AUSTRALASIAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

REPORT

OF THE

THIRD MEETING

OF THE

AUSTRALASIAN ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE

HELD AT

CHRISTCHURCH, NEW ZEALAND, IN JANUARY, 1891

EDITED BY

SIR JAMES HECTOR, K.C.M.G., M.D., F.R.S.

PUBLISHED BY THE ASSOCIATION

PERMANENT OFFICE OF THE ASSOCIATION

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OBJECTS AND RULES OF THE ASSOCIATION.

OBJECTS.

The Association has been founded upon the same lines as the British Association, and its rules are practically the same. It should be particularly noticed that this Association also "contemplates no interference with the ground occupied by other institutions. Its objects are: To give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate science in different parts of the British Empire, with one another and with foreign philosophers; to obtain a more general attention to the objects of science, and a removal of any disadvantages of a public kind which may impede its progress."

RULES.

1. All persons who signify their intention of attending the first meeting shall be entitled to become original members of the Association upon agreeing to conform to the rules.

2. The officers, members of the council, fellows, and members of the literary and philosophical societies publishing Transactions or Journals in the British Empire shall be entitled in like manner to become members of the Association. Persons not belonging to such institutions shall be elected by the General Committee or Council to become life-members of the Association, annual subscribers, or associates for the year, subject to the payment of the prescribed subscription, and the approval of a General Committee.

3. All members who have paid their subscriptions (£1 per annum) shall be entitled to receive the publications of the Association *gratis*.

4. The Association shall meet for one week or longer. The place of meeting shall be appointed by the General Committee two years in advance.

5. There shall be a General Council, having the supreme control, to be composed of delegates from the different colonies or colonial scientific societies. The number of delegates from each society or colony shall be proportionate to the number of members from the particular colony or society, subscribing or otherwise, taking part in the proceedings (*i.e.*, after the preliminary meetings). Each colony or society shall be allowed to nominate a delegate for each one hundred of its members.

6. There shall be a General Committee, consisting of members of the Council, Presidents, Vice-presidents, and Secretaries of Sections, contributors of papers to the Association, and such others as may be elected.

7. A local committee shall be appointed at the place of meeting to make arrangements for the reception and entertainment of the visitors, and to make preparations for the business of the general meetings.

8. Sectional committees shall be appointed for the following subjects:—

Section A—Astronomy, mathematics, physics, and mechanics.
" B—Chemistry and mineralogy.
" C—Geology and palæontology.
" D—Biology.
" E—Geography.
" F—Economic and social science and statistics.
" G—Anthropology.
" H—Sanitary science and hygiene.
" I—Literature and fine arts.
" J—Architecture and engineering.

9. Ladies are eligible for membership.

10. The rights and privileges of membership shall be in the main similar to those afforded by the British Association, subject to revision and alteration after the first meeting of the Australasian Association for the Advancement of Science.

OFFICERS AND COUNCIL, 1891.

President:

Sir JAMES HECTOR, K.C.M.G., M.D., F.R.S., Director of the Geological Survey of New Zealand.

Vice-Presidents:

His Excellency Sir R. G. C. HAMILTON, K.C.B., President of the Royal Society of Tasmania.

A. LEIBIUS, M.A., Ph.D., F.C.S., President of the Royal Society of New South Wales.

Professor W. C. KERNOT, M.A., C.E., President of the Royal Society of Victoria.

W. SAVILLE-KENT, F.L.S., F.Z.S., President of the Royal Society of Queensland.

E. C. STIRLING, M.D., M.A., President of the Royal Society of South Australia.

General Treasurer:

H. C. RUSSELL, C.M.G., B.A., F.R.S., F.R.A.S., Government Astronomer, Sydney.

General Auditor:

FRANK T. CLARK.

General Secretaries:

A. LIVERSIDGE, M.A., F.R.S., Professor of Chemistry and Mineralogy, Sydney University (Permanent Secretary).

W. BALDWIN SPENCER, M.A., Professor of Biology, Melbourne University.

F. W. HUTTON, F.G.S., Professor of Geology, Canterbury College, Christchurch.

Local Treasurer:

H. R. WEBB, F.R.M.S., Hereford Street, Christchurch.

Local Auditor:

J. E. WRIGHT.

Local Secretaries:

T. J. PARKER, B.Sc., F.R.S., Professor of Biology, Otago University, Dunedin.

A. P. THOMAS, M.A., F.L.S., F.G.S., Professor of Biology and Geology, University College, Auckland.

A. DE BATHE BRANDON, B.A., Wellington.

A. MORTON, F.L.S., Curator of the Museum, Hobart.

F. WRIGHT, Italian Consulate, Adelaide.

J. SHIRLEY, B.Sc., F.L.S., Brisbane.

A. VAUGHAN JENNINGS, F.L.S., Science Schools, South Kensington, London.

Ordinary Members of Council:

Publication Committee:

Sir J. Hector.
Professor Liversidge.
Professor Baldwin Spencer.
Professor Hutton.
The Hon. W. B. D. Mantell.
W. T. L. Travers.

Recommendation Committee:

Sir James Hector.
Baron von Mueller.
Professor Hutton.
Professor Liversidge.
Professor Warren.
Professor Kernot.
A. Morton.
R. L. Jack.
W. Dixon.

PRESIDENTS, VICE-PRESIDENTS, AND SECRETARIES OF THE SECTIONS AT THE CHRISTCHURCH MEETING, JANUARY, 1891.

A.—Astronomy, Mathematics, Physics, and Mechanics.

President—Professor T. R. Lyle, M.A.

Vice-President—C. H. H. Cook, M.A., Professor of Mathematics, Canterbury College.

Secretary—A. C. Gifford, M.A., Christ's College, Christchurch.

B.—Chemistry and Mineralogy.

President—Orme Masson, M.A., D.Sc., Professor of Chemistry, Melbourne University.

Vice-Presidents—A. W. Bickerton, F.C.S., Professor of Chemistry, Canterbury College; W. Skey, F.C.S., Government Analyst, Wellington.

Secretary—George Gray, F.C.S., School of Agriculture, Lincoln, N.Z.

C.—Geology and Palæontology.

President—R. A. Murray, F.G.S., Melbourne.

Vice-Presidents—A. P. Thomas, M.A., F.L.S., F.G.S., Professor of Natural Science, Auckland University College; H. Hill, B.A., F.G.S., Inspector of Schools, Napier.

Secretary—J. D. Enys, F.G.S.

D.—Biology.

President—W. A. Haswell, M.A., D.Sc., Professor of Biology, Sydney University.

Vice-Presidents—T. J. Parker, B.Sc., F.R.S., Professor of Biology, Otago University; Sir W. Buller, K.C.M.G., F.R.S., Wellington; Thos. Kirk, F.L.S., Wellington; T. F. Cheeseman, F.L.S., Museum, Auckland.

Secretaries—C. Chilton, M.A., B.Sc., Port Chalmers; G. M. Thomson, F.L.S., Dunedin.

E.—Geography.

President—G. S. Griffiths, F.R.G.S., F.G.S., Melbourne.

Vice-Presidents—S. Percy Smith, F.R.G.S., Surveyor-General, Wellington; F. R. Chapman, Dunedin.

Secretary—R. M. Laing, M.A., B.Sc., Christchurch.

F.—Economic and Social Science and Statistics.

President—The Hon. G. W. Cotton, M.L.C., Adelaide.

Vice-Presidents—W. T. L. Travers, F.L.S., Wellington; W. R. E. Brown, Registrar-General, Wellington.

Secretaries—A. de Bathe Brandon, B.A., Wellington; A. T. Bothamley, Wellington.

G.—Anthropology.

President—A. W. Howitt, F.G.S., Melbourne.

Vice-Presidents—The Hon. W. B. D. Mantell, M.L.C., F.G.S., Wellington; T. M. Hocken, M.R.C.S., Dunedin; Edward Tregear, F.R.G.S., Wellington.

Secretary—A. Hamilton, Napier.

H.—Sanitary Science and Hygiene.

President—The Hon. Allan Campbell, M.D., M.L.C., Adelaide.

Vice-Presidents—J. H. Scott, M.D., Professor of Anatomy and Physiology, Otago University; I. de Zouche, M.D., Dunedin; C. Nedwill, M.D., Christchurch.

Secretary—F. Ogston, M.D., Lecturer on Medical Jurisprudence and Public Health, Otago University.

I.—Literature and Fine Arts.

President—R. H. Roe, M.A., Brisbane.

Vice-Presidents—F. W. Haslam, M.A., Professor of Classics, Canterbury College; G. F. Tendall, Mus. Bac. Oxon., Christchurch.

Secretaries—A. Wilson, M.A., Dunedin; A. J. Merton, Christchurch.

J.—Architecture and Engineering.

President—John Sulman, F.R.I.B.A., Lecturer on Architecture, Sydney University.

Vice-Presidents—R. Wilson, F.R.S.E., M.I.C.E., Christchurch; E. Dobson, M.I.C.E., Christchurch; C. Napier Bell, M.I.C.E., Greymouth; W. N. Blair, M.I.C.E., Engineer-in-Chief, Wellington.

Secretary—R. J. Scott, A.M.I.C.E., Lecturer in Charge of Engineering School, Canterbury College.

PROGRAMME FOR THE MEETING.

The Board of Governors of Canterbury College, Christchurch, have kindly granted the use of their buildings for the meeting.

The reception-room at Canterbury College will be open on Tuesday, the 13th January, and following days, from 9 a.m. to 5 p.m., for the issue of tickets to Members and for supplying information to strangers on their arrival.

From 3.30 to 5.30 p.m. on the afternoon of Thursday, the 15th January, the President-elect will hold a reception in the grounds of Christ's College, and the first general meeting will take place at 8 p.m. on the evening of that day, when Baron F. von Mueller, K.C.M.G., F.R.S., will resign the chair, and Sir James Hector, K.C.M.G., F.R.S., President-elect, will assume the Presidency and deliver an address.

The official journal, containing announcements of the arrangements for the day, will be laid on the table each morning for distribution. A branch post-office will also be opened for the convenience of Members and Associates.

A room will be provided for the reception of apparatus and specimens illustrative of papers communicated to the sections.

Visits to places of interest in the immediate neighbourhood of Christchurch will be made during the meeting. After the meeting is over excursions will be made to the West Coast Sounds, to the top of Ruapehu, and, if possible, to the Upper Rakaia. The trip to the top of Ruapehu will start from Napier, and will be accompanied by Mr. H. Hill, F.G.S. The trip to the Sounds will start from Port Chalmers, and will be accompanied by Professor Hutton, F.G.S.

General Committee

Consists of the general and sectional officers of the Association, delegates from colonial scientific societies, and contributors of papers to the Association. It will meet in Canterbury College at 10 a.m. on Thursday, the 15th January, 1891, to confirm the election of sectional officers and transact other business.

Reports on the Progress of Science, and of Researches intrusted by the General Committee to individuals or to Scientific Committees, must be forwarded to the General Secretaries for presentation to the Sectional Committees, accompanied by a statement whether the author will be present at the annual meeting.

Organizing Sectional Committees.

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election. From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon papers likely to be submitted to the Sections, and of preparing reports thereon to be presented to the Committees of the Sections at their first meeting. The Sectional Presidents of former years are *ex officio* members of the Organizing Committee.

The Organizing Committees for the several Sections determine the acceptance of papers before the beginning of the meeting. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an abstract of his paper of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original paper, to the Secretary of the Section before which it is to be read, so that it may reach him on or before the 1st January, 1891.

Members may communicate to the Sections the papers of non-members.

The author of any paper is at liberty to reserve his right of property therein.

During the annual meeting the Sections will have about twelve hours for the reading and discussion of papers.

Sectional Committees.

At 2 p.m. on the first day of the meeting the Organizing Committees meet in the rooms of their respective Sections, together with previous Presidents and Vice-Presidents of the Sections, and form themselves into Sectional Committees, with power to add to their number.

On the second and following days the Sectional Committees will meet at 10 a.m.

The Sectional Committees will determine the days on which the different papers are to be read.

No report, paper, or abstract can be inserted in the annual volume unless it be handed to the Secretary before the conclusion of the meeting.

The Sectional Committee will report to the Publication Committee what papers it is thought advisable to print.

They will also take into consideration any suggestions which may be offered for the advancement of science.

In recommending the appointment of Scientific Committees all members of the Committee should be named, and one of them should be appointed to act as Secretary who has notified his willingness to accept the office. The number of members appointed to serve on a Scientific Committee should be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

All recommendations adopted by Sectional Committees are to be forwarded without delay to the Recommendation Committee; unless this is done the recommendation cannot receive the sanction of the Association.

At 11 a.m. precisely the chair will be taken, and the reading of papers will commence. In the middle of the day an adjournment for luncheon will be made, and at 4 p.m. the Sections will close.

At the close of each meeting the Sectional Secretary will correct, on a copy of the official journal, the list of papers which have been read, and add to it a list of those appointed to be read on the next day, and send it to the General Secretaries.

Recommendation Committee.

The General Committee, at its first meeting, will appoint a Committee of Recommendations to receive and consider the reports of the Scientific Committees appointed at last meeting, as well as the recommendations from Sectional Committees, and also to report to the General Committee, at a subsequent meeting, the measures which they would advise to be adopted for the advancement of science.

All proposals for the appointment of Scientific Committees must be sent in through the Recommendation Committee.

This Committee will meet at 2 p.m., the 19th January, and again at 2 p.m. on the 21st January.

MEMBERS AND ASSOCIATES.

Members of scientific societies publishing journals in the British Empire can become members of the Association on payment of the annual subscription of £1.

Persons not belonging to such scientific societies may become members by payment of an entrance-fee of £1 as well as an annual subscription of £1.

Or they may become associates for the year by the payment of the annual subscription of £1.

Ladies may become members or associates.

Applications for admission may be addressed to any of the General or Local Secretaries.

Tickets of membership may be obtained from any of the Secretaries on and after the 15th December, 1890, by those who have qualified by the payment of their subscription for 1890–91.

Members of the British and American Associations for the Advancement of Science visiting New Zealand for the purpose of attending the meeting at Christchurch will be entitled to the same privileges as members of the Australasian Association.

PROCEEDINGS.

MEETINGS OF THE GENERAL COMMITTEE.

First Meeting: *Thursday, 15th January, 1891.*

The General Committee met at 11 a.m. in the room of Section F in the new School of Engineering. About forty members were present, and the chair was occupied by Baron von Mueller, retiring President.

Baron von Mueller said: Gentlemen,—Let me offer to you my sincere felicitations on this occasion on the part of my Australian *confrères* and myself. As a stranger in these beautiful islands, it seems fitting that I should, on behalf of my colleagues, tender to you my congratulations. I express the hope that the meeting which we are this day inaugurating will be characterized throughout by goodfellowship, harmony, and good results in the cause of science, and that it will leave its mark in the history of this beautiful and interesting country. I trust that one result of the meeting of the Australasian Association for the Advancement of Science will be to draw closer together the bonds of science which should exist between us all here in Australasia. I do not intend to address you on this occasion at any great length. My duties at this meeting are to a large extent formal, and I will now content myself with simply once more offering the congratulations of my colleagues from Victoria and myself on this occasion. In the ordinary course of official business the minutes of the meeting at Melbourne will have to be confirmed. As we have a good deal of work to get through to-day in two hours, and our distinguished colleague and General Secretary, Professor Liversidge, has prepared the minutes very carefully, I will crave your indulgence to have them taken as read.

This was done, and the minutes confirmed by the President.

Professor Kernot (Victoria) moved, That the appointment of sectional officers and Committees, and all the arrangements made by the Committee in Christchurch, be confirmed. As this was the first meeting, and members were scattered all over the colonies, they could not arrange this, and therefore their friends in Christchurch had prepared a most elaborate programme. Their friend Professor Hutton had worked most indefatigably, and all those who knew what the work was would agree with him that Professor Hutton deserved their very best thanks. All the arrangements for the reception and comfort of visitors had been made under his superintendence. They were indebted to him for the very complete pamphlet and all the excursions which had been arranged for them; and therefore he begged to add to his motion, That the hearty thanks of the Association be tendered to Professor Hutton for his zeal and indefatigable labours in connection with the meeting of the Association.

Professor Haswell, of Sydney University, seconded the motion, and expressed his high appreciation of the labours of Professor Hutton, and also of his scientific researches.

The Chairman, in putting the motion, expressed his high appreciation of the work done by Professor Hutton. They all knew the work which devolved on the Honorary Secretaries of an Association like this; and in this he desired to couple with the name of Professor Hutton that of Professor Liversidge, whose work they all knew and appreciated.

The motion was carried amidst acclamation.

The CHAIRMAN conveyed the thanks of the Association to Professor Hutton and the Local Committee, and to Professor Liversidge.

Professor HUTTON acknowledged the compliment, and spoke of the way in which the Local Committee had worked with him. He trusted all the arrangements would be found to be complete and satisfactory, and that the members would have a pleasant visit.

Appointment of Officers for 1892.

Sir JAMES HECTOR moved, That the following be the officers of the Association for 1892: President, Sir R. Hamilton (Governor of Tasmania and President of the Royal Society of Tasmania); General Secretary, Mr. Alex. Morton (Tasmania); General Treasurer, Mr. H. C. Russell, C.M.G., F.R.S. (Sydney); Local Secretaries, Professor Baldwin Spencer (Victoria), F. Wright (South Australia), J. Shirley (Queensland), Professor Parker, F.R.S. (Otago University, New Zealand).

Mr. ROE (Brisbane) seconded the motion, which was carried.

Mr. MORTON expressed his thanks for the high position to which he had been elected, and said that the devotion of His Excellency Sir R. Hamilton to science would be a guarantee that the office of President would be filled satisfactorily.

Place of Meeting in 1893.

The Hon. G. W. COTTON, M.L.C. (Adelaide), moved, That the fifth meeting of the Association be held at Adelaide in September, 1893.

Dr. OGSTON (Otago) pointed out that the medical sessions were on in New Zealand in September, and therefore it was impossible that any one could come from New Zealand.

Mr. SAMUEL DIXON (Adelaide) pointed out that the reason why September had been fixed was that they did not wish to have their visitors there in the summer.

Professor LAURIE suggested that the best way would be to fix the place of meeting only, leaving the date to be fixed at a future time.

Mr. DIXON said he was quite willing, on the part of South Australia, that this should be done.

The Hon. Mr. COTTON having amended his resolution in accordance with the suggestion of Professor Laurie, it was resolved, That the fifth meeting of the Association be held in Adelaide.

The question of the year and the month was next discussed.

Professor HUTTON moved, That the date be left to the Local Committee in Adelaide to settle. He thought this would be the best way to get over the difficulty.

Professor LIVERSIDGE seconded the proposition, as he thought it would be far better to leave the minor arrangements in the hands of the Local Committee at Adelaide.

Dr. OGSTON said that the date of the meeting was one of the most important things the Association had to settle, and he thought that they should settle it.

Mr. DIXON said that the Adelaide Society had considered the matter, and had decided on September as the date. They could not ask their New Zealand friends to come in the hot weather.

The CHAIRMAN said that if the meeting were held in September they would not be able to get the Professors to attend. They had their lectures, and he thought that it would be better to hold the meeting in midsummer.

Mr. TREGEAR (Wellington) moved, as an amendment, That the question of the time at which the Association will meet in Adelaide be discussed at the Hobart meeting.

Professor BICKERTON seconded the amendment, which was carried.

Appointment of Recommendation Committee.

Professor HUTTON said the next business was to appoint a Recommendation Committee. This was a new departure as regarded the Australasian Association, but it was carried out in the British Association. The work of the Recommendation Committee was to consider all the recommendations made by the Sections, and bring them before the General Committee. This would prevent crude work being done. He now moved, That the Committee comprise the President-elect, Sir James Hector; the retiring President, Baron von Mueller; Professors Hutton, Liversidge, Warren, and Kernot; Messrs. Jack, Morton, and Dixon.

Professor LIVERSIDGE seconded the motion, which was carried.

Report of Special Committee on New Rules.

The report of the Special Committee appointed at last meeting to draft a revised code of laws for the Association was brought up, and copies were distributed amongst the members of the Committee, for consideration.

The CHAIRMAN said the General Committee would discuss the recommendations of the Special Committee at the second meeting on Tuesday next.

Professor HUTTON explained what had been done by the Special Committee, and said it was not intended finally to settle the amendments at this meeting, but to leave it to the Hobart meeting to decide on and confirm the new rules. He now moved the reception of the report of the Special Committee.

Professor LIVERSIDGE seconded the motion, which was carried, and the report stood referred to the Recommendation Committee.

The Committee then adjourned.

SECOND MEETING: *Tuesday, 20th January, 1891.*

The General Committee met at 2 p.m. Sir J. Hector, President, was in the chair, and eighteen members were present.

The PRESIDENT said that, as this was the first occasion on which he had presided over a meeting of the Committee, he would take the opportunity of expressing his thanks to the members for his election as President of the Association, and was proud that his name would be handed down to posterity in connection with it.

A letter was received from Mr. S. Black, the Secretary of the Nelson Philosophical Society, forwarding the following resolution: "The Council of the Nelson Philosophical Society desire to give expression to the interest and gratification with which their members view the approaching meeting in New Zealand of the Australasian Association for the Advancement of Science, and to state that should any of its members visit this district they would gladly assist them with all the information in their power; and regret that, owing to the illness of their President, they are unable to offer any formal reception."

Professor HUTTON stated that, though the letter was dated the 9th January, it had not reached him in time to be brought before the first meeting of the Committee.

The letter was ordered to be acknowledged with thanks.

New Rules.

The rules of the Association, with a number of amendments suggested by the Recommendation Committee, were brought up for further consideration.

Resolved, on motion of Dr. OGSTON, seconded by Mr. JACK (Queensland), That the rules as amended by the Recommendation Committee be adopted, printed for circulation among members, and brought up for confirmation at the general meeting in Hobart. (See page xxiv.)

Appointment of Local Treasurer for 1892.

Mr. A. MORTON (Hobart) moved, That Mr. James B. Walker, of Hobart, be the local Treasurer for the next session of the Association, to be held in Hobart.

The motion was carried *nem. con.*

The Committee then adjourned to 9.30 a.m. on Thursday.

THIRD MEETING: *Thursday, 22nd January, 1891.*

The General Committee met at 9.30 a.m. on Thursday, 22nd January; Sir J. Hector, President, in the chair.

Report of Recommendation Committee.

The following report of the Recommendation Committee was read:—

1. That the following Research Committees be appointed, to report to the Association at its next session:—

(1.) Committee on "Seismological Phenomena in Australasia:" Mr. A. Biggs, Mr. R. L. J. Ellery, Sir James Hector, Mr. H. C. Russell, Professor Threlfall, and Mr. C. Todd. Secretary, Mr. G. Hogben.

(2.) Committee on "The Tides of South Australia:" Professor Bragg, Captain Inglis, and Professor Lyle. Secretary, Mr. R. W. Chapman.

(3.) Committee on "The Composition and Properties of the Mineral Waters of Australasia:" Professor Liversidge and Mr. W. Skey. Secretary, Mr. G. Gray.

(4.) Committee "To consider and report on the Standards and similar Matters connected with the Adulteration of Food Acts of the Australasian Colonies:" Mr. C. R. Blackett, Mr. G. Gray, Mr. W. M. Hamlet, and Professor Rennie. Secretary, Professor Bickerton.

(5.) Committee "To investigate the Movements of the New Zealand Glaciers:" Professor Cook, Mr. A. Harper, Mr. F. Huddleston, Professor Hutton, and Mr. G. E. Mannering. Secretary, Mr. J. H. Baker.

(6.) Committee on "The Fertilisation of the Fig in the Australasian Colonies:" Mr. T. F. Cheeseman, Professor Haswell, Mr. Thomas Kirk, Baron von Mueller, Mr. Skuse, Professor Tate, and Professor Thomas. Secretary, Mr. C. French.

(7.) Committee on "The Improvement of Museums as a Means of Popular Education:" Professor Haswell, Professor Hutton, Sir F. McCoy, Mr. A. Morton, Professor Spencer, Dr. Stirling, and Professor Thomas. Secretary, Professor Parker.

(8.) Committee on "Protection of Native Birds and Mammals:" Mr. S. Dixon, Professor Haswell, Mr. R. M. Johnston, Professor Spencer, Professor Tate, Professor Thomas, Mr. G. M. Thomson. Secretary, Mr. Alex. Morton.

(9.) Committee on "Rust in Wheat:" Mr. C. A. Topp and Mr. F. Wright. Secretary, Mr. A. N. Pearson.

(10.) Committee on "Antarctic Exploration:" Mr. J. H. Baker, Mr. James Barnard, Mr. F. R. Chapman, Mr. R. L. J. Ellery, Mr. G. S. Griffiths, Baron von Mueller, Mr. Percy Smith. Secretary, Captain Pasco.

(11.) Committee on "Polynesian Bibliography, with Special Reference to Philology:" Rev. S. Ella, Rev. W. Wyatt Gill, Dr. Hocken, Rev. J. W. Stack, and Mr. E. Tregear. Secretary, Dr. Fraser.

(12.) Committee on "General Sanitation:" Dr. Bancroft, Hon. Dr. Campbell, and Professor Warren. Secretary, Dr. Ogston.

2. That a grant of £25 be placed at the disposal of the Committee to investigate the Movements of the New Zealand Glaciers (No. 5).

3. The following was received from Section D: "That in the opinion of this Section it is desirable to secure greater uniformity in biological nomenclature, especially in the department of morphology." "That in order to secure such uniformity the following steps be taken: (*a*) The appointment of an international committee to define terms of general importance, *e.g.*, terms common to botany and zoology, terms relating to position, &c.; (*b*) the preparation of an authoritative historical glossary of biological terms; (*c*) the systematic record of new terms in the various recording publications." "That copies of these resolutions be transmitted to the British and American Associations and to the Anatomische Gesellschaft."

4. The following resolutions from Section D were considered, and the General Committee is hereby requested to give effect to them: "That, in the interests of science, it is most desirable that some steps should be taken to establish one or more reserves, where the native flora and fauna of New Zealand may be preserved from destruction." "That the Little Barrier Island and Resolution Island, Dusky Sound, appear to be most suitable localities for such reserves." "That a copy of the above resolutions be forwarded to the Hon. the Minister of Lands for New Zealand."

5. Section E recommended, "That, inasmuch as the sea between New Zealand and the islands to the north-west of New Zealand on the one hand, and Australia and Tasmania on the other, has received no definite name, the Australasian Association for the Advancement of Science recommends that the name of Tasman Sea be given to it; and that a communication be sent to the Lords of the Admiralty, requesting them to adopt this name by entering it upon the charts."

Mr. J. D. Enys moved the adoption of the report.

The Rev. T. Flavell seconded the motion, which was carried.

Appointment of Publication Committee.

A Publication Committee to superintend the publication of the annual volume was appointed, as follows: The President, the General Secretaries, Messrs. Mantell and Travers.

Votes of Thanks.

Mr. Grant, of Tasmania, moved, That votes of thanks be accorded the following: To the Government of New Zealand, for the liberal recognition and substantial assistance they have given to the Association; to the Chairman and Governors of Canterbury College, for the use of the College buildings; to the Bishop of Christchurch and the Chapter and the Choir of the Cathedral; to the Chairman and Directors of the Belfast Freezing-works; to the Chairman and Directors of the Kaiapoi Woollen Factory; to the Railway Commissioners; to others who have extended hospitality to members of the Association; to the daily journals, for the completeness with which they have reported the proceedings of the Association and otherwise furthered its objects.

Mr. Jack, of Queensland, seconded the motion, which was carried unanimously.

The Association was then formally closed, to meet again in Tasmania.

NEW RULES.

Adopted at the Christchurch Meeting in January, 1891; to be submitted for confirmation at the Hobart Meeting, January, 1892.

Objects of the Association.

The objects of the Association are to give a stronger impulse and a more systematic direction to scientific inquiry; to promote the intercourse of those who cultivate science in different parts of the Australasian Colonies and in other countries; to obtain more general attention to the objects of science, and a removal of any disadvantages of a public kind which may impede its progress.

Rules of the Association.

Members and Associates.

1. Members shall be elected by the Council; the annual subscription shall be £1, but after the 30th June, 1895, members will be required to pay an entrance-fee of £1 in addition.

2. The annual subscription shall be £1, due on the 1st July in each year.

3. A member may at any time become a life-member by one payment of £10, in lieu of future annual subscriptions.

4. Members who fail to pay their subscription before the annual session of the Association cease to be members, but may rejoin by paying the entrance-fee in addition to the annual subscription.

5. The Local Committee may admit any person as an associate for the year on the payment of £1.

6. Associates are eligible to serve on the Local Reception Committee, but are not eligible to hold any other office, and they are not entitled to receive gratuitously the publications of the Association.

7. Ladies' tickets (admitting the holders to the general and sectional meetings, as well as to the evening entertainments) may be obtained by full members on payment of 5s. for each ticket. Ladies may also become either members or associates on the same terms as gentlemen.

Sessions.

8. The Association shall meet in session periodically for one week or longer. The place of meeting shall be appointed by the Council two years in advance, and the arrangements for it shall be intrusted to the Local Committee.

Council.

9. There shall be a Council consisting of the following: (1) Present and former Presidents, Vice-Presidents, Treasurers, and Secretaries of the Association, and present and former Presidents, Vice-Presidents, and Secretaries of the Sections. (2) Authors of reports or of papers published *in extenso* in the Annual Reports of the Association.

10. The Council shall meet only during the annual meeting of the Association, and during that period shall be called together at least twice.

Local Committees.

11. In the intervals between the sessions of the Association its affairs shall be managed in the various colonies by Local Committees. The Local Committee of each colony shall consist of the members of Council resident in that colony.

Officers.

12. The President, five Vice-Presidents (elected from amongst former Presidents), a General Treasurer, one or more General Secretaries, and Local Secretaries shall be appointed annually by the Council.

13. The Governor of the colony in which the session is held shall be *ex officio* a Vice-President.

Reception Committee.

14. The Local Committee of the colony in which the session is to be held shall form a Reception Committee to assist in making arrangements for the reception and entertainment of the visitors. This Committee shall have power to add to its number.

Office.

15. The permanent office of the Association shall be in Sydney.

Money Affairs of the Association.

16. The financial year shall end on the 30th June.

17. All sums received for life subscriptions and for entrance-fees shall be invested in the names of three Trustees appointed by the Council, and the interest only arising from such investment shall be applied to the uses of the Association.

18. The subscriptions shall be collected by the Local Secretary in each colony, and by him forwarded to the General Treasurer.

19. The Local Committees shall not have power to expend money without the authority of the Council, with the exception of the Local Committee of the colony in which the next ensuing session is to be held, which shall have power to expend money collected or otherwise obtained in that colony. Such disbursements shall be audited, and the balance-sheet and the surplus funds forwarded to the General Treasurer.

20. All cheques shall be signed either by the General Treasurer and the General Secretary, or by the Local Treasurer and the Secretary of the colony in which the ensuing session is to be held.

21. Whenever the balance in the hands of the banker shall exceed the sum requisite for the probable or current expenses of the Association, the Council shall invest the excess in the names of the Trustees.

22. The whole of the accounts of the Association, *i.e.*, the local as well as the general accounts, shall be audited annually by two Auditors appointed by the Council; and the balance-sheet shall be submitted to the Council at its first meeting thereafter.

Money Grants.

23. Committees and individuals to whom grants of money have been intrusted are required to present to the following meeting a report of the progress which has been made, together with a statement of the sums which have been expended. Any balance shall be returned to the General Treasurer.

24. In each Committee the Secretary is the only person entitled to call on the Treasurer for such portions of the sums granted as may from time to time be required.

25. In grants of money to Committees, or to individuals, the Association does not contemplate the payment of personal expenses to the members or to the individual.

Sections of the Association.

26. The following Sections shall be constituted:—

A.—Astronomy, Mathematics, and Physics.
B.—Chemistry.
C.—Geology and Mineralogy.
D.—Biology.
E.—Geography.
F.—Ethnology and Anthropology.
G.—Economic Science and Agriculture.
H.—Engineering and Architecture.
I.—Sanitary Science and Hygiene.
J.—Mental Science and Education.

Sectional Committees.

27. The Presidents, Vice-Presidents, and Secretaries of the several Sections shall be nominated by the Local Committee of the colony in which the next ensuing session of the Association is to be held, and shall have power to act until their election is confirmed by the Council. From the time of their nomination, which shall take place as soon as possible after the session of the Association, they shall be regarded as an Organizing Committee for the purpose of obtaining information upon papers likely to be submitted to the Sections, and for the general furtherance of the work of the Sectional Committees. The Sectional Presidents of former years shall be *ex officio* members of the Organizing Committees.

28. The Sectional Committees shall have power to add to their number.

29. The Committees for the several Sections shall determine the acceptance of papers before the beginning of the session. It is therefore desirable, in order to give an opportunity to the Committees of doing justice to the several communications, that each author should prepare an abstract of his paper of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original paper, to the Secretary of the Section before which it is to be read, so that it may reach him at least a fortnight before the session.

30. Members may communicate to the Sections the papers of non-members.

31. The author of any paper is at liberty to reserve his right of property therein.

32. The Sectional Committees shall meet at 2 p.m. on the first day of the session in the rooms of their respective Sections, and prepare the programmes for their Sections and forward the same to the General Secretaries for publication.

33. On the second and following days the Sectional Committees shall meet at 10 a.m.

34. No report, paper, or abstract shall be inserted in the annual volume unless it be handed to the Secretary before the conclusion of the session.

35. The Sectional Committees shall report to the Publication Committee what papers it is thought advisable to print.

36. They shall also take into consideration any suggestions which may be offered for the advancement of science.

Research Committees.

37. In recommending the appointment of Research Committees all members of such Committees shall be named, and one of them who has notified his willingness to accept the office shall be appointed to act as Secretary. The number of members appointed to serve on a Research Committee should be as small as is consistent with its efficient working. Individuals may be recommended to make reports.

38. All recommendations adopted by Sectional Committees shall be forwarded without delay to the Recommendation Committee; unless this is done the recommendation cannot be considered by the Council.

39. The President of each Section shall take the chair, and proceed with the business of the Section at 11 a.m. In the middle of the day an adjournment for luncheon shall be made; and at 4 p.m. the Sections shall close.

40. At the close of each meeting the Sectional Secretaries shall correct, on a copy of the official journal, the lists of papers which have been read, and add to them those appointed to be read on the next day, and send the same to the General Secretaries for printing.

Recommendation Committee.

41. The Council at its first meeting in each year shall appoint a Committee of Recommendations, to receive and consider the reports of the Research Committees appointed at the last session, and the recommendations from the Sectional Committees. The Recommendation Committee shall also report to the Council, at a subsequent meeting, the measures which they would advise to be adopted for the advancement of science.

