms a distinct ridge, although I have not seen it so prominent as in Hincks' figure of *L. Kirchenpaueri*, var. *teres*. It can always be distinguished

* Floridan Bryozoa, Part II., p. 58. Fig. 206.
† Annals and Mag. of Nat. Hist., July, 1880.

by the peculiar shape of the mouth and the vibracula, or the mark of their attachment, which in the oldest specimens is very conspicuous.

Hincks notices a form from Bass's Straits as *L. Poissonii* (Audouin), to which he doubtfully refers *L. setigera.* He does not describe it, but gives as its remarkable peculiarity the line of spines fringing the base of the cell for about half its length, which are not described or figured by Smitt. Smitt's and the present species are undoubtedly identical, and it is probable that they are referable to *L. Poissonii*; but as I have not seen Savigny's figure of the latter, I have thought it better to retain Smitt's name.

Lepralia magnirostris, n. sp. Fig. 6.

Cells large, confused, indistinct, surface with numerous perforations; mouth rounded above, nearly straight below, peristome raised; a very large avicularium on each cell opposite the side of the mouth with the mandible projecting upwards and inwards.

Port Phillip Heads.

In this species, of which all the specimens I have seen are in the Hemeschara form, the polyzoary is thick, and the posterior surface smooth. The cells are arranged in irregular quincunx, with no distinct divisions; they project slightly forwards superiorly; the mouth is raised, rounded above, and nearly straight below. There is a very large avicularium on each cell; it is situated opposite the middle of the mouth, the base being in the hollow between two adjacent cells, and the mandible is directed nearly transversely inwards, so that the point almost touches the summit of the mouth. In some specimens the mandible is much more slender than in that figured, and is pointed to the side or bottom of the mouth, although the normal arrangement is as represented.

Lepralia striatula, Smitt. Fig. 17.

Gemellipora glabra, forma *striatula*, Floridan Bryozoa, Pt. II., p. 37. Fig. 202.

Polyzoary encrusting; cells irregularly shaped, elongated, usually attenuated downwards or pyriform, arranged more or less in linear series, distinct, very slightly prominent; surface glassy, marked with irregular, mostly transverse, fine striæ, and thickly punctate with small white-bordered pores; mouth horse-shoe shaped above, with a large, wide and deep sinus below; at the junction of the sinus and upper part there is a prominent sharp denticle on each side for the articulation of the operculum; a small, broadly oval avicularium on a separate punctured area at the base of the cell; ovicell large, slightly elevated, appressed to the cell above, punctate, and with an avicularium on the summit.

Port Phillip Heads, on *Eschara mucronata.*

Lepralia longipora, n. sp. Fig. 18.

Cells much elongated, distinct, arranged in linear series, convex, surface smooth and sparsely punctured; mouth nearly circular, with the lower lip slightly straighter, margin thickened; ovicell large, rounded, smooth.

Port Phillip Heads.

Smittia oculata, n. sp. Fig. 12.

Cells elongated, distinct; surface glassy, thickly covered with slight elevations, which, on deeper focussing, appear as large rounded pores; primary orifice horse-shoe shaped or rounded; secondary orifice, with the sides very largely raised and a thickening below, on which is a rounded avicularium, and inside a denticle; ovicell slightly prominent, with a slightly raised vertical ridge, on each side of which is a rounded pore, with a slightly thickened margin.

Port Phillip Heads, Mr. J. B. Wilson.

The surface of the cell is covered with numerous large, slight elevations, which, in deeper focussing, are shown to be elevated pores, covered by a thin layer. The pores on the ovicells, which are probably of the same nature, are usually two, but occasionally three. It is allied to *S. Landsborovii,* which, as well as *S. trispinosa,* is abundant at the Heads.

Smittia reticulata, var. *spathulata.* Fig. 14.

Cells elongated, separated by distinct, raised margins, deeply punctured or areolated round the margins; mouth rounded in young cells, with three or four spines, the peristome in older cells produced on each side, leaving a narrow sinus below, inside of which is a squared denticle, with a smaller one on each side; a single large, spatulate avicularium on one side, opposite the lower part of the mouth, with the mandible pointed downwards; ovicell prominent, thickly perforated by round foramina, and frequently with a thickened rim.

Port Phillip Heads.

Hincks (Ann. and Mag. Nat. Hist., August, 1881) has already noticed this variety, which, as he points out, differs only from the normal form in the position and shape of the avicularium. This is situated on one side of the mouth, with the large, spatulate mandible pointed directly downwards. The size of the mandible varies considerably, being sometimes very broad, and extending the whole length of the cell, while in other cases it is much shorter and narrower. Rarely there is another smaller one on the opposite side. There are occasionally small isolated raised patches of more prominent cells, with the avicularia enormously developed. I have not found the normal form of *S. reticulata*, but Hincks mentions it as occurring in Bass's Straits.

Mucronella munita, n. sp. Fig. 10.

Cells oval, indistinct, glassy; when young deeply areolated on the margins, when older smooth or with irregular elevations; mouth with a projecting denticle on each side, above which is a long, articulated, cylindrical spine, and sometimes one or two others on the upper margin; mucro squared above; usually a sessile avicularium, with the mandible pointed outwards, on one or both sides of the cell; ovicell large, frequently somewhat umbonate in front.

Port Phillip Heads, Mr. J. B. Wilson.

I am not sure that this may not prove to be a form of *M. coccinea*, from which it seems to differ in the smaller size of the cells, the greater development of the mucro, and the form and position of the avicularia.

Mucronella lævis, n. sp. Fig. 16.

Cells broadly ovate, arranged in linear series, slightly convex, smooth; mouth rounded above, a broad denticle deep in the lower lip; peristome raised round the lower lip, produced in the centre into a prominent square or blunt mucro; six stiff, articulated spines on the upper margin; ovicell small, globose, smooth, three spines shewing on each side in front of it.

Sorrento, Mr. J. B. Wilson.

Allied to *M. Peachii*, from which it differs in the greater prominence of the mouth, the larger size of the mucro, the stouter spines (the articulations of which are usually dark-coloured), and the presence of three spines on each side in front of the ovicell. It is probably also closely related to *M. teres*, described by Hincks, from specimens dredged off Curtis Island.

Mucronella serratula, n. sp. Fig. 9.

Cells irregular in shape, rhomboidal or elongated, distinct, separated by faintly raised margins; front slightly convex, glassy, and more or less covered with distinct round granulations; mouth with margin smooth or usually with a rounded somewhat digitiform projection of the peristome, about the middle on each side; mucro large, upper edge straight and serrated, and seemingly with a transverse avicularium on its summit; a central and two lateral denticles inside the lip; ovicell large, granular.

Dredged at Port Phillip Heads, by Mr. J. B. Wilson and myself.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. *Microporella renipuncta.* Fig. 1*a.* A single cell, showing spines.

Fig. 2. *Lepralia setigera.* The division on the ovicell ought to be more marked.

Fig. 3. Older specimen of same, showing marks of attachments of vibracula.

Fig. 4. *Microporella stellata.*

Fig. 5. *Membraniporella distans.* Fig. 5*a.* To show growth of costæ. Fig. 5*b.* Outline of cell and ovicell.

Fig. 6. *Lepralia magnirostris.*

Fig. 7. *Schizoporella lata.*

Plate II.

Fig. 8. *Microporella malusii*, var. *personata.* One cell, showing young ovicell. Fig 8*a.* To show ovicells and collars.

Fig. 9. *Mucronella serratula.*

Fig. 10. *Mucronella munita.*

Fig. 11. *Schizoporella insignis.*

Fig. 12. *Smittia oculata.* Two marginal cells. Fig. 12*a.* Single cell, showing elevations on surface. Fig. 12*b.* Portion more deeply focussed, to show the pores, &c.

Plate III.

Fig. 13. *Schizoporella punctigera.*

Fig. 14. *Smittia reticulata*, var. *spathulata.* Two young marginal cells. Fig. 14*a.* Older cells, showing the large lateral avicularia and ovicells.

Fig. 15. *Lagenipora tuberculata.*

Fig. 16. *Mucronella lævis.*

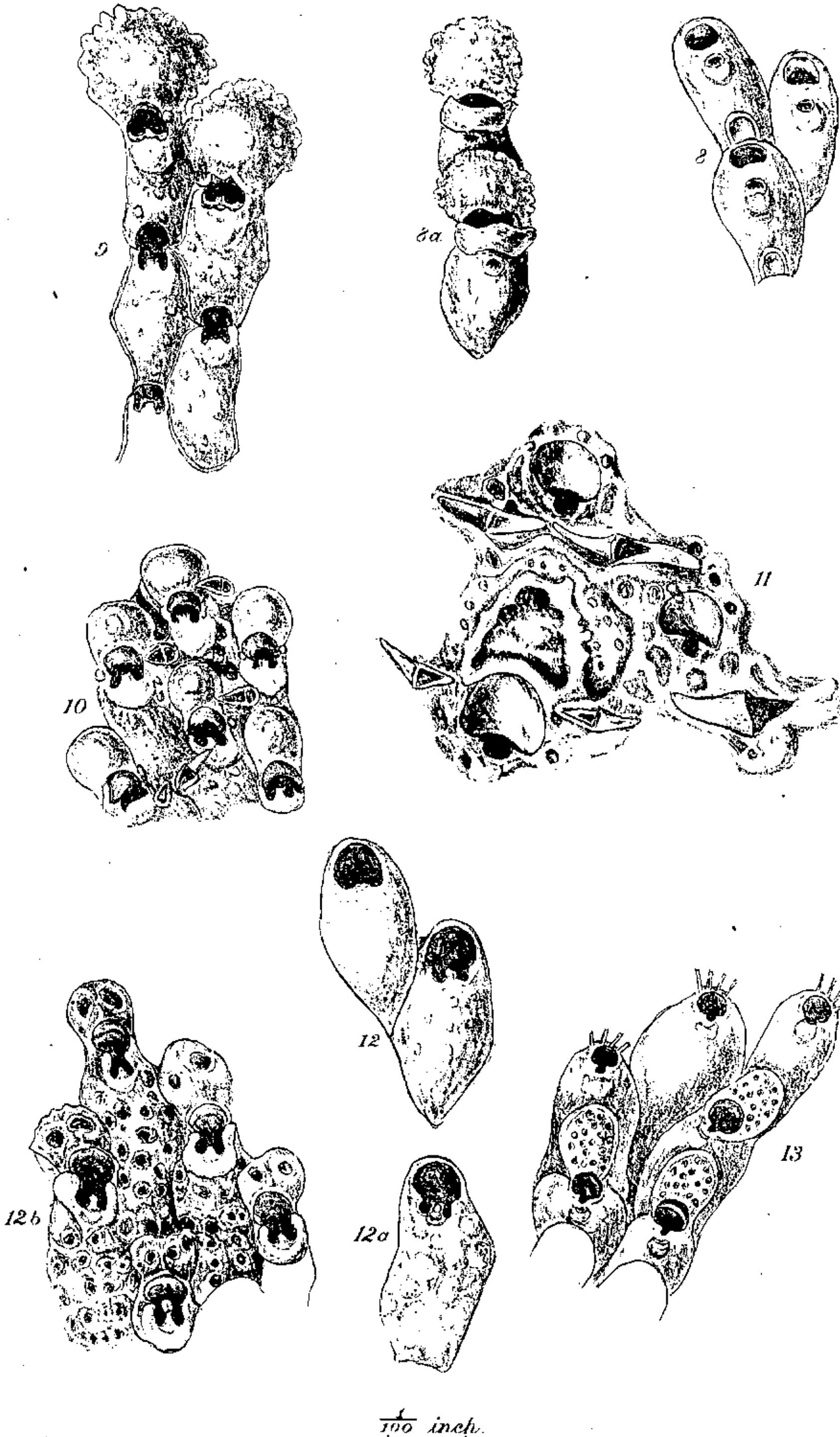
Fig. 17. *Lepralia striatula.* Fig. 17*a.* Part of a cell more highly magnified, to show the form of the mouth.

Fig. 18. *Lepralia longipora.*

Plate 1.

P.H.McG. del & lith.

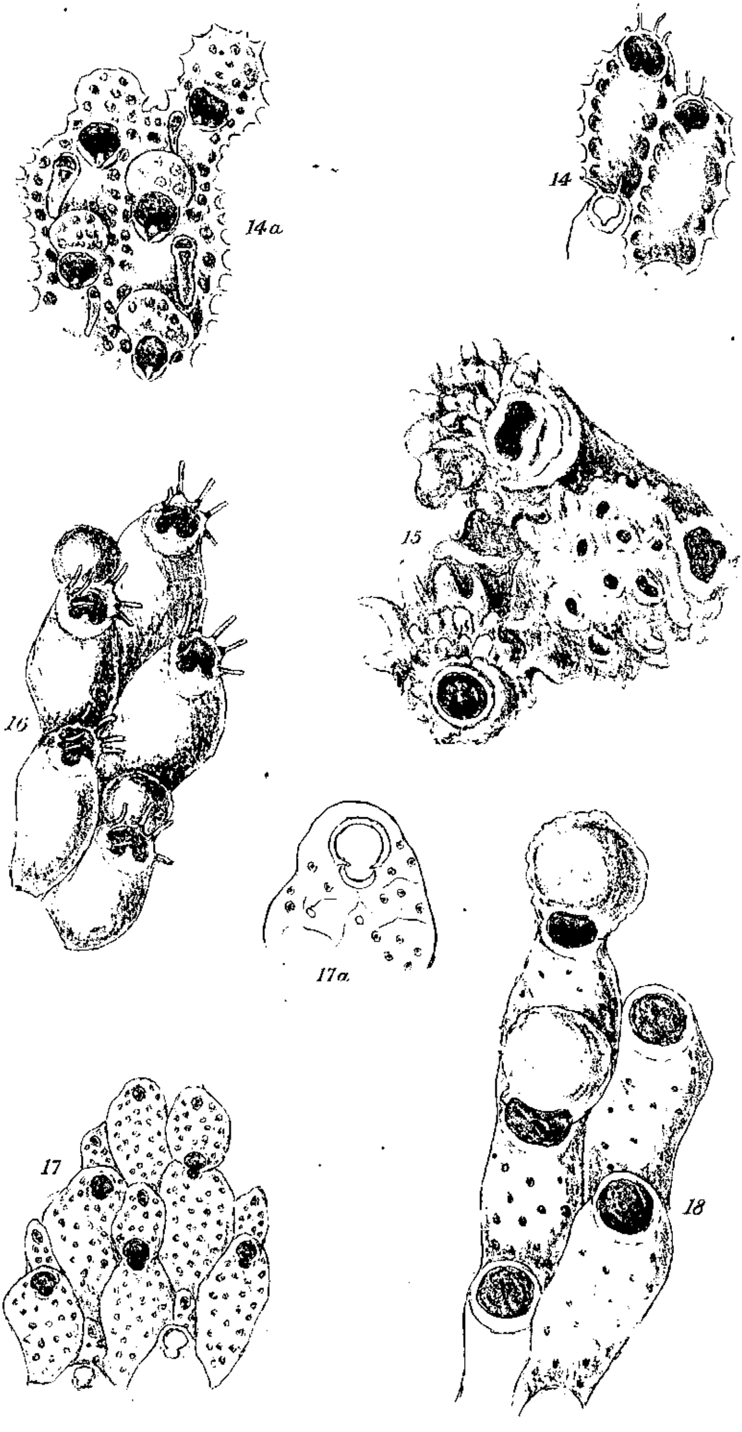
C. Troedel & Co. imp



F.H.F. G del & lith.

C. Troedel & Co imp

Plate III.



$\frac{1}{100}$ inch.

P. H. McG del & lith.

C. Troedel & Co. Imp.

ART. X.—*Notes on the Storms of High South Latitudes.*

By D. W. BARKER, F.M.S.

[Read 13th July, 1882.]

IT is to the southern hemisphere that we must look for an explanation of phenomena attendant on all cyclonic and anti-cyclonic systems. To the southward of the 39th parallel there is nothing to stop the storms in pursuing an uninterrupted course round the world, and none of those disturbing areas of high temperature that are found in the northern hemisphere.

It is my intention, in this paper, to endeavour to show, from an isolated and entirely observational point—first, the general appearance of this region between 39 deg. and 60 deg. S., as seen by a spectator placed at some distance above the earth (supposing it to be possible to see the storms actually); second, general formation and weather attendant on them; third, cloud motions, and general prognostics to be obtained from them; and fourth, direction of propagation or movement.

If an observer outside, and perfectly independent of the earth, were to watch the motions of the atmosphere over this belt, he would probably see that there is a general prevailing set of the surface-wind towards a south-easterly point, and a set in the upper regions towards a north-easterly point; but this would be so broken up in some places by cyclonic and anti-cyclonic systems as scarcely to be discernible. In some places would be large irregular anti-cyclonic areas, while in others there would be strings of cyclonic disturbances. If he still watched, he would see the anti-cyclones broken down by the cyclonic disturbances, and forming again in other places; in fact, the whole system would be propagated round in an easterly direction. In summer time the appearance would be much more irregular, caused by the sun's influence. Off the continents of Australia and South America there would always be breaks, caused especially in the former by the large interior hot surface.

2. I propose the following ideal figure to represent approximately the shape of these storms, which seems to answer to all the veerings, &c., much better than anything else I have seen. Of course it is very unlikely that one would ever be seen so regular; but this is only to give a general idea. The shape they seem more generally to assume is elliptical, the southern half being a great deal broken up and more irregular than the northern, though it still exists, and can generally be traced. The isobars in front are very much compressed, caused by the resistance to its propagation, while in the rear they are often greatly extended. The following general description of one will show reasons for this, and also the general incurving of the wind outside and near the centre:—Barometer steady; light airs or calms; then light wind begins to make from N., with cir.-s. spreading over sky. Wind backs more to N.N.E., and barometer begins to fall. Soon after the clouds begin to lower, and it becomes quite overcast; barometer falling fast, and rain coming on; wind steadily freshening with hard gusts, backing still more to N.E. by N., where it keeps steady for some time. When the barometer falling more rapidly, rain comes on heavy, and wind again backs to N.E. The glass will now stop going down, and there is generally a lull for a few moments, and the wind suddenly shifts round to the westward with hard squall. This is supposing the centre to pass over observer. It will now clear up, but keep squally till the wind veers round to S., falling lighter all the time, and barometer rising. When S.E. there will be light airs and calms. They seldom go single, but several follow one another in succession, the wind then, after getting to S., backs again instead of going round. It is a remarkable thing how very seldom the wind goes right round to E. and N.E. by S.E. It may apparently seem to, but in most cases that this is observed light airs and calms are noted, and the cases are rarer of its going completely round the other way. After several of these an anticyclone will probably be experienced, the wind conditions in which are almost exactly the reverse. The weather fine and dry, and a good deal of a well-known dry weather stratus about. The wind changes quickly from S. or S.W. to a north-westerly point, and the stratus cloud breaks up before the next disturbance comes on. The anticyclones seem to have little or no movement in them.

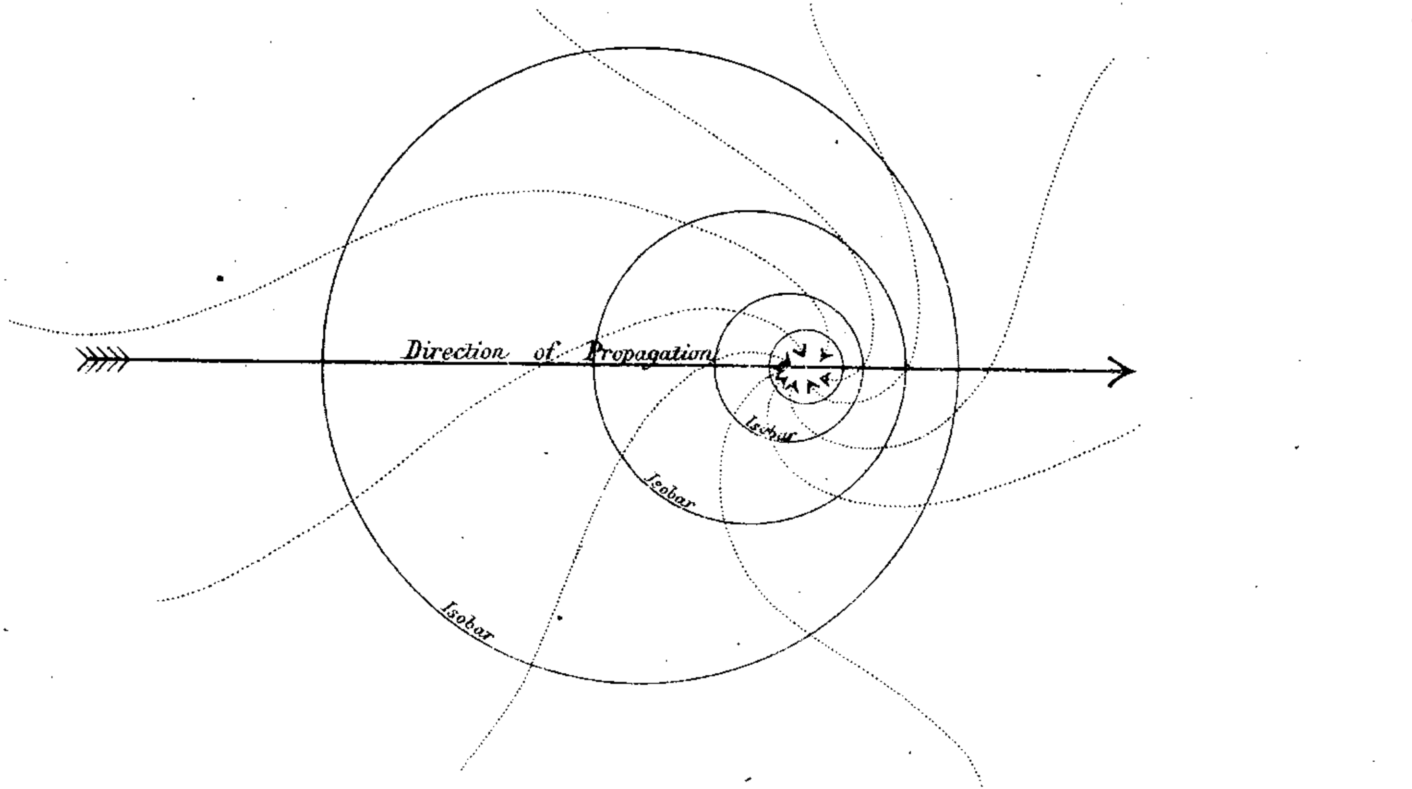
In a case where the centre passes well to southward of an observer, the wind does not shift suddenly, but veers gradually round to the westward. Heavy gales are occasionally experienced from the eastward of S., and when they come are generally lasting, and the weather takes some time to clear up. One thing especially tends to show the prevalence of westerly winds, which are the prevailing winds in the rear of these disturbances, is the constant, steady swell from that quarter, which can, with a few rare exceptions, be always traced. It is very noticeable before the cyclonic disturbances set in, and when the wind gets round to the quarter from which it is coming, it soon mounts up into the tremendous, regular seas, only to be seen in these parts of the globe. The temperature of the water does not seem at all affected by the shifting of the wind, though the air generally is to the extent of several degrees.

3. The movement of the upper clouds in these storms seem to be much more regular than they are in the northern hemisphere. Observations on their movements as observed from a ship are very difficult, on account of the double motion of rolling and going ahead, and especially when there are other clouds beneath, which then makes it appear as if the upper were in movement. I have frequently found old sailors even giving a point from which they are coming almost opposite to their real one. I shall now again take the case of a storm passing over an observer. It will be found that cirri first appear on and parallel to north-western horizon, and will apparently be moving from that point; but it will soon be seen that their movement is almost from a point at right angles to this, but they will appear to be spread over the sky from N.W., and the motion would probably be noted in nine cases out of ten that they were coming from N.W. But it will be found when they arrive overhead that they are moving from S.W., but are still being propagated from the north-westward; they thus have a twofold motion. These lines are often very perfectly formed, and all appear to meet at two points—S.W. and N.E. There will also be a slight short stratification across the lines at a large angle.

The more gradual the forming and propagation over of the upper cloud, together with its perfect form, as above described, the more severe and lasting the storm; but it must be understood that there are storms which are not forecasted in this perfect way. As the storm approaches the cirrus becomes denser and lower, till the sky is covered with a uniform layer, without any stratification; and, if the motions can be made out, they will still be found to come from some point to southward of W. The stratification often appears at intervals after the rain has set in, when the threads or lines will be found to have backed—that is to say, the line of direction of the threads will have moved round till they lay from N.W. to S.E. The storm is now in full force, and it is only at intervals that the upper clouds can be seen; they will be seen to be moving from a north-westerly point till the centre has passed over. It often happens that at or near the centre the weather clears up for a time, when the sky will be seen full of dense fragments of cir., cir.-s., and cir.-c., very much broken up and watery-looking, enveloped in a thick haze, all moving from a north-westerly point. But the sky soon becomes overcast again till the wind shifts round to a south-westerly point, when all the upper clouds will be found to have left, fragments only here and there moving from a south-westerly point. Large cumuli clouds are now continually formed, which are edged by cirrus-looking clouds, and seem a good deal affected by electric action, as seen by their abrupt serrated edges, sticking out in all directions above the cloud, and apparently strongly repelling each other's ends. These are also more or less attended by vivid flashes of lightning, which at night-time are a valuable warning of the approaching squall, before the cloud itself becomes visible. There is generally a strong gust of wind in them, and heavy downpours of hail and rain, but only for a short time, the wind also being unsteady, varying at times several points, mostly towards a more southerly point.

One thing may be worth noticing before passing on—it is the warning that the wind will soon veer to the southward when it is at W. or W.N.W., with fine weather. Fine high hard-looking cirrus clouds which, in the neighbourhood of the sun exhibit the most beautiful prismatic colours, and when the moon is up at night-time a green corona, at times very well defined, round it against the blue sky. It would be a valuable help to upper-cloud observations if the places where the cirrus is parallel to the horizon, and the apparent radiant points were always noted down, for, although it is noticeable that in the northern hemisphere the movements are very eccentric at times, yet to the southward I have always noticed that they move from a point, almost, if not quite, at right angles to the point to which they are parallel; and these points could always be noted with great exactness, whereas the point from which they move is not exact often,

Ideal Cyclonic Disturbance, S. Hemisphere.



D.W. Barker F.M.S.
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unless the observer can or will give the time to notice them properly.

4. The direction of propagation of these storms seems, as nearly as possible, to be about E.S.E. From numbers of opportunities I have had of observing them while the ship was going on this course, the storms follow one another much more regularly, and follow out all the necessary conditions of the diagram, while in steering either more to the northward or southward the conditions are altered, but still agree with the translation of the storm along this particular point. But until a number of really good sychrmous observations are to be obtained, this will always be more or less doubtful. I have every reason for knowing that ships' logs are not as accurate as to winds' direction and the weather as they might be; different people writing up the same log alone causing considerable errors, more especially in the velocity of the wind, which is generally considerably overrated. The subject has lately been taken in hand here, and we may hope soon to have some valuable information, only here again land influences tend considerably to alter these storms, and will not tend to throw very much light on their true formation over the sea.

Art. XI.—*Propulsion of Steam Vessels without Machinery.*

By Captain Griffiths.

[Read by Mr. Kernot, 13th July, 1882.]

ART. XII.—*A Physical Description of the Island of Tasmania.*

BY THE REV. J. E. TENISON-WOODS, F.G.S., F.L.S., HON. MEM. ROY. SOC. N.S.W., TASMANIA; COR. MEM. ROY. SOC. VICT.; VICE-PRES. LINNÆAN SOC. N.S.W., &c., &c.

[Contributed 10th August, 1882.]

THE island of Tasmania lies off the south-east extremity of the continent of Australia. It is separated from it by straits about 150 miles wide, and lies between lat. 43° 39′ and 40° 44′ S., and long. 144° 38′ and 148° 24′ E. It is somewhat wedge-shaped, the narrow end being towards the south, as in most islands and continents. Its area is estimated at about 27,000 square miles. Its contour is extremely diversified with numbers of deep indentations, estuaries, and bays, which give it a coast line of very great extent, far superior to any equal area in Australia. It may almost be described as a cluster of high mountains, with a large lake area on its tablelands, and a very extensive drainage or river system.

Tasmania is generally considered as a detached portion of the great Australian Cordillera, or mountain system of the eastern side of the continent, which extends from Wilson's Promontory right up to Cape York, in Torres Straits. Tasmania is nearly in the same line south of this mountain range, and is more or less connected by long islands lying in the same direction and a chain of rocks. But this unity of direction would not of itself prove them to belong to the same mountain system. The two separated portions should belong to the same geological formations, and owe their elevations to the same forces. That this is the case is capable of demonstration.

The great Australian Cordillera may be described as a mountain system composed of certain definite formations, which are more or less well represented in the whole of its course. There is first a granitic axis, on the sides of which altered rocks, schists, slates, and gneissose rocks of uncertain age are seen to rest. Above these are rocks belonging to the Cambrian, Siluro-Cambrian, and Silurian systems, on which are found quartz veins with gold and other minerals. The stratified rocks of this system are always much folded and crusted together so as to give them an almost vertical dip, and lead to great mistakes as to their thickness, unless attention be paid to the way the same strata are repeated in the various folds. Above these are found the Devonian rocks. They lie unconformably upon the Silurian strata, and though in places they have been much disturbed, yet are, as a rule, not so much inclined as the older system. Above these again are found the carboniferous rocks, consisting of lower and marine beds, as they are termed, and the upper or fresh-water series. These beds do not lie comformably upon the Devonian. They are nearly horizontal, but perceptible dips can be observed where they are studied over large areas. These beds are again succeeded by sandstones, called by various names. The two formations do not pass quite conformably from one to another, and the line of division is well marked. It is probable that these beds may be considered as Trias, or Lias, but this is of no moment just now. Their age will depend upon the age ascribed to the coal deposits of which so much has been written. Quite conformably with these are the strata next in succession, which are called the Wianamatta shales, which may be Liassic. Certain sandstones of aërial origin next succeed, whose true position is not yet decided. They lie above the Cretaceous rocks in Queensland, and, possibly, those of N. S. Wales (the Hawkesbury sandstone) may be older. Associated with all these are igneous or metamorphic rocks, called greenstones, or diorites. They are partly volcanic, and partly, no doubt, ash beds, or dykes, but so altered that we can only speculate generally upon their origin. But it is clear that some are the most recent in age, for they have broken through all the older formations, and in some cases altered and disturbed them. They form a very large portion of the rock system of the country. They overspread and completely hide immense tracts of the underlying formations, and sometimes, no doubt, they have broken them up and destroyed them.

Above the sandstones of aërial origin we find nothing of a more recent age until we come to the tertiary drifts, tertiary volcanic rocks, and recent alluvial deposits. These are more or less well represented, but the tertiary volcanic rocks by far the best of the three. Some very large tracts of country are covered with very recent basaltic lavas, doleritic for the most part, but evidently belonging to several periods of deposition. On the southern and extreme northern portions of the chain there is no vestige of any marine formation of later mesozoic or tertiary age. In the middle or central portions of the chain there are a few outliers of secondary formation, but with these exceptions there is an immense blank between the epoch of the carboniferous and geologically recent times.

All these features of the great Cordillera are found in the mountain system of Tasmania. There is the granite axis, then the metamorphic rocks, the Silurian strata, the Devonian, the carboniferous, and probably the Hawkesbury sandstones. After these and amidst them we have an immense development of intrusive greenstones. Then follows a vast blank, until the tertiary basaltic rocks and alluvial drifts are reached. In the whole island there is not the slightest trace of any marine mesozoic rock. On the extreme north side there is a small patch of miocene tertiary, and no doubt there are other such fragments underlying the basaltic rocks on the low lands of the north coast. Such deposits form no exception to its general resemblance to the great Australian Cordillera. On the low-lying flats of those mountains similar miocene or later formations occur, at least on the side opposite to those of Tasmania.

Thus we have in Australia and Tasmania a mountain system composed of the same elements, apparently upheaved under the same conditions, probably belonging to the same epoch, and subject to the same changes afterwards. The differences between the two systems are that the development of greenstones is much more extensive in Tasmania than in any equal area in Australia; and the disturbance and dislocations of all the strata have been more violent and numerous. Thus it is that no single formation can he followed for any great distance in Tasmania. It is broken up and faulted and overlaid by the intrusive rock. This has a most important economic bearing on the mineral productions of the rocks. Coal of fine quality and in thick seams is of frequent occurrence in the carboniferous rocks, but mining has not been very successful hitherto, partly because of the continued dislocations or faulting of the seams. It would appear as if the disturbances which during a long course of ages uplifted the Cordillera, had its period of greatest activity in the southern extremity, which is now represented by the Tasmania mountain system. Before dealing with these various formations separately, it will be necessary to say something about the general direction of the mountain ranges of the island.

As in south-east Australia, the most precipitous portions of the ranges are on the east side. They seem to abut upon the ocean at various places in the whole mountain chain, but this peculiarity becomes more marked towards the south, and most of all in Tasmania. On the east side the mountains confront the ocean with little or no intervening level ground. On the north side there is a considerable area of low-lying ground between the sea and the mountain ranges. This is not a level tract. These are spurs from the elevated plateau which divide the basins of the Tamar, the Mersey, the Forth, the Leven, and other rivers. All these streams empty upon the north side of the island; they have their origin in the elevated tableland, but descending from that have a long course through the comparatively lower land which intervenes between the plateau and the ocean. In some of the valleys or river basins there are patches of tertiary rocks. Some are fresh-water deposits, with abundance of leaves and plant impressions. Some tertiary marine shells have also been found. The dividing ridges between the streams are the usual paleozoic rocks of the Cordillera. As the same rocks are found upon the tableland, there must be a great fault, or a series of them, between these sedimentary rocks and the more elevated plateau This causes the inclined edges of the fossiliferous rocks to abut upon the greenstone masses of the interior.

The plateau or tableland occupies the centre, or perhaps a little to the north of the centre, of the island. In its highest portion it is over 4000 feet above the sea, and the average is not much under that height. It is distinguished by possessing large and deep lakes of fresh water. The Great Lake has a length of thirteen miles, with a maximum width of eight miles, and an average of three to four. It covers an area of 28,000 acres. There are besides Lakes Sorell, Crescent, St. Clair, Arthur, and Echo. They are the sources of all the important rivers in the island. This tableland is for the most part covered with beautiful grass lands, with no important mountains in their vicinity, unless in the case of Lake St. Clair. It is probable that the descent from this plateau is by a series of terraces (notably the Middlesex Plain and Mount Bischoff plateau, averaging 1800 to 2000 feet); and there are also in various parts of the island other tablelands of smaller extent and lower elevation. Thus Lakes Tiberias, Dulverton, and Tombs, on the east side of the island, are similar features. They are seen again in the south-east of New South Wales. The outline of the country around Lakes Bathurst and St. George in that colony is very similar to the lake districts of Tasmania. They are of good elevation, and the geological structure of the rocks is the same.

But though the elevation of the island of Tasmania has resulted in a certain extent of elevated plateaux, yet it has produced in far the greater portion of its extent an uneven surface, composed of broad or narrow mountain ridges or isolated hills. There are three phenomena which are visible here as elewhere:—1. Elevation; 2. Intrusion, or overflowing of volcanic rock; 3. Denudation, or weathering. All these causes may have been in operation until recently, and the last is still going on. The results of endless change, breaking up, and redistribution have produced such alteration in the strata that it is next to impossible to assign any particular appearance to its original cause. Thus a mountain which is now a pinnacle may originally have been a dome, and a sharp or jagged range may have been the edge of a tableland. There are many and various chains of mountains running through the island, some on the edges of the plateaux, and some running actually through their midst. Thus different directions have been traced by Count Strzelecki and others. It must be borne in mind when studying them that they are not certainly axes of elevation, and do not correspond in every respect with the general configuration of the coast line.

Beginning at the north-east extremity of the island—Cape Portland—we find a small ridge about 700 feet high. At a point called the Black Ridge the commencement of the great area of elevation is reached, and the land suddenly rises to above 3000 feet. The chain then takes a south-west direction, and sends off three long branching spurs. The first is the source of the River Boobiala, and terminates in a cluster of conspicuous granite hills, of which the most prominent is Mount Cameron. Next to that is the greenstone of Mount Horror, Mount Barrow, Mount Arthur, and Mount Direction. This spur continues as far as the mouth of the Tamar and ends with Mount Royal. The last spur is the highest part of the mountain system of this side of Tasmania, including the lofty summit Ben Lomond. "It is impossible," says Count Strzelecki,* "to give an adequate

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* *Physical Features of N. S. Wales, &c.*, p. 66.

idea of the outline which these spurs have produced; of those endless sharp-edged ridges, which run in all directions, interbranch, and form, as it were, a network of mountain chains woven intricately together. At times the eye can seize upon their distinct and independent courses, radiating from a common centre, and gradually sloping into flat-bottomed valleys; at times their flanks are erect and perpendicular, imparting to the ridges an appearance of having been rent asunder, and presenting between dark chasms and gorges, from which roaring torrents make their escape." From the northern extremity of what the Count called the "lofty and precipitous battlements" of Ben Lomond, the mountain overhangs profound and tortuous abysses. The central part of the mountain top is a mass of prismatic greenstone columns, 8 or 10 feet in diameter, and their ends projecting over chasms more than 3000 feet in perpendicular depth.

The chain of which Ben Lomond forms the culminating point reaches the sea at St. Patrick's Head. It then takes a south-west course for about sixty miles. It turns westward between Lake Tomb and the Eastern Marshes, and runs north of west to St. Peter's Pass. A spur runs out south at St. Peter's Pass, which separates the Coal River valley from that of the Jordan; and another which separates the Jordan from the Clyde. In this spur, Table Mount (3596 feet) is very conspicuous. It is a slope of tableland which, at a distance, appears like elevated strata of sandstone, though I believe it is an escarpment of greenstone.

The main axis or chain then proceeds northwards, dividing Lake Sorell from Lake Arthur, and extending to Dry's Bluff (4257 feet). The latter is a commanding elevation which forms a conspicuous abutment to the plains of the north coast. Between Dry's Bluff and the Western Bluff the chain has a semi-circular bend, and sends one spur to the north, which terminates at Quamby's Bluff. It also sends others to the south, which divide the lakes from some of the tributaries of the Derwent. At Western Bluff it sends to the north-east a long spur, which divides the valleys of the Mersey and Meander. The range from St. Peter's Pass averages 3500 feet in height, and presents an extremely dark, rugged aspect. Its crests are almost all greenstone very rocky and barren. To the southward it is still bolder "Its spurs in the vicinity of Lake St. Clair, to the north, north-west, and west, are topped for the most part by more lofty, bare, and cloven summits of quartz rock and syenite, and are divided by darker gullies, the beds of which are furrowed by the torrents" (*Strzelecki*, p. 69). The greenstone and basaltic spur which divides the Forth from the Leven, and that which stretches to Cape Grim on the extreme north-west, are all equally rugged and wild. South of Lake St. Clair there is a spur which divides the valleys of the Gordon and King Rivers, which empty on the west coast. This culminates in the mountain called Frenchman's Cap (4756 feet). The country in this neighbourhood is very little explored, and it is of wild and picturesque character. Another spur makes a semi-circular curve to the eastward, and divides the basins of the Huon and Derwent Rivers, terminating in Mount Wellington (4166 feet). The chain beyond these two spurs bends in a south-easterly direction, sending forth minor spurs, and, with Mounts Adamson (4017 feet), La Perouse (3800 feet), Bathurst Range, and Wilmot Range, barren mountains, standing out conspicuously from various parts, until the axis terminates at South Cape.

The above is only a very general idea of the mountain system of the island, which is more or less picturesque and ruggedly uneven throughout. As the west and south coasts are not settled upon except by a few scattered families of splitters, and as it has been very little explored, much has to be learned about the physical structure and geology of the mountain system of Tasmania. I have not specified all the offshoots from the main chain. Thus the north-west spurs send off two westerly offshoots in succession, one of which divides the Arthur and Pieman Rivers, and another—the Eldon Range (4789 feet)—dividing the Pieman, and its tributary the Murchison, from the King River, which flows into Macquarie Harbour. The south end of this port receives the River Gordon, which drains the north side of another spur from the Wellington Range. The southern side of this spur drains by many tributaries into the Huon. Mount Picton (4340 feet) is one of the highest peaks of this very little known mountain chain.

The general aspect of these mountain ranges is picturesque in the extreme. The summits of the hills are for the most part bare, and studded with romantic crags and precipices. Where the soil is derived from greenstone, and not too precipitous, the forest is extremely dense. The gigantic *Eucalyptus amygdalina* and *E. obliqua* grow thickly with tapering stems of extraordinary height; while the undergrowth is of moss and fern, and shaded by almost impassable thickets of *Pomaderris elliptica, Fagus Cunninghami,* and tree ferns (*Dicksonia antarctica*). The sides of the smaller streams are thus nearly always surrounded by forest. But there is a great difference between the dense vegetation of the comparatively level and open rivers of the plains and those which are supplied from the mountain gullies. The latter are all completely shaded in by a thick growth of forest extending for a long distance on either side. The tablelands are, as already stated, grassy, and free from timber; and in all the country to the south and west, between the densely wooded gullies, the land is open, and clothed with a sedge called button grass (*Gymnoschœnus sphærocephalus,* Hooker) and *Xyris gracilis, Schizæa bifida,* and many mosses, fungi, and lichens. In all the elevated regions of the western and southern mountain systems the soil is open, poor, and wet. The snow lies upon it for many months, and its humidity and exposed situation render it worthless for settlement.

I will now describe the various geological formations which form the mountain systems of the island.

Granite, syenite, and *porphyritic* granite are well represented on the east coast at George's Bay. It is also found at Mount Bischoff, and occasionally along the Eldon Range, near Ben Lomond, Mount Barrow, and other places. Its connection with other formations is not well made out. As a rule it does not play the most important part in the geology of Tasmania. It does, however, contribute a very important item to the mineral richness, as it is in connection with the granite formation that the remarkable deposits of tin have been found.

Metamorphic Rocks.—It is probable that the base of most of the mountain ranges to the westward consist of metamorphic rocks. They are principally varieties of quartz rock and schist, which appear to alternate and pass into one another. They are especially developed in the country about the Eldon, Arthur, and Frankland Ranges, Frenchman's Cap, Mount Murchison, &c. The mica schist, according to Mr. Charles Gould, consists of quartz and mica in varying proportions. These minerals are sometimes arranged in alternate laminæ, while at others the quartz is aggregated into nodules, which are imbedded in soft micaceous, or occasionally chloritic schists. Those varieties are the most abundant in which the quartz preponderates over the mica, frequently passing into a homogeneous quartz rock. The greater part of these beds possess a very foliated structure, with a lamination in general definite directions. There are no quartz reefs in connection with these deposits. Whatever quartz there is exists in the form of bed rock, and is part of the whole altered strata.

There can be no doubt that these belong to some formerly stratified rocks lying below the Silurian, or even the Cambrian. They are too much altered to contain fossils, if, indeed, they ever did possess them. It is very singular that there are no quartz reefs in connection with them. The beds contain gold in small quantities. Possibly the metamorphic action which changed them from the stratified state has been too partial or limited to segregate thoroughly the gold and quartz into reef deposits. The metamorphism to which they have been subjected is due to—1. The pressure to which they have been subjected when covered by great masses of formations, which have subsequently been nearly all denuded away; 2. Heat accompanying that pressure; 3. Water also much compressed and heated.

Silurian.—At the base of the western half of the Eldon Range, and extending southwards to the Collingwood Valley, certain strata are found a considerable thickness of dark grey mudstones and clay slates with slight admixture of arenaceous rocks, and towards the base calcareous bands and limestones. The dip is not easily ascertained, from the cleavage which affects the upper beds and the contortion of the lower ones. Succeeding these are highly micaceous beds, siliceous grits and clay slates, the latter resting uncomformably upon the metamorphic rocks. On the north shore of the Macquarie Harbour, and the course of the Gordon River for thirty miles from its mouth, and for a short distance of the courses of the King's and Franklin Rivers, and on the line of country between the Eldon Ranges and the West Coast, the usual upper paleozoic and greenstone formations, so common on the east side of the colony, are absent. Their places are taken by several marked divisions of the Silurian rocks, but their exact sequence has not yet been determined. According to Mr. Charles Gould they are chiefly of Silurian, and some of them of Cambrian formation. The most prominent formation consists of fossiliferous limestones, the *entire* thickness of which is not less than 1000 feet, called by Mr. Gould the Gordon limestones.* They are, in some cases, slightly argillaceous and thickly bedded, but ordinarily compact and massive. They are jointed in a variety of directions, and the fissures have been filled with calcareous spars. Irregular fissures or veins of calcareous spars and quartz ramify through the formation. These vary in thickness, and contain galena. These limestones appear again at the great bend of the Gordon River, and at Point Hibbs on the West Coast, at the junction of the Franklin and Gordon. They are then succeeded by sandstones and grits. Below these is a coarse conglomerate consisting of quartz pebbles in a siliceous cement, succeeded by siliceous grits and a variety of sandstones, micaceous sandstones, purple grits, and streaked with quartz veins, apparently passing down into clay, slate, quartzite and micaceous schists. The conglomerate forms the most conspicuous summits of the ranges west of the King's River. Steel grey and yellow clay slates, with fossils, are found in the Mersey district. The organisms include Phacops and Ogygia, Calymene Conocephalites, Orthis Euomphalus.† Messrs. Etheridge, Lesquereux, and Dana have considered the fossils as indicating one of the Lower Silurian formations. Similar formations, but of undetermined age, have been received from Fingal.

The following Lower Silurian fossils have been recorded from Western Tasmania:—Retzia minima, Cyrtodonta auriculata, C. compressa, C. distorta, C. gibbulosa, C. inflata, C. obliquata, C. pinguis, C. reversa.‡ Tellinomya amygdala, T. antipoda, Bellerophon pugnus, Eunema æmula, Helicotoma Milligani, H. pusilla, Holopæa munica, Hormotoma nerinæa, H. usitata, Murchisonia Franklinii, M. mimetica, Raphistoma æterna, Scatites australis, Trochonema, Bigsbyana, Lituites Gouldii, Orthoceras, antilope, P. Murchisoni, P. theca, C. Youngii. There is no Upper Silurian fossil recorded from Tasmania.