42. All proposals for the appointment of Research Committees and for grants of money must be sent in through the Recommendation Committee.

Publication Committee.

43. The Council shall each year elect a Publication Committee, which shall receive the recommendation of the Sectional Committees with regard to publication of papers, and decide finally upon the matter to be printed in the volume of Transactions.

Alteration of Rules.

44. No alteration of the rules shall be made unless due notice of all such additions or alterations shall have been given at one annual meeting, and carried at a subsequent annual meeting of the Council.

AFTERNOON MEETINGS.

Thursday, 15th January, 1891.

In the afternoon Sir James and Lady Hector received the members of the Association and their friends in the grounds of Christ's College. A very large number were present.

Saturday, 17th January, 1891.

In the afternoon a large number of the members of the Association and ladies were entertained by Mr. and Mrs. Leonard Harper at Ilam.

Tuesday, 20th January, 1891.

In the afternoon a number of the members and their friends were entertained at a garden-party at Hambleden by the Bishop of Christchurch and Mrs. Julius.

EVENING MEETINGS.

Thursday, 15th January, 1891.

There was a very large audience at the Provincial Council Chamber when the President for the year was installed. The chair was occupied by Baron von Mueller, the retiring President, who was supported on his right by His Excellency the Earl of Onslow (Governor of New Zealand), and on his left by Sir James Hector, the President-elect.

Baron von Mueller said: Your Excellency, Sir James Hector, ladies and gentlemen,—For nearly sixty years, since the British Association for the Advancement of Science was founded by Sir David Brewster, it has been the rule that the elected President should be introduced by his predecessor. This is the only reason why I have the privilege, to a small extent, of sharing actively this evening in this inaugural meeting. And, availing myself of the privilege to address you, I beg, in the first instance, that we pay our homage to the noble representative of Her Majesty who supports this meeting in his vice-regal capacity. Each of these meetings is like a link in the chain which will lengthen as the years roll on, which will strengthen as generations pass by, and, as far as human foresight and human forethought go, we can expect that they will last through centuries. We owe to the British Association that great advance of science, and especially of applied knowledge, which has been made throughout the world. I shall avail myself also of the opportunity to tender my honoured colleagues in Melbourne, the office-bearers, and the originator of this movement, and all who shared in the formation of this society, my grateful acknowledgments. I do this all the more as I cannot hope to attend many of these meetings on future occasions. At best, by Divine grace, there can be but only a few more meetings in which I can have the privilege of sharing. I have also to add a word which is one of sadness. We sadly miss one from amongst us—from the scene of his labours, from the principal place of his trials—we miss Sir Julius von Haast. Now, in fulfilling what is really the duty which devolves on me this evening—the introduction of the President at this inaugural meeting—let me say that he is one who took part in the exploration of the Rocky Mountains in 1857–60. Some thirty years ago he was selected for the position he now holds under the Government of New Zealand, which he has so worthily filled to this time, and during this period he has exercised a great, an enormous influence upon the development of his adopted country. Sir James Hector stands high in the scientific world by the universality of his knowledge. It is remarkable in how many directions he has been useful; and of the application of his knowledge there are many testimonies existing. If any testimony were wanting, it is to be found in the series of volumes published by the New Zealand Institute. They show in a remarkable manner the power of his administrative abilities and the great amount of his own research, which resulted in this long series of volumes; for, although in all the colonies there has been an honourable and noble competition in science, New Zealand carries the palm by the long series of publications of its Institute. I beg with pleasure to induct Sir James Hector into the Presidential chair; and I trust, Sir, that your term will be, as I feel sure it will be, a glorious success.

Baron von Mueller then vacated the chair, which was taken by Sir James Hector.

His Excellency the Governor of New Zealand said: Sir James Hector, ladies and gentlemen,—Before proceeding to any further business this evening, I ask your permission to say a few words of welcome to those who are strangers in our midst upon the occasion of their visiting New Zealand. I think nothing strikes the English visitor to the colonies more than the constant recurrence of institutions similar to those which he has left behind him in England. He finds that the colonies have grafted on to their social system those institutions which the experience of nine centuries has enabled England to bring to their present perfection. At the same time you have carefully striven to prevent, and at their first appearance to uproot, those evils from which the Mother-country has not yet been able to free herself. Thus you find the same beautiful forms of divine worship in Christchurch Cathedral, in your churches and chapels, as we have at Home. The youth of all classes have the advantages of elementary education as they have at Home, with this difference: that here it is without direct cost to the parents, who are relieved of the charge of their children during the troublesome years of infancy, and who, by leaving them at school till riper years, may obtain for them something more than an education which is elementary. You have public schools on the lines of those of Eton and Harrow, to whose agency illustrious statesmen and warriors have attributed much of England's pre-eminence among nations; and you possess richly-endowed institutions for training adults, not only in intellectual pursuits, but also in those arts which enable men to subdue the wilderness, and to make the earth bring forth her increase. Let me, in passing, pay a warm tribute to the valuable work carried on by the University of New Zealand, whose career and position, both in respect of curriculum and number of students, compare favourably with the older institutions of Sydney and Melbourne. The ladies present will not forget that recognition is due from their sex to the liberal-minded action of this University in having been the first to open its doors to women-students by conferring on them equality with men in the matter of degrees. On the other hand, you have not allowed that great social question which is convulsing Europe, the disposal of the indigent poor, to become a source of discontent and disturbance. You have avoided the pauper workhouses where the State grudgingly gives a maintenance to the aged lifelong worker, under conditions the least agreeable in life lest any should be found to wish to go and do likewise. What wonder, then, that such an institution as the British Association should have its counterpart in Australasia—an association eminently fitted to flourish in such communities as these, removing science from the pursuit only of the few, and marking the democracy of knowledge, by sympathy begetting knowledge and adding again to sympathy! You have chosen as your place of meeting this year the colony over which I have the honour to preside in the name of Her Majesty; and, in my dual capacity as the Queen's representative—for does not your very name denote a bond of Imperial unity in its purpose?—and as the mouthpiece of this important community, I bid you a hearty welcome to our shores. If a layman may express an opinion on such a point, I would say that I think the selection has been eminently a wise one, and that there are reasons why this meeting should be the most interesting yet held by the Association, for in New Zealand you may find objects of scientific interest which will, I believe, amply repay you for your voyage of twelve hundred miles, as I have found them repay my less cultured mind for its voyage of twelve thousand. Certain I am that no word of regret ever fell from any member of the British Association that that Association should have transferred its sphere of operations in 1884 from Great Britain to one of the younger members of the British Empire; and, if in Canada, why, at some future time, with our present improved steam communication, should not the British Association meet in Australia, or even in New Zealand? On that occasion Lord Lansdowne, the Governor-General of Canada, commented on the difficulty with which science would have to contend in competing with material activity in a young country. No doubt the leisured class is less numerous, till recently had no existence in the colonies, and is of slow growth, being constantly depleted by those who, having earned their leisure, choose to spend it elsewhere. There is much truth in his remark; but, on the other hand, the outdoor life of a very large section of the community is conducive to a knowledge of and interest in nature and natural history. The toil here is not so unremitting or so unremunerative as in other older communities, and more spare moments can be devoted to the observation and study of living forms and natural features. It is in this respect, I apprehend, that you welcome among you so large an admixture of the popular or, if I may so distinguish it, "lay" element, and especially may I say of ladies, whose time is likely to be more at their own disposal, and who can take an active and seemly interest in scientific research. I venture to think that the Association should urge upon this "lay" class particularly the value not only of the acquisition and diffusion of knowledge, but also of scientific method. Scientific method is of special value in these days, because information is so easily acquired from textbooks, popular lectures, and magazine articles that people are tempted to plume themselves on the possession of scientific knowledge, whereas they are in reality acquiring slipshod habits of thought and study. Moreover, with more careful direction their talents might enable them to act as guides and instructors in science to those who must be trained from its elements. Again, in a country like New Zealand, where there exist so many new varieties of life, how desirable is accuracy of observation! What to observe, when to observe, and how to take notes of our observations, are habits specially needful of acquisition. It is better to err on the side of noting something which may have been already observed than to risk missing an opportunity of contributing information concerning the structure and habits of those plants and animals as to which science is still in a state of infantile ignorance. Although our President is a gentleman of the first rank in the field of scientific research, and although we have among us many eminent men who devote themselves to the study of various phenomena, there are many problems still unsolved. But we entertain high expectations that the assembling of so many men of science from other parts of the world will illumine our efforts to fathom some of the mysteries with which Nature has surrounded this, to us, new world of life. I think, ladies and gentlemen, that both in respect of scenery and natural phenomena you will find much that is not only interesting, but unique, in New Zealand. No matter to which special branch of science you may have devoted yourself, you will find something to study in New Zealand, and in New Zealand alone. Meteorologists will find something remarkable in the diversities of climate over a country containing, from semi-tropical Auckland to antarctic Southland, but 100,000 square miles. They will note the action produced on our rainfall by our great central range of Alps, and the wonderful difference within a few miles in the vegetation and appearance of the country—on the western side dense green forests, and on the eastern side vast brown plains; and they will, perhaps, be able to explain to us why Cook Strait has earned the reputation of being the blast-pipe of the Pacific. The naturalist will have ample opportunity to study the marvellously successful results of acclimatisation. The Australian members will be specially interested to compare whether those results have been most successful here or on the continent in the cases of the rabbit and the sparrow. Interesting and curious also are our deep-sea fish, such as the frost-fish, which never allows man to capture him, but which occasionally offers himself as a voluntary sacrifice on the gastronomic altar. As regards New Zealand quadrupeds, the labours of the naturalist will be considerably lightened by the knowledge that but one existed, and that that one is believed to be extinct. He may, however, be able to enlighten us as to the true character of the vegetable caterpillar, which, going into the ground a grub, ought, according to European ideas, to emerge as a perfect insect, but, in very antipodean fashion, appears to become a plant instead. The ornithologist, under the able guidance of Sir Walter Buller, will be able to study our so-called wingless birds, and to tell us what prospect they have, now that men and dogs have come to chase them, of recovering the use of those limbs of which long desuetude appears to have deprived them; and whether there is any chance of curing the kea of his acquired taste for sheep-fat, which has turned a comical and interesting parrot into one of the anathematized class of native pests. The botanist should revel in our wealth of ferns and alpine plants, and may perhaps decide for us whether that complete illustration of parasitical growth, the rata, initiates its all-devouring embrace as a suppliant at the feet of its victim or round the neck of the devoted object of its affection. Also, may not our farmers look to the botanist for some help in the pursuit of agriculture, to learn something new of plant-life, of suitability of soils and of insect-pests?—so that not only our moral but also our material position may be the better for this meeting. The geologist will find an opportunity for studying the effects of volcanic eruption, of which Tarawera offers an example hardly to be equalled within easy reach of civilisation. The Australian mineralogists may find an opportunity for comparing their more continuous auriferous reefs with our rich but sadly broken strata in New Zealand. The palæontologists will find a curious remnant of otherwise extinct reptiles in the tuatara lizard, and, close at hand, in the admirably-arranged museum at Christchurch, materials for a study of the extinct moa. Possibly they may give us some contribution to the controversy respecting the co-existence in New Zealand of that gigantic bird with man. The anthropologist will find in the Maoris a most interesting example of the advanced civilisation of a native race, and will be able to witness not only the effects of their participation in the advantages enjoyed by Europeans, but also the results of an admixture of the two races in all classes of society. Statisticians and social economists at Home will look with interest for some fresh light on the interesting thoughts suggested by Mr. Ravenstein at Leeds concerning the future of the human race, as to the period of time which may be estimated to elapse before the world will cease to be able, under present conditions, to support its increasing population. These are only a few subjects of interest which strike the least scientific observer among you, and without doubt many more will reveal themselves to the searching eye of science in New Zealand. Your labours should teach us that neither in the case of nations nor of individuals do the pleasures of life consist solely in the making of money, and that there are many who, disregarding selfish considerations of material wealth, prefer to devote their talents to the pursuit of knowledge and the discussion of its results. These philosophers have embraced the principles which Plato, in his "Republic," counsels us to adopt towards our rulers and guardians, the people, that they "may grow up, not amid images of deformity which will gradually poison and corrupt their souls, but in a land of health and beauty, where they will drink in from every object sweet and harmonious influences."

Mr. Morton (of Hobart) said: Mr. Chairman, your Excellency, ladies and gentlemen,—I consider that I have a most pleasant duty to perform. It is to move, as a delegate from the Royal Society of Tasmania, a vote of thanks to our renowned scientist who has just vacated the chair. With such able Presidents as those who have filled the chair, and with those able ones who are to come, the Association will certainly improve and prove to be a great success; and I have only to refer to the first President, Mr. Russell, and then to our most illustrious scientist, Baron von Mueller, who has just now handed over the reins of government to our worthy and scientific friend Sir James Hector; and then come to the next meeting, when such a worthy man as our own Governor of Tasmania, Sir Robert Hamilton, is to preside, and I venture to say that he will be equally successful with those Presidents who will have preceded him. I will not detain you any further, but, with feelings of gratitude, say I have great pleasure in proposing a hearty vote of thanks to the retiring President, Baron von Mueller.

Professor W. H. Warren (Sydney) said: I rise to second the motion; and I fully indorse all that Mr. Morton has said of the attainments of Baron von Mueller as a scientist. He enjoys a world-wide reputation as a botanist, and he is undoubtedly the greatest living authority on the botany of Australia. You will agree that the Association is indebted to him for the kind manner in which he has devoted his time and his talents to its interests.

The President put the motion, which was carried by acclamation.

Baron von Mueller said: I feel deeply touched by this mark of recognition and acknowledgment of the little I may have done in my lifetime for the advancement of knowledge. It comes truly unexpectedly to me. I do not think I am entitled to such graceful appreciation of that small share which I have taken in the development of Her Majesty's Australian dominions. There are legions of men in older settlements who have given their time, knowledge, and talents in advancing these beautiful colonies, who are better deserving of thanks than I am. Still, there is a real privilege in having lived through this century, in helping, as in my case, even to the smallest extent in the development of these lands. In New Zealand, what a grand future is there! I see in the young generation which is growing up here the rosy bloom of health so impressed in every face, and the strength of the Anglo-Saxon race is seen in its highest cultivation. And how could it be otherwise in this beautiful climate in this colony, where your educational institutions give every opportunity for the advancement of knowledge? Yet, above all this, there is a higher motive, and we must not forget the pious element in a British community, the keeping-up of the Divine service in its sacredness, and in the observance of the Sabbath, which is disregarded in many other supposed enlightened countries. I have most sincerely to thank you for the kindly acceptance of this unexpected motion.

Baron von Mueller afterwards alluded in a graceful manner to the election of Sir R. Hamilton as President for 1892.

The President then invited Professor Goodale, President of the American Association for the Advancement of Science, to address the meeting.

Professor Goodale said: Mr. President, your Excellency, ladies and gentlemen,—My first duty this evening is to thank you very heartily, Sir James, and you, my dear Baron, for the very warm welcome you have extended to me. Be assured that these cordial expressions are most sincerely appreciated. My second duty is to bring to you greetings from the American Association for the Advancement of Science. When, a few years ago, we learned that one of your most energetic professors had taken in hand the formation of an Australasian Association, somewhat on the lines of the British Association and our own, we took the deepest interest in the plans, for we hoped that you would realise what we have secured. In these days of extreme specialism there is need of a broad general association, so that specialists may confer together; so that they can widen the outlook, and that those who are cultivating small portions of the field can see that the ground near to the fence is not neglected. Now, under a general association like this, specialists can meet and confer together, and they can preserve that which they certainly hope to preserve. Then, again, we have found, and I have no doubt you will find, that general meetings of associations like this diminish, if they do not fully prevent or remove, personal misunderstandings. Sometimes these misunderstandings are allowed to grow until they at last become intensified. In associations like the British Association and our own we find the tendency to anything like personal differences to diminish and disappear; and I hope you will find the same. We have found that the British Association and our own have always done good, by their visits, to the community where the meetings were held. A good many have criticized unfavourably this migratory tendency, holding that it was better to have the meetings in some central place. But it seems that in this the old fable comes back—that "strength seems to be restored every time we touch new ground." This migratory tendency is the survival of the migratory tendency inherited from our ancestors. I feel very sure if you were to put it to the vote in the British Association you would not receive a single positive vote in favour of substituting for these missions, as we may call them, a permanent meeting-place. When we heard that an Australasian Association was to be formed in this manner, our hopes and best wishes went out to you, and when the opportunity came to present felicitations on your success it was most eagerly accepted; so that I have now great pleasure in presenting, on behalf of the Association I represent, our congratulations upon the pronounced success of the Association. The American Association is not limited to the United States. As His Excellency the Governor has told you, the British Association has met on Canadian soil. Some of our meetings are also held in the large centres of the Dominion of Canada, and the meeting of the British Association was really a joint meeting of the two Associations. We sometimes read disturbing telegrams, but I love to think that blood is thicker than water. Now, my honoured colleagues, through me, extend to you an invitation to visit our Association. Do not regard it as one of those general invitations which mean, "Just drop in as you pass by;" but, if you find you can be present at any of our meetings, just inform our General Secretary, and, when you were present, then the general invitation, you would find, would be converted into a most specific one. I again thank you for your cordial welcome, and, congratulating the Association upon its past and present success, I have only now to express on behalf of our Association, and on my own behalf, our best wishes for Australasia and the Australasian Association.

The PRESIDENT then gave his inaugural address. (See page 1.)

Mr. F. DE C. MALET said he had been asked to propose, on behalf of the Association, a resolution which he was sure would be carried by acclamation. The presence of His Excellency the Governor of the colony there that evening could not be regarded otherwise than as a high compliment to the Association, and a matter of congratulation for its President and officers, and those who had the interests and welfare of the Association at heart. They would readily understand that His Excellency had attended the meeting at considerable personal inconvenience, especially when they bore in mind the official and other calls upon Her Majesty's representative in the colony at the present time. He had great pleasure in moving, That the best thanks of the Australasian Association for the Advancement of Science be accorded to His Excellency the Governor for the distinction he has conferred upon the Association by his presence here this evening.

The MAYOR of CHRISTCHURCH had much pleasure in seconding the proposition of Mr. Malet. It was conferring a very great honour upon the city to select Christchurch as the meeting-place of such a scientific body.

The motion was carried by acclamation.

His Excellency the GOVERNOR, in acknowledging the vote, said that he had learned a good deal by listening to the addresses that had been made, and hoped that he and many others would be present on the following evening to hear the experiences of a young New-Zealander who had made a gallant attempt, in which he was almost successful, to scale one of the giant mountains of the Southern Alps, which he (the speaker) had had the opportunity of admiring.

The PRESIDENT said he had received a telegram from Sir R. Hamilton, the President of the Royal Society of Tasmania, accepting the position of President for 1892, and congratulating the Association upon its meeting here.

The proceedings then terminated.

Friday, 16th January, 1891.

In the evening an address was given by Mr. G. E. Mannering, at the Provincial Council Chamber, before a large audience, on "The Glaciers of the Tasman Valley." Fifty-two photographic views, specially taken by Messrs. Wheeler and Son, illustrative of the scenery of the alpine region of Mount Cook and the Tasman and Murchison Glaciers, were exhibited; also a map showing the geological formation of New Zealand. The views were shown by means of a powerful lime-light under the direction of Mr. Seager.

The PRESIDENT briefly introduced Mr. Mannering, who, he understood, had succeeded in reaching the highest point which had been reached by any person in New Zealand. He stated that His Excellency the Governor had just come from the alpine district, and they would no doubt be pleased if he made a few remarks before the address was given.

His Excellency the GOVERNOR said that when one had come from places he had recently visited he was supposed to know more about them than did other people. What he would like to say, as having been in the vicinity of Mount Cook, was that excursions could be made there without any great amount of difficulty. The Government had made a track up the Tasman Glacier, and were now building a hut, and from what he could see when he was there he believed any one who visited it in this season or next would have the opportunity of making a most successful excursion up to the dividing-point of the range, from which they would be able to see over to the West Coast; and he believed it was the intention of the Government to make a path up the Hooker Glacier, to the site of the ice-falls and other interesting features of glacier-formation. His desire in making these remarks was that people should understand that there was no real difficulty in ascending to a certain point in these mountains; that no alarm should be created by the illustrations of Messrs. Mannering and Dixon; and that in time the glaciers we possessed would not be the property only of alpine mountaineers, but of the general public.

Mr. MANNERING then gave his address. (See page 591.)

Mr. J. H. BAKER, Commissioner of Crown Lands, moved a hearty vote of thanks to Mr. Mannering.

Baron VON MUELLER seconded the motion, and, in doing so, conveyed to Mr. Mannering the thanks of the Association for enlightening them on the matter of alpine explorations in New Zealand. He felt certain that the excursion arranged by the Association to the Alps would be a most interesting one, and that the visitors would bring back with them recollections which would never be obliterated. The mountaineer had shown a specimen of that chivalry and courage which had made the British nation so great, and he felt sure they would all agree with him when he said that an enterprise like that to an account of which they had listened should be generously supported.

The PRESIDENT put the motion, which was unanimously adopted, as one of thanks to Messrs. Mannering and Dixon for the information given, and to Messrs. Wheeler and Seager for the splendid lime-light views.

Monday, 19th January, 1891.

A lecture on "Oysters and Oyster-culture in Australasia," by Mr. W. Saville-Kent, F.L.S., F.Z.S., was read in the Provincial Council Chamber.

The PRESIDENT, after expressing regret for the unavoidable absence of Mr. Saville-Kent and the photographs and diagrams illustrating his subject, called upon Professor Parker to read the paper. (See page 551.)

Professor THOMAS proposed a vote of thanks to the author of the paper, Mr. Saville-Kent, and to the reader, Professor Parker. Speaking on the depletion of the Auckland oyster-beds, he said that even since the Act forbidding the exportation of rock-oysters was passed many cases of the bivalves were sent away under the name of mud-oysters.

Mr. F. R. CHAPMAN seconded the vote of thanks, and spoke on the necessity of protecting our oyster-beds; and said that he was glad to hear Mr. Saville-Kent's paper, as it was the beginning of a feeling of real interest in our marine resources. He suggested the advisability of biologists like Mr. Saville-Kent being secured for New Zealand, and moved, That the Association should ask the Government to print and circulate his paper.

The President, after remarking that many of the oysters mentioned by Mr. Saville-Kent were named by Professor Hutton, called upon that gentleman to speak on the subject.

Professor Hutton said that New Zealand possessed in the Stewart Island mud-oyster and the Auckland rock-oyster the best specimens of Australasian bivalves. He said that New Zealand oysters had a better flavour than those of Australia; that, although artificial propagation was the first essential step, it might be found profitable to spread young oysters for the purpose of fattening in such places as the Sumner Estuary, Lyttelton Harbour, or any suitable places where at present there are no oysters.

Mr. Morton, Commissioner of Fisheries for Tasmania, said that on many of the New Zealand oysters imported into Tasmania he had noticed quantities of young ones, and he thought steps ought to be taken to stop this waste. Mr. Morton seconded the motion that Mr. Saville-Kent's paper should be printed by Government.

Mr. Kent (Auckland) gave some valuable information on oysters in North Island waters, and gave an instance of Auckland rock-oysters being transported by accident to a place on the east coast of Wellington Provincial District, and taking firm growth there.

Mr. H. R. Webb, in alluding to the subject of cultivating oysters in places away from their natural beds, said that at one time Messrs. Garrick and Cowlishaw introduced oysters into some bay on Banks Peninsula, but, although the oysters increased in numbers, the venture was not a financial success.

Mr. Thomson gave some valuable information on Stewart Island oyster-fisheries, and the limits of the bed; and said that the dredges used in capturing the oysters were calculated to destroy them in large numbers.

The President congratulated the meeting on the interesting discussion raised by the reading of the paper, and, after describing a peculiar and valuable specimen of oyster that once existed on Cape Farewell Spit and at the mouth of Catlin's River, moved, That a vote of thanks be transmitted to Mr. Saville-Kent and given to Professor Parker.

After Professor Parker had referred to the advisability of a marine laboratory being established in New Zealand, the meeting adjourned.

Tuesday, 20th January, 1891.

There was a very large attendance at a lecture given by Mr. G. F. Tendall in the Provincial Council Chamber on "The History of Vocal Music." (See page 574.)

A vote of thanks was carried by acclamation to Mr. Tendall and the choir, on the motion of Professor Laurie, seconded by Mr. A. Wilson, who expressed regret at the want of adequate provision in New Zealand for instruction in the science of music.

Thursday, 22nd January, 1891.

Spohr's oratorio, "The Last Judgment," was given before the members by the Cathedral choir in the evening, when a very large congregation assembled in the building. The solos were taken by Masters R. T. Harper, H. Andrews, and Bünz, and Messrs. H. Weir, A. McIntosh, and A. Millar, while Mr. Tendall presided at the organ. The production of the oratorio was a thoroughly successful one.

EXCURSIONS.

Tuesday, 20th January, 1891.

Excursion to the Addington Workshops.

Members of the Association visited the Addington Workshops under the guidance of Mr. J. P. Maxwell and Mr. R. J. Scott.

They were met at the workshops by Mr. Rotherham, Superintendent of Locomotives, and Mr. McDonald, Locomotive Engineer, and inspected the works according to a well-arranged programme. One of the first objects seen was a beautiful high-speed engine—the Porter Allen—running evenly and noiselessly at some hundreds of revolutions a minute. They next visited the sand-blast machine, which, by the aid of a jet of sand driven out of an orifice by an air-blast, grinds glass or roughens any hard surface. The man in charge of this machine was grinding the patterned glass one sees in the skylights and smoking-cars of railway-carriages. The pattern, of gelatine or even brown paper, is pasted on the glass, and the shower of sharp sand, though it cuts the smooth surface of the glass, rebounds from the softer substance, and leaves the pattern in smooth relief against the ground surface. A little apparatus for making pads for lubricating purposes out of blanketing and wire, and a steam-room for driving sap and resin out of new timber, were noticed; then the party moved into the car-and-waggon shop, where scores of men and machines were at work fitting up old cars and building new ones. The machinery in this department was very interesting. One machine was engaged mortising holes in some stout square pieces of timber. First a tool came down with a swinging movement, rapidly revolving at the same time, and cutting an oblong hole with rounded ends; then a chisel shot down and squared the mortise to its size with a few sharp blows. Close to this machine was a band-saw slicing through two-inch wood as easily as the man guided it along the pencilled pattern. There were planing-machines carving long boards into smoothly-finished mouldings, tenoning-machines, and nearly every other kind of machinery used for working wood into various forms. In one part of the shop was a new railway-carriage, nearly completed, with an open platform running along its side — a luxury which travellers wishing to see the country and enjoy fresh air at the same time will appreciate.

From the car-and-waggon shop the party went into a yard where men were engaged bending cold steel rails into points and crossings, and then were conducted into the smiths' and boiler shop, where machinery was dealing with iron almost as easily as that working the wood. A steel circular saw was cutting through a plate of cold iron an inch in thickness. A punching-machine was driving holes through boiler-plates as easily as one drives a pencil through thin paper. Another machine was riveting inch rivets with a single blow. Another machine was stamping out hooks, clips, and bolts, and moulding them into the desired shape with a few blows. Brawny smiths were working iron into all kinds of shapes. At one end of this shop were a great steam-hammer and a low square-built furnace. Into the furnace went compact heaps of scrap-iron—old chains, old bolts, cuttings and clippings of all sorts. They came out of the furnace partly fused and were conveyed to the steam-hammer, which, with blows that shook the ground, hammered the mass into square blocks, which were again heated to be hammered again into buffer-heads, couplings, and the massive gear used to attach railway-trucks and carriages. At the other end of the shop men were at work putting new plates on to boilers. With power conveyed by endless cotton ropes a drilling-machine was worked that had a pliable shaft of coiled steel wire, something like that on a sheep-shearing machine. This enabled the men to drill holes in all sorts of places from inside the boiler or in corners where even a ratchet-brace could not easily be used.

From the smiths' and boiler shop the party went into the brass-moulding shops, and saw the molten brass taken from the furnaces in plumbago crucibles and poured into the moulds made in sand, to come out as brackets and scrollwork in graceful designs, which had only to be trimmed and polished to be ready for use. After seeing the molten brass moulded into various shapes, the party visited the pattern-shops, where models in wood of pieces of machinery or anything required to be cast in metal are made; and after visiting the coppersmith, who was brazing tubes, they went into the machine-shop. There they saw the brass castings being trimmed and cleaned by machinery. There were machines that carved brass into all the curious and perfect shapes required for engine-fitting; machines that planed cold steel rails, shaving off the hard metal in thick coils that grew to wonderful lengths; a machine that planed six great bronze carriage-bearings at once; drilling-machines, a milling-machine, a rapidly revolving emery wheel, polishing slide-bars and emitting showers of sparks; lathes turning rough iron bars into straight polished shafting; lathes cutting the tires on waggon-wheels, and a radio-drill that cut holes through thick copper plating, and a machine on the drill principle that cut grooves in brass or iron. The visitors also inspected safety-valves and slide-valves, and the many and manifold parts that go to make an engine. Then they examined the engine itself, a brand-new locomotive, nearly completed, and saw men lagging the boiler with silicate cloth, a material made from the refuse slag from a blast-furnace. They saw a travelling crane lift a heavy boiler out of its frame and move it about this way and that to the fraction of an inch. They saw spark-arresting gear for preventing that shower of fire which one sees sometimes issuing from the chimneys of engines burning lignite coal, perforated dampers, the water-service on a locomotive, and all the intricacies of the locomotive. Lastly they went into the tarpaulin-room, where machines were sewing double seams through thick canvas, and men were at work painting new tarpaulins with a patent weather-proof composition, stencilling on them the broad arrow and other signs denoting that they were the property of the Government of the colony. Other men were engaged repairing some of the five thousand-odd tarpaulins with which the railway service of the country is provided. The tarpaulin-room was the last place to be inspected, and the party learned there all its mysteries, even to the fact that tarpaulins could be made at £2 10s. each.

Wednesday, 21st January, 1891.

Visit to the Belfast Freezing-works.

About thirty members and several ladies made an excursion to the Belfast Freezing-works and the Kaiapoi Woollen-works, under the leadership of Mr. F. Strouts and Mr. F. Waymouth.

The party first drove to Belfast, where they inspected the freezing-works.

They were first shown the engine-room, where one of Haslam and Co.'s engines of 150-horse power was at work, supplying the motive-power of the factory. At one end of the engine-room were cylinders whose ends were coated with ice, and below them was a square iron compartment fitted with doors. One of these doors was opened, and out poured a frozen vapour amongst the visitors—snow, veritable snow on a summer's day.

The party next visited a room where four girls were at work sewing bags in which sheep were to be inserted before freezing. The sewing-machines were driven at an unusually rapid rate by steam-power, and the girls handled the light material they were sewing with wonderful adeptness. One of these girls can make as many as five hundred bags per day, and, what is more important, they can earn as much as 6s. 3d. in the same time. The bags when made are printed by machinery with the well-known brand of the company.

The party, after seeing the large centrifugal pump at work, descended to the lower rooms and to arctic regions. A stream of sheep hooked on pulleys ran down an iron bar and passed through a narrow doorway. It was stopped for a moment to allow the visitors to pass through this door into a freezing-chamber, where, in the soft light of electric lamps, some six hundred sheep were seen hanging in a temperature of 25°. This temperature was too chilly for the live visitors, though it would be reduced considerably for the dead ones, so the place was quickly vacated, and the party, passing through rows of freshly-killed pigs, entered the salting-room, where in an atmosphere kept constantly cool by artificial means lay hams and shoulders, sides and chaps, covered with salt, and taking in the brine that was to preserve them for export as bacon.

The party then entered another freezing-room, colder even than the first, where one's breath froze as it issued, and blocks of ice could be seen scattered around in all directions. The hundreds of sheep that lined the room, wrapped in their white covers, were hard as frost could make them, and seemed brittle enough to fall to pieces at a blow. From this cold, dark apartment the visitors went into daylight and warmth, into the room where men were at work boiling tongues, trimming them, putting them into tins, soldering up the tins, and labelling the tins ready for the market. After inspecting this interesting and appetising work the party entered the slaughterhouse, where twenty-seven men were at work killing and dressing sheep in a manner which would surprise an upcountry butcher. Some of these men can kill more than fifty sheep per day of eight hours, and as they get £1 per hundred and are allowed to work overtime they can make big wages; but they have to labour hard for their reward and be skilful, for if they spoil a sheep they have to buy it themselves.

Visit to the Kaiapoi Woollen-works.

The party then drove to the Woollen-works at Kaiapoi. After they had been entertained at luncheon, Mr. Blackwell, Managing Director, welcomed his guests in the name of the Kaiapoi Woollen Company. Professor Warren proposed the health of Mr. Blackwell, coupled with the name of the company, and it was drunk with much cordiality. Mr. Morton, from Tasmania, seconded the motion. The party then inspected the works.

The site of the works was acquired in 1873. The capital is £100,000, and the value of the premises and plant is estimated at £45,000. The mill has an intercolonial reputation as being one of the most extensive of its kind in Australasia; and the products of woollen goods, mainly in tweeds, blankets, and flannels, possess a world-wide fame for their sterling quality and durableness in wear. It is stated that the waters of the River Cam flowing past the mills possess exceptional properties for the washing and cleansing of wool, imparting to the same an exceedingly soft, silky texture. The visitors were enabled to witness the process of manufacture, from the opening of bales of greasy wool, thence through washing, drying, dyeing, teasing, scribbling, twisting into yarn on the mules, weaving on the looms, milling, and finishing, till the brightest doeskin or the best ladies' tweed was produced from the raw material. Throughout the details were highly interesting, and the mill, which is under the management of Mr. James Leithhead, was in beautiful trim, everywhere regularity, order, industry, and cleanliness being noticeable. After having examined the various processes of manufacture the members drove to the Maori Pa, and returned to Christchurch.

Refreshments were provided for the visitors, who expressed their pleasure at the importance and success of the mill, and were evidently also interested in the charming appearance of the country in its neighbourhood.

Thursday, 22nd January, 1891.

VISIT TO LINCOLN COLLEGE.

The weather was fine, and the party numbered about sixty. A start was made at 10.30 a.m., and the route chosen was by Tai Tapu, enabling the visitors to get a look at the fertile homesteads in that favoured district. On reaching the College the party were received by the Board of Governors, headed by Mr. F. de C. Malet, the Chairman, and Mr. and Mrs. Ivey, and at once inspected the grounds, the garden, and orchard. The visitors were then entertained at luncheon by the Board of Governors. The chair was occupied by Mr. Malet, having on his right Sir James Hector, the President of the Association, and Lady Hector; and the vice-chairs were filled by Messrs. H. R. Webb, J. Grigg, and the Hon. J. T. Peacock.

After lunch the CHAIRMAN gave the toast of "The Queen," which was loyally responded to.

Sir JAMES HECTOR said that his friend the Chairman had hinted to him that there were to be no speeches. But he (Sir James), though in dread of the authority of the Chairman in his domain, could not allow the opportunity to pass without expressing officially (speaking as the President of the Association and in the name of its members and himself) their deep appreciation of the kindness, hospitality, and courteousness which had been shown to them by the Board of Governors of Canterbury College and the people of Christchurch as a whole. The Governors of the College had in the most handsome manner placed their spacious and commodious buildings in connection with the Canterbury College at their disposal for the work of the Association, and now this was crowned that day by the hospitality extended to them, and the opportunity afforded of inspecting what to him, and, he felt sure, to all the visitors, was one of the most interesting of the many institutions to be found in Canterbury. Of the kindness which they had received at the hands of the people of Christchurch, what could he say except to record their heartfelt thanks, and to say that the remembrance of their visit to Christchurch would long remain a green spot in their memories? With respect to the institution in which they were now met, its success was known and appreciated throughout the Australasian Colonies. He took a special personal interest in it from the fact that one of his boys had been a student, and, under the able instruction of his friend the Director, Mr. Ivey, had been able to acquire a knowledge of scientific farmwork and business. Like every other institution in the colony, Lincoln College had its initial difficulties. These, however, had been bravely surmounted and overcome, and he was pleased to find the Board of Governors fostering and encouraging, so far as they were able, so admirable and important an institution. In a country like this it was impossible to overrate the importance and value to the community of an establishment like the College, particularly when it was carried on under such able management. As they had yet to go through the interior of the buildings and to see what was most interesting to their lady friends, the dairy, he would not detain them longer, but would ask them to join with him in wishing continued success to the Lincoln Agricultural College.

The CHAIRMAN said he desired to thank Sir James Hector for the kindly words he had spoken as regarded what had been done by the Board of Governors. He might say that his colleagues and himself had the greatest possible pleasure in doing anything they possibly could to make the meeting of the Australasian Association a success. They in Christchurch felt honoured that New Zealand had been selected as the place for the annual meeting of the Association, and specially as their city had been the place at which that meeting had been held. He was exceedingly pleased that Sir James Hector had spoken in such complimentary terms of the institution. The Board of Governors, with the assistance of Mr. Ivey, had endeavoured to make it worthy of the colony and of Canterbury; and it was highly gratifying to find that their efforts were appreciated. He would now ask them to join him in drinking "Success to the Australasian Association for the Advancement of Science," and he would couple with this the name of Mr. Nesbit, of Adelaide.

Mr. NESBIT, in a few well-chosen words, responded, adding, on the part of the visitors, his testimony to that of Sir James Hector as to the kindness and courtesy with which the people of Christchurch had treated them.

The party then proceeded on a visit of inspection through the buildings, the dairy, and the farm, and, having noted the admirable arrangements of the College, were entertained by Mrs. Ivey, and then returned to Christchurch.

TABLE showing the NUMBER of MEMBERS PRESENT, RECEIPTS TO, and GRANTS MADE AT, the ANNUAL MEETINGS of the ASSOCIATION.

Date of Meeting.	Place of Meeting.	Presidents.	Attended by						Amount received up to and during the Meeting.	Sums voted as Grants for Scientific Purposes.
			Old Life-members.	New Life-members.	Annual Members.	Ladies.	Visitors.	Total.	£ s. d.	£ s. d.
1888—August, Sept.	Sydney ..	H. C. RUSSELL, B.A., F.R.S.	..	..	805	45	..	850	858 8 0	..
1890—Jan. ..	Melbourne ..	BARON VON MUELLER, K.C.M.G., F.R.S., M. & Ph. D.	..	..	1,081	81	..	..	2,084 0 0	..
1891—Jan. ..	Christchurch	Sir J. HECTOR, K.C.M.G., F.R.S., M.D.	..	..	..	..	..	550	785 13 7	25 0 0

The Australasian Association for the Advancement of Science.

The Hon. Treasurer's Accounts of Receipts and Expenditure from 1st January, 1890, to 30th June, 1891.

Date	Dr.	£	s.	d.
1889. Dec. 31.	To Balance in bank	533	12	6
1891. June 30.	Composition fee, New Zealand ..	10	0	0
	Sale of volumes, New South Wales ..	5	5	0
	Subscriptions received, ditto, £402 10s. 9d.; less deficiency by late collector, £26 3s. 6d.	376	7	3
	Subscriptions received in Queensland ..	10	0	0
	" " Tasmania ..	12	0	0
	" " Victoria ..	198	0	0
	" " New Zealand	269	7	0
	Donation, Medical Association of New Zealand	5	0	0
	Sale of excursion tickets	8	0	0
	Interest from bank	2	10	0
	Grant from New Zealand Government	500	0	0
		£1,930	1	9

Date	Cr.	£	s.	d.
1890. Mar. 14.	By Remittance to Melbourne	300	0	0
Aug. 21.	Fixed deposit, Commercial Bank ..	300	0	0
1891. June 30.	Binding 2,000 copies of Report	142	6	8
	Freight and distribution of Report ..	12	3	2
	Printing and stationery	25	3	2
	Advertising	25	0	6
	Exchange, carriage, and petty expenses	4	7	4
	Postage	9	19	3
	Clerical assistance	26	6	0
	Expenses incurred in South Australia by Professor Bragge in 1889 ..	6	8	2
	Expenses incurred in South Australia, 1890	2	9	0
	Expenses incurred in Tasmania ..	3	0	6
	Balance retained in Tasmania	8	19	6
	Expenses incurred in Victoria	6	11	0
	Balance retained in Victoria	191	9	0
	Expenses incurred in New Zealand ..	308	11	3
	Remittance from New Zealand, fixed deposit, Commercial Bank	477	5	9
	Balance	80	1	6
		£1,930	1	9

Audited and found correct.- Frank T. Clark, 22/10/91.

H. C. Russell, Treasurer, 23/10/91.

INAUGURAL ADDRESS

BY

SIR JAMES HECTOR, M.D., K.C.M.G., F.R.S.,

PRESIDENT.

CHRISTCHURCH, THURSDAY, 15TH JANUARY, 1891.

When I rashly replied in the affirmative to the telegram which I received from our Secretary in Melbourne, asking me to undertake the honourable and responsible duties which I have to commence this evening, I fear I did not fully realise the difficulties of the position; but since then the sense of my unfitness for the task has become very oppressive. To address an assembly of this kind on general science must involve unusual difficulties, owing to the audience being largely composed of those who, only taking a casual interest in scientific discussions, look chiefly to the results; while, at the same time, there are present professional specialists in almost every branch of knowledge. How is it, then, possible for any one who, like myself, has never enjoyed opportunities for gaining experience as a teacher and public speaker, so to balance his words as to avoid offending the specialists with crude and imperfect statements, and, at the same time, escape wearying the general audience with the discussion of matters that will find a more fitting battle-ground in the sectional work of our Association?

I feel that on this occasion I must be ruled by the interest of the majority, and claim the forbearance of my fellow-workers in science if I have to refer in a sketchy way to subjects in which they are deeply interested, and far more learned than I profess to be.

Seeing that I am addressing a Christchurch audience, I hope I may be permitted, in the first place, to say a word concerning one whose scientific services should, without doubt, have obtained for him the position of first President in New Zealand of the Australasian Association. We naturally recall the name of Sir Julius von Haast on this occasion, and mourn for the loss the colony has sustained by the death of one who for thirty years occupied a most prominent position. His early researches in the North Island, in company with Von Hochstetter, were followed by the exploration of the remote districts on the west coast of Nelson; after which Canterbury secured his distinguished services, and enabled him to leave that monument of his varied scientific knowledge, shrewd capacity, and indefatigable industry, which is to be found in the Canterbury Museum.

There are others of our fellow-colonists whose wide range of experience would have peculiarly fitted them to act as your President, and I am able to say that had our veteran colonist and explorer, Sir George Grey, felt more assured in health and strength it would have been your pleasure this evening to listen to a flood of eloquence on all scientific topics that relate to the future development of Australasia. There is another name I feel must be mentioned as one who should have been in this position had his health permitted. I refer to the Rev. William Colenso, who is recognised as the greatest authority on the folk-lore of the Maoris, on whom he was among the first to confer a printed literature in their own language. His long-continued work as a field naturalist, especially as a botanist, is exceedingly interesting, seeing that it forms a connecting link that has continued the early spirit of natural-history research in New Zealand that commenced with Banks and Solander, and was continued by Menzies, Lesson, the two Cunninghams, and Sir Joseph Hooker, prior to the arrival of colonists. Thus we still have in my esteemed friend Mr. Colenso an active veteran naturalist of what we may call the old school of explorers.

It is wonderful to reflect that little more than fifty years ago this European colony was represented by a few fishing hamlets on the seaboard of a country occupied by a considerable Native population. To the early explorers, and even down to a much later date, the obstacles that beset their paths were very different from those of the present time—often obstructive Natives, no roads, no steamers, no railways. Had an association then existed and desired to promote science by giving our visitors an opportunity of visiting the remote parts of the Islands, the same excursions which have been on this occasion planned to occupy a few days would have occupied as many months, and would even then have been accomplished only with great hardship and difficulty. I must ask the young and rising generation of colonial naturalists to bear this in mind when they have to criticize and add to the work of their precedessors. Such names of early colonists as Bidwill, Sinclair, Monro, Mantell, Travers, and many others should ever be held in esteem as those who, amidst all the arduous trials of early colonisation, never lost sight of their duty towards the advancement of science in New Zealand. I will not attempt to particularise other names from amongst our existing and, though small in number, very active corps of scientific workers. They are here, or should be, to speak for themselves in the sectional work; and I have no doubt some of those who did me the great honour of placing me in my present position are secretly congratulating themselves that they have secured for themselves the position of free-lances on this occasion.

This is now the third annual gathering of this Association; and New Zealand should feel honoured that it has, at so early a date in the Association's history, been selected as the place of meeting from among so many divisions of the great Colony of Australasia. The two volumes of the Transactions of the Association already in the hands of members are quite sufficient to prove that the hopes of its founders—or, rather, I may almost say, the founder, Professor Liversidge, of Sydney—have been amply fulfilled. The papers read before the different sections, and the addresses delivered, have, in my opinion, to a most remarkable extent embodied information and discussions which were not likely to have been produced as the result of any of our local scientific organizations. The authors seem to have felt it incumbent on them to place their subjects in the environment of Australasia, and not in relation to the colony they happened to represent. This, I take it, is the first truly effective step towards Federation which has yet been achieved, and I trust that all our members will continue to be imbued with this spirit. Politicians should take this well to heart. Let them continue to aid all efforts that will tend to bring scientific accumulations in these colonies into a common store, so that each may discover for what purpose it has been best adapted by Nature; and, by paying proper political respect in fiscal policy to one another, each may prosper to the full extent of its natural advantages. But it is not alone in the value of the papers communicated that the Association contributes to the advance of true civilisation in the colonies. The face-to-face conference, the personal contact, of the active workers in different lines of scientific work, must greatly facilitate the more thorough understanding of the work which has been done and of that which has still to be done.

A vague idea, simmering in the brain of one scientist who thinks light of it because it has no special application in his particular environment, may, by personal converse, flash into important results in the mind of another who has had the difficulties facing him, but without the happy thought. It would be rather interesting for some one with leisure to endeavour to recount how many great discoveries have eventuated in this manner.

In casting my thoughts for a particular subject on which to address the Association I felt perplexed. Presidents of similar associations in the Old World, who are in constant contact with the actual progress in scientific thought, feel that a mere recital of the achievements during their previous term is sufficient to command interest; but in the colonies most of us are cut off from personal converse with the leading minds by whom the scientific afflatus is communicated, and in our suspense for the tardy arrival of the official publications of the societies we have to feed our minds with science from periodical literature. But even in this respect my own current education is very defective, as I reside in a city which, though the capital of New Zealand, has no college with a professional staff whose duty, pleasure, and interest it would be to maintain themselves on a level with the different branches of knowledge they represent. I therefore decided that, instead of endeavouring to review what had been done in the way of scientific progress, even in Australasia, it would be better to confine my remarks to New Zealand—the more so that this is the first occasion that there has been a gathering of what must, to some extent, be considered to be an outside audience for the colony.

To endeavour to describe, even briefly, the progress made in the science of a new country is, however, almost like writing its minute history. Every step in its reclamation from a wild state of nature has depended on the application of scientific knowledge, and the reason for the rapid advance made in these colonies is chiefly to be attributed to their having had the advantage of all modern resources ready to hand.

As in most other matters in New Zealand, there is a sharp line dividing the progress into two distinct periods: the first before, and the second after, the foundation of the colony in 1840. With reference to the former period it is not requisite that much should be said on this occasion. From the time of Captain Cook's voyages, owing to his attractive narrative, New Zealand acquired intense interest for naturalists. His descriptions of the country and its productions, seeing that he only gathered them from a few places where he landed on the coast, are singularly accurate. But I think rather too much is sometimes endeavoured to be proved from the negative evidence of his not having observed certain objects. As an instance, it has been asserted that if any of the many forms of the moa still survived Captain Cook must have been informed of the fact. Yet we find that he lay for weeks in Queen

Charlotte Sound and in Dusky Sound, where all night long the cry of the kiwi must have been heard just as now, and that he also obtained and took Home mats and other articles of Native manufacture trimmed with kiwis' skins; and that most likely the mouse-coloured quadruped which was seen at Dusky Sound by his men when clearing the bush was only a grey kiwi; and yet the discovery of this interesting bird was not made till forty years after Cook's visit. As a scientific geographer Captain Cook stands unrivalled, considering the appliances at his disposal. His longitudes of New Zealand are wonderfully accurate, especially those computed from what he called his "rated watches," the first type of the modern marine chronometer, which he was almost the first navigator to use. Indeed, the result of a recent measurement of the meridian difference from Greenwich by magnetic signals is only two geographical miles east of Captain Cook's longitude. He also observed the variation and dip of the magnetic needle, and from his record it would appear that during the hundred years which elapsed up to the time of the "Challenger's" visit the south-seeking end of the needle has changed its position $2\frac{1}{2}^{\circ}$ westward, and inclines $1\frac{1}{2}^{\circ}$ more towards the south magnetic pole. Captain Cook also recorded an interesting fact which, so far as I am aware, has not been since repeated or verified in New Zealand. He found that the pendulum of his astronomical clock, the length of which had been adjusted to swing true seconds at Greenwich, lost at the rate of $40''$ daily at Ship Cove, in Queen Charlotte Sound, which is, I believe, an indication of a greater loss of the attraction of gravity than would occur in a corresponding north latitude. The additions to our scientific knowledge of New Zealand, acquired through the visits of the other exploring ships of early navigators, the settlement of sealers and whalers on the coast, and of pakeha-Maoris in the interior, were all useful, but of too slight a character to require special mention. The greatest additions to science were made by the missionaries, who, in the work of spreading Christianity among the Natives, had the services of able and zealous men who mastered the Native dialects, reduced them to a written language, collected and placed on record the traditional knowledge of the interesting Maori, and had among their numbers some industrious naturalists who never lost an opportunity of collecting natural objects.

The history of how the country, under the mixed influences for good and for evil which prevailed almost without Government control until 1840, was gradually ripened for the colonist, is familiar to all. So far as science is concerned, the new era may be said to have begun with Dieffenbach, a naturalist who was employed by the New Zealand Company. He travelled and obtained much information, but did not collect to any great extent, and, in fact, appears not to have anticipated that much remained to be discovered. For his conclusion is that the smallness of the number of species of animals and plants then known—about one-tenth of our present lists—was not due to want of acquaintance with the country, but to paucity of life-forms. The chief scientific value of his published work is in the appendix, giving the first systematic list of the fauna and flora of the country, the former being compiled by the late Dr. Gray, of the British Museum.

The next great scientific work done for New Zealand was the Admiralty survey of the coast-line, which is a perfect marvel of accurate topography, and one of the greatest boons the colony has received from the Mother-country. The enormous labour and expense which were incurred on this survey at an early date in the history of the colony is a substantial evidence of the confidence in its future development and commercial requirements which animated the Home Government.

On the visit of the Austrian exploring ship "Novara" to Auckland in 1859, Von Hochstetter was left behind, at the request of the Government, to make a prolonged excursion in the North Island and in Nelson; and he it was who laid the foundation of our knowledge of the stratigraphical geology of New Zealand.

Since then the work of scientific research has been chiefly the result of State surveys, aided materially by the zeal of members of the New Zealand Institute, and of late years by an increasing band of young students, who are fast coming to the front under the careful science training that is afforded by our University colleges.

In the epoch of their development the Australasian Colonies have been singularly fortunate. The period that applies to New Zealand is contemporaneous with the reign of Her Majesty Queen Victoria, which has been signalised by enormous strides in science. It has been a period of gathering into working form immense stores of previously-acquired observation and experiment, and a period marked by the escape of the scientific mind from the trammels of superstition and hazy speculation regarding what may be termed common things. Laborious work had been done and many grand generalisations had been formerly arrived at in physical science; but in the work of bringing things to the test of actual experiment investigators were still bound by imperfect and feeble hypotheses and supposed natural barriers among the sciences. But science is now established as one and indivisible, and such subdivisions as physics, chemistry, biology, are only adopted for the convenience of study. The methods are the same in all, and their common object is the discovery of the great laws of order under which this universe has been evoked by the Supreme Power.

The great fundamental advance during the last fifty years has been the achievement of far-reaching generalisations, which have provided the scientific worker with powerful weapons of research. Thus, the modern "atomic theory," with its new and clearer conceptions of the intimate nature of the elements and their compounds that constitute the earth and all that it supports, has given rise to a new chemistry in which the synthetical or building-up method of investigation is already working marvels in its application to manufactures. It is, moreover, creating a growing belief that all matter is one, and reviving the old idea that the inorganic elementary units are either simple or aggregated centres of motion specialised in a homogeneous medium, and that these units have been continued on through time, but with such individual variations as give rise to derivative groups, just as we find has been the case in the field of organic creations. The idea embodied in this speculation likens the molecule to the vortex-rings which Helmholtz found must continue to exist for ever if in a perfect fluid and free from all friction they are once generated, as a result of impacting motion. There is something very attractive in the simplicity of this theory of the constitution of matter, which has been advocated by Sir William Thomson. He illustrates it by likening the form of atoms to smoke-rings in the atmosphere, which, if they could be formed under circumstances such as above described, must continue to move without changing form, distinguished only from the surrounding medium by their motion. As long as the original conditions of the liquid exist they must continue to revolve. Nothing can separate, divide, or destroy them, and no new units can be formed in the liquid without a fresh application of creative impact.

The doctrine of the conservation of energy is a second powerful instrument of research that has developed within our own times. How it has cleared away all the old cobwebs that formerly encrusted our ideas about the simplest agencies which are at work around us, how it has so simplified the teaching of the laws that order the conversion of internal motions of bodies into various phases which represent light, heat, electricity, is abundantly proved by the facility with which mechanicians are every day snatching the protean forms of energy for the service of man with increasing economy.

These great strides which have been made in physical science have not as yet incited much original work in this colony. But, now that physical laboratories are established in some degree at the various college centres, we shall be expected, ere long, to contribute our mite to the vast store. In practical works of physical research we miss in New Zealand the stimulus the sister colonies receive from their first-class observatories, supplied with all the most modern instruments of research wielded by such distinguished astronomers as Ellery, Russell, and Todd, whose discoveries secure renown for their respective colonies.

Of course I am quite prepared to admit that the reduplication of observatories in about the same latitude, merely for the study of the heavenly bodies, would be rather a matter of scientific luxury. The few degrees of additional elevation of the South Polar region which would be gained by an observatory situated even in the extreme south of New Zealand could hardly be expected to disclose phenomena that would escape the vigilance of the Melbourne observatory. But star-gazing is only one branch of the routine work of an observatory. It is true that we have a moderate but efficient observatory establishment in New Zealand, sufficient for distributing correct mean time, and that our meridian distance from Greenwich has been satisfactorily determined by telegraph. Also, thanks to the energy and skill of the Survey Department, despite most formidable natural obstructions, the major triangulation and meridian circuits have established the basis of our land-survey maps on a satisfactory footing, so that subdivision of the land for settlement and the adoption and blending of the excellent work done by the Provincial Governments of the colony are being rapidly overtaken. Further, I have already recalled how much the colony is indebted to the Mother-country for the completeness and detail of the coastal and harbour charts.

But there is much work that should be controlled by a physical observatory that is really urgently required. I may give a few illustrations. The tidal movements round the coast are still imperfectly ascertained, and the causes of their irregular variations can never be understood until we have a synchronous system of tide-meters, and a more widely extended series of deep-sea soundings. Excepting the "Challenger" soundings on the line of the Sydney cable, and a few casts taken by the United States ship "Enterprise," the depth of the ocean surrounding New Zealand has not been ascertained with that accuracy which many interesting problems in physical geography and geology demand. It is supposed to be the culmination of a great submarine plateau; but how far that plateau extends connecting the southern islands towards the great Antarctic land, and how far to the eastward, is still an unsolved question. Then, again, the direction and intensity of the magnetic currents in and around New Zealand requires further close investigation, which can only be controlled from an observatory. Even in the matter of secular changes in the variation of the compass, we find that the marine charts instruct that an allowance of increased easterly variation of 2′ per annum must be made, and, as this has now accumulated since 1850, it involves a very sensible correction to be adopted by a shipmaster in making the land or cruising along the coast; but we find from the recently-published work of the "Challenger" that this tendency to change has for some time back ceased to affect the New Zealand area, and, as the deduction appears only to have been founded on a single triplet observation of the dip taken at Wellington and one azimuth observation taken off Cape Palliser, it would be well to have this fact verified.

With regard to the local variation in the magnetic currents on land and close in-shore, the necessity for exact survey is even more imperative. Captain Creak, in his splendid essay on the magnetic observations of the "Challenger" Expedition, quotes the observations made by the late Surveyor-General, Mr. J. T. Thomson, at the Bluff Hill, which indicate that a compass on the north side was deflected more than 9° to the west, while on the east side of the hill the deflection is 46° to the east of the average deviation in Foveaux Strait. He remarks that if a similar island-like hill happened to occur on the coast, but submerged beneath the sea to a sufficient depth for navigation, serious accidents might take place; and he instances a case near Cossack, on the north coast of Australia, where H.M.S. "Medea," sailing on a straight course in eight fathoms of water, experienced a compass deflection of 30° for the distance of a mile. A glance at the variation entered on the meridian-circuit maps of New Zealand shows that on land we have extraordinary differences between different trig. stations at short distances apart. In close vicinity to

Christchurch—for instance, at Mount Pleasant, behind Godley Head lighthouse, which stands at the entrance to Lyttelton Harbour — the variation is only 9° 3′ east, or 6° less than the normal; while at Rolleston it is 15° 33′, and at Lake Coleridge 14° 2′. In Otago we have still greater differences recorded, for we find at Flagstaff Hill, which is an igneous formation, 14° 34′, while at Nenthorn, thirty-five miles to the north, in a schist formation, we find an entry of 35° 41′.

In view of the fact that increased attention has been recently directed to the marked effects on the direction and intensity of the terrestrial magnetic currents of great lines of fault along which earth-movements have taken place, such as those which bring widely different geological formations into discordant contact, with the probable production of mineral veins, this subject of special magnetic surveys is deserving of being undertaken in New Zealand. In Japan and in the United States of America the results have already proved highly suggestive. A comparison between this country and Japan by such observations, especially if combined with systematic and synchronous records by modern seismographic instruments, would be of great service to the physical geologist. There are many features in common and many quite reversed in the orographic and other physical features of these two countries. Both are formed by the crests of great earth-waves lying north-east and south-west, and parallel to, but distant from, continental areas, and both are traversed by great longitudinal faults and fissures, and each by one great transverse fault. Dr. Nauman, in a recent paper, names this transverse-fault area in Japan the *Fossa Magna*, and it corresponds in position in relation to Japan with Cook Strait in relation to New Zealand. But the *Fossa Magna* of Japan has been filled up there with volcanic products, and is the seat of the loftiest active volcano in Japan. In Cook Strait, and its vicinity, as you are aware, there are no volcanic rocks, but there and southward through the Kaikouras evidence of recent fault-movements on an extensive scale is apparent, and it would be most interesting to ascertain if the remarkable deviations from the normal in direction and force of the magnetic currents, such as are experienced in Japan, are also found in New Zealand. For it is evident that, if they are in any way related to the condition of stress induced by cross-fractures in the earth's crust, the observation would tend to eliminate the local influence of the volcanic rocks which are present in one case and absent in the other. With reference to earthquakes also, few, if any, but very local shocks experienced in New Zealand have originated from any volcanic focus we are acquainted with, while the westerly propagation of the ordinary slight vibrations rarely passes the great fault that limits active volcanic disturbance on its eastward side. In Japan, also, out of about 480 shocks, which are felt each year in that country, each of which, on an average, shakes about one thousand square miles, there are many that cannot be ascribed to volcanic origin. There are many other problems of practical importance that can only be studied from the base-line of a properly-equipped observatory. These will readily occur to students of physics, who are better acquainted with the subject than I am.

I can only express the hope that the improved circumstances of the colony will soon permit some steps to be taken. Already in this city, I understand, some funds have been subscribed. As an educational institution, to give practical application to our studies in physical science, geodesy, and navigation, it would clearly have a specific value that would greatly benefit the colony.

Another great branch of physical science, chemistry, should be of intense interest to the colonists in a new country. Much useful work has been done, though not by many workers. The chief application of this science has been, naturally, to promote the development of mineral wealth, to assist agriculture, and for the settlement of fiscal and sanitary questions. I cannot refrain from mentioning the name of William Skey, Analyst to the Geological Survey, as the chemist whose researches, during the last twenty-eight years, have far surpassed any other in New

Zealand. Outside his laborious official duties he has found time to make about sixty original contributions to chemical science, such as—an inquiry into the electrical properties of metallic sulphides; the discovery of the ferro-nickel alloy *awaruite* in the ultra-basic rocks of West Otago, which is highly interesting, as it is the first recognition of this meteoric-like iron as native to our planet; the discovery that the hydrocarbon in torbanite and other gas-shales is chemically and not merely mechanically combined with the clay base; the discovery of a remarkable colour-test for the presence of magnesia; and the isolation of the poisonous principle in many of our native shrubs. His recent discovery that the fatty oils treated with anilines form alkaloids also hints at an important new departure in organic chemistry. His suggestion of the hot-air blow-pipe, and of the application of cyanide of potassium to the saving of gold, and many other practical applications of his chemical knowledge, are distinguished services to science, of which New Zealand should be proud.

In connection with the subject of chemistry, there is a point of vast importance to the future of the pastoral and agricultural interests of New Zealand, to which attention was directed some years ago by Professor Thomas, and Mr. Pond, of Auckland—that is, the rapid deterioration which the soil must be undergoing by the steady export of the constituents on which plant and animal life must depend for nourishment. Mr. Pond calculated that in 1883 the intrinsic value of the fixed nitrogen and phosphoric acid and potash sent out annually was £592,000, taking into account the wool and wheat alone. Now that we have to add to that the exported carcases of beef and mutton, bones and all, the annual loss must be immensely greater and probably not less than £1,000,000. The proper cure would, of course, be to bring back return cargoes of artificial manure, but even then its application to most of our pastoral lands would be out of the question. I sincerely hope that the problem will be taken in hand by the Agricultural College at Lincoln, as a matter deserving of practical study and investigation.

I have already referred to several great generalisations which have exercised a powerful influence in advancing science during the period I marked out for review; but, so far as influencing the general current of thought, and almost entirely revolutionising the prevalent notions of scientific workers in every department of knowledge, the most potent factor of the period has been the establishment of what has been termed "the doctrine of evolution." The simple conception of the relation of all created things by the bond of continuous inheritance has given life to the dead bones of an accumulated mass of observed facts, each valuable in itself, but, as a whole, breaking down by its own weight. Before this master-key was provided by the lucid instruction of Darwin and Wallace, it was beyond the power of the human mind to grasp and use in biological research the great wealth of minute anatomical and physiological details. The previous ideas of the independent creation of each species of animal and plant in a little Garden of Eden of its own must appear puerile and absurd to the young naturalists of the present day; but in my own College days to have expressed any doubt on the subject would have involved a sure and certain pluck from the examiner.

I remember well that I first obtained a copy of Darwin's "Origin of Species" in San Francisco when on my way home from a three years' sojourn among the Red Indians in the Rocky Mountains. Having heard nothing of the controversies, I received the teaching with enthusiasm, and felt very much surprised on returning to my *alma mater* to find that I was treated as a heretic and backslider. Nowadays it is difficult to realise what all the fuss and fierce controversy was about; and the rising school of naturalists have much cause for congratulation that they can start fair on a well-assured logical basis of thought, and steer clear of the many complicated and purely ideal systems which were formerly in vogue for explaining the intentions of the Creator and for torturing unfortunate students. The doctrine of evolution is the single-minded acceptance of the invariability of cause and effect in the organic world as in the inorganic; and, to understand his subject in any branch of natural science, the learner has now only to apply himself to trace in the minutest detail the successive steps in the development of the phenomena he desires to study. With energetic teachers such as Hutton, Parker, and Thomas educated in such views, and who, after their arrival in the colony, felt less controversial restraint, it is not wonderful that natural history, and especially biology, should have attracted so many ardent workers, and that the results should have been so good.

A rough test may be applied by comparing the number of species of animals and plants which had been described before the foundation of the colony and those up to the present time. In 1840 Dr. Gray's list in Dieffenbach's work gives the number of described species of animals as 594. The number now recognised and described is 5,498. The number of Mammalia has been doubled through the more accurate study of the seals, whales, and dolphins. Then, the list of birds has been increased from 84 to 195, chiefly through the exertions of Sir Walter Buller, whose great standard work on our Avifauna has gained credit and renown for the whole colony. The number of fishes and Mollusca has been more than trebled, almost wholly by the indefatigable work of our Secretary, Professor Hutton. But the greatest increase is in the group which Dr. Gray placed as Annulosa, which, chiefly through the discovery of new forms of insect-life, has risen from 156 in 1840 to 4,295, of which over two thousand are new beetles described by Captain Broun, of Auckland.

When we turn to botany we find that Dieffenbach, who appears to have carefully collated all the references to date 1840, declares the flora to comprise 632 plants of all kinds, and, as I have already mentioned, did not expect that many more would be found. But by the time of the publication of Hooker's "Flora of New Zealand" (1863), a work which has been of inestimable value to our colonists, we find the number of indigenous plants described has been increased to 2,451. Armed with the invaluable guidance afforded by Hooker's

"Handbook," our colonial botanists have continued the search, and have since then discovered 1,469 new species, so that our plant census at the present date gives a total of 3,920 species. It would be impossible to make mention of all who have contributed to this result as collectors, and hardly even to indicate more than a few of those to whom science is indebted for the description of the plants. The literature of our post-Hookerian botany is scattered about in scientific periodical literature, and, as Hooker's "Handbook" is now quite out of print, it is obvious that, as the new discoveries constitute more than one-third of the total known flora, it is most important that our young botanists should be fully equipped with all that has been ascertained by those who have preceded them. I am glad to be able to announce that such a work, in the form of a new edition of the "Handbook of the Flora of New Zealand," approved by Sir Joseph Hooker, is now in an advanced state of preparation by Mr. Thomas Kirk, F.L.S., who has already distinguished himself as the author of our "Forest Flora." Mr. Kirk's long experience as a systematic botanist, and his personal knowledge of the flora of every part of the colony, acquired during the exercise of his duties as Conservator of Forests, point to him as the fitting man to undertake the task.

But, quite apart from the work of increasing the local collections which bear on biological studies, New Zealand stands out prominently in all discussions on the subject of geographical biology. It stands as a lone zoological region, small in area, but on equal terms, as far as regards the antiquity and peculiar features of its fauna, with nearly all the larger continents in the aggregate. In consequence of this, many philosophical essays—such, for instance, as Hooker's introductory essay in the early quarto edition of the "Flora Antarctica," the essays by Hutton, Travers, and others in the colony, and also the New Zealand references in Wallace's works—have all contributed essentially to the vital question of the causes which have brought about the distribution and geographical affinities of plants and animals, and have thus been of use in hastening the adoption of the doctrine of evolution. But much still remains to be done. Both as regards its fauna and its flora New Zealand has always been treated too much as a whole quantity, and in consequence percentage schedules prepared for comparing with the fauna and flora of other areas fail from this cause. It is absolutely necessary not only to discriminate localities, but also to study more carefully the relative prevalence of individuals as well as of species before instituting comparisons. The facility and rapidity with which changes are effected at the present time should put us on our guard against rashly accepting species which may have been accidental intruders, though wafted hither by natural causes, as belonging to the original endemic fauna or flora. The most striking feature in the New Zealand fauna was the extraordinary development of many forms of the Dinornis, or the moa of the Maoris, which were struthious birds, and also of the other birds in which the power of flight was either altogether absent or only feebly developed. They represent many genera and species, and the individuals, up to a comparatively recent date, must have been exceedingly numerous. How such an astonishing variety of bird-forms, many of which were of gigantic size, came to be crowded together on a small island like New Zealand is one of the most difficult problems in geographical zoology. There is only one ostrich in the vast continent of Africa, one emu in Australia, one rhea in South America. The only large struthious birds now existing which have a limited distribution are some of the cassowaries; but here in New Zealand there were many species living intermixed within a limited area. Their bones were found by the early settlers scattered in great profusion on the surface in some parts of the country, buried in swampy places, and heaped in caves, into which they had been washed just as the bones of sheep and cattle are at the present time. The ample material which has been collected during the past fifty years has been elaborated by the masterly genius of the great anatomist Owen, whose work on the osteology of the extinct birds is, perhaps, the most famous contribution to science which has been made for New Zealand. But the study of the bones of the birds alone —often fragments—will not satisfy the requirements of the biologist who desires to trace their structural affinity, and to trace the steps in the history of their evolution. It is therefore a matter for congratulation that Professor Parker has taken up the subject of the minute anatomy and embryology of the allied genus, the Apteryx or kiwi, which has, fortunately, as yet, escaped extermination.