Silurian strata, but without fossils, were reported by Mr. Charles Gould (at one time Government geologist) from the north-eastern part of the island, in the county of Dorset. He says it would be impossible to define the limits of these forma-

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* The Gordon limestones are most probably the equivalent of the Chudleigh and Midland Plains beds.

†*Proceedings of the Royal Society of Victoria for* 1874, p. 27.

‡ All these are quoted as MS. names of Salter in Bigsby's *Thesaurus Siluricus*, 1868, p. 140.

tions, as they are covered by a drift of sand clay and rounded quartz pebbles. The paleozoic beds are regarded as connected with the Silurian schists of Fingal and the west side of the island. Cambrian rocks are also reported by the same authority along the valley of the Tamar, on low ridges parallel with the ranges, and which have been eroded by the river. Silurian rocks have also been reported from the south side of the island, near Port Cygnet, but I am not aware of the occurrence of any fossils.

Silurian rocks are also stated to occur in the neighbourhood of Mount Bischoff, in the north-west, but are so overlaid by basaltic lava as only to be visible in a few places.*

Devonian.—No fossils peculiar to this formation have been found in Tasmania, though the period is well represented in the Cordillera of New South Wales. As, however, a great many carboniferous fossils are common to the Devonian rocks, it is not at all unlikely that when an accurate survey is made many of the rocks now regarded as carboniferous will prove to belong to a lower horizon.

Upper Paleozoic Carboniferous.—These formations are so very extensively developed in Tasmania that a very long list would be required to name all the localities. As a rule they are exposed in alternate layers of yellow and white sandstones, with shales and thin beds of limestone over which again other sandstones are found. The sandstones are generally firm and hard, but the limestones fall to pieces very readily in some places, and in others these qualities are interchanged. The dip varies, and in many localities there is scarcely any dip at all, but where there has been much faulting from intrusive basalts or greenstones the dip is almost at every angle. No attempt has ever been made to settle geologically the regular sequence of the strata or to determine the horizon to which the various fossils belong. Until a geological map of the east side of the island is drawn after a careful survey it would be premature to say anything decided from the fossil evidence, which is very abundant. Coal is more or less abundant throughout the island. It belongs clearly to the period of the carboniferous fossils. These marine beds, as they are called, are found both above and below the coal. Fossil plants are also found both above and below the marine fossils. It is said that

* "Geology of the Tin Country:" a series of very interesting letters in a local paper, by S. H. Wintle.

the aspect of some of these fossil plants is not paleozoic; and at one time discredit was thrown upon the statement that such plant remains were found under the marine paleozoic fossils. There can be no question whatever that they are found under the marine paleozoic organisms.* It is generally admitted that some of the coal beds are more recent than others, as for instance those of Fingal, but the relative position has not been accurately worked out. As instances of where the fossiliferous strata are found I may mention the valley of the Derwent, New Norfolk, Mount Dromedary, Tasman's Peninsula, the valley of the Tamar, the Mersey, the Don, many places on the East Coast of the island, Oatlands, Fingal, &c.

The following fossils are recorded as from Tasmanian carboniferous deposits:—*Plantæ,* Glossopteris browniana, G. ampla, G. elongata, G. linearis, G. reticulatum (var. browniana ?), Lepidodendron sp ? Phyllotheca hookeri, Alethopteris australis, Thinnfeldia odontopteroides, Sphenopteris alata, Vertebraria australis ? Endogenophyllites wellingtonensis, Zengophyllites elongatus.

Animalia, Favosites ovata, Stenopora informis, S. tasmaniensis, Fenestella plebeia, F. ampla,†E. antiqua (F. densa) (F. fossula), F. gracilis, Orthis michelini, Productus cora, P. murchisonianus, P. pustulosus, P. rugatus, P. scabriculus, P. n.s. close to P. prattianus (Davidson ms.), P. brachythœpus, P. granulosus, P. n. s. (Davidson fide lit), Spirifera clàrkei, S. convoluta, S. rassicostata, S. glabra, S. stokesii, S. strzeleckii, S. tasmaniensis, S. trigonalis, S. vespertilio, S. 12-costatus, S. darwinii, S. duplicostata, Strophomena crenistria, Terebratula ambigua, T. sacculus, Astartilla ? Aviculopecten limæ-formis, A. squamuliferus, A. tasmaniensis Othonota (?) compressa, Pachydomus carinatus, P. globosus, Pterinea macroptera.

It must be admitted that this is a most imperfect list, but the fact is, that Tasmania, though extremely rich in fossils of the upper Paleozoic rocks, has never had its paleontology fairly worked out. It must also be remarked that there are probably two coal floras. One, Oolitic (?),

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* See *Proc. Roy. Soc. Tasm., 1873,* p. 36, where, in a paper on the Mersey Coal Measures, by T. Stephens, Esq., M.A., the occurence of *Glossopteris browniana* in beds *underneath* marine paleozoic fossils is recorded.

† Proretepora, according to De Koninck, who unites four of the species. *See Foss. Pal., N.S.W.,* p. 178.

characterised by Thinnfeldia (Jerusalem); the other, Permian (?), with Glossopteris, &c.

Carbonaceous Sandstone.—In the Oatlands district there is a tableland forming an inclined plane, of which the highest portion is Lake Tiberias. This is about 1460 feet above the sea. The floor of this plain is almost entirely composed of sandstone, which very closely resembles the Hawkesbury rocks. The strata are in two divisions slightly uncomformable to each other. The upper beds are formed of a fine grained sandstone, more or less ferruginous, in thin layers with much false beddings decomposing into a worthless soil from the upper beds. Small seams of coal and carbonaceous bands are met with in the formation, just as they are in a similar deposit in New South Wales. I have no doubt on my own mind, from all I have seen of this district, that the formations are the same. The town of Oatlands is built upon it, and it is well seen round the borders of Lake Dulverton. I am not aware how far this formation extends in Tasmania. I never noticed it except on the Oatlands tableland. It is not fossiliferous. I should say it was of considerable thickness, 200 or 300 feet at least. The line of junction between it and the coal formation is well marked. They are not quite conformable; the coal measures having a slight dip to the south, which brings them to the surface at the north side of York Plains. The junction often shows pebbles of coal and rodled masses of shale and coal measures, marking the denudation previous to the deposition of the sandstone. Both formations are very extensively overlaid by outflows of greenstone; and no doubt were an accurate geological survey to be made many faults would be found as well.

Greenstone.—The rock which bears this name in Tasmania no doubt belongs to several distinct groups of intrusive or metamorphic rocks. It plays such an important part in the geological structure of the island that a detailed examination will be necessary. Its appearance is certainly posterior to the deposition of the carbonaceous sandstone, as it breaks through that rock and overflows it. It forms the capping of nearly all the mountains of the island, from which we gather an important insight into the denudation to which the rocks have been subjected. It is probable that all these deposits of greenstone formed large, unbroken deposits, covering much of the undulating surface of what is now Tasmania. This may have been then a sea-bottom, formed in some places by carboniferous and in others older paleozoic rocks. It did not come from one outlet; in fact, dykes are as commonly distributed as the stone, but the dykes do not always correspond with the mountains. We must, therefore, imagine that the high-peaked summits crowned with this igneous rock mark former points of ejection. They may in some cases, but in the majority these mountains are the jagged, uneven portions of a surface which has been broken by upheaval, volcanic outbursts, earthquakes, and dislocations of various kinds, then cut and scarred by the denudation of wind and rain and sea and flood. The evidence of all this is found in the strata below. They are faulted and wedged out by dykes and intrusive masses of rock in many localities; but there are others where, though the greenstones are in very thick masses above, the strata underneath are very little disturbed. On the extreme west coast, for instance, near Macquarie Harbour, greenstone occurs only rarely, and then it is at great elevations and in the form of capping to the underlying stratified deposits. According to Mr. Chas. Gould, it has the appearance of outliers from the great mass of trappean rocks upon the east; for the regularity and undisturbed condition of the stratified formations below preclude the idea of its having been ejected through. It seems rather to have flowed across from east to west. Boulders of greenstone occur occasionally of great size and in considerable quantities at distances remote from where it exists *in situ*. The junction of the greenstone and underlying rocks is at various elevations, and this is not due to any upheaval, but to the irregularly eroded surface upon which it was deposited. It has been suggested that some of the lakes of the interior have been formerly craters, and Lake St. Clair, with a depth of nearly 600 feet, has been especially cited. What lends a colour to this supposition is that it is surrounded by mountains of greenstone. But, according to Mr. Gould, sandstone crops out from below the greenstone of Mount Olympus, and these sandstones are nearly horizontal, and there are no scoriæ, ashes, or other deposits around the lake.* The more solid portions of ash deposits are often converted into greenstone, and the lighter portions may have easily

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* There is, however, one large deep lake-crater in South Australia named Mount Gambier. The ashes lie there upon perfectly horizontal limestones, which are full of tertiary fossils.

disappeared in the course of time. This is only mentioned to show that the reasons alleged by Mr. Gould are not decisive of the question; but, at the same time, he gives a much more feasible explanation of the lake than a crater origin, which most persons will be disposed to accept. According to him the waters have been penned up in a natural valley by a recent outflow of basalt. It is hardly to be supposed that we should be able to trace the craters which have been formed during the overflow of the greenstones. It may be safely affirmed that the amount of basalt which has been outpoured in recent times in New South Wales or Victoria, or in South and South-east Australia, fully equals, if it does not surpass, the greenstone deposits. The basalts are comparatively very recent, for they are but little, if at all, altered, yet there does not remain a single crater in all South-east Australia, and in the colony of Victoria they are very few. It is only as we go westward to where the evidence of volcanic action dies out that we find undoubted ash craters with tufaceous deposits.

In all probability the greenstones of Tasmania are ordinary basaltic lavas, alternated by metamorphic action, or chemical change, in which time and weathering were probably the principal agents. After the researches of Mr. J. A. Phillips on the "greenstones" of Cornwall, we cannot hesitate to pronounce on those of the island. In Cornwall they are proved to be lava, closely resembling those of modern date. They are, in fact, dolerites, in which the augite has gradually been transformed into hornblende and viridite*, while the felspar merges into a granular mass. The titanic iron is gradually replaced by a greyish-white product of alteration, and a little epidote subsequently appears. The quartz, when found in these, is a result of aggregation. No attempt has been made to my knowledge to determine the character of the Tasmanian greenstones. They are described thus by Count Strzelecki (*Loc. Cit.*, p. 101):—

Diabase.—Brongniart; Diorite, Haüy.—The varieties of this kind of rock are uniformly composed of felspar and hornblende, in the state of grains or small crystals, in

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* Viridite.—This term refers to microscopic petrography, and is used to express green or transparent substances visible in thin sections under the microscope, forming scaly or fibrous aggregations, resulting from decomposition of augite, hornblende, or olivine. The composition varies, but consists chiefly of silicates of monoxyde of iron and magnesia.

proportions somewhat different, but in which the hornblende predominates. They vary, also, in their structure, being—1. slaty; 2. prismatic; 3. amorphous. 1. Slaty greenstones or schistoid Diabase. Colour, in recent fracture between leek and pistachio green, decomposing on the external surface to a dull reddish brown. Internal surface has a waxy lustre. The imbedded crystals of hornblende are generally brilliant. Its structure is schistose, but the layers are never parallel, and are running from a thickness of two or three inches to a wedge-like termination. For the most part its seams present a lenticular form resembling convex lenses, thus (says the Count) beautifully illustrating the successive overflowings of the incandescent matter. It does not adhere to the tongue, and exhales an argillaceous odour. The streak varies. Its powder is a brownish yellow colour. Structure, compact and hard. The Count adds that the localities which supply the most important facts bearing on its geological relation are between Launceston and Mount Direction, Mount Direction and George Town, Stony Head, Cape Portland and St. Patrick's Head, Break-o'-Day River and the Tyne, Ben Lomond, Ben Nevis, Port Sorell, Day's Bluff, Lake Arthur, Lake Sorell, the Great Lake, Lake St. Clair, Western Bluff, Mount Cradle, and the source of the Nive, and Mount Cameron West. He says, also, that this variety of greenstone occurs at various heights, capping all the prominent elevations of the interior of the island. It is invariably and intimately associated with porphyries, argillaceous schist, mica, slate, syenite, granite, siliceous slate, and limestone. When it is isolated from the prismatic or amorphous greenstone, its seams are horizontal. When, however, these varieties are in contact with it, the seams are vertical, broken, and distorted.

The examination of the great area which this schistose greenstone covers in Van Diemen's Land, leads to the discovery of sources from which it overflowed the island. The principal sites appear to have existed in the vicinity of Cape Portland, between Mount Barrow and Mount Arthur, on the north side of Ben Lomond, on Mount St. Patrick, at Port Sorell, on Mount Cradle, Mount Cameron West, and at the source of the Nive. In all these places the schistose greenstone is associated with porphyry. This association strongly led the Count to believe that the greenstone flowed along the pre-existing slope of the consolidated porphyry.

2. *Prismatic Greenstone.*—This rock does not differ from the preceding, except that its structure is prismatic, the prisms having from three to seven sides. It is principally seen on Ben Lomond, where prismatic columns are found from three to eight feet in diameter, and sometimes one hundred feet long. There have been no observations on this rock in Tasmania. Similar rocks in New South Wales, Victoria, and Queensland have been microscopically examined. Mr. Allport, of Birmingham, says of that of Gympie (Queensland) that it is a diorite, containing hornblende triclinic felspar, orthoclase, biotite, and pyrites. There was also a little chlorite and quartz filling up the spaces between the crystals. Many of the crystals were imperfectly crystallised, but the rock was not much altered.

Some of the diorites of Victoria have formed the subject of a very elaborate paper by Mr. A. W. Howitt, F.G.S., read recently before the Royal Society of Victoria. He says that dykes of diorite are of very frequent occurrence at the Swift's Creek diggings. They are from one to five feet wide, and have not any common direction of strike. They are sometimes visibly crystalline, and composed of white plagioclase and dark green hornblende. A microscopic examination shows quartz, viridite, apatite, and combinations of iron.

There can be no doubt that these rocky masses and dykes of diorite wherever they are found are portions of one continued period of volcanic disturbance to which this part of the globe was subject during mesozoic times. In New South Wales and Queensland many of the igneous rocks are intercalated with the carbonaceous deposits. I am not aware that this has been noticed in Tasmania, though the examinations have been very imperfect. But one thing seems to be very certain, and that is that the bulk of the Tasmanian diorites flowed out after the coal period, and probably at the end of the mesozoic epoch alluded to. In a paper on the Hawkesbury sandstone, read before the Royal Society, New South Wales, May, 1882, I have stated my reasons for believing this formation to be an aërial one. It may, therefore, have accumulated round the igneous rocks, and is not in reality under them, though it has that appearance. This may be the explanation of the greenstone cappings or outliers.

Has the island been submerged since the mesozoic period? On the north side it has—that is, the low-lying portion of the north coast, far away from the table-land. But with regard to the rest we may say that there is an extreme probability that it has not. It is true that we have evidence of immense denudation in the greenstone, and that in north-east Australia we have an extensive development of secondary rocks and formations ranging from the oolitic to the cretaceous, but these formations seem to be confined to the north-east side of the continent. It is hardly likely that any formations could have existed here without leaving any trace, not merely of fossils, but of other changes.

It must be admitted that this negative evidence is not conclusive. It receives a little more confirmation from the extensive outbursts of basaltic lava which are found throughout the island. These lava-flows lie either upon the carbonaceous deposits, or upon drifts, or directly upon the greenstone. They are of various ages, but probably not earlier than the tertiary period. If there be yet any hope of finding secondary formations in the island it will be underneath these basalts. The tertiary lava flowing over them would thus preserve them from wearing. No such deposits have yet been found, as far as marine fossils are concerned, but plant remains are not uncommon. This shows clearly that the land was above the sea at the time of the outpouring of the basalts.

These modern volcanic rocks are nearly of similar character throughout. They are black or dark blue vesicular basalts, similar to what are found in New South Wales and Victoria. They are almost as extensively distributed as the greenstones, and are found at every altitude. They form densely wooded hills on the south-east side of the island, and are more or less visible in the east and north coast, on the table land, and through the island, such as near Oatlands, Lake Arthur, Lake St. Clair, Launceston, Table Cape, Cape Grimm, &c., &c. Near Brighton a very fine section of columnal basalt is visible. The general character of the rock is doleritic. The only specimen I ever had an opportunity of examining appeared to me to show a felspathic dolerite, with triclinic felspar, augite, magnetite, and either olivine or pseudomorphs, after olivine. The augite is in small brown crystals. Mr. Ulrich, of Victoria, made sections of the basalt at Table Cape, and found the composition to be very similar to some of the recent basalts in Victoria. It was a felspar, with very little augite. Vitreous quartz, magnetite, and olivine basalt from Breadalbane, where there are plant remains and leaf deposits, contained well-developed crystals of augite. No conclusion as to the age of the rocks can be formed, except that they are tertiary. Of that we may be certain—first, because at Table Cape they overlie marine tertiary beds of miocene age; secondly, because at Breadalbane some beds overflow plant remains, which are tertiary, and identified by some of the plants with pliocene vegetable remains in Victoria and New South Wales. These two outbursts must be of different age, because the Table Cape beds have flowed over the bottom of the sea, which has since been upheaved; but those of Breadalbane have flowed later, over dry land.

No crater remains to show the points of ejection. It does not take long to destroy such records, but we may conclude at least that there has been no volcanic activity in very recent times in Tasmania, such as we know existed in Western Victoria or the south-eastern district of South Australia, where several craters are still visible. The more westerly they are situated the more recent in character they become. The one most to the westward is quite modern.

The tertiary marine beds at Table Cape form a small patch of fossiliferous strata which owe their preservation entirely to the capping of basaltic lava. Probably similar patches are to be found under the basalt on the north coast. At Breadalbane, miocene fossils are sometimes found in wells. The formation is part of the great tertiary deposits of Southern Australia, which extends with occasional interruption over 20° of latitude and 10° of longitude. It consists at Table Cape of bands of limestone, marl, and clays, the latter often ferruginous and containing gravel, as if the beds had been derived from decomposing traps. The fossils identified are:—Murex eyrei, Fusus meredithæ, F. roblini, F. johnstonii, F. tateana, F. transenna, Triton abbotti, T. minimum, Buccinum fragile, Trophon fragile, Cominella lyræcostata, C. cancellata, Thala marginata, Nassa marginata, Terebra additoides, T. simplex, Cassis sufflatus, Cassidaria reticulospira, Syrnola bifasciata, Actæon scrobiculatus, Columbella oxleyi, C. caniozoica, Pleurotoma johnstonii, P. paracantha, P. sandleroides, P. pullulascens, Ancillaria mucronata, Voluta hannafordii, V. anticingulata, V. antiscalaris; V. weldii, V. macroptera, V. granatina, V. maccoyi, Marginella wentworthi, M. strombiformis, M. octoplicata, C. platyryncha, C. gastroplax, C. eximia, C. archeri, Trivia mimina, T. avellanoides, Daphrella columbelloides, D. tenuisculpta, D. gracillima, Mangelia gracillina, N. wintlei, N. vixumbilicata, N. polita, Turbonilla lyræcostata, T. pagoda, Eulima danæ, Cerithiopsis johnstonii, Turritella tasmanica, T. sturtii, T. warburtonii, Vermetus conohelix, Tenagodus occlusus, Rissoa stevensiana, Rissoina varicifera, R. tateana, R. johnstonii, Turbo etheridgei, Imperator imperialis, Trochus josephi, Thalotia alternata, Gibbula crassigranosa, G. clarkei, G. æquisulcata, Astralium flindersii, A. ornatissimum, Margarita Keckwickii, Zizyphinus blaxlandi, Delphinula tetragonostoma, L. tasmanica, L. discoidea, L. lamellosa, Solarium gibbuloides, Fissurella concatenata, Emarginula transenna, Crepidula lævis, Trochita turbinata, Cylichna arachis, Humphreya arachis, Dentalina kicksii, D. lacteum, Terebratulina davidsoni, Waldemia gerybeldiana, W. macropora, W. gambierensis, Terebratella compta, Rhynconella lucida, Ostrea sp., Lima bassi, L. sp., Plicatula, Spondylus gaderopoides (?), Cucullea corioensis, D. cainozoica, Arca sp., Pectunculus laticostatus, Limopsis belcheri, L. aurita, Nucula tumida Leda crebricostata, Chama lamellifera, Venus allporti, V. propinqua, V. cainozoica, Cardita gracilicostata, Cardium sp., Crassatella, oblonga, C. aphrodina, Tellina cainozoica, Solecurtus legrandi, Lyonsia agnewi, Myodon, Trigonia acuticostata, T. semiundulata, Vulsella sp. Balanus, Micraster brevistella, Lovenia forbesi, Leiocidaris, Heliastrea ———, Thamnastrea sera, Balanophyllia australiensis, Dendrophyllia epithecata, Trochoseris woodsi, Conotrochus maccoyi, Sphenotrochus excisus, S. deltoideus, Montlivaltia discus, Placotrochus elongatus, Conocyathus viola, Dendrophyllia duncani, Flabellum duncani, F. victoriæ, F. gambierensis, Cellepora gambierensis, C. spongiosa, C. nummularia, C. hemispherica, Spiroporina typica, Retepora sp.

Tertiary Plant Beds.—In Mr. Chas. Gould's report of the exploration of Macquarie Harbour, he gives the following account of a tertiary formation existing there. He says that on the north side of Macquarie Harbour and for some miles up the Gordon River there are cliffs, at many points, 70 or 80 feet in height, consisting of coarse sand, rock and shales, largely impressed with leaves of existing plants, and containing occasional thin seams of lignite, which have caused reports of coal there. Raised beaches (?) of loose quartz-pebbles surmount them, and form elevated pleateaux of marsh land on the southern as well as on the northern side of the harbour. I am not aware of any further attempts to explore these tertiary beds. Mr. Gould is right in supposing the plant impressions to be those of existing species. The formation is probably a pliocene one, and the rolled pebbles above suggest a drift like that in which the alluvial deposits of gold are found in Victoria. The lignite is, however, not usual.

Other plant beds of tertiary age have been ably described by Mr. R. M. Johnston. In the immediate vicinity of Launceston and scattered over the westward plains there are accumulations of water-worn gravel, one to three feet thick, arranged in horizontal layers, and associated with clays and tufa more or less laminated. The most extensively exposed bed is on a railway cutting between Perth and Longford. This is on a tableland about 115 feet above the present channel of the South Esk, at Longford, and 630 feet above the level of the sea. These beds are principally composed of siliceous pebbles and gritty concretions, all more or less waterworn and cemented together. Opalized wood is scattered throughout the whole of the gravelly accumulations. With them are also associated pebbles of limestone, derived from the carboniferous beds, and containing casts of fossils characteristic of that formation. In the laminated clays are found beds of lignite intercalated with beds of fine blue clay, containing remains of water plants, fragments of branches, twigs, and leaves, and occasional *Unio* shells. In a cutting beyond Breadalbane a section of tufaceous rock is exposed, in which there are numerous fragments of branches and trunks of trees disposed horizontally. These are principally composed of lime.

Mr. Johnston divides all the beds into the upper, middle, and lower, which he thus characterises :—Lower beds: Composed of series of beds of blue and white clays, occasionally inter-laminated with thin bands of tenacious clay, containing leaves, for the most part exogenous, and a considerable portion coniferous. Myrtaceous forms do not seem to predominate, but there are leaves very similar to our finely pinnate acacias. In an exposed cliff section on the North Esk, Mr. Johnston states that he found fragments of Banksia and Eucalyptus, which, of course, would approximate the deposits to the living flora. The middle beds are chiefly composed of beds of clay and sand, with leaf impressions. The upper beds are represented by the low rounded hills and terraces flanking the present course of the River Tamar. They are composed of alternate beds of conglomerates, breccias, and gravels, and the detritus of the lower strata. At a bend in the River Tamar, called Stevenson's Bend, there is a very rich deposit of leaf impressions in the banks; and at Breadalbane Mr. Johnston gives the following section:—Superficial soil, 2 to 3 feet; basalt, 50 to 60 feet; conglomerate of waterworn fragments of basalt, 3 to 4 feet; white arenaceous clays, 20 to 30 feet; lignite, with embedded trunks and branches of pine and other trees, 3 feet. White and grey arenaceous sands of unknown depth.

From this it would appear that the plant beds denote a flora which existed at the time of some of the volcanic outbursts, but Mr. Johnston is of opinion that the lowest beds rest upon a very old basaltic stratum. My own impression is that the lowest sands are contemporaneous with the older pliocene deposits of Victoria (?) and South Australia, where they are manifested in a similar manner. They rest upon older basalts which cover marine miocene formations, and these may be the basalts which overlie the Table Cape deposits, and which were deposited on the bottom of the miocene sea.

Close to Hobart, on the south side of the island, tertiary plant remains, with land shells, have been found. They occur in a deposit of travertin in Geilston Bay, on the Derwent River, on the opposite side to Hobart. Abundant leaf impressions, with fossil leaves and wood, have been found in this travertin, with two species of Helix, a Vitrina and a Bulimus. The plant beds have been displaced by a basaltic dyke. The displacement of the stratified beds by the dyke has caused many fissures and cavities, in which the bones of existing animals are lying in abundance. The seeds found in the travertin beds show the deposit to be contemporaneous with the pliocene drifts of Victoria.

I have now dealt with all the evidence that is known in Tasmania as to physical condition of the island in former geological periods. The question remains to be asked whether we have any evidence that it was formerly united to the Australian continent? There is no geological evidence. It forms a part of the continent geologically, and the space between the two is bridged over by islands. They are of the lowest formations known in Tasmania, covered, in some cases, with miocene and pliocene marine deposits. In the tertiary era, therefore, it is extremely probable that the sea rolled between them, even to a larger extent than it does now. The evidence is in favour of Tasmania, like South-east Australia, being dry land during the latter part of the Mesozoic period. We have nothing to show us that the lands were connected then, except the present similarity of the fauna and flora, which I hope to deal with at some future time. Let it be well borne in mind, however, that the similarity or identity of a fauna and flora is not a proof that the lands were formerly continuous. This similarity may arise from many independent causes, which I need not specify.

ART. XIII.—*An Improved Grab Crane.*

BY C. W. MACLEAN.

[Read 10th August, 1882.]

THE system of dredging by means of a bucket formed of two hinged scoops or forks, known as grabs or clam-shells, having mechanical contrivances for opening and closing by chains worked by a derrick crane in such a manner as to grapple and lift spoil, has long been known and used by engineers on the Continent, India, Great Britain, America, and other parts of the world.

Having observed several defects in the working of the usual forms of grab cranes, I designed a new grab and crane which effectually overcomes these defects, and which I will now proceed to describe, prefacing the description by an extract from my British patent specification:—

"My improvements in grabs relate to the contrivances through which the grappling portion receives its necessary motions of opening, closing, hoisting, and lowering. The improvements in the contrivances used for working the same consist, first, in the substitution of a counterbalance barrel, supported and running in racks at the back of the crane, for the ordinary counterbalance weight, and in so arranging such counterbalance barrel that it assists instead of retards the engine in all the operations of working the grab;

and, second, in a modified construction of crane for working my grab, by which it is made a portable machine."

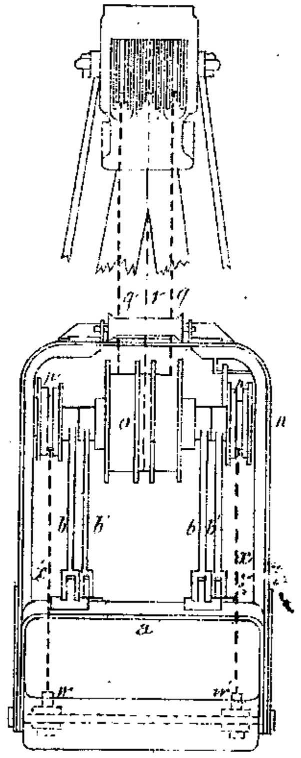
The sketch shows the grab crane, which has pivoted jaws, *a a*, and connecting links, *b b*, similar to the ordinary grab; but the crosshead and shaft of the ordinary grab are combined in one shaft, *n*, which is capable of a vertical motion between guides in a frame, also of a rotary motion, and is supplied with a barrel, *o*, and two smaller warping barrels, *p p*. The larger barrel has two lifting chains, *q q*, which are at one end wrapped round and fastened to it, then led over two jib-head sheaves to two chain pulleys, *r r* (one close to each cheek of the crane), which are capable of being revolved by the hoisting engines, or of being stopped by a brake; thence by a series of guide pulleys to the roling counterbalance barrels, *s s*, round which they are wrapped and fastened. The main barrel of the grab has also a lowering chain, *v*, wrapped round it in the opposite direction to that of the lifting chains, and led over a jib sheave to a barrel, *t*, which is capable of being put into gear and revolved by the hoisting engine, or stopped by a brake by the action of one lever acting on an eccentric and friction wheel. The two warping barrels have each chains, *x x*, the ends of which are wrapped round and fastened to them and to a fixed point, *w*, of the framing at the pivots of the jaws in such a manner that when the lifting chains, *q q*, are pulled by the engine the bucket closes, and when the lowering chain, *v*, is pulled the bucket opens. Two rolling counterbalance barrels, *s s*, which have the ends of the lifting chains attached to their circumferences, are fixed to a shaft, having pinions shrouded to their pitch lines, keyed to each end, which are free to roll down or up inclined shrouded racks as the lifting chains are either pulled or let out by the engines, and at the same time coiling or uncoiling the chains on their outer circumferences in a self-acting manner.

By this new machinery, which I have endeavoured to describe, the various operations of closing, digging, hoisting, opening, lowering, and partly counterbalancing the grab jaws, are effected in a novel and improved manner, as follows:—

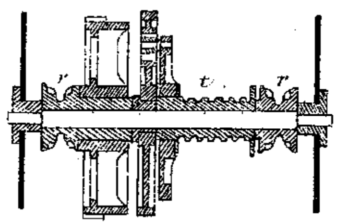
Assuming that the grab is resting in the open position on the material to be lifted, the grab is then closed by putting the chain pulleys, *r r*, into gear with the engines, and thus pulling the lifting chains, *q q*, which, being wound round the main barrel of the grab, causes the warping barrels, *p p*, to revolve and drag down the shaft, *n*, by the warping chains winding round their respective barrels. During this operation of closing and digging, the counterbalance barrels, *s s*, take in the slack of the two hoisting chains, and assist, instead of retard, the engine while performing the operation. The engines by continuing to pull the lifting chains, after the jaws are closed, raise the grab with its load, the counterbalance barrel still taking in the slack of the lifting chains, and assisting the operation of hoisting. When the grab has attained the required height the brake is applied to stop the lifting chain pulleys on the crane, the engines being at the same time disengaged. The engines are next engaged to pull the lowering chain, *v*, which being wound round the larger chain barrel, *o*, on the grab, causes it to revolve, thus unwinding the warping chains from their respective pulleys, and dragging up and opening the grab jaws. When the grab is opened the lowering chain is held by its brake, and and the grab remains open, partly suspended by the lowering chain and partly by the lifting chains. The grab can now be lowered by the pressure being slightly taken off the lowering chain brake.

Having gone through these operations, it will be observed that, unlike other machines for effecting a similar purpose, the digging of the grab in any material is not interfered with by the counterbalance, which assists, instead of retards, the engines in performing this operation; while the whole weight of the grab bears on the points, and enters the material to be lifted. In other machines the grab cannot be raised open, but in the machine just described the grab jaws can be opened by the opening chain when the grab is in any position whatever, and the grab can be raised while open to any required height. Again, in other machines when opening the grab the load is suddenly transferred from the lifting to the lowering chain, which throws a severe strain on the chains and other parts of the crane; but in this machine the load is discharged while all the chains are taking part of the strain, and there is no sudden strain put at any time on them. Another advantage is gained by having two lifting chains, either of which will continue the work should the other break, and when they are both at work they prevent the grab from swinging and twisting the chains, which goes on to some extent in other machines. The weight of the barrel shaft of the grab tends to close the jaws.

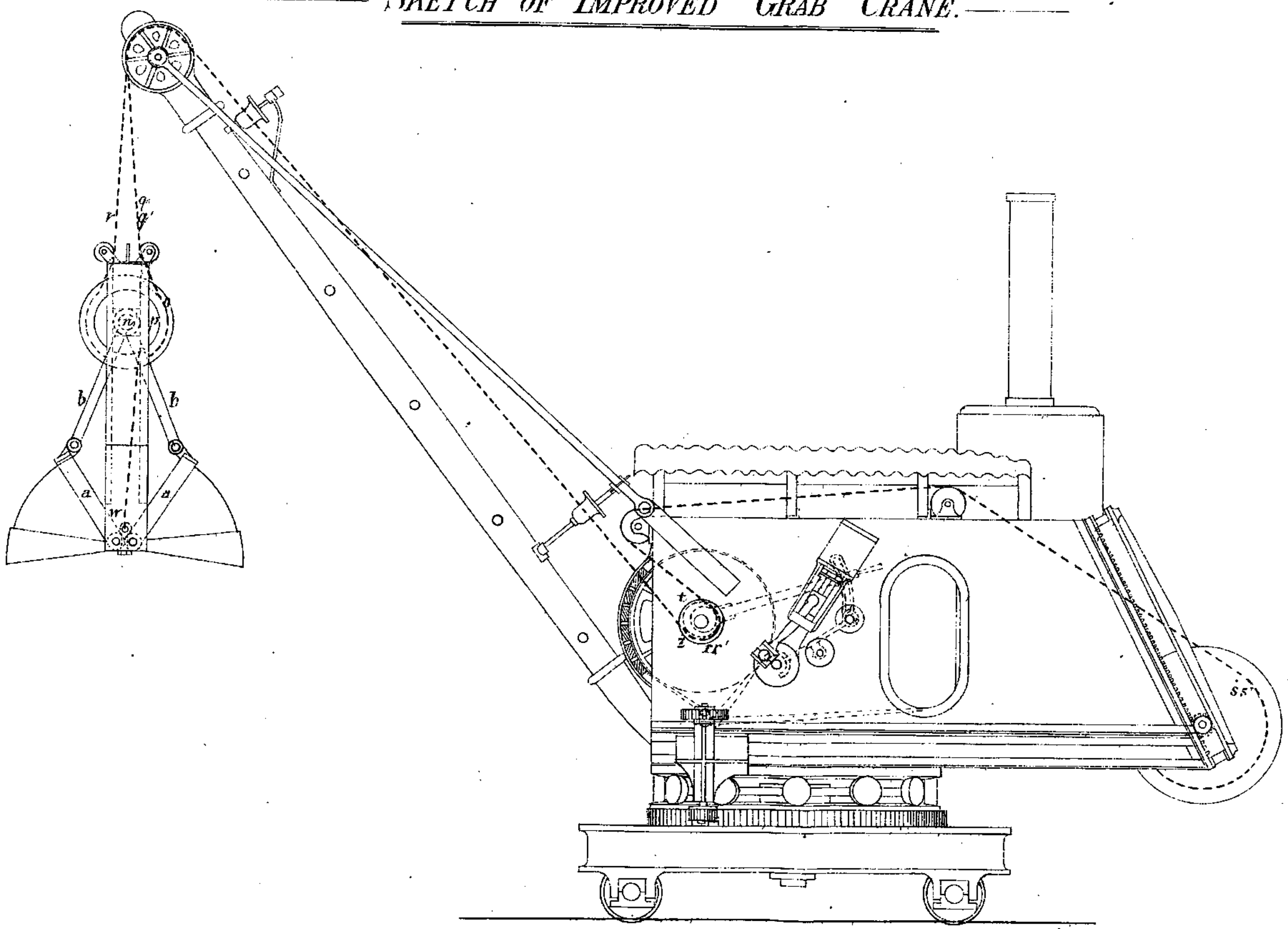
SKETCH OF IMPROVED GRAB CRANE.



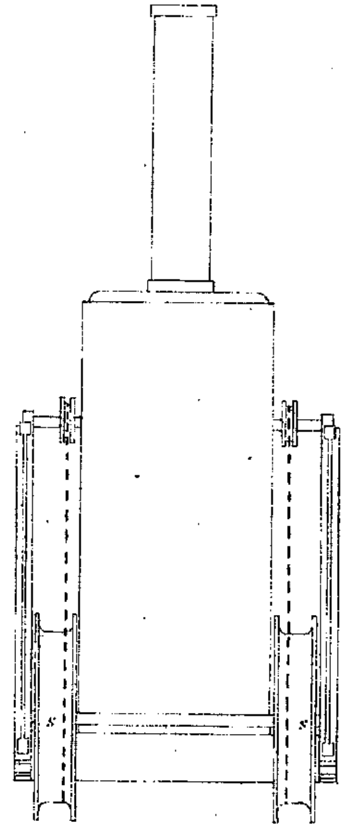
Front Elevation of Bucket and Jib.



Section of Shaft Z.



Side Elevation.



Back Elevation of Boiler and Counterbalance Gear.

The grab bucket can be opened in three ways—(1) By pulling the lowering chain while holding the lifting chains, which raises as well as opens the bucket; (2) By holding the lowering chain and letting out the lifting chains, which lowers as well as opens the bucket; (3) By a combination of the first two methods, which simply open the bucket without altering its height. These methods of opening the bucket have been found to be of great advantage, for the driver need not be very particular as to the height of the grab bucket when about to open it, as he has complete control of all its actions.

The cheeks of the crane are formed of wrought iron, and with a roof serve as a protection from the weather.

The Melbourne Harbour Trust Commissioners having had a crane on this principle constructed, mounted on a Smeaton's ring and built on a special pontoon for dredging purposes, I have been enabled to prove by actual experiment that the dynamical principles of the machine, as described, are correct. The crane is now at work on the Yarra, where it is found to be capable of making a complete set of dredging operations in forty-five seconds, so that the bucket, containing from two and a-half to three tons of silt, can be lifted easily within one minute, controlled by one man.

The crane is capable of being constructed in a portable form. The modification referred to in the patent specification is designed for digging dams and other pastoral station work, and for portability.

Art. XIV.—*A Note on the Apparatus to be used in Viewing the forthcoming Transit of Venus, in December*, 1882.

By R. L. J. Ellery.

[Read 14th September, 1882.]

ART. XV.—*On the Performance of Some Timekeepers.*

BY E. J. WHITE, F.R.A.S.

[Read 14th September, 1882.]

AT the International Exhibition held in Melbourne in 1880-1881, there was a fine display of clocks and watches of nearly every kind, as almost every country celebrated for their manufacture was well represented. The principal deficiency was with the clocks; of these the English sent few specimens, and the principal part of the American exhibit was lost by shipwreck. It became part of my duty, as a juror, to examine these, and from my position in the Observatory I had to take part in their testing. The result has been published in the Official Record of the Exhibition. I have been several times asked, however, whether the method of testing adopted, in which the watches were kept in stands, was a proper trial for an article like a watch, which is generally carried in the pocket, and is, therefore, subjected to all the motions of the body; that these motions are anything but slight, even in inactive persons, may be proved by a ride in a vehicle along the St. Kilda Road. My interest having been excited, and having unusual facilities for the purpose at the Observatory, I determined to test some watches in what may be called a natural way—that is, whilst being worn during the day and put under the pillow or hung up at night. For this purpose I purchased one or two of the fine watches from the Exhibition; these, together with one in my possession before, and some confided to me by friends for regulating, formed the subjects of my trials, the results of which, together with a few others from different sources, form the subject of my paper to night.

Nearly all the timekeepers of the present day may be divided into two classes—clocks and watches; the former, I shall call those which have their motions regulated by a pendulum, controlled by gravity; and the latter, those whose motions are regulated by a spring governed by its elasticity. Many of these latter are commonly called clocks, such as carriage clocks, lever clocks, &c.; they are, however, really watches, and will go in any position, whereas a clock requires to be kept at a certain definite angle with the horizon, and although marine chronometers are intended to be kept in one position, yet they will go in any, and they are only a superior class of watches. In using the term watch, however, without any qualification, we usually mean one of from about an inch to two inches diameter, so that it can be conveniently worn in the waistcoat pocket.

In ordinary talk, watches are usually named from their outward cases, as a gold watch, a silver watch, an open face, or a hunter; it is needless to observe that this classification is totally useless as a guide to the quality of the mechanism. Occasionally they are called after their nationality, English, American, or Swiss watches; in this case we can generally form an idea as to their internal arrangements, though the lines of demarcation are now much more faint than formerly. The typical English watch has a full-plate movement, covered with a cap, the whole of which opens out from the case on a hinge, and the hands are set from the front; its most distinguishing feature, however, is the fusee with its chain to equalise the motion of the mainspring, which is retained in watches of even the lowest class. English watches were formerly noted for their durability and timekeeping qualities. In this latter quality, however, they are now greatly excelled by the American (and when I say American, I mean Waltham, for I have had little experience of their other makes) and by the better class, yet moderately priced, Swiss watches. Still, the highest class English watch, which is also a very expensive article, is a perfect triumph of skilled work, and is unrivalled as a timekeeper. At the same time, the other extreme is reached by the low-priced English productions, which are a disgrace to the science of horology. The Waltham watch has usually a three-quarter plate, a going barrel without stopwork, so that the mainspring can act throughout its whole length; the case opens, and the hands are set at the back, and it has a real compensation balance in lower grades than is usually found in English and Swiss watches. No other escapement is used, I believe, than the lever with open jewels for pallets. The pivots are larger than in most other watches. It is, on the whole, a most substantial piece of work, and is a first-class timekeeper. In this respect, indeed, I think the lower grades of Walthams are unapproachable. I have found them keeping better time than English watches costing five times the money. Their moderate price is due mainly to the absence of much of that manual labour which is used in other countries to finish the parts after they have been formed by the machines; so, to a watchmaker's eye, they do not present that finished appearance he so dearly loves; but, as Sir Edmund Beckett says, "so long as smooth work which everybody can see is easier than accurate work which few people can judge of, watches, like other things, will be got up for show." Old Mr. Dent used to say—"We must work for the fools." First-class Walthams, however, have no lack of finish—indeed, they gained the first prize at our Exhibition for their artistic qualities.

Swiss watches are characterised by great delicacy of construction, and by delicacy I do not necessarily mean weakness. They have going barrels with stopwork, so that only a selected portion of the mainspring is brought into action. The cases open, and the hands are set at the back; and the top pivots, instead of turning in holes made in a full or three-quarter plate, work in cocks and bridge pieces, so that most of the wheels may be removed without disturbing the others. The best Swiss watches, though somewhat expensive, are excellent timekeepers, and in the making of small, complicated, and low-priced watches the Swiss are unsurpassed. They also exhibit great variety in their escapements. A few years ago I should have said that the cylinder, or horizontal escapement, was a special feature in Swiss watches. It is now, however, getting supplanted by the lever.

French and German watches were also shown at our Exhibition. They are constructed somewhat like the Swiss, but I think that they are scarcely brought to Australia yet in commercial quantities. The former were not sent to be tested at the Observatory, so that I cannot speak of their performances; and some of the watches sent out were not exhibited at all, owing to some trouble at the Custom-house. The German watches, as exhibited by the celebrated makers, Lange and Söhne, of Glashütte, near Dresden, proved themselves to be of first-rate excellence and moderate in price.

Instead, however, of a national classification, watches for scientific purposes are generally called after their escapements. The mechanism of a watch, as is well known, consists of a train of wheels impelled by a large coiled spring at one end, and regulated by the reciprocating motion of a very small spiral spring attached to the axis of a wheel with a heavy rim, called the balance, at the other end, together with hands and a dial to indicate the revolutions of some of the wheels. If the short hand of a common watch makes two revolutions while the earth is turning once round, as referred to a fictitious regularly-moving sun in the heavens, which is never very far from the real sun, then the watch is said to be keeping exact time. If, however, the watch be required for astronomical work, and to keep what is called sidereal time, then the short hand should make two revolutions while the earth turns once on its axis, as referred to a fixed star. There is, therefore, no difference in the mechanism of a mean-time and sidereal watch; the latter simply gains 3 mins. 56·55 secs. a day on the former, or one day in a year. In a watch train that part of the mechanism which converts the continuous revolutions of the last, or, as it is called, the scape wheel, into the reciprocating motion of the balance, is called the escapement, and on its construction, as well as that of the regulating spring (which is called the hair or balance spring) and the balance itself, the timing qualities of a watch chiefly depend.

The oldest form of escapement is that known as the verge or vertical escapement. From the time of the invention of watches till about the commencement of the present century, a period of about two hundred years, it was almost the only escapement used. It is now rarely met with, in Australia at least, except in the form of the old, thick, double-cased watch—the well-known "turnip" as it is somewhat irreverently called. I see, however, according to Saunier, that more than 300,000 of watches with verge escapements are annually made in one of the cantons of Switzerland. Very few of these, however, find their way out here. In this escapement the plane of the scape wheel is at right angles to those of the other wheels, so that when the watch is laid flat it stands vertical. Hence the name. This necessitates the watch being of considerable thickness, as well as the use of either bevelled or crown wheels. The principal advantage of the verge escapement seems to be that the impulses are given so directly that the pallets require no oil. It seldom requires cleaning, so that the watch will go with an amount of dirt that would be fatal to the action of most others. Its disadvantages are that the impacts are so severe and so applied as to cause a recoil action of the train. This causes it to wear out rapidly. At the same time it so hampers the free motion of the balance spring that, notwithstanding the presence of the fusee to equalise the action of the motive power, which is absolutely necessary with this escapement, it is a very poor timekeeper. Sully, a celebrated English watchmaker of the last century, found that in the verge watches of his day an increase of one-half in the motive power caused a variation of six hours a day. Captain Cuttle's watch, immortalised by Dickens, had undoubtedly a verge escapement.

The duplex escapement derives its name from the double set of teeth on the scape wheel—a short set to give the impulse to the balance, and a long set to keep the train at rest, except at the moment of escape. It was invented near the end of the seventeenth century. Its inventor is not known with certainty. It was claimed, however, by the celebrated Robert Hooke, the contemporary, and in some degree the competitor, of the great Newton, many of whose discoveries he claimed for himself. He was undoubtedly one of the greatest inventors that ever existed. We owe to him the first investigation of and discovery of the isochronal properties of springs, and their application to regulate the motions of a watch. This escapement is a very good one. It is one of the simplest in construction; at the same time, it requires the most delicate adjustment and first-class workmanship. The impulse is given directly, so that it goes without oil; but it never allows the balance to be perfectly free from the train, as the long tooth is always rubbing against the axis. It requires less frequent cleaning than the lever, and, with careful wearers, gives equally good results. Where, however, it is subjected to a rotatory motion, such as many people give to their watches in the action of winding them, it is liable to set—that is, to stop—owing to the motion communicated to it. It also occasionally trips—that is, allows two teeth to pass the notch instead of one—when the motion is such as to accelerate the balance. This escapement, owing to its inferiority to the lever for general use, was gradually dying out. It has, however, been lately made in large numbers of very cheap watches by the Waterbury Watch Company, in America.

The horizontal, as it was called, to distinguish it from the old vertical escapement, and now usually known as the cylinder escapement, was invented by the celebrated English watchmaker, Graham, about the year 1720. It was never largely used in the country of its birth, but it was so extensively adopted by the French and Swiss that at one time nearly all their watches were made with this escapement. Its principles have been so thoroughly investigated by the latter nation that it is still a favourite among them, though it is gradually being supplanted by the lever. It has the advantage of being compact, and the parts may be so proportioned that a sort of rough compensation for change of temperature can be produced with the ordinary balance; but it has the disadvantages of not being substantial, the impulses are given obliquely, rendering the use of oil a necessity, and the balance is never detached from the influence of the train. It also wants cleaning rather frequently. Saunier says that a cylinder watch, if small, should commence going with the second turn of the key, ordinary size at the third turn, and large ones on the fourth turn.

The lever escapement, otherwise called the detached or patent lever, is generally known on the continent of Europe as the anchor escapement. It seems to have been first conceived in France. It was invented, however, in its present shape by Mudge, of London, about ninety years ago. The English, as became their practical character, took kindly to this escapement, and for many years it formed one of the principal features of an English watch. It is now, however, in great use everywhere, and seems likely to supersede all the other forms, for watches which have to be worn. It has the advantages of being simple and substantial, and, above all, it leaves the balance quite free from the influence of the train during nearly the whole of its vibration. The impulses are given obliquely, so that it requires oil, and therefore more frequent cleaning than direct impulse escapements. It has proved itself capable, however, of giving results nearly equal to those of the chronometer escapement —indeed, when the watch is worn in the ordinary way, I think it will prove the better timekeeper of the two.

The chronometer, detent, or detached escapement is the one universally employed in the large class of watches, usually called chronometers, used for finding the longitude at sea. It is occasionally employed in the superior sort of watches known as pocket chronometers—indeed, many watchmakers maintain that only watches with this escapement are entitled to be called chronometers. They therefore term the superior class of lever watches furnished with a chronometer balance half-chronometers. In this escapement the impulses are given directly, and the balance is completely free from the influence of the train. It works without oil, and though delicate in construction, it gives the best results as a timekeeper where the watch is kept in one position, as in marine chronometers. In pocket watches, however, it is, in my opinion, a mistake, and is not so trustworthy as the lever.

Although many other escapements have been proposed and constructed—indeed, scarcely any year passes without a new one being invented—yet the five just mentioned are now the only ones in common use. We will therefore pass on to the consideration of the hairspring and balance.

As mentioned before, Hooke was the first to study the action of springs. He found that the amount of bending of a spring was proportional to the weight that produced it, or, as he expressed it in the learned language of the time, "*ut tensio sic vis.*" From this property, then, when a spring is set vibrating, all the vibrations, whether long or short, ought to be isochronal—that is, performed in the same time. If Hooke had carried out his experiments more carefully, he would have found that in practice this did not strictly apply. The complete investigation was carried out by the celebrated French horologist, Pierre Le Roy, who, in the year 1766, announced his discovery in the following terms:—"There is in every spring, providing it be long enough, a length that causes all the vibrations, whether long or short, to be isochronal. Having fixed upon this length, if you shorten the spring the long vibrations will be quicker than the short. If, on the other hand, you lengthen it, the short arcs will occupy less time than the long." The great object in a good timekeeper, therefore, is to secure a good spring, determine its isochronal point, fix it there, and attach to it a balance of the proper weight and size, so that its inertia, combined with the elasticity of the spring, may cause them to vibrate in the interval of time required by the train, generally one-fifth of a second in a watch and one-fourth of a second in a marine chronometer. No alteration in the length of the spring should be made after this. Any change of rate that may be required should be brought about by changing the weight or dimensions of the balance. In marine and some pocket chronometers this procedure is strictly observed. In watches, however, change of rate is generally made by altering the length of the spring, as any interference with the balance of a watch that has to go in all positions would be likely to produce much larger errors than would result from a slight deviation from the isochronal length of the spring; and here it may be remarked that the usual way of making this alteration by means of a lever, containing two curb pins, which works radially round the spring, is by no means delicate enough. Some of the Waltham watches have very beautiful arrangements for this purpose, so that very minute alterations may be easily effected. Yet, strange to say, I find only their watches in hunting cases so provided; the similar grades of open face watches have the ordinary radial arm. The usual form of balance spring for watches is the well known flat spiral. In marine chronometers the heliacal spring is used, and for lever watches of the best class, especially those that have large arcs of vibration, amounting occasionally to 540 degs., a flat spring, with the outer end bent over and fixed not far from the centre coil, is preferred. Such a spring is known among the English as a Breguet, or overcoil, spring. The French call it *spiral coudé*. Many other forms of springs are sometimes found, but, judging from the results of the severe timing contests that take place among the Swiss manufacturers, no one form of spring is certain of proving itself superior to another. From what has been said above it will be seen that the selection of a proper spring for a watch demands great care, for unless the spring be isochronal great variations of rate would take place during the day, as the arc of vibration diminished with the uncoiling of the mainspring. This diminution, according to the observations of M. Phillippe, amounts to from 65 to 112 degrees. The English have endeavoured to evade this difficulty by the use of a fusee to equalise the force of the mainspring. This, however, considerably complicates the mechanism. It also renders rather difficult the application of the keyless mechanism, which is fast superseding the old style of winding, and worthily so, for, independently of its great convenience, the winding is done in a plane at right angles to that of the watch, so that there is no fear of disturbing the arc of vibration, as is done by those careless persons who, when they wind with a key, turn the watch as much, or even more, than the key itself. Keyless watches also keep clean longer than others. It has been remarked that the introduction of the keyless watch will be the death blow to the fusee. Strictly speaking every mainspring should have its own proper fusee, a point that was generally attended to in the best class of old verge watches; but

I suppose that it is owing to want of attention to this that I frequently find expensive English watches, furnished with a fusee, showing a greater variation of rate during the twenty-four hours than a Waltham watch without fusee and without stopwork. Very likely the Swiss going barrel watches would go as well, but I have not had the opportunity of testing high class Swiss watches. Those that were officially tested at the Observatory during the Exhibition trials were only timed once in twenty-four hours. In these circumstances this variation would not show itself. As a matter of fact, I have in my possession a Waltham watch purchased in Melbourne four years ago. It has such a long mainspring and runs so easily that it will go forty-eight hours without stopping. I have on three or four occasions forgotten to wind it, so that at the end of the two days I have found it moving very sluggishly, barely escaping, yet the greatest difference of rate I have found from this cause has been only nine seconds a day. It is sometimes less. The last occasion was on the 8th of the present month, when it was not wound. The two previous rates had been 5·7 secs. and 5·5 secs. losing, and between the 6th and the 8th the rate was 1·7 secs. losing.

Supposing the watch to be now put together in good condition and the balance perfectly poised, we will consider the causes that will make it change its rate. First and foremost will be change of temperature; and unfortunately its effects will be all in one direction, an increase of temperature will weaken the elasticity of the balance spring, increase its length, and also enlarge the diameter of the balance, each of which makes the watch go slower, so that the whole effect will be the sum of these partial ones. A decrease of temperature will act in a contrary direction, and cause the watch to gain. By far the principal cause of variation is the alteration of the elasticity of the spring; according to experiments made by Berthoud, and confirmed by Mr Dent, the effect of this amounts to more than four times that of the enlargement of the balance, and that the total effect will be to make an ordinary watch lose 63 seconds a day for an increase of 10° Fahr.; whereas an ordinary clock with an iron rod to the pendulum would only lose 3 seconds a day for the same increment of heat. To obviate this difficulty, the first chronometers were supplied with an apparatus that moved the curb pins, and thus shortened the effective part of the balance spring as the temperature increased; as this plan interfered with the isochronal quality of the spring, it was soon abandoned in favour of the compensation balance invented by Julien Le Roy, and afterwards much improved by Arnold and Earnshaw, who left it in very nearly the form it has retained ever since. According to this construction, the balance, instead of being a complete circle, consists of a steel cross bar, to each end of which is fixed a nearly semi-circular strip. These strips are composed of two metals, brass on the outside and steel on the inside. The old makers used to connect these metals by a number of very fine rivets. The modern practice is to melt one on the other. Screws called timing screws are fixed at the end of the cross-bar; any motion of these simply alters the inertia of the balance, without interfering with the compensation. They are therefore used for changing the rate. Heavy screws or weights are also attached to the bi-metallic strips. These are moved further from or nearer to the cross-bar, as we want to increase or diminish the effect of change of temperature. This balance acts in the following manner:—An increase of heat will cause the brass on the outside to expand more than the steel on the inside. This will cause the strips to curve inwards, and carrying the weights with them they thus diminish the inertia of the balance and compensate for the diminished elasticity of the spring; a decrease of heat will in a similar manner make them open outwards, and increase the inertia of the balance. This is still the style of balance most generally used. It is called simply a compensation balance. Its action, however, is not perfect. This was first explained by Mr. Dent, in 1833, though its defect had been a matter of observation in good chronometers for some time before. It was found that while the chronometer would go very well for a moderate range of temperature, yet it always lost above or below these limits when the range was considerable; or, if it went right at two extreme temperatures, it always gained at the mean one. The explanation is this: The effects of temperature on the spring would cause changes in its strength proportional to the changes of temperature. To compensate for this the moments of inertia of the balance ought to change in the same proportion. Instead of this, however, equal variations of heat will cause the compensating weights to alter their distances from the centre of the balance by equal variations of space; but the moments of inertia of the balance are proportional, not to the distances of the weights from the centre, but to the squares of these distances, so that while graphically the effect on the spring would be represented by a straight line, that on the balance would be a curve, which, near the point of contact with the straight line, would nearly coincide with it for a moderate distance, or would cut it in two points with a moderate deviation half-way between them. It is in the latter way that the chronometer is generally adjusted, so that it goes right at 55° and 85°, and it then gains about six-tenths of a second a day at 70°, the mean temperature. Various methods have been proposed for getting rid of this secondary error. The most successful seems to have been Kulberg's, which was exhibited in his marine chronometers at our late Exhibition. Another plan, invented by the superintendent of the Waltham factory, was used in some of their watches tested at the Observatory. The watches, however, were in very bad order, so that its efficiency was not made apparent. Watches that are carried in the pocket by day and placed under the pillow at night are in a great measure guarded from extreme changes of temperature. Carriage and similarly governed clocks are generally, however, exposed to great and sudden variations, so that, if not well compensated, their going must be greatly inferior to that of a common pendulum clock. From records kept at the Observatory I find that the maximum temperature of my room there, which has thick walls and a room above it, during the last ten years has been 90°, and the minimum 47°. This would cause a difference of four and a-half minutes a day in an uncompensated watch. In a weatherboard-lined room at my quarters, without a fire-place, the maximum has been 102°, and the minimum 31·5°. I have also carried a delicate thermometer in my watch pocket, to ascertain the temperature a watch is ordinarily submitted to. Sitting in my room where the thermometer indicated 59·3°, the temperature of the pocket was 82·4°. Another time the room was 58·0°; pocket, 80·0°. Open air, 55·5°; pocket, 70·4°. Air, 57·5°; pocket, with back to the sun, 72·0°; facing the sun, 81·0°. Bedroom, 63·0°; under pillow, 71·5°. Air 91·0°; pocket, 85·1. Room, 74·0°; pocket, 85·0°. Bedroom, 77·0°; under pillow, 81·8°. Air, 101·0°; pocket, in shade, 96·4°. Bedroom, 52·0°; under pillow, 59·0. Air, 50·0°; pocket, 71·0°. According to the above observations, the watch had been kept in temperatures varying from 59·0° under the pillow to 96·4° in the watch pocket while walking in the open air. This would correspond to a variation of nearly four minutes a day for a common watch, and shows how utterly useless all such refinements as finish, jewelled holes, &c., are to the timekeeping qualities of a watch if it is not provided with a compensation balance. One objection I have heard urged against the compensated balance is that, necessarily being heavy to get sufficient change of inertia, it is not suited for riding or other violent exercise. If this objection has a real foundation, it may be met by reverting to the old compensation curb, when the balance might be made as light as possible. It would also have the advantage of not being put out of poise by the alteration of the compensating weights. Decided objections might be raised to this in the case of the highest class watches, where the spring is firmly fixed to the collet and stud, and has no curb pins; but where a lever and curb pins are already fixed, as in most watches, I do not see why they should not be moved automatically as well as by hand.

A marine chronometer, properly adjusted for temperature as above, ought now to be in a condition to perform very well, as it is only kept in one position, except during the few seconds while it is being wound. A pocket watch, however, which is expected to go equally well in any position, needs very delicate adjustment in the poising of the balance and the regulation of the friction of the pivots. It will, I expect, surprise many persons when they know the high ratio the adjusting of a watch bears to its first cost. From an official return I find that the average price of the English watches sent to Australia is £5 8s. Of the foreign ones that come here *viâ* England the average price of the gold ones is £8 15s., and the silver ones 27s. Now, I am informed that in Geneva, where labour is not at all highly paid, an adjuster at the factories gets 25 francs, equal to £1 for each watch, and I see, from a discussion in the *English Mechanic*, that the principal London makers charge from 50s. to 60s. for adjusting a watch in temperature and position. To show the large errors even expensive watches are sometimes afflicted with, I append the following table, and I may state that I have only selected new watches for this purpose :—

DAILY RATES OF WATCHES IN SIX DIFFERENT POSITIONS.

POSITIONS.	*a.*	*b.*	*c.*	*d.*	*e.*	*f.*	*g.*
	s.	s.	s.	s.	s.	s.	s.
Pendant up -	4·00	5·71	0·00	5·19	10·37	9·00	9·3
„ right	2·14	4·69	1·61	2·98	6·58	7·05	7·3
„ down	0·00	0·00	0·14	0·99	0·00	0·37	0·0
„ left -	2·27	4·12	2·99	4·60	2·58	0·00	11·6
Face up - -	3·89	1·21	2·29	0·99	7·32	9·38	0·0
„ down -	6·69	1·49	4·06	0·00	4·45	10·20	19·3

POSITIONS.	*h.*	*i.*	*j.*	*k.*	*l.*	*m.*
	s.	s.	s.	s.	s.	s.
Pendant up -	40·1	2·2	83·0	0·0	0·0	253·1
„ right	13·0	0·0	165·0	117·2	86·5	0·0
„ down	0·0	58·5	4·0	175·5	254·7	372·3
„ left -	21·2	36·3	0·0	76·6	202·0	526·0
Face up - -	25·5	50·3	111·0	118·0	155·0	349·4
„ down -	31·3	58·9	119·0	91·0	156·9	350·0

The above numbers are not the actual rates, a constant having been added to each rate to make them all positive or gaining, and zero for the least rate.

a was the watch that came out best at the official testing; it had a pivoted detent escapement, called by the Swiss who made it, a bascule, and a heliacal spring. Melbourne retail price, about £50.

b was the best lever watch, it was English, Breguet spring. Price, in gold case, about £60.

c was the second best Swiss watch, lever escapement, Breguet spring.

d was the second best English lever, flat spring. Price, £64.

e was the best German watch, lever, Breguet spring, cost, £26 in gold case.

f was the second best German watch, lever, Breguet spring, cost, £10 18s. in silver case.

g was a cheap Waltham, purchased in Melbourne for £4 near the end of 1878.

h was a third grade Waltham, cost, £20 in gold case.

i was a fine finished London watch with a fusee, cost, £9 in silver case.

j was a fine finished London fusee watch, selected from the exhibition, cost, £9 10s. in silver case.

k was one of the cheapest Swiss cylinder watches, in nickel case, cost, retail, 25s.

l was one of the cheapest Swiss levers, in nickel case, cost, retail, 27s. 6d.

m was a machine made English lever, in silver case. Price, about 80s.

The Melbourne retail prices given above are estimated as nearly as possible from information supplied, the costs are given from actual sales.

Rates of Watches Carried in the Pocket, a Marine Chronometer, and an Astronomical Clock.

h.	*h.*	*h.*	*g.*	*g.*	*e.*	*e.*	*e.*	*i.*	*Marine Chronometer.*		*Astronomical Clock.*		
s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.	s.
+ 3·6	+ 2·4	+ 1·7	− 2·6	+ 0·5	− 3·3	− 1·6	− 3·0	+ 34·5	− 0·5	+ 0·4	− 0·39	− 0·24	+ 0·05
+ 4·0	+ 3·3	+ 4·7	− 2·6	− 1·6	− 3·3	− 2·2	− 2·3	+ 15·5	− 0·7	+ 0·3	− 0·37	− 0·16	+ 0·12
+ 2·2	+ 1·5	− 0·8	− 1·9	− 2·2	− 2·7	− 3·8	− 2·9	+ 33·5	− 0·2	− 0·2	− 0·47	− 0·22	+ 0·07
− 1·8	+ 1·0	− 0·5	− 4·3	− 1·2	− 2·2	− 3·8	− 3·3	+ 32·3	− 0·1	0·0	− 0·35	− 0·21	+ 0·05
+ 1·2	− 1·0	+ 5·0	− 3.8	− 2·6	− 1·1	− 3·7	..	+ 30·7	+ 0·5	− 0·3	− 0·42	− 0·36	+ 0·01
+ 0·9	+ 1·3	+ 1·2	− 4·5	+ 0·6	− 4·8	− 3·4	..	+ 24·5	+ 0·3	− 0·3	− 0·30	− 0·16	+ 0·06
+ 0·8	+ 2·3	+ 3·1	− 1·3	− 0·6	− 3·0	− 2·0	..	+ 30·4	+ 0·2	− 0·3	− 0·45	− 0·16	+ 0·15
− 0·3	+ 0·3	+ 0·5	− 3·3	− 1·8	− 1·2	− 3·5	..	+ 30·2	− 0·1	+ 0·1	− 0·24	− 0·19	+ 0·16
− 0·2	+ 0·7	+ 4·8	− 1·8	− 1·1	− 1·8	− 3·0	..	+ 24·1	− 1·3	− 0·2	− 0·31	− 0·19	+ 0·06
+ 2·3	− 0·7	+ 4·8	− 2·6	− 1·5	− 2·1	− 2·9	..	+ 35·4	− 0·8	0·0	− 0·40	− 0·30	+ 0·03
− 1·9	+ 2·2	+ 3·2	− 2·0	− 2·9	− 3·1	− 3·5	..	+ 30·1	− 0·3	− 0·3	− 0·39	− 0 27	− 0·06
− 1·7	+ 0·8	+ 2·3	− 2·4	− 0·1	− 2·8	− 3·7	..	+ 25·6	− 1·1	− 0·6	− 0·17	− 0·26	+ 0·02
− 0·9	− 1·6	+ 4·4	+ 0·7	+ 2·3	− 1·6	− 3·5	..	+ 30·1	− 0·5	+ 0·5	− 0·11	− 0·20	− 0·05
− 0·8	+ 3·4	+ 3·8	− 3·0	− 0·5	− 3·9	− 4·2	..	+ 33·2	− 0·3	− 0·6	− 0·18	− 0·22	+ 0·06
+ 1·8	+ 3·3	+ 4·2	− 0·5	− 1·6	− 1·8	− 2·7	..	+ 29·1	− 0·3	− 0·5	− 0·04	− 0·25	+ 0·10
+ 1·3	+ 2.4	+ 2·0	− 2·0	− 2·1	− 1·3	− 3·2	..	+ 30·9	+ 0·2	0·0	− 0·11	− 0·15	+ 0·09
− 1·3	+ 3·8	− 4·4	− 1·1	− 2·2	− 3·4	− 3·5	..	+ 34·2	0·0	− 0·4	− 0·19	− 0·02	+ 0·15
− 2·1	+ 2·8	+ 0·2	− 1·6	− 1·6	− 4·0	− 4·5	..	+ 34·0	− 0·4	− 0·1	− 0·11	+ 0·09	+ 0·16
− 5·9*	+ 0·3	+ 0·4	− 1·8	− 1·1	− 2·4	− 4·0	..	+ 25·5	0·0	0·0	− 0·19	+ 0·02	+ 0·26
− 0·9	+ 2·6	− 0·1	− 3·3	+ 0·6	− 2·9	− 3·3	..	+ 9·1	+ 0·3	+ 0·5	− 0·09	− 0·06	+ 0·19
− 0·7	+ 3·6	− 2·5	− 4·2	− 2·2	− 3·4	− 4·0	..	+ 38·7	+ 0·3	0·0	− 0·15	+ 0·08	+ 0·34
+ 0·1	+ 3·2	− 0·3	− 3·7	− 1·5	− 2·7	− 2·7	..	..	− 0·4	0·0	− 0·24	+ 0·04	+ 0·27
+ 3·0	− 1·6	+ 2·6	− 5·7	− 0·9	− 2·5	− 3·3	..	..	− 0·3	0·0	− 0·16	+ 0·08	+ 0·27
+ 0·2	+ 2·2	+ 0·1	− 5·3	− 0·4	− 4·9	− 3·4	..	..	− 0·1	0·0	− 0·25	+ 0·01	..
+ 1·2	+ 0·6	− 5·1	− 3·4	− 0·7	− 2·0	− 4·1	..	..	− 0·2	0·0	− 0·24	+ 0·01	..
+ 1·1	+ 1·5	− 1·0	− 1·8	− 2·1	+ 0·4	− 2·7	..	..	− 0·1	− 0·4	− 0·39	− 0·01	..
+ 1·1	+ 1·9	+ 0·2	− 2·8	− 0·2	− 3·5	− 4·8	..	..	− 0·2	− 0·7	− 0·21	+ 0·09	..
+ 1·2	+ 1·7	+ 2·0	− 1·2	− 1·4	− 1·3	− 3·0	..	..	− 0·1	− 0·4	− 0·25	+ 0·02	..

* Not wound for 38 hours.

In referring to the above list of watches, it may be mentioned, that *a, b, c, d, e,* and *f* were specially selected and adjusted by the makers for exhibition and competitive trial, the others were purchased from ordinary stock. The marine chronometer is a very fine one by George Timewell, of Liverpool, which has not been cleaned for four years, and the astronomical clock is the celebrated Frodsham 991, which, when its rates were examined by the horological jury of the Paris exhibition of 1867, was pronounced to be one of the best in existence, its rates are found by celestial observations, generally taken every second or third day. Those given in the above list extend from near the beginning of February to the end of August in the present year, they, therefore, include the hottest and coldest periods, the gradual change of rate is owing to the clock being slightly under-compensated. The iron jar containing the quicksilver is only 8½ inches long inside; this has proved to be not quite enough. The rates of the watches and chronometer have been determined by means of daily comparisons with the standard mean time clock of the observatory, they have all been obtained from trials made during the last few months, with the exception of watch *g*, whose rates are given for November and December 1879, as I have not often worn it since. All the errors of position have been determined since the beginning of last year. It should be stated also that the rates of the astronomical clock have been corrected for the variations of atmospheric pressure, as it has been found for this particular clock, that a rise of one inch of the barometer causes it to lose half a second per diem.

On examining the above table of rates, it will be seen at once to what enormous dimensions the error of position sometimes attains; in watch *m*, the English machine-made watch, it amounts to a daily difference of eight minutes and forty-six seconds between pendant right and pendant left; while in the Waltham, costing the same money, and also a machine-made watch, the greatest difference is only nineteen seconds. Again, in watch *j*, a finely-finished London fusee watch, the error reaches two minutes forty-five seconds a day. Comparing these with the two high-class expensive London watches *b* and *d*, whose largest errors of position are only somewhat over five seconds, it shows what English watchmakers can do when they are well paid for their work; their ordinary watches, however, are very badly adjusted, and if they do not improve in this particular, they are likely to lose their trade. According to a notice in the *Horological Journal,* Australia is England's best customer for watches, still the manufacture has lately fallen off to such an extent, that England does not now export one watch per head of her watchmaking population. The competition the English have to contend against is shown in the case of watch *g,* whose rates were given before, which came into my possession in a very ordinary way. On passing down Swanston-street I saw it in Mr. Joseph's window; it was simply marked "Waltham," with the price, four guineas, attached. I went in on the afternoon of December 4th, 1878, purchased it, and took it home with me. I compared it with our standard clock, and got the following results :—

Date.				Error.	Date.				Error.
	d.	h.	m.	s.		d.	h.	m.	s.
Dec.	4.	5	26	12 slow	Dec.	8.	21	0	13·5 slow
,,	4.	21	0	13 ,,	,,	9.	1	0	12·5 ,,
,,	5.	21	0	12·0 ,,	,,	9.	5	5	11·2 ,,
,,	6.	1	0	13·0 ,,	,,	9.	21	3	11·3 ,,
,,	6.	4	0	12·5 ,,	,,	10.	1	0	10·5 ,,
,,	6.	21	0	12·5 ,,	,,	10.	4	0	10·5 ,,
,,	7.	7	23	12·0 ,,	,,	10.	9	35	10·5 ,,
,,	7.	20	31	12·5 ,,	,,	10.	22	12	12·0 ,,

I was fairly astonished at such a result. On the last mentioned day I left Melbourne for New Zealand. During the voyage I used the watch as a chronometer for finding the longitude, as I had carried a small sextant with me for my amusement. On reaching Dunedin I found that in seven days the watch had altered its error about half a minute, having lost more in the much colder temperature at sea, than in Melbourne. I subsequently found by direct experiment that it was over-compensated to the extent of gaining twelve seconds a day for an increase of ten degrees Fahr. About a year ago I had the screws shifted, and the compensation is now nearly perfect. I still occasionally wear it, and it goes as well as ever; the improvement in the compensation being partly neutralised by an increase in the position error. Mr. Dent says that an adjusted going barrel lever may be expected, with an ordinary wearer, to have a daily variation of rate from 2 to 4 seconds. The above watch did not profess to be adjusted, yet it is within those limits; I consider myself, however, a careful wearer.

To dispense with the tedious and expensive process of adjustment for position, an arrangement has been introduced by the Swiss, called a "tourbillon."* In this system the escapement and balance are mounted on a frame which makes a complete turn in the watch every two or three minutes. Some of these tourbillons have given very good results. The method does not seem, however, to be growing into favour, owing, perhaps, to its being less stable than the ordinary construction. A somewhat similar plan is found in the Waterbury watches, mentioned before in connection with the duplex escapement, where the whole movement turns in the case once in an hour.

As a final remark to the purchasers and owners of watches, I would say to the former, buy your watches from trustworthy men—those whose words are as good as their bonds. Do not be led away by surface appearances, the number of jewels, &c. Saunier remarks that—"In a vast number of modern watches, and, unfortunately, even in many of those which pretend to be of superior quality, the jewels are rather a blind than in any sense beneficial. Badly worked and of insufficient hardness, these are less serviceable than good, carefully hammered brass." Watch jewels are by no means so valuable as is usually supposed. The cost of a jewelled hole of good average quality, ready for fixing in the plate, is, I am informed, in Geneva, only one shilling. The Swiss occasionally put a glass back to their watches in place of the usual metal dome, so that the works may be seen without opening and exposing them to dust, &c. It is a very bad style, however, for should the glass get fractured the particles fall at once into the movement, and do great damage. I am told that one of the fine Swiss watches that came out highest at our Observatory testing has been lately irretrievably ruined owing to this. Compensation balances also, unless carefully made, are worse than plain ones, for, independently of their never having been adjusted, the arms oftentimes move unequally with change of temperature, and thereby cause great errors of position. As a general remark, it may be stated that good watches are seldom unsightly. To the owners of good watches I would say, treat them with the greatest care and gentleness, for they are most delicate machines, and worthy of being treasured as specimens of man's intelligence and manipulative skill. Never allow them to go so long as to stop of themselves from the drying of the oil and the accumulation of dirt, for excessive wear results from this. As a general rule two years is the longest time a good watch should go without cleaning, especially if it is wound with a key, which conveys most of the dirt into the interior, as may easily be seen by an inspection of the winding square. Dust proof cases and keyless winding may enable a watch to perform well for a longer period than two years, but it will be found bad economy in the end to allow them to do so. Above all, never trust good watches with inferior workmen. A good watch is easily ruined, but restored with great difficulty. In the present state of the watch manufacture, where the division of labour is so minutely carried out, the watch repairer, or jobber, as he is sometimes contemptuously called, requires more science and skill in his work than the watchmaker. In conclusion, I would recommend to those engaged in practical watchwork the large treatise by Saunier, an English edition of which has been lately issued; and to those who only take an interest in the matter, the little book in Weale's series by Sir Edmund Beckett, Bart., on clocks and watches, where diagrams will be found of the different escapements, &c., mentioned in this paper, and where the subject is treated in such a charming and popular manner that, although the work is full of information, it is as entertaining as a novel.

Art. XVI.—*Experiments on Model Girders.*

By W. C. Kernot, M.A., C.E.

[Read 14th September, 1882.]

It has been the practice for several years past, in connection with the Engineering School of the University, to try various experiments upon the strength of model girders and frames, representing to scale existing or proposed structures. These experiments have, until recently, been made on wooden or cardboard models only. The desirability of testing iron models riveted together in the same manner as the actual structures, has all along been recognised, but practical difficulties in the way of obtaining the proper sections of metal in sufficiently small sizes, have hitherto prevented anything being done in this direction. Recently, however, a quantity of very small angle iron has been obtained, and this has removed the obstacle.

The first case chosen for experimental investigation was that of a small bridge for pedestrian traffic, crossing the lines of railway in the large goods station at Spencer-street. This structure is as a rule very lightly loaded, it rarely occurring that more than two or three persons are upon it at once, but, at the same time, it is quite within the bounds of possibility for a dense crowd to assemble upon it, testing its endurance to the utmost, and rendering any weakness a matter of most serious importance. The reasons why this particular bridge was selected were, first, that its construction being comparatively simple, the labour of making the model was but moderate; and, second, that calculation based upon established dynamical laws led to the conclusion that some parts were considerably deficient in strength, while others were needlessly lavish, both in material and the amount of riveting employed. The former criticism applies to the compression diagonals, which consist merely of thin flat bars, while the latter refers to the end vertical pieces, which are of comparatively masssive and complex construction, containing many times the quantity of iron theoretically necessary.

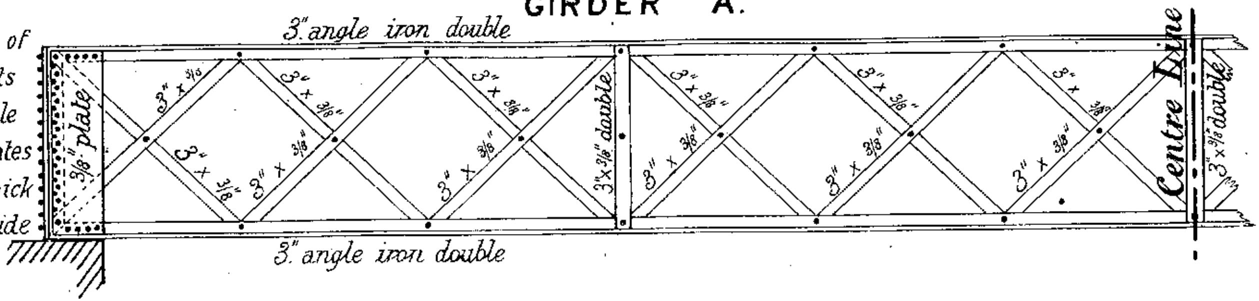
The model marked A represents accurately to a scale of one-twelfth full size one of the girders of this structure. That marked B is constructed according to an amended design, characterised by the strictest adherence to the indications of mathematical calculation compatible with simplicity of construction. In general appearance, girder B is hardly distinguishable from A; a close inspection reveals the following differences—(1) The replacing of the massive ends, each of which consists of five separate pieces of metal united by numerous rivets, by a single angle iron; (2) The omission of certain minor vertical members, upon which there is no calculable load; (3) The introduction of angle irons instead of the plain flat bars for the compression diagonals. The time taken in construction was carefully noted, also the weight of metal, number of rivets, and other particulars, for which see subjoined tabular statement. The great reduction in the amount of time expended in the case of girder B was due mainly to the simplification in the construction of the end vertical pieces.

In testing, the girders were supported and loaded exactly as in the actual structure, the top members being braced to prevent lateral deflection. The difference in strength, and the mode and nature of the fracture in each case, was in accordance with what was predicted on theoretical grounds.

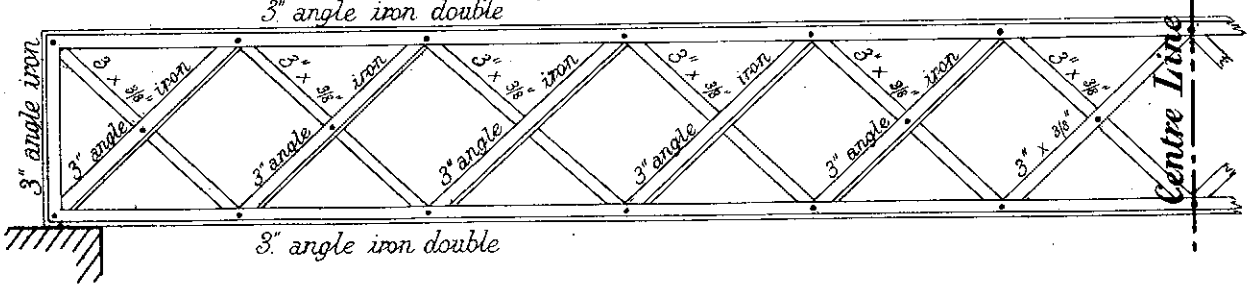
	Girder A.	Girder B.
Weight of metal ...	1 lb. 9 oz.	1 lb. 5 oz.
Time occupied in making	14 hours 10 minutes	5 hours 30 minutes.
Actual breaking load	208 lbs.	771 lbs.
Calculated ditto	182 lbs.	800 lbs.
Ratio of breaking load to weight of girder	133 to 1	587 to 1.
Nature and position of fracture	Buckling of compression diagonals, leading to general collapse of structure	Terminal tension diagonal torn across through rivet hole.

GIRDER A.

Note.—End of girder consists of two 3" angle irons, two plates 12" wide, & 3/8" thick one plate 8" wide 7/8" thick, and 40 rivets.



GIRDER B.



N.B. – The load was distributed uniformly along the lower member.

Art. XVII.—*Descriptions of New, or Little Known, Polyzoa.*

Part III.

By P. H. MacGillivray, M.A., M.R.C.S., F.L.S.

[Read 12th October, 1882.]

Membranipora serrata, M'G. Fig. 5.

In a paper communicated in December, 1881, I figured this species which I had previously described, and also described and figured a seemingly distinct form as *M. acifera.* I have since then dredged a specimen at Port Phillip Heads, which shows them to belong to the same species. In some parts at the centre and circumference of the colony the cells are wide, the margins either unarmed or with one or more sharp uncinate spines; in other cells the spines are forked, or broad and serrated, and in many so large that those of opposite sides inter-digitate, and occasionally coalesce.

Cribrillina setirostris, n. sp. Fig. 3.

Cells distinct, elongated; surface thickly covered with round or pyriform white-bordered pores, frequently arranged in irregular single or double transverse rows; mouth arched above, nearly straight below, with a slightly thickened margin; an avicularium at the base of the cell with a very long setiform mandible directed close up one margin of the cell.

Port Phillip Heads. Dredged by Mr. J. B. Wilson and myself.

Schizoporella Ridleyi, n. sp. Fig. 1.

Polyzoary encrusting; cells rhomboidal or elongated, in radiating linear series, separated by slightly raised margins; surface when young smooth; when older deeply areolated at the edges; mouth semi-circular above, straight below, with a small rounded sinus; below the mouth a small vertical elliptical avicularium on an elevated part of the cell; ovicell rounded.

Port Phillip Heads.

In a paper in the *Proceedings of the Zoological Society*, of June, 1881, Mr. Stuart O. Ridley describes this species, from a specimen dredged during the voyage of the "Alert," in the Strait of Magellan, as *S. marsupium*, M'G. Unfortunately, when I drew up my original description of *Lepralia marsupium*, the specimens I had were worn and imperfect, so that the exact structure of the mouth was not distinctly seen. Consequently the present and the true species, of which I have since procured numerous perfect specimens, have been confounded. In the present paper I give a more correct figure and fuller description of *L. marsupium*.

In young specimens of *S. Ridleyi* the mouth, with its semicircular upper margin and straight lower lip with rounded sinus, is well seen, as well as the small elliptical suboral avicularium, situated on the raised semilunar portion of the cell. In older and more calcified cells this raised portion frequently becomes so developed as to obscure the view of the mouth and avicularium; in these also there is usually a series of deep grooves, converging from the margin to the raised suboral portion.

Schizoporella arachnoides, n. sp. Fig. 4.

Polyzoary encrusting; cells oval, distinct, convex, smooth; mouth arched above, with a deep rounded notch in the straight lower lip; a series of (usually) seven stiff spines, several of which, especially the lower, are situated at a distance from the mouth; ovicell rounded, smooth, the margin usually sculptured.

Port Phillip Heads.

This very beautiful species is at once distinguished by the arrangement of the oral spines. These are usually seven in number. The lowest on each side is situated below and to one side of the angle of the mouth, and several others are frequently situated at a little distance from the mouth margin. The edge of the ovicell is usually sculptured, as in *Microporella Malusii*; sometimes, however, it is smooth.

Porella marsupium, M'G. Fig. 2.

Cells elongated, distinct, arranged in linear series, surface smooth, minutely punctured or areolated at the margin;

mouth in young specimens nearly round with a projecting mucro below; in old specimens contracted downwards, and usually with a squared denticle in the lower lip, which is also slightly thickened; below the mouth is a small elliptical avicularium on the upper part of a bullate projection; ovicell small, globular, smooth, with faint radiating lines.

Common.

As already stated, this species was originally described from bad specimens, and I have, therefore, given a more correct figure and an amended description. Hincks had already (Annals & Mag. Nat. His., 1881) given a figure, and noticed the oral denticle (which is frequently absent) and suboral avicularium.

Cellepora exigua, M'G. Fig. 7.

The figures represent a common form which I described in 1860. I now think that it is probably identical with the very variable *Rhynchopora bispinosa*, and shall, in a future communication, give additional figures and a full description.

Rhynchopora profunda, n. sp. Fig. 8.

Polyzoary encrusting; marginal cells oval, smooth or areolated at the edges; in the youngest the mouth arched above, slightly hollowed below; when a little older one side becomes enlarged, and from it projects an unciform process, the point of which is turned slightly upwards; as growth advances a calcareous deposit, at first arranged in a reticulate manner on the margins of the cells, increases in bulk until the original cell is much thickened, and the mouth is buried at the bottom of a deep cavernous opening; in these cells the upper lip is sometimes minutely crenulate; the uncinate process is always plainly seen deep down, and has an avicularium in the front with a broadly triangular mandible opening forward; the surface of the raised calcareous parts is irregularly nodulated, and there are a good many large avicularia with more or less spatulate mandibles scattered over it.

Port Phillip Heads; Mr. J. B. Wilson.

I refer this species doubtfully to Hinck's genus *Rhyncopora*. The characteristics are the triangular mandible of the avicularium on the uncinate process opening directly forward, and the extraordinary calcareous growth which originates on the margins of the cells, and increases to such an extent as to leave the mouth buried at the bottom of a deep cavern. The figures are taken from different parts of the same small colony.

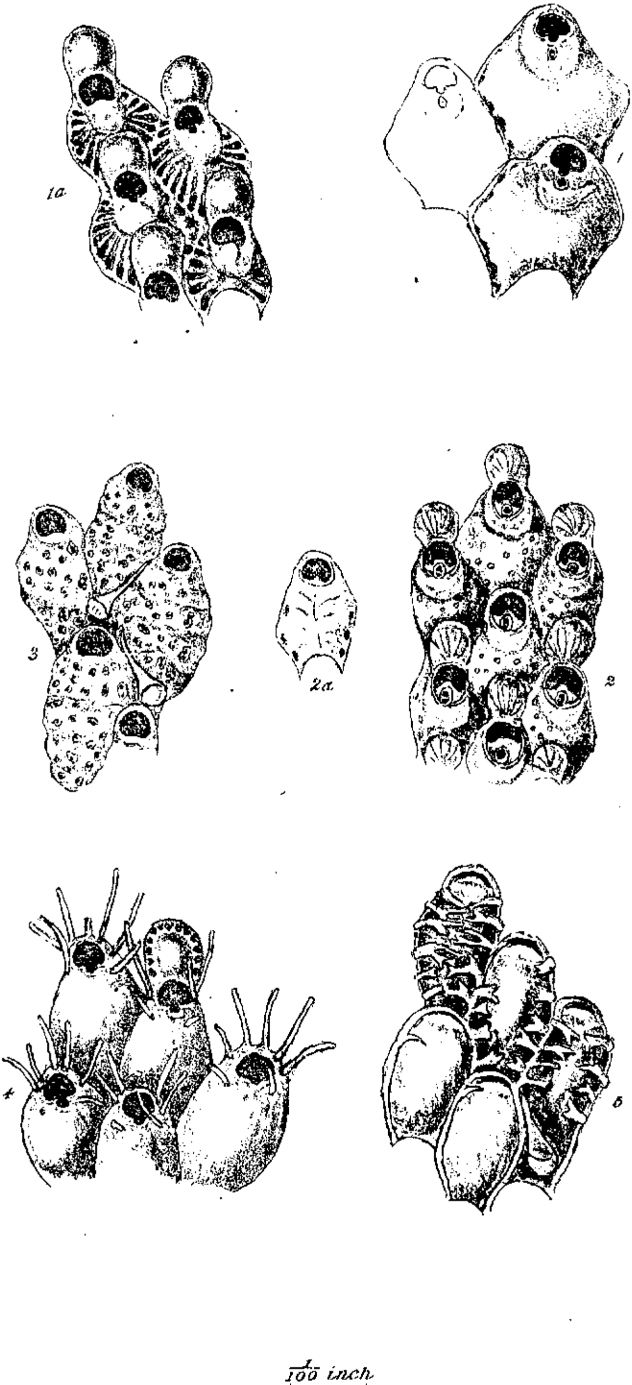
Lekythopora, n. genus.

Polyzoary erect, branched; cells arranged round the branches, more or less flask-shaped or elongated, oblique or erect, and crowded together; mouth irregularly rounded; peristome thickened and becoming produced into a long tube, on one side of the orifice of which is a small avicularium; ovicell forming a projection on the side of the cell below the mouth, the summit deficient in calareous matter, and formed by an oval lens-shaped membrane.

L. hystrix, n. sp. Fig. 6.

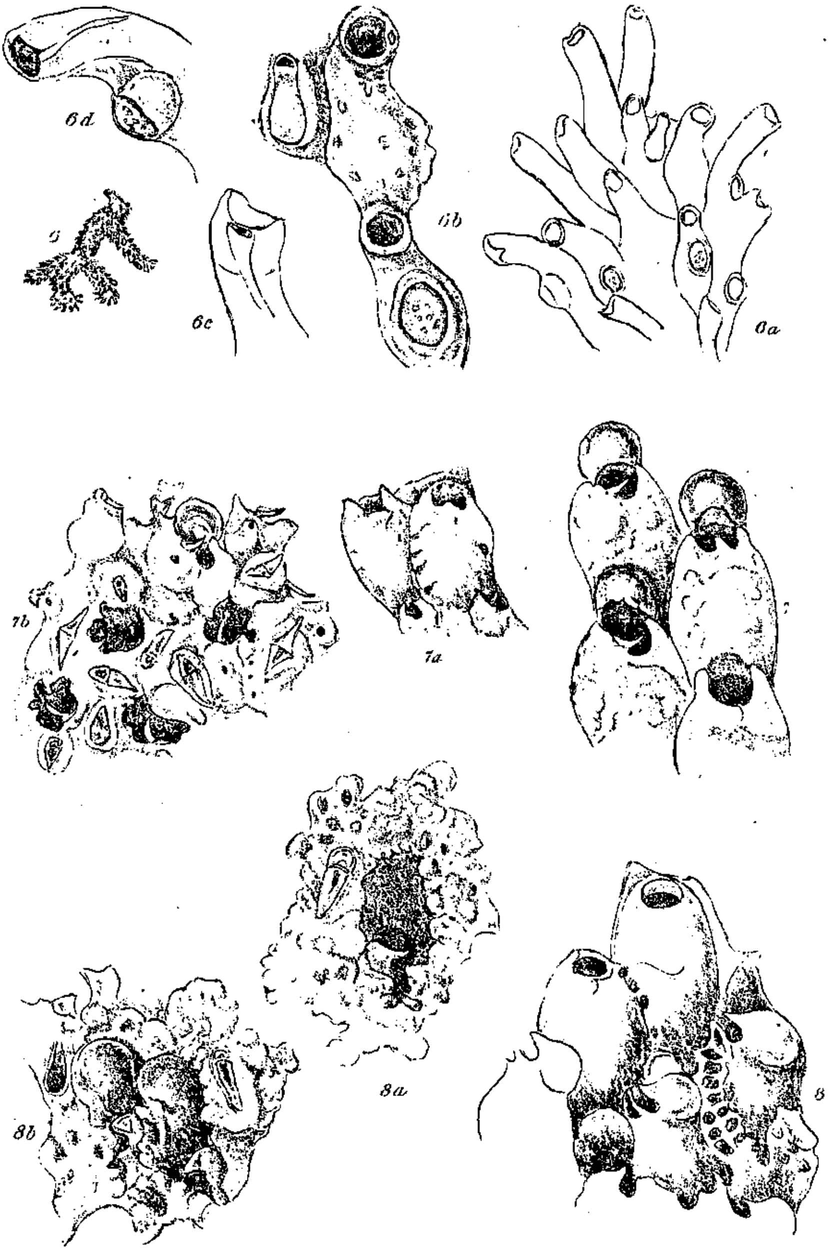
Of this, the only species, I have procured several specimens at the Heads. Mr. Wilson, I believe, has also found it. My specimens form small branching rigid tufts, like some of the small erect *Celleporæ.* The cells are very much crowded together, and, where not too much compressed by their neighbours, may be seen to be flask-shaped; the surface is nearly smooth, or granular and pitted. The primary orifice seems to be nearly circular, but the peristome in all the cells is thickened, and in most is produced into a very long slightly prismatic tube. On one side of the summit of this peristome there is a small horizontal avicularium, with a bluntly triangular mandible opening directly upwards. From this avicularium a minute tube can be traced, extending in a spiral manner downwards. There are also a few large avicularia, with large spatulate mandibles, scattered among the cells. The ovicell is peculiar. It is an enlargement on the front of the cell below the mouth. The summit is not calcareous, but consists of an elliptical convex chitinous membrane. The genus evidently belongs to the *Celleporidæ.*

Plate I.