Further close and extended study, especially, of our marine fauna is urgently required. We have little knowledge beyond the littoral zone, except when a great storm heaves up a gathering of nondescript or rare treasures from the deep. Of dredging we have had but little done, and only in shallow waters, with the exception of a few casts of the deep-sea trawl from the "Challenger." When funds permit, a zoological station for the study of the habits of our sea fishes, and for the propagation of such edible species as the lobster and crab, would be advantageous. I observe that lately such an establishment has been placed on the Island of Mull, in Scotland, at a cost of £400, and that it is expected to be nearly self-supporting. With respect to food fishes, and still more with respect to some terrestrial forms of life, we, in common with all the Australasian Colonies, require a more scientific and a less casual system of acclimatisation than we have had in the past. One must talk with 'bated breath of the injuries that have been inflicted on these colonies by the rash disturbance of the balance of nature. Had our enthusiasm been properly controlled by foresight, our settlers would probably not have to grieve over the losses they now suffer through many imported pests, through small birds and rabbits, and which they will in the future suffer through the vermin that are now being spread in all directions.

Speaking of geology, I may say that the early explorers seem to have had only the most vague ideas of the geology of the countries they explored. Indeed, the whole science may be said to have been almost entirely developed during the last fifty years; and this is very natural, as it is perhaps more dependent than any other branch of knowledge on assistance from other branches of science. It has to rely on physics not only for the solution of great dynamical problems, but also for the application of the science of optics to unravel the intimate structure and mode of production of rocks and minerals, on biology for deciphering the embedded organic remains, and on chemistry in almost every branch of the subject; and thus it barely existed as a science until these branches had become established. The first great advance was made by Sir Charles Lyell, who, although commencing as one of the great opponents of evolutionary doctrines, was himself the greatest apostle of evolution, for he struck the true key-note when he said that the order of nature was uniform. He lived to see the effect of the great change brought about. In New Zealand our geological explorations began since the matters I have referred to were settled, and the result has been that we have rapidly attained a tolerably complete knowledge of the structure of the country, for a full description of which, seeing that time presses, I must refer you to the various Geological Reports and maps which have been published.

In ethnology and the study of the Maori race there is an ample field for research, and it is a very great pleasure to me to state that, at the sectional meeting dealing with the subject, will be presented the proof sheets of a great lexicon embracing the languages of the Polynesian races compared with that of the Maori. This important work is in an advanced state of preparation, under the hands of Mr. Tregear, known as one of the most profound students of Maori mythology.

There is another subject which I should have liked to say something about, and that is the great Antarctic Continent; and to a purely scientific man, utterly devoid of all considerations of expense, the exploration of that little-known region appears a matter of great urgency. I understand, however, that Baron von Mueller wishes that the discussion on that subject should be reserved for the special sectional meeting on Saturday morning.

I may say, in conclusion, that I have the most perfect confidence in the success of this Association. It is twenty-four years ago since Mr. Travers got an Act passed constituting the New Zealand Institute, which was in a small way an "association for the advancement of science." It was in an endeavour to combine the efforts of the workers in the cause of science in all parts of the colony that the Institute was formed. How it succeeded is known to you all. Baron von Mueller has attributed this success to me. I must disclaim it; it is due to the manner in which, despite local jealousies, the Institute has been supported by the public, and to the zeal and enthusiasm of its members throughout the colony. This Association is an extension of the principle of the Institute to the whole of the colonies. I think it is necessary for these colonies, if they are ever to become a nation, to apply the principle still further, and to federate. I have again to thank you, and to hope that you may have a pleasant sojourn in New Zealand. If I have succeeded in showing our visitors from Australia that New Zealand has great capabilities for scientific research, then I have not altogether failed to justify the choice of New Zealand as our place of meeting for this year.

Section A.

(ASTRONOMY, MATHEMATICS, PHYSICS, AND MECHANICS.)

President of the Section—Professor Lyle, M.A.

ADDRESS BY THE PRESIDENT.

Advances in Physical Science and its Application.

Plates I. and II.

In opening the proceedings for which we are assembled, I wish to thank the Australasian Association for the Advancement of Science for the honour it has done me in electing me President of Section A, which includes astronomy, mathematics, and physics. I sincerely wish that the post was filled by some one better qualified to perform the duties belonging to it, though at the same time I must admit that I am very proud of the distinction.

I propose as my task to-day to review briefly, and in some cases explain in as simple terms as I can, a few of the wonderful advances that have been made of late in physical science and its applications.

The most tremendous of the many achievements of the latter half of the nineteenth century is, without doubt, the development of our knowledge of the properties of the ether, of the ethereal theory of electricity, and the absolute proof that light and electro-magnetic radiation are one and the same phenomenon.

The idea that something must of necessity fill space is by no means new. The unthinkableness of the "action at a distance" of one body on another across empty space with nothing between them as a means of communication was seen by Newton. He could not understand how the sun and earth mutually attracted each other by gravitation unless there was some medium between them by which the action was communicated.

If you apply yourselves seriously to think of the matter, you will see that there can be only two possible modes of communication between distant bodies. It can take place—(1) by direct contact, or by means of some medium that is continuous between the bodies and connects them; (2) by one body sending a projectile to the other.

This is so well illustrated by Mr. Oliver Lodge that I cannot do better than quote from his work: "To call the attention of a dog, there are several methods: one plan is to prod him with a stick, another is to heave a stone at him, a third is to whistle or call, while a fourth is to beckon him by gesture or, what is essentially the same process, to flash sunlight into his eye with a mirror. In the first two of these methods the media of communication are perfectly obvious—the stick and the stone. In the third, the whistle, the medium is not so obvious, and this case might easily seem to a savage like action at a distance, but we know of course that it is the air, and that if the air between be taken away all communication by sound is interrupted. But the fourth or optical method is not so interrupted: the dog can see through a vacuum perfectly well, though he cannot hear through it; but what the medium now is which conveys the impression is not so well known. The sun's light is conveyed to the earth by such a medium as this across the emptiness of planetary space. The only remaining typical plans of acting on the dog would be either by electric or by magnetic attraction, or by mesmerism; and I would have you seek for the medium which conveys these impressions with just as great a certainty that there is one as you feel in the other cases."

Every possible means of communication—namely, either by continuous medium or by projectile—are fully illustrated by the two simplest methods quoted above: by "the stick and the stone."

Explanations of the phenomena of light and gravitation have been given, making them simply cases of the projectile method of communication. These corpuscular theories, as they are called, of light and gravitation are however exploded nowadays. The phenomena connected with the sense of smell and the transmission of pressure by gases are true examples of the projectile method.

Cutting the matter short, I may say that we are as certain of the existence of the ether filling all space and interpenetrating the grosser matter of all bodies as we are of the existence of the bodies themselves. The evidence in favour of the existence of the one is as strong as that in favour of the existence of the other. If the existence of the one be denied, so must that of the other.

The constitution of the ether, as far as it is at present known to us, is that of a continuous, frictionless medium, possessing inertia, density, and rigidity. It pervades all space, penetrates between the molecules of all ordinary matter, and acts as the transmitter of motion and energy from one body to another.

Professor Fitzgerald has shown that if the ether be supposed a perfect fluid in turbulent motion made up of columnar vortices interlaced with one another, and having their axes at all possible angles, and the atoms of ordinary matter free vortices threading between these interlaced ones, all the phenomena of nature could be explained as due to different movements in space.

Sir W. Thomson has proved that a perfect liquid in motion of this kind is in a stable state of motion. On this theory, then, atoms of matter would be the free vortex-rings. Electricity would be the interlaced vortices: positive, those that rotate in one direction; negative, those that rotate in the other. Magnetism would be a displacement of the interlaced vortices, thus reversing the usual theory that electricity is a displacement or flow, and magnetism a twist or whirl. The fact that magnetism causes a rotation of the plane of polarisation of light and other rotatory phenomena is no objection to Fitzgerald's theory, for there is no reason why a direct flow should not cause a rotation, as any one will see on considering the case of an ordinary water-wheel.

The theory that light is an electrical phenomenon we owe to Maxwell. It was his greatest discovery, and is without doubt one of the greatest of this century. Since he stated it in 1865 confirming evidence has been accumulating on all sides, and now it may be considered as completely verified.

The main proof of the theory is that both light and electric disturbance or radiation are propagated through the ether by the same kind of motion, and that both disturbances travel with exactly the same velocity.

We know that light is due to a periodic vibration which is communicated across the ether by a particular kind of wave-motion. It has long been known that the discharge of a Leyden jar is not a single rush in one direction, but a series of rushes of the electricity oscillating backwards and forwards between the coatings, and having a definite period which depends on the capacity and the inductance of the jar. The oscillations gradually become smaller as the energy of the charge is frittered away in heat, but while they last they send out electric waves through the surrounding medium, just as an incandescent molecule sends out light-waves. If now another jar exactly similar to the first, so that its period of oscillation is the same, be placed in the neighbourhood, the oscillations of the former, communicated through the intervening space as ether-waves, will be taken up by the latter, exactly as one tuning-fork will vibrate in sympathetic resonance with another in unison with it and placed in its vicinity, and the oscillations of the second jar may accumulate sufficient intensity to enable them to burst across a short air-space arranged between the coatings, and thus give a visible spark. If we vary the capacity and thus the period of the second jar, it will no longer be excited in sympathetic resonance by a discharge of the first.

Hertz, to whom we owe the complete experimental verification of Maxwell's theory, used as a vibrator or originator of his electric waves not a Leyden jar, but two equal and similar pieces of brass cylinder with rounded ends. These he placed in line with a small sparking-distance between them, and connected each to one of the terminals of a small induction coil. At every discharge of the coil the electricity surged up and down these cylinders, oscillating at a regular calculable rate, and disturbing the ether in a manner exactly similar to a diverging beam of plane polarised light.

As a resonator or detector of the arrival and presence of the ether disturbance, Hertz used a looped conductor with its ends brought close together, or a pair of cylinders like those used as vibrator. When the detector is in unison with the vibrator, and the spark-gap small, the presence of the electric disturbance is manifested by a series of microscopic sparks across the air-space between the ends of the resonator.

Fitzgerald lately discovered that if the two ends of the resonator be connected through a very high-resistance galvanometer there will be a deflection when the resonator is disturbed by ether vibrations. The reason of this phenomenon is unknown, but it renders the performance of Hertz's experiments very much easier, and enables one to show them all to a large audience, as he has done lately at the Royal Institution, London.

With this apparatus one is fully equipped to prove that electric oscillations and light are the same thing. The oscillator corresponds to the source of light, the resonator or detector to the eye. Fitzgerald's arrangement of the galvanometer added to the resonator simply corresponds to rendering the eye more sensitive. The only difference between the two phenomena is that the wave-lengths of the ether disturbances we call light lie between four ten-millionths ($\frac{4}{10000000}$) and eight ten-millionths ($\frac{8}{10000000}$) of a metre approximately, while we can get electric waves of any length from a few feet up to ten thousand miles. With Hertz's apparatus they are usually a few feet long; while those sent out from an ordinary alternating-current dynamo, running at a speed corresponding to 100 periods per second, are about 2,000 miles long. With the apparatus described above it can be shown that everything that can be done with light can be done with electric waves. They can be reflected, refracted, polarised, and made to interfere. Thus, it has been proved, both by theory and experiment, that light is simply an electric phenomenon.

During the last few years an enormous amount of valuable work has been done in the department of chemical physics, of which, perhaps, the most important is that which began with Raoult's study of the freezing-points and vapour tensions of dilute solutions, and led to the discovery by Raoult himself of new methods for the determination of molecular weights, to the formulation by van't Hoff of a new theory of the nature of solutions based on the laws of osmotic pressure, to a great extension by Arrhenius of the theory of dissociation of electrolytes (first conceived by Williamson and Clausius), and to the discovery and application by Ostwald of the method of deducing the coëfficient of chemical affinity from measurements of electric conductivity.

As I understand that this department of modern research is to be treated at this meeting by the esteemed President of the Chemical Section, Dr. Masson, who has made a special study of the subject, I will not run the risk of displaying my ignorance by saying anything more about it.

Considerable advances have been made in the study of the behaviour of definite liquid compounds with regard to changes of temperature, pressure, and volume in the neighbourhood of their critical points, particularly by Professors Ramsay and Young. Some of the theoretical conclusions of Van der Waals have been thus put to the test of experiment, and shown to be erroneous, while others are apparently confirmed.

In this connection may be noticed our increasing knowledge of the properties in the liquid state of those substances which we ordinarily know as gases. It is not so many years since Andrews's classical research on the continuity of the liquid and gaseous states first bore practical fruit in the liquefaction by Pictet and by Cailletet in 1877 of the old permanent gases.

Since then methods have been so much improved that experiments can be carried on at as low a temperature as -210° C. To Wroblevsky, Olszweski, and others we owe quite an intimate knowledge of liquid oxygen, nitrogen, marsh-gas, and nitric oxide; but it appears to be doubtful whether hydrogen does not maintain a unique position as an uncondensed, though surely not uncondensable, gas. Experiments seem to show that at these exceptionally low temperatures chemical action is at a standstill, and it is hardly to be wondered at when such proximity to the absolute zero is attained.

In few branches of physical science has so great an advance of late been made as in the methods for measuring extremely small variations of temperature or excessively minute amounts of heat-radiation. Ten years ago a good thermopile with a very sensitive galvanometer was considered almost beyond being improved on. This apparatus, with the assistance of a large refractor or reflector, was delicate enough to indicate the heat received from some of the brighter stars, but, when you know that at present we have instruments more than one thousand times as sensitive, you will understand how wonderful the advance has been.

We always measure change of temperature by the resulting change in one or other of the properties of a piece of matter. The resistance of a conductor to an electric current is always increased if its temperature be increased, and we can measure any variation in the resistance of a conductor with enormous accuracy.

Making use of this principle, Professor Langley in 1881 invented an instrument which he called a bolometer. It consists essentially of a Wheatstone's bridge with a very delicate galvanometer. The arms r_1 and r_2 of the bridge are made of a substance whose resistance varies considerably with temperature (usually thin strips of iron). A balance is made when both r_1 and r_2 are unexposed, or at the same temperature. If now one arm, r_1, be screened while the other, r_2, is exposed to radiation, the galvanometer will be at once deflected, due to the increase in the resistance of r_2 disturbing the balance; and a modification of the usual formula for the bridge will enable you to calculate from the observed deflection of the galvanometer the change of resistance, and hence the increase in temperature, of r_2, the exposed arm. This is, in general terms, the theory of the instrument; but of course very great precautions must be taken in its manufacture and arrangement so as to exclude disturbing influences. With a good modern galvanometer this instrument will measure a variation of temperature of $\frac{1}{100000}$ of a degree centigrade.

With this instrument its inventor, Professor Langley, has conducted a most interesting and valuable investigation, extending over four years, about the temperature of the moon. His most interesting conclusion was that the mean temperature of the sunlit lunar soil is very much lower than was formerly supposed, and cannot be very much above the freezing-point of water. In addition, he discovered many facts of great meteorological interest.

Wonderful as this bolometer of Langley is, it has been superseded by another instrument still more wonderful, the radio-micrometer of Professor Boys. The working of this instrument depends on properly utilising the fact that if a complete circuit be made of two or more metals, and if one junction be at a different temperature from that of the rest of the circuit, an electric current will flow round. Roughly speaking, it consists of a circuit of one turn in the form of a square or rectangle approximately 1 square centimetre in area; three sides of which are of fine copper wire, the upper side being 1cm. long, while the fourth or lower side is a compound very light bar of antimony and bismuth, each piece being about $5 \times 1 \times \frac{1}{4}$ mm., soldered edge to edge. This rectangle is carried by a thin rod on which is a small mirror, the whole being suspended from the upper end of the rod by a very fine quartz fibre. This single circuit is then suspended so that its plane is parallel to the lines of force of the field of a powerful magnet. A beam of light falls on the mirror and is reflected on a scale. If now the least amount of heat-radiation fall on the junction of the antimony and bismuth, an electric current will traverse the circuit, which then tends to set itself across the lines of magnetic field. The least motion of the circuit, however, causes the reflected beam of light to travel along the scale, and it can be thus easily seen and measured. With one of these instruments the inventor got a deflection of the reflected beam on the scale of 38mm. when the image of a candle 250 yards distant formed by a mirror of 16in. aperture was allowed to fall on the sensitive disc that is at the junction of the antimony and bismuth. The same candle, at the distance of about one mile, would at that rate have caused a deflection of 1mm., which is by no means the smallest deflection that can be accurately read.

The great delicacy of the radio-micrometer depends entirely on the quartz fibre by which the circuit is suspended. To Professor Boys do we also owe the discovery of the method of preparing these fibres. Two pieces of quartz crystal are melted in the oxy-hydrogen flame and drawn into small rods. One is fastened to an arrow, while the other is fixed. The arrow is placed in a drawn bow, both pieces of quartz are again melted and joined together, and the arrow is discharged. A very fine fibre of quartz is thus drawn.

Until this discovery the most delicate suspension that we could use for measuring very small forces by the method of torsion was got by taking a single silk fibre, as spun by the silkworm, and splitting it down the middle. For any purposes of measurement a silk torsion-fibre is most unsatisfactory. It is viscous, and never brings the deflecting body back to the zero position when the deflecting force is removed. It is also very much affected by moisture and change of temperature. Quartz fibres have none of these defects. They can easily be drawn out a hundred times finer than is the finest unspun silk. They are enormously strong, stronger than the best steel, being able to bear a strain of from 60 to 80 tons to the square inch.

As the measurement of very small forces enters at present largely into all scientific work, and is very likely in the future to enter still more largely, the importance of this, one of the many of Professor Boys's discoveries, can scarcely be overestimated.

In this connection, mention should also be made of a most difficult and valuable piece of research—the determination of the elastic constants of quartz fibres, which has lately been performed by Professor Threlfall, my predecessor in the presidency of this section. Considering the many uses that in future scientific work these fibres can be put to, these results of Professor Threlfall's labours are of extreme value.

Within the last few years an enormous extension of our knowledge about magnetic induction has taken place. This has undoubtedly been called forth by the necessity for the knowledge of correct principles on which dynamos and transformers could be constructed.

It is a well-known fact that when a voltaic current passes along a wire it establishes a magnetic field in the medium surrounding the wire, and that the direction and magnitude of the magnetic force at any point of the field can be very simply stated by aid of Faraday's conception of lines of force, the lines being parallel to the direction, while if the medium be a vacuum or air the number of them that passes through an area of one square centimetre represents the force perpendicular to that area.

It was discovered by Faraday that if a second conductor forming a loop be suddenly brought into the field a momentary current would be produced in it, and he proved that the whole quantity of electricity that flowed round, multiplied by the resistance of the loop, was numerically equal to the number of lines of force piercing the loop that had been added by the motion. If a ballistic galvanometer be included in the circuit of this loop its needle will be deflected, and it is well known that the sine of half the angle of deflection is proportional to the total quantity of electricity that has formed the momentary current. Thus we have a method of measuring the increase or decrease of the number of lines of magnetic force piercing the coil due to the motion.

Let us now suppose that we have a ring of any substance wound uniformly with an insulated wire in the circuit of which we have a battery, a commutator for reversing the direction of the current at will, a tangent galvanometer for measuring the current, and a set of resistances with which we can vary its intensity. Call this the primary circuit, and let there be n turns of the wire per centimetre of length of the ring.

Let us also at any point of the ring have for simplicity a single turn (in practice a number of turns would be necessary) of another wire wound close to the former, and form a circuit in which a ballistic galvanometer is placed. This will be called the secondary circuit.

If now, when a current, C, is flowing through the primary current, it be suddenly reversed, the needle of the ballistic galvanometer in the secondary circuit will suffer a momentary deflection, which informs us that a certain quantity, Q, of electricity has passed as an instantaneous current through it. This is due to the fact that, when the current is flowing in one direction through the primary, a certain number, N, of magnetic lines of force pierce the single loop of the secondary, and that when the primary current is reversed the same number of magnetic lines pierce the secondary loop in the opposite direction, so that the total change of lines of force due to reversing the primary current is 2N, and the swing of the needle of the ballistic galvanometer is proportional to this change; or, more exactly, if R be the resistance of the secondary circuit, the total number N of lines of induction that passed through the single loop of it when C was flowing in the primary may be defined as $\frac{1}{2}$RQ (or if, as is necessary in practice, instead of having a single loop we have a number m, say then $N=\frac{1}{2m}RQ$), where Q is the total current measured by the ballistic galvanometer.

The induction B, in its modern signification, may be defined as the number of these lines that pass through every square centimetre of the loop, and the magnetizing force H of the primary current as $4\pi \times C \times n$, where n is the number of turns of the primary wire per cm. length of the ring. The ratio of the induction B to the magnetizing force H is called the magnetic permeability of the material of the ring, and is usually represented by μ.

So, then, H, the magnetizing force, is proportional to the current in the primary, and B, the induction, to the momentary deflection of the ballistic galvanometer in the secondary circuit when the current in the primary is suddenly reversed. These terms and their relations must be thoroughly understood before any knowledge of any value about the modern theory of magnetic induction can be at all grasped.

If, with apparatus of the form I have described, we make a series of experiments in the following way, with rings of different materials, some very striking results will be obtained.

Begin with a very small current in the primary; reverse it, and take the deflection of the galvanometer in the secondary; increase the primary current; reverse it, and take again the deflection of the galvanometer in the secondary; and so on, increasing the magnetizing current by steps. Plot out the results on a diagram, as in Fig. I. (Pl. I.), where the abscissæ represent magnetizing forces H, and the ordinates the induction, B, corresponding; and, if rings of different material be used, two most striking facts will be at once apparent:—

(1.) If the material of the ring be of iron, we may get B as much as 2,000 H; if of cobalt, as much as 120 H; and, if of nickel, 170 H; while, if of any other substance (unless a few compounds of these three), B will be found to all intents and purposes simply equal to H.

This is a very wonderful fact: that, of almost all known substances, only three are magnetic, and these enormously so, while all others are non-magnetic.

(2.) While, in the case of non-magnetic substances, no matter how much H may be increased, B is always equal to it, we find that in the case of the magnetic metals B is not even proportional to H, but increases in a very peculiar manner as the magnetizing force H is increased.

Fig. I., taken from Rowland's work, shows this clearly. For small values of H, B increases slowly as H increases; then, when the magnetizing force has reached a certain value, B increases with enormous rapidity as H increases—just as if at this stage the internal magnetic structure of the iron was in a state of unstable equilibrium; then, as H is still further increased, the rate of increase of B becomes small again, and gradually decreases as H is still further increased—thus indicating a saturation limit. Fig. II. (Pl. I.), which is deduced from Fig. I., shows how the permeability μ—that is, the ratio B/H— varies as the magnetizing force is increased.

Diamagnetic bodies, when the above method of classification is applied to them, may be considered non-magnetic, as the following table (Hopkinson) will show:—

If the ring be of iron, B may = 2,000 H.
If the ring be of brass, wood, &c., B = H.
If of bismuth (the strongest diamagnetic body known), B = 0·999 H.

There are many other most interesting properties peculiar to these three magnetic bodies, the most important of which I will now describe; but I must first explain another method of conducting the experiments necessary to obtain the curve that represents the relation between B and H.

With the same apparatus we begin by starting a small current in the primary, and noting the deflection caused in the secondary; then, after the needle of the ballistic galvanometer has come to rest at zero, increase the current in the primary suddenly from its last value to a higher one, and note again the deflection caused in the secondary, and so on, increasing H by steps, and calculating from the deflections the corresponding increases in B. Thus the whole induction through the ring will at any stage be determined by summing up the different additions caused by the successive increases to the primary current. Let us now by this last method perform the following series of experiments, using an iron ring: First, increase the magnetizing force H by steps until it reaches a certain value, A; then diminish it by steps until it reaches an equal negative value, $-A$; then increase again by steps until H has once more attained the value A,—noting, of course, at each step by the galvanometer swing the increase or decrease of the induction B caused by that step. Plotting as before the results, we shall find that the history of the magnetic state of the iron of the ring while undergoing this cycle of operations will be given by a curve of the form represented in Fig. III. (Pl. II.), which is taken from Professor Ewing's work. In this the ascending curve OS represents the way the induction increases with the magnetizing force when we begin with an unmagnetized ring, and it is similar to the curves in Fig. I. (Pl. I.), as it ought to be. The descending curve SC′S′ tells how the induction diminishes as the magnetizing force is decreased by steps from 15 C.G.S. units to -15 C.G.S. units. The ascending curve S′CS tells how the induction B increases as H is increased from -15 units to $+15$ units.

This is a very remarkable figure, and tells us many interesting things about the behaviour of iron when it is being subjected to a steadily-varying cycle of magnetizing forces.

The first fact you will notice is that the descending curve SC′S′ is not the same as the original ascending one OS, nor as the ascending one S′CS of the cycle. This shows that the iron has a tendency to remain in its previous magnetic condition—a property which has been called hysteresis by Professor Ewing, to whom a great many of the recent advances in this subject are due.

You will see from this figure also that when the magnetizing force has been actually reduced to zero the induction has still the large value 11,000. This is the residual induction or retentiveness, which in some kinds of iron is as much as 90 per cent. of the maximum induction.

Following the curve downwards, you see that a demagnetizing force, represented on the diagram by OC′, is required to reduce the induction to zero. To this definite quantity OC′ Dr. Hopkinson has applied the old and vaguely-used term *coercive force*. The upward curve S′CS again exhibits the hysteresis of the iron, the value of the retentiveness and of the coercive force.

Another very important piece of information can be got from this curve. It has been shown by Maxwell that, when a magnetizing force H produces an induction B in any medium, the

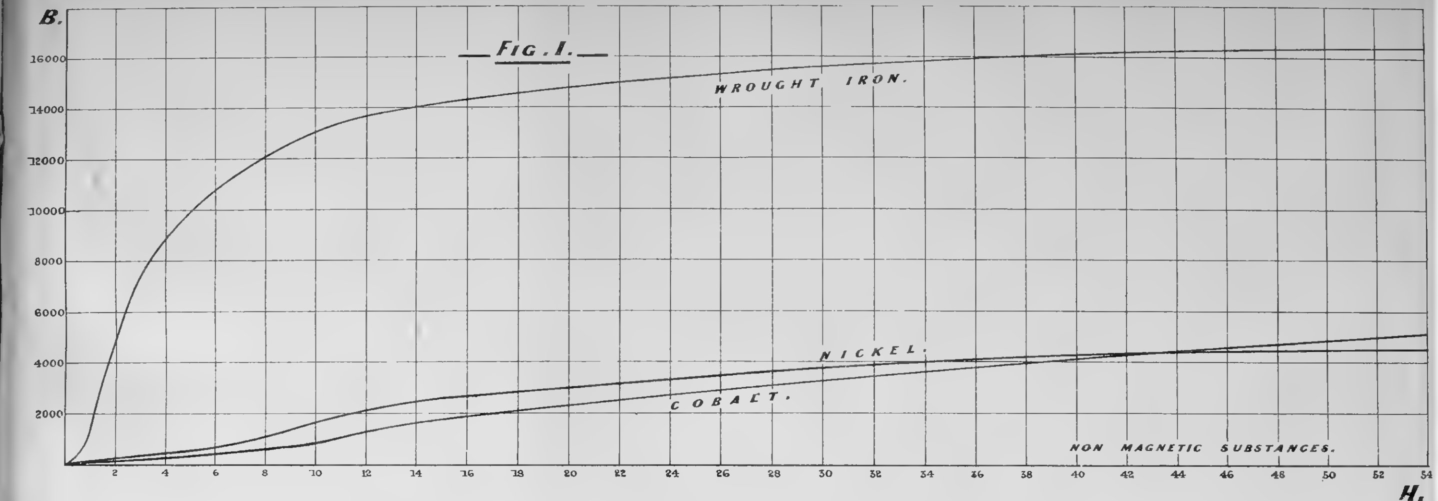
FIG. 1.
B.
16000
14000
12000
10000
8000
6000
4000
2000
WROUGHT IRON.
NICKEL.
COBALT.
NON MAGNETIC SUBSTANCES.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54
H.

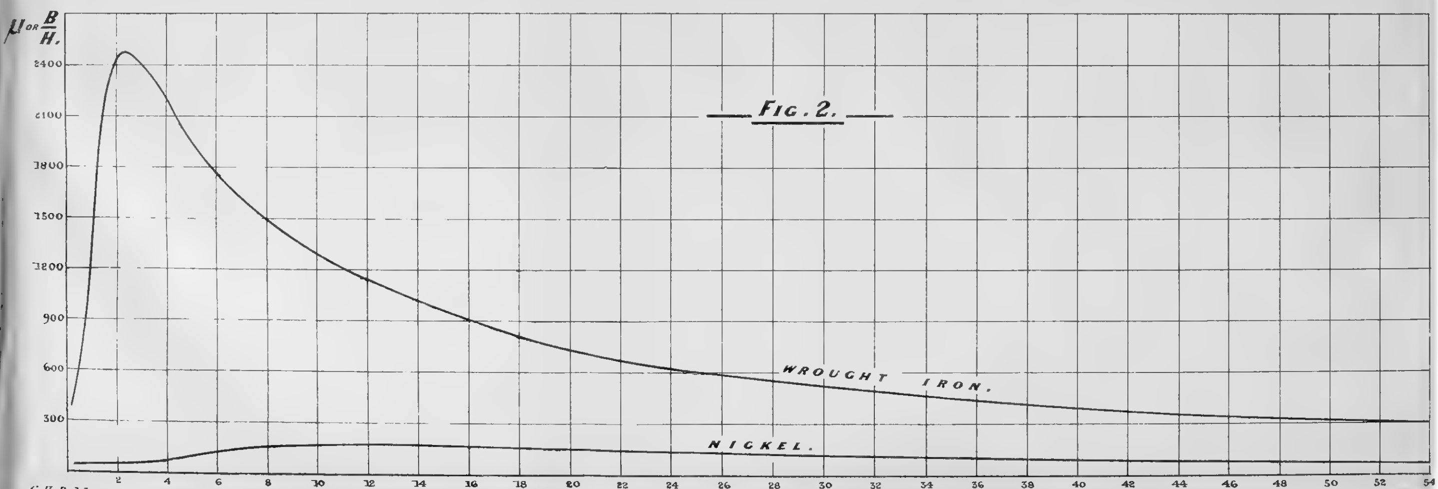
FIG. 2.
μ OR B/H.
2400
2100
1800
1500
1200
900
600
300
WROUGHT IRON.
NICKEL.
2 4 6 8 10 12 14 16 18 20 22 24 26 28 30 32 34 36 38 40 42 44 46 48 50 52 54

C H P del

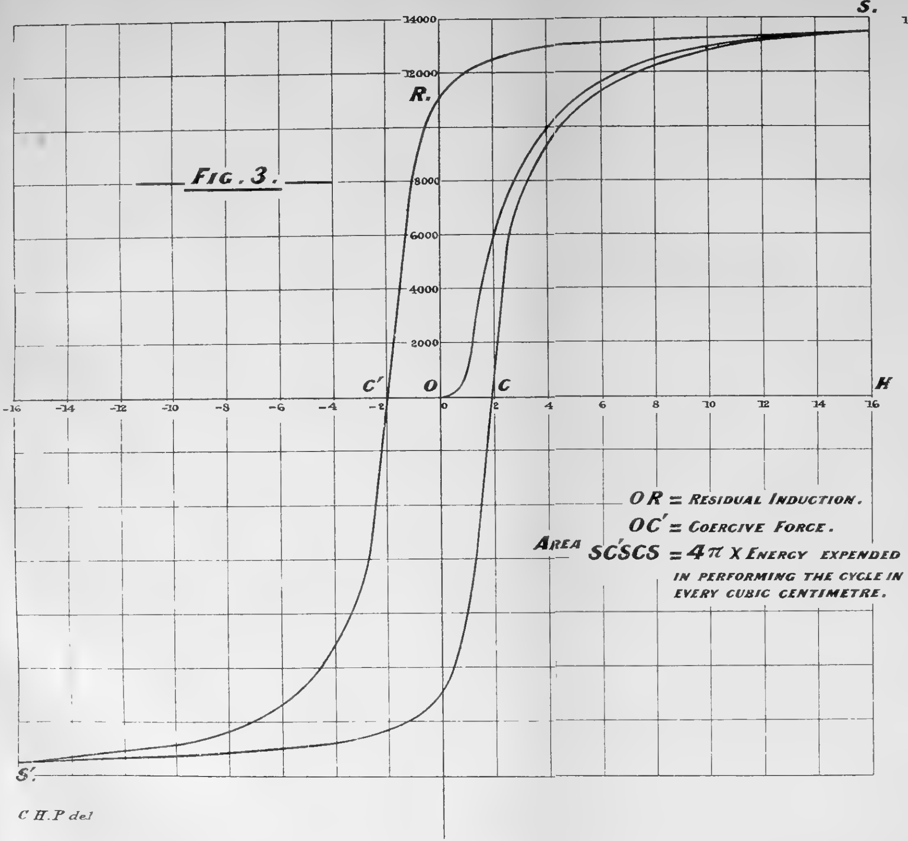

FIG. 3.

C H.P del

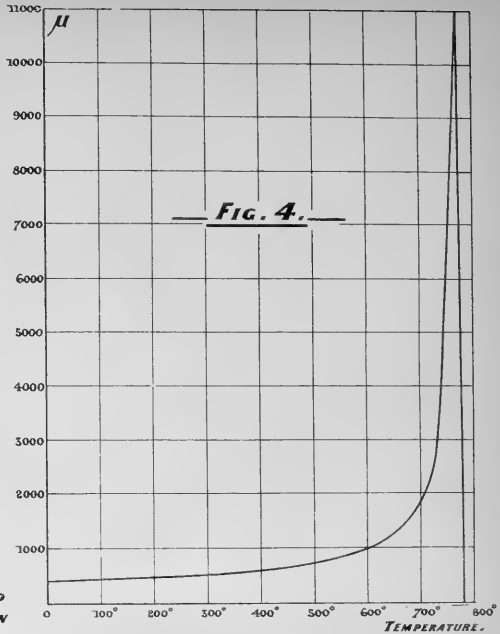

FIG. 4.

Variation of Permeability with Temperature for Small Magnetising Force (·3 C.G.S. Units). (Hopkinson.)

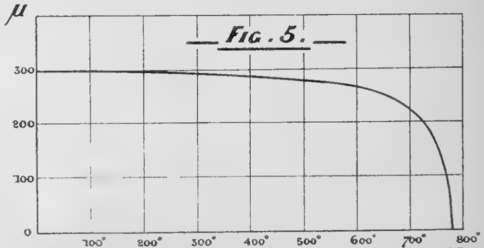

FIG. 5.

Variation of Permeability with Temperature for Large Magnetising Force.

To illustrate Paper by Prof: Lyell.

energy stored up in every cubic centimetre of the medium in consequence is numerically equal to $-\frac{1}{8\pi}$ BH.

From this it can easily be shown, as Ewing has done, that the area of the curve SCS′C′S divided by 4π represents the energy expended in every cubic centimetre of the iron by the current in performing the cycle of operations represented by the curve. This is energy wasted, dissipated in heating the iron during the process of reversal, and it is obvious how necessary it is to keep the amount so wasted as small as possible in the case of armatures of dynamos and cores of transformers. For very soft iron this waste is small, but with hard steel it may be as much as 20 per cent. Professor Ewing has also shown that the amount of energy so wasted by hysteresis can be very much lessened by mechanical vibration.

The effect of temperature on the magnetic properties of iron is very remarkable. If we insulate the wires round the ring of soft iron with asbestos, and make a series of experiments by the first method, always using the same current in the primary, but gradually increasing the temperature of the iron, we shall find, if the magnetizing current be small, that the permeability, μ, of the iron—that is, the ratio $\frac{B}{H}$—increases slowly with the temperature at first. When the temperature is about 600° C. μ begins to increase at an enormous rate, and at 770° is as much as 11,000. The addition of a few more degrees of temperature at this point reduces iron to a non-magnetic metal. The relation between the permeability and the temperature for a small magnetizing current is shown on Fig. IV. (Pl. II.), taken from Hopkinson.

The variation of the permeability of the iron would have followed a very different order had we used a large magnetizing force instead of a small one. In this case, instead of increasing with the temperature, μ steadily decreases, slowly at first, but when the temperature is about 600° C. μ decreases more rapidly, and finally at the same temperature as for small currents the iron becomes non-magnetic. (Fig. V., Pl. II.).

In general terms, we may state that for small magnetizing forces increase of temperature makes iron more magnetic until a certain critical temperature, 770° C., is reached, when it suddenly becomes non-magnetic.

For large magnetizing forces increase of temperature makes iron less magnetic, its magnetic properties vanishing at the same critical temperature as for small forces. Evidently some very striking change must occur in the molecular condition of the iron at this critical point. It is the temperature of the recalescence phenomenon of Barrett, which is interesting enough to mention here: If an iron wire be heated to a bright-red heat, and allowed to cool in the air, you will see, if you watch it carefully, that just when it has become of a very dull red colour it suddenly glows out quite bright, and afterwards cools regularly. Some molecular change must occur here in which latent heat is liberated, for the iron, though giving out heat by radiation, suddenly increases in temperature.

Every circumstance that affects the molecular condition of iron has a considerable effect on its magnetic properties. Mechanical vibration, stress, even light, falling on iron affects, and admixture with other metals in a wonderful degree changes, its magnetic properties. Iron with 10 per cent. of manganese is almost non-magnetic.

Within the last few months Ewing, who had already made his name famous by his researches on the subject about which I have just been speaking, has crowned these labours by giving to the world a new theory of magnetism—a theory that works, or, in other words, explains the known facts of magnetism.

All the older theories have failed: Poisson's, in which every molecule of a piece of iron contained two magnetic fluids that were separated on magnetization; Weber's, in which the molecules of a magnetic body were permanent magnets whose axes lay in all directions irregularly in an unmagnetized body, while the act of magnetization imparted a certain amount of direction to them, they at the same time offering a certain resistance to change of direction; Maxwell's, which is merely Weber's with the additional proviso that if the molecules by any chance got turned through more than a certain angle they were unable to return to their original positions; Hughes's chain-theory, in which the molecules of unmagnetized iron are magnets arranged in groups forming closed chains, and thus exert no external action, while the act of magnetization breaks several of these chains, and thus a certain amount of magnetic moment is imparted to the mass.

From what I have already said on magnetic induction it is evident that any magnetic theory has a great number of facts to account for. It must be in agreement with what is known about permeability, residual magnetism, hysteresis, the effects of stress, vibration, and temperature. Poisson's theory explained nothing. He was right only in his idea that each molecule was a magnet. Weber's accounted for the saturation limit of magnetization; while Maxwell's only added the explanation of residual magnetism.

Ampère did not propose a theory of magnetism. He only stated that each molecule was a magnet, its magnetism being due to electric currents circulating incessantly, flowing round it, in fact, in a circuit of no resistance. With this conception

Professor Ewing sets out, and he arrived at his theory by making a large number of little magnets, mounting them on pivots on a horizontal plane, and arranging them in groups, so that they may on a large scale represent the molecules within a magnetic body. These little needles are, of course, subject to their own mutual actions. Professor Ewing, by surrounding them with a large wire spiral through which an electric current could be sent, could subject them to the action of a magnetic field of any intensity, and at the same time have a direct view of how they behaved. He found that with the rough model of a magnetic body that I have described he was able to imitate much of the known behaviour of magnetic substances. With no magnetizing force acting on them they arranged themselves in equilibrium under their own mutual actions, and exerted no external action. With small magnetizing current they are a little deflected from their mutual equilibrium position, and the system acquires a small magnetic moment. If the magnetizing force be removed they return to their former positions. If larger forces be applied, some of the little magnets are so far deflected that, reaching a position of unstable equilibrium, they will turn farther round, and, having done so, they will remain in a new position of equilibrium even when the magnetizing force is removed. The system will thus have acquired a permanent magnetic moment, or, in other words, will have become permanently magnetized. Finally, when a very large magnetizing force is applied, the small needles will all place themselves approximately in alignment with that force, and so the maximum amount of magnetic moment will be acquired by the system, or, in other words, the point of saturation will have been reached. Hysteresis, the effects of temperature stress and mechanical vibration, can all be easily imitated with this model. The theory of magnetism, so deduced by Ewing, may be stated thus: The molecules of a magnetic body are magnets, they are free to turn about, and they mutually act on each other.

Turning now to the practical applications of science that have rendered social economy so different nowadays from what it was half a century ago, I find that the field is so extended that the most I can do is to briefly direct your attention to one or two of them that may possibly interest you.

Electricity of course leads the van, and of some of its applications alone will I speak.

So much has been said and written about electric lighting that I need scarcely do more than mention it. The fact that all London will shortly be supplied, both in streets and houses, with the electric light, says enough for its progress as a commercial undertaking.

The introduction within the last few years of the three-wire system and of the alternating-current-transformer system has done much to reduce the expense of distribution.

In dynamo construction electric engineering may be said to have reached such a point of excellence that the study of minor points is all that remains to be done. This was due principally to the application of Kapp's theory of the magnetic circuit to their construction, and to the almost perfect knowledge we now have of the magnetic behaviour of iron.

Though electric railway and tram traction has already reached a high standard of efficiency, many difficult problems in connection with it still remain unsolved. Practical experience gained from systems working under the various conditions to which they may be subjected will do much to clear the ground in this branch of electric industry, in which it is extremely likely that we shall see great developments in the course of the next few years.

Many examples of the applications of electricity I might give; but, as I fear I have already occupied too much of your time, I will bring my address to a close with a short description of two of these which at the same time are both simple and interesting.

Great interest has lately been executed by some experiments made by a Russian, Specnew, on the application of electricity to agriculture. He conducted all his experiments, extending over a period of five years, in a thoroughly scientific way. He first investigated the effect of the electric current on different seeds, and then submitted growing plants to two kinds of electric action. In one case, he placed large plates of copper and zinc—3ft. square—in the ground, and connected them above ground with a wire, thus forming a zinc–earth–copper element. Between the plates he sowed the various seeds. In the other case, he set up a number of insulating-rods having comb collectors mounted on them, and planted his seeds about. In all cases he found that the electric action helped the growth of the plants, and in some cases as much as 200 per cent.

The other application of electricity to which I wish to direct your attention—namely, welding by electricity—is one of great commercial importance. It is the invention of Elihu Thomson, an American professor; and is remarkable, like very many great inventions, for its simplicity.

It has long been known that when the ends of any two conductors are brought together, and a strong electric current passed, the junction becomes very hot (as in the case of the electric arc), due to the resistance at the loose junction being much greater than that of the solid conductors. The application of this simple fact is all that is involved in the invention. The apparatus required for the process is particularly simple—

an alternate-current dynamo working at a tension of about 400 volts, and a transformer by means of which the current from the dynamo is reduced to one of enormous value at very low pressure. This transformation is necessary, as heating effect is proportional to the square of current strength.

The terminals of the large current circuit are two massive clamps, one of which is fixed while the other can move to and fro. The latter is provided with a powerful screw used for applying end pressure to the weld.

When two pieces of bar are to be joined their ends are prepared, and they are then placed in the clamp with the prepared ends in contact. The current is turned on, the junction soon becomes white-hot, all the other parts of the bar remaining cool, pressure is applied by the screw, and the thing is done.

The beauty of the process from a scientific point of view is the fact that in it almost all the energy required, either as heat or work, is given to the place where it is required, and to nowhere else, so that extremely little is lost.

The number of industries to which this art has already been applied is enormous, and it is impossible to foresee by how much the number of its applications may be increased.

I must now conclude. I hope that the few examples of the late advances in science have sufficiently interested you. Many others I might have spoken of, but I think I have said enough to convince you that the last decade has been one of very great scientific activity.

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1. *The Earthquakes of New Zealand.*

By George Hogben, M.A., Timaru, New Zealand.

Plate III.

This paper is founded upon the records of 775 earthquake-shocks felt in New Zealand, between the years 1848 and 1890, inclusive. These records have been obtained by a systematic search of some of the leading journals, from the list and notes thereon published annually in the Appendix to the "Transactions of the New Zealand Institute," from private sources, and, since December, 1889, by means of notices forwarded by officers of the Telegraph Department from stations in various parts of the colony.

The records are incomplete in the following respects:—

(1.) They do not include all existing records: the systematic search of the newspapers of past years has not been completed yet; and many valuable private records of whose existence I am aware have not so far been available for use. When all are included, I anticipate that the number of shocks recorded will be found to be nearly nine hundred for the years in question.

(2.) A large number of earthquakes were unobserved, especially in the earlier years. Slighter shocks will escape notice until we have seismographs in use at the chief stations; but under the present system it is hardly possible for a perceptible shock (felt at several places) to escape the record.

(3.) Many of the records are inexact. This fault, again, can only be fully corrected by the use of instruments; but once more I may claim that the system, which I shall presently describe in brief, has introduced a greater degree of exactness than has (except occasionally) been possible before. Notwithstanding these drawbacks, much may be learned from the records as to the distribution of New Zealand earthquakes in place and time, and as to the origins of disturbance. If nothing else were done, it would, I venture to submit, be useful to summarise our knowledge of the past, and so to place ourselves in a position to see towards what points future inquiry may profitably be directed.

I. Distribution in Time.

This is perhaps the least important part of the subject, and may be dismissed in a few words. Table A shows the number of shocks recorded (or, rather, included in my list) per year from 1848 to the present time. Its chief value is to indicate the nature of the records themselves.

Table B shows the number of shocks recorded for each month of the year from 1848 to 1890. Its accuracy is not affected in any special way by the incompleteness of the earlier records, which are almost as likely to fail in any one month as in any other. The number of earthquakes for the months October to March is 341; for the months April to September, 404—thus confirming the general rule stated in Milne's "Earthquakes," p. 257, namely, that "generally the greater number of shocks have happened during the cooler seasons." Professor Milne, indeed, remarks that the rule is not true in the Southern Hemisphere; but his table (given on the same page) seems to show that it is, and our present list certainly proves that the law holds as far as New Zealand is concerned.

C is a chart (Pl. III.) of the curves of Monthly Seismic Intensity (after Mallet—see Milne's "Earthquakes," p. 256) for the Northern and Southern Hemispheres, with the corresponding New Zealand curve, based upon Table B, for comparison. The number of earthquakes is a maximum in September, with two lower maxima in January and March. The minimum is in April, with another (nearly as low) in November, and a lesser fall in February.

As the number of observations on which Mallet's curve for the Southern Hemisphere was based is only 223, it is obvious that it might be considerably modified by the inclusion of the remainder of the 775 earthquakes in the New Zealand record. Of course, to form a revised curve we should need also the records for Australia, South America, and South Africa.

D [exhibited] is simply an enlargement of C. I cannot perceive any law of connection between the season of the year and the number of earthquakes--at least, as far as New Zealand is concerned.

II. Distribution in Place.

E [exhibited] is a map of New Zealand shaded to show the regions of greater or less earthquake-frequency. It is constructed in the following manner: Out of the 775 shocks, 116 were felt (or recorded) at three or more places. Each earthquake is plotted on the map by joining the outermost places at which the shock was felt, and the included area receives one wash. No attempt is made by difference in the washes to mark differences in the intensity of the several shocks; but all the washes are of the same depth. The remaining earthquakes are marked by similarly shading a circular area of ten miles radius round the place at which each shock was recorded, omitting those places at which the total number of such isolated shocks since 1848 has been less than six.

F is a photograph of the same map. It will be seen at once that the darkest part of the map is that part of Cook Strait* included in the triangle Wellington, Blenheim, Wanganui: in other words, wherever the origin may be, the earthquakes felt at these three places are commoner than any other earthquakes except, perhaps, those that are local in a still stricter sense and are felt at one place only. The next shade of frequency includes Christchurch; the next, Nelson. Then we must extend the area to include New Plymouth, Masterton, Reefton; next, Hokitika with Greymouth and Westport; then Napier; and so on. There is an isolated district of local earthquakes round Rotorua and Tarawera; and a larger district extending eastwards (and probably westwards, too, if we had records) from Queenstown. Two large tracts of country are not shaded—the extreme north and south-west of the colony. In the latter this is due to lack of records, but that is certainly not the case in regard to the country north of Auckland.

* I use "Cook Strait" in this paper in the widest sense—that is, to include the region from Cape Campbell to Cape Farewell and Taranaki.

Of the isolated earthquakes the Wellington records show by far the most, the number being 121. Wanganui is second* (41); and Rotorua (32) third. Next after Rotorua we have—from 1848 to 1890: Nelson, 24; Christchurch, 23; New Plymouth, 23; Napier, 21; Queenstown, 18.

These apparently isolated or local earthquakes, or the records of them, are more uncertain than the 116 felt at three or more places, upon which the general shading is founded. The latter I think we are justified in taking as fairly accurate, especially when the large number of shocks included is taken into account. If we apply tests, such as using the earthquakes of the last few years only, we find that the general shading remains the same relatively, but the relative darkness of the small circular areas varies considerably.

The radius of the small circles (10 miles) is more or less arbitrary. It was suggested by the fact that from private information I was aware that some of these isolated shocks were felt at that distance from the respective towns.

It may be convenient to state here that the earthquakes immediately connected with the eruption of Mount Tarawera in 1886 have not been included in the list of earthquakes, as I take it that they should be considered as part of the phenomena of the eruption: seventy-one shocks were felt at Opotiki at the time of the great outburst and the few hours that succeeded. I have not excluded the warning earthquakes that preceded the eruption, or those that took place after activity had ceased, for probably they belong to the same class as all the other earthquakes confined to that region. It is to such earthquakes, notably perhaps to earthquakes like those of 1866, that the term "volcanic earthquakes" may be applied, or the expression be used that "the earthquake is an unsuccessful attempt to form a volcano." That is to say, the cause is possibly the presence of water in a cavity or quasi-cavity at high pressure and temperature. At Ruapehu and Tongariro we might expect similar shocks; and I believe shocks of a very slight nature are felt at Ruapehu, but only, as a rule, on the mountain itself. There is a general impression that some of the shocks felt in the south-west portion of the North Island have proceeded from the Ruapehu-Tongariro district; I have searched right through the records for indications of this, and have found not a single piece of evidence in favour of it: on the contrary, the data of the earthquakes said to have come from that supposed origin point to utterly different conclu-

* It is possible that if as good records had been kept at Wanganui as at Wellington the numbers might have appeared more nearly equal. At all events, the number of earthquakes felt at one or two places only during 1890 shows: Wellington, 3; Wanganui, 10; Rotorua, 8.

sions. The shocks there are accordingly strictly local, or do not extend farther than Taupo at most. In fact, we know from other parts of the earth that earthquakes connected with volcanoes are often local in character.

III. Earthquake-origins in New Zealand.

G is a table showing the origins of disturbance, so far as they have been worked out, under four divisions:—

(1) *Ascertained*—in which the degree of accuracy is as great as it can be in the absence of instruments.
(2) *Approximate*—in which the epicentrum found agrees with the data, but can be only roughly determined.
(3) *Probable :* the epicentrum found agrees with the mass of the data, but is inconsistent with some; or the data are not sufficient in number for certainty or exactness.
(4) *Doubtful :* the evidence inclines to the region shown, but leaves room for doubt.

In this table I have also given the depth of the centrum and the velocity of propagation (where possible).

H is a map of New Zealand with the epicentra or epicentric areas marked upon it, and classified as in Table G.

I is a sketch-map on a reduced scale to show the same origins. (Pl. III.)

The epicentrum of the earthquake of the 1st September, 1888, was determined by Professor Hutton, who has also pointed out, in the case of the series of shocks at Wellington on the 23rd January, 1855, and following days, that, inasmuch as part of the ground at Wellington itself was raised 4ft. or 5ft., the epicentric area must have included Wellington.

The remaining earthquake-origins, thirty-four in number, have been determined by myself, three of them forming the subjects of papers read before the Philosophical Institute of Canterbury during the past year: time-methods have been used for the most part, other methods being only auxiliary.

The epicentra, as will be seen at once, fall into several groups, most of which are on or near the line drawn through White Island, Tarawera, Taupo, Tongariro, Ruapehu, D'Urville Island, Queenstown. Between Lakes Sumner and Christabel is the epicentrum of the great earthquake on the 1st September, 1888, which brought down the spire of the Christchurch Cathedral, and also of the earthquake of the 5th December, 1881, which did a slighter injury to the same structure. To the same region I refer five other earthquakes, and there are others that might very reasonably be assigned to it. Most of the heaviest shocks felt in Christchurch come from the Lake Sumner origin, certainly those that do the most damage; and, if it be of any practical advantage to know it, the fact is one that should be borne in mind by the architects charged with the rebuilding of the cathedral spire.

The second group of origins lies south of the scene of former volcanic activity, Banks Peninsula. Here are two well-determined epicentra, those of 31st August, 1870, and 27th December, 1888. The data for the last were very exact, and the depth of the centrum could be determined very nearly; it was about twenty-four miles: the depth of the first was about the same. Four other earthquakes may be definitely referred to the same or nearly the same spot, and we might in all probability be quite safe in adding twenty or thirty more—perhaps the majority of the earthquakes felt at Christchurch. The shocks from this region are generally short and sharp, and do no damage.

The fifth of the ascertained origins, situated beneath the bed of the Pacific Ocean 198 miles from Napier and 280 miles from Wellington, is that of the 7th March, 1890; and from that place or near it have probably proceeded other shocks felt in the south and east of the North Island.

None of the origins of the Cook Strait earthquakes have, so far as I am aware, been exactly determined. Three I have succeeded in finding approximately, to the west of the line already named; and six others are shown as probable—two north of Cape Farewell; two near D'Urville and Stephen Islands, not far from a steep slope, 1 in 36, in the sea-bottom, near which the first recorded New Zealand earthquake was felt by Captain Furneaux on the 11th May, 1773; one north-north-west of Picton; and one south of Wanganui. As "doubtful" I have marked the position of six more—two south of Wanganui, and four north and north-east of Picton. One red circle marks the probable position of the epicentrum of severe earthquakes in the Tarawera and Mount Edgecumbe district on the 22nd and 23rd September, 1866, and of other earthquakes also. In the south of the South Island, the circle south-east of Oamaru marks the limits within which we must probably locate the source of the shocks experienced at Oamaru and in South Canterbury and North Otago in February, 1876. A large number of small shocks are recorded in the lake district of Otago, many of them being felt as far east as Port Chalmers, and from Oamaru on the one hand to the Bluff and Riverton on the other. Only one of these can be determined with any degree of probability—that of the 18th December, 1883—which I put at thirty-five or forty miles west-north-west of Queenstown. Three others are placed, more doubtfully, among the lakes to the south-west, and one of these has a secondary earthquake attached to it with an origin south-east of Otago Peninsula.*

It goes without saying that seismographs are an essential in the exact determination of the facts of earthquake phenomena: we should need at least eight in New Zealand, and there would be very little difficulty in pointing out the best stations for them, or in getting qualified persons to take charge of them. The total cost of obtaining these instruments would not exceed about £600. Is it too much to hope that at no distant date either the Government of the colony or some generous private individual may venture this moderate sum in the cause of science? Meanwhile much may be done, far more than most people are willing to grant, with the means at our disposal. Since the beginning of December, 1889, I have had forms printed, and supplied to the Telegraph officers at about fifty stations in New Zealand, a specimen of which I place before you. By the courtesy of Dr. Lemon, Superintendent of the Telegraph Department, these have been filled in and forwarded to me after each earthquake from all places at which the shock has been felt. Many of the officers exhibit considerable intelligence in filling up the forms; the greater completeness of the records is shown by the fact that, though the year 1890 was undoubtedly a barren year comparatively, yet the number of shocks recorded (forty-seven) is far above the average; and, again, the data of a comparatively slight earthquake (7th March, 1890) were sufficient to determine beyond reasonable doubt the epicentrum and velocity.

Though I have failed hitherto to determine exactly the origins of the Cook Strait earthquakes, that is due partly to the special difficulty of the case, and partly to the fact that the earthquakes of that region during the year were all of so slight a character. I hope, however, by an increase of the number of stations to completely surround the sources of disturbance, and so to hunt down the earthquake as to be able to determine the position and extent of the epicentric areas. The same remarks apply to the earthquakes whose origins are in the Otago lake region.

The assistance afforded in the choice of new stations is not the least of the purposes served by including on the map what I have called *approximate*, *probable*, and *doubtful* epicentra.

It appears to me to be too early to attempt to frame theories in regard to New Zealand earthquakes. Any classification of

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* I might venture a conjecture that the Oamaru shocks, and perhaps the Otago lake ones too, are secondary to others proceeding from a region at some distance to the south-east. This may seem rather a wild guess to those who have not gone through all the records, but it would explain much that at present is inexplicable. We need, however, much more evidence before we can speak positively.

them must, surely, rest upon a more or less accurate determination of the origins: for instance, a classification based upon the character of the surface-rocks or of the uppermost crust of the earth seems too much like *a priori* reasoning, and might be very misleading, especially where the earthquakes are so deep-seated as they are in New Zealand. I shall feel quite satisfied if I have succeeded in grouping our present knowledge, and in indicating the most profitable lines for future work.

K is a list of the 775 earthquakes on which the paper is founded.

Table A.—Records of Earthquakes—New Zealand, 1848–90.

Year.	No. of Shocks.	Year.	No. of Shocks.	Year.	No. of Shocks.
1848 ..	3	1867 ..	2	1880 ..	22
1853 ..	1	1868 ..	27 [b]	1881 ..	24
1855 ..	11 [a]	1869 ..	40	1882 ..	29
1856 ..	3	1870 ..	31	1883 ..	20
1857 ..	10	1871 ..	34	1884 ..	25
1858 ..	6	1872 ..	35	1885 ..	14
1859 ..	1	1873 ..	42	1886 ..	58 [c a]
1860 ..	1	1874 ..	36	1887 ..	19
1862 ..	1	1875 ..	23	1888 ..	43 [a]
1863 ..	5	1876 ..	35	1889 ..	19
1864 ..	5	1877 ..	28	1890 ..	47
1865 ..	3	1878 ..	31		
1866 ..	19	1879 ..	22	Total ..	775

[a] Number recorded; certainly a great many more.
[b] The earthquake tidal waves of August, 1868, not included, though the earthquake shocks proper on previous and succeeding days are included.
[c] The shocks occurring at the date of eruption of Tarawera are not included. Seventy-one shocks are recorded at Opotiki on the day of the great outbreak.

Table B.—Number of Shocks (745) recorded each Month of the Year, 1848–90.[a]

Month.	Total Number of Shocks.	Month.	Total Number of Shocks.
January ..	67	July	67
February ..	52	August ..	79
March	70	September ..	88
April	47	October ..	51
May	56	November ..	50
June	67	December ..	51

[a] Thirty records, recently received, are not included in this table: they do not affect the relative number per month.

TABLE G.—EARTHQUAKE-ORIGINS IN NEW ZEALAND.

(1) Ascertained; (2) approximate; (3) probable; (4) doubtful.

Date.	Where felt.	Epicentrum.	Depth.	Velocity.	Mark on Map.	Remarks.
		(1.) Ascertained.				
31 Aug., 1870	Canterbury, Westland, North Otago	172° 49′ E., 44° 7′ S. (24 miles from Akaroa)	24 miles (or a little more)	1,786ft. to 1,874ft. per sec.	·1	Cf. 27 Dec., 1888.
5 Dec., 1881	Canterbury, Westland, Wellington, Dunedin	172° 16′ E., 42° 34′ S. (10–10½ miles north of middle of Lake Sumner)	Uncertain (? less than 10 miles)	632ft. per sec.	2	Cf. 1 Sept., 1888.
1 Sept., 1888	Greater part of both Islands	Circle of 5 miles radius, with centre a little east of the Amuri Pass and 16 miles W.N.W. of Glynn Wye	About 20 miles (16 to 23 or 24 miles)	968ft. per sec.	3	*See* Prof. Hutton's paper, Trans. N.Z. Inst., 1888.
27 Dec., 1888	Banks Peninsula, Mid and North Canterbury, Westland	172° 51′ E., 44° 10′ S. (458 miles S. by E. from Christchurch; nearly opposite Akaroa Heads and mouth of Rakaia)	24·2 miles	1,690ft. per sec.	4	Northern boundary of epicentric area probably runs 8 miles nearer to Akaroa in E.N.E. direction, and possibly in opposite direction towards Ashburton.
7 Mar., 1890	Tauranga to Blenheim, especially at Napier and Gisborne	179° 49′ W., 40° 54′ S. (280 miles from Wellington, 198 from Napier)	Doubtful ..	1,364ft. per sec. (nearly)	5	Possible fissure below ocean-bed, running 15 or 20 miles each way, W.S.W. and E.S.E., from given place.

TABLE G.—EARTHQUAKE-ORIGINS IN NEW ZEALAND—*continued*.

Date.	Where felt.	Epicentrum.	Depth.	Velocity.	Mark on Map.	Remarks.
		(2.) Approximate.				
23 Jan., 1855	North and South Islands	Epicentric area included Wellington	..	..	H	Land at Wellington raised 4ft. or 5ft.
5 June, 1869	Christchurch, &c. ..	Near 4 (south of Banks Peninsula)	..	..	B	Cf. 27 Dec., 1888.
14 Sept., 1878	Wellington, Nelson, Marlborough, Westland, Canterbury	70 miles from Christchurch, 65 miles from Greymouth (near 3)	..	880ft. to 1,056ft. per sec.	A	Cf. 1 Sept., 1888.
21 Oct., 1878	Same, with Queenstown and Wanganui	80 miles from Christchurch, 70 miles from Greymouth, or between that and Lake Sumner (near 3)	..	1,050ft. to 1,100ft. per sec.	C	Cf. 1 Sept., 1888.
28 July, 1880	North Island, south of Napier and New Plymouth; Nelson	An area 104 to 106 miles from Wellington, 94 to 104 miles from Wanganui	..	600ft. to 700ft. per sec.	D	Cf. 19 July, 1876.
22 Mar., 1882	Christchurch, &c. ..	Near 4	..	..	E	Cf. 27 Dec., 1888.
20 Feb., 1890	Blenheim, Wanganui, Wellington	70 miles from Wellington, 70 miles from Wanganui	..	..	F	
15 Aug., 1890	Ditto	97 miles from Wellington, 69 miles from Wanganui	..	2,464	G	
		(3.) Probable.				
22–23 Sept., 1866	Maketu, and south of it	Below Tarawera, or between Mount Tarawera and Mount Edgecombe	..	? less than 880ft.	*a*	
1 Feb., 1868	Wellington to Dunedin (east and west coasts)	Near 3	..	..	*b*	Cf. 1 Sept., 1888.

3 Oct., 1870	Wellington, &c. ..	78 miles from Wellington, 19 miles from Wanganui	..	?300ft. per sec.	*c*	
27 Aug. – 1 Sept., 1871	Wellington to Canterbury	Near 3	..	..	*d*	Cf. 1 Sept., 1888.
25 Mar., 1874	Christchurch, Banks Peninsula	Near 4	..	..	*e*	Cf. 27 Dec., 1888.
26 – 29 Feb., 1876; 10 April, 1876	Oamaru, &c... ..	Probably within a circle of 17 miles radius; centre 22 miles S.E. of Oamaru, say in east quadrant of it, or 25–30 miles E.S.E. of Oamaru	..	..	*f*	
19 July, 1876	Tarawera to Christchurch	Probably area elliptical, axes 35 and 28 miles; major axis N.N.W. to S.S.E., 100 miles from Wanganui, 100 to 125 miles from Wellington	..	..	*g*	
6 Mar., 1880	Canterbury, Otago, Southland	Near 4	..	..	*h*	Cf. 27 Dec., 1888.
1 Feb., 1882	Gisborne and Tauranga to Canterbury	Area, 25 to 50 miles north of Cape Farewell	..	..	*i*	
18 Dec., 1883	Westport to Bluff ..	Probably 35 to 40 miles W.N.W. of Queenstown	..	..	*j*	
11 April, 1884	Hawera to Canterbury	Near 3	..	..	*k*	Cf. 1 Sept., 1888.
2 Mar., 1890	Blenheim, Wellington	56 miles from Wellington, 85 miles from Wanganui	..	..	*l*	
16 July, 1890	Wanganui, Blenheim	61 miles from Wellington, 92 miles from Wanganui	..	..	*m*	
30 Aug., 1890	Blenheim, Wellington	46 miles from Wellington, 95 miles from Wanganui	..	..	*n*	

TABLE G.—EARTHQUAKE-ORIGINS IN NEW ZEALAND—*continued*.

Date.	Where felt.	Epicentrum.	Depth.	Velocity.	Mark on Map.	Remarks.
		(4.) Doubtful.				
11 Sept., 1866	Dunedin, Clyde ..	Near Lake Manapouri or south of it	..	..	? 27	
24 Jan., 1868	Otago and Southland..	Near northern half of Lake Te Anau, west of Queenstown, or W.N.W.	..	..	? 28	
20 Nov., 1872	Otago	N.W. of Queenstown, or S.E. of Otago Peninsula; apparently two earthquakes, one secondary	..	..	? 29	
20 Sept., 1872	Hawera to Canterbury	Cook Strait, north of Picton ..	..	..	? 30	
12 June, 1873	Opunake to Nelson ..	Cook Strait, east side, between Wanganui and Wellington	..	..	? 31	
25 Sept., 1875	Nelson, Wellington, Cape Campbell	Cook Strait, north of Picton ..	..	..	? 32	
10 Dec., 1889	Woodville to Wellington	Cook Strait, 61 miles from Wellington, 43 miles from Wanganui	..	1,760ft.–1,848ft.	? 33	Epicentrum almost certainly an area about some point joining Picton and Marton; Wellington time makes it near Picton end. Cf. 15 Dec., 1889.
15 Dec., 1889	Same	Same (*or* 30 miles from Wellington, 72 miles from Wanganui)	..	1,056ft.	? 34	Cf. 10 Dec., 1889.
25 Sept., 1890	Wanganui, &c. ..	65 miles from Wellington, 33 miles from Wanganui (*or* 78 and 18 miles respectively)	..	..	? 35	

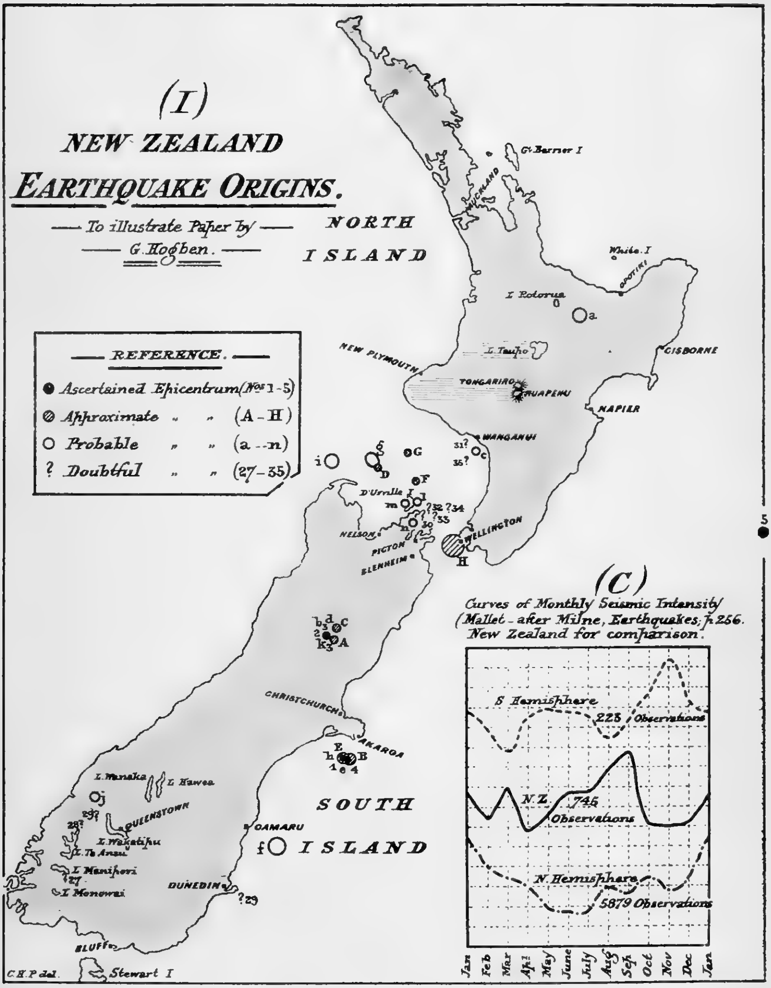
(I)
NEW ZEALAND
EARTHQUAKE ORIGINS.
To illustrate Paper by
G. Hogben.
REFERENCE.
Ascertained Epicentrum (Nos 1-5)
Approximate " " (A-H)
Probable " " (a--n)
Doubtful " " (27-35)
NORTH
ISLAND
SOUTH
ISLAND
Gt Barrier I
AUCKLAND
White I
OPOTIKI
L Rotorua
L. Taupo
NEW PLYMOUTH
TONGARIRO
RUAPEHU
GISBORNE
NAPIER
WANGANUI
D'Urville I
NELSON
PICTON
BLENHEIM
WELLINGTON
CHRISTCHURCH
AKAROA
OAMARU
DUNEDIN
BLUFF
Stewart I
L. Wanaka
L Hawea
QUEENSTOWN
L. Wakatipu
L. Te Anau
L Manipori
L Monowai
C.H.P del.
(C)
Curves of Monthly Seismic Intensity
(Mallet - after Milne, Earthquakes; p. 256.
New Zealand for comparison.
S Hemisphere
223 Observations
N.Z. 745
Observations
N. Hemisphere
5879 Observations
Jan
Feb
Mar
Apl
May
June
July
Aug
Sep
Oct
Nov
Dec
Jan

Table K.—List of Earthquakes recorded in New Zealand, 1848–90.