P.H.McG. del. & lith.

C. Troedel & Co. imp.



$\frac{1}{100}$ inch.

P.H.McG del. & lith.

C. Troedel & Co. imp.

EXPLANATION OF PLATES.

Plate I.

Fig. 1. *Schizoporella Ridleyi*, young cells. Fig. 1*a*. Older group, showing the converging grooves and ovicells.

Fig. 2. *Porella marsupium.* Fig. 2*a*. Young cell.

Fig. 3. *Cribrillina setirostris.*

Fig. 4. *Schizoporella arachnoides.*

Fig. 5. *Membranipora serrata.* Two of the cells, showing the condition described as *M. acifera.*

Plate II.

Fig. 6. *Lekythopora hystrix*, natural size. Fig. 6*a*. Outline of portion magnified. Fig. 6*b*. Two cells showing roughened and pitted surface, membranous covering of ovicell, oral and separate large avicularia. Fig. 6*c*. Part of peristome, showing avicularium and spiral tube. Fig. 6*d*. Profile of cell to show situation and projection of ovicell.

Fig. 7. *Cellepora exigua*, showing oral avicularia and ovicells. Fig. 7*a*. Young cells from growing margin. Fig. 7*b*. Portion of older colony, showing scattered avicularia.

Fig. 8. *Rhynchopora profunda.* Cells from growing margin, showing the commencement of the calcareous growth. Fig. 8*a*. More advanced stage of this growth. Fig. 8*b*. Two cells with calcareous overgrowth, showing scattered avicularia and commencing development of ovicells.

Art. XVIII.—*On Electric Railways.*

By Mr. Peter Behrendt.

[Read 12th October, 1882.]

Art. XIX.—*Methods of Election.*

By Professor E. J. Nanson.

[Read 12th October, 1882.]

If there be several candidates for an office of any kind, and the appointment rests in the hands of several persons, an election is held to decide who is to receive the appointment. The object of such an election is to select, if possible, some candidate who shall, in the opinion of a majority of the electors, be most fit for the post. Accordingly, the fundamental condition which must be attended to in choosing a method of election is that the method adopted must not be capable of bringing about a result which is contrary to the wishes of the majority. There are several methods in use, and none of them satisfy this condition. The object of this paper is to prove this statement, and to suggest a method of election which satisfies the above condition.

Let us suppose, then, that several persons have to select one out of three or more candidates for an office. The methods which are in use, or have been put forward at various times, may be divided into three classes.

The first class includes those methods in which the result of an election is arrived at by means of a single scrutiny.

The second class includes those in which the electors have to vote more than once.

The third class includes those in which more than one scrutiny may be necessary, but in which the electors have only to vote once.

In describing these methods, the number of candidates will in some cases be supposed to be any whatever, but in other cases it will be assumed, for the sake of simplicity, that there are only three candidates. The case in which there are only three candidates is the simplest, and it is of frequent occurrence. I propose, therefore, to examine, for the case of three candidates, the results of the methods which have been proposed, and to show that they are erroneous in this case. This will be sufficient for my purpose, for it will be easily seen that the methods will be still more liable to error if the number of candidates be greater than three. I shall then discuss at some length the proposed method in the case of three candidates, and afterwards consider more briefly the case of any number of candidates.

Methods of the First Class.

In the first class three methods may be placed, viz., the single vote method, the double vote method, and the method of Borda. In these methods the electors have only to vote once, and the result is arrived at by means of a single scrutiny.

The Single Vote Method.

This is the simplest of all methods, and is the one adopted for Parliamentary elections in all English-speaking communities in the case in which there is only one vacancy to be filled. As is well known, each elector has one vote, which he gives to some one candidate, and the candidate who obtains the greatest number of votes is elected. This method is used for any number of candidates; but in general the larger the number of candidates the more unsatisfactory is the result.

In this method, unless some candidate obtains an absolute majority of the votes polled, the result may be contrary to the wishes of the majority. For, suppose that there are twelve electors and three candidates, A, B, C, who receive respectively five, four, and three votes. Then A, having the largest number of votes, is elected. This result, however, may be quite wrong; for it is quite possible that the four electors who vote for B may prefer C to A, and the three electors who vote for C may prefer B to A. If this were the case, and the question

That A is to be preferred to B

were put to the whole body of electors, it would be negatived by a majority of two, and the question

That A is to be preferred to C

would also be negatived by a majority of two. Thus the single vote method places at the head of the poll a candidate who is declared by a majority of the electors to be inferior to each of the other candidates. In fact, if A and B were the only candidates B would win; or if A and

C were the only candidates C would win; thus B and C can each beat A, and yet neither of them wins. A wins simply because he is opposed by two men, each better than himself.

Thus the single vote method does not satisfy the fundamental condition. It appears also not only that the best man may not be elected, but also that we are not even sure of getting in the second best man. It is clear that if any candidate obtain an absolute majority of the votes polled this error cannot occur. All we can say, then, about the single vote method is that if any candidate obtain an absolute majority the method is correct, but if no one obtains such a majority the result may be quite erroneous.

These results are well known, and consequently in elections under this plan great efforts are generally made to reduce the number of candidates as much as possible before the polling day, in order to avoid the return of a candidate who is acceptable to a small section only of the electors. This reduction can, in practice, be made only by a small number of the electors, so that the choice of a candidate is taken out of the hands of the electors themselves, who are merely permitted to say which of two or more selected candidates is least objectionable to them.

The Double Vote Method.

In this method each elector votes for two candidates, and the candidate who obtains the largest number of votes is elected. This method is erroneous, for it may lead to the rejection of a candidate who has an absolute majority of votes in his favour, as against all comers. For suppose that there are twelve electors, and that the votes polled are, for A, nine; for B, eight; for C, seven, then A is elected. Now, in order to show that this result may be erroneous it is merely necessary to observe that it is possible that each of the seven electors who voted for C may consider C better than A and B; that is to say, an absolute majority of the electors may consider C to be the best man, and yet the mode of election is such that not only does C fail to win, but in addition he is at the bottom of the poll. This is an important result; we shall see presently the effect it has on other methods of election.

In the case in which there are only three candidates this method is, in fact, equivalent to requiring each elector to vote against one candidate, and then electing the candidate who has the smallest number of votes recorded against him.

Borda's Method.

This method was proposed by Borda in 1770, but the first published description of it is in the volume for 1781 of the *Memoirs of the Royal Academy of Sciences.* For some remarks on the method see Todhunter's *History of Probability*, p. 433, where the method is described. In the case of three candidates, it is as follows. Each elector has three votes, two of which must be given to one candidate, and the third vote to another candidate. The candidate who obtains the greatest number of votes is elected.

In order to show that this method may lead to an erroneous result, suppose that there are twelve electors, of whom five prefer A to B and B to C, whilst two prefer A to C and C to B, and five prefer B to C and C to A. Then the votes polled will be, for A, fourteen; for B, fifteen; for C, seven. Thus B is elected. It is clear, however, that this result is wrong, because seven out of the whole twelve electors prefer A to B and C, so that, in fact, A has an absolute majority of the electors in his favour. Hence, then, Borda's method does not satisfy the fundamental condition, for it may lead to the rejection of a candidate who has an absolute majority of the electors in his favour.

It may be observed that the result of the poll on Borda's method may be obtained, in the case of three candidates, by adding together the corresponding results in the polls on the methods already described.

If there be n candidates, each elector is required to arrange them in order of merit; then for each highest place $n-1$ votes are counted; for each second place, $n-2$ votes, and so on; $n-r$ votes being counted for each r^{th} place, and no votes for the last place. The candidate who obtains the greatest number of votes is elected.

Borda does not give any satisfactory reason for adopting the method. Nevertheless he had great faith in it, and made use of it to test the accuracy of the ordinary or single vote method, and arrived at the extraordinary conclusion that in any case in which the number of candidates is equal to or exceeds the number of electors, the result cannot be depended upon unless the electors are perfectly unanimous. This in itself is sufficient to show that Borda's method must be capable of bringing about a result which is contrary to the wishes of the majority.

There is, however, another objection which is of great importance. Borda's method holds out great inducements to the electors to vote otherwise than according to their real views. For if an elector strongly desires the return of a particular candidate, he not only gives his two votes to that candidate, but he also takes care to give his remaining vote to the least formidable of the other candidates. The effect of this is to give a great advantage to second-rate candidates. Thus not only does Borda's method fail to interpret the true wishes of the electors, supposing that they vote honestly, but it holds out great inducements to them to vote otherwise than according to their real views.

Laplace discussed the question of the best mode of electing one out of several candidates, and by an analytical investigation was led to Borda's method.* He states distinctly that this method is the one indicated by the theory of probabilities. He then proceeds to point out the objection just stated, and expresses the opinion that the method would, without doubt, be the best if each elector would write the names of the candidates in what he thinks the order of merit. We have seen, however, that this is far from being the case.

Methods of the Second Class.

The simplest method of the second class is the French method of double elections. In this method each elector has one vote, as in the single vote method, already described. If, however, no candidate obtain an absolute majority of the votes polled, a second election is held. For this second election only the two candidates who obtained the largest number of votes at the first election can be candidates. The result is that the successful candidate is returned by an absolute majority of those who vote at the second election, so that it would appear, at first sight, that the successful candidate represents the views of a majority of the electors. We must not lose sight, however, of two facts, first, that all the electors who vote at the first election may not vote at the second election; second, that those who do so vote merely have to choose between the two remaining candidates, and that, consequently, they may not be repre-

* *Journal de l'Ecole Polytechnique*, cahiers vii. and viii., pp. 169, 170; *Théorie Analytique des Probabilités*, pp. 101, 299; Todhunter's *History of Probability*, pp. 547, 548.

sented in any sense by the candidate they vote for; they may merely be in the position of having a choice of evils.

This plan has frequently been proposed for adoption in England, and quite recently it has been proposed by more than one speaker in the Legislative Assembly of Victoria. The method is indeed a great improvement on the present system of single voting, and if the election be merely a party contest, and neither side runs more than two candidates, the result cannot be wrong. But if these conditions be not satisfied, the method may easily lead to an erroneous result. The method may be used whatever be the number of candidates; but it is sufficient to show that it is erroneous in the case of three candidates only. This is at once done by a further consideration of the example already given in discussing the single vote method. For in that example C is at the bottom of the poll, and, according to the present system, he is rejected, and a second election is held to decide between A and B, because no one has an absolute majority at the first election. The result of the second election is, for A, five votes; for B, seven votes; so that B wins. In order to show that this result may be erroneous it is only necessary to suppose that the five electors who voted for A prefer C to B. For then, if the question

That C is to be preferred to B

was put to the whole body of electors, it would be carried by a majority of four. Now, we have already seen that the question

That C is to be preferred to A

would be carried by a majority of two. Hence, then, this method leads to the rejection of a candidate who is declared by a majority of the electors to be superior to each of the other candidates. This method, then, clearly violates the condition that the result must not be contrary to the wishes of the majority.

We may consider this example from a slightly different point of view. In discussing it under the single vote method, the important result arrived at was that A was inferior to each of the other candidates, and, therefore, ought to be at the bottom of the poll, instead of being at the top, as he was, in consequence of his being opposed by two good men, B and C. Thus, instead of excluding C, as in the French method, A is the one who ought to be excluded. Having arrived at the result that A is to be excluded, the whole of the electors have now a right to decide between B and C. On putting this question to the issue, we find that C is preferred by the electors.

We see, then, that the French method may lead to error through throwing out the best man at the first election. And this is the only way in which it can err; for if there be a best man, and he survive the ordeal of the first election, he must win at the second, seeing that he is, in the opinion of the electors, better than each of his competitors.

Comparing the French method with the single vote method, we see that in the case of three candidates the worst candidate may be returned by the single vote method, but that it would be impossible for such a result to be brought about by the French method. By that method we are at least sure of getting the second best man, if we fail to get the best.

There is, however, a grave practical objection to this method. It is that a second polling may be necessary. This is of great importance; for in the case where the number of electors is large, as in a political election, great expense has to be incurred, not only by the authorities in providing the necessary machinery, but also by the electors themselves in coming to the poll again. Besides this, the excitement of the election is kept up much longer than it would be if the whole matter could be settled by a single polling. There can, I think, be little doubt that this objection has been one of the chief obstacles with which the advocates of this method have had to contend. Accordingly, we find that the single vote method is employed, as a rule, in those cases in which there are some hundreds of electors, and it would be inconvenient to hold a second election. On the other hand, when the number of electors is small, so that they can all meet together, and remain till a second or third election has been held, the number of candidates is generally reduced to two by means of a preliminary ballot or ballots. This very fact shows that the defects of the single vote method are recognised, because in those cases in which it is considered to be practicable to do so a preliminary election is held, so as to try to avoid the glaring defect of the single vote method—that is, to avoid returning a candidate who is acceptable to a small section only of the electors. It is a mistake, however, to suppose that it is not practicable to hold one or more preliminary elections when the number of electors is large. It is generally thought that in order to do so a fresh set of voting papers must be used for the second election, and that this second election cannot be held till the result of the first is known, so that the electors have the expense and trouble of going to the poll a second time. This, at all events, appears to be the practice in France, Germany, and Italy. This, however, is not necessary; for, by a very simple expedient, any number of preliminary elections, on any plan whatever, may be held by means of a single set of voting papers, and without troubling the electors to vote more than once. The expedient is to require each elector to indicate his order of preference amongst all the candidates. Once get this information from the electors, and we can tell how any elector will vote on any question that may be put as to the merits of the candidates. It is here assumed that an elector will not change his opinion during the course of the election. This expedient of making each elector indicate his order of preference amongst all the candidates is necessary in order to carry out Borda's method, which has been described above; indeed, it was suggested by Borda himself. But Borda does not appear to have noticed that it might be made use of for a series of elections without requiring the electors to vote again; this appears to have been first pointed out by Condorcet. The idea of a preferential or comparative voting paper is one of the fundamental ones in Hare's system of proportional representation. We are not concerned with this subject here, as the only question under consideration is that of filling a single vacancy. It is, however, worthy of notice that the preferential voting paper which is such an important feature in Hare's system, is of such old origin, and that it was suggested by Condorcet as a means of filling several vacancies, which is the very question considered by Hare. The method of Condorcet, however, is quite different to that of Hare.

If the expedient here described were adopted, the French system would be free from the practical objection which has been indicated. It would still, however, be open to the objection that the result of the election might be contrary to the views of the electors. Notwithstanding this, the method would be a good practical one for elections on a large scale; it would be very suitable for party contests, and if neither side ran too many candidates, the result could not be wrong. The method, however, would be altogether unsuitable if there were three distinct parties to the contest. Under any circumstances, however, the method would be very little more complicated than the present system of single voting, and it would give much better results. If, however, it be considered desirable to reform the present electoral system so far as to introduce this French system of double elections, it would be as well to at once adopt the method of Ware, described below. This is the same, in the case of three candidates, as the French method, but in other cases it is a trifle longer. No difference whatever would be required in the method of voting, but only a little more labour on the part of the returning officer. The results of this method would be much more trustworthy than those of the French method.

OTHER METHODS OF THE SECOND CLASS.

Before passing on to the methods of the third class, it may be stated that each of the methods described under that heading may be conducted on the system of the second class. In order to do so, instead of using a preferential voting paper, as in the methods of the third class, we must suppose a fresh appeal made to the electors after each scrutiny. This, of course, would make the methods needlessly complex, and, in the case of a large number of electors, totally impracticable. This, however, is not the only objection to the methods of the second class. For if the electors be allowed to vote again after the result of one of the preliminary elections is known, information is given which may induce an elector to transfer his allegiance from a candidate he has been supporting to another candidate whom he finds has more chance of success. A method which permits, and which even encourages, electors to change their views in the middle of the contest cannot be considered perfect. This objection does not apply to those cases in which there are only three candidates, or to any case in which all but two candidates are rejected at the first preliminary election, as in the French system.

There is another objection, however, which applies to all cases alike; it is that, at the first preliminary election, an astute elector may vote, not according to his real views, but may, taking advantage of the fact that there is to be a second election, vote for some inferior candidate in order to get rid, at the first election, of a formidable competitor of the candidate he wishes to win. If this practice be adopted by a few of the supporters of each of the more formidable competitors, the result will frequently be the return of an inferior man.

On account of these objections, I consider it unnecessary to enter into any further details as to the methods of the second class.

Methods of the Third Class.

In the methods of the third class each elector makes out a list of all the candidates in his order of preference, or, what comes to the same thing, indicates his order of preference by writing the successive numbers 1, 2, 3, &c., opposite the names of the candidates on a list which is supplied to him. Thus one voting only is required on the part of the electors. These preferential or comparative lists are then used in a series of scrutinies; and the methods of the third class differ from one another only in the way in which these scrutinies are conducted. Three different methods, which may be called Ware's method, the Venetian method, and Condorcet's practical method, have been proposed for use, and these will now be described.

Ware's Method.

This method is called Ware's method because it appears to have been first proposed for actual use by W. R. Ware, of Harvard University.* The method was, however, mentioned by Condorcet,† but only to be condemned. This method is a perfectly feasible and practicable one for elections on any scale, and it has recently been adopted by the Senate of the University of Melbourne. It is a simple and obvious extension of the French system, and it is obtained from that system by two modifications, viz.:—

(1.) The introduction of the preferential or comparative method of voting, so as to dispense with any second voting on the part of the electors.

(2.) The elimination of the candidates one by one, throwing out at each scrutiny the candidate who has fewest votes, instead of rejecting at once all but the two highest.

In the case in which there are three candidates only, the second modification is not necessary. It will, perhaps, be convenient to give a more formal description of this method. The mode of voting for all methods of the third class has already been described; it remains, therefore, to describe

* See *Hare on Representation*, p. 353.

† *Œuvres*, 1804, vol. xiii., p. 243.

the mode of conducting the scrutinies in Ware's method.

At each scrutiny each elector has one vote, which is given to the candidate, if any, who stands highest in the elector's order of preference.

The votes for each candidate are then counted, and if any candidate has an absolute majority of the votes counted he is elected.

But if no candidate has such an absolute majority, the candidate who has fewest votes is excluded, and a new scrutiny is proceeded with, just as if the name of such excluded candidate did not appear on any voting paper.

Successive scrutinies are then held until some candidate obtains on a scrutiny an absolute majority of the votes counted at that scrutiny. The candidate who obtains such absolute majority is elected.

It is obvious that this absolute majority must be arrived at sooner or later.

It is clear, also, that if on any scrutiny any candidate obtain a number of votes which is greater than the sum of all the votes obtained by those candidates who each obtain less than that candidate, then all the candidates having such less number of votes may be at once excluded.

Ware's method has been shown to be erroneous for the case of three candidates in the remarks on the French method, of which it is in that case a particular form. It is easy to see that if there be more than three candidates the defects of this method will be still more serious.

The objection to this method, concisely stated, is that it may lead to the rejection of a candidate who is considered by a majority of the electors to be better than each of the other candidates. At the same time, the method is a great improvement on the single vote method; and the precise advantage is that whereas the single vote method might place at the head of the poll a candidate who is considered by a majority of the electors to be worse than each of the other candidates, it would be impossible for such a candidate to be elected by Ware's method.

To illustrate fully the difference between the two methods and the defects of each, suppose that there are several candidates, A, B, C, D, . . P, Q, R, and that in the opinion of the electors each candidate is better than each of the candidates who follow him in the above list, so that A is clearly the best, B the second best, and so on, R being the worst. Then on the single vote method R may win; on Ware's method A, B, C, D, . . P, may be excluded one after another on the successive scrutinies, and at the final scrutiny the contest will be between Q and R, and Q, of course, wins, since we have supposed him better than R in the opinion of the electors. Thus the single vote method may return the worst of all the candidates; and although Ware's method cannot return the worst, it may return the next worst.

A great point in favour of Ware's method is that it is quite impossible for an astute elector to gain any advantage for a favourite candidate by placing a formidable competitor at the bottom of the list. On account of its simplicity, Ware's method is extremely suitable for political elections. In cases of party contests, the strongest party is sure to win, no matter how many candidates are brought forward. The successful candidate, however, will not always be the one most acceptable to his own party.

The Venetian Method.

For the sake of simplicity, I describe this method for the case of three candidates only. Two scrutinies are held; at the first scrutiny each elector has two votes, which are given to the two candidates, one to each, who stand highest in the elector's order of preference. The candidate who has fewest votes is then rejected, and a final scrutiny is held between the two remaining candidates. At the final scrutiny each elector has one vote, which is given to that one of the remaining candidates who stands highest in the elector's order of preference. The candidate who obtains most votes at the final scrutiny is elected.

This method is very faulty; it may lead to the rejection of a candidate who has an absolute majority of the electors in his favour. For we have seen, in discussing the double vote method, that such a candidate may be rejected at the first scrutiny. In fact, unless the candidate who has fewest votes at the first scrutiny has less than N votes, where 2N is the number of electors, we cannot be sure the result is correct. For, for anything we can tell, the candidate who is rejected at the first scrutiny may be, in the opinion of an absolute majority of the electors, the best man for the post. If, however, the candidate who has fewest votes on the first scrutiny has less than N votes, then the method will certainly give a correct result. For, since there are only three candidates, to require an elector to vote for two candidates comes to exactly the same thing as to ask him to vote against one candidate. Now, if with the two votes any candidate get less than N votes, it is clear that there are more than N votes against him, for each candidate must be marked first, or second, or third on each paper. Thus, in the opinion of an absolute majority, the candidate is worse than each of the other candidates, and, therefore, ought not to be elected. Unless, therefore, the lowest candidate has less than N votes, this method violates the fundamental condition.

I do not know that the method has ever been used in the form here described; but in the still more objectionable form of the second class, which differs from the one just described only by dispensing with the preferential voting paper, and allowing the electors to vote again after the result of the first scrutiny is known, it is exceedingly common, and is frequently used by committees. An instance which was fully reported in the Melbourne papers occurred some time ago in the selection of a candidate to stand on the constitutional side at the last election for Boroondara. It is fair, however, to say that the result of the method appears to have been correct in that case; but that was due to accident, and not to the method itself.

If there be more than three candidates the method is very complicated, and the defects are more serious. It seems, however, hardly worth while going into any details in these cases.

Condorcet's Practical Method.

This method was proposed in 1793 by Condorcet, and appears to have been used for some time at Geneva. It is described at pp. 36—41 of vol. xv. of Condorcet's collected works (edition of 1804), and may be used in the case of any number of candidates for any number of vacancies. We are at present concerned only with the case of a single vacancy; and for the sake of simplicity I describe Condorcet's method for the case in which there are only three candidates.

Two scrutinies may be necessary in order to ascertain the result of the election in this method. At the first scrutiny one vote is counted for each first place assigned to a candidate, and if any candidate obtains an absolute majority of the votes counted he is elected. But if no one obtain such an absolute majority a second scrutiny is held. At the second scrutiny one vote is counted for each first place, and one vote for each second place, exactly as in the first scrutiny on the Venetian method, and the candidate who obtains most votes is elected. At first sight we might suppose that this method could not lead to error. Comparing it with the Venetian method, described above, we see that Condorcet supplies a remedy for the obvious defect of the Venetian method—that is to say, the rejection of a candidate who has an absolute majority is now impossible. A little examination, however, will show, as seems to have been pointed out by Lhuilier,* that the method is not free from error. For, let us suppose that there are sixteen electors, of whom five put A first and B second, five put C first and B second, two put A first and C second, two put B first and A second, and two put C first and A second. Then the result of the first scrutiny will be, for A, B, C, seven, two, seven votes respectively. Thus, no one having an absolute majority, a second scrutiny is necessary. The result of the second scrutiny will be—for A, B, C, eleven, twelve, and nine votes respectively. Thus B, having the largest number of votes, is elected. This result, however, is not in accordance with the views of the majority of the electors. For the proposition, "B is better than A," would be negatived by a majority of two votes, and the proposition, "B is better than C," would also be negatived by a majority of two votes, so that in the opinion of the electors B is worse than A and also worse than C, and, therefore, ought not to be elected.

Summing up the results we have arrived at, we see that each of the methods which have been described may result in the return of a candidate who is considered by a majority of the electors to be inferior to each of the other candidates. Some of the methods—viz., the double vote method, the method of Borda, and the Venetian method—may even result in the rejection of a candidate who has an absolute majority of votes in his favour as against all comers. It would, however, be quite impossible for such a result to occur on the single vote method, or the methods of Ware and Condorcet.

Method Proposed.

Having pointed out the defects of the methods in common use, it now remains to describe the method proposed for adoption, and to show that it is free from these defects. It

* See Montucla's *Histoire des Mathématiques*, vol. iii., p. 421.

consists merely in combining the principle of successive scrutinies with the method of Borda, and at the same time making use of the preferential voting paper, so that the proposed method belongs to the third class. I propose, first, to describe and discuss the method for the case of three candidates, and then to pass on to the general case in which there may be any number of candidates.

Let us suppose, then, that there are three candidates, A, B, C. Each elector writes on his voting paper the names of two candidates in order of preference, it being clearly unnecessary to write down a third name. If we prefer it, the three names may be printed on the voting paper, and the elector may be required to indicate his order of preference by writing the figure 1 opposite the name of the candidate of his first choice, and the figure 2 opposite the name of the candidate of his second choice, it being clearly unnecessary to mark the third name. In order to ascertain the result of the election two scrutinies may be necessary.

At the first scrutiny two votes are counted for each first place and one vote for each second place, as in the method of Borda. Then if the two candidates who have the smallest number of votes have each not more than one-third of the whole number of votes, the candidate who has most votes is elected, as in Borda's method. But if one only of the candidates has not more than one-third of the votes polled (and some candidate must have less), then that candidate is rejected, and a second scrutiny is held to decide between the two remaining candidates. At the second scrutiny each elector has one vote, which is given to that one of the remaining candidates who stands highest in the elector's order of preference. The candidate who obtains most votes at the second scrutiny is elected.

The method may be more briefly described as follows:—Proceed exactly as in Borda's method, but instead of electing the highest candidate, reject all who have not more than the average number of votes polled. If two be thus rejected, the election is finished; but if one only be rejected, hold a final election between the two remaining candidates on the usual plan.

In order to show that the proposed method is free from the defects above described, it is necessary and it is sufficient to show that if the electors consider any one candidate, A, say, superior to each of the others, B and C, then A cannot be rejected at the first scrutiny. For if A be not rejected at the first scrutiny he cannot fail to win at the second scrutiny. Let therefore the whole number of electors be 2N, and let the number who prefer B to C be $N + a$, and consequently the number who prefer C to B be $N - a$; similarly, let the number who prefer C to A be $N + b$, and therefore the number who prefer A to C be $N - b$, and let the number who prefer A to B be $N + c$, and therefore the number who prefer B to A be $N - c$. Then it is easy to see that the numbers of votes polled by A, B, C at the first scrutiny will be

$$2N - b + c,\ 2N - c + a,\ 2N - a + b$$

respectively. For if the compound symbol A B be used to denote the number of electors who put A first and B second, and similarly for other cases, it is clear that A's score at the first scrutiny will be

$$2AB + 2AC + BA + CA.$$

Now this expression can be written in the form

$$(AB + AC + CA) + (AC + AB + BA),$$

and it is clear that the three terms in the first pair of brackets represent precisely the number of electors who prefer A to B, which number has already been denoted by $N + c$. In the same way the remaining three terms represent the number of electors who prefer A to C, which number has been denoted by $N - b$. Hence the score of A on the first scrutiny is $2N - b + c$. In exactly the same way it may be shown that the scores of B, C are $2N - c + a$ and $2N - a + b$ respectively. The sum of these three numbers is 6N, as it ought to be. Thus 2N is the mean or average of these three numbers, and consequently the highest of the three candidates must have more than 2N votes, and the lowest must have less than 2N votes. Now, let us suppose that a majority of the electors prefer A to B, and likewise that a majority prefer A to C; then c must be positive, and b must be negative. Hence the score of A, which has been shown to be $2N - b + c$, is necessarily greater than 2N, for it exceeds 2N by the sum of the two positive quantities $-b$ and c. Thus A has more than 2N votes, that is, more than one-third, or the average of the votes polled. He cannot, therefore, be rejected at the first scrutiny, so that B or C or both must be rejected at the first scrutiny. If either of the two, B and C, be not rejected, A must win at the second scrutiny, for there is a majority for A against B, and also against C. Hence, then, it has been demonstrated that if the opinions of the electors are such that there is a majority in favour of A as against B, and likewise a majority in favour of A as against C, the method of election which is proposed will certainly bring about the correct result; whereas it has been shown by the consideration of particular examples that the methods in ordinary use may easily bring about an erroneous result under these circumstances. Thus the proposed method cannot bring about a result which is contrary to the wishes of the majority, so that the proposed method satisfies the fundamental condition.

The method which is proposed has, I think, strong claims. It is not at all difficult to carry out. The result will, as often as not, be decided on the first scrutiny. We simply require each elector to put down the names of two of the three candidates in order of preference. Then for each first name two votes are counted, and for each second name one vote is counted. The number of votes for each candidate is then found. The third part of the sum total may be called the average; then all candidates who are not above the average are at once rejected. The lowest candidate must, of course, be below the average. The second is just as likely to be below as above the average. If he is below, the election is settled; but if he is above the average, a second scrutiny is necessary to decide between him and the highest candidate.

CASES OF INCONSISTENCY.

We have now to consider what is the result of the proposed method in those cases in which there is not a majority for one candidate against each of the others. The methods which have been described have been shown to be erroneous by examining cases in which either one candidate has an absolute majority of the electors in his favour, or a candidate A is inferior to B and also to C, or a candidate A is superior to B and also to C. Now it is not necessary that any of these cases should occur. If a single person has to place three candidates in order of preference he can do so, and it would be quite impossible for any rational person to arrive at the conclusions

B is superior to C ... ... (1)
C is superior to A ... ... (2)
A is superior to B ... ... (3)

When, however, we have to deal with a body of men, this result may easily occur, and no one of the candidates can be elected without contradicting some one of the propositions stated above. If this result does occur, then, no matter what result any method of election may give, it cannot be demonstrated to be erroneous. We have examined several methods, and all but the one now proposed have been shown to lead to erroneous results in certain cases. It may fairly be urged, then, that that method which cannot be shown to be erroneous in any case has a greater claim to our consideration than any of the other methods which can be shown to erroneous. On this ground alone I think the method proposed ought to be adopted for all cases.

We can, however, give other reasons in favour of the method proposed. We have seen that it gives effect to the views of the majority in all cases except that in which the three results (1), (2), (3) are arrived at. In this case there is no real majority, and we cannot arrive at any result without abandoning some one of the three propositions (1), (2), (3). It seems most reasonable that that one should be abandoned which is affirmed by the smallest majority. Now, if this be conceded, it may be shown that the proposed method will give the correct result in all cases. For it is easily seen that the majorities in favour of the three propositions (1), (2), (3) are respectively $2a$, $2b$, $2c$. Hence, then, in the case under consideration, a, b, c, must be all positive. Let us suppose that a is the smallest of the three. Then we abandon the proposition (1), and consequently C ought to be elected. Now let us see what the proposed method leads to in this case. B's score at the first scrutiny is $2N - c + a$, and this is necessarily less than 2N, because c is greater than a, and each is positive. Again, C's score is $2N - a + b$, and this is necessarily greater than 2N, because b is greater than a, and each is positive. Thus B is below the average, and C is above the average. Therefore, at the first scrutiny B goes out and C remains in. If A goes out also, C wins at the first scrutiny. But if A does not go out, C will beat A at the second scrutiny. Thus C wins in either case, and, therefore, the proposed method leads to the result which is obtained by abandoning that one of the propositions (1), (2), (3) which is affirmed by the smallest majority. We have already seen that in the case in which the numbers a, b, c are not all of the same sign, the proposed method leads to the correct result. Hence, then, if it be admitted that when we arrive at the three inconsistent propositions (1), (2), (3) we are to abandon the one which is affirmed by the smallest majority, it follows that the proposed method will give the correct result in all cases.

We have, then, arrived at two results. First, that if the electors affirm any two of the propositions (1), (2), (3) and affirm the contrary of the remaining one, and so affirm three consistent propositions, then the result of the method of election which is here proposed, will be that which is the logical consequence of these propositions, whilst the methods in ordinary use may easily give a different result. Second, that if the electors affirm the three propositions (1), (2), (3) which are inconsistent, then the result of the method proposed is that which is the logical consequence of abandoning that one of the three propositions which is affirmed by the smallest majority.

Another way of Applying Proposed Method.

The method may be stated in another form, which may sometimes be more convenient. For each first place count one vote; then, if any candidate has an absolute majority, elect him. But if not, count in addition one vote for each second place; then, if the lowest candidate has not got half as many votes as there are electors, reject him, and proceed to a final scrutiny between the remaining two. But, if not, take the aggregate for each candidate of the results of the two counts; then reject all who have less than one-third of the votes now counted, and, if necessary, proceed to a final scrutiny.

This process will give the same final result as the method already described. This is readily seen as follows:—1st. If any one has an absolute majority on the first places, the election is settled at the first scrutiny, and the result is manifestly correct, and therefore the same as that of the proposed method. 2nd. If no one has an absolute majority on the first places, but some one has on first and second places less than half as many votes as there are electors, it is manifest that more than half the electors consider that candidate worse than each of the others, so that he ought to be rejected, and hence the result of the final scrutiny will be correct, and therefore in accordance with that of the proposed method. 3rd. If neither of the above events happen, we take the aggregate. Now (as has already been remarked) the result of taking the aggregate is to give us exactly the same state of the poll as in the first scrutiny of the proposed method. Thus the second way of applying the method will give the same final result as the proposed method. This second way is very convenient, for if there be an absolute majority for or against any candidate, it is made obvious at the first or second count, and the election is settled with as little counting as possible. The two counts are conducted on well known plans, and if the circumstances are such that either of these necessarily gives a correct result, that result is adopted. But if it is not obvious that a correct result can be arrived at, then we take the mean, or what comes to the same thing, the aggregate of the two counts. This might appear to be a rule of thumb, and on that account may perhaps commend itself to some persons. This is not the case, however; and it is remarkable that that which might suggest itself as a suitable compromise in the matter should turn out to be a rigorously exact method of getting at the result in all cases. The view of the proposed method which has just been given shows exactly what modifications require to be made in Condorcet's practical method in order to make it accurate.

Laplace's Objection.

It may be said that the proposed method is open to the objection raised by Laplace to the method of Borda. To this I think it a sufficient answer to say, that if we have a method which will truly interpret the wishes of the electors, as expressed by their voting papers, we need not trouble ourselves whether they vote honestly or not; that is their own concern. If we provide a method which will bring out a correct result for honest electors we need not try to go further, and endeavour to construct a method which will force dishonest electors to vote honestly. Nevertheless, it may be pointed out that Laplace's objection is not of so much force in this case as in the case of Borda's method. For if an elector vote otherwise than according to his real views it will be at the risk of having his vote at the final scrutiny counted against the candidate whom he considers most fit for the office to be filled. This risk would be sufficient to deter most electors from voting otherwise than according to their real opinions. If, in spite of this risk, an elector persists in voting otherwise than according to his real views we must take him at his word. To illustrate this objection, let us suppose that B and C are two formidable candidates, and that A is in reality inferior to each of them, but that the voting is as follows, BA = 5, CA = 4, AB = 1, AC = 1; so that B's supporters, in their anxiety to defeat C, put A second, and C's supporters, in their anxiety to defeat B, put A second. The result at the first scrutiny is A 13 votes, B 11 votes, C 9 votes. Thus C is rejected and A wins in the final scrutiny. A wins because the whole of C's supporters put him second. Had one of C's supporters voted according to his real views, and put B second, the result would have been different.

If the preferential mode of voting were not employed, this objection would be of great force; for then the supporters of each candidate would put his most formidable opponent at the bottom of their list at the first scrutiny, knowing that they would have at the second scrutiny an opportunity of reviewing their vote.

A Modification of Proposed Method.

It may be mentioned that there is another, but in general a more tedious, method of getting at a result, which cannot be shown to be erroneous in any case. This method has been adopted by the Trinity College Dialectic Society. It is as follows:—In the method proposed above, instead of rejecting all the candidates who are not above the average, reject the lowest only. It is obvious from what has been said above that this cannot lead to error. But a second scrutiny will always be required, whereas in the proposed method one scrutiny only may be necessary. There is another disadvantage: the result will not in all cases agree with that of the proposed method. For, let us suppose that a, b, c are all positive, and that a is the least of the three, and at the same time that $2c$ is less than $a + b$. On the method proposed, as we have already seen, C would be elected, but on the method now under discussion B would be elected. For the scores of A and B at the first scrutiny are $2N-b+c$, $2N-c+a$, respectively, and the first of them is the smallest, because $2c$ is less than $a + b$, and therefore $c-b$ is less than $a-c$. Thus A would be thrown out at the first scrutiny, and a second scrutiny would be held to decide between B and C, and B would win because a is positive. Thus the result is that which would follow from abandoning the proposition "A is better than B," which is affirmed by a majority of $2c$, whereas the result of the proposed method is that which would follow from abandoning the proposition

" B is better than C," which is affirmed by a majority of $2a$, which is smaller than the former majority.

There is, however, one point in favour of the modified method. The first scrutiny will at once give us the values of the three differences $b-c$, $c-a$, $a-b$. From these, of course, we cannot find a, b, c. In the modified method, however, a second scrutiny is always necessary, and this will at once give us the value of one of the three a, b, c. Having already found the three differences, we can at once find each of the quantities a, b, c, and hence we can ascertain if the result is demonstrably correct. Thus if the modified method be used, we can always ascertain, by a simple calculation, whether the result is perfectly satisfactory or not. The same remark applies to the proposed method in those cases in which two scrutinies are necessary.

Algebraic Analysis.

Before leaving the case in which there are three candidates only, it may be of interest to give a short algebraical analysis of the question. As before, let the compound symbol AB stand for the number of electors who put A first and B second, and similarly for other cases. Let us suppose, as is clearly possible, that six quantities, $a, b, c, \alpha, \beta, \gamma$, are found from the following equations:

$$\begin{array}{lll} AB=\beta+c & BC=\gamma+a & CA=\alpha+b \\ AC=\gamma-b & BA=\alpha-c & CB=\beta-a \end{array}$$

Also let us suppose that 2N denotes the whole number of electors, which is clearly equal to $2(\alpha+\beta+\gamma)$, then the states of the poll on the different modes of election which have been discussed are as shown in the following table:—

Analysis of Votes.	Single Vote.	Double.	Borda.	Condorcet.		
A $\begin{cases} AB=\beta+c \\ AC=\gamma-b \end{cases}$	$\beta+\gamma-b+c$	$N+\alpha$	$2N-b+c$	*	$N-b$	$N+c$
B $\begin{cases} BC=\gamma+a \\ BA=\alpha-c \end{cases}$	$\gamma+\alpha-c+a$	$N+\beta$	$2N-c+a$	$N+a$	*	$N-c$
C $\begin{cases} CA=\alpha+b \\ CB=\beta-a \end{cases}$	$\alpha+\beta-a+b$	$N+\gamma$	$2N-a+b$	$N-a$	$N+b$	*
$2N=2(\alpha+\beta+\gamma)$	2N	4N	6N	2N	2N	2N

In the first column is set out an analysis of the votes. In the second is the result of the poll on the single vote method. For instance, in the first line we have the quantity $\beta+\gamma-b+c$, which is the sum of AB and AC, *i.e.*, it denotes the number of electors who put A first. In the third column is the result of the poll on the double vote system, in which each elector has two votes. For instance, in the first line we have $N+\alpha$, or what is the same, $2\alpha+\beta+\gamma$, and this is equal to AB+AC+BA+CA, *i.e.*, it denotes the number of electors who put A first or second. In the fourth column is the result of the poll on Borda's method. For instance, in the first line we have $2N-b+c$, and this is equal to 2AB+2AC+BA+CA, as it ought to be. It is also seen at once that $2N-b+c$ is the sum of the two numbers in the first line in the second and third columns. This shows the truth of what was stated above, viz., that the poll on Borda's method is the aggregate of the polls on the single and double vote systems. In the fifth, sixth, and seventh columns, under the heading Condorcet, are set down the states of the poll on the supposition that each of the candidates, A, B, C, is excluded in turn. Thus, if A be supposed excluded for a moment, we have $N+a$ votes for B in preference to C, and consequently $N-a$ for C in preference to B. For $N+a$ is equal to AB+BC+BA, as it ought to be. Thus it is clear that $2a$ is the majority for B as against C, so that the letters a, b, c, have the same meaning as in the previous part of this paper. It is clear too, as has been proved before, that the number in any row in the column headed Borda, is the sum of the two numbers in the same row in the columns headed Condorcet.

The result of the method of election proposed in this paper depends solely upon the numbers a, b, c. The same is true of the method of Borda. On the other hand, the result of the double vote method depends solely on the values of α, β, γ. Consequently, whatever be the result of the proposed method or of Borda's method we can clearly construct cases in which the result of the double vote method shall be what we please. The same is true of the single vote method; for although the result of the single vote method depends upon a, b, c as well as upon α, β, γ, it is easy to see that we can choose α, β, γ so as to eliminate the effect of the quantities a, b, c, whatever may be the values of the latter. The results of the Venetian method and of Ware's method depend on the values of a, b, c as well as upon those of α, β, γ, so that although for given values of a, b, c we cannot bring about any result we please, still we can choose α, β, γ so as to bring about a result different from the true one. This, of course, is to be done by choosing α, β, γ, so that the best candidate is thrown out at the first scrutiny. We have already seen that this is possible.

It is clear that no one of the quantities $\beta + \gamma, \gamma + \alpha, \alpha + \beta$ can be negative. For we have $\beta + \gamma = \text{BC} + \text{CB}$, and BC, CB can neither of them be negative. Again, $\beta + \gamma = \text{N} - \alpha$; thus α cannot be greater than N. So also β, γ can neither of them exceed N. Since $\beta + \gamma$ cannot be negative, β and γ cannot both be negative; thus one only of the three α, β, γ can be negative. If α be negative it is clear that the numerical value cannot exceed N, for $\alpha + \beta$ cannot be negative, and β cannot exceed N. So for β and γ. Thus no one of the three α, β, γ can numerically exceed N, and one at most can be negative.

The limits between which a, b, c must lie are at once found from the consideration that AB, AC, &c., must none of them be negative. Thus $a + \gamma$, $\beta - a$ can neither of them be negative; thus a cannot be less than $-\gamma$ nor greater than β. Hence, *a fortiori*, no one of the three a, b, c, can be numerically greater than N. This last result is obvious from the fact that no one of the numbers in the columns headed "Condorcet" can be negative.

Formal demonstrations will now be given of a few results.

(i.) If any candidate have less than N votes on the double vote method, he ought not to be elected.

This has already been seen, but the following proof is given. Suppose A has less than N votes; then α must be negative, and therefore c must be negative and b positive. Thus A is worse than B, and also worse than C.

(ii.) Even if every elector put A in the first or second place it does not follow that A ought to be elected.

For if A has no third places we must have $\text{BC} = 0$ and $\text{CB} = 0$, thus $\alpha = \beta = -\gamma$. Suppose β positive and therefore γ negative. Then by preceding case C ought to go out and A or B ought to win as c is positive or negative. Now c may be negative so that B may win; for the only conditions with reference to c are that c must be greater than $-\beta$ and less than α, and as β is positive it is clear that c may be negative.

(iii.) It is impossible to arrive at the true result by merely counting the number of first places, the number of second places, and the number of third places for each candidate.

This result seems obvious enough after what has been given. It may, however, be formally proved as follows.

Let A_1, A_2, A_3 denote the numbers of first, second, and third places respectively for A, and let corresponding meanings be given to B_1, &c., C_1, &c. Then we have

$$A_1 = \beta + \gamma - b + c$$
$$A_2 = 2\alpha + b - c$$
$$A_3 = \beta + \gamma$$

with corresponding equations for B's and C's. We see at once from these equations that it is impossible to find a, b, c even if A_1, A_2, A_3, B_1, &c., be all given. We can, however, find α, β, γ and the three differences $b - c$, $c - a$, $a - b$, viz., the results are

$$\alpha = N - A_3,\ \beta = N - B_3,\ \gamma = N - C_3$$
$$b - c = A_3 - A_1,\ c - a = B_3 - B_1,\ a - b = C_3 - C_1,$$

where $2N = A_1 + B_1 + C_1 = A_3 + B_3 + C_3$ . . . . (i)
thus any five of the quantities A_1, B_1, C_1, A_3, B_3, C_3, may be chosen at pleasure; the sixth and N are then determined by the conditions (i) and A_2, B_2, C_2 are then given by the equations

$$A_2 = 2N - A_1 - A_3, \text{ \&c.}$$

(iv.) If there be a demonstrably correct result, say A better than B and B better than C, so that c, a, are positive and b negative, then if Ware's method be wrong, Venetian method is right, and if Venetian method be wrong, Ware's method is right.

For if Ware be wrong A must be lowest on the single vote method, and therefore we must have

$$\alpha + \beta - a + b > \beta + \gamma - b + c$$
$$\text{or } \alpha > \gamma + a + c - 2b$$

i.e., *a fortiori* $\alpha > \gamma$ because a, c are positive and b negative. Thus A cannot be lowest on double vote method, so that A will win on the Venetian method. Again, if Venetian be wrong, A must be lowest on double vote method, and therefore we must have $\gamma > \alpha$ and therefore $\beta + \gamma - b + c > \alpha + \beta - a + b$ because a, c are positive and b negative. Thus A cannot be lowest on single vote method, so that A will win on Ware's method.

(v.) If we agree to accept the proposed method as correct in all cases, then the conclusions of the last proposition will be true in all cases.

For, in the demonstration of the last proposition, the essential condition is that $a + c - 2b$ should be positive. Now, if we suppose as before that the accepted result is A better than B, and B better than C, we must have a, b, c all positive and b the smallest of the three, so that it is clear that $a + c - 2b$ is positive.

Comparing then Ware's method with the Venetian method, we see that both may be right, or one wrong and one right, but both cannot be wrong; so that, if these two methods agree, the result cannot be shown to be wrong. If, however, they do not agree, we cannot tell which is right without in effect having recourse to the proposed method.

(vi.) If $a = b = c$, single and double vote methods give different results.

For A's scores on the two methods will be respectively $N - \alpha$ and $N + \alpha$. Thus, if $\gamma > \beta > \alpha$, the candidates are in the order A, B, C on the single vote method, and in the order C, B, A on the double vote method. In this case Borda's method leads to a tie, and consequently the proposed method also. Ware elects A or B as c is positive or negative, and Venetian method elects C or B as a is negative or positive. Thus, in this case, Ware and Venetian method give different results.

(vii.) If $\alpha = \beta = \gamma$, double vote method, and therefore also Venetian method, gives a tie; single vote method and Borda lead to same result; but Ware and proposed method will not necessarily lead to same result. If one only of the three, $b - c$, $c - a$, $a - b$, be negative, Ware and proposed method will lead to same result; but if two be negative the results may or may not agree.

(viii.) If AB = AC, BC = BA, CA = CB, all the methods will give the same result, and that result will be demonstrably correct.

This is the case in which the strong supporters of each candidate are equally divided as to the merits of the remaining candidates. In this case we have

$$a = \beta - \gamma, b = \gamma - \alpha, c = \alpha - \beta,$$

and A's scores on the single, double, and Borda's method are respectively 2α, $N + \alpha$, $N + 3\alpha$. Thus, if $\alpha > \beta > \gamma$, it is obvious that each of these methods will put A first, B second, and C third, and it is clear that this result is correct, for a, c are positive and b negative. It is at once seen that all the methods which have been discussed will lead to the same result in this case.

(ix.) If we suppose that

$$\alpha = \frac{N}{3} + p\,(b - c),\ \beta = \frac{N}{3} + p\,(c - a),\ \gamma = \frac{N}{3} + p\,(a - b),$$

then A's scores on the single, double, and Borda methods will be respectively

$$\frac{2N}{3} - (p + 1)\,(b - c),\ \frac{4N}{3} + p\,(b - c),\ 2N - (b - c).$$

Hence we see that

If $p < o$ and > -1, the results of all three methods will be the same.

If $p < -1$, double and Borda methods will give the same result, which will be opposite to that of single method.

If $p > o$, single and Borda methods will give the same result, which will be opposite to that of double method.

Thus, if $p > o$ or < -1, single and double methods will give different results. If we suppose that b, c are positive and a negative, and also that $2b < c + a$, then it may be shown that these different results will both be wrong.

Cases of More than Three Candidates.

It remains now to state and examine the method proposed for the case in which there are more than three candidates.

A series of scrutinies are held on Borda's system of voting, and all candidates who on any scrutiny have not more than the average number of votes polled on that scrutiny are excluded. As many scrutinies are held as may be necessary to exclude all but one of the candidates, and the candidate who remains uneliminated is elected.

The method proposed cannot lead to the rejection of any candidate who is in the opinion of a majority of the electors better than each of the other candidates, nor can it lead to the election of a candidate who is in the opinion of a majority worse than each of the other candidates. These results are an extension of those already proved for the case of three candidates, and they may be proved as follows :—
As before, let 2N be the number of electors, and let the candidates be denoted by A, B, C, D, &c. Let the compound symbol ab denote the number of electors who consider A better than B, and let corresponding meanings be given to ac, ad, ba, &c., so that ba will denote the number of electors who prefer B to A, and we shall, therefore, have $ab + ba$

= 2N. Now suppose that at the commencement of any scrutiny the unexcluded candidates are A, B, C, ... P, then the score of A on that scrutiny will be

$$ab + ac + ad + \ . \ . \ . \ . \ + ap.$$

For suppose that there are n unexcluded candidates, and consider a voting paper on which A now occupies the rth place. For this A gets $n - r$ votes. Now on this paper A stands before $n - r$ other candidates. Thus the $n - r$ votes which A receives may be considered each as due to the fact that A stands before one of the following $n - r$ candidates. Thus we see that on any one voting paper A receives one vote for every candidate placed after him. Summing up for all the voting papers, we see that A receives one vote for each candidate placed after him on each paper. Now ab denotes the number of times B is placed after A on all the papers, and similarly for ac, ad, &c. Thus it is clear that A's score is

$$ab + ac + ad + \ . \ . \ . \ . \ + ap.$$

This result was stated by Borda,* but proved only for the case of three candidates.

The whole number of votes polled is

$$2N\ (1 + 2 + 3 + 4 \ldots + n{-}1)$$

or $Nn\,(n{-}1)$. Thus the average polled by all the candidates is $N(n{-}1)$. Now let us suppose that there is a majority for A as against each of the other candidates, then each of the $n{-}1$ numbers ab, ac, ad, ... ap is greater than N; thus the sum of these numbers, which is equal to A's score, is necessarily greater than $(n{-}1)$ N, that is, greater than the average score. Thus A will be above the average on every scrutiny, so that he must win on the proposed method.

Next, let us suppose that there is a majority for each of the other candidates against A. Then each of the numbers ab, ac, . . . ap is less than N, and therefore their sum, which is equal to A's score, is less than $(n{-}1)$ N, that is, less than the average score. Thus A is below the average, and will, therefore, be excluded at the first scrutiny.

The results which have just been proved are particular cases of a more general theorem, which may be enunciated as follows:—

If the candidates can be divided into two groups, such that each candidate in the first group is, in the opinion of a

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* *Mémoires de l'Académie Royal des Sciences*, 1781, p. 663.

majority of the electors, better than each of the candidates in the second group, then the proposed method cannot lead to the election of a candidate of the second group.

The results which have just been proved are obtained from the above by supposing, first, that the first group contains one candidate, and the second group all the rest; and second, that the first group contains all but one of the candidates, and the second group the remaining candidate.

Let the first group consist of the l candidates, A, B, C, &c., and let the second group consist of the m candidates, P, Q, R, &c., and let $l + m = n$, so that n is the whole number of candidates. Because each of the candidates A, B, C, &c., is better than each of the candidates P, Q, R, &c., each of the numbers ap, aq, ar, &c. . . . bp, bq, &c. . . . &c., is greater than N. Now the scores of A, B, C, D, &c., at the first scrutiny are respectively

$$
\begin{array}{llllllllll}
* & ab + ac + ad + \&c. & \ldots\ldots & + ap + aq + ar + \&c. \\
ba & * + bc + bd + \&c. & \ldots\ldots & + bp + bq + br + \&c. \\
ca + cb & * + cd + \&c. & \ldots\ldots & + cp + cq + cr + \&c. \\
da + db + dc & * + \&c. & \ldots\ldots & + dp + dq + dr + \&c. \\
\&c. & \&c. & & \&c. \quad \&c.
\end{array}
$$

If we add together all these numbers, we shall get the sum of the scores of A, B, C, D, &c. Now the numbers in the first l columns can be arranged in pairs, such as ab, ba, and $ab + ba = 2\text{N}$, and then are $\frac{1}{2}\,l\,(l - 1)$, of these pairs; thus, the sum of the first l columns is $\text{N}l(l - 1)$. Again, the numbers in the last m columns are each greater than N, and there are lm of these numbers; thus, the sum of the last m columns is greater than $\text{N}lm$. Thus, the sum of all the numbers is greater than $\text{N}l(l - 1) + \text{N}lm$; that is, than $\text{N}l(l + m - 1)$; that is, greater than $\text{N}l(n - 1)$. Thus the sum of the scores of the l candidates of the first group is greater than $\text{N}l(n - 1)$. Hence the average score of the candidates of the first group is greater than $\text{N}(n - 1)$. Hence the candidates of the first group cannot all be rejected at the first scrutiny. By the same reasoning it follows that those of the first group who survive cannot all be rejected at the second scrutiny; and so on. Thus some candidate of the first group must win on the proposed method; or, in other words, no candidate of the second group can be elected.

If the candidates can be divided into two groups in the manner just indicated, it is quite clear that no candidate of the second group ought to win. At the same time, whichever of the candidates of the first group wins, the result cannot be shown to be erroneous. If the division into groups can be made in more than one way it is clear that the last statement applies only to the smallest group of the first kind. Now in the proposed method the successful candidate must belong to the smallest group of the first kind. Hence then it is clear that the result of the proposed method cannot be shown to be erroneous in any case.

It is clear that no candidate can have more than N $(2n - 2)$ votes on any scrutiny, n being as before the number of unexcluded candidates at the commencement of that scrutiny. For a candidate could only have this number by obtaining the first place on each voting paper.

Again, if any candidate obtain N $(2n - 3)$ votes on any scrutiny, there is an absolute majority in his favour, so that we can at once elect him. For if a candidate were not put first on half the papers, he could not have so many as $(n - 1)$ N + $(n - 2)$ N votes, this being the number he would have if he were put first on one half of the papers and second on the other half. It is clear, too, that if any candidate has less than N votes there is an absolute majority against him; for if a candidate has less than N votes, he must be last on at least half of the papers. These results are not of much use except in the case of three candidates; for if there be more than three candidates, it is only in cases of remarkable unanimity that a candidate can have so many as N $(2n - 3)$, or so few as N votes. If, however, there be three candidates only, the above results may be stated as follows:—The average is 2N; the largest number of votes any one candidate can have is 4N; if any candidate has 3N votes, or more, there is an absolute majority for him, and we can elect him at once, no matter whether the second candidate is above the average or not; if any candidate has less than N votes, there is an absolute majority against him, so that the result of the proposed method is demonstrably correct.

In the case of any number of candidates it will sometimes save a great deal of trouble if we first examine if there be an absolute majority for or against any candidate. This is easily done, and the results arrived at in the inquiry will be of use in carrying out the proposed method, if such be found necessary. For let A_1, A_2 . . . A_n denote the numbers of papers on which A occupies the first, the second . . . the last or nth place, and let similar meanings be given to B_1, B_2, &c., C_1, &c. If A_1 be greater than N, there is an absolute majority for A, and we may at once elect him. If A_n be greater than N, there is an absolute majority against A, and we may at once exclude him. If neither of these results hold good for any candidate, we must use the proposed method in its general form. Now A's score on that method is

$$(n-1)A_1 + (n-2)A_2 + \ldots + (n-r)A_r + \ldots + A_{n-1}.$$

Thus to find A's score we must find $A_2, A_3 \ldots A_{n-1}$. Now to find these it is not necessary to count all the votes for A. For we have

$$A_1 + A_2 + A_3 + \ldots + A_n = 2N,$$

and A_1, A_n having been already found, we see that it is sufficient to calculate any $n-3$ of the $n-2$ quantities, $A_2, A_3 \ldots A_{n-1}$, and the remaining one can then be found from the above equation.

It would, however, in practice be better to calculate each of the n quantities, $A_1, A_2 \ldots A_n$, and then to use the above equation as a test of the accuracy of the counting of the votes. Similar remarks apply to the numbers $B_1, B_2 \ldots B_n$, $C_1, C_2 \ldots C_n$, &c.

We have also n equations of the former

$$A_r + B_r + C_r + \ldots = 2N$$

where r may have any one of the values $1, 2, 3 \ldots n$. This gives us n independent tests of the accuracy of the enumeration of the votes. In fact, if we arrange the n^2 quantities, $A_1, A_2 \ldots A_n$, B_1, &c., in the form of a square array

A_1, A_2, A_3, &c.
B_1, B_2, B_3, &c.
C_1, C_2, C_3, &c.
&c., &c., &c.

the sum of every row and of every column ought to be 2N, so that we have altogether $2n-1$ independent tests of the accuracy of the enumeration of the votes.

The proposed method is not so laborious as might appear at first sight. The number of scrutinies will not usually be large; for we may reasonably expect to halve the number of candidates at each scrutiny. At each scrutiny we reject all who are not above the average. Now in the long run we may expect to find as many below as above the average on a poll. Thus, if there be eight candidates we should not, on the average, require more than three scrutinies. There can be no doubt, however, that the method would be tedious if the number of electors were very large, unless the number of candidates was very small indeed. In cases where the number of electors is large Ware's method has great practical advantages; for in that method we only require to count one vote for each paper examined at each scrutiny, and at every scrutiny except the first the number of papers to be examined is but a small fraction of the whole number of papers.

Condorcet's Theoretical Method.

A method of election was described by Condorcet in 1785, but on account of its complexity it was never proposed for actual use. On this account, and in order to distinguish it from Condorcet's practical method (which has been already described), I propose to call it Condorcet's theoretical method. This method is described by its author in the following terms:—

"There exists but one rigorous method of ascertaining the wish of the majority in an election. It consists in taking a vote on the respective merits of all the candidates compared two and two. This can be deduced from the lists upon which each elector has written their names in order of merit."

"But, in the first place, this method is very long. If there are only twenty candidates, in order to compare them two and two we must examine the votes given upon one hundred and ninety propositions, and upon seven hundred and eighty propositions if there are forty candidates. Often, indeed, the result will not be as satisfactory as we could wish, for it may happen that no candidate may be declared by the majority to be superior to all the others; and then we are obliged to prefer the one who is alone judged superior to a larger number; and amongst those who are judged superior to an equal number of candidates, the one who is either judged superior by a greater majority or inferior by a smaller. But cases present themselves where this preference is difficult to determine. The general rules are complicated and embarrassing in application." (*Œuvres de Condorcet*, vol. xv., pp. 28, 29.)

By this method Condorcet showed that the single vote method and the methods of Ware and Borda are erroneous. I do not think however, that any one has hitherto noticed that Borda's method may lead to the rejection of a candidate who has an absolute majority of the electors in his favour as against all comers. It has also been shown above by the help of this theoretical method that Condorcet's practical method is erroneous. Thus it will be seen that the theoretical method is of use in testing the accuracy of other methods. From the description which has been given above, however, it is not clear what the result of the theoretical method is, even in the simplest cases, when discordant propositions are affirmed, for if there be three candidates only, and with the notation already used, we have $a = 1$, $b = 2$, $c = 3$, each candidate is superior to one other candidate, and A is superior by most, whilst C is inferior by least. Thus, according to the above description, it is not certain which of the two, A or C, wins. In another passage, however,* Condorcet explains how he deals with any case of three candidates, and the process he adopts in the case of inconsistent propositions is to reject the one affirmed by the smallest majority. This is exactly the process which has been described above, and which was shown to be in accordance with the method proposed. Thus it is clear that in the case of three candidates the result of the proposed method will always be the same as that of Condorcet's theoretical method.

The general rules for the case of any number of candidates as given by Condorcet† are stated so briefly as to be hardly intelligible. Moreover, it is not easy to reconcile these rules with the statements made in the passage quoted above, and as no examples are given it is quite hopeless to find out what Condorcet meant.

Comparison of Proposed Method with Condorcet's Theoretical Method.

Comparing the method proposed in this paper with Condorcet's theoretical method, we see that, so far as any conclusion can be drawn from the votes of the electors the two methods always agree. In those cases in which no conclusion can be drawn from the votes the results of the two methods will not always be the same. It is equally impossible to prove either of these results wrong. Con-

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* *Œuvres*, vol. xiii., p. 259.

† *Essai sur l'application de l'analyse à la probabilité des decisions rendues à la pluralité des voix*, pp. 125, 126.

dorcet's method always shows whether the result is incapable of being proved wrong or not, but the proposed method gives us no information on this point. With the proposed method, however, there is no difficulty in arriving at the result in any case, whereas Condorcet's method is, by his own admission, so complicated as to be quite impracticable. Condorcet returns the candidate who is superior to the largest number of other candidates, without reference either to the numbers of votes by which the candidate is superior to those other candidates, or to the number of votes by which the candidate is inferior to the remaining candidates. Now in the proposed method both these elements are taken into consideration. Each candidate is, in fact, credited with the numbers of votes by which he beats all candidates he is superior to, and is debited with the numbers of votes by which he is beaten by all candidates he is inferior to. All candidates who have the balance against them are excluded, and the election then proceeds as if the remaining candidates were the only ones eligible.

It seems clear, then, that the proposed method is quite as rigorous as that of Condorcet. It gives the same result as Condorcet's in the case of three candidates, and it agrees therewith in all cases so far as any conclusion can be drawn from the votes. In those cases in which no valid conclusion can be drawn from the votes the two methods may not agree, and although nothing can be proved one way or another in these cases, the principles on which the proposed method is founded seem quite as sound as those of Condorcet's method. The proposed method has, however, great practical advantages over Condorcet's method, for the process of arriving at the result is the same in all cases; the operations throughout are of the same kind. The number of numerical results which have to be arrived at is much smaller than in Condorcet's method. For instance, if there be sixteen candidates we should expect, in the long run, to have four scrutinies, involving thirty numerical results, whereas Condorcet's method would require the computation of the votes for and against one hundred and twenty different propositions. When the numerical results are arrived at there is not the slightest difficulty in applying them, whereas in Condorcet's method the rules are very complicated. It may be claimed, then, that the proposed method has all the rigour of Condorcet's method and none of its practical difficulties.

Incomplete Voting Papers.

There is a point of some practical importance to be considered in connection with the proposed method. If the number of candidates was large, some of the electors might not be able to make out a complete list of the candidates in order of preference. We have then to consider how voting papers, on which the names are not all marked in order of preference, are to be dealt with. Such a voting paper may be called incomplete. In order to examine this question, let us first suppose, for the sake of simplicity, that there are only three candidates A, B, C, and that the votes tendered are of one of the forms AB, BA, C, that is to say, that all the electors who put A first put B second, that all who put B first put A second, and that all who vote for C mark no second name. In accordance with the proposed method, for each paper of the form AB, two votes would be given to A and one to B; and for each paper of the form BA, two votes would be given to B and one to A. The question arises, however: is a paper of the form C, that is, a plumper for C, to be counted as one vote or as two votes for C? If it be counted as one vote only, it is clear that C might be defeated even if he had an absolute majority of first votes in his favour. For if we suppose $AB = BA = a$, and $C = c$, it is clear that the scores of A and B will each be equal to $3a$, and that of C to c. Thus C will be defeated unless $c > 3a$; but if $c > 2a$, there is an absolute majority for C. Hence, then, we may be led into error if each plumper for C be counted as one vote only. If, on the other hand, a plumper be counted as two votes, it is clear that C might win even if there were an absolute majority against him. For the score of C will now be $2c$, and C will win if $2c > 3a$. But if $2c < 4a$, there is an absolute majority against C. Thus we should also be led into error if each plumper be counted as two votes. If, however, we agree to count a plumper as three halves of a vote, neither of these errors could occur. This course is readily seen to be the proper one in any case of three candidates, for it clearly amounts to assuming that the electors who plump for C are equally divided as to the merits of A and B. For if a^1, b^1, c^1 denote the numbers of plumpers for A, B, C respectively, and if we agree to consider all the electors who plump for A as being equally divided as to the merits of B and C, the effect of the a^1 plumpers for A would be to give $2\,a^1$ votes to A, and $\frac{1}{2}\,a^1$ each to B and C. Now, as we are only concerned with the differences of the totals polled for each candidate, we see that the result of the first scrutiny will be the same if we take away $\frac{1}{2}\ a^1$ votes from each candidate. Thus the result will come out the same if we give $\frac{3}{2}\ a^1$ votes to A, and none to B or C, so far as the plumpers are concerned. Similarly the result will not be altered if the b^1 plumpers for B be counted, as $\frac{3}{2}\ b^1$ votes for B and nothing for C and A, and so for C's plumpers. Thus the final result will be in accordance with the views of the electors, if each plumper be reckoned as three halves of a vote

The assumption that the electors who plump for A are equally divided as to the merits of B and C, appears to be perfectly legitimate, for the electors have an opportunity of stating their preference, if they have one, and as they have, in the case supposed, declined to express any, it may be fairly concluded that they have none.

At the final scrutiny (if held), all plumpers for the candidate who has been rejected will have no effect.

If there be more than three candidates, and incomplete papers are presented, we should have to make a similar assumption, viz., that in all cases where the preference is not fully expressed, the elector has no preference as regards the candidates whom he has omitted to mark on his voting paper. Thus, for example, if there be four candidates, A, B, C, D, a plumper for A ought to count as two votes for A and none for B, C, D. Again, a voting paper on which A is marked first and B second, and on which no other names are marked, ought to count as two and ahalf votes for A and three halves of a vote for B. If there be more than four candidates the varieties of incomplete papers would be more numerous, and the weights to be allotted to each would be given by more complicated rules. Practically it would be best to count one vote for each plumper in the case in which only one candidate is marked on a voting paper; one for the last, and two for the first, when two names only are marked on a voting paper; one for the last, two for the next, and three for the first, when three names only are marked on a voting paper, and so on, giving in all cases one vote to the candidate marked lowest on any paper, and as many votes to the candidate marked first as there are names marked on the paper. By this means the rules for computing the votes would be the same in all cases and at all scrutinies. We have seen, it is true, that this method may lead to error. The error has the effect of decreasing the votes for the candidates who are marked on any incomplete paper, and it arises solely in consequence of the papers being incomplete. Thus, if the electors do not fully express their preference, the effect is to injure the chances of their favourite candidates. If, then, we adopt the plan just described for incomplete papers, it will be sufficiently simple for practical purposes, and its use will tend to elicit from electors a full statement of their various preferences.

Cases of Equality.

No case of equality can occur in the proposed method except when all the candidates poll exactly the same number of votes on a scrutiny, for if less than the whole number of candidates have the same number of votes in any scrutiny, if that common number be not greater than the average, all the equal candidates are excluded. If it be greater, no one of them is excluded; and in either case we pass on to another scrutiny.

If on any scrutiny all the candidates poll exactly the same number of votes, that number, of course, must be the average, and it is necessary that some one should have a casting vote. If it is thought proper to do so, one casting vote can then be made to settle the election, by allowing the casting vote to decide who is to win. But if it is thought that this is giving too much weight to the casting vote, then we may permit the casting vote to decide who is to be excluded, and then proceed to a fresh scrutiny between the remaining candidates. It will be observed, however, that the chance of a casting vote being required at any scrutiny except the last, when only two candidates remain, is very minute, seeing that it depends upon all the candidates polling exactly the same number of votes on a scrutiny.

Statement of Method.

It is convenient to give here a formal statement of the method which it is proposed should be used when incomplete papers are presented.

Each elector is furnished with a list of the candidates in alphabetical order, upon which he indicates his preference amongst the candidates by placing the figure one opposite the name of the candidate of his first choice, the figure two opposite the name of the next in order of preference, the figure three opposite the next, and so on, to as many names as he pleases.

It is, of course, unnecessary to mark all the names; it is sufficient to mark all but one. In what follows, if all the names be marked, it is unnecessary to pay any attention to the name marked lowest in order of preference.

The mode of dealing with the papers is as follows:—For the lowest candidate marked on any paper count one vote, for the next lowest two votes, for the next three votes, and so on, till the highest is reached, who is to receive as many votes as there are names marked on the paper. The total number of votes for each candidate is then to be ascertained; and thence the average number polled. All candidates who have not polled above the average are then to be excluded. If more than one candidate be above the average, then another scrutiny must be held as between all such candidates.

In counting up the votes for the second, or any subsequent scrutiny, no attention must be paid to the names of any candidates who have been excluded.

As many scrutinies as may be necessary must be held, so that finally all the candidates but one are excluded, and the last remaining candidate is elected.

Practical Details.

In order to show precisely the amount of labour which would be required to carry out the proposed method, it may be as well to state what appears to be the most convenient way of making up the result. As in the ordinary methods, it would be necessary to have a poll-book in which to keep a tally of the votes. In this book the names of the candidates should be printed from the same type as the ballot papers are printed from. Each ballot paper should be placed with the names in a line with the corresponding names in the poll book, and the numbers written opposite to the names on each ballot paper should then be copied into the successive columns of the poll-book. In this way the risk of error in transcription would be exceedingly small, and any error which was made would be at once detected on placing the ballot paper side by side with the column in which its numbers are recorded. When this is done many of the columns would contain vacant spaces. In every vacant space in each column write a number greater by unity than the largest number copied from the voting paper into that column. After doing this add up the figures in each row; then find the mean or average of the sums. Every candidate who has a sum *equal* to or *greater* than the average is to be excluded. A little consideration will show that this process will give the same result as the method described above. When the papers have once been copied into the poll-book as just described, all subsequent scrutinies that may be necessary can be conducted without handling the voting papers again.

Cases of Bracketing.

Under the head of "Incomplete Voting Papers" we have considered a case in which an elector does not fully express his preference. There is, however, another way in which an elector may fail to fully express his preference. An elector may have no difficulty in putting a number of candidates at the bottom of his list, and yet he may have considerable difficulty in deciding as to the precise order in which to place the candidates at the top end of his list. In such a case an elector might wish to put two or more candidates equal for the first, second, or some other place on his list. This may be called a case of bracketing. It is now to be shown that this system of bracketing can be permitted without causing any difficulty in the practical working of the system. Let us suppose that an elector brackets m_1 candidates for the first place, m_2 for the second place, and so on; so that $m_1 + m_2 + m_3 + \ldots = n$, the case in which one candidate only is put in the r^{th} place being provided for by supposing $m_r = 1$. Then in the poll-book already described enter the number one for each of the m_1 candidates in the first bracket, the number two for each of the m^2 candidates in the second bracket, the number three for each of the m_3 candidates in third bracket, and so on. Suppose, for example, that there are seven candidates, A, B, C, D, E, F, G, and that an elector wishes to bracket B, E for the first place and A, D, F for the second place, and that he does not care to say anything about C, G. Then he would mark his paper as shown in the margin. As nothing is said about C, G, we should consider them as bracketed for the third or last place. Now in order to record this vote in the poll-book it is merely necessary, as before, to copy the column of numbers on the

2A
1B
C
2D
1E
2F
G

voting paper into a column of the poll-book, taking care to write in two 3's in the two blank spaces opposite the names C, G. After copying the numbers from each ballot-paper into the poll-book and filling up all the vacant spaces, we should add up the different rows and proceed exactly as before to ascertain the result of the election. Thus it is clear that the method of dealing with the papers is exactly the same no matter how many or how few names be marked, nor how many are bracketed in the various brackets, and that there is very little risk of error in the process.

If this system of bracketing be permitted we at once get rid of the objection that the proposed method could only be used in a highly educated constituency, because it is only highly educated electors who can possibly arrange the candidates in order of merit. The method can easily be used by the most ill-informed electors. In fact, an elector, if he so pleased, could vote in exactly the same manner as in elections under the common "majority" system of voting in cases where there are several candidates—that is, the elector may simply cross out the names of all the candidates he objects to and leave uncancelled as many names as he pleases. In such a case the uncancelled names would all be considered bracketed for the first place, and the cancelled ones as bracketed for the second or last place.

Exactly as in the case of incomplete papers previously discussed, it is easy to see that the method just given is not strictly accurate, that the strictly accurate method would be too complicated for practical purposes, and that the error has the effect of decreasing the chances of success of the favourite candidates of the elector who resorts to bracketing. In fact it may be shown that the numbers which ought strictly to be entered in the poll-book for the candidates in the successive brackets are

$$0, \frac{m_1}{2} + \frac{m_2}{2}, \quad \frac{m_1}{2} + m_2 + \frac{m_3}{2}, \dots . \qquad (1)$$

$$\frac{m_1}{2} + m_2 + m_3 + \dots + m_{r-1} + \frac{m_r}{2}, \text{ \&c.}$$

Now the plan just described comes to the same thing in the end as entering instead of these the numbers

$$0, \quad 1, \quad 2, \quad \dots . \quad (r-1), \text{\&c.} \qquad (2)$$

and as no one of the numbers m_1, m_2, m_3, &c., can be less than unity, it is easy to see that no one of the numbers (2) can be greater than the corresponding one of the numbers (1), that when no bracketing occurs the two sets (1), (2), are the same, and that the two sets agree until the first bracket is reached. Now observe that the numbers entered in the poll-book are in reality negative votes, and we see at once that the moment an elector begins to bracket, he diminishes the influence of his own vote on the result of the election, and also decreases the chances of success of all candidates who on his own list are placed higher than the bracket. Each additional bracket will have precisely the same effects. Thus it is clear that the effect of the proposed method will be to discourage the practice of bracketing. If we do not wish to discourage this practice we must resort to the accurate method, and use the numbers (1) instead of (2). This is not very difficult to do, but as it introduces a new method for the bracketed votes, it would give considerable extra trouble to the officers who make up the poll-books. The most convenient way of stating the accurate method would be as follows:—For each first place count one negative vote, for each second place count in addition $\frac{1}{2}(m_1 + m^2)$ negative votes, for each third place count in addition to the last $\frac{1}{2}(m_2 + m_3)$ negative votes, for each fourth place count in addition to the last $\frac{1}{2}(m_3 + m_4)$ negative votes, and so on. As before remarked, the numbers for the successive places would be the natural numbers 1, 2, 3, 4, &c., until a bracket was arrived at. When brackets do occur we shall in general have to deal with half-votes, but no smaller fraction could occur.

Another Method for Cases of Bracketing.

Another plan might also be adopted for dealing with cases of bracketing. It is as follows. For each candidate in the first place count one vote; for each candidate in the second place count $m_1 + 1$ votes; for each candidate in the third place count $m_1 + m_2 + 1$ votes; for each candidate in the fourth place count $m_1 + m_2 + m_3 + 1$ votes; and so on. The plan now under consideration comes to the same thing as counting for the successive places the numbers $0, m_1, m_1 + m_2, \ldots \ldots m_1 + m_2 + \ldots + m_{r-1}$, &c. instead of the proper numbers (1). Thus the errors for the successive places are

$$0, \quad \frac{m_1 - m_2}{2}, \quad \frac{m_1 - m_3}{2}, \quad \ldots \ldots \quad \frac{m_1 - m_r}{2}, \quad \&c.$$

Hence we see that

(i.) If the same number of candidates be bracketed for each place, the plan is accurate.

(ii.) If m_1 be greater than each of the numbers m_2, m_3, &c., that is, if more candidates are bracketed for the first place than for any other place—then the errors will be all positive, and the effect will be to give the elector more negative votes than he is entitled to, and, consequently, to increase unduly the chances of the candidates bracketed for the first place.

(iii.) If m_1 be less than each of the numbers m_2, m_3, &c.—that is, if fewer candidates are bracketed for the first place than for any other place—then the errors will be all negative, and the effect will be to give the elector fewer negative votes than he is entitled to, and, consequently, to decrease unduly the chances of the candidates placed at the top end of the elector's list.

(iv.) If m_1 be equal to the mean of the numbers m_2, m_3, &c., the elector will have just as many votes as he ought to have, but he will give more negative votes to some candidates and less to others than they ought to have.

(v.) If m_1 be not equal to the mean, then the elector will have more or less votes than he is entitled to, according as m_1 is greater or less than the mean.

The results just given apply to each scrutiny; but the numbers m_1, m_2, m_3, &c., will generally be altered at each scrutiny. Thus it is in general impossible to tell at the commencement of an election what will be the effect of different modes of bracketing. Sometimes the elector will get too many votes, sometimes too few. At some scrutinies the candidates at the top end of his list will get too many votes, and at others those at the lower end will get too many votes.

If there be one candidate only in each place except the last, or, in other words, if the only bracket be for the last place, we have the case of incomplete papers discussed above. In this case the plan just described, and the method adopted above, agree; and the effect is, as has already been pointed out, to give the elector too few votes; and this would be the case at each scrutiny, until all but one of the candidates in the bracket are rejected.

If, however, an elector bracket a number of candidates for the first place and arrange all the rest in order of merit, he would get more votes than he is really entitled to and this would be the case at each scrutiny until all but one of the candidates in the bracket are rejected. Electors would very soon find this out. Each elector would ask himself the question, How must I vote in order to get as much electoral power as possible; and the answer would very soon be seen to be—I must bracket all the candidates I don't object to for the first place, and I must arrange all the rest in numerical order. Thus, instead of encouraging the electors to arrange all the candidates in order of merit, this plan would lead to each elector trying all he could to defeat objectionable candidates without expressing any opinion as to the relative merits of those he does not object to.

Rule for Forfeit.

If the method which is proposed were adopted for parliamentary elections, it is clear that the number of candidates would be very much greater than at present. In order to prevent the number becoming so great as to make the election unmanageable, it is necessary to provide some method for keeping the number of candidates within reasonable bounds. Such a provision exists for the method now in use. It is that any candidate who fails to obtain one-fifth of the number of votes polled by the lowest successful candidate forfeits the deposit which he has lodged with the returning-officer. This rule is, of course, purely empirical, and we must fix upon some rule of the same kind for the proposed method. I will first state a rule for the method as first described—*i.e.*, when positive votes are used. This rule is as follows :—

If at the first scrutiny any candidate has a number of votes which is less than half the number of votes polled by the candidate who is highest at the first scrutiny, he shall forfeit his deposit.

In the mode of applying the method which is most convenient in practice this rule takes a somewhat more complicated form, as follows :—

If at the first scrutiny any candidate has a number of votes which, together with a number which is equal to half the number of electors, exceeds half the number of votes polled by the candidate who has the smallest number of votes by the average for the first scrutiny, he shall forfeit his deposit.

Case of Several Vacancies.

Hitherto we have supposed that there is only one vacancy to be filled. If there be more than one vacancy we have to settle a most important question before we can consider what method of election is to be adopted. This question is as follows:—Is the majority of the electors to fill the whole of the vacancies, or are the successful candidates supposed to represent the different sections of the electoral body? The first case is that of the selection by a board of governors of officers to fill various offices. No question of representation is involved, but simply the selection of those persons most fit, in the opinion of the whole electoral body, to fill the different offices. The second case is that of the selection of representatives by a large electoral body. In the first case the whole electoral body has to decide for itself once for all, and the majority must rule. In the second case the electoral body has to select representatives, who are to decide and act for it in a variety of matters; and in order that the decision may be as far as possible in accordance with the views of the electoral body, it is necessary that all the different sections thereof should, as far as possible, be represented.

In the first case there is only one method of arriving at the correct result, and the method is to fill each vacancy separately. Thus one person must be elected by the method described above; then by means of the same set of voting papers we must proceed to a second election for the next vacancy, and so on till all the vacancies are filled. After each vacancy is filled we must of course suppose the name of the successful candidate erased from all the voting papers.

The second case—that of the selection of representatives—has been considered by Hare, Andræ, and other writers. It is not proposed here to discuss this question beyond pointing out that it follows from the principles which have been established in this paper that the process of "elimination" which has been adopted by all the exponents of Hare's system is not satisfactory.

Art. XX.—*The Oceanic Languages Shemitic: a Discovery.*

By Rev. D. Macdonald.

[Read 16th November, 1882.]

(A list of abbreviations will be found at the end.)

Under the name Oceanic I do not include the Australian languages, for though there are undoubtedly Oceanic words in the Australian vocabularies, the grammar seems essentially different. Cardwell, in his *Dravidian Grammar* ("Introduction," p. 53) says:—The grammatical structure of the Australian dialects exhibits general agreement with the languages of the Scythian group. In the use of post-positions instead of prepositions; in the use of two forms of the first person plural, one inclusive of the party addressed, the other exclusive; in the formation of inceptive, causative, and reflective verbs, by the addition of certain syllables to the root; and generally in the agglutinative structure of words, and in the position of words in a sentence, the dialects of Australia resemble the Dravidian, as also the Turkish, the Mongolian, and other Scythian languages, and in the same particulars, with one or two exceptions, they differ essentially from the dialects which are called Polynesian." "The Malagasi," says Latham, "is essentially a Malay language. . . . Of African elements in the Malagasi none have been pointed out, . . . which, as a phenomenon in the distribution and dispersion of languages, is the most remarkable on all the earth's surface" (Latham, *Comp. Phil.*, p. 294). Oceanic stands out quite distinct from the languages of America. This was known as early as the time of Captain Cook's discoveries. According to Crawford (*Dissertation*, p. 285), in 1000 words of Javanese there are 110 of Sanscrit, but 50 in the same number of Malay, and none in Polynesia; yet this Sanscrit was in Javanese and Malay probably before the Christian era, and introduced with Hinduism. Mohammedanism has been introduced along with modern Arabic, of which there are 52 words in 1000 of Malay, and none in Polynesia. The same great authority on this subject (*Dissertation*, p. 287), speaking of the languages of South-eastern Asia generally, the continental languages nearest geographically to Malaysia, says:—"The languages of these countries are generally monosyllabic and the Malayan polysyllabic. They refuse to amalgamate or intermix, of which we have some striking proofs. The Chinese have been settled in great numbers throughout the Archipelago for many centuries, and intermarried with the native inhabitants, yet there are certainly not a dozen words of any Chinese language in Malay, Javanese, or any other native tongue of the Archipelago."

The Oceanic is described by Professor Whitney (*Life and Growth of Languages*, ch. xii., International Scientific Series), following Muller, as "a vast and perfectly well-developed family, the Malay-Polynesian," comprising the Malagasy, Malayan, Polynesian, and Melanesian, better called the Papuan. By Latham (*Comp. Phil.*, ch. 54) the Oceanic is divided into two great branches, the one of which may be called the Malay, if we include under that name, for convenience' sake, the Malagasy, Micronesian, and Polynesian proper; the other is the Papuan, which prevails in New Guinea, the New Hebrides, and intervening islands. The Oceanic languages are more widely diffused than any other. Between Madagascar and Easter Island there are two hundred degrees of longitude. The family thus widely diffused over two oceans, and having no apparent connection* with those of the adjacent mainlands of Africa, Asia, and America, some have suggested, by way of accounting for its existence, that the isles in which it is spoken may be the hill-tops of an ancient submerged continent; others that this so-called family is not really a family, but a multitude of heterogeneous indigenous languages, with a number of common Malay words added to them by Malayan immigrants. The former of these suggestions never attracted much attention, and the latter, though elaborately asserted by Crawford in his dissertation prefixed to his Malay dictionary, has always had the great majority of scholars against it, and may be

* From what central point (says Whitney the migrations of the tribes and their dialects took place it is not possible to tell. The family is strictly an insular one.—*Life and Growth of Language*, p. 242. London, 1880, International Scientific Series.

regarded as a mere crotchet. The affinity of the Malagasy to the Malay was known two centuries ago; that, also, of the Polynesian to the Malay has been known since the time of Captain Cook's discoveries. The common theory first stated by Forster in 1778, to the effect that "all these languages were derived from one very ancient tongue now lost," has been effectively supported by Marsden, who calls (*vide* his *Malay Grammar*, "Introduction," p. xviii.) the original language the Polynesian, and maintains that one of its dialects stands in the same relation to the Malay as the Saxon to the English.

The relation, then, between the Shemitic and Oceanic is, generally speaking, that of an ancient to a modern language, as Latin to French, Saxon to English. This implies that we shall find the Oceanic, as compared with the Shemitic, characterised by phonetic and grammatical decay, the abbreviation and corruption of words by a principle of voice economy, and the substitution of separate auxiliary words or particles for the inseparable forms of declension and conjugation; and that allowance must be made for the existence of ancient vulgar dialects, in addition to the literary, just as is done in tracing the Romance to the Latin. In the Shemitic we find that this process of decay had been operating; in the Oceanic we find it carried further, but on the same lines. Gesenius (*Heb. Gr.*, "Introd.," sec. 16), glancing over the Shemitic field, says:—"The Aramæan dialects exhibit the earliest and greatest decay, and next to them the Hebrew-Canaanitish. The Arabic was the longest to maintain the natural fulness of its forms, being preserved undisturbed among the secluded tribes of the desert until the Mohammedan revolution, when it suffered considerable decay. It was not till so late a period as this that the Arabic reached nearly the same point at which we find the Hebrew, even as early as the times of the Old Testament." "This," he adds, "accounts for the facts (erroneously considered so very surprising) that the ancient Hebrew in its grammatical structure agrees more with the modern than with the ancient Arabic." It is the Aramæan, with its "simplicity, occasioned, in fact, by derangement of structure and curtailing of forms," that the Oceanic most resembles.

According to Latham (*Comp. Phil.*, ch. 66) the Shemitic languages are essentially dialects of a single language from which is to be inferred either the comparatively recent diffusion of the Shemitic forms of speech, which he thinks the more likely, or a great indisposition to change. Latham (*Ib.*, ch. 54), encountering a similar phenomenon in Polynesia, interprets it in the same way, saying of the Polynesian dialects that "they have spread both recently and rapidly;" the sole foundation for his theory being the uniformity of these island dialects, and the consequent difficulty of conceiving of them as existing separately for ages, and still preserving that uniformity. Of the fact no one doubts; but Latham is, perhaps, almost alone in his inference from it. "The unity of the Polynesian dialects," says Alexander ("Introduction" to *Hawaiian Dictionary*), "is still an astonishing fact. Tribes like the Hawaiians and New Zealanders, separated from each other by one-fourth of the circumference of the globe in space, and thousands of years of time, speak dialects of one language, and have the same customs and mythology. The laws of euphony in the several dialects which regulate the changes of consonants are so fixed and uniform that, a New Zealand or Samoan word being given, we can generally tell with certainty what its form will be in each of the other dialects." "It was the belief of Wm. Humboldt," he adds, "that the Polynesians exhibit the original state of civilisation of the Malay race, when they first settled in the Indian Archipelago, and before they had been changed by foreign influence." The one fact which is truly wonderful and unparalleled is the substantial sameness of the language whose varieties are spoken in the numberless isles of Oceania. As this cannot by any possibility be accounted for by recent diffusion, the only other alternative is that of a peculiar inherent permanency or indisposition to change. This peculiarity, which is also Shemitic, is as such thus referred to by Whitney (ch. xii.):—"The scale of dialectic differences is much less in Semitic than in Indo-European; all the great branches, even, are, as it were, the closely related members of a single branch. This is not necessarily because their separation has been more recent than that of the branches of our family; for Semitic speech has shown itself much more rigid and changeless than Indo-European, or, it is believed, than any other variety of human speech."

In comparing Oceanic and Shemitic it may be necessary to say a few words at the outset as to phonesis.

Speaking of the Malay, Crawford points out that "there are a good many monosyllabic words; . . . the great majority of radical words are bisyllables." This is true of Oceanic universally, whose radical words, as Whitney says, "are prevailingly dissyllabic;" and it is true, also, in like manner of Shemitic.

As was to be expected, there is no Oceanic language that has retained all the Shemitic consonants; the Malagasy has perhaps retained more than any other. There is much less difference between the Malagasy and Hebrew or Arabic than there is between the Polynesian and Malay or Malagasy. For, as Crawford remarks, "the dialect of the Sandwich Islands wants no fewer than thirteen, that of the Marquesas twelve, and that of New Zealand eleven consonants of the Malayan system." As used here, the vowels have the continental sound; and it has to be borne in mind that the short sounds of i and e are almost identical, and somewhat like that of short u or y. As in Shemitic so in Oceanic, vowel sounds are peculiarly interchangeable. In what follows the consonants have the English powers. The Shemitic words are transliterated as nearly as possible, according to the system of Gesenius, set forth in the comparative table of alphabets prefixed both to his grammar and dictionary. Cheth is hh or ch; in Efatese, as there is no h or ch, cheth is either k or quiescent. Efatese has but the one sibilant, s, that can represent the Shemitic z, sh, and s. Tzade or tz can only be t or s as pronounced by an Efatese native; koph (q), k, and g can only be k; and d, t, and th can only be t. In Efatese k and ng are very frequently interchanged, and in the vast majority of instances ng is merely dialectic for k; p (or b) and v (or f) are frequently interchanged for the sake of euphony. What may be called double euphonic consonants are somewhat common in Oceanic, as mb or mp for b or p, and tr or nr for r. In Oceanic the vowel at the end of a word is often euphonic. The same rules for the commutation and omission of letters apply as well to the Oceanic as to the Shemitic. As in Assyrian (Sayce and Norris) so in Oceanic, ayin is a vowel or quiescent, and is here denoted by a comma, thus (,). In what follows when the third person singular preterite of a Shemitic verb is given with certain of its letters italicised the letters not italicised are the radicals of the "stem-word."

Dr. Thomas Young "has calculated by the theory of probabilities that if three words were identical in two languages, the odds would be more than 10 to 1 that in both cases they must have been derived from a common parent tongue; that for 6 words the chances would be 1700 to 1; and for 8 words in common, 100,000 to 1; so that in the two latter cases the evidence would be little short of certainty that the languages in question, and consequently the natives who speak them, had a common origin. But according to the more learned modern ethnographers, the affinity of languages is not so much to be sought in the coincidence of words as in the grammatical structure." So says Mrs. Somerville. "The philologue," says Latham (ch. 1.), "who looks upon languages from the historical point of view has, in most cases, to infer the relationship from the likeness. . . . For historical purposes, the important parts of a language are the details—the details in the way of its words, glosses, roots, and vocables; its nouns and verbs; its adverbs and pronouns. Where these are common to two languages the chances are that the actual relationship is in proportion to the extent of the community."

The parts of Oceanic words italicised are non-radical, and explained in the part treating of grammar.

Vocabulary.

(Any word without the name of the language to which it belongs prefixed is Efatese.)