1848.

Oct. 16: Wellington.

Oct. 17: Wellington, Nelson, Wanganui.

Oct. 19: Wellington.

1853.

Jan. 1: Nelson.

1855.

Jan. 23–25: Wellington, Hutt, Wairarapa, New Plymouth, Nelson, Wairau River, Wainui, Otago, Christchurch.

1856.

Dec. 11: Wellington (2 shocks).

Dec. 13: Hutt Valley.

1857.

Feb. 21: Wellington.

March 18: Pourau Harbour.

March 28: Otago.

April 9: Wellington (2 shocks).

July 30: Wellington (2 shocks).

Aug. 23: Wellington.

Sept. 6: Wellington.

Sept. 27: Wellington.

Oct. 8: Wellington (2 shocks).

Dec. 27: Port Napier.

1858.

Jan. 6: Napier.

April 16: Napier.

April 18: Napier.

July 20: Napier.

Aug. 2: Napier.

Aug. 23: Napier.

1859.

July 1: Napier.

1860.

April 22: Nelson.

1862.

April 25: Wellington, Sydney (N.S.W.).

1863.

Feb. 22: Dunedin, Port Chalmers.

Feb. 23: Christchurch, Napier, Auckland, Otago, Southland, Picton, Nelson, Taranaki, Wellington.

March 23: Dunedin, Port Chalmers, Otago Lakes.

May 30: Christchurch (8 a.m.), Dunedin (10 p.m.).

1864.

May 2: Dunedin.

Dec. 17: Nelson (4 shocks).

1865.

May 27: Dunedin, Queenstown, and lake district.

July 3: Otago lakes.

Sept. 6: Christchurch.

1866.

Jan. 29: Bealey, Christchurch.

March 29: Nelson, Wellington, Picton.

May 20: Nelson, Canterbury, Christchurch.

May 21: Canterbury.

Sept. 22: Mount Edgecombe, Rangitaiki Gorge (12 shocks).

Sept. 23: Rangitaiki Gorge, Te Awa-o-te-Atua, Maketu, Rangitaiki.

Nov. 4: Hokitika.

Dec. 11: Dunedin, Clyde.

1867.

July 9: Wellington.

July 14: Oamaru.

1868.

Jan. 20: Kaiapoi, Woodend, Saltwater Creek, Leithfield.

Jan. 24: Port Chalmers, Dunedin, Green Island, Waikouaiti, Riverton, Martindale.

Jan. 29: Wellington, Wairarapa, Wanganui, Cook Strait (at sea).

Jan. 31: Kaiapoi.

Feb. 1: Picton, Christchurch, Lyttelton, Kaiapoi, Wellington, Dunedin, Bealey.

Aug. 14: Wellington (10.45 a.m. and 3.10 p.m.).

Aug. 15: Wellington (3 a.m.), Kaiapoi.

Aug. 15: Taieri, Bluff (8.9), Port Chalmers, Oamaru, White's Bay, Nelson, Wellington, Castlepoint, Napier, Lyttelton, Pigeon Bay, Le Bon's Bay, Gollan's Bay, Akaroa. (Tidal wave.)

Aug. 16: Christchurch, Wellington (11 a.m.).

Aug. 17: Wellington, Christchurch, Kaiapoi, Saltwater Creek, Hokitika, Greymouth, Featherston, Blenheim, White's Bay, Akaroa, Charleston, Nelson, Napier, Waipukurau, Castlepoint, Greytown.

Aug. 19: Wellington.

Oct. 13: Kaiapoi.

Oct. 18: Auckland, Thames, Taranaki, Christchurch, Kaiapoi, Lyttelton, Leithfield, Hokitika, Nelson, Westport, Wanganui.

Oct. 19: Nelson (6 shocks), Taranaki (4 shocks).
Oct. 20: Nelson.
Dec. 26: Lyttelton, Gollan's Bay (Banks Peninsula).

1869.

Jan. 3: Nelson, Blenheim.
Jan. 4: Nelson.
Jan. 9: Wellington.
Jan. 10: Taranaki.
Jan. 14: Bluff, Dunedin, Lawrence, Tuapeka.
Feb. 10: Southland.
Feb. 11: Christchurch, Hokitika, Kaiapoi, Rangiora, Lyttelton, Wellington, Nelson, Invercargill, Napier, Auckland.
Feb. 22: Taranaki.
Feb. 23: Taranaki.
Feb. 27: Napier.
March 4: Taranaki.
March 10: Taranaki.
March 13: Nelson.
March 15: Taranaki.
April 20: Taranaki.
May 24: Nelson.
June 1: Wellington.
June 5: Christchurch (4 shocks), Lyttelton, Ohinitahi, Halswell, Akaroa, Okain's Bay, Templeton.
June 6: Christchurch, Lyttelton, Wellington, Templeton.
June 9: Christchurch.
June 24: Dunedin, Port Chalmers, Bluff, Oamaru, Lawrence, Teviot, Alexandra, Queenstown, Balclutha, Waikouaiti, Timaru, Hokitika, Dunstan, Cromwell, Naseby, Tokomairiro, Fairfax, Taieri.
July 4: Wellington.
July 16: Taranaki.
July 23: Christchurch, Lyttelton, Opawa.
July 27: Christchurch.
Aug. 4; Christchurch, Kaiapoi, Wellington, Nelson.
Aug. 5, 6: Christchurch (several slighter shocks besides first severe shock).
Aug. 23: Christchurch.
Sept. 30: Wellington.
Oct. 11: Southland.
Oct. 17: Dunedin, Queenstown, Invercargill.
Nov. 3: Christchurch.
Nov. 28: Nelson.
Dec. 25: Cromwell, Queenstown, Bluff.

1870.

Jan. 8: Napier.
Jan. 10: Bealey.
Jan. 15: Napier.
Jan. 17: Napier.
Feb. 12: Napier.
March 17: Christchurch.
March 18: Kaiapoi.
April 4: Taranaki.
May 3: Wellington.
May 14: Hokitika.
May 21: Bealey.
May 25: Wellington.
June 13: Bealey.
June 25: Napier.
July 7: Taranaki, Wellington, Nelson.
July 8: Taranaki, Nelson.
Aug. 11: Wellington.
Aug. 22: Nelson.
Aug. 24: Bealey.
Aug. 31: Christchurch, Bealey, Hokitika, Dunedin, Kirwee, Leeston, Lyttelton, South Rakaia, Ashburton, Waimate, Timaru, Temuka, Waihi, Oamaru, Kaiapoi, Southbridge, Saltwater Creek, Bangor Station, Greymouth.
Sept. 1: Hokitika.
Sept. 29: Taranaki.
Sept. 30: Wellington.
Oct. 2: Hokitika.
Oct. 3: Taranaki, Wellington, Nelson, New Plymouth.
Nov. 2: Napier.
Nov. 10: Wellington.
Nov. 19: Wellington, Nelson.
Nov. 29: Taranaki.
Dec. 18: Wellington, Nelson.
Dec. 19: Hokitika.

1871.

Jan. 1: Havelock, Picton, White's Bay, Nelson, Hokitika.
Jan. 8: Greymouth.
Jan. 20: Wellington.
Jan. 30: Wellington.
Feb. 14: Taranaki.
March 13: Napier.
March 16: Wellington.
March 19: Bealey.
March 28: Christchurch.
April 19: Waikato, Napier, Queenstown, Clyde, Cromwell ,Dunedin, Southland, Longbeach, Bluff, Timaru, Waitahuna.
April 20: Hokitika, Dunedin, Southland.
June 4: Bay of Plenty.
June 5: Bay of Plenty.

June 22 : Bealey.
June 28 : Wellington.
July 25 : Taupo, Napier.
Aug. 1 : Cromwell.
Aug. 15 : Te Teko.
Aug. 16 : Te Teko, Tauranga.
Aug. 27 : Lyttelton, Christchurch.
Aug. 28 : Mount Grey, Rangiora.
Aug. 30 : Christchurch.
Aug. 31 : Wellington, White's Bay, Kaikoura, Cheviot, Kaiapoi, Rangiora, Christchurch, Little River (2 shocks).
Sept. 1 : Hokitika, Cheviot Hills, Rangiora.
Sept. 26 : Wanganui, Foxton, Wellington, White's Bay, Napier.
Oct. 1 : Wellington.
Nov. 10 : Wellington, Christchurch.
Nov. 23 : Wanganui, Foxton, Masterton.
Nov. 25 : Patea, Wanganui, Foxton, Otaki, Featherston, Hutt, Wellington, Picton, Blenheim, White's Bay.
Nov. 26 : Nelson.
Dec. 4 : Wellington.
Dec. 5 : Featherston, Queenstown.

1872.

Jan. 15 : Tauranga, Maketu.
Jan. 24 : Timaru, Christchurch.
Jan. 26 : Timaru.
Feb. 9 : Queenstown.
Feb. 10 : Farewell Spit.
Feb. 14 : Wanganui.
Feb. 15 : Cheviot.
March 3 : Wellington.
March 6 : Queenstown.
March 14 : Napier.
April 10 : Wellington.
June 5 : Taupo.
June 6 : Taupo.
June 7 : Tarawera.
June 11 : Nelson.
June 18 : Tarawera, Napier.
July 2 : Wanganui, Foxton, Bull's, Greytown, Wellington.
July 29 : Queenstown.
Aug. 2 : Waipukurau, Foxton.
Aug. 4 : Wellington.
Sept. 5 : Patea.
Sept. 6 : Queenstown.
Sept. 10 : Wanganui.
Sept. 20 : Patea, Hawera, Wanganui, Foxton, Bull's, Hutt, Wellington, White's Bay, Nelson, Kaiapoi, Rangiora.
Sept. 24 : Wellington.
Oct. 4 : Foxton.
Oct. 10 : Wanganui.
Oct. 14 : Wellington, Nelson, Blenheim.
Oct. 29 : Christchurch.
Nov. 1 : Wellington.
Nov. 20 : Dunedin, Taiaroa Head, Port Chalmers, East Taieri.
Dec. 1 : Greytown.
Dec. 13 : Wellington.
Dec. 16 : Bluff.
Dec. 26 : Taranaki, Blenheim, Nelson, Wellington.

1873.

Jan. 4 : Hokitika.
Jan. 6 : Wanganui.
Jan. 26 : Timaru, Nelson.
Jan. 31 : Queenstown.
Feb. 10 : Wanganui, Foxton, Marton.
March 13 : Wanganui.
March 16 : Wanganui, Mana Island.
March 17 : Wellington.
March 18 : Wellington.
March 23 : Wanganui.
March 24 : Nelson.
March 27 : Wellington, Greytown.
March 31 : Wanganui.
April 1 : Wellington, Nelson, Kaiapoi, Mana Island.
April 5 : Wanganui.
April 14 : Wellington.
April 17 : Wellington, Mana Island.
May 17 : Wanganui.
May 19 : Wanganui.
June 4 : Napier.
June 8 : Wanganui.
June 12 : Opunake, Patea, Hawera, Wanganui, Wellington, Mana Island, White's Bay, Nelson, Foxton, Hawera.
June 13 : Wanganui.
June 18 : Wanganui, Foxton, Marton.
June 22 : Wanganui.
June 29 : Wanganui, Foxton.
July 5 : Taranaki.
Aug. 24 : Bealey.
Aug. 29 : Wanganui, Foxton, Wellington, White's Bay, Nelson, Christchurch.
Sept. 11 : Wanganui.
Sept. 18 : Tarawera.
Sept. 21 : Wanganui.
Oct. 1 : Wellington.

Oct. 18: Opunake, Wanganui, Nelson.
Oct. 23: Akaroa.
Nov. 2: Wellington, Havelock.
Nov. 14: Havelock.
Dec. 1: Taranaki.
Dec. 6: Taranaki.
Dec. 8: Taranaki, Patea, Hawera, Wanganui, Wellington, Nelson, Mana Island.
Dec. 16: Hawera, Wanganui, Foxton, Bull's, Wellington.
Dec. 29: Mana Island.

1874.

Jan. 21: Tauranga.
Jan. 23: Tauranga.
Jan. 24: Tauranga.
Jan. 28: Lyttelton.
Jan. 29: Napier.
Feb. 1: Dunedin, Queenstown.
Feb. 2: Riverton, Bluff.
Feb. 4: Dunedin.
Feb. 8: Riverton.
Feb. 28: Tauranga.
March 1: Wellington, Masterton.
March 7: Tarawera.
March 9: Taranaki, Patea, Wanganui, Foxton.
March 11: Foxton.
March 17: Wellington.
March 25: Christchurch, Lyttelton, Akaroa, Rakaia, Selwyn, Irwell, Dunsandel.
June 6: Christchurch, Lyttelton.
June 9: Rotorua.
June 20: Dunedin, Riverton, Bluff.
July 4: Opunake.
July 28: Opunake, Wanganui.
Aug. 3: Napier, Wairoa.
Aug. 4: Napier, Akitio.
Aug. 5: Wellington.
Aug. 6: Akitio.
Aug. 9: Masterton.
Aug. 15: Wellington.
Aug. 18: Wanganui.
Sept. 14: Taranaki.
Oct. 18: Queenstown.
Oct. 28: Auckland.
Nov. 14: Napier.
Nov. 27: Cape Campbell.
Dec. 1: Christchurch.
Dec. 15: Opunake.

1875.

Jan. 4: Wellington.
Jan. 18: Napier.
March 7: Napier, Wanganui, Foxton, Wellington, Nelson, Christchurch.
March 13: Wellington.
April 14: Opotiki, Maketu.
April 17: Wairoa.
April 19: Wellington.
April 25: Wanganui.
May 12: Wellington.
May 24: Wellington, Blenheim.
July 4: Wanganui.
July 23: Queenstown, Riverton, Invercargill, Wallacetown.
Aug. 20: Foxton.
Aug. 25: Wellington.
Sept. 5: Napier, Queenstown, Wellington.
Sept. 18: Nelson.
Sept. 20: Cape Campbell.
Sept. 21: Havelock.
Sept. 22: Cape Campbell.
Sept. 25: Wellington, Nelson, Havelock, Cape Campbell, Blenheim.
Sept. 28: Wellington, Havelock, Cape Campbell, Blenheim.
Dec. 13: Queenstown.
Dec. 15: Queenstown.

1876.

Jan. 10: Hokitika.
Jan. 13: Napier, Wanganui.
Feb. 25: Queenstown.
Feb. 26: Oamaru, Port Chalmers, Naseby, Waimate, Queenstown, Dunedin, Timaru, Akaroa, Waiareka, Hampden, Kakanui, Cave Valley, Totara.
Feb. 27: Dunedin, Timaru, Oamaru, Maheno.
Feb. 28: Oamaru.
Feb. 29: Wellington, Oamaru, Totara (2 shocks).
March 7: Wanganui.
March 9: Oamaru.
March 10: Oamaru.
March 26: Nelson.
March 27: Taranaki.
April 10: Timaru, Oamaru, Port Chalmers, Naseby, Queenstown, Dunedin, Palmerston.
April 11: Oamaru, St. Bathans, Port Chalmers, Naseby, Waimate, Queenstown, Waikouaiti, Dunedin, Palmerston.
April 13: Wanganui.
May 3: Foxton, Invercargill, Bluff.
May 5: Wanganui, Wellington.
May 6: Lyttelton.
May 14: Queenstown.
May 20: Oamaru, Port Chalmers.
May 26: Taranaki.

May 31: Wellington, Oamaru.
June 28: Wellington.
July 19: Taranaki, Wairoa, Porangahau, Tarawera, Napier, Patea, Waipawa, Wanganui, Foxton, Greytown, Upper Hutt, Wellington, Havelock, Blenheim, Hokitika, Christchurch, Lyttelton, Marton, Westport, Greymouth, Featherston, Castlepoint, Gisborne, Opunake, Taupo, Kaikoura.
July 20: Tarawera, Napier.
Aug. 7: Wellington.
Aug. 14: Bealey.
Sept. 3: Wellington (3 shocks).
Sept. 13: Wellington (3 shocks).
Sept. 23: Taranaki.
Sept. 25: Wellington (3 shocks).
Sept. 28; Napier, Havelock.
Oct. 24: Queenstown.
Nov. 21: Queenstown.
Dec. 7: Napier, Wanganui.

1877.

Jan. 10: Wellington.
Feb. 2: Lyttelton.
Feb. 5: Manawatu.
Feb. 7: Wanganui.
Feb. 9: Wellington.
Feb. 10: Wellington.
April 13: Upper Shotover.
May 2: Queenstown.
May 8: Taranaki.
July 4: Wellington, Nelson, Westport.
July 11: Wellington, Nelson, Westport.
July 16: Wellington.
July 23: Taupo.
Aug. 11: Wanganui, Wellington.
Aug. 14: Queenstown.
Sept. 15: Wellington.
Sept. 16: Rakaia.
Sept. 22: Foxton, Wellington, Blenheim, Picton, Havelock.
Sept. 25: Napier.
Sept. 29: Wellington.
Oct. 1: Port Chalmers.
Oct. 9: Port Chalmers, Kaitangata, Timaru, Waimate, Wellington, Nelson, Dunedin, Roxburgh, Lawrence, Balclutha, Palmerston South, Oamaru, Naseby.
Oct. 10: Wellington, Timaru, Waimate.
Oct. 25: Napier, Wairoa.
Nov. 6: Wellington.
Nov. 7: Wellington.
Nov. 21: Kaiapoi, Rangiora.
Dec. 8: Taupo.

1878.

Jan. 15: Queenstown.
Feb. 12: Queenstown.
March 11: Hokitika.
April 4: Wanganui.
April 11: Cape Campbell, Blenheim.
April 25: Queenstown.
April 28: Wellington.
June 3: Cape Campbell.
June 5: Napier.
June 23: Napier, Wanganui, Wellington.
June 24: Nelson.
July 5: Foxton, Greytown, Wellington.
July 20: Wanganui, Wellington.
July 21: Wanganui.
July 29: Hokitika.
Aug. 8: Taranaki, Wanganui, Wellington.
Aug. 23: Queenstown.
Aug. 24: Lawrence, Arrow, Queenstown.
Aug. 25: Wallacetown.
Sept. 14: Lyttelton, Rangiora, Waiau, Hurunui, Wellington, Cape Campbell, Kaikoura, Nelson, Westport, Lyttelton, Christchurch.
Sept. 30: Rangiora.
Oct. 21: Westport, Greymouth, Wanganui, Wellington, Cape Campbell, Nelson, Hokitika, Christchurch, Queenstown.
Oct. 27: Cape Campbell.
Nov. 8: Queenstown.
Nov. 14: Queenstown.
Nov. 27: Queenstown.
Dec. 6: Wellington.
Dec. 7: Wellington.
Dec. 12: Wellington.

1879.

Jan. 5: Wanganui, Wellington.
Jan. 12: Wanganui, Wellington.
Jan. 16: Napier.
March 4: Cape Campbell.
April 20: Queenstown.
April 24: Wellington.
May 3: Wellington, Cape Campbell.
May 9: Waitangi (Chatham Islands).
May 25: Wellington.
July 9: Queenstown.
July 21: Wanganui.
July 22: Christchurch.
July 27: Wellington.
Aug. 5: Wellington.
Aug. 8: Wellington.

Aug. 18: Wellington.
Sept. 17: Taranaki.
Sept. 23: Bealey.
Oct. 30: Napier, Palmerston North, Foxton, Wellington, Cape Campbell.
Nov. 17: Taranaki, Wellington, Christchurch, Rangiora.
Nov. 19: New Plymouth.
Nov. 25: Queenstown.

1880.

Jan. 9: Queenstown.
Feb. 10: Napier.
Feb. 22: Hokitika.
March 4: Queenstown.
March 5: Queenstown, Dunedin.
March 6: Christchurch, Rangiora, Timaru, Hokitika, Oamaru, Dunedin, Invercargill.
March 10: Wanganui.
March 11: Wanganui.
April 17: Wanganui.
April 24: Wellington.
April 29: Queenstown.
May 4: Queenstown.
May 9: Wanganui.
May 27: Queenstown.
June 8: Queenstown.
July 4: Wanganui.
July 12: Hokitika.
July 28: New Plymouth, Napier, Waipawa, Porangahau, Turakina, Wanganui, Wellington, Palmerston North, Foxton, Bull's, Nelson, Hawera.
July 31: Gisborne.
Aug. 4: Wellington, Blenheim.
Nov. 27: Wanganui, Nelson.

1881.

Jan. 3: Wellington.
April 8: Castle Hill (Canterbury).
May 6: Castle Hill.
May 14: Castle Hill.
May 22: Nelson.
May 23: Nelson.
May 24: Nelson.
May 27: Lincoln.
May 29: Lincoln.
June 26: Both Islands.
June 27: Both Islands.
June 29: Both Islands.
July 6: Wellington.
July 12: Wellington.
Aug. 8: Wellington.
Sept. 1: Wellington.
Sept. 14: Wellington.
Sept. 15: Wellington.
Dec. 3: Wellington.
Dec. 5: Lincoln, Dunedin, Christchurch, Lyttelton, Rangiora, Waikuku, Saltwater Creek, Cust, Oxford, Prebbleton, Leeston, Sheffield, Kowai Pass, Ashburton, Lyell, Waiau, Westport, Greymouth, Kumara, Hokitika, Timaru, Dunedin, Hurunui, Rakaia, Kaiapoi, Ahaura, Akaroa.
Dec. 6: Lincoln, Christchurch.
Dec. 9: Lincoln, Christchurch.
Dec. 23: Wellington.
Dec. 31: Wellington.

1882.

Jan. 7: Christchurch.
Jan. 9: Wellington.
Jan. 10: Christchurch.
Jan. 17: Christchurch.
Feb. 1: Nelson, Collingwood, Tauranga, Gisborne, Napier, Hawera, Marton, Motueka, Lyttelton, Kaiapoi, Carterton, Wellington, Nelson, Christchurch, Ashburton, Rangiora, Oxford, Hurunui, Lincoln, Hokitika, Greymouth.
Feb. 20: Wellington.
Feb. 21: Wellington.
March 22: Christchurch, Lincoln.
March 24: Napier.
April 4: Queenstown.
April 6: Hawera, Opunake, Wanganui, Wellington, Normanby, Nelson, Blenheim, Christchurch, Lincoln.
April 16: Wellington.
May 5: Dunedin.
May 14: Wellington.
May 15: Wellington, Blenheim.
June 6: Wellington.
June 11: Wellington.
July 15: Oamaru.
July 20: Kumara.
July 24: Patea, Wanganui, Wellington.
July 25: Wellington.
July 26: Wanganui.
Aug. 20: Rangiora.
Aug. 31: Seafield.
Sept. 25: Springfield.
Oct. 20: Carterton, Wellington, Dunedin.
Oct. 25: Gisborne, Napier.
Nov. 18: Wellington.
Nov. 25: Wellington.

1883.

Feb. 5: Wellington, Kaikoura.
Feb. 14: Wellington.

Feb. 22: Greymouth.
Feb. 24: Taupo.
Feb. 25: Taupo.
June 24: Kaikoura, Christchurch.
July 4: Wellington.
July 5: Wellington.
July 9: Wellington.
Aug. 15: Gisborne.
Aug. 29: Patea.
Sept. 26: Blenheim.
Sept. 27: Wellington.
Dec. 8: Wellington.
Dec. 18: Hokitika, Westport, Timaru, Balclutha, Dunedin, Greymouth, Queenstown, Invercargill, Bluff, Waimate, Christchurch.
Dec. 19: Timaru.
Dec. 24: Wanganui.

1884.

Jan. 7: Taupo, Wanganui.
Jan. 19: Christchurch.
Jan. 30: Wellington.
Feb. 2: Christchurch.
Feb. 6: Wellington.
Feb. 8: Gisborne.
March 19: Taupo.
March 20: Taupo.
March 21: Taupo.
April 11: Hawera, Feilding, Patea, Masterton, Wellington, Blenheim, Nelson, Christchurch, Lincoln, Westport, Greymouth, Lyell, Rangiora, Sefton, Lyttelton, Kaiapoi, Balcairn.
April 16: Wellington, Blenheim.
April 25: Wellington, Blenheim.
May 1: Wellington.
May 8: Wellington.
June 2: Blenheim.
June 5: Wellington, Greytown.
July 31: Greymouth.
Aug. 20: Invercargill, Bluff.
Sept. 22: Wellington.
Sept. 24: Napier.
Oct. 6: Wanganui.
Oct. 8: Kaikoura, Christchurch.
Oct. 10: Christchurch.
Dec. 24: Kaikoura.
Dec. 31: Woodville, Palmerston, Wellington.

1885.

Jan. 5: Woodville, Wanganui, Wellington, Blenheim, Nelson, Christchurch, Sefton, Napier.
Feb. 19: Wellington.
Feb. 25: Westport, Kumara, Hokitika.
Feb. 27: Oamaru.
March 20: Hawera.
May 9: Foxton.
June 20: Ross.
July 18: Wellington.
July 26: Feilding, Patea, Wellington, Blenheim, Christchurch, Ashburton, Lincoln, Westport, Greymouth, Hokitika, Kaiapoi, Sefton, Prebbleton, Little River, West Melton.
Aug. 5: Foxton, Wellington.
Sept. 27: Ashburton, Timaru.
Oct. 11: Blenheim.
Dec. 13: Wellington.
Dec. 26: Oamaru.

1886.

Jan. 26: Rotorua.
Feb. 7: Gisborne.
March 30: Rotorua.
April 19: Wellington.
April 22: Rotorua.
April 28: Rotorua.
April 30: Rotorua.
May 16: Wellington.
June 10–24: Rotorua (Tarawera eruption).
June 23: Christchurch, Dunedin, Invercargill.
June 29: Wellington.
July 2: Dunedin.
July 7–14: Rotorua.
July 12: Wellington, Blenheim.
Aug. 27: Rangitikei.
Aug. 29: Rotorua.
Aug. 30: Otaki.
Sept. 1: Gisborne.
Sept. 3: Wellington, Hawera, Kaikoura, Nelson, Blenheim, Christchurch, Westport, Greymouth, Kaiapoi, Lyttelton, Akaroa, Patea.
Sept. 5: Kaikoura.
Sept. 7: Wellington, Kaikoura, Nelson, Blenheim.
Sept. 20: Rotorua.
Sept. 26: Kaikoura.
Sept. 27: Kaikoura.
Oct. 11: Wellington.
Oct. 13: Wellington.
Oct. 25: Rotorua.
Oct. 28: Taupo.
Nov. 5: Rotorua.
Nov. 10: Wellington.
Nov. 14: Wellington.
Nov. 17: Rotorua.
Nov. 26: Wellington, Feilding, Greytown, Masterton, Carterton, Wanganui, Upper Hutt.
Nov. 28: Rotorua.
Nov. 29: Rotorua.

1887.

Jan. 16: Wellington.
Jan. 31: Wellington.
March 12: Napier, Wellington.
March 15: Wellington, New Plymouth.
March 28: Rotorua.
March 29: Rotorua.
May 13: Kaitoke, Wellington.
May 22: Wellington.
June 11: Wellington.
June 21: Rotorua.
June 27: Wellington.
Aug. 5: Waipukurau.
Aug. 9: Christchurch, Culverden, Amberley, Rangiora, Waiau.
Aug. 13: Wellington.
Oct. 6: Wellington.
Nov. 11: Wellington.
Nov. 13: Rotorua.
Dec. 18: Rotorua, Masterton.

1888.

Jan. 18: Greymouth, Westport.
Jan. 19: Lincoln, Kaiapoi.
Feb. 14: Rangiora.
Feb. 17: Wellington.
March 23: Feilding, Wanganui.
March 31: Wellington.
April 3: Wellington.
April 21: Wellington.
May 3: Wellington.
May 4: Wellington.
May 21: New Plymouth, Blenheim, Nelson, Christchurch.
May 29: Rotorua.
May 31: Rotorua.
Aug. 1: Greymouth.
Aug. 2: Greymouth.
Aug. 9: Waikari.
Aug. 16: Wellington.
Aug. 17: Wellington.
Aug. 30: Greymouth, Westport, Hokitika, Lincoln, Christchurch, Kaiapoi, Rangiora, Springfield, Amberley, West Oxford, Waikari.
Aug. 31: Wellington.
Sept. 1: Wellington, Kaikoura, Greymouth, Westport, Hokitika, Timaru, Christchurch (two shocks), Waikari, Dunedin, Boatman's, Reefton (daily, nine days, several shocks), Hanmer Plains (continual shocks), New Plymouth, Manaia, Wanganui, Feilding, Masterton, Nelson, Havelock, Blenheim, Rangiora, Lyttelton, Akaroa, Selwyn, Lauriston, Ashburton, Leeston, Kirwee, Bealey, Fairlie Creek, Lyell, Notown, Queenstown, Dunedin, Invercargill, Glentunnel, Amberley, Kaiapoi, Culverden, Waiau.
Sept. 2: Christchurch, Reefton, Wellington.
Sept. 3: Christchurch, Reefton, Hanmer Plains.
Sept. 5: Wellington, Reefton, Hanmer Plains.
Sept. 6: Christchurch, Reefton, Hanmer Plains.
Sept. 9: Christchurch, Reefton, Hanmer Plains, Greymouth, Westport, Hokitika, Waikari.
Sept. 15; Stewart Island.
Sept. 20: Wellington.
Sept. 28: Christchurch, West Coast (South Island).
Oct. 12: Taupo, Woodville, Masterton, Wellington, Lincoln, Christchurch, West Coast (South Island).
Oct. 17: Rotorua.
Oct. 23: Taupo, Patea, Napier, Marton, Woodville, Hawera, Masterton, Wellington, Castlepoint, Wanganui, Blenheim, Nelson, Palmerston North, Manaia, Havelock, Kaikoura, Greymouth, Westport, Hokitika, Timaru, Lincoln, Christchurch.
Oct. 26: Wellington.
Oct. 28: Christchurch, Hanmer Plains, West Coast (South Island).
Nov. 13: Christchurch, Hanmer Plains, West Coast (South Island).
Nov. 23: Dunedin.
Dec. 8: Wellington.
Dec. 27: Lincoln, Christchurch, Dunedin, South Malvern, Sheffield, Akaroa, Dunsandel, Ashburton, Greymouth.

1889.

March 6: Woodville, Masterton, Feilding, Palmerston North.
April 19: Rotorua, Wellington.
May 13: Wellington.
May 27: Napier, Woodville, Wellington, Waipawa, Feilding, Palmerston North.
June 12: Woodville, Masterton, Castlepoint, Feilding.
June 24: Gisborne.
July 20: Rotorua.
July 21: Rotorua.
July 22: Rotorua.
July 23: Rotorua.
July 25: Rotorua.
Aug. 13: Rotorua.
Sept. 19: Wellington.
Nov. 29: Wellington.

Dec. 1: Wanganui.
Dec. 3: Bull's.
Dec. 10: Woodville, Masterton, Wellington, Feilding, Bull's, Foxton, Wanganui.
Dec. 15: Feilding, Masterton, Wanganui, Foxton.
Dec. 20: Feilding, Marton.

1890.

Jan. 26: Oamaru (9.50 p.m.), Rotorua (5.54 p.m., 7.22 p.m.).
Jan. 27: Rotorua (6 a.m., 8.20 p.m.).
Jan. 29: Wanganui.
Jan. 30: Rotorua.
Feb. 20: Blenheim, Wanganui, Wellington.
March 2: Blenheim, Wellington.
March 7: Blenheim, Bull's, Wanganui, Napier, Feilding, Taupo, Wellington, Tauranga, Gisborne.
March 15: Wanganui.
March 30: Cromwell, Queenstown (7.40 p.m., 10.50 p.m.).
March 31: Queenstown.
April 7: Bealey.
April 10: Wellington.
May 1: Queenstown.
May 5: Bealey.
May 6: Napier.
June 24: Bull's, Wanganui.
June 27: Riverton.
July 6: Blenheim, Rotorua.
July 16: Wanganui, Blenheim, Feilding.
Aug. 15: Wanganui, Blenheim, Feilding, Wellington, Bull's.
Aug. 16: Bealey.
Aug. 17: Timaru.
Aug. 30: Blenheim (3.23 a.m., 3.45 a.m.), Wellington.
Sept. 16–17: Wanganui (midnight).
Sept. 24: Wanganui.
Sept. 25: Bull's, Wanganui (3), Feilding.
Sept. 29: Westport.
Oct. 3: Wanganui.
Oct. 4: Rotorua (1.55 a.m., 4.33 p.m.), Wanganui (4 a.m.).
Oct. 5: Wanganui (2 shocks).
Nov. 11: Napier, Wanganui.
Nov. 12: Grahamstown, Coromandel (2 shocks, 5.11 p.m. and 5.22 p.m.), Thames, Auckland, Paeroa, Hikutaia, Thames (7 a.m.).
Nov. 13: Coromandel (7.15 a.m.).
Nov. 20: Gisborne.
Nov. 23: Rotorua.
Nov. 27: Wanganui.
Dec. 23: Wellington, Wanganui.

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2. *The "Elastic Medium" Method of treating Electrostatic Theorems.*

By Professor W. H. Bragg, M.A., Royal Society of South Australia.

It is usual to deduce the ordinary theorems of electrostatics from the law that two amounts of electricity repel one another with a force proportional directly to the product of these amounts and inversely to the square of the distance between them. Faraday pointed out that the results so deduced, and confirmed by experiment, could be explained by assuming the existence of an elastic medium, the straining of which was electrification, and the consequent stress electrical force. The elastic constant of such a medium Maxwell proposed to call the "coefficient of electric elasticity." Dr. Lodge has used the idea with the best of results in his book on "Modern Views of Electricity."

The reading of Dr. Lodge's book suggested to me the working-out of the results contained in this paper.

The object of the paper is to draw attention to the advantages that are to be derived, especially by the student, from taking as hypothesis, not, as is usual, the law of the inverse square, but the existence of this elastic medium. The hypothesis may not be exactly true, but it is as nearly true, and in the same manner true, as that a wave of sound may be represented by a wavy line. We have as much right to deduce theorems of electrostatics from consideration of the behaviour of this medium under stress, as to deduce the law of interference of sound from the summation of waves upon a diagram. In both cases the whole truth is not presented, but sufficient to insure the accuracy of the deduction.

Suppose, then, with Dr. Lodge, the existence of an incompressible perfect fluid filling all space and all bodies. Suppose that in some bodies—silver, copper, and conductors generally —the fluid finds exceedingly little opposition to motion, but that in others—air, glass, silk, and insulators generally—the particles of the body are so entangled or embedded in the fluid that the fluid cannot move without carrying along the particles with it, and that whenever displacement of the body takes place there is called into play a force of restitution proportional to the displacement, to the amount of the moved particles, and to a quantity depending on the nature of the body. This last quantity is Maxwell's coefficient of electric elasticity.

In making these suppositions we are not laying upon that maid-of-all-work the æther any burden other than those she has for other purposes been already taught to bear.

Further, suppose that a charge of positive electricity is really an increase of the amount of fluid—æther—contained by a body, a negative charge the reverse of this.

If we make these suppositions it is easy to show that phenomena must occur similar to those ordinarily ascribed to the attractions and repulsions of electrified particles.

1. Since the æther is incompressible and fills all space, if æther be pumped into one of the first class of bodies (conductors), it must, as Dr. Lodge points out, be drawn from somewhere else, and, since it cannot be got out of bodies of the second class (dielectrics), it must be drawn from bodies of the first class. In other words, if the dielectric surrounding some conductor be pushed back to any extent, it will encroach to an exactly equal extent on some other conductor or conductors. In ordinary language, if any electrical charge be imparted to a conductor, an equal and opposite charge will be induced on some other conductor or conductors.

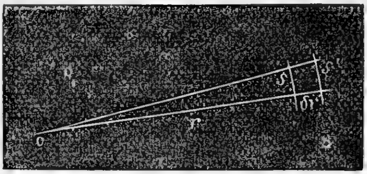
2. Let us consider the strain phenomena resulting from the simplest case of "charging," *i.e.*, pumping in or drawing out

æther from a spherical conductor, the conductor being far from all other conductors. The strain is obviously symmetrical.

Let Q = amount of charge, a the radius of the conductor. Then, all round the conductor the medium is pushed back a distance $\frac{Q}{4\pi a^2}$; and at a distance r from the centre of the sphere the displacement is $\frac{Q}{4\pi r^2}$.

Suppose that, when a unit volume of the medium is displaced a distance x, the force called into play is Ex.

Draw a cone of very small angle from o, the centre of the sphere. Let it intercept on the surface of radius r an area s, and on that of radius $r+\delta r$ an area s'. The angle of the cone being exceedingly small, s may be considered equal to s'. The volume included by the cone and the two surfaces $= s\delta r$.



Hence the force of restitution due to the displacement of this amount of matter through a distance $\frac{Q}{4\pi r^2}$

$$= \mathrm{E}\,.\,s\delta r\,.\,\frac{Q}{4\pi r^2},$$

E being the elastic constant.

If, now, p be the pressure at a distance r from o, and $p+\delta p$ the pressure at a distance $r+\delta r$, we have at once

$$-\delta p\,.\,s = \frac{\mathrm{E}\delta r\,.\,\mathrm{Q}\,.\,s}{4\pi r^2}$$

$$-\frac{dp}{dr} = \frac{\mathrm{EQ}}{4\pi r^2}$$

$$\text{Or } p = \frac{\mathrm{EQ}}{4\pi r} + \text{constant}.$$

The constant must = 0, since p must vanish at ∞.

$$\therefore p = \frac{\mathrm{EQ}}{4\pi r}.$$

3. If we consider the case of a "charge" imparted to a conductor of any shape whatever, it will not be ordinarily possible by this method to determine the actual state of any part of the dielectric; neither is it possible by the other method. But, just as in the ordinary case lines of force and equipotential surfaces may be drawn, so here we may learn a great deal by drawing lines of displacement and surfaces of equal pressure.

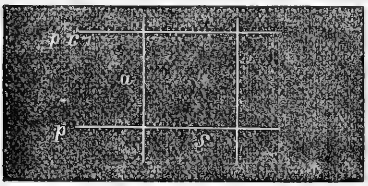
It is obvious that these lines and surfaces are always at right angles the one to the other, for, in whatever direction there is displacement, in that direction pressure must be changing.

Also, if a number of lines of displacement be taken so as to form a tube, there will be no displacement across the walls of the tube: so, if S be the area of any section, and x the average displacement across it, $Sx =$ a constant, the tube being small.

Such a tube can only, of course, proceed from a place where the dielectric is pushed back from the conductor to a place where it is drawn in; and if $Q =$ charge at one end of the tube, $-Q =$ charge at the other end.

Suppose that the strain of the dielectric due to the charges on any system of conductors is *mapped out* by drawing surfaces of equal pressure in such a way that the pressure on any one differs by unity from the pressure on either of the adjacent surfaces, and by drawing tubes of displacement, so as to fill all space, and each of such size that the flux $(S \cdot x)$ along it is unity.

The dielectric is then divided into cells, each of which can be shown to contain half a unit of energy.



For consider the cell in the figure.* Let $a =$ distance between two consecutive surfaces of equal pressure, s area of section of the surface p by the tube.

Now, if a unit volume be displaced a distance x, the force of restitution is $\mathrm{E}x$, and the energy of displacement $= \frac{1}{2} \cdot \mathrm{E}x^2$.

So, if $x =$ displacement across s,

$$\text{Energy} = \tfrac{1}{2} \cdot \mathrm{E}x^2 \cdot a \cdot s.$$

But $(p+1)s - ps = \mathrm{E}xas$,

$$\text{Or } \mathrm{E}xa = 1.$$

Also, the tube is a unit tube;

$$\therefore xs = 1;$$

$\therefore$ Energy in the cell $= \frac{1}{2}$.

As long as the cell is of finite size this reasoning is incorrect, though the result is true; but, obviously, whatever the size of the cell, it may be divided into a very large number of equal small cells, say, a million. Then each of these contains one two-millionth of a unit of energy.

Hence, in any particular case, if we can count the cells, we can find the energy of the system. Now, if a system of conductors contain charges Q_1, Q_2, Q_3, and so on, they will

* In the figure, for $px1$, read $p+1$.

respectively contribute Q_1, Q_2, Q_3 unit-tubes; and if a conductor be at pressure V (every part of a conductor must be at the same pressure, of course, as the æther in it is weightless and under no molecular forces), each tube that leaves the conductor must meet V surfaces of equal pressure before it comes to a region of no pressure at all.

So the total number of cells is $\Sigma Q . V$; and energy of system $= \frac{1}{2} \Sigma Q . V$.

4. As a particular case, consider the energy of strain of a charge Q on a sphere of radius a.

The pressure at the surface $= \frac{E}{4\pi} \cdot \frac{Q}{a}$ ... (§ 2.)

$$\therefore \text{Energy} = \tfrac{1}{2} \cdot \frac{E}{4\pi} \cdot \frac{Q^2}{a}.$$

Also the energy of strain of the medium between a sphere of radius a and a concentric conductor of radius a' is, for similar reasons,

$$\tfrac{1}{2} \cdot \frac{E}{4\pi} \left\{ \frac{Q^2}{a} - \frac{Q^2}{a'} \right\} \quad \ldots \quad \ldots \quad (\S\ 2.)$$

5. Next consider the strain due to charges Q_1 and Q_2 on two spheres of radii r_1 and r_2 placed at a distance b from each other, b being large compared with r_1 and r_2.

The pressure at any point is the sum of the pressures due to the two charges. Thus the pressure at a point on the surface of the 1st sphere is very nearly $\frac{E}{4\pi}\left\{\frac{Q_1}{r_1} + \frac{Q_2}{b}\right\}$, for r_1 is so small compared with b that $\frac{1}{r_1 + b}$ may be taken as equal to $\frac{1}{b}$.

Similarly the pressure at any point on the second sphere is $\frac{E}{4\pi}\left\{\frac{Q_1}{b} + \frac{Q_2}{r_2}\right\}$.

Hence, by end of § 3,

Energy of strain of medium

$$= \tfrac{1}{2} \cdot \frac{EQ_1}{4\pi} \cdot \left\{\frac{Q_1}{r_1} + \frac{Q_2}{b}\right\} + \tfrac{1}{2} \cdot \frac{EQ_2}{4\pi} \cdot \left\{\frac{Q_1}{b} + \frac{Q_2}{r_2}\right\}.$$

$$= \tfrac{1}{2} \cdot \frac{E}{4\pi} \left\{\frac{Q_1^2}{r_1} + \frac{2Q_1 \cdot Q_2}{b} + \frac{Q_2^2}{r_2}\right\}.$$

Thus the energy depends upon b—*i.e.*, the distance apart of the two spheres. The force of separation may be obtained by differentiating the expression for the energy with respect to b. This gives—

Force of repulsion

$$= \frac{E}{4\pi} \cdot \frac{Q_1 Q_2}{b^2}. \text{ (The law of the inverse square.)}$$

From this and the foregoing results it is evident that $\frac{E}{4\pi}$ is $\frac{1}{K}$ —*i.e.*, the reciprocal of the specific inductive capacity of the medium.

It is worth noticing that it is only when the radius of each sphere is small compared to the distance apart of the two spheres that the law of the inverse square holds.

6. It is not, perhaps, at once evident what corresponds in this "elastic medium" theory to the "force at any point due to the attraction of an electrical system," and in particular to the law that just outside a conductor the attractive force $= 4\pi\rho$, or, more strictly, $\frac{4\pi\rho}{K}$.

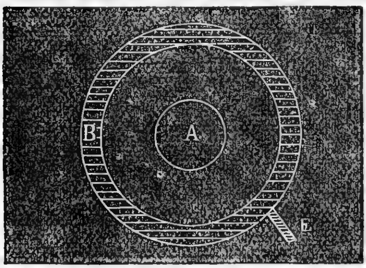
But it must be remembered that these "forces" are only mathematical quantities, and have no real existence. The "force at any point due to the attraction of an electrical system" is the attraction on a unit of electricity *supposing the presence of that unit not to disturb the pre-existing distribution of electricity*—an impossible condition.

Instead of the law that just outside a conductor the force $= \frac{4\pi\rho}{K}$, we have the simple and obvious fact that, if x be the distance the dielectric is pushed back, there is a force of restitution per unit volume equal to Ex.

And the "force at any point" corresponds to the actual force of restitution per unit volume due to the strain existing at that point.

Or, more simply, force $= E \times$ displacement.

7. The conception of the action of a condenser, and the mathematical theory of it, become very simple.



A and B are two concentric spherical conductors, enclosing a shell of dielectric between them. B is in communication with the earth.

A quantity Q of æther being pumped into A, the dielectric round it is pushed back and encroaches on B, also to an amount Q. But the excess of æther in B runs away; so the dielectric outside B is not strained, and the whole of the strain takes place between A and B. Thus the energy of the system (see § 4)

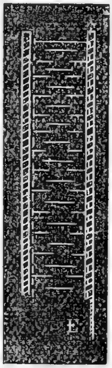
$$= \frac{EQ^2}{8\pi} \left\{ \frac{1}{a} - \frac{1}{a'} \right\},$$

a and a' being the radii of A, and the inner surface of B.

The "capacity" C may be defined—as in the ordinary theory—as such that, if Q be the charge, the energy stored up in the condenser $= \frac{1}{2} \cdot \frac{Q^2}{C}$.

Hence capacity $= \dfrac{1}{\frac{1}{a} - \frac{1}{a'}} \cdot \dfrac{4\pi}{E} = \dfrac{aa'}{a'-a} \cdot \dfrac{4\pi}{E}$.

Also the capacity of a sphere is equal to its radius $\times \frac{4\pi}{E}$, for by § 4 the energy of a charged sphere $= \frac{1}{2} \cdot \frac{Q^2}{a} \cdot \frac{E}{4\pi}$.



8. The case of two parallel plates is simpler still. The plates are, as usual, supposed to be very large compared to the distance between them, so that the disturbing effect of the edges may be neglected. Let ς = area of either plate, d = the distance between them, x = the displacement.

Then, the energy $= \frac{1}{2} . E . \varsigma . d . x^2$.

Let Q = charge on either plate; then $Q = \varsigma x$.

Hence the energy $= \frac{1}{2} . E \dfrac{dQ^2}{\varsigma}$;

$\therefore$ capacity $= \dfrac{2\varsigma}{dE}$.

Also (differentiating energy) force of attraction $= \dfrac{EQ^2}{2\varsigma}$.

Or, we may express the force of attraction in terms of the difference of pressures, which is equal to $Ed.x$, being the spring back of a tube of unit area.

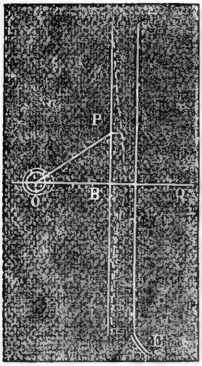
Then, since the energy $= \frac{1}{2} . E . \varsigma d . x^2$

$$\therefore \text{attraction} = \tfrac{1}{2} . E . \varsigma x^2$$

$$= \frac{V^2 \varsigma}{2 . Ed^2},$$

V being the difference of pressures.

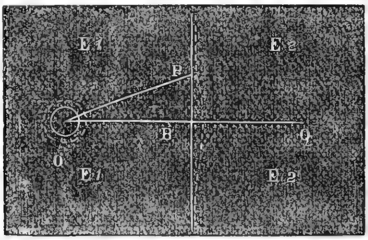
The theory of images finds, of course, its place in this method of treating the subject, as much as in the ordinary one. But we have now this very great advantage: that the student can form easily a mental picture of the problem, and roughly forecast the result. Especially is this true of such problems as deal with the nature of the field when two or more different dielectrics in juxtaposition are strained by electrical charges: problems which, by the ordinary method, are most difficult to grasp completely.



In the case of a charged sphere placed on one side of a large conducting plate put to earth, it is obvious that there is —as represented in the figure—a *bulge* of the dielectric into the plate; and it may be readily proved that the displacement at P is perpendicular to the plate and the same as if there were no plate, only uniform dielectric, and the strain were due to a charge Q at O and $-Q$ at the point Q, which is the image of O in the plate. The amount of the displacement is therefore

$$2 \cdot \frac{Q}{4\pi \cdot OP^2} \cdot \frac{OB}{OP}.$$

Let us consider a more difficult problem, the strain arising from a charge Q placed on one side of a plane which separates dielectric of elasticity E_1 from dielectric of elasticity E_2. Suppose $E_2 < E_1$. Evidently there is a bulge in this case also.



Now, if E_2 were equal to E_1, *i.e.*, if the medium were homogeneous throughout, the displacement of P perpendicular to the plane would be

$$\frac{Q}{4\pi \cdot OP^2} \cdot \frac{OB}{OP}$$

If E_2 were equal to zero, the displacement would be

$$2 \cdot \frac{Q}{4\pi \cdot OP^2} \cdot \frac{OB}{OP};$$

i.e., it would just be doubled; the bulge would be exactly similar, but twice as big.

It is natural to guess, then, that when E_2 is $<E$ and >0, the displacement of P is equal to

$$(1+\mu) \cdot \frac{Q}{4\pi \, . \, OP^2} \cdot \frac{OB}{OP},$$

where μ is <1 and >0, and is the same for every position of P.

If this be so, the state of strain of the medium to the left of the plane is that due to a charge Q at O, and a charge $-\mu Q$ at the point Q (the medium being for the moment supposed uniform).

Consequently the pressure at P

$$= \frac{E_1}{4\pi} \cdot \frac{Q}{OP} \cdot - \frac{E_1}{4\pi} \cdot \frac{\mu Q}{QP} \cdot \quad \ldots \quad \ldots \quad \text{(i.)}$$

And the state of strain of the medium to the right of the plane is that due to a charge $(1 + \mu)$ Q at O, the medium being again supposed uniform.

Consequently the pressure at P

$$= \frac{E_2}{4\pi} \cdot \frac{(1+\mu) \, Q}{OP} \cdot \quad \ldots \quad \ldots \quad \text{(ii.)}$$

Hence for equilibrium, equating (i.) and (ii.):

$$E_1 (1-\mu) = E_2 (1+\mu)$$

$$\mu = \frac{E_1 - E_2}{E_1 + E_2}.$$

This value of μ is independent of the position of P: so the state of strain, of the nature guessed at, and having this particular value of μ, is one which gives complete equilibrium, and is therefore the solution of our problem.

Since the strain of the medium to the left of the plane is that due to a charge Q at O, and a charge $-\frac{E_1 - E_2}{E_1 + E_2} \, . \, Q$ at the point Q, the pressure at the surface of the sphere at O is very nearly

$$\frac{E_1}{4\pi} \cdot \left\{ \frac{Q}{a} - \frac{E_1 - E_2}{E_1 + E_2} \cdot \frac{Q}{2b} \right\},$$

where a is the radius of the sphere, and b the distance of the centre from the plane.

The energy of the strain is therefore

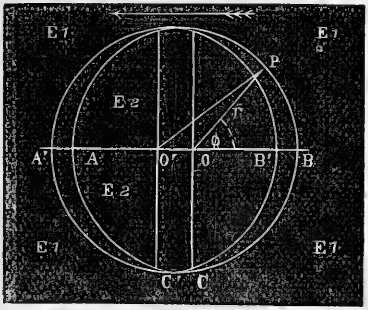
$$\frac{E_1 \, . \, Q^2}{8\pi} \left\{ \frac{1}{a} - \frac{E_1 - E_2}{E_1 + E_2} \cdot \frac{1}{2b} \right\};$$

and there is a force of attraction towards the plane equal to

$$\frac{E_1 \, . \, Q^2}{16\pi \, . \, b^2} \cdot \frac{E_1 - E_2}{E_1 + E_2}.$$

The advantage of being able to form a mental picture of one's problem is, I think, specially evident in the determination of the effect of placing in a field of uniform force—*i.e.*, displacement—a sphere of dielectric different from that of the rest of the field.

Let E_1 be the elastic constant of the field, E_2 of the sphere, and suppose $E_2 < E_1$.



It is obvious that, since the medium of which the sphere is composed is weaker than that surrounding the sphere, the sphere will give as a whole, and be displaced further in the direction of the existing displacement of the field. The lines of displacement behind the sphere will converge on the gap left by the sphere; those in front will correspondingly diverge.

General considerations show that the sphere will not be distorted, but simply translated; for, from symmetry, the positive charge at A must be numerically equal to the negative charge at B, and so for other corresponding points on the sphere. Hence, as the sphere is not distorted longitudinally, and is incompressible, it is not distorted laterally.

Let us suppose then that the sphere is displaced bodily to the left through a distance a, in addition to the displacement it has in common with all the rest of the field—viz., b. We shall find that by this supposition we do indeed obtain complete equilibrium, and that we have therefore solved the problem; and we can find the value of a. In the figure,

$$AA' = BB' = OO' = a.$$

The effect on the surrounding dielectric of moving the sphere bodily a distance a to the left is the same as would be produced if (the dielectric being for the moment supposed uniform) there were placed at O a charge $-2\pi r^3$, and at O′ a charge $+2\pi r^3$.

For the normal displacement at P due to these charges would be $\frac{1}{4\pi}\cdot\frac{2\pi r^3}{O'P^2} - \frac{1}{4\pi}\cdot\frac{2\pi r^3}{OP^2}$

$$= \frac{r^3}{2}\left\{\frac{1}{O'P^2} - \frac{1}{OP^2}\right\}$$

$$= \frac{r^3}{2}\cdot\frac{2.OO'\cos\phi}{OP^3}, \text{ since OP nearly} = O'P.$$

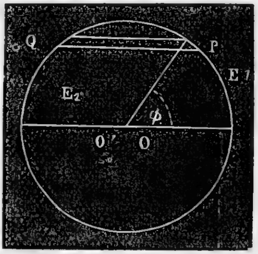
$$= a\cos\phi.$$

= the thickness of the gap left by the sphere.

So the state of the field is simply this: The sphere is moved to the left a distance $a + b$, and the surrounding dielectric bears in addition to its ordinary displacement (b to the left everywhere) the strain due to a charge $-2\pi r^3$ at O, and a charge $2\pi r^3$ at O′.

Now let us see whether equilibrium is secured by supposing the field strained in this way.

Consider two points, P and Q, on the sphere, PQ being parallel to the displacement of the field. The difference of pressures at P and Q is, since every point in PQ is displaced to the left a distance $a + b$,



$$E_2 (a + b) . 2r \cos \phi.$$

But, considering the strain in the outer medium, the difference of pressures at P and Q is due (i.) to a uniform strain b to the left, and (ii.) to a strain from charges $-2\pi r^3$ at O and $2\pi r^3$ at O′.

This latter produces a difference of pressures—

$$\frac{E_1}{4\pi} . \left\{ -\frac{2\pi r^3}{OP} + \frac{2\pi r^3}{O'P} \right\}$$
$$= -\frac{4\pi . E_1 . r^3 . a \cos \phi}{4\pi . r^2}$$
$$= -E_1 . r a \cos \phi.$$

Hence, for equilibrium we must have—

$$E_2 (a + b) 2r \cos \phi = E_1 b . 2r \cos \phi - E_1 r a \cos \phi.$$

$$\therefore E_2 (a + b) = E_1 \left\{ b - \frac{a}{2} \right\}, \text{ or } \quad a = \frac{2b (E_1 - E_2)}{2E_2 + E_1}.$$

Thus the total displacement to the left at B (*i.e.*, the density of the charge) $= a + b$

$$= b . \frac{3 E_1}{2E_2 + E_1}.$$

If $E_2 = 0$—*i.e.*, if the sphere is a conductor—the total dis placement to the left at B $= 3b$.

The loss of energy occasioned by the pressure in the field of this sphere can also be easily found.

To do this, let us calculate the work that must be done first to restore the surrounding dielectric to its uniform state, and then to replace the sphere of elasticity E_2, displaced a distance $a + b$ by a sphere of elasticity E_1, displaced a distance b.

Since the difference of pressures at P and Q is, when the sphere is displaced a distance x to the left,

$$E_1 b . 2r \cos\phi - E_1 r . x . \cos\phi \quad \text{(see above)}$$

then, if $d\varsigma$ be the sectional area of such a tube as that running from P to Q, the work done in restoring the external medium to its original state—by pushing the sphere left to right a distance a—is:

$$\int\int_o^a (E_1 b \cdot 2r\cos\phi - E_1 r x \cos\phi)\, dx \cdot d\varsigma$$

—where the first integral is to be taken so as to include all the tubes that make up the sphere.

This integral $= E_1\left(ab - \frac{a^2}{4}\right) \times V$ (the volume of the sphere; for $\int 2r\cos\phi\, d\varsigma = V$).

Again, to replace the sphere of elasticity E_2, displaced $a+b$ to the left, by a sphere of elasticity E_1 displaced b to the left, requires an extra amount of energy.

$$VE_1 \cdot \frac{2}{b^2} - VE_2 \cdot \frac{(a+b)^2}{2}$$

$$= VE_1 \cdot \frac{b^2}{2} - VE_1 \cdot \frac{b^2 - \frac{a^2}{2} + \frac{ab}{2}}{2},$$

since $E_2(a+b) = E_1\left\{b - \frac{a}{2}\right\}$.

Adding these, we find that the loss of energy occasioned by the presence of the sphere

$$= E_1 \cdot \frac{3ab}{4} \cdot V$$

$$= 4\pi r^3 \cdot E_1 \cdot \frac{E_1 - E_2}{2\,(E_1 - 2\,E_2)} \times b^2.$$

For the purpose of comparison with the result obtained by the other method, put—for E_1, $\frac{4\pi}{K_1}$; for E_2, $\frac{4\pi}{K_2}$; and for $E_1 b$, F.

We then obtain

$$\text{Difference of energy} = r^3 \cdot \frac{K_2 - K_1}{2(2\,K_1 + K_2)} \cdot K_1 \cdot F^2.$$

This does not quite agree with Equation 118 on page 128 of Gray's "Absolute Measurements in Electricity and Magnetism," as we have here an extra factor, $\frac{K_1}{2}$. The K_1, however, is necessary, and is evidently an accidental omission in Gray's form of the equation: without it the dimensions of the equation are wrong. I do not know why the factor $\frac{1}{2}$ occurs in this work and not in Gray's.

Whether the $\frac{K_1}{2}$ be present in the equation or not, the results obtained by Boltzmann are unaffected; as he uses the *ratio* of the differential of the above expression obtained in two cases—(i.) when a ball of required specific inductive capacity is placed in the field; (ii.) when a similarly-shaped ball of conducting material is placed there. In the equation he uses, therefore, the $\frac{K_1}{2}$ divides out.

The nature of the field due to a charged ellipsoidal conductor is by this method found without much difficulty; but, as the proof differs but little, except in language, from the ordinary proof, I will only state it briefly.

It may be shown that, if every ellipsoidal surface confocal to the original one be supposed to expand *similarly*—*i.e.*, so as to become a similar and similarly-situated ellipsoid—then the strain so produced will be one of equilibrium.

Let $\frac{x^2}{a^2} + \frac{y^2}{b^2} + \frac{z^2}{c^2} = 1$ be the original ellipsoid; and let λ_1, λ_2, λ_3, be the parameters of three confocals to it, λ_1 being the ellipsoid.

Let p_1, p_2, p_3, be the perpendiculars from the centre on the tangent planes to the three surfaces where they intersect.

Now, if the ellipsoid λ_1 expand, its linear dimensions altering in the ratio 1 to $1+\rho$, we must have—

$$\frac{4\pi}{3}\sqrt{(a^2+\lambda_1)(b^2+\lambda_1)(c^2+\lambda_1)}\ [(1+\rho)^3-1]=Q;$$

Q being the charge.

$$\therefore\ \rho=\frac{Q}{4\pi\sqrt{(a^2+\lambda_1)(b^2+\lambda_1)(c^2+\lambda_1)}}.$$

Also the normal displacement at λ_1, λ_2, λ_3, is easily proved to be $\rho\,.\,p_1$.

Now, consider the tube formed by the confocals, λ_2, $\lambda_2+\delta\lambda_2$, λ_3, $\lambda_3+\delta\lambda_3$: the area of section of this tube at λ_1, λ_2, λ_3, is $\frac{\delta\lambda_2}{2p_2}\times\frac{\delta\lambda_3}{2p_3}$, these two factors being the lengths of the sides of the section.

$$\text{Now, } p_1=\frac{\sqrt{(a^2+\lambda_1)(b^2+\lambda_1)(c^2+\lambda_1)}}{\sqrt{\lambda_2\lambda_3}};$$

p_2 and p_3 have similar values.

Hence, $\rho p_1\times\frac{\delta\lambda_2}{2p_2}\times\frac{\delta\lambda_3}{2p_3}$ is independent of λ_1.

Thus, the total displacement across this or any similar tube is a constant along the tube; and so the tubes are tubes of displacement of the supposed strain.

We have yet to show that the strain produces equilibrium. But it may be easily shown that, if V be the pressure at any point, the rate of variation of V in any direction is equal to $-E \times$ displacement in that direction.

In this case the displacement at $\lambda_1, \lambda_2, \lambda_3$, is $\rho . p_1$; and the normal distance between the surface λ_1 and the surface $\lambda_1 + \delta\lambda_1$ is $\frac{\delta \lambda_1}{2 p_1}$.

$$\text{Hence } \frac{d V}{\frac{\delta \lambda_1}{2 p_1}} = -E \rho p_1$$

$$\text{or } \frac{d V}{d \lambda_1} = -\frac{E}{2} \cdot \frac{Q}{\sqrt{(a^2+\lambda_1)(b^2+\lambda_1)(c^2+\lambda_1)}}.$$

Hence, if V be constant over one confocal ellipsoid, it is constant over all. But V is zero at infinity, and one of the confocal ellipsoids is an infinite circle.

Hence the confocal ellipsoids are surfaces of equal pressure. This proves the proposition.

I should like here to point out the curious fact that in an ordinary proof of part of the above theorem—viz., that part which asserts the distribution of the charge on the ellipsoid to be represented by the expanding of the ellipsoid *similarly*—the reasoning has to do with attractions *inside* the ellipsoid, and takes no account of actions *outside*.

It should be noticed that this ordinary form of proof is very incomplete, for it is upset entirely if the dielectric within the ellipsoid be not uniform, as in that case calculation of the attractions would become impossible. The proof here given is, of course, independent of the nature of the dielectric within the ellipsoid. Moreover, the ordinary proof would apparently be unaffected by any want of uniformity in the external dielectric: a student might therefore be easily led astray.

In connection with this subject it is worth noticing that the method of this paper leads to a most simple proof of the law that a closed conductor screens its interior from the action of external charges.

For the only way in which the pressure of the ether in the conducting shell could affect the dielectric—*uniform or not*—in the interior, would be by changing the shape of it, pushing it in in some places, and therefore allowing it to bulge in others. But the pressure is uniform over the conductor, and the interior of the shell is unalterable in volume, and so no work can be done by any such deformation. Hence no energy can be imparted to the interior of the conductor, and consequently no changes can be forced to take place in it.

I hope that I have made it clear that this method of treating electrostatic theorems is of value. It seems to me to possess several advantages. In the first place, the student is able to form a mental picture of the physical meaning of every step in the mathematical theory, and he therefore finds it easier to understand the step, to remember it, and give it its proper relative importance. And, again, the expression for specific inductive capacity appears naturally in every equation, as it should do, and its significance is at once comprehended. A student's ideas of this quantity formed from the ordinary definitions of it are often very hazy.

Lastly, the method offers the student a new standpoint, and a fresh view of his subject; and the view not only makes clear to him many things which were confused before, but is well adapted for giving him an insight into the more modern advances in the Electrical Theory.

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3. *Note on the Gregorian Calendar.*

By A. C. Gifford.

The length of the tropical year is 365d. 5h. 48m. 45·51sec., or 365·2421934d. (Young's "General Astronomy.")

The fraction of a day is equivalent to the following continued fraction:—

$$\frac{1}{4+}\frac{1}{7+}\frac{1}{1+}\frac{1}{3+}\frac{1}{10+}\frac{1}{11+}\frac{1}{3+}\dots$$

The convergents to this fraction give us a series of approximate values, each more accurate than the preceding, and it happens that the fourth suggests a rule for the interpolation of leap-years, which is very simple and yet far more accurate than the Gregorian one.

The first four convergents are—

$$\frac{1}{4},\quad \frac{7}{29},\quad \frac{8}{33},\quad \frac{31}{128}.$$

The first is the value of the fraction used in the Julian calendar. The error amounts to one day in about 128 years.

Had the second been adopted, the error would have taken 1,111 years to amount to one day.

The third, which was adopted in the Persian method of interpolation, gives a result correct for 4,348 years.

The fourth is so near the true value that, were it used, the error would not amount to a day for more than 169,000 years.

To adopt this value it would only be necessary to make every year whose number is divisible by 4 a leap-year except those divisible by 128.

4. *The Origin and Development of the North-west Winds of New Zealand.*

By John T. Meeson, B.A.

The nor'westers of Canterbury—though they seem, and in some respects are, so exceptional in character—in point of fact are nothing but the winds common to the whole of New Zealand, and, indeed, common to our latitudes in the Southern Hemisphere, right round the earth—winds blowing towards the area of abnormally low pressure (29° to 29·3°) which prevails generally about lat. 56° S., but modified very materially in character by their passage across the Southern Alps, which, though not much higher than two miles even in their topmost peaks, have power to affect the currents of air shown by cirrus clouds to prevail to the height of five miles. These winds are, in fact, the *Return Trades*, and would be north winds if they followed the direction which they first take after forming at the Zone of Calms; but, having come from parts of the earth where the rotatory motion is great to places where it is less, they have acquired, for the opposite reason to that which Hadley gives to explain the western tendency of the Trades, an eastern proclivity: and as they proceed to higher latitudes after becoming lower surface winds at the Tropic of Capricorn, they become more and more westerly until they merge into the "roaring forties" with which all voyagers to this part of the world have a somewhat intimate acquaintance. Dove remarks that "all winds are liars," and it must never be forgotten that the apparent horizontal direction of a wind, on account of the shape and aërial motion of the earth, is never or hardly ever the real one.

These roaring westerly winds show frequently unmistakable cyclonic disturbance, which, by applying Buys Ballot's, or, as it should perhaps be called, Galton's law, can be roughly located. That law recognises the fact that the wind blows along isobars with less pressure on the left in the Northern Hemisphere, but on the right in the Southern: in other words, if you stand with your back to the prevailing wind, in the Southern Hemisphere the lowest depression of the barometer will be on your right hand—*i.e.*, in the case of the nor'westers, to the south-west. If we knew in New Zealand, as meteorologists in the Old World do know, the exact measurement of the acute angle between the direction of the wind and the lie of the isobar—that is, the inclination of the wind to the isobar—we might fix the position of the cyclonic centre much more precisely. But the narrowness of New Zealand, the few observing stations therein established, the waste of waters round about, and the small number of ships navigating it and bringing in their weather reports, must make it extremely difficult to draw isobars of a thoroughly reliable nature in our colony.

Now, the cyclones, formed at various points in the north-west gale like eddies in a mighty stream, sometimes are so large as to absorb the whole current and stretch over vast areas. But, just as Loomis shows (*Nature*, 11th July, 1878) that American storms in the Northern Hemisphere originate in a district near the Rocky Mountains, two-thirds of them north of lat. 36°, and move on to the east through the general circulation of air in that direction, and as Dove considers that many of the storms of the Temperate Zones are tropical ones diverted from their path at or about lat. 30° north and south, and as the English meteorologists recognise certain fairly-definite storm-tracks across the Atlantic, ramifying frequently from certain definite spots and skirting the North Atlantic anticyclone while journeying usually in a north-east direction, so it perhaps should be possible for us to arrive at some conclusion as to the starting-points and general paths of our New Zealand cyclones, though the means that we have of doing so, for reasons already indicated, are exceedingly limited. Even in Europe, with its army of observers, its delicate appliances, and numerous stations, it is very difficult to trace the connection, by continuously advancing minima, between tropical cyclones and their prolongations into the Temperate Zone. Here, therefore, the work must be considerably harder.

In the North Atlantic there is a great anticyclone stretching over the intertropical area and the more southern part of the North Temperate Zone. Along the northern edge of this is the birthplace of the innumerable cyclones of every size and intensity which incessantly move to some point east or north-east along the shores of and crossing the British Isles—to be worn out in the polar regions north of the Scandinavian peninsula. Similarly, in the Southern Hemisphere and in corresponding latitudes there is formed in winter a more or less continuous anticyclone, producing the fine weather of Australia at that season, interrupted, however, occasionally by bad spells, squalls, and thunderstorms, and thoroughly broken in the summer season, when the vast mass of the Australian Continent, with its atmospherical rarefaction in the Torrid Zone (when the sun is south of the Equator), must exercise large attractive action on all sides. This anticyclone at the latter season contracts very much, and leaves a breadth of low pressure over the Pacific between New Zealand and Queensland, in the vicinity of which a considerable number of the north-west storms which dash against or cross our Islands are probably generated. Hence the forecasts of Mr. Wragge, the Government Meteorologist at Brisbane, have a special value for New Zealand. On our western coasts these storms meet with a great impediment to their further progress south-eastwards in the masses of the Southern Alps, over which many of them fail to pass, and either spend themselves in dashing against the mountains or, with that affection for skirting mountain-chains and coast-lines for which they are remarkable all over the world, go off to the south and round the Island at Foveaux Strait. To what extent the Southern Alps modify the character of the north-west storm before it reaches the Province of Canterbury, and how this modification is brought about, I have considered in another paper.