1. Father; ava, ap. My., pa; Ch., aba.

2. Strong; bur; Heb., abir.

3. To walk in a rolling manner, or backwards and forwards, banga; Syr., abak.

4. Wing, avar; Heb., abar, a wing feather.

5. A reward; keroa; Syr., agroa, *cf.* Heb., agorah, a silver coin.

6. To gather together; kur, ngur; Heb., gur.

7. To gather together; kuruk; Ch., gareg.

8. To take in, draw in (i.e., lay up, to put in store for oneself); kar, ngaru, ngarukaru, *ta*garu; Heb., gar'a.

9. Heb., gar'a, also means to diminish; Ef., kir, small. My., korang; Java, kirang; *ma*kur, thin, lean; My., kuru. My., karu*t*, kari*k*, kukur, &c., are all belonging to the same root.

10. The radical meaning of Heb. gar'a and cognates, as garr, is to scrape, scratch; Ef. ngura, v. and s., and My. garu, v. and s. Ef., kar, ngarakar.

11. An article. Ef., e or a; Heb., he, ha; Phen.,* a.

12. To put together in a bundle, tar; Heb., tzarr.

13. A shadow; ate; Po., ata; Heb., ad, exhalation, vapour.. From the same root (Heb., aid; Arb., ada, to bend, be strong, heavy, &c.), we have—Ef., ate, a spirit, the soul; My., ati, heart, mind; Po., aitu, a ghost, and atua, a god; also, Ef., Po., My., and Mg., ate, ati, the liver.

14. Male; anoi; Tah., oni; My., inu; Heb., on (aon), virile and genital power.

15. To spin or weave, sel, (Fiji., sulu, cloth); Heb., azal. Like the Heb. and Ch., this Ef. word sel or sal also means to go, depart, and sela is a way or road; *mi*sal is separate (departed), cf., Arb., cognate, 'azal.

16. To creep, slip,; sol, sosol; Sam., solo (transitive, sol*i*; Sam., solo*i*, to wipe); Heb., zahhal. Like the Arb. and Arm., which, however, substitute d for z, the Sam. sola, solo, means also to run, run away.

17. To bind around; ser; Heb., azar; Arb., zarra. Ef., *ma*seri, woman's waist dress. My., saru*ng*, the cloth wrapped or girded round the loins of men and women.

18. A kinsman, ak, ek; Heb., ach.

19. To howl, cry out; au (aw'); Arb., 'awi.

20. Narrow; wos; Heb., autz (wutz).

21. A mark; wot; Heb., aoth (woth).

22. A pot; Fiji., yawe. Heb., ahh, a pot or furnace. Ef., ua (uwa), the native oven.

23. To take; us, wis, was; Heb., ahhaz.

24. Tail; nger; My., ekor; Heb., achor, hinder part, rear end.

25. Not; e; (Heb., ai, i); Api., i, like Eth. i, prefixed to verbs.

26. Empty, vain; lala; Heb., elil.

27. Sam., ngali, to gnaw; (Heb., akal, to eat, bite); Ef., ngol, lips.

28. To say, li; (le or lo, voice, speech); Arb., alla, to cry out; Amh., ala, to say, speak.

29. Hand, arm, *l*ima; Po., id; Api., ma; Heb., amah, the forearm.

30. To languish, hang down the head (be ashamed, weak); mal; My., malu; Heb., am*a*l.

31. To be strong; met, mat*ua*; Fiji and Po., mat*ua*; Heb., ametz.

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* Phenician.

32. Sav.—Heb., as*a*f; cognates, suf, s*a*f*a*h, y*a*s*a*f; meanings common to Ef. and Heb., to scrape, scrape off, together, surpass (be great), collect, take, take off, away. Causative, cause to go away; passive (modern), *mi*sav, taken away, separated; and (ancient) siv; cf. Heb., ps. part., asuf, to be gathered together, to vanish, perish.

33. To bind to anything; sera; Heb., as*a*r.

34. Weak; pwel (pel), wel; Heb., af*i*l, ap*i*l.

35. End; abis; My., abis; Heb., apes.

36. To surpass; bong, pong; Arb., paq; hence,

37. Extremity; pango, pang (much used in names of places throughout Oceania); Arb., pauqon or pauq.

38. To go round; ova or epa; Heb., aff or app.

39. To weave, intertwine; rav; Heb., ar*a*v.

40. To go; arowo, aroo, *p*orou; My., *p*erga; Heb., ar*a*ch or ar*a*hh.

41. A time; rak, rang; Arb., ar*a*ch, to appoint a time.

42. To delay; *f*irak; Arb., Heb., ar*a*ch.

43. A foundation; isi (issi); Ch., Arb., ash (osh, ush).

44. To come (dialect); da (nda); My., data*ng*; Heb., ath*a*h.

45. Food, a present; vang; Erom., vang; An., hang; Mg., faha*na*. In Bible, only in Ez. and Dan., bag or vag.

46. To cut; bit; (knife, bīt); Heb., badd or padd.

47. Quickly, swiftly, tremblingly; bile, bele; Heb., b*a*hel; Ch., beh*a*l, hence,

48. Bile, file; to flash, lighten, and s., lightning; Po., id. Fiji., vula; My., bula*n*, moon.

49. To shut, cover; bon, won, fun, bun; Heb., b*a*h*a*n. The secondary meanings in Ef. are, to finish (from closing or sealing), to blot out, kill; and the word is widely used in Oceania. Ef., bunu; My., bunoh; Mg., vono; Ef., bunu*ta*; Java, bun*tu*; Sam., pupuni. Ef., fona; Mg., fono, cloth covering, or wrapper. Ef., fonu; Java, panu, a turtle (because covered). With auxiliary m.—Ef., *m*ono, *m*unu; Mg., *m*amono (for mafono); this change on prefixing auxiliary *m* to verbs beginning with a labial takes place invariably in Mg., and only occasionally in other Oceanic languages.

50. To come in, come upon, enter, to go; pa, va, pa*n*, va*n*; also bua, fua (hence *na* pua, a road, way); Heb., ba, (bua). Bua, to procure, bring; My., bawa; Heb., bua, ba. Pa to, or pa ta; My., pada; even, equal; Heb., ba'ad. Baki; My., bagi; to, unto; Heb., ba ki. Baka; My., bagai; Fiji, baka;

Maori, whaka—as, like, as if; Heb., ba k, ba ka. Ba, va, baka, vaka; (Fiji, vaka; Sam., faa), prefixed to verbs in Papuan and Polynesian languages forms a kind of causative; Heb., ba; Arb., ba; to be equal (My., baya), to make equal, to come to pass, cause to come to pass. The ka in baka means *as*; Heb., ka; hence vakamauri, to save, is literally not to cause to live, but to cause to be as alive. Modern causative ba*i*, to bring in, insert; ancient causative ova, or ava, to carry; Heb., Hiphil, hevia (avi), which means in Hebrew also, to put in; Ef., to entomb, bury. With m or um (49) we have umai (dialect), mai; to come; also used widely in Papuan and Polynesian as a particle to denote direction towards the speaker, and like the prep. from. Fa, be, pa be, (usually va*n mai*), to come; Heb., ba bo, or va bo, (Dan. xi. 10).

51. To tread with the feet, trample on; pas; Heb., bus (bas)

52. To snatch away; bass; Syr., baz, hence,

53. A prey; bes; Heb., baz or bizah.

54. To confide in; fafatu, (fatu); Heb., b*a*t*a*hh, prt., batuahh.

55. Principal or public house; fare; Tah., fare; Maori, ware; Fiji, bure; Heb., Ch., birah, palace. Eth., nabar, to dwell.

56. This, that; nin, nen; My., nun, nin, nen, inun; Syr., enun, enen.

57. To be not, empty, worn out, without anything; bol, buel, bal, wol; Api., buel; Heb., b*a*l*a*h.

58. A wave (swell); peau; Sam., id.; Ch., be'aa, to swell, boil up.

59. To burn up; *tu*bara; Heb., ba'ar: to kindle an oven, bouria, būria; Heb., prt., bo'erah, Hos., 7-4.

60. Stupid, brutish; bär; Heb., ba'ar.

61. Precipice; patir; Heb., batzir, inaccessible, high.

62. To strike; baka, boka, buka, puka; Heb., p*a*g'*a*.

63. To inquire into, examine; bous; Ch., b*i*hh*a*sh.

64. Bora, wora, bara; to beget; Heb., b*a*ra; hence,

65. Offspring; wor; Heb., bar, and

66. Fat; barua; Heb., baria.

67. To make a humming sound; buruma; Arb., b*a*r*a*m.

68. To raise up, *ra*kai; *ta*kai; Heb., gaah. In Ef. and Heb. it also means to adorn.

69. To be polluted, defiled; ngolo*pa*; Heb., g*a*al.

70. To thunder; kat, ngat; Eth., redupl, gidgad.
71. To cut; kut, ngut; Heb., gadd.
72. To cut, break; koto, ngoto; Heb., gad'a.
73. To pluck off, break off; kotev; Heb., q*a*t*a*v.
74. To cleave, cut; kob, ngob; Heb., gub.
75. A dog; kuria; Syr., guroa.
76. To shear, cut off; kosi; Syr., g*a*zi.
77. To shave, shear; kosum; Heb., kasam.
78. A slender stem; kusou; Syr., guz'o.
79. To hide; kor, ngor; Heb., gahhar.
80. To bind; kat, ngat; Arb., qad.
81. A wave; ngalu; Sam., id. Syr. galo.
82. Husk, peel; ngalu; Syr., gelo.
83. To bind together, tie; kela; Arb., '*a*q*a*l.
84. To be bent, twisted; *ma*ngal, *ta*kel, *ta*kelkel, *ta*ngelengele; Heb., '*a*q*a*l.
85. To absorb; kumi, ngumi; Heb., g*a*ma.
86. A wing; Santo, kave, kav; Ch., gaf.
87. To call, cry out; kua, ngua; Syr., g'oa, q'oa.
88. To feel, explore; kis, ngis; Syr., gas.
89. This; te, to, tu; Ch., do, dā.
90. To fear; *mi*taku; My., taku*t*; Heb., dag.
91. To cover; tak; Heb., d*a*g*a*h.
92. Breast; My., dada; Heb., dad.
93. To pound, beat; tuk; Heb,, duk.
94. To roll, round, &c.; tal; Heb., tzall; Arb., dd*a*ll'*a*.
95. To incline to one side; tale; Heb., tz*a*l'*a*; Arb., dd*a*l'*a*; hence,
96. A side; tale; Heb., tzel'a.
97. Fatigued, wearied; *ta*ngiengi, (angi); Heb., y*a*gi'*a*, yagi'a.
98. A heap of stones; *ta*ngur; Ch., ygar.
99. To delay; *t*aleale, (āle); Sam., *t*ali, wait for; Heb. y*a*hh*a*l.
100. To push; tō; Heb., d*a*hh*a*h.
101. To thrust, push; tōv; Heb., d*a*hh*a*f.
102. To thrust, push; tak; Heb., d*a*hh*a*q.
103. To thrust out, expel, drive away; tīa; Heb., hidīahh, Hiph. of n*a*d*a*hh.
104. To be many; et (dialect); Arb., adi.
105. Lord; tui, ti; Po., id; My., tua*n*; Arb., dzu, or thu, thí.
106. That, so that, because, he who, that which; t, te; Ch., d, dī, de.

107. This; tik, tuk; Ch., dek.
108. To disturb water; tuletul, (tule); Heb., d*a*l*a*hh.
109. This; tun; Ch., den.
110. To thrust, push, strike; tiba, tuba, tapa; Heb., d*a*p*a*h, tapp; Arb., dabba.
111. To knock; tavangk; Heb., d*a*f*a*q.
112. To sing, cry (as a child), speak, &c.; kei, ngei; Heb., h*a*g*a*h. Kī, to squeak; Heb., Hiphil; Sam., 'i'i (kiki). An., eka; Fiji, kaya, to speak.
113. To break, utter sound; at; Heb., h*a*dd; Arb., h*a*dd*a*.
114. To beat with a club; watu, atu; Heb., y*a*t*a*hh; Arb., w*a*t*a*hh.
115. This, he, she, it; wa (ua), ia (ia); Heb., hua, hia.
116. To be; pi, bi, vi, ba, pa, bu, vu, bo, pu; future, fo, wo, o. Heb., h*a*v*a*h. Ch., h*a*v*a*h, h*a*v*a*a.
117. To go away; Sam., alu; Arb., halla: hence, a road, Ef., lel; Po., ala; Mg., lala.
118. To walk, go; Santo, Fiji, lako; My., laku; Heb., h*a*l*a*k, y*a*l*a*k: to pour out; lingi; Heb., Hiphil, id.
119. To be brilliant, glorious; *m*iel; Heb., h*a*ll; Arb., halla: hence, elo, or al, the sun; Abyssinian, aloh; ali, day; li*n*, light; aliati, (for aliali), day; to dawn.
120. Multitude, riches; mān; Heb., hamōn.
121. They; mai, máne; Ch., himō, himōn.
122. To wander in perplexity; bingo; Heb., buk.
123. Crooked, twisted; pangpango*a*; Heb., hapakpak.
124. A star; *ma*sei, *ma*sai, (*what* shines); Arb., z*a*ha, or z*a*y*a*i, to shine.
125. To be filthy, loathsome; samasama*na* (sam); Heb., z*a*h*a*m.
126. To flow out, go out; tav; Heb., davv; Syr., duv; Sam., tafe, flow; tafe, a flood, Ef., id.
127. To deceive, lie; sur; Arb., zar; zur, a lie.
128. Milk, breast; sus; Mg., My., Sam., id.; Heb., ziz, zuz.
129. To draw out; tila; Heb., d*a*l*a*h; Syr., dela.
130. To scatter; siri; Heb., z*a*r*a*h.
131. Bosom, inside; kob, kupu; Heb., chob; Ch., chuba.
132. Fire; kap; cf. Syr., ch*a*b, to burn; My., afi; Arb. wafi, to cook.
133. To tie; ut; Heb., hhud; Arb., hhad.
134. To return; liliu, (liu, lyu); Arb., ala.
135. To dance; wul; Heb., hhul.

136. House; *s*uma, um; My., *r*umah; Java, umah; An., *ne*om; Heb., hhomah, wall of a town or house.

137. To be; ka; Heb., chayah, to live; hence,

138. Ika, a fish; Po., id.; Heb., chayah, (water) animal.

139. War; *fa*kal; My., kalahi; Heb., chayil.

140. To do with ardour, be earnest; kara; Heb., ch*arah*.

141. To scrape, scratch; karas; Arb., ch*aras*.

142. To be dried; kara; Arb., charra.

143. To be bright, clean; tär; Heb., t*a*h*e*r.

144. To twist; taui, tawi; Arb., t*a*wi.

145. To be long; tali; Arb., tal*a*: hence, tali, a rope; Po., My., id.

146. Clay, earth; tano, tan; Po., My., Mg., id.; Ch., tin.; Syr., tino.

147. To cover, or soil with clay or earth; tan, tun; Arb., tan.

148. An egg; tole; Arb., tala, a young animal of any sort. My., tulo*r*; Mg., *a*tody; egg.

149. To be heavy, laden; *mi*ten; Syr., t'en.

150. To cast down; toro; Heb., tarahh, be cast down, wearied; Ch., terahh: hence, to sleep, *ma*turu; My., tidor; Mg., *ma*tory.

151. To pour over (smear); bulu; Arb., b*a*ll*a*; Heb., b*a*ll.

152. A cutting instrument; karab; Heb., chereb.

153. To know; atai, tai; My., tau; Heb., yad'a; Ch., yd'a.

154. To tread; us; Arb., wahass; Heb., yahatz.

155. A day; ma, (mei, me); Ch., emphatic, yomā.

156. A shoot; niko, or iniko; Heb., ynikah.

157. Beautiful, good; pia, wia, wi; Heb., yapeh. My., ba*ik*; Arb., baha, to be beautiful.

158. To go out, forth; sei; Eth., wasza.

159. To go out, forth, cause to go out, forth; tou; Heb., yatza; Hiph., hotzia or hotziya; hence,

160. Gate, fountain, origin; mita; Heb., motza; which also in Ef. means, (after the analogy of Heb., 'yn), the eye; Po., My., mata; Mg., maso; hence, also,

161. Excrement; tai; Sam., tae; My., tai; Heb., tzah tzeah, and,

162. To be filthy; *mo*ta; Sam., oteota; Syr., Heb., tzoah. Cf. Syr., tzaa, to stain; tzoa, filthy; hence, also,

163. To spring forth, up; as in Heb.; then, to become, exist, continue; Ef., tou, or tau; Fiji, Sam., id.; (cf. My., jadi. Java, dadi. Ef., tou and tu, offspring, like Heb. tzeetzayim; hence, also,

164. A year, season, (harvest); tou; My., tau*n*; Mg., tao*na*. A year in pigeon English is "one yam."

165. Established, firm; supe, sup; Ch., yatzib.

166. To dwell near, sit, be on; tab, tav; Heb., *ya*sh*a*b; Arm., ythib; Arb., w*a*th*a*b.

167. Like, so, as, as if; ke, ki, ka; Heb., ke, ka; My., ka.

168. Weak, faint-hearted, &c.; ki*n*, ka*n*; Heb., kah, and cognates.

169. So, thus, here, this; ku, kua, ko, ka; Heb., koh; Ch., kah; My., iki, iku.

170. A vessel, basket; kat, kot; My., water vessel, kandi (n euphonic); Heb., kad.

171. A pot; Fiji, kuro; Heb., kir.

172. To catch, seize, fall upon; karak; Heb., ch*a*r*a*k. (only in Prov. xii. 27).

173. A joining, the elbow; wusik; Heb., hhashuq; My., siku: Heb., hh*a*sh*a*q or hh*a*z*a*k; Hiphil, hehziq, to join to, adhere, take hold of, seize; Ef., siku.

174. To pierce, dig, cut round; kor; My., kore*k*. Heb., kur; My., karis, kris, a dagger.

175. To pant; ngaingai, (ngai); Syr., kahh; Arb., kahh, to overcome in battle; Heb., koahh; My., gagah, strength, might, valour; Fiji, ngu.

176. That, in order that; ki, ka, nga; Heb., ki; Arb., ka.

177. Clothing; kul; Heb., keli; My., kuli*t*, skin.

178. A vessel; My., kulah; Heb., keli.

179. To be covered, hid; kus; Heb., k*a*s*a*h, ps.

180. To bow down; kav; Heb., kaff.

181. To stoop; tak; My., *tu*nduk. Syr., v. Jno. xx. 5—11. (Adiq, to stoop, Aphel of daq, to look, look round, &c.)

182. A deep cavity; luk, lok; Heb., log.

183. To stick, adhere; liko; My., laka*t*; Arb., lahhiqa.

184. To be exhausted, languid, fade; li; My., layu; Heb., lah, l*a*ah.

185. A knife, (sword); lova; Heb., lahavh.

186. To be mad; elielia; Fiji., lialia; Heb., lahah.

187. To burn, flame; livaliva; Fiji., livaliva, lightning; Arb., l*a*hh*i*vh*a*; Samaritan, lavhlavh, to shine.

188. To shine, be bright; langa; Arb., lacha.

189. To be strong, firm; let; Arb., lath*a*.

190. A fissure or chasm; las; Arb., las'.

191. To bite; leti, lati; Arb., lat'a.

192. To be mild, gentle; *ma*ilum; Mg., *ma*lemy; My., lumah; Arb., hhaluma.

193. To cut off skin or bark; mulu; Heb., mul; also the word is used both in Ef. and Heb. in the sense of, to circumcise. Circumcision prevails among a part of the Efatese, very extensively in the New Hebrides, and in other parts of Oceania.

194. Defilement; mym, (mim); Heb., mum.

195. The Heb. word for eye, 'yn (160), literally means fountain; from 'in, to flow out. This word or root is found in Mg. as ony, river, and in Ambrym as un, in un miten, flowing of the eye, tears.

196. To die; mat, mate; My., Sam., id.; Mg., maty; Heb., muth, math.

197. To separate; mas; Arb., maza.

198. To strike upon, extend to; mau, (mawa); Heb., mahhah.

199. To chew; ma; Sam., mama; My., mamah; Syr., mahha, to bite.

200. To rub; mā; Heb., mahhah.

201. A hollow; mele, (const.); Heb., mĕhillah.

202. Who? Ero., me? Heb., mi?; (pl.) Ero., me ume? Heb., mi wami?; Who? (sing.). My., mana? Syr., man?

203. Feeble, soft; malua; Sam., malu, (Ef., malilua. Sam., malulu); Arb., malīhh.

204. To flee, (slip, glide away); mila; Heb., malahh.

205. To cut off, clear; mal; Heb., mall: hence the Po. malae or marae, (familiar to the readers of Cook, &c.), the open (clear) public place of the village; in Ef. mala or malla (or malel).

206. A beam; nerou; Syr., niroa.

207. Short; mwit; Heb., ma'at, to be diminished.

208. A covering; mwit; Heb., ma'ateh.

209. Treachery, perfidy; mal; Heb., ma'al.

210. Above (Ef. dialect); mahil; Heb., ma'al: (ayin here represented by h).

211. To be angry; maieto; Arb., ma'idda.

212. A hollow, cave; mōru; Heb., me'arah; (Ef. const., merite); Heb., me'arath: Ef. pl., moruta (name of a valley full of caves); Heb., me'aroth.

213. To come; masa; Eth., maza.

214. A gathering together, company; mikau (mikawa); Heb., miqeweh.

215. Man, lord; mera, mare; Ch., mare. In Mar-Saba, maranatha, &c.

216. To stroke with the hand, anoint; masa, masamaso; Heb., mashahh.

217. A portion; maso; Heb., mashhhah.

218. To show, declare, tell; tili, tule; Sam., tala; Arb., dalla.

219. To speak, say; nova, nowa, noa; Heb., navha, naba.

220. To speak, say; Ero., nam; Heb., nam.

221. To contend; Fiji, leti; Heb., l*a*dd.

222. Water; wai; Po., vai; Heb., naba' or bu'a, to well up, gush forth, (mabu'a, a fountain); Abyss., waha, water.

223. To rain; bowa, wa, bwa; Heb., naba', or bu'a, Hīph., to gush forth.

224. Rain, shower; us; My., uja*n*; Sam., ua; Arb., wadz'a, to flow, to run.

225. A wave; wa, (*v.* 222). This Shemitic root, or group of cognate words, as Heb. nub, napag, means also to swell up, to sprout, to produce (fruit); hence the word wa in Ef. is used to denote not only a wave, water, and to rain, but also

226. Fruit, and to fruit; Sam., fua; My., buwah; Mg., voa; of which last the verb is mamoa (49).

227. Hence, young shoots, offspring; pia; My., pia*t*; Sam., fua; and

228. Young; fau, or fou; Sam., fou; Fiji, vou; Mg., vaovao; and

229. To begin, be first; be, ve; Sam., fua; Fiji, vu; An., hu; My., püu*n*, beginning, source, foundation; Ef., bua, ancestor, progenitor; hence also,

230. Blossom, flower, bu*ma*; Mg., vo*ny*; Sam., fu*nga*; My., bu*nga*.

231. To rest, dwell; *ma*nak; Arb., nach.

232. Progeny, offspring; nan; Heb., nin.

233. To move to and fro; nua; Heb., nua'.

234. To sprinkle, scatter, shake forth; nopa; Heb., nup, Hiph., henif; hence Ef., nīvi, to shake (a fan), to fan, a fan.

235. To drop; tev, tetev; Heb., nataf.

236. Before, face, front; nako; Heb., nokahh.

237. To fall; bul; Heb., n*a*p*a*l.

238. To take up, carry, to suffer, to bear any one's sin; su; Heb., n*a*sa: Arb., to grow; nashā; Ef., *pi*sou; hence,

239. Height (top), sū; Heb., si, sya; and

240. Vapours which ascend from the earth; nsou; Heb., nasya.

241. To saw; sar; Heb., n*a*s*a*r.

242. To bite; kat; Ch., nekath. (The Heb. is nashak.)

243. To kiss; sung; Heb., nashaq.

244. Hill; tav; Abyss., debba; Arb., natab, to be lofty.

245. To cut; niti; Heb., Piel, nitahh.

246. To lift up; sela; Heb., s*a*la.

247. To kiss; sum: My., chyum, to kiss, to scent, to smell; Arb., shamma, to smell.

248. To be hid; bwei; Arb.. 'abiya.

249. To do, make; bat, pat; My., buat; Aram., 'bad; hence

250. A slave; viti; My., beta; Heb., 'ebed.

251. That, to, in order that; An., par; Ero., wor; Heb., ăbur.

252. (Sandy) shore, ground, land (opp. to sea); uta; My., uta*n*, a forest, as in Orang-utan; Bisaya, uta*n*, a garden of pot-herbs; Arb., 'uta, soft, sandy ground, irrigated with water and planted with trees.

253. To dwell, to be; ana; My., id.; Heb.,'un; Arb., ana.

254. To arise (as the wind); *ma*uri; Heb., 'ur.

255. To live; *ma*uri; My., idu*p*; Java, uri*p*; Tanna, *m*uri*f*; Po., ora; Heb., 'ur, to be awake, alert.

256. To cover; My., tutup (tup): Ef., tove; Po., tapa, clothing. Heb., 'atap, to cover, be clothed; Syr., 'tap or 'taf, to be clothed; Arb., 'itap, a cloak.

257. To run; ur; Heb., 'ir.

258. As, for, because, on account of; oli; My., ulih; Heb., 'al.

259. To aid; ouli; Heb., ya'al.

260. To go up, &c.; liu; Heb., 'alah; hence,

261. Up, heaven (sky); le*n* or le*ng*, lang; Po., lang; My., langi*t*; Mg., lani*tra*; Santo, lon; Ch., 'elyon.

262. To be; im, um, ma, mi; Ero., um; My., ma; Tanna, Mg., id; Arb., '*a*mm*a*, to be in common.

263. To dwell, to be; ne, no; Heb., nah, n*a*w*a*h.

264. To work, wiswis (wis); Mg., asa; Heb., 'asah.

265. To roll, twist; bulo, *m*ul (49); Po., *m*ilo; Mg., voly, *ma*moly; My., bali*t*, &c., &c.; v. Ges., Heb. Dict., pol.

266. To exhale odour; boa, *na*boa; Arb., pahh*a*.

267. To search out, elect; pili, *m*ili; My., pilih, *m*ilih (49); Syr., pela.

268. To ascend; sak; Arm, nesaq.

269. To roll, revolve; polos; Heb., p*a*l*a*sh.
270. Food; vinanga; Heb., Ezek, pannag, a cake.
271. To break; bor, por; Heb., p*a*rr.
272. Space between, middle; but, put; Heb., poth.
273. To part in pieces, divide; pot; Heb., p*a*thth.
274. To open; puka; My., buka; Heb., p*a*q*a*hh.
275. A flat dish; seloa; Heb., tzelahhah.
276. To cry out with a loud and clear voice; tare; Eth. t*a*ra.
277. To meet; ngara, kor; Heb., q*a*r*a*h.
278. Hard, strong; kasu*a*; My., kwasa; Heb., q*a*sh*a*h.
279. To make a noise; ra; Heb., ra'a'.
280. To love, pity; rum; Heb., r*a*hh*a*m.
281. To look at; sikō; Ch., sĭkā.
282. To rejoice; samasama (sama); Heb., samahh.
283. To sweep, rush, stand on end (hair); sara, sera; Heb., sa'ar.
284. To draw water; saov; Heb., sh*a*avh.
285. To make a noise; so; Heb., sh*a*ah.
286. To look at; sao; Heb., sh*a*ah.
287. To be evil, bad; sa; My., jaha*t*; Arb., sa.
288. To sink down; suk; Heb., shuach.
289. A cloud; sok; Heb., shahhaq.
290. To praise; surosuro (suro); Heb., shur.
291. To deceive; seli; Heb., sh*a*l*a*h.
292. To delineate, mark out; *mi*tir; Heb., t*a*ar.
293. To mark, cut; ta; Heb., taah.
294. To find; *ma*soko; Ch., shekahh.
295. Spittle; top; Ch., tup, to spit out.
296. To be, to dwell; to; Arb., tawa.
297. To remain; tok; Syr., tuk.
298. To be broken; *mi*tela; Arm., talahh.
299. To desire; *ma*sik; Heb., shuq.
300. To cry out; tangi; Sam., id.; My., tang*is*; Heb., tza'aq.
301. A place, ki. Assy., ki. (In Assy. Dict written ci.)
302. A land; mot; Oc. names of places—mota lapa, big land; pau motu, cloud of lands; Assy., matu; very frequently occurring in Assy., and, according to Sayce, of Accadian origin. (Sayce, Assy. Gr., Norris, Assy. Dict.)

It would be interesting, were this the place for it, to take the principal names of relationship, of members of the human body, of animals, and of the great objects of nature in all their variety as actually found in Oceania, and to show that they are Shemitic. One or two examples will indicate this: Bird—Cocos Island, ufa; Tagala, ibo*n;* Heb., 'of. Mg., vuro*na;* My., vurong; Heb., parahh, to fly. Ef., Api., Amb., Mallicollo, to; Heb., dah, to fly. Nest, *ne* kin; Mg., *a* kany; Heb., qen, qin.

Dog—Ef., kuri; Maori, kuri; Heb., Syr., gur, gura, a whelp, puppy.

Fish—Ef., Po., ika; My., ika*n;* Heb., chayah, an animal; My., ikan-ayar, water animal. Like Mg., haza-*ndrano;* Paama, New Hebrides, asa; Amharic, assa.

Water—Ef. (dialect), ra*n;* Mg., dra*no* or ra*no;* Arb., riy*on*, watering. Ef., ra*nu*, to pour fresh water over after a sea-bath; Fiji., dra*nu* id.; Fiji., dra*no*, a lake; Ef., ra, a lake or pool of fresh water. My., ayar; Java, er; Malo. (N.H.), reuh; Heb., r*a*w*a*h (to be full of), water. Ef., me (urine); Heb., Syr., me, id.; Ef., mua, to flow (the tide); Heb., mua, to flow.

Sea, salt—Ef., Sam., *t*asi; sea; Patos, asih; My., *t*asi*k*, literally the salt (water, *i.e.*); Mangarei, wae-tasik; Ende, ora-*m*asi*;* Java., ra*nu*-*m*asi*n;* Mg., ra*no*-*m*asi*na;* Asi, salt, very widely used, from Syr., 'az, to boil forth: Like My., gara*m;* Celebes and Tanna, gara, salt; Heb., gir, to boil up. And Mg., tsira; Matabello, sira, salt; Ef., sira (ferment); Heb., sir; to boil up. In Ef. salt is tas-men—*i.e.* the boiling up, foam, or ferment of the sea, men; Arb., yamon; Amboyna, met, mit; Syr., mata or ymata. Tagala, daga*t;* Ero., tok; sea; Heb., daki, "crashing, dashing (of waves)." Ef., lou or lau; My., lau*t;* Bouru, ola*t;* Api, ela; Arb., 'alla, to strike with repeated blows, &c. Celebes, lauduk, is a combination of these last two words.

Land; fanua, vanua, benua, so widely used in Oceanica for for district, country, is literally a house or building (a dwelling-place); Heb., b*a*n*a*h, to build. In Santo it still has this meaning. Ef., ure, land; Ch., ara', (Heb., eretz).

Rain, Mg., ora*na*. Celebes, ura*n*, *n*aro; Abyss., heri, iro; Heb., yoreh.

GRAMMAR.—It will now be well to go over the principal points of grammar, and

§1. Demonstrative pronouns meaning this (here), or that, or simply calling attention to, or pointing out, or emphasising a word, simple or compound, separate or attached to a word, prefixed or postfixed—

Ma; Assy, ma; The Heb. mah mostly interrogative; √m.
Wa, ua; Heb., hua, hu; √ a, u, (ĭ, y̆, ĕ).
In, ini, ne, na; Heb., hen, henah, an, in, √ n.
Se, si, sa; Heb., zeh, √ s.
Tu, ta, te, to; Ch., da, √ t.
Eri, ru, ra, ri; Ch., aru, √ r.
Lu, la, li; Ch., alu; Heb., al, aleh; Arb., al, √ l.

If the two latter, l and r, were originally one in Sh., as Gesenius thinks, so in Oc.

Ko, ka, ki, ku, ke; Heb., kah (from kahu), √ k.
Fa, ba, be, pa, pe, va; Heb., pa, pah, fa (from bahu), √ b.

Compounds of these are very common in Sh. and Oc., thus (v. voc. 56.)

Nin, nen; My., nun, nen, nin; Syr., enun, enen.
Susa; Assy., sasa, sasu.
Rik, erik; Syr., hereka; My., ma*rika*.
Nanga (naka); Ch., henak.
Tuk; Ch., dek.

Thus, in Ef. we have nis, wis, kis, sin, wai, wan, netu; nai, Syr., hnu (used for third personal pronoun, singular); and nara (third plural). So—Mg., izato, (Heb., zath), izao, izany, ity, iroa, iny, ireto, ireny, &c.; and used as third personal pronoun, singular, izy; plural, izareo. Sam., lenei, sinei, lea, lena, lela, sea, sisi, ia, na, nei, &c.; used as third personal pronoun, singular, ia; plural, ila-tou. My., ini, tu, itu, nun or nen; and used as third personal pronoun, singular, iya; plural, marika.

Remarks.—The pronoun used for the third singular contains as its principal part the one used in all the Sh. languages for the same purpose: thus, Assy., su—(*i.e.*, √ s., above, and hu or u) is in Mg. izy (the y representing this u, sounding like short i or ü). The Ambarie further compounds this word by adding √ r, thus, arsu. Ef., nai is the same i or y with na prefixed, as in Syr., instead of sa, as in Assy. Sam., ia or o—*i.e.*, ko ia. My., iya.

The one used for the third plural is like the Heb. al, aleh., "plural according to use, and not according to grammatical inflexion." Ef., nara (n. r.). Mg., izareo (z. r.). Api., *n*ala. Paama., *ke*ila. Heb., aleh. In My., marika, we have the √ m that appears in the Arb. and Heb. pronouns plural. It only remains to add that the various pronouns used in the Sh. for the third plural are all, like the Oc. just explained, compounds of the above simple demonstratives. Thus, Heb., hem; Arb., hum; is hu and m. Ch., anun is an, hu or u, and n; so anin fem. is an, hi or i, and n; and from these Assy. sun, sin, differ only by prefixing √s instead of √n; and thus, it may be remarked, we solve the mystery of the Sh. inflexion of number, both in nouns and verbs, for the numeral particles, whether prefixed or postfixed to nouns and verbs, are simply these or other of the above demonstratives abridged or unabridged. After nouns we find hum or hem represented by ym or im, and anun, anin, by un, in: -oth. Heb. fem. pl. is √t instead of √n or √m. In the inflexion of the verb the final n demonstrative of un, is frequently dropped so as to leave simply u.

§2. In Oc., as in Sh., demonstratives, simple or compound, are used as indefinites, thus, Maori, mea; Heb., mah; Arb., ma, anything. Ef., matuna; Assy., matina; Ch., ma dun, anything whatever, &c., &c.

§3. In Oc., as in Sh., the article is a demonstrative put before the noun, as in Heb., or after it, as in Ch. In Ef., the New Hebrides generally, and Mg., the common article is in, an, ni, ny; to be compared with an, Heb. and Ch.; and Syr., hno, hono, in, *e.g.*, Acts viii. 35, hno ketobo, the Scripture. Thus the Latin ille has become an article in the Romance languages, and thus generally every Sh. simple demonstrative (in §1) may be found used as an article in Oc. Thus, *e.g.*, the word uma, house (Heb., hhomah) in Ef. is *s*uma; My., *r*umah; An., *ne*om: child, Heb., yanak (suckling, Ps. viii. 2), in My. is anak, and *k*anak, sometimes *z*anak, as it is commonly in Mg. Heb., h.; Phen., a.; in Ef. is a. Arb., al, in Sam., is the equally common article le. The My., like the Ch. and Syr., commonly uses the article postpositive.

§4. In Oc., as in Sh., the interrogative is a demonstrative used interrogatively (see for Heb., mi. Arm., man. Voc., 202).

§5. The reflexive or emphatic pronoun self in Ef. is tuma; Heb., 'atzem; and followed by the pronominal suffix as the same word in Heb., or the analogous words in the cognate languages—*e.g.*, raman in Assy. The Heb. verb 'atzam means to bind; Ef., tuma*n*, is a bundle.

§6. The personal pronouns in Sh. are distinguished as separate of full form, or attached of shortened form. These latter are used to denote the persons of the verb, accusative of the pronoun, and its genitive. They have no case inflexion; the full form, usually nominative, is sometimes accusative or genitive, and generally the same suffix is accusative or genitive, according as it is attached to a verb or a noun; and the shortened form is sometimes nominative, though usually accusative or genitive. Demonstratives are found attached to these pronouns, whether separate or suffix (nun epenthetic). Generally all these statements are equally applicable to Oc.

First Singular.

I, *k*inau—*i.e.*, inau, inu; Heb., anī.; Syr., ina u, (u, hu, dem.).

Verbal person, a; Heb., a.

Verbal suffix, nau, nu; Heb., nī.

Nominal suffix, k, ku. Cf., Assy., ku, v. p. (separate form, anaku; Heb., anoki; An., ainyak). My., aku, ku.; Mg., aho, ahy, ko; Sam., a'u—*i.e.*, aku. This My. ku is used as v. p., v. s., and n. s.

First Plural.

In Oc., as in Heb., there are two pronouns of the first person plural.

1. Ef., *ki*nam—*i.e.*, inam, inim, or inüm (commonly called the exclusive). Heb., anu, originally anum (Green's Hebrew *Grammar*); is, ina, I, and m, the indefinite plural demonstrative as used after Sh. pronouns and nouns.

V. p., au—*i.e*, a, the singular above, and u; Heb., u, plural. My. and Ef. (dialect), kami, kam, we—*i.e.*, ku (above), I, and m, plural; hence, Ef.,

N. and v. s., kam, ngam.

2. Ef., akit; My., kita; Ef., ningita—*i.e.*, nikit; Heb., anachnu; Arm., anachna. This pronoun is commonly called the inclusive (*i.e.*, it means I you they) and it is probable that this is what the Heb. anachnu originally meant, being composed of ana, I; ch, -ch-, you; and nu, they (anun). So Oc. akit, a, I; -k-, you; and ta (tu), they, as in Amharic, in which arsu is he, arsa*tu* they (*i.e.*, he, they).

Second Singular.

Nango, ang (ng, *i.e.*, k). Arm., Heb., Arb., ka, thee, thou; v.p., ku, v. pl. (like Eng., you for thou): v.s., -ko, -k. Arm., Heb., Arb., -ka, -k: n.s., ma (mu); v. pl., like your for thy. My., angkau, ang, kau (*i.e.*, ka u). Api, tau, ta u; Heb., attah.

Second Plural.

Ef., kum. (kumu); Arb., v. and n. s., kum (ko, sing. and m, pl.): v. p., ku; k, sing., u, pl., as in Assy. and Heb.: n. and v. s., Ef., mu, kumu shortened; Arb., kum; Heb., kem. My., kamu, -mu, as in Ef.

Third Singular.

V. p., e. (i, y); Heb., i (y): v. s., -s.; Assy. -s; a, e, na, nia; Heb., ah, eh, nah; Ch., e: n. s., na (as in v. s.); Mg., ny., My., nya, (nun epenthetic).

Third Plural.

V. p., ëu; Heb. i——u (he they): v. and n. s., ra or ta, analagously formed to Heb. m, and already explained above:—ta same as Amharic - tu. It is the same *t* that is used in Sh. to form the plural of nouns.

For the separate pronouns sing. and plural of the third person (see above, §1). In Oc., as in Sh., the dual is a modification of the plural. It only remains to notice the personal pronouns with epenthetic demonstratives, of which nun epenthetic is one that may be regarded as typical. Gesenius says "this nun is of a demonstrative nature, and belongs to the appended accusat. of the personal pronoun, to which it seems to direct attention as the object of the verb. This nun is frequent in Chaldee. In Samaritan it is appended also to the preterite, and in similar cases even a t (th) inserted. In the Syriac there is a yodh with a consonant power used in the same way." This last is the *i* of Sam., Ef., and My. The Ef. (and Fiji) epenthetic demonstratives are numerous, but are simply the demonstratives in §1. Thus we have Ef., third sing., acc., bia, mia, ria, tia, sia, ngia (kia), nia; second sing., acc., fik (or fiko), mik, rik, tik, sik, kik, nik, &c., &c. Then we have compounds thus—makinia (ma ki ni) sakinia (sa ki ni), &c., and note especially the compound kin or kan, which, as *kan* is one of the most important words of the My. grammar and dictionary, turning every verb after which it is put into a transitive or causative. It does the same in Ef., but is not so much used.

Remark 1. It seems that many, perhaps all, of these are in use in the My., but not observed or noticed. They being epenthetic, or always coming after the verb, have at last been written as if part of the verb root. This is very interesting, as throwing light, as will be seen, upon a somewhat obscure problem of Sh. philology, the tri-consonantal form of a large part of the Sh. vocabulary. Thus, take the common Ef. words *minu*, to drink; *rongo*, to hear; *turu*, to descend; *tangi*, to wail. These in the My. are given as *minum, dangar, turun, tangis,* in which the final m, r, n, s, are the demonstratives epenthetically used, as above shown, but exhibited as a part of the root. There are examples in Ef. of the same thing. If I mistake not, it will be found that the third consonant of many of the Shem. stems has a similar origin—*e.g.*, the f in Heb., g*a*d*a*f, properly like the "Arb., to cut off;" Ef, kotef, whose final f is the Sh., fa of §1: the real stem is biliteral, or monosyllabic; Ef., kot, kut. Heb., gad, gud, &c. (*vide* Vocabulary, 71-3, 76-7; *vide* Ges. *Heb. Gr.*, §30, 2.) This, if correct, would partly explain the tri-consonantal, or dissyllabic mystery. When the third consonant is prefixed, as Syr. *n*akas (Ges., l.c.), it probably is an auxiliary verb. But this by the way.

2. The so-called numeral and case inflexions have already been noticed. The inflexion of gender has also to be noticed now, as connected with the pronouns. In Ef. we have traces of it, thus—

Ma, a mas. demonst., used only before the names of males; it is the same m which forms in Heb. the mas. plural of nouns and pronouns.

Li, lai, similarly used before the names of females is the demonst. la, with i suffixed to make it fem. The very same *i* is similarly suffixed to pronouns in all the Sh. languages.

Tete (te), a pronoun used only in addressing females, is the same t as is used to form the Heb. fem. plural of nouns. It is a fem. demonst. in Arb. It appears as v. p., third person singular, fem., generally in all the Shemitic languages. Heb. t (th) is a fem. termination in the demonst. zath, and in some fem. nouns sing.

§7. The noun. In Efatese the number of nouns is denoted by plural demonstratives; so, for the most part, in the Sh.; but in the Sh. these plural pronouns are suffixed, whereas in Oc. they are usually found separate, though sometimes by "printer's grammar" suffixed. Ef., mara, manga, manang, maro Mg., id.; Maori, ma; Tannese, mi. In all these m is the principal demonstrative; Heb. m, also plural. The Tannese use of m for plural is especially remarkable; it has been printed suffixed to nouns just as in Heb. In the My. the plural is often represented by doubling, or re-duplicating the noun; not only is re-duplication much used in the Sh. generally, but it is found used also in this particular way—*e.g.*, Assy., mami, waters; and Syr., doka doka, places, leson leson, tongues (Mark xiii. 8; Acts ii. 4).

2. In Ef. and Oc., as in Heb. and Sh., a noun is in the construct state when followed by a noun in the genitive or by a pronominal suffix, and exhibits also, to some extent, vowel changes connected with the throwing forward of the accent ("to which," in Heb., as Gesenius says, "is commonly given the name declension"). Thus, to take the Ef. word túo, foot, with suffixes, the accent is thus Shemitically thrown forward.

Tuóngu, my foot; tuongámi, our foot (ngami being a "grave suffix"); and, to give an example of vowel as well as accentual change, Ef., máta, eye—

Mitángu, my; mitáma, your; mitána, his eye; mitangámi, our eye. Before nouns, thus, mál, place, but, middle—

Mălē but, place of the middle; and so natamol, man; mĭta natamol, eye of man. Naturally there is not nearly the same fulness of declension by vowel and accentual change in Oc. as in Sh. In My. the rule is thus given by Marsden (in his Malay grammar), a name ever to be mentioned with respect by a student of Oc.—"The most general rule, but admitting exceptions as will hereafter appear, is, that upon annexing a particle, the long vowel in the first syllable of the primitive, if a dissyllable, or, if a trisyllable, in the penultimate (the situations where they usually occur), becomes short, and the short vowel (expressed or understood), in the second or last syllable, becomes long . . . bīnĭ (I omit his Arabic characters), wife, with nia (nya), becomes bĭnī-nia, his wife." As in Sh., in some cases the noun in the const. state differs only by its position from the noun in the absolute state, so, perhaps, more frequently in Oc. But we have traces in Oc. of Sh. grammatical forms now no longer in living use, but regarded as parts of the root. Thus, to take the Heb. pah or fah, fem., side; const., peth or feth (pet or fet), we have it in Ef. fā or va, side, and const., fit or vit (always in const. in Ef., as fitina, his side; fiti natamol, side of man). Now, this form was not only const., but const. fem., and exhibits in Ef. all the original changes of case and gender, and, it may be added, of number, for this is the common, the universal Oc. word denoting four, Ef., bāt, pāt—*i.e.*, literally and originally, as will be explained under the numerals, sides or quarters, of which there are four, hence four. It is the plural of *pah*, a side or quarter. I could give other examples, and hundreds of such relics are waiting to reward the diligent student of Sh.-Oc. There is a peculiar redundant Syr. idiom found in Oc. Thus (Acts iv. 35) "apostles' feet," literally, feet of them the apostles. So (John xviii. 10), "his ear the right." Ef., talingena ni matua, his ear the right, is exactly analogous. This idiom is common in Fiji and Madagascar. Corresponding to Syr., Ch., d, Assy., s, signs of genitive, we have Ef. and Mg., ny, ni.; Java, ne, &c., &c., all of which Sh. and Oc. are to be found in §1. I need not say that in both Sh. and Oc. the relative pronouns were originally demonstratives.

3. In Oc. we have nouns of the type of Heb., ab, Ef., ava, ab; formed from verbs by a change of vowel, as in Sh., thus --Ef., bēs, a prey from bass, to snatch, like Heb. biz from bazz, Ef., tīko, a pole (thrusting), from taka, to thrust, &c., &c.; and formed from verbs, as in Sh., by attaching particles, thus—Ef., moru, Heb., ma'rah, a hole, is formed from the verb by prefixing the demonstrative m (§1); so Ef., mwit, Heb., ma'teh, a covering. Usually Ef. and Mg. prefer ni, ny, and My., ka, to m. A kind of verbal noun is formed universally in Ef., Tannese, My., and Mg., by suffixing n to the verb: the n in Heb., korba*n*, an offering, is the same n used in the same way.

§8. The Verb. The late Bishop Patteson thought that the Oc. tense usages threw light upon the perplexed subject of the Sh. usage, and wrote a book on the subject, which I have not seen. To express the tenses in Ef. auxiliary verbs are used. This usage had already become common in Ch. and Syriac, the verb substantive, future or preterite, with the participle of any verb, denoting the future or past tense. In Ef. the verb *to be* is ba or bi, fa, fi, future wo, fo, or o; An., pu; Mg., hi or ho; Heb., havah; Ch., id.; and the Syr. often dropped the initial h. The Ef. wo is used before a verb to denote the future exactly as the Syr. 'wu—

e.g., Acts vi. 4; Dan. ii. 43. This Ef. verb substantive and the next mentioned are perhaps the only ones that have preserved their original Sh. futures; in another Ef. dialect mi is used as v.s. instead of bi, future mo (*vide* above, Voc., 262), used for wo, fo, o, with all verbs; corrupted to ma in Tagala and Mallicollo. This ma, mi, am, &c., is the most prevalently used v. s. in Oc. as a kind of redundant auxiliary of the present tense—*e.g.*, it is thus prefixed to almost every verb in Mg., My., and Tannese, and to a good many in Ef.

The commonest way of expressing the future in Ef. is by prefixing a conjunction to the above wo, fo, or o; and this is exactly analogous to what was done in Ch.—*e.g.*, in the passage above cited (Dan. ii. 43), the Syr. expresses the future by 'wu, without a prefixed conjunction, but the Ch. prefixes the conj. l = that. The Ef. conj. = that, in order that, to, is ki, so Raratongan; Heb., ki. The Arm. equivalent of ki is d, di. As l is used before the future of the verb subs. in Ch. to denote the future, so k, ki in Ef., and so t in Tannese. Like the Syriac, the Mg. does not thus use a conjunction.

This conj. alone in Ef. put before any verb gives it the force of a subjunctive, optative, imperative, precative, or infinitive, according to the context or design of the speaker: so the l Heb. and Ch. just mentioned was used in Sh. As in Heb., when one verb follows another, according to a frequent usage, the second is in the infinitive, with or without this conj. prefixed to it, so exactly in Ef. The Syr. m forming the infinitive is the Fiji *me*, doing the same; and also, like the Ef. ki, forming the imp. and subjunctive. We should, therefore, expect to find that ma (Sh.) had anciently been used, not only as a demonst. and interrogative pronoun, but also as a conjunction, like the English *that;* accordingly we find Assy. "ma, conj. that" (Norris' *Assy. Dict.*, s. v.).

I have already spoken (above) of the formation of verbal substantives.

The simple verb in Ef. is either in the present or the past tense, according to the context and intention of the speaker, and often no auxiliary of the past is used. Sometimes, however, the v. s. ka (cf. its use in Maori), Heb. chayah, is used like the cognate word in Syr. A pluperfect is formed in Ef. by suffixing to this ka (which may be regarded as a preterite), another verb subst. i, Heb. hih (hayah), thus, kai (ka i): so analogously a Syr. pluperfect is formed by putting the cognate verb subst. after a preterite.

The passive. Gesenius says of the Heb. (Paul part.) that it "is probably a remnant of a lost passive form of qatal," and remarks that "in the Aramæan the passives of Piel and Hiphil are in like manner lost, except in the participles." Now, this shows a tendency to lose passives considerably developed even in ancient Sh. In the Oc. we naturally find this tendency carried further. Instead of the ancient passives we see in Ch. and Syr. substitutes consisting of a syllable ath, eth or ith (cf Arb. t, Conj. V.) prefixed to the active, which syllable is probably originally the verb subst. ath or ith. Accordingly we find the ethpeel, ethpaal, ethtaphal, and eshtaphal "conjugations" having a reflexive or reciprocal as well as a passive signification. What we find in Oc. is exactly analogous; but, first, it may be noted that of the original Sh. passives there are only traces in Oc., thus, Ef. bārua, to be clear of, free from; Heb., bārua (Paul part. of bara) which, in Arb., means to cut, plane (cf. Voc., 179). The later Arm. method of indicating the passive by prefixing a verb subst. we find well represented and in living use, thus, ta—perhaps the Ch. ita (itha), cf- Arb., tawa (*vide* Voc., 296)—ma, and bi, in Ef.; and di (Ef. ta), tar, Heb. dur, and ka (Ef. aux. verb) in My. So in My. ma and be are used before instransitives, as in Ef.; and bar, Eth. nabar, to dwell (*vide* Voc. above, 55.)

These, or some of them, as Ef., bi, fi; Sam., fi; Mg., fa, are also used in a reflexive or reciprocal sense; and sometimes these particles, like the Arm. ath, &c., are merely intensitive.

The intensive effect is also secured by re-duplication, as in the Sh; in My., as Crawford (My. Gr.) says, "by the simple repetition of the radical;" so also in Ef., where, however, as well as in Po. and My., the radical is sometimes abbreviated according to the following rule, taken from Sayce's *Assy. Grammar*:—"When a monosyllable is repeated the last consonant of the first syllable is generally assimilated to the first consonant of the second syllable," as kakabu for kabkabu. The same thing is found very prevalent in Oc., as a glance at any respectable vocabulary will show (*vide* for examples Voc., 49, 54, 150, 235, 256). This is simply the Pilpel conjugation, which, as Gesenius says, is analogous to Piel, and which is in living use every day all over Oceania.

Of Piel and Hiphil we have traces in Oc. (*vide* for examples Voc., 103, 112, 118, 159, 173, 234, 50, 245). They are no longer in living use. The Oc. causative is formed by prefixing ba or baka (explained Voc., 50) to the verb. Mg., ampa. Ero., ampi (m euphonic), seems to be the original Sh. Hiphil or Aphel of ba, and prefixed to verbs, denotes *to make to come to be,* what the verb signifies. The My., and sometimes the Ef., forms a causative by suffixing to the verb *kan* or *i*. These are simply epenthetic demonstratives, as already explained above.

Here note a curious example that may throw light on a word occurring but once in the Bible, and whose meaning is disputed—the word charak (as to which see Ges. *Dict.*). Ef., karák, to catch, seize, lay hold upon, more especially by clasping or becoming intertwined with, to catch and cling to, and to seize in order to slay (Voc., 172).

§9. ADVERBS. There are certain adverbs in Oc., as in Sh., consisting of the particle k, as, prefixed to a demonstrative thus, kasa, ngasa; so; Heb., kazeh: ku, ngu (k*u*a); so; Heb. koh (from kehu, Ges.): ngaku (kaku); so, thus; Heb., kakah: kĭte; Ch., kĕti (or kĭte); as, as if, when, &c.

2. Certain demonstratives are used interrogatively, as follows:—Se? we or wabe? sabe? wabe? &c., where? Mg., aiza? Sam., o fea? My., mana? Ngasa (kasa), above, with na prefixed, in Ef. means when? Sam., afea? Bia or bisa, how many? Mg., firy? Sam., fia? My., birapa? In Heb. how many? is kemah? to which is analogous Tannese kefa only substituting √ f, for √ m (*vide* §1).

3. Certain demonstratives are used as adverbs of affirmation, as ia; Mg., eny; Sam., io; My., iya; so the Heb. hua, &c., means not only *this,* but sometimes *it is,* &c.

4. Adverbs of negation. The Shemitic negatives are usually formed from verbs signifying to be void, null, to be empty, &c.; Ef., ta, ti, tu; My., same; Heb., t*a*hh (whence tohu, Gen. 1.), to be waste, empty. Cognate to this is Heb. shah, and the Santo negative is sa; Mg., tsy. Heb., *all* is described by Ges. as "a verb having the force of nothing, emptiness," whence the common Heb. negative la, which Ges. says was "anciently pronounced lē;" the Sam. negative is lē. Another negative occurs in My. and Tanna, bu or pu, and the Arb. verb bahi signifies "to be void and empty." Ef. e, or i (Voc., 25); Heb. e, is from un or in, according to Ges., which signifies nothing, negation: in Api, i, as in Eth. and Amh., is used before the verb. As in Arm. (Ch. and Syr.) a verb substantive is suffixed to the negative, forming a word

literally meaning *it is not*, lath, leth, so in Oceanic, thus—Ef. tika (*vide* Voc., 137, for ka, *is*); My., tiada, tada (ada, *is*, Arm. ata, or atha; Syr. lath is formed exactly like tada, with same verb substantive); My., bukan (kan, *is*; Arb., kan, to be, used as an auxiliary verb); Mg., tsia (ia, Heb. hih or hayah, to be); Ef., ewo, or awa (wa Voc., 116, *is*).

In Efate and many other Papuan languages a demonstrative is placed after the verb to emphasise the negative that is before it. This demonstrative in Ef. is mau (ma u), Futuna, ma. In Amharic, mo is constantly used in the very same way (*vide*, *e.g.*, Jno. i. 5, 8). This is all the more striking as it is the very same demonstrative that is thus strangely used in places so widely apart as the New Hebrides and Abyssinia.

5. The following are demonstratives used as expletives:—My., pun; Ch., pun or pon. Ef., la; My., lah (very much used); Arb., la; Heb., lu.

§10. Prepositions. Mg., amy, "the only preposition in the Mg. language," "from, with, to, &c.; "its precise meaning is determined by the verb that precedes it;" Heb., 'am or 'im. Ef., ki.; My., ka.; Heb., k(e).; Assy., k(i); Amh., ka.; Heb., k, prob. from ki (*vide* Ges. Dict., s. v. and Gr., §118, 3, Rem.); as, as if, according to, of, from, by, with, to (Amh., Jno. i. 15). My., pada; *to*, &c.; Heb., ba, 'ad. Ef., baki (ba ki).; My., bagi (or baki); to, unto.; Heb., ba ki (same as 'ad ki). My., ulih.; Java olih; for, from; Heb., 'al.; An., ehele, to, from, Heb., 'al.; Ef., ole, for, on account of, Heb., 'al.

§11. Conjunctions., Sam., Ef., ma, *and*; Assy., ma; Amh., mo. Ef., ngo (ko); Mg., koa; also; Heb., koh; so. My. joins the two foregoing, thus—maka, literally, and-so, a, word which begins nearly every sentence in My., and is often untranslatable. Ef., k, ka, nga, that, in order that, but. Heb., ki. Ef., te, that, in order that, because; Ch., di. Ef., kin, but; Amh., gin. An., par; Ero., wor; that, in order that; Heb., 'ăbūr.

§12. Interjections. Ef., na! Heb., na! Ef., mo! Heb., mah! Arb., ma! Ef., wana! Heb., hineh! Ef., ita, come! Common Oceanic: Heb., eta, imperative of atah, to come, go. Ef., ito, farewell!* (go!); Heb. imp. of atah. Ef., ako! exclamation of mourning, pain; Heb., akah, ekoh!

* Cf. Arb. "wada', farewell."

13. The numerals.

1. Tesa, Ef., Sam.; Assy., edisu.

Fiji, edua; Assy., edu; Amh., andy, &c., &c.

2. Ef., trua, rua; Mg., roa, &c.; Ch., trī.

3. Ef., tolu; New Guinea (one dialect), told; Mg., telo, &c.; Syr., tholth, tolt.

4. The Oc. four, like the Sh., is a word originally meaning side; then, because there are four sides to a square and four principle points of the compass, it came to denote four. This word in Ef. is bate, pāte, plural of pah (Heb.), as already explained*, and it is universal in Oceania; Sam., has the sing., fa: Mg., fatra; My., ampat, pl., as in Ef. Pah is thus explained Ges. Dict.:—" 1. A quarter of the heaven, prop. wind (?), so called from its blowing. Compare in Targg. arba' ruchin, four winds; for Heb., arba't kinpot haaretz . . . fet yam, the west quarter (Josh. xiv. 14); fet tzafon, the north quarter (Ex. xxvi. 18, 20.) Hence—2. Side, region," &c. The Sh. arba' four is analogously from reba', "a side (one of four sides). The word so used is found in Abyss. (Arkiko), as ubah, four; Savu (Oc.), uppah.

5. The Oc. numeral five is a Sh. word (explained Voc. 29); meaning hand, which it also means in Oc.; Ef., lima; Mg., dimy; Po., rima, &c., &c. (the l, d, r being articles).

10. Bulu, pulu, folo, hul, &c., &c., is literally a gross; Heb., yabal, to grow, flow, whence bul, produce, wealth.

6—9 are formed† in Oc. by attaching a demonstrative or the numeral five to the first four numerals, so that 6 is literally 1 + 5 or 5 + 1. The same thing is found among the Abyss. Sh. languages.

1000. Mg., arivo; My., ribu; Heb. and Ch., ribo, a myriad.

I shall now conclude by remarking—first, that this discovery clears up the hitherto impenetrable mystery surrounding the origin of Oceanians. The Sh. language could only have been carried into Oceania by Shemites from the Sh. mainland. The numeral system of Oceania, and the relics of ancient civilisation found in the islands, prove that these Shemites belonged to an ancient powerful commercial Shemitic state or empire that lasted for ages, and navigated the Indian or Southern—that is, the Oceanian—seas. That empire we find at the head of the Persian Gulf, and it matters little whether we call it Chaldean, Babylonian, or Euphratean. It was the commercial meeting place of East

* §7, 2. † Usually, not always.

and West in the ancient world. It was from there that the Phœnicians, and Hebrews (in the person of Abraham), emigrated to the West. The Chaldean ships sailed the Oceanian seas, just as did the Phœnician the Mediterranean; and as the Phœnicians planted colonies on the Mediterranean shores, so, but with more lasting effects, did the Euphrateans in the multitude of the isles. Not only did they establish secondary commercial states in Southern Arabia and Abyssinia, but they sowed men in Madagascar and Malaysia. The negro element among the Shemitic-speaking Oceanians can be accounted for best in this way. They were in the homes and ships of the ancient Shemites as slaves, and learned their language just as the American negro slaves learned English. There are no negroes in Asia. Ancient history is not altogether silent, but seems to stand with uplifted hand and parted lips, and just stops short of uttering the whole secret. Herodotus gives a celebrated account of a voyage round Africa undertaken by Phœnicians for Pharaoh-Necho, king of Egypt; and it is not to be supposed that the circumnavigators of Africa were ignorant of Madagascar. Isaiah mentions China by name. I have only further to mention the magic word Ophir, to which Solomon's fleet went on three years' voyages, and which Josephus declares to be Malacca. These, the first ocean voyages recorded by history, were performed in Oceania and by Shemites, whose ships, according to so sober an authority as Chambers' *Encyclopædia*, may have gone as far even as the Spice Islands, near New Guinea. Finally, the fact that Madagascar and Easter Island, or Efate, are peopled by the same race cannot be accounted for so well on any other hypothesis; and, if their language is Shemitic, as I think I have proved, can be accounted for on no other hypothesis whatever.

In solving the problem of the origin of the Oceanians there are four groups of facts, or possible facts, to be considered and compared; and the consensus of these, so far as they are obtainable, gives the highest certainty possible. These are the philological, ethnological, geographical, and historical. It may be said that, strictly speaking, there are only two theories possible, that Oceania has been peopled from South-Eastern Asia, or, as I maintain, from South-Western Asia, or the Persian Gulf. You may assert the former of these, but philology is totally against it. History, so far as it speaks, is totally against it, for it shows that the Malays emigrated to Malacca from the islands, and not *vice versa.* Ethnology gives no utterance for, and unambiguous utterance against it, inasmuch as it cannot account for the negro element of blood, but not of language, among the Oceanians, and it cannot account for such facts, for instance, as that the Tannese and some others in the New Hebrides dress their hair in the very remarkable style of the ancient Assyrians, which obtained among no other Asiatic people. But I refrain from a comparison of customs. Geography, which at first sight appears to be for it, turns out, on closer examination, to be more against it, inasmuch as it utterly fails to account for the peopling of Madagascar, which the other theory most satisfactorily does. Therefore the theory of the peopling of Oceania from South-Eastern Asia fails from the utter want of evidence to support it. And I have already shown that all the evidence obtainable, philological, ethnological, geographical, and historical, harmonises into a body of proof irresistibly establishing that South-Western Asia, or the Shemitic mainland of Oceania, at the time when the Shemites were supreme in civilisation, navigation, and commerce, was the home from which hived off the people whose descendants we now find inhabiting these isles of the sea.

Secondly, this discovery has an important bearing upon the evolution theory: in so far as that theory endeavours to draw support from the existence of savages, and the supposition that they are descended—or shall I say ascended? —from "hairy quadrupeds," it tends utterly to overthrow it; for it shows, as to one of the greatest bodies of savages, that they are descended from the most renowned and civilised people of antiquity.

Thirdly, I consider this discovery more important on the whole than that of the Assyrian or Euphratean inscriptions, deciphered of late with such marvellous ingenuity. In these inscriptions we have only a fragment of the dead language of a lost people, but very valuable as throwing a happy light upon historical parts of Holy Scripture. But here we have, so to speak, that people found, their language full-orbed and in all its living vigour. It will probably be found that every recorded word of ancient Sh. has its cognate in Oc.; and, in investigating and illustrating the meaning of the words and the grammatical usages of the Hebrew and

Chaldee of the Bible, it will become necessary henceforth to refer not merely to the Arabic and Syriac, Phœnician and Ethiopic, but also to the Oceanic. Moreover, as men and as Christians, we owe a duty to these men and women of the isles of the sea, and it is to be hoped that the discovery of their high birth, of their ancient and noble ancestry, and remarkable and sad history, will engage us to the performance of that duty with more interest and sympathy, even as by the increase of knowledge it gives us for performing it additional means of the highest value, and greater power.

Fourthly and finally, I invite other workers into the field. There has been discovered a mine of inexhaustible wealth. Let all who will come and dig. A wealthy gentleman of New South Wales some time ago fitted out a scientific expedition to New Guinea, and for this his name is worthy to be held in high honour as long as Australia shall exist. The "Cheviot"—that was the ship of that expedition—now lies a dismasted hull in Havannah harbour, Efate,* within sight of the writer's residence. Let some such gentleman, or scientific body, send an expedition to Oceania and the Shemitic mainland, from which its population originally came, to gather knowledge, philological and ethnological, in accordance with the discovery announced in this paper, and the results, as certain as harvest to the husbandman, will be altogether adequate and worthy, in a great and sensible addition to the permanent and public stock of wisdom and knowledge.

ABBREVIATIONS:

Oc., Oceanic	Sh., Shemitic
Ef., Efate	Ch., Chaldee
My., Malay	Heb., Hebrew
Po., Polynesian	Syr., Syriac
Mg., Malagasy	Arb., Arabic
Tah., Tahitian	Amh., Amharic
Sam., Samoan	Arm., Aramaic
An., Aneityumese	Eth., Ethiopic
Ero., Eromangan	Abyss., Abyssinian
Mall., Mallicollan	Assy., Assyrian

* Efate, Fate, or Vate, was discovered by Captain Cook, who called it Sandwich Island: it is about the middle of the New Hebrides Group.

Art. XXI.—*On the Occurrence of Alcohol and Idoform in a supposed Non-Alcoholic Wine.*

By Mr. E. S. Marks.

[Read 16th November, 1882.]

Art. XXII.—*Patent for "Improvements in Contrivances for Varying the Gauge of the Wheels of Rolling Stock for Rail and other Permanent Ways."*

By D. Anderson.

[Read 16th November, 1882.]

The nature and working of my invention may be described in these terms, viz.:—

The axle is made with a solid collar in the centre. On each side of this collar is a sleeve, to the outer end of which the wheel is fastened, and these sleeves are drawn out *from* or *in to* the solid collar by right and left-handed screws fastened to a double platform, on which the wheels rest in recesses shaped to their bottoms. On the inner end of each sleeve is a flange, which is held by a hinged clamp on each side of the solid collar. In these hinged clamps are recesses for the reception of the flanges when the clamps are closed. The hinged clamps are opened and allowed to fall back by the partial unscrewing of two nuts, working on two hinged bolts, thus enabling the sleeves with their flanges to slide along the solid axle, either away *from* or *to* the solid collar, according to whether the wheels are to be adjusted to run on a broad or a narrow gauge.

A truck with its load by this method, and with the aid of machinery to work the right and left-handed screws, can, without unloading, be made to run on either a broad or a narrow gauge in a few minutes. When the clamps are closed the nuts are screwed home, and a split key or pin is inserted through the bolt, thus rendering it impossible that they can get loose or shift in the slightest degree. If preferred, Ibbotson's safety nuts can be used without the split pin.

By my patent the inconveniences and delays in transmitting goods over country laid down with lines of different gauges can be reduced to a minimum. Should the Governments of Victoria and New South Wales adopt my plan, goods can be carried from Melbourne to Sydney as quickly as if the two lines were of the same gauge, allowing for a detention of, say, one hour at the break of gauge if one truck at a time is altered by my platform, or half an hour only, if each truck be provided with a platform.

If machinery be used to work the right and left-handed screws, I estimate that a truck can be altered from the broad to the narrow gauge, or *vice versa*, in five minutes. If a platform be provided for each truck, any number can be altered, after the hinged clamps are opened and thrown back, in the same time as one, by the aid of an engine in the pit working an endless cogged chain which would turn all the right and left-handed screws simultaneously.

Between Victoria and New South Wales I propose using an axle of 5 inches diameter, and as my sleeves are 1¼ inches in general thickness, I add to the strength instead of diminishing it. The first axles made according to my patent will be more expensive than those now used, because the sleeves and hinged clamps are difficult to make; but as they are practically indestructible, it will only be the first lot that will be expensive. As the sleeves are prevented by the feathers from revolving on the axles, there will be no friction, and when the journals of the solid axles are worn out the same sleeves and hinged clamps can be used for the new solid axles required. The forging of the solid collar on the axle will be troublesome, but I think it better to do this than risk any failure. At the same time, I consider that were the centre of the axle recessed a little all round, a collar in two parts, fastened together by strong riveted bolts, would answer the purpose equally well, and would, of course, be less expensive. This, however, is for the consideration of the Governments who adopt the patent. In bringing dead meat from the interior of New South Wales to Melbourne my invention gets over the present difficulty of break of gauge, for it can be placed in refrigerating cars and sent to Melbourne without re-handling, thus avoiding all risk of thawing by being exposed to the warm air, as must follow if the contents of the cars are transferred from New South Wales' to Victorian trucks. Again, in bringing coal from New South Wales to Victoria, all the trouble, expense, and loss of time in unloading would be avoided. Provided that an axle according to my patent is made wide enough to run on the broader gauge, all that is necessary to enable trucks to run on a narrower line is to shorten the sleeves and make the hinged clamps wide enough to carry recesses to keep the flanges in position. As there is a difference of 6½ inches between the gauges of the Victorian and New South Wales lines, I make my solid axle 5 inches in diameter, being half an inch thicker than the present Victorian axles, in order to allow for the overhang. Between New South Wales and Queensland, the difference of gauge being 14½ inches, I propose making the solid axle 5½ inches thick. For South Australia and Tasmania, where the gauges are 5 feet 3 inches and 3 feet 6 inches, the difference being 21 inches, I propose making the solid axle 6 inches. The sleeves and hinged clamps, however, will be of the same thickness in every case. It is reasonable to suppose, however, that if the axles are made of the very best steel procurable, these dimensions may with safety be lessened, and the cost, as a consequence, diminished. Experience only will prove this, and the various Governments must decide upon these points after trial. My invention can be applied to passenger cars as well as goods trucks; but as persons can walk from one train to another in a few minutes, there is no absolute necessity for it. Each passenger train may, however, be provided with luggage trucks placed upon my axles, and these can be altered to the broad or narrow gauge as required. The alteration of brake fastenings and blocks can be effected in a variety of ways, and I show a simple and inexpensive one on my model.

Letters patent have been granted to me for Victoria, New South Wales, New Zealand, and the United States, while they have been applied for in the other colonies, Great Britain, Canada, India, and most of the European States. Plans were sent to England on 5th September last for the manufacture of two sets of axles and wheels, which ought to arrive in Victoria in the latter end of March next, when I hope to get permission from the Governments of Victoria and New South Wales to run a truck, provided with my axles, from Melbourne to Sydney and back again. No alteration of truck will be required, as my axles can be placed under any of the Victorian ones now in use.

SPECIFICATION

OF

DAVID ANDERSON, of Fairview, Stawell, in the Colony of Victoria, Gentleman, for an invention entitled

"IMPROVEMENTS IN CONTRIVANCES FOR VARYING THE GAUGE OF THE WHEELS OF ROLLING STOCK FOR RAIL AND OTHER PERMANENT WAYS."

MY invention consists mainly of certain improvements in railway and other rolling stock, by which the gauge of the wheels may be adjusted; and, secondly, of machinery whereby such alteration or adjustment of gauge is effected.

The first part of my invention consists of a peculiar construction of the axles of rolling stock for rail and other permanent ways in which either wheel is keyed to a sleeve, the inner end of which terminates in a flange. This sleeve slides over and upon the axle and the feathers thereon. The axle I make with a solid collar in the centre, and on either side of such collar I place a clamp or hinged collar having two or more recesses or hollows to fit over the flange of the sleeve and a strong hinged bolt to tighten said clamp thereon. I bolt both clamps or hinged collars together through the solid collar of the axle.

The second part of my invention consists of a certain combination and arrangement of machinery in which a sole plate carries the bearings for two sets of rollers. Each set consists of two rollers upon which travels a platform, the upper side of which is recessed to the shape of the tire of a wheel, or carries a rail. The underside carries a nut (right or left handed as the case may be) in which one end of a right and left handed screw works. This screw has a thrust bearing in the centre of the sole plate, and is provided with a collar having sockets for a crowbar or other means of turning it.

In order, however, that my invention may be more perfectly understood, I will now describe the same with reference to the accompanying drawings, in which Fig. 1 shows a side elevation, partly in section, of a pair of wheels, provided with my improved axles, resting in the recesses upon the platforms of my improved machinery as they would be just previous to narrowing their gauge. Fig. 2 is an end elevation of the same. Fig. 3 a plan of the machinery alone, and Figs. 4 and 5 detail views of the hinged clamps.

AA are the wheels which may be of any description so long as their bosses A1 are large enough. B is the axle with solid collar B1 in the centre. B2 are steel feathers properly secured to said axle. C are the sleeves terminating in flanges C1. DD are the clamps or hinged collars having two recesses D1 and D2 in each. D3 are the hinged bolts having plate washer D4. D5 are the bolts through the clamps and the solid collar of the axle and having connecting plates D6 at either end. E is the sole plate of my improved machinery firmly bolted to a solid foundation, and E1 and E2 are the two sets of rollers thereon. F are the platforms carrying recesses F1 and nuts F2. G is a right and left handed screw with turning collar G1 and thrust bearing G2.

The mode of operation is as follows:—When it is desired to use the rolling stock of a rail or other permanent way upon another way of different gauge, my improved machinery is placed where the break of gauge occurs. To transfer the rolling stock, the rails or recesses F1 on the platforms F of such machinery are set by means of the screw G to the gauge of the line on which the stock is. A vehicle provided with my improved axles is then pushed upon such platforms, the clamp bolts D3 of such axles unscrewed so as to admit of the clamps being opened on their hinges D5, so freeing the flanges C1 of the sleeves C, to which the wheels A are keyed. The rails or recesses on the platforms are next adjusted by means of the right and left-handed screw G to the gauge of the line upon which it is desired to run the vehicle. The flanges C1 of the sleeves C on the axles should now fit in another recess D2 in the clamps, which are closed and tightened up as shown in Fig 4, and the vehicle then moved on to the second line.

In the drawings illustrating this invention the vehicle is shown at its widest gauge and with only one vacant recess in each of the clamps on the centre of the axle, thus admitting of its alteration to one other gauge only, but of course the number of these recesses might be increased and the length of the sleeve altered so as to admit of its adjustment to as many gauges as may be required.

Having thus described the nature of my invention and the manner of performing same, I would have it understood that

WHAT I CLAIM AS MY INVENTION IS:—

First, constructing axles of railway rolling stock with an extensible sleeve or sleeves to admit of the alteration of the gauge of their wheels.

Second, constructing such axles with a solid collar in the centre and with a hinged clamp on either side having recesses for receiving and holding the flanges on the inner ends of the axle sleeves substantially as herein described and explained.

Third, The combination of the sole plate E, the rollers E2, platforms F having recesses F1 (or their equivalent in the shape of rails) with a right and left handed screw G, turning collar G2 and thrust bearing G3, in the manner and for the purpose herein described and explained.

D. ANDERSON.

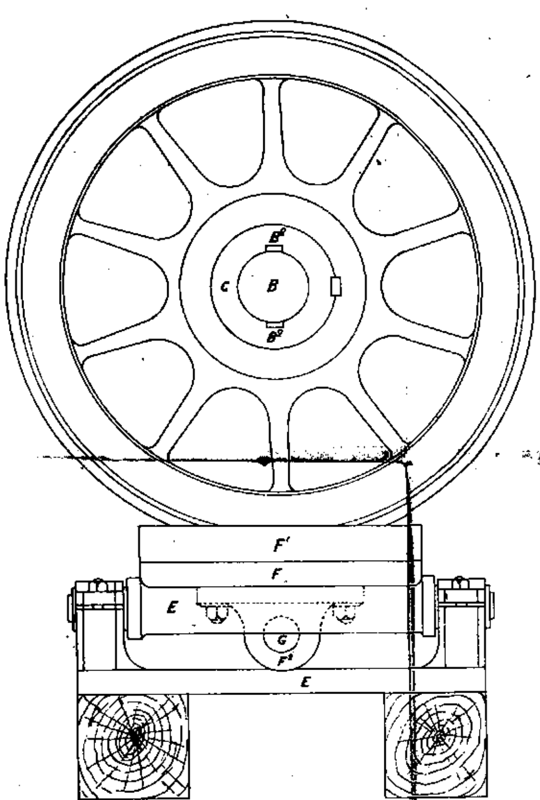


Fig: 2.

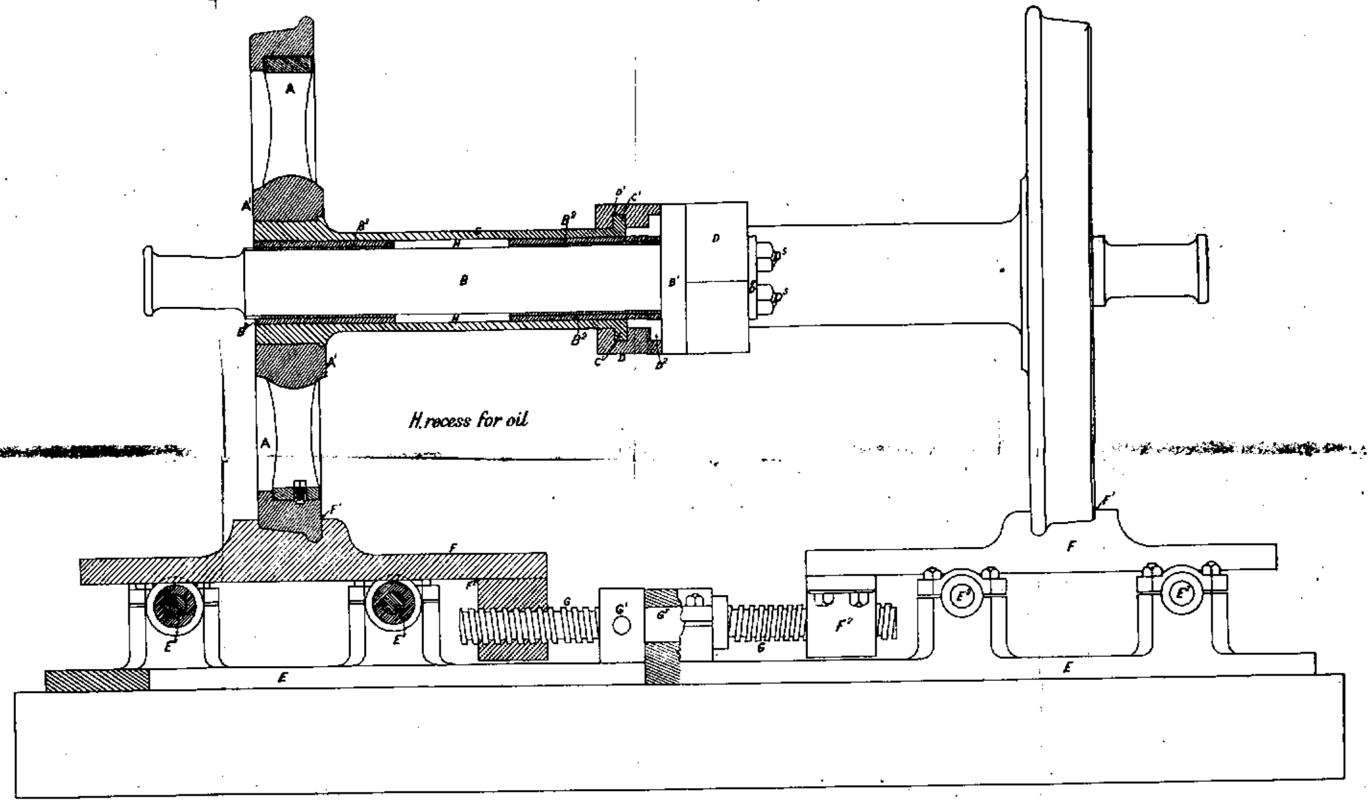


Fig: 1.

—D. Anderson's Patent—

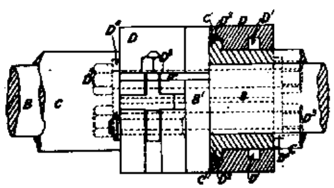


Fig: 4.

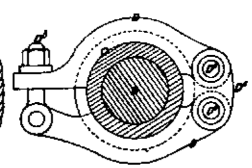


Fig: 5.

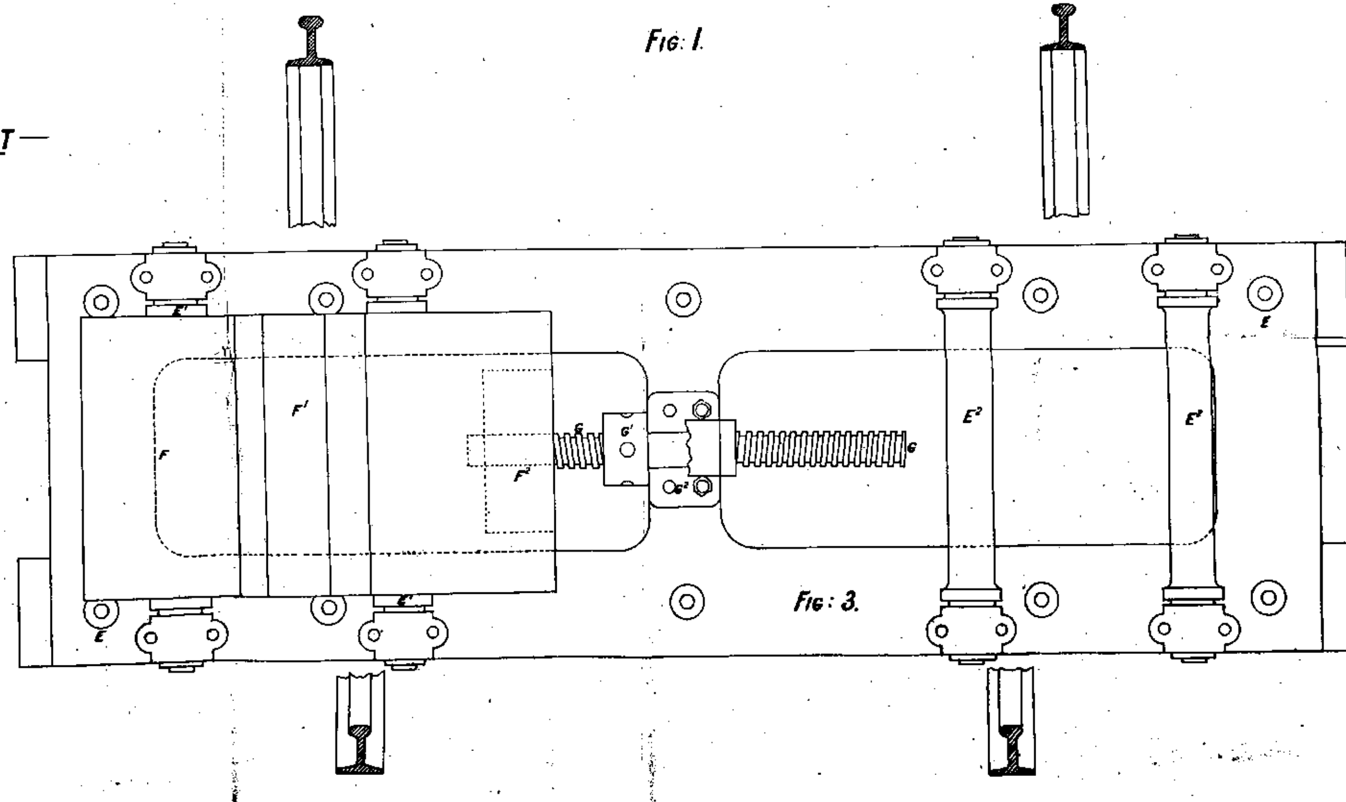


Fig: 3.

Art. XXIII.—*On the Lateral Stability of the Victoria-street Bridge.*

By Professor Kernot.

[Read 16th November, 1882.]

Numerical Particulars Relative to the Victoria-Street Bridge.

Height of highest pier ...	86 feet from rock foundation. 74 feet from bed of river.
Breadth of base, extreme ...	19 feet.
Breadth to centres of cylinders	16 feet.
Weight of highest pier and corresponding portion of superstructure	105 tons.
Moment of stability, $105 \times \frac{18}{2}$ =	945 ft. tons.
Overturning wind pressure ...	69 lbs.
Moment of stability if provided with additional cylinders on the down-stream side only	On up-stream side, 2625 ft. tons. On down-stream side, 1574 ft. tons.
Overturning wind pressure ...	North, 192 lbs. South, 115 lbs.

The Victoria-street bridge occupies a peculiarly difficult site, one bank of the river being unusually high and the other comparatively low. To overcome this extreme difference of level it was necessary to adopt an unusually high bridge, and to place it upon a considerable slope. The funds available being very limited, it was not possible to adopt what may be called the heroic style of engineering, of which we unfortunately have so many examples in this country. The usual competition having been held a design was chosen, which happened to be the production of two young and comparatively inexperienced men; and the subsequent troubles have given rise to various remarks as to the undesirability of entrusting important designs to inexperienced persons. In reply to these remarks, it is to be pointed out that the choice of the design from a considerable number of competitors was made by experienced practical engineers, and the execution of the work supervised by a gentleman of high standing in the profession, and thus the responsibility was entirely removed from the shoulders of the original designers.

The engineer in charge of the execution of the work departed from the original design as far as the construction of the abutments was concerned, and a partial failure took place in this part of the structure. With the question of the desirability of this departure I do not propose at present to deal, but would merely say that the failure does not appear to me to be by any means as serious as it has been represented, or as similar movements in other structures with regard to which the public mind is at rest.

Before the failure took place the bridge was subjected to an unusually severe test by being traversed by the heavily-loaded drays carrying earth and rock from the cutting on the high side to the bank on the low side of the stream. Under this ordeal no sign of weakness appeared in the iron columns or girders.

On the occurrence of the partial failure of the abutments considerable alarm arose, and a Government engineer of high standing was called in to advise as to the remedy. This gentleman not only proposed a most complicated and costly reconstruction of the abutments, but went further, and condemned the rest of the bridge as unsafe under wind pressure, and insisted upon the width of the base of the taller piers being increased threefold. The arguments used in favour of this startling proposal were as follows:—

1. It was ascertained that on one occasion a wind pressure of 35 lbs. had been registered at the Observatory.

2. This pressure was multiplied by 3, giving 105 lbs. to the square foot as the extreme pressure the structure ought to be able to endure.

3. The moment of stability of the highest pier and corresponding portion of the superstructure was computed, and the ultimate overturning wind pressure determined as only 56 lbs. per square foot.

4. It was proposed to increase the width of the piers threefold in order to give the requisite resistance to wind pressure.

In conclusion, the case of the Tay Bridge was cited as an example confirming the preceding recommendation.

Let us consider the above investigation in detail.

1. The assumption that the bridge was liable to be exposed to a wind pressure of 35 lbs. per square foot is erroneous. No doubt such a pressure was once recorded at the Williamstown Observatory, which is excessively exposed. The bridge, however, is quite differently situated, and is protected on the north by a high range of hills. Whatever may have happened at Williamstown, the Victoria-street bridge is not likely to be exposed to a wind pressure of above 25 lbs., either from the north or the south.

2. The multiplying of the wind pressure by 3 involves a confusion between stability and strength. In a question of strength we need to allow a large factor of safety to cover the gradually weakening effect of a series of strains, each of which may be considerably less than what would be needed to cause immediate fracture. In the case of stability no such factor is needed, or as yet been proposed. If it takes a pressure of 35 lbs. to overturn a given object, a pressure of 34 lbs. may be allowed to act for ever, or may be exerted and removed a million times with perfect safety.

3. The calculation that makes the overturning wind-pressure of the structure only 56 lbs. per square foot is not a fair one. It arises from taking the distance between the centres of the cylinders (16 feet) as the effective base of the structure. As the cylinders are 3 feet in diameter the extreme width of base is 19 feet, and the effective width in view of overturning at least 18 instead of 16. Taking this into account, and calculating the weight and the area exposed to the wind with extreme care, I come to the conclusion the resistance to wind pressure of the highest pier is 69 lbs. per square foot, or 2·7 times the greatest possible wind pressure. Nor is this all. The adhesion of the concrete filling of the cylinders to the bed rock, the friction of the soil in which they are imbedded, and the assistance derived from the ends of the bridge through the medium of a wide and well-braced platform, constitute additional sources of stability, the effect of which cannot be exactly calculated, but which may at the most moderate estimate be taken as increasing the resistance to wind pressure to at least 100 lbs. per square foot. Thus

the bridge is seen to have most abundant stability against wind pressure, far beyond the practical requirements of the case.

As comparative examples confirming this view, it may be noted that ordinary chimneys have a resistance to wind pressure of from 20 to 50 lbs. per square foot, and that hundreds whose resistance is less than 30 have been standing for many years in positions far more exposed than the Victoria-street bridge. Further, that ordinary railway carriages have a resistance of in no case more than 55, and in many cases of less than 30 lbs., and yet have for many years traversed high embankments and viaducts in positions far more exposed than the structure in question, and that without accident.

In view of what has been above stated, it might appear unnecessary to refer to the proposed alteration. It is, however, a very singular fact that the recommendation greatly exceeds the requirements of the calculation upon which it is supposed to be based. Granting for the time being the 35 lbs. wind pressure as observed, and the desirability of providing a resistance of threefold the greatest force that can be brought to bear, all requirements may be complied with in a far simpler and cheaper way than that proposed. Instead of placing additional cylinders on both sides of the pier, as shown in Fig. 1, suppose we place them on the down-stream, or south side, only, as in Fig. 2. We shall find that the overturning wind pressures become 192 lbs. per square foot on the north side and 115 lbs. on the south; and as the greatest observed pressures are 35 and 23 lbs. respectively, it will be seen that in this way much greater stability might be obtained than the calculation requires.

A strong protest having been entered against the preceding proposals, a second engineer was called in, and he endorsed the recommendation to place additional cylinders on both up and down stream sides, but refrained from submitting any calculation, contenting himself with briefly expressing an opinion that it was desirable in view of floods.

This aspect of the question we must next proceed to examine, for it is manifestly conceivable that, though amply safe against wind, the structure might be dangerous when exposed to high floods. Particulars as to flood velocities and pressures are difficult to obtain, and consequently the only way to proceed is to institute comparisons with existing successful structures whose moment of stability does not exceed that of the bridge in question. On the Goulburn Valley railway, at Toolamba, is a very large timber bridge crossing the Goulburn. The highest pier of this structure is 69 feet high, and 27 feet wide at the base. It consists of redgum piles, driven through 7 feet of soft material, and then resting on the bed rock. At first sight the Toolamba pier seems much more stable than that at Victoria-street. But calculation tells a different tale. The former structure is composed of timber, a material which loses its weight entirely when immersed in water, while the latter is composed of iron and concrete, and will not lose more than one-third of its weight under similar conditions. Allowing for this circumstance, we find by a calculation, the details of which need not be given, that the moment of stability of the Toolamba bridge when the river is at high flood is barely half that of Victoria-street under similar conditions. As the Goulburn is a larger, deeper, and swifter river than the Yarra, and as the Toolamba bridge has already endured uninjured one very heavy flood, in which the floating timber formed a complete dam across the river, it follows that there are no grounds of apprehension at Victoria-street; and even if there were, additional cylinders on the down-stream side only would increase the resistance threefold, and render the bridge more than double as strong as the somewhat similar structures at Johnston-street, Collingwood, and Swan-street, Richmond. Thus the proposed alteration is seen to be as unnecessary from the flood as from the wind point of view.

The Victoria-street bridge question derives its importance from the fact that it is a point of contact and of conflict between two opposing schools of thought on engineering subjects. Those who belong to the old, or empirical, school, who hold that mathematical investigation is "mere theory," and that practice is the only guide, unanimously condemn it because it departs from the proportions to which they have been accustomed. Those who belong to the new and scientific school, who hold that the principles of statics are really and universally true, and constitute the essential basis of all sound engineering practice, approve of it because they find that its proportions throughout agree with the requirements of exact mathematical calculation; and the question before us to-night is, which of these opposing views is correct. If the recommendations of the two engineers who condemn the bridge are well founded, it will then follow that the principles of statics as laid down by all the authorities, and as taught in all our universities, are unreliable, and calculated to lead to serious errors when applied to engineering questions. If, on the other hand, the mathematicians are in the right, if the laws of statics are universally and practically true, then it follows that the engineers who have condemned the Victoria-street bridge are in the unfortunate position of being under a most serious misapprehension as to the correct mode of proceeding in the solution of the problems of engineering practice. Which of these two alternatives we are to adopt is the question I submit to the Royal Society to-night.

Fig: 1.

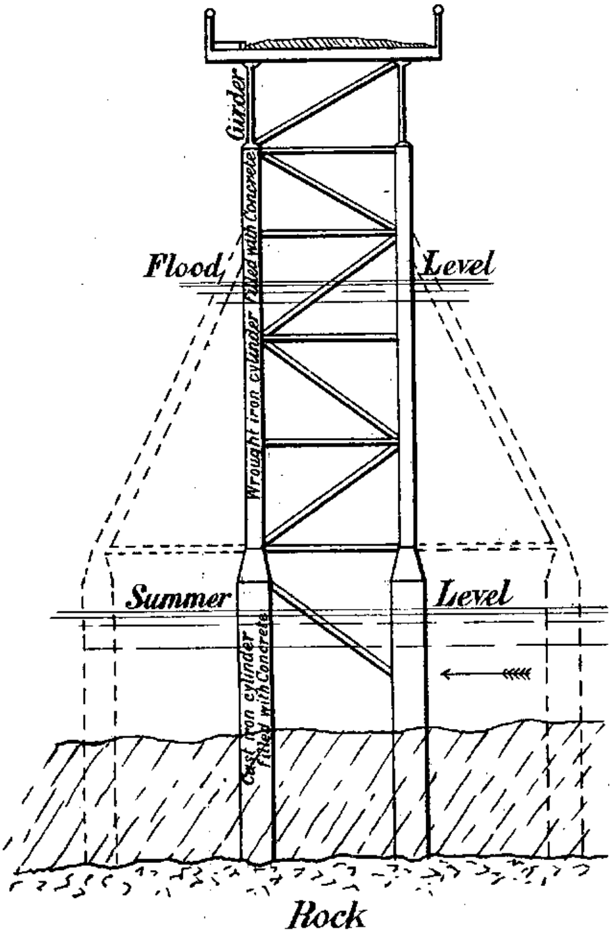
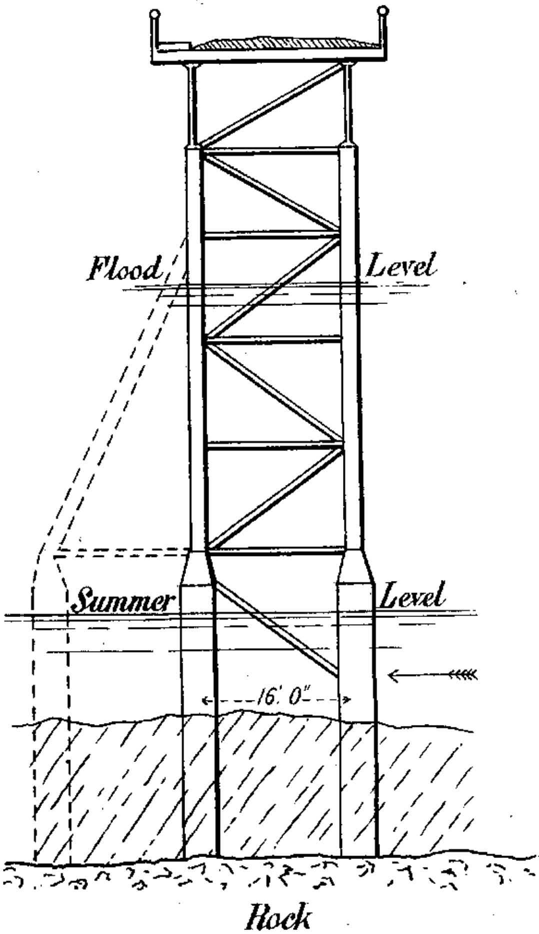

Girder
Wrought iron cylinder Filled with Concrete
Flood Level
Summer Level
Cast iron cylinder Filled with Concrete
Rock

Fig: 2.


Flood Level
Summer Level
16' 0"
Rock

ART. XXIV.—*Descriptions of New, or Little Known, Polyzoa.*

PART IV.

BY P. H. MACGILLIVRAY, M.A., M.R.C.S., F.L.S.

(WITH TWO PLATES.)

[Read 14th December, 1882.]

OF the species of Retepora described in this paper, three are new; three others have already been briefly described by me in the *Society's Transactions* for 1869. Two of these, *R. granulata* and *R. porcellana* (as *R. robusta)*, have since been more fully described by Mr. Hincks, in a valuable paper in the *Annals and Magazine of Natural History* for May, 1878. We have one or two other undescribed species, as well as *R. monilifera* (McG.), *R. phœnicea* (Busk), *R. tessellata* (Hincks), and what I believe to be *R. cellulosa.* Of the last, I have not had an opportunity of examining European specimens, but I expect to receive authentic ones soon.

Retepora serrata, n. sp. Fig. 4.

Polyzoary expanded. Fenestræ about the same width as the interspaces, or slightly wider. Cells much elongated separated by raised lines; mouth nearly circular, or oval, projecting forwards, with a small sinus below, and a fringe of about twelve short, pointed processes arranged round the margin. Ovicell rounded, smooth. A sessile avicularium, with a long, narrow, pointed mandible at the bottom of each fenestra, opening directly upwards. Back obscurely tubercular, strongly vibicate.

Of this species I have one perfect specimen, dredged off Port Phillip Heads in about fifteen fathoms. The entire specimen forms a small expansion three-quarters of an inch in diameter, curved on itself on one side, where it is attached to the calcareous tube of an annelid. The colour is leaden grey. The cells are elongated, narrow, slightly expanded upwards, separated by narrow raised lines. In the youngest the mouth is smooth, the lower lip straight, slightly hollowed, or with a slight sinus. The peristome is rapidly developed to form a serrated circle of small, sharp teeth, projecting forwards; at the lower part of this circle is a small sinus. The ovicell is rounded, projecting, smooth, and destitute of a fissure. At the bottom of each fenestra is a sessile avicularium, the rostrum with a tooth on each side behind the strong curved apex, the mandible long, narrow, curved, and pointed. There are a few other large avicularia, situated on mound-like elevations on the cells, and with spatulate, or linguiform mandibles. The back is obscurely tubercular, glistening, divided into numerous angular spaces by narrow, sharply-raised ridges; a few scattered, rounded avicularia about the edges of the fenestræ.

Retepora aurantiaca, n. sp. Fig. 5.

Polyzoary expanded, foliaceous, convoluted. Fenestræ elliptical, or oval, about the same width as the interspaces. Cells quadrate, separated by narrow raised margins; mouth rounded above, straight below, with a deep narrow sinus, on one side of which is a rounded avicularium; a long, jointed spine articulated on each side of the mouth; usually a round, vertical, or oblique avicularium on the front of the cell. Ovicell large, pyriform, with a vertical narrow fissure, wider above, and with thickened margins. Back strongly vibicate, granular, and with numerous, small, rounded avicularia, similar to the anterior ones, especially abundant near the fenestræ.

Dredged off Port Phillip Heads.

The largest complete specimen I have found forms a foliaceous, convoluted polyzoary, three inches wide by about two in the other diameters. The base of attachment is about an inch long. Some fragments indicate that it attains a still larger size. The avicularium on the front of the cell is by no means constant. The ovicells are abundant, and have a very distinctive appearance. It is of a beautiful orange colour.

Retepora avicularis, n. sp. Fig. 6.

Polyzoary expanded, curled. Fenestræ elongated, wider than the interspaces. Cells elongated, separated by distinct margins; mouth arched above; lower lip with a small suboral avicularium at the centre (frequently absent, and leaving a loop-shaped notch), on each side of which is a triangular projection pointing upwards; a long spine articulated on each side of the mouth. Numerous large avicularia, the rostrum elevated, and with strong curved beak, the mandible triangular and pointed. Ovicell rounded, widely open below, crossed by an obscure ridge. Back smooth, vibicate, with scattered avicularia, with triangular mandibles.

Off Port Phillip Heads.

Of this elegant species I have only one complete specimen. It is three-quarters of an inch in length, by half-an-inch at the broadest part, and forms a slightly convoluted, leaf-like polyzoary. I have also three or four other fragments, which all present the same character. The small, central, suboral avicularium, with the triangular process on each side, is very characteristic. In place of the avicularium there is frequently a loop-shaped opening, no doubt formed by the destruction or loss of the chitinous part. The ovicell also is very distinct from that of any other species, and the huge avicularia, situated on the front of many of the cells, form very striking objects.

Retepora porcellana, M'G. Fig. 9.

(*R. robusta*, Hincks, *Ann. and Mag. N. Hist.*, May, 1878.)

Polyzoary massive, expanded, convoluted, or calyculate. Fenestræ elongated, narrower than the interspaces. Cells separated by distinct raised lines, terminating superiorly opposite the lower part of the mouth; mouth arched above, straight or slightly hollowed below; lower lip entire, with (usually) an avicularium immediately below it; a spine articulated on each side; an elliptical avicularium on the front of the cell toward the lower part, directed straight or obliquely downwards. Ovicell rounded, smooth, entire, not much projecting; when young with a broad, short, vertical opening, which, as growth advances, becomes filled in, and in some cases forms a prominent ridge. Posterior surface obscurely granular or slightly areolated, traversed by numerous raised lines, and usually with one or more small oval avicularia situated on each part defined by these vibices.

Port Phillip Heads and elsewhere.

Varies a good deal in appearance, according to age, old specimens being very massive, the fenestræ shorter and interspaces thicker than in younger ones. The form of the lower lip varies; it is usually straight and entire, with a rounded avicularium immediately below; sometimes there is a slight fissure in place of the avicularium, and occasionally there is a fissure towards one side, and on the wider part of the lip an avicularium. In young marginal cells there is no appearance of any sinus. In one specimen, which I was inclined at first to refer to a distinct species, the fenestræ are very long, and are formed by the irregular anastomoses of branches from a main stem. The cells are longer, the separating raised margins not so prominent, the avicularia not so regularly placed, and many of the oral spines, of which in the marginal cells there are frequently four or five, present the same telescope-like appearance as is seen in *R. monilifera.* The back is smooth, the vibices not so prominent, the enclosed spaces not so angular, and each with a small round avicularium near its centre. In another older and somewhat worn specimen, in which the mode of branching is precisely similar, many of the cells present the characters of the typical form.

Retepora granulata, M'G. Fig. 7.

Polyzoary massive, convoluted. Fenestræ rounded, small, much narrower than the interspaces. Cells elongated, separated by narrow raised lines; mouth arched above, straight below; lower lip with a narrow vertical sinus, on one side of which is a rounded avicularium; surface of cells granular or tuberculate; numerous small oval avicularia scattered over the cells, and a few larger situated on rounded elevations. Ovicells large, rounded, granular. Back of polyzoary granular, vibicate, with small, scattered, rounded avicularia.

Port Phillip Heads.

Of this, the most massive species with which I am acquainted, I have one perfect specimen four inches high, and of the same width at its widest part. It is attached by a stout calcareous basis. The polyzoary is very thick, foliaceous, twisted, and united so as to form several calyculate chambers. It is of a brownish colour (dried). The other specimens I have are mostly fragments. In addition to the usual granulations over the surface, in many cases there is a row forming small processes on the upper margin of the mouth. The young ovicell is fissured, the fissures becoming filled in as calcification advances. In some specimens there are numerous rounded avicularia scattered over the cells and ovicells, occasionally raised on small elevations. There are also other large avicularia with triangular mandibles, on large mound-like elevations.

Retepora fissa, M'G. Fig. 8.

Polyzoary expanded. Fenestræ narrower than the interspaces. Cells separated by narrow raised lines; mouth rounded above, lower lip hollowed, entire, or with a loop-shaped mark about the centre; a considerable avicularium with a triangular mandible near the middle of the cell, directed downwards and outwards. Ovicells large, rounded, prominent, with a vertical fissure wider above; posterior surface vibicate, slightly granular, with a few small avicularia.

Allied to *R. cellulosa*. The lower lip is usually entire, although sometimes (as in the figure) with a small loop-shaped mark or notch. The avicularium about the middle of the cell varies in its direction, being usually pointed obliquely outwards and downwards, sometimes nearly transversely outwards, and occasionally slightly upwards. It is sometimes very large, the rostrum much elevated on a calcareous basis, and the mandible long and triangular.

Hornera robusta, n. sp. Fig. 1.

Polyzoary composed of one or more thick, flattened stems, from which lateral branches extend on either side, these lateral branches frequently anastomosing with each other and with those from adjacent stems. Cells arranged in numerous longitudinal rows, separated by raised ridges; mouth in central cells slightly exserted; in the lateral and those near the edge the peristome produced and irregularly dentate. Back of polyzoary longitudinally sulcate; the narrow intermediate ridges thickly punctate. Ovicell large, posterior, elongated in the direction of the branch, pitted.

Port Phillip Heads.

My largest specimen measures an inch and three-quarters in height, and is of the same width at its broadest part. It originates in a single stem, which immediately divides into two, these again sub-dividing into several main branches.

From the main branches others spread on each side, nearly at right angles, in a penniform manner, and these again give origin to still smaller branches; these anastomose irregularly together, and the large branches from the neighbouring main stems frequently unite in the same way. Some specimens consist only of a single stem with lateral branches, frequently not so regular, while in others these stems are still more numerous. The resulting polyzoary in those with several stems is more or less expanded and curled. The anastomoses of the branches and branchlets are very irregular, being absent in some specimens, while in others they are very numerous. There is nothing like the regular fenestrate arrangement, which is seen in *Retihornera foliacea.*

Pustulopera regularis, n. sp. Fig. 3.

Polyzoary dichotomously branched. Cells arranged in nearly regular sub-spiral series, projecting above, indistinct below; mouth rounded, directed forwards; surface subgranular.

Port Phillip Heads.

I have only examined two specimens, the larger the one figured. The cells follow more or less spiral lines in both directions, so as to result in a nearly quincuncial arrangement. The upper part is prominent, the lower indistinct. The mouth is nearly circular, and the peristome sometimes produced into a very short tube.

It is closely allied to some of D'Orbigny's fossil species, and may prove to be identical with his *Entalophora subregularis.*

Fasciculipora gracilis, n. sp. Fig. 2.

Cells very long; arranged in flattened bundles, the upper parts usually distinct and free; surface thickly punctate.

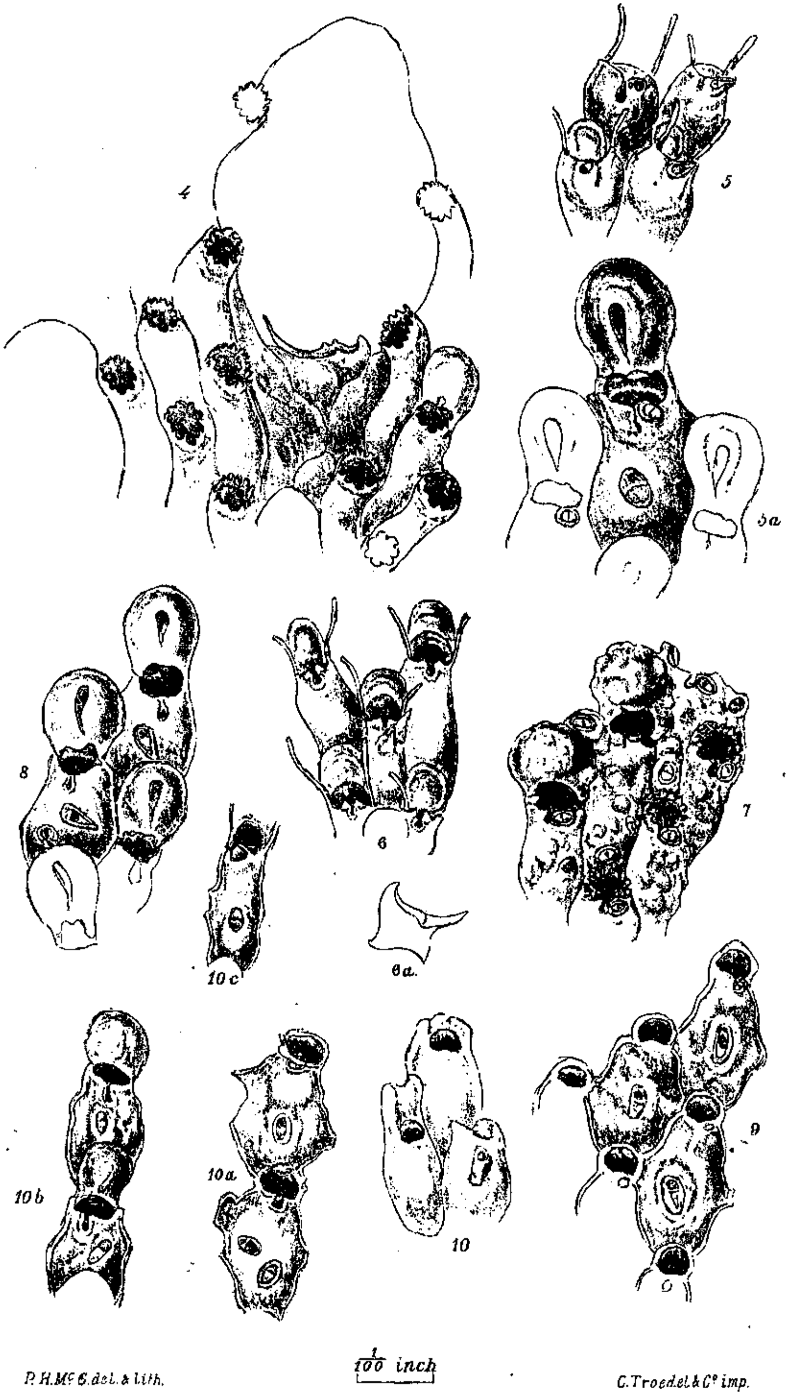
Port Phillip Heads.

The specimen, of which a portion is figured, grows on a small specimen of *Retepora aurantiaca.* There are two groups springing from the same calcareous basis. The cells are arranged in flat fasciculi, closely bound together at their bases, but at the summit separating into smaller bundles, or being each distinct and considerably projecting. The whole surface, including part of the free portions, is thickly

Plate I.

R.H.McG del. & lith.

Plate II.



P. H. Mc G. del. & lith.

C. Troedel & Co imp.

punctate. The mouth is circular and entire, and the part of the cell (peristome) immediately below it is smooth or with obscure transverse wrinkles. In many of the fasciculi the cells all end at the same level, are closely packed together, and have prismatic orifices. This is generally owing to the free portions of the cells being broken off.

EXPLANATION OF FIGURES.

PLATE I.

Fig. 1. *Hornera robusta.*
Fig. 2. *Fasciculipora gracilis.*
Fig. 3. *Pustulopora regularis,* natural size. Fig. 3*a*. Portion of same magnified.

PLATE II.

Fig. 4. *Retepora serrata.*
Fig. 5. *R. aurantiaca.* Young cells, showing oral spines. Fig. 5*a*. Older cell and ovicells.
Fig. 6. *R. avicularis.* Fig. 6*a*. Avicularium in profile.
Fig. 7. *R. granulata.*
Fig. 8. *R. fissa.*
Fig. 9. *R. porcellana.* Group of cells from old, worn specimen.
Fig. 10. Young cells from the growing edge. Figs. 10*a*, *b*, and *c*. Other cells, from the same specimen as 10.

Obituary.

THOMAS E. RAWLINSON, C.E.

Mr. Rawlinson was one of the founders of the Philosophical Institute, in 1854. He was subsequently active in promoting the union of that society with the Victorian Institute, the combined society receiving the name of the "Royal Society of Victoria." For many years Mr. Rawlinson was a member of the Council, and devoted himself with much zeal to extend the usefulness of the Society.

In 1856 Mr. Rawlinson read a paper entitled "The Importance of Sanitary Works for Towns, having Especial Reference to Collingwood, with Suggested Remedial Works for that District."

In 1857 he read a short note on a sawfish recently captured in Hobson's Bay.

In 1862 he read "Suggestions for the Formation of a Colonial Navy, and for Securing Speedy and Certain Communication with Europe and Defence of our Coast in Time of War."

In 1863 he read reports on the entrance to the Gippsland Lakes.

In 1864 he read "Notes on the Tidal Phenomena of Hobson's Bay, as Affecting the Discharge of Flood Waters from the River Yarra."

In 1865 he read a paper on the "Probable Erosion of the Mountain Ranges of Gippsland."

In 1874 he read "Notes on the Discovery of Keys near Geelong;" also a paper on the "Importance of a More Close and Systematic Observation of the Oceanic and Atmospheric Phenomena of our Coasts;" also a paper on the "Past and Present of the Port of Melbourne, and Proposed Works for its Improvement."

In 1876 he again returned to the subject of the improvement of the port of Melbourne.

In 1877 he read a paper on the "Coast-line Formation of the Western District, and Proofs of the Uniform Condition of Meteorological Phenomena over Long Periods of Time."

Mr. Rawlinson was in 1858 a member of the Exploration Committee which prepared and carried out the arrangements for the memorable expedition of Burke and Wills, and at other times he took a prominent part in the schemes of the Society.

In 1880, when he returned to England, he ceased to be an active member, though still connected with the Society; but he left the colony greatly broken in health, and after a long and tedious illness he died of heart disease, in Lancashire, on the 3rd of February, 1882.

Mr. Rawlinson was one of the few surviving original members; for nearly thirty years he maintained the same steady interest in its work. His papers were all of them intended to be of only temporary interest, and having done their work they are apt to be forgotten, but their author is worthy of remembrance for his zeal in helping to found and his industry in assisting to maintain a learned society in so small a community as that of Victoria in 1854.

MR. JOHN FLANAGAN

Became a member of the Society in May, 1861. He was for some years an active member of the Society, though he never contributed to the *Transactions*. He was born in 1835, at Manchester, and educated for the profession of architect in Dublin. He had no sooner served his articles than he emigrated to Melbourne, where in 1858 he entered into business as an architect. Some of the prominent buildings of the colony were built from his designs.

In 1871 he won the prize of £200 offered for the best design for the Eastern Market in Melbourne, but the building was not then erected. Five years later, when fresh designs were called for, he declined to compete, on the ground that he had already done so, and been successful. The erection of the building passed into other hands, and Mr. Flanagan suffered severely in health from the disappointment. In September, 1882, he died of consumption, at the comparatively early age of forty-six.

SIR CHARLES WYVILLE THOMSON

Was born in 1830. At the early age of twenty-one he became a lecturer on botany in the King's College, Aberdeen. Two years later he accepted the chair of natural history in the Queen's College, Cork. He had scarcely begun his work there, however, when the selection of Professor M'Coy to fill a chair in the University of Melbourne left a vacancy in the Queen's College, Belfast, which Professor Thomson was appointed to fill. The original work carried on by him while filling these positions was so great and valuable that he rapidly rose to occupy a leading position among the naturalists of Europe, and in 1868 he was chosen by the British Government to accompany a scientific expedition which explored the bed of the Atlantic. His well-known work, *The Depths of the Sea*, was a description of the expedition and its results.

Professor Thomson next occupied the chair of natural history in Edinburgh, and there carried on his original researches with still greater zeal. In 1872 he was selected to accompany the "Challenger" expedition in the capacity of chief of the scientific staff. Three and a half years were spent in an expedition on a grander and more successful scale than the world had previously seen. In every quarter of the globe the depths of the seas were carefully examined, and an enormous collection of specimens was gathered.

It was during the stay of the "Challenger" in Melbourne that Professor Thomson became an honorary member of this Society.

On the return of the expedition to England, Professor Thomson commenced the enormous task of editing the report. He had completed the two introductory volumes, and made a beginning of the detailed account, when, in 1879, an attack of paralysis forced him to desist, and leave the work in other hands. His health declined for some time, and at last, in March, 1882, a third attack of paralysis ended, at the age of fifty-three, one of the most distinguished careers of our time.

Professor Thomson was in 1876 knighted, as a testimony to the the value of his scientific services.

"During the year the Society held ten meetings in addition to the usual conversazione.

"On the 20th April Mr. J. Stirling read a paper on 'The Phanerogamia of the Mitta Mitta Source Basin and their Habitats.' Mr. W. W. Culcheth, M.I.C.E., read a paper on 'The Quantity of Water Consumed in Irrigation.' A paper by Mr. W. Mitten was contributed by Baron von Mueller, and ordered to be printed.

"On the 11th May Mr. Joseph read a paper on 'Electric Lighting.' Mr. Kernot, M.A., read a paper compiled by Mr. F. A. Campbell, C.E., on 'Experiments upon the Hard Woods of Australia.' Mr. White, F.R.A.S., reported that the committee appointed to examine the papers left by the late Governor Latrobe had perused them, and that the Government had consented to print them.

"On the 8th June Mr. Kernot, M.A., read a paper on 'Floods on the River Barwon.' Dr. Jamieson read a paper on 'The Influence of Light on the Development of Bacteria.' Mr. Rudall, F.R.C.S., read a paper, 'Remarks on Railway and Marine Signals, and on the Necessity of Accurate Testing of the Sight of Signal and Look-out Men by Land and Sea.' A short discussion took place on Mr. Culcheth's paper on 'The Quantity of Water Consumed in Irrigation.'

"On the 13th July Dr. MacGillivray read extracts from his paper, 'Descriptions of New or Little Known Polyzoa, Part II.' Mr. Ellery, F.R.S., read a paper by Mr. Barker, 'On Cyclones of the Southern Hemisphere.' Mr. Kernot, M.A., read a paper by Captain Griffiths, entitled, 'Propulsion of Steam Vessels without Machinery.'

"On the 10th August Mr. R. L. J. Ellery, F.R.S., read a paper by the Rev. J. E. Tenison-Woods, F.G.S., on 'A Physical Description of the Island of Tasmania.' Mr. C. W. Maclean read a paper on 'An Improved Grab Crane.'

"On the 14th September Mr. E. J. White, F.R.A.S., read a paper 'On the Performance of Some Timekeepers.' Mr. Kernot, M.A., read a paper on 'Experiments on Model Girders,' and Mr. Ellery, F.R.S., read some notes on 'The Coming Transit of Venus.'

"On the 12th October Dr. MacGillivray read his paper, 'Descriptions of New or Little Known Polyzoa, Part III.' Professor Nanson, M.A., read his paper on 'Methods of Election,' and Mr. P. Behrendt gave a 'Description and Estimate of an Electric Railway Suitable for Melbourne.'

"On the 16th November Mr. D. Anderson read a paper on the 'Improvements in Contrivances for Varying the Gauge of the Wheels of Rolling-stock for Rail and other Permanent Ways.'

Mr. W. C. Kernot, M.A., read his paper on the 'Lateral Stability of the Victoria-street Bridge.' A paper by the Rev. D. Macdonald was read, on 'The Oceanic Languages Shemitic : a Discovery.'

"On the 14th December Dr. MacGillivray's paper, 'Descriptions of New or Little Known Polyzoa, Part IV.,' was ordered to be printed.

"Volume XVIII. of the Transactions of the Society was issued on the 1st June, and forwarded to the members and to the Societies entitled to receive it. Volume XIX. is expected to be ready for members of the Society at the April meeting.

"The Council has to announce with regret the loss by death of the following members :—

"Mr. Thomas Rawlinson, C.E., who has been a member since the foundation of the Society. Sir Charles Wyville Thomson, who was elected an honorary member in 1874. Mr. John Flanagan, Architect, who was elected a member in 1861."

On the motion of Mr. Rosales, seconded by Mr. Blackett, the Report and Balance-sheet were adopted.

The office-bearers of the preceding year were re-elected for 1883. The following gentlemen were elected members of the Council:— Professor Andrew, M.A., Joseph Bosisto, M.L.A., Dr. James Jamieson, James T. Rudall, F.R.C.S., James Duerdin, LL.B., William H. Steele, C.E., C. R. Blackett, R. S. Bradley, T. B. Muntz, S. W. M'Gowan, R. E. Joseph, J. Cosmo Newbery, B.Sc.

1882.

PROCEEDINGS.

ROYAL SOCIETY OF VICTORIA.

ANNUAL MEETING.

March 15*th*, 1883.

THE President in the chair. Present, 22 members and associates.

The Annual Report and Balance-sheet for 1882 were read, as follow:—

"*Report of the Council of the Royal Society of Victoria, for the Year* 1882.

"Your Council has again to report the conclusion of a satisfactory year, during which the number of members increased, and the activity shown in the preparation of papers, in the attendance at the meetings, and in the discussion evoked by the various subjects of interest brought under the notice of the Society, was generally gratifying.

"We continued to send our Transactions to all the leading scientific societies of the world, and in return have received 59 volumes and 432 parts of scientific publications.

"The Council has agreed to set aside a certain sum annually for the binding of the valuable scientific works now stored away upon our shelves, and during the year have had sixty-three volumes bound.

"The Crown grant of the land on which the Society's hall is situated is now in course of preparation, and will ere long be in the possession of the Society. It will be issued in the names of Sir William Stawell, Mr. R. L. J. Ellery, Mr. E. J. White, and Mr. W. C. Kernot, as trustees for the Society.

"During the past session there have been elected 21 members and 8 associates. The Society now consists of 163 members, 6 corresponding members, 8 honorary members, and 41 associates; or, in all, 218 gentlemen belonging to the Society.

BALANCE-SHEET.

The Hon. Treasurer in Account with the Royal Society of Victoria.

Dr.

To Balance in Bank				£62	9	0
" Government Grant—1881-82				200	0	0
" Sale of "Transactions"				0	5	0
" Rents				4	10	0
" Eighteen Entrance Fees				37	16	0
" Subscriptions—						
66 Members	£138	12	0			
5 do. (Half-years) ...	5	5	0			
21 Country Members	22	1	0			
2 do. (Half-years)...	1	1	0			
26 Associates	27	6	0			
3 do. (Half-years) ...	1	11	6			
Arrears	26	5	0			
Commission	0	2	6			
				222	4	0
				£527	4	0

Cr.

By Printing and Stationery	£166	7	0
" Binding	14	10	6
" Alterations to Hall	78	15	0
" Books	5	16	0
" Freight and Charges of Books and "Transactions"	14	6	2
" Conversazione and Teas	18	14	6
" Rates	4	13	4
" Gas and Fuel	4	15	4
" Repairs	13	7	9
" Clerical Assistant	26	0	0
" Hall-keeper	6	0	0
" Collectors	20	11	6
" Insurance	3	10	0
" Postage	22	8	9
" Petty Cash	3	10	0
	£403	5	10
" Balance in Bank	123	18	2
	£527	4	0

Compared with the Vouchers, Bank Pass-book, and Cash Book, and found correct.

2nd March, 1883. (Signed) JAMES E. GILBERT, ROBERT E. JOSEPH } AUDITORS.

STATEMENT OF LIABILITIES AND ASSETS.

Dr. **LIABILITIES.**

	£	s.	d.
To Three Debentures outstanding	£15	0	0
,, Interest unclaimed	12	12	0
,, Estimated Amount of other Outstanding Liabilities	10	0	0
	£37	12	0
,, Balance	3111	6	2
	£3148	18	2

ASSETS. Cr.

	£	s.	d.
By Estimated Value of Outstanding Subscriptions ...	£20	0	0
,, do. do. Rents due	5	0	0
,, Hall, Library, Furniture	3000	0	0
,, Balance in Bank	123	18	2
	£3148	18	2

20th April, 1882.

The President in the Chair—Present, 19 members and associates.

The following members signed their names in the members' book: —Mr. J. Stirling, Mr. Lane, and Mr. Chesney.

Mr. Spencer R. Deverill was nominated for membership. Mr. O. R. Rule and Professor Halford were elected members. Mr. W. Luplan, Mr. E. F. Pittman, Mr. J. Oddie, Mr. M'Lelland were elected country members.

Mr. H. V. Champion and Mr. H. M'Lean were elected associates.

Mr. Stirling then read a paper on the "Phanerogamia of the Mitta Mitta Source Basin," and exhibited a collection of plants made by him.

In answer to questions, Mr. Stirling said that the pepper-tree grows at the height of 5000 feet on the Australian Alps, and bears a dark bluish-black berry. There is a shrub with a large bushy top and woolly leaves called the "flannel plant," whose properties are as yet quite unknown. When cut down, and left for two or three days, horses and cattle will eat it as fodder. The clematis often climbs to the top of eucalypti 200 feet in height.

The President then laid on the table a paper on the "Mosses of Australia," by Mr. Mitten, of Sussex, England, which that gentleman had forwarded to Baron von Mueller for presentation to the Society.

Mr. Culcheth then read his paper entitled "Notes on Irrigation."

Mr. Kernot said the countries in which irrigation is most used in cultivation are Northern Italy and India. There the channels are placed 30 feet apart, and the ground between is cut up into small beds, surrounded by little trenches, which fill up when the channels overflow. In both these countries labour is so cheap that irrigation pays, but circumstances are very different here.

Mr. Ellery and Mr. Culcheth agreed that with a population so widely scattered as ours irrigation would be very costly, and would not give adequate returns.

Mr. Kernot said that he had recently noticed that the fall from Shepparton to Numurkah was only one foot in a thousand; the evaporation in excessively warm weather amounts to only one-eighth of an inch per day; the soil is of a retentive, basaltic character, and offers every facility for irrigation.

Mr. Culcheth considered that the cheapest kind of irrigation was that of the water channels of India, where beds of about 500 to the acre are arranged on a gentle slope. As soon as the seed is sown, men admit the water to the different beds in succession by opening sluices in the channels.

Mr. Lane remarked that in America for small areas they irrigate by means of pipes let down below the surface, and containing numerous apertures, by which the water flows out after being pumped up from a river or lake.

After some conversational remarks as to the probability of success in any scheme of irrigation for Victoria the meeting closed.

11*th May*, 1882.

The President in the Chair—Present, 45 members and associates.

Mr. O. R. Rule and Mr. H. V. Champion, two new members, were introduced to the meeting.

Mr. Spencer Deverill was elected a member of the Society.

Mr. D. B. W. Sladen, B.A., and Mr. T. Shaw were proposed as members. Mr. John Booth was proposed as an associate.

Mr. E. J. White reported that the committee appointed by the Royal Society to confer with a committee of the trustees of the Public Library, in reference to the publication of the letters and historical documents left by the late Governor Latrobe had appointed a sub-committee, consisting of Professor Irving, Mr. Sutherland, and himself, to examine and report on these papers. This sub-committee had reported that the papers were all worthy of publication, and the Government had, with great liberality, promised to have them printed.

Mr. R. E. Joseph then read a paper on "Electric Lighting."

Mr. Kernot said that, while it was possible that in Melbourne, where coal was of comparatively easy access, gas might be cheaper than electricity, in many of the country townships there could be no doubt that the advantage lay with the latter. In a country like Switzerland the abundant waterfalls might make the cost of light almost nominal; but even in Australia such townships as have abundance of fuel in the shape of timber would find electricity much the cheaper. In so warm a climate as this the electric light presents a great advantage in not raising the temperature of the room lighted up by it.

Mr. Ellery and Mr. Foord said that the secondary battery invented by Mr. Sutton, of Ballarat, may perhaps be of much assistance to the success of electric lighting.

Mr. Blackett asked which of the incandescent lamps was considered to be the best?

Mr. Joseph said that he had tested only one, the "Swan;" but it was said that the "Moxim" was superior. It had a thicker carbon; but though it might give better light it certainly did not last so long. After 800 hours it breaks down completely.

Mr. Kernot said that the chief objection to the arc light was that either a great quantity of light or none at all must be used. The light given by the incandescent lamp is more expensive, but more useful.

Mr. Kernot then read a paper by Mr. Campbell on the "Strength of Colonial Timber."

At the conclusion of the meeting the President mentioned that a memorial was being erected to the memory of the late Professor Wilson, one of the earliest and most active members of the Society; he asked the Society to contribute so far as they could to this desirable object. Professor Wilson died while engaged on the greatest scientific work yet done in Australia.

8th June, 1882.

The President in the Chair—Present, 19 members and associates.

Mr. D. B. W. Sladen, B.A., and Mr. Thomas Shaw, were elected members, and Mr. John Booth, C.E., was elected as an associate.

The following associates were introduced to the meeting:—Mr. John M'Lean, Mr. W. Finney, and Mr. J. C. Jones.

A further discussion of Mr. Culcheth's paper on irrigation then took place, after which Mr. Kernot read a paper entitled "Some Remarks on the Barwon Flood of 1880."

The papers elicited some conversational discussion.

Dr. Jamieson read his paper, "The Influence of Light on the Development of Bacteria."

Dr. Rudall read his paper on "The Necessity of Accurately Testing the Sight of Signalmen by Land and Sea."

13th July, 1882.

The President in the Chair—Present, 17 members and associates.

The following new members and associates were introduced to the meeting:—Mr. D. B. W. Sladen, B.A., Mr. S. R. Deverill, Mr. Steane.

A ballot for the election of Mr. H. Cornell, as a member, and of Mr. H. Sutton and Mr. C. E. Oliver as country members, resulted in the election of these gentlemen.

The Hon. Librarian reported that during the month 7 volumes and 83 parts of scientific publications had been added to the library, and that 63 volumes had been bound.

Dr. MacGillivray then read some "Notes on New Australian Polyzoa, of the Species *Membranipora, Microporella, Lepralia, Schizoporella*," mentioning that they closely resembled the species found in the Gulf of Florida. He then exhibited some plates of specimens.

Mr. Ellery mentioned that these plates had been drawn on stone by Dr. MacGillivray himself, and that the Society was very much indebted to that gentleman for the great care with which he had prepared them.

Mr. Ellery then read a paper by Captain Barker, of the ship "Sobraon," on "The Cyclones of the Southern Hemisphere." After the paper was concluded, Mr. Ellery said—We generally get two days' warning of the approach of these storms—that is, if they move in a true course. But they do not always move in the curve which theory assigns to them, owing, I suppose, to the intervention of causes hitherto unknown to us. By electric telegraph from Western Australia we are warned under ordinary circumstances two clear days before they reach us. So far as I am aware, this paper is one of the first attempts to give a definite account of the cyclones of southern latitudes.

Mr. Kernot.—Is it yet definitely established how these cyclones originate?

Mr. Ellery.—The temperature of the air is undoubtedly the primary cause, but the friction of the earth has much to do with their force and direction. We may take it as an ascertained fact that cyclones, wherever they may be, are always attended with anticyclones.

Captain Barker.—The duration of these storms varies from a few hours to a couple of weeks. Their diameter often exceeds 600 miles.

Mr. Kernot then read a paper by Captain Griffiths, on a "Proposal for the Propulsion of Steamers Without the Intervention of Machinery." He observed that the method proposed had no advantage over the present system, either in cheapness or in the actual speed attained.

Several members related the attempts already made by engineers and scientific men to attain this object.

August 10*th*, 1882.

The President in the chair—Present, 15 members and associates.

Mr. John Wall was elected a member. Mr. J. P. Wilson, M.A., was elected an associate.

Mr. H. Cornell, a new member, was introduced to the meeting, and signed the members' book.

Mr. Ellery then read a paper, "A Physical Description of the Island of Tasmania," by the Rev. J. E. Tenison-Woods.

In connection with this paper, Mr. Ellery gave a description of a remarkable mimosa scrub found in Tasmania. This grows on elevated places, where it is blown down by the wind. The branches take fresh root in the soil, and new plants spring up, which are in turn blown down, and again take root. In this manner immense tracts of land are rapidly covered with a dense brushwood.

Mr. Kernot described a somewhat similar phenomenon he had witnessed on the top of the Buffalo Ranges, 4000 feet high. The scrub there is so thick that the only mode of progress is to walk on top of it 5 feet above the ground.

Mr. M'Lean then read his paper on "A New Dredge Crane," and exhibited a fine model of the contrivance.

Mr. M'Lean, in answer to questions, said that it had raised about 600 tons in eight hours, but that was with many stoppages, on account of an insufficient supply of barges. Without stoppages, he thought 1000 tons in eight hours might be a fair average. The dredging we have to do in the South Channel is something over 30 feet deep. The new crane will dredge to 30 feet. It need not be confined to silt and light soils. It can be used to excavate solid earth for reservoirs. Mr. M'Lean then pointed out the main difference between this crane of his invention and previous grab cranes. In answer to further questions, he said that with the old cranes, when the scoop seized a rock or root that could not be moved, a diver had to be sent down to release it. He showed on the model how the simple pulling of a rope would release the new scoop. With the ordinary dredge the buckets are raised much higher than necessary, thus wasting time and power. The new one merely lifts the weight to the height actually required, swings it round and deposits it. It lifts three tons per minute.

14*th September*, 1882.

The President in the Chair—Present, 19 members and associates.

Mr. J. R. Corr, M.A., and Mr. P. Behrendt were elected members. Mr. D. Anderson was elected as an associate.

Mr. J. P. Wilson and Mr. Chas. Rowan, two new members, were introduced to the meeting.

Mr. E. J. White read his paper on the "Performance of Some Timekepeers," and in answer to questions said that the chief causes of variation were change of temperature and change of position. Most watches would go at different rates when lying horizontally and when standing upright.

Mr. Ellery then said that a transit of Venus was fast approaching. There had been one eight years ago, but the next would not occur for 121½ years. From England and the Continent there are many observing parties coming out to Australia and New Zealand. Here the sun will rise at a quarter to five on the 6th December, and at that time the planet will be in the middle of the sun's disc, so the egress will be distinctly visible to us.

Mr. Kernot then exhibited two models of iron girders—one representing a girder on a railway footbridge in Melbourne; the other that girder as it ought, on scientific principles, to be. The latter contained half the material, but sustained a load of 770 lbs., while the former broke with 208 lbs.

Mr. Barnes objected to the manner in which Mr. Kernot held up to ridicule the work of practical men, who had in the early days of the colony done the best with the material at their disposal.

Mr. Kernot said he had studiously avoided ridicule. All he wished to show was that the designers of these girders had wasted their materials without gaining strength.

Mr. Ellery thought it Mr. Kernot's duty, as professor of engineering at the University, to call attention to the faults of defective structures wherever he found them.

12*th October*, 1882.

The President in the Chair—Present, 35 members and associates.

Mr. R. Stephens, B.A., was duly elected a member; Mr. Wakelin a country member.

The Hon. Librarian reported that during the month 14 volumes and 47 parts of scientific publications had been received.

Dr. MacGillivray then read the third portion of his paper on "New, or Little Known, Polyzoa," and exhibited engravings of them.

Mr. Behrendt read a paper entitled "Description and Estimate of an Electric Railroad for Melbourne."

Mr. Kernot remarked that electric railways had many advantages for city traffic. Not only were the annoyances of smoke and noise avoided, but by their elevation these railroads interfered less with traffic than any other street railway. There was no ponderous locomotive to carry, hence a saving in the permanent way and in the power used.

Several other members concurred in the idea that such railways would be of great advantage in Melbourne.

Professor Nanson read his paper on "Methods of Election," the discussion on which was postponed to a future meeting.

16*th November*, 1882.

The President in the Chair—Present, 26 members and associates.

Mr. Joseph Summers was elected a member, Mr. J. A. Stuart a country member, and Mr. J. H. Horner an associate.

A communication was received from Mr. E. L. Marks, lecturer at the School of Mines, Sandhurst, stating that he had analysed a specimen of a so-called non-alcoholic wine, with the result that alcohol was shown unmistakably to be present, as well as iodoform.

Mr. D. Anderson then read his paper on "Improvements in Contrivances for Varying the Gauge of Wheels of Rolling Stock for Rail and other Permanent Ways." He likewise exhibited a model of his invention.

Mr. Kernot pointed out that the gauge in use in New South Wales being 4 ft. 8½ in., while that of Victoria is 5 ft. 3 in., some such contrivance became of the utmost utility in encouraging intercolonial traffic. Mr. Anderson's invention was not costly, and might be used on a large scale.

Mr. White said that New South Wales was entirely responsible for the differences in gauge.

Mr. Kernot then read his paper, "The Lateral Stability of the Victoria-street Bridge."

Mr. Ellery said that a considerable lateral stability was very necessary, as so little was known of the force of sudden wind gusts in ravines.

Mr. Kernot said that the result of some experiments he had recently made was that even in gusts the ordinary pressure of the wind was only some 3 lbs. or 4 lbs. to the square inch; 5½ lbs. was an uncomfortably strong breeze. There are many of our Melbourne chimneys and steeples which will fall if the wind pressure exceeds 12 lbs. to the square foot.

The Rev. D. Macdonald read extracts from his paper, "The Oceanic Languages Shemitic: a Discovery."

14*th December*, 1882.

The President in the Chair—Present, 14 members and associates.

Mr. G. S. Griffiths and Mr. Thomas Walters were elected members, and Messrs. J. H. Fraser and H. W. Mills associates.

The Hon. Librarian announced the receipt of 8 vols. and 105 parts.

Mr. M'Ivor then read a paper on "Whakaari, a New Zealand Sulphur Island."

Mr. M'Ivor exhibited specimens of sulphur he had collected when in New Zealand.

In answer to questions, Mr. M'Ivor stated that the springs generally shoot straight up—some to the height of 50 feet—and that there are ten fumeroles on one side of the centre lake. The total area is estimated at about 640 acres. The meaning of the

Maori word "whakaari" is "the mouth or place of vapour." All action appears to have ceased on one side of the lake, and as far back as the Maorics can recollect it has been in the same state. It is a remarkable thing that the escape of gas in these springs is much more violent in the middle of the day than at any other time. It gradually lessens in the afternoon, till it reaches a minimum in the night.

Mr. Ellery remarked that in all perennial and intermittent springs this has been observed.

In reply to a question from Mr. Ellery, Mr. M'Ivor stated that the quantity of mineral matter in solution was as much as 2 lbs. to the gallon. After some few further remarks the discussion closed.

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