Dove divides the storms of the Temperate Zones into—

1. Extensions of Torrid Zone storms;
2. Storms arising at the external edge of the Torrid Zone, from the meeting of the Return Trades with surface winds opposed to them;
3. Storms produced by the mutual lateral interference of polar and equatorial currents flowing in opposite directions.

Our north-west storms seem to belong to the classes 2 and 3, though occasionally we may have one which is simply a prolongation of a Torrid Zone atmospherical disturbance. Some of our storms are undoubtedly identical with those that dash up against the south side of the Australian anticyclonic area—traceable sometimes so far to the north-west as Mauritius—the region, be it remembered, of Indian Ocean hurricanes—but sometimes apparently coming from points much farther to the south, bringing bad weather to the extreme southerly districts of Victoria and to Tasmania, and then crossing over from Bass Straits to New Zealand in twenty-four hours. Such storms, after leaving Australia, always seem to make for the south-east. Even when at first, after leaving Bass Straits, they hug the east coasts of New South Wales and apparently make for the north-east, they turn at right angles to their course before they go very far, and merge into the Return Trades.

It does not follow that, because much of our north-west weather is cyclonic in character, all of it necessarily is so. Some of it may be produced by broad gales which are defined by Dove as strong winds, blowing in with tolerable steadiness from one point of the compass. The phenomena, as far as we in Canterbury are concerned, would be nearly the same whether this were so or not, for the gyration of the wind on one side of a cyclone is the same as that produced by the ordinary currents of the atmosphere, and the effect of the mountains would be similar in both cases. It therefore, as far as our present investigation is concerned, does not seem very important whether we adopt the *rotary theory* of Redfield or the *inblowing theory* of Espy. Dove certainly seems to speak of gales as something quite distinct from the cyclones of Piddington. But, as has been remarked, "the law of storms is the law of wind everywhere," and the terms "gale," "cyclone," and "tromb" only indicate similar movements of the atmosphere affecting areas of different magnitudes. A gale, in fact, may be assumed to be a portion of a huge cyclone whose true character is concealed from us because we are not able to carry on sufficiently wide simultaneous observations. The true cyclone itself is perhaps popularly misunderstood. It does not necessarily imply the violence of the tempest or hurricane, such violence only occurring when the isobars are very near—that is, when the depression is deep and the baric gradient steep. It sometimes is as much as 0·2, though the normal rate of barometric change is not more than 0·02 to more than 0·05.

Do our violent north-westers evidence the passing of cyclones over our heads to the south-east? Loomis and other meteorologists agree that storms as a rule in our latitude travel to the eastward—to the north-east in the Northern Hemisphere, to the south-east in the Southern. They make their way in that direction because of the rotation of the earth, the rain being drawn eastward, Blasius thinks, by traction of deficient air. That being so, however, I do not think that many of our north-west cyclones pass directly over Canterbury to the south-east, for the following reasons: It is very seldom indeed that the wind goes suddenly round from north-west to south-east, or that the central calm of the cyclone is observable, which would always be the case if we were here in the direct path of the storm. Rain falls also very rarely, and the fall of the rain determines, or is supposed to determine, to a large extent the path of the disturbance; for it gives out heat and thus causes the air to expand and whirl upwards, making a comparative vacuum which the air behind fills, and so the direction of the whole slanting and inverted aërial whirlpool is determined.

What Loomis says about rain or snow on the west side retarding the progress of a cyclone is instructive. It favours the idea that our north-west storms, through the heavy rain they deposit on the Southern Alps, are stopped, worn out by dashing against or amongst the mountains, or else diverted, as already observed, along the coast-line and the flanks of the range. North-westers are experienced in the Chatham Islands, but there, as on the west coast of New Zealand, they are the rain-bringers and quite different from our dry *föhn.* They have similar origin to ours, but an independent one. As to whether we are in the line or path of the cyclone or not—apart from barometrical indications—the winds and clouds, especially cirrus and cirro-stratus, if we could perfectly interpret them, would be an infallible sign.

(1.) When we are in the line of the storm—*e.g.*, the anti-cyclone being to the north-east—cirrus clouds would be over the north-west and parallel to the horizon.

(2.) When we are north-east of the line of the storm, the bank of cirro-stratus is visible on the west or west-south-west horizon, and the upper current is south-west. The bank spreads, and a north-west wind springs up beneath; the clouds above are cirro-cumulus, not cirro-stratus.

(3.) When the depression is to the east or left of us, the cirro-stratus bank is north-north-west; the sky thickens; the south-east wind freshens; the upper wind is north-east. If there be rain, it is cold and continuous; the sky clears slowly; the barometer rises, and stratus clouds come into view.

(4.) If we are in the rear of the cyclone, which has already passed to the south-east, the clouds are frequently cumulus; there will be a few upper threads of cirrus stretching from north-east to south-west; south-west winds with showers will come, and there will be the same wind to the highest regions.

Some such rules as these—which I have adopted from Ley—will show us how we are situated with regard to the cyclonic centre. The diagnosis of our "nor'westers" almost invariably brings them under rules (2) and (4). But, of course, full and detailed synoptic charts—if we could obtain them in New Zealand—would be a far more certain criterion as to the point in question than clouds and winds. When the anticyclone is not to north-east but to east of us, and depression going south,—or west of us, and depression going north-east,—similar rules will apply; the system of points, however, being moved, in the first case, 4 points back, or, in the second case, 8 points forward.

To understand the development and character of our north-west gales in New Zealand we cannot do better than study closely the nature of the south-west storms of Great Britain, under the guidance of such meteorologists as Ley, Abercrombie, and Scott. The British sou'wester is the counterpart of the New Zealand nor'wester. But the former is accompanied usually, and almost everywhere, by heavy rains, because of the absence of a huge mountain-chain athwart its path; whereas the latter is so accompanied only along the west coast of New Zealand. The requisite changes in the direction of wind, &c., for the Northern Hemisphere being made, we see, however, the strong resemblance between the two winds. The barometer falls in England as the south-west wind approaches; the thermometer rises in the south-east or right side of the cyclonic path, and, as the storm progresses, the wind gradually veers to the west, and eventually into the bracing north-west. Abercrombie explains these phenomena as being the marks of a V depression formed either along the south prolongation of the trough of a cyclone, or else in the *col* between two adjacent anticyclones. If this be so, and our north-west, followed by south-west, storms (or some of them) be similar in origin, we experience under their influence the result of a V depression formed along the northern prolongations of the troughs of cyclones passing away to the south-east. When pouring rain comes from the south-west after a north-west wind of long or short continuance, we are, indeed, forcibly reminded of the "southerly bursters" of Australia, which also, it appears, are owing to a V depression passing to the south-eastward along the southern coasts of that island, the point of the V being to the north, with the wind north in front, and south-west or south in rear. The phenomena of our north-west weather, although possessing a general similarity, are, it must be remembered, of various types, and some of these types may be explicable in the above fashion. The arch is sometimes absent altogether; the increase of temperature varies considerably; so does the duration of the storm, and the character of the south-west wind which supervenes; and therefore we can readily understand that, with somewhat similar north-west weather, the same fundamental shape of isobar will not always be found.

Mr. Cockburn Hood and Mr. Charles Knight (Trans. N.Z. Inst., vol. vii.) think our north-west winds are simply the hot winds of Australia which mount high into the atmosphere after leaving that island-continent, and gather moisture from the intervening sea. But surely there is a fallacy here. A high upper wind would not lick up moisture, and, if it did, it could not hold it for a journey of 1,200 miles, because of the low temperature it would acquire at its elevation. Sometimes, truly, as on "Black Thursday," the north-west weather of Australia may reach as far as New Zealand, for general weather is occasionally very widespread in its influence, as was evidenced quite recently (9th and 10th September, 1889) when the ship "Otago," two or three thousand miles to the south-east of New Zealand, nearly succumbed to the same succession of north-west followed by south-west cyclones as swept at that time over this colony. There is also such great similarity in some respects between the hot winds of Australia —blowing for two or three days together with excessive heat and violence from the north-west, and followed as they are by the cold south-west with deluges of rain and a fall of the thermometer often of 30° or 40° in an hour or two—and the nor'westers of Canterbury, that, making allowance for differences arising from local geographical peculiarities, it is impossible to suppose otherwise than that the two have some similarity of origin. The Australian wind blows however over an arid continent, and thus increases rather than diminishes its heat as it travels, and it meets with little or no obstruction from high mountains calculated to drive it up into higher and colder regions. On the other hand, the north-west wind of New Zealand by the time it reaches our shores has crossed a wide ocean and gathered from it both moisture and heat as it travelled, and here it meets at a comparatively high latitude with mountains 10,000ft. high, which are quite capable of relieving it of its watery burden. The distance between Australia and New Zealand is not so great as to lead us to doubt the occasional identity of some of our cyclonic disturbances with those prevailing over the water, and it must be remembered we are directly in the line of travel; and cyclones, though they often fill up or diverge from their path, and otherwise conduct themselves in a most unreliable manner, yet as a rule keep a definite track and travel very far. Notwithstanding all these considerations, I do not argue for any identity, except a very occasional one, between the hot winds of Australia and New Zealand. Our nor'westers for the most part have quite an independent origin.

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5. *On the Characteristics of the Nor'-westers of Canterbury, New Zealand.*

By JOHN T. MEESON, B.A., Christchurch, New Zealand.

1. INTRODUCTION and description of phenomena of nor'-westers.

2. Inquiry into the cause of their excessive heat. Compression, the usual explanation, inadequate. True explanation must take account of—(1) Original heat of equatorial aërial current, (2) heat given out when rain precipitated, (3) different capacities of wet and dry air for holding heat, and Dr. Hann's reasoning about the Swiss *föhn*, (4) development of heat on the left front of all cyclones; why south-west winds not hot though over high mountains. Original and acquired heat of equatorial winds. Great effect of warm ocean-currents in heating air above them. Conclusion *re* heat.

3. Cold nor'westers.
4. The behaviour of the barometer in a nor'wester.
5. The north-west arch (of clouds).
6. The south-west wind and subsequent gyration.
7. North-west rains east of the Southern Alps.
8. Other *föhn* winds than the New Zealand nor'westers.
9. Their generally beneficial character.

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6. *On Constructive Cosmical Impact.*

By Professor A. W. Bickerton.

1. Stars, being suns in indiscriminate motion, are liable to collision.

2. This tendency to collision is increased by the mutual attraction of the bodies. In two bodies such as the sun this tendency would be increased above four thousand times by mutual attraction.

3. Almost all considerable impacts would be of a grazing character, and all impacts produced by attraction would certainly not be direct.

4. A tangential or grazing impact would not necessarily result in complete coalescence. Often only the parts actually coming into collision would coalesce, the remainder passing on into space. It is obvious this would be the case with a mere graze.

5. The part grazed off would exercise a retarding action on the escaping part, that would often prevent its entire escape. Two bodies similar to our sun would be prevented escaping even if a much less part be grazed off than one-hundredth. Here, as already suggested by Stoney Johnson and Sir William Thomson on other grounds, is a probable origin of double stars. If the stars had no initial proper motion, the grazing-off of a third of each would exercise such a retarding influence that the resulting bodies would not pass out of contact.

6. The part coming into collision would be intensely heated by the impact. The temperature developed will be independent of the amount of grazing; with similar substances it will depend only on the velocity destroyed, so that the coalesced body produced by the merest graze will be as hot as though the whole sun collided.

7. The molecular velocity of such a high temperature may be sufficient to carry away every particle entirely into space,

the mass of the body not having sufficient attractive power to retain them.

8. Hence an intensely-brilliant body is produced in less than an hour; it then expands, and increases in size and total luminosity for perhaps a few hours to a day or so; then the diffusion would be so great as to gradually lessen luminosity, until in a few months or a year the star would have disappeared into space. This represents all the peculiarities of temporary stars.

9. If the graze be more considerable the attraction will be greater, yet the molecular velocity the same: a hollow globe of gas may then result, giving us a planetary nebula. According to Lord Lindsay this is the condition of the temporary star of the Swan.

10. If the graze be still more considerable the slower-moving molecules of heavy metals may not travel far from the centre, and may be attracted back and form a brilliant mass, giving us the appearance of a nebulous star.

11. The two stars that grazed each other will be heated on the colliding sides. They will also be set revolving in such a manner that the heated sides are alternately presented on opposite sides of the heavens, giving us the appearance of a pair of variable stars. But this inequality of temperature would slowly subside, but at different rates in the two stars, leaving only one variable.

12. If this were so, then variable stars should be sometimes in pairs. The 100 variables in Chambers's list were charted to ascertain if this was the case: forty were found to be in pairs, twenty so close as to occupy only ten spaces; they were too close not to coalesce when drawn on a 10in. chart, a result absolutely free from the possibility of being a chance coincidence.

13. If variable stars were formed this way they would lessen in irregularity, and also would for many reasons have inequality of times of rotation and inequality of intensity. All these peculiarities are known to be common to variable stars.

14. If double stars were formed this way they would sometimes be variable. After three years of search for this fact, it was discovered (in 1862) that Struvé has found this property to be common with double stars. They are often coloured—a result that must generally follow and be associated with variability in consequence of the heavy metallic centre being brought to the surface.

15. If this be the origin of double stars, they should also often be associated with nebulæ. Herschel says, "The association of double stars and nebulæ is truly remarkable."

16. If two bodies were composed of hydrogen and were to collide, the temperature would be two hundred times less than

were two similar masses of mercury to collide, but with mixed bodies this difference of temperature of different chemical substances would equalise rapidly by conduction and radiation. Then, the hydrogen would be moving more than a dozen times as fast as the mercury: thus in any cosmical collision the light atoms would tend to escape into space and the heavy be retained, thus spreading space with wandering molecules of light gas. This fact is of importance in the study of the immortality of the cosmos. All the phenomena connected with this escape of molecules I have grouped under the title of "selective escape."

17. If the collision of two bodies were as great as a half of each, it is scarcely likely they would escape each other's attraction; they would whirl round each other, forming a bun-shaped mass of very high temperature. In such a mass any bodies originally associated with them would tend to be entrapped in this nebulous mass, and would revolve about them in the general plane of motion, and would tend to produce a group of bodies similar to our solar system. The details of this action are described in a paper on "Agencies tending to lessen the Eccentricity of Planetary Motion."

18. Where there was considerable rotation in the case of a nebula composed chiefly of heavy molecules of infusible material, there would be a tendency to aggregate into meteoric dust. This dust would not coalesce entirely; it would ultimately settle down into a star-cluster.

19. Amongst groups of large bodies like nebulæ, such as are found at the Galactic poles, impacts would be frequent. Impacts of two nebulæ would produce—(1) Twin nebulæ; (2) Twin nebulæ with an incipient spindle-nebula between them; (3) Isolated spindle-nebulæ; (4) Spindle-nebulæ with an incipient spiral at the centre; (5) Complete spiral nebulæ. All these varieties of nebulæ are to be found in abundance at the Galactic poles, and have been drawn by Herschel and others.

20. During the impact of two globular nebulæ, the two parts colliding would be intensely heated, there would be pressure produced, and it will be found on examination that this could find relief only in a direction perpendicular to the plane of motion: there would thus be a tendency to the formation of an annular nebula, with gauze-like caps of nebulæ at the two poles of the ring. There are some such nebulæ.

21. The impact of two universes, such as the Magellanic Clouds, would tend to produce such a configuration; but the original stars and other bodies would not be likely to come into impact except in the grazing part, but would naturally spread out into an annular mass of a roughly double spiral character. The grazing part would be projected along the axis of the ring,

and would form nebulous caps. This configuration corresponds almost exactly with the form of the visible universe, which may thus be the result of the slow impact of two previously-existing universes, the impact obviously occupying a period comparable with thousands of millions of years.

22. If our universe be proved from its form and character to have been formed of two previously-existing universes, then the entire cosmos may be made up of an infinity of universes.

23. Space is dusty both with wandering dark bodies and also with countless myriads of molecules of light gas. It is probably due to the meteoric dust of space that we see no distant universes other than the Magellanic Clouds.

24. If this be the case, radiation must all be caught by the dust of space, and this dust must be gradually increasing in temperature.

25. Bodies not in orbits occupy but a short time at high velocity. They occupy longer and longer periods as the velocity is reduced. Thence hydrogen gas independent of matter will generally be moving slowly. But slowly-moving gas is cold: hence hydrogen gas may be at a lower temperature than any other matter in space.

26. Whenever by their mutual motion hydrogen gas meets cosmic dust the hydrogen will acquire its temperature: that is, it will increase its molecular velocity. It will thus have a new start of motion that will tend to carry it further away from matter.

27. Moving matter not in orbits will tend to move slowest where there is least matter—that is, where potential gravitation is highest—because in these places it has done most work against gravitation. Where bodies moving indiscriminately move slowest they obviously tend to aggregate: in other words, the hydrogen of space tends to accumulate in the sparsest portions of space.

28. Thus radiant energy falls upon the dust of space, and this heat gives motion to hydrogen, and this hydrogen tends to use this energy to pass to positions of high potential, thus converting low-temperature heat into potential energy of gravitation.

29. This action will tend to go on until attraction is equal in different parts of space; but then we have in one part of space bodies in mass, in another diffused hydrogen.

30. Free bodies moving indiscriminately will tend to pass through a group of masses similar to our universe, as 1,840 Groombridge is passing through it now. But they will tend to be entrapped in a mass of hydrogen. Thus the place that was most void of matter now commences to have more than the regular distribution of matter. A new universe has begun to form.

31. Where three bodies pass near each other, one at least has its velocity increased. In this way it is possible to account for the enormous velocity of 1,840 Groombridge. Whenever the velocity is great enough to escape the attraction of the universe the body is lost to it, and the other bodies are moving slower. If this should only occur once in a thousand cases, seeing that when it does occur the body escapes, if we only give time enough most of the energy of any individual system must be used up in allowing the escape of bodies.

32. Thus, in opposition to the theory of dissipation of energy, there is seen to be the possibility of an immortal cosmos in which we have no evidence of a beginning or promise of an end.

Section B.

(CHEMISTRY AND MINERALOGY.)

President of the Section—Orme Masson, M.A., D.Sc.

ADDRESS BY THE PRESIDENT.

The Gaseous Theory of Solution.

Plate IV.

It is a matter of great regret to myself that I am unable to visit Christchurch so as to take part in the meetings of the Chemistry Section, and personally discharge the duties of my office. I greatly value the honour of having been elected to your presidency, and hold it to be one of which much better chemists than myself might well be proud. Nevertheless, had I foreseen my inability to do more than communicate with you by post I should have felt bound to decline the office. As it is, I can but send you cordial greeting, and hearty wishes for a successful meeting, and do what little I can from a distance to contribute to that success.

It is now about five years since the first active steps were taken to form the Australasian Association which is now holding its third meeting. During that time an immense amount of valuable work in our science has been done in Europe, and a little—I fear a very little, and vastly less than should satisfy our ambition—in Australasia. Not only has our knowledge of the properties and constitutions of individual substances and of whole classes of substances been greatly extended, but new methods of inquiry based on or leading up to ingenious theories have come into vogue. Among such new developements there is one which has already achieved much, and promises to achieve more; and of this I propose to speak to you now, trusting that the interest of the subject will compensate for the poverty of my treatment of it.

This subject is what may be called the gaseous theory of solution, as developed by Raoult, van't Hoff, Arrhenius, Planck, Ostwald, Duhem, Vernst, de Vries, and other physical chemists, chiefly in Germany. The literature of the subject is already very large, and is scattered through many scientific journals, some of which have not been accessible to me here in Melbourne; so that such knowledge as I have of this part of the literature is derived at second hand from the abstracts published by the Chemical Society of London. I should mention, however, that Professor Ostwald's recent book, "Outlines of General Chemistry," which has been translated into English by a younger worker in the same field, Dr. J. Walker, of the Edinburgh University, contains an admirable exposition of the theory by a master-hand. Having myself derived untold pleasure and profit from the perusal of this book, I feel that I shall have done some good if by this address I do no more than induce others to read it too.

Briefly stated, the new theory amounts to this: that matter in the state of solution is subject to exactly the same laws of volume, pressure, and temperature as regulate matter in the gaseous state, and that the part played by the solvent in the former case is similar to that played by space in the latter. Imagine two vacuous chambers of equal size, capable of being placed in communication with one another or separately with the air. Call one A, and the other B. Now allow a certain quantity of air to enter A. It will, according to its quantity and the size of the chamber A—that is to say, according to its concentration—exercise a definite pressure. If now A be put in communication with B, part of the air will enter B in virtue of this pressure; and the redistribution will be such that in a little time A and B will have divided the air equally between them; and this air, filling twice the space it did before, will have only half the original concentration and therefore only half the original pressure. Now imagine the same two chambers filled, A with a solution of salt in water, and B with pure water. Both chambers are, as a matter of fact, filled with water, just as they were filled in the other case with space; and throughout A there is also distributed a definite quantity of salt particles, comparable to the air which we then allowed to enter. This salt, like the air, must possess a definite concentration, determined by its amount and the size of A—that is to say, its amount and the volume of the solution; and in right of this it will exercise a definite pressure, just as the air did. And so, when we open the door from A into B, the salt will gradually become equally distributed throughout both chambers, and by the time that equilibrium is established it will possess but half the concentration and half the pressure that it did before. This is the phenomenon so long known as diffusion, the term being applied to gases and to solutions alike. The other terms essential to a description of the process are also equally applicable to both — namely, concentration, volume, and pressure; but in the last case it is desirable to avoid any possible confusion between the pressure which characterizes the dissolved salt and the totally different vapour-pressure of the solution, and so the term *osmotic pressure* is employed. Every dissolved substance exercises, then, an osmotic pressure, the magnitude of which depends in the first instance on its concentration.

Pfeffer's experiment makes this fact plain. A vessel of porous material, such as terra cotta, can be so doctored by the deposition of a colloid matter within its pores as to render it impermeable to dissolved substances while it remains permeable to water. Such a "semi-permeable cell" may be filled with a solution of (say) sugar, closed, and immersed in pure water; and, if the interior of the cell be properly connected with a manometer, this will indicate excess of pressure inside as compared with outside—an excess which increases to a maximum and then remains steady. The manometer then indicates the osmotic pressure of the sugar at the particular concentration which characterizes that solution. The theory of the experiment is plain. As water is free to pass through the walls of the cell either way, the pressure inside and out will become equal *so far as the water causes it*, but inside the cell there is also the pressure of the sugar, which is prevented from diffusing outwards. A proper understanding of this experiment removes any doubts one may start with as to the osmotic pressure being really a characteristic of the dissolved substance and independent of the solvent.

But the experiment has done much more. It has given a method of quantitatively studying the osmotic pressure and its variation (1) with change of concentration, for the same substance and temperature; (2) with change of temperature, for the same substance and concentration; (3) with change of substance, for the same concentration and temperature.

The general outcome of such experiments may be briefly stated, and it will be seen to give a striking justification of the title "the gaseous theory of solution." (1.) Boyle's law holds good for matter in solution. (2.) Charles's law holds good for matter in solution. (3.) Avogadro's law holds good for matter in solution. These are the three gaseous laws which, as you know, may be compressed into the single formula $p . v . \mathrm{M} = \mathrm{R} . \mathrm{T}$, where p is pressure, v is the volume of unit weight of the gas, M is its molecular weight, T is its absolute temperature, and R is a constant—the same for all gases under all conditions. We may now safely apply the same formula to the state of solution, using p for osmotic pressure, v for the volume of that quantity of the solution which contains unit weight of the substance, and M and T as before. R is still a constant for all substances; but has it a different value in this new connection? Well—and this is our fourth point—experiments have proved (4) that R has the same value for the dissolved state as it has for the gaseous state. To put this in words, we may say that the osmotic pressure of a substance in solution is equal to that pressure which the same quantity would exercise if it could be confined as a gas at the same temperature and within the same space as its solution now occupies.

It is hardly necessary to say that the gaseous laws are not absolutely and rigidly true in this new connection, any more than when applied to gases and vapours themselves; but I shall have occasion to say a good deal about one class of exceptions—or apparent exceptions—that would at first sight appear to contradict the laws altogether. First, however, let us consider the rule, before we go to the exceptions. Remember that all that I have told you has been proved by exact experiments with Pfeffer's semi-permeable cell. But it is interesting to find that, as usual, Nature forestalled man by many ages with this invention. It has been shown that plants are provided with cells which act on exactly the same principle; in which the sap is enclosed by a membrane through which water can pass but the dissolved matter cannot, and this is enclosed by another membrane permeable to both water and dissolved matter. Certain ingenious experimenters (particularly de Vries) have turned such delicate organic apparatus to account in the labotory, and have thus conducted reseaches, the general result of which has been to amply confirm the laws of osmotic pressure as deduced from Pfeffer's work.

Now, if you accept the laws as expressed in the equation $p.v.M=R.T$, an important result at once follows. If we have a substance whose percentage composition is known, but whose molecular weight is not known, we may deduce the molecular weight from the measurement of its osmotic pressure in a solution of ascertained concentration at a definite temperature, for then in the equation M will be the only unknown quantity. I need hardly remind an assemblage of chemists that hitherto the only reliable method of determining the molecular weight of a body has been the measurement of its volume, temperature, and pressure in the gaseous state, and that there are a vast number of compounds which cannot be vaporised by heat without decomposition. The extension of the same method to these very substances in solution is the direct consequence of the discovery that solution *is* vaporisation, and is as important practically as it is interesting theoretically.

There are drawbacks, however, to this method from a practical point of view. Exact experiments with osmotic cells, whether of the natural or the artificial kind, are difficult to carry out. It is fortunate therefore that the laws of osmotic pressure lead up to two other generalisations, each of which has given us a method for determining molecular weights that is of greater value to the chemist, because practically easier, than the theoretically simpler parent method. Parenthetically I should explain that I am by no means following the chronological order of discovery.

Starting with the laws of osmotic pressure, van't Hoff has mathematically demonstrated that the vapour-pressure of a solution must be lower than that of its pure solvent at the same temperature, and that the relation between these two pressures may be expressed by the following formula:—

$f' = f\left\{1 - \frac{n.s}{N.s'}\right\}$, where f' is the vapour-pressure of the solution, f that of the pure solvent, n the number of molecules of the substance in N molecules of the solvent, and s and s' the specific gravities of solvent and solution respectively. If only very dilute solutions be employed, s and s' are so nearly equal that they may be left out of account, but this is not true of stronger solutions. In the former case the equation becomes $f' = f\left\{1 - \frac{n}{N}\right\}$; so that one gramme-molecular weight of any substance dissolved in a hundred gramme-molecular weights of any solvent lowers its vapour-pressure by $\frac{1}{100}$ of its value. It follows from this that dilute solutions of different substances in the same solvent which have the same osmotic pressure (or are *isotonic*) have also the same osmotic pressure. Obviously, then, measurements of vapour-pressure may take the place of measurements of osmotic pressure for the determination of molecular weights. Raoult was the first to use the method; indeed, he did so before the theory of it had been explained. But we owe the prettiest and simplest development of it to Tamman and Walker. This consists in passing the same current of air for some time through first the solution and then the pure solvent, contained in modified Liebig's bulbs, which are weighed separately. The loss of weight of the solution is proportional to f', and that of the solvent to $f - f'$, while the sum of the losses is proportional to f. If, then, we know the concentration of the solution, we have all the necessary data for ascertaining the molecular weight of the substance.

The second generalization concerns the freezing-point. When a dilute solution is cooled to the point at which the pure solvent would freeze, it does not do so, but at a somewhat lower temperature the solvent begins to separate out in the solid state, leaving the other substance in solution. Thus water freezes below 0°C., or ice melts below 0° when it is in presence of dissolved salt; but it is pure ice that separates. Now, it has been deduced from theory as well as proved experimentally (by Ramsay and Young) that the freezing-point of a liquid is that point—the only one—at which the curves meet which represent the change of vapour-pressure of the solid and of the liquid with change of temperature; and the forms of these curves are such that this common point must necessarily fall at a lower temperature if by any cause the vapour-pressure of the liquid is reduced. But we know that the presence of dissolved matter does reduce the vapour-pressure of a liquid, so that we have at once an explanation of the lowering of the freezing-point in such cases. Moreover, for very dilute solutions in one and the same solvent (but not otherwise), it can be easily shown that this reduction of the freezing-point is directly proportional to the reduction of vapour-pressure, and so, as we have seen, to the osmotic pressure and to the molecular concentration.

Moreover, starting from the laws of osmotic pressure and thermo-dynamical considerations, van't Hoff has shown that the effect on the freezing-point can be calculated from the absolute temperature of the original freezing-point of the solvent and its latent heat of fusion, and the numbers calculated by him agree with the experimental numbers of Raoult. The freezing-point of water is lowered 1·028° by the solution of a substance in the ratio of one molecule to a hundred; while in the case of acetic acid and of benzene the effect is somewhat less—namely, 0·64°. Here, then, we have another practical method for the determination of molecular weights of substances to which the older methods cannot be applied; and, indeed, this is so simple and (with certain limitations) so reliable that it might often be substituted for the vapour-density method as a matter of choice. The apparatus is of the simplest kind, provided a sufficiently delicate thermometer be available. Obviously solvents are to be preferred which, like the three I have named, have freezing-points not far removed from the ordinary temperature of a laboratory, but in special cases solvents of much higher or lower freezing-points may be employed.

To give an account of the interesting results that have been obtained already by Raoult and the experimenters who have followed him with this and the vapour-pressure methods as applied to organic compounds would take too long; but I may direct your attention to the attempts to determine the molecular weights of the metals by their effect on the vapour-pressure of mercury (Ramsay), on the freezing-point of sodium (Tamman), and more particularly on the freezing-point of tin

(Heycock and Neville). The result of these experiments is to show that at all events the majority of metals resemble mercury in having monatomic molecules, and thus the impression founded on vapour-density experiments at high temperatures with zinc and cadmium is confirmed. On the other hand, it may be mentioned that the belief in the complexity of the molecules of some of the non-metallic elements under certain conditions, such as phosphorus and sulphur, on which doubts have been cast by recent observations of vapour-density, has been strengthened by the evidence afforded by these new methods.

I have hinted at the existence of difficulties in the way of the advocates of van't Hoff's gaseous theory of solution. Difficulties—and great ones—were met with at the outset. A law to which there are a large number of unexplained exceptions has very little right to the name of law; and those who seek to clothe the law in a theory must make it large enough to include the exceptions or give up the attempt. Avogadro's law, as applied to gases, was long in suspense; for did not ammonium salts, phosphorus pentachloride, and other substances exhibit "abnormal" vapour-density? But, as we know, the conception of dissociation came to the rescue, by which the law was not only saved from destruction, but strengthened and greatly enriched. And exactly so has it been with van't Hoff's extension of Avogadro's law to matter in solution; only that the difficulties in this case were obvious from the first, and it was not so hard to find the means of conquering them.

Since direct experiments on osmotic pressure were difficult, and not many had been made, the new theory had to be tested chiefly by recorded experiments on the freezing-points of solutions, on which much work had been done, chiefly by de Coppet and Raoult. Here the exceptions were met with. Among inorganic salts especially, abnormal results were obtained where one might have least expected them. Some salts and acids gave practically twice the molecular reduction of freezing-point that should have been, while others gave more or less apparently erroneous results. The inference one would naturally draw at first sight would be that the gaseous laws do not really hold good in solutions. But examination of the facts brought out a striking result: these apparent exceptions were one and all electrolytes. This suggested that the explanation was to be found in a theory of electrolytes put forward first by Arrhenius—an explanation which is in accord with many other phenomena not hitherto understood, and which has led already to most important developements. The new hypothesis may be put thus: The doctrine of dissociation, known to be an essential adjunct of the theory of gases, may fairly play a part in the gaseous theory of solution: the abnormal behaviour of electrolytic solutions can thus be explained: for other reasons Clausius has already taught us to believe that at least a small percentage of the molecules of an electrolyte must be dissociated into its ions at any given moment: assume therefore that this percentage is large enough, and all difficulties disappear. Take, for instance, the case of potassium nitrate. A dilute solution of this salt gives practically twice the osmotic pressure, twice the lowering of vapour-pressure, twice the depression of freezing-point, that it should give by comparison with non-electrolytes on the assumption that its molecule is KNO_3. During electrolysis we know that this salt is split into the ions K and NO_3. If this dissociation pre-exists in the solution, and if it be practically complete, there are in reality *two* molecules where we reckoned on only one, and the results obtained no longer contradict the law, but support it. So also with other electrolytes. The extent of dissociation is by no means always the same; and it is easy to see how, if the hypothesis be accepted, the exact extent—the ratio of molecules decomposed to molecules intact—may be calculated from the degree of departure from normal osmotic effects. Now, this has been proved to vary with concentration and temperature, for the most part just as would be expected from the influence of pressure and temperature in ordinary cases of dissociation, so that a great support is here afforded to the hypothesis. Again, a number of facts are accounted for that it is very difficult to understand without the dissociation theory—facts which show that an electrolyte in solution owes many of its properties to two independent factors, one supplied by and characteristic of the positive ion, the other due to the negative ion. Arrhenius and Ostwald have made these arguments clear; and the latter has called attention especially to the following one. The heat of neutralsiation of an acid by a base in dilute solution has been shown by Thomsen to be practically independent of the nature of either, so long as only strong acids and bases are considered. This, according to old ideas, is extraordinary; for why should the actions

$$HCl + KOH = KCl + H_2O$$

and

$$HNO_3 + NaOH = NaNO_3 + H_2O$$

be of equal thermal value, different salts being formed? By the new ideas, on the other hand, we could expect nothing else, for the dissociation of such strong acids and alkalis is practically complete in dilute solution; and why should the actions

$$H + Cl + K + OH = Cl + K + H_2O$$

and

$$H + NO_3 + Na + OH = NO_3 + Na + H_2O$$

be of different thermal value, one molecule of water being formed in each case from hydrogen and hydroxyl? Such thermal differences as are found in different neutralisations are accounted for by different degrees of dissociation.

From the purely chemical point of view a good deal may be said effectively in favour of this, to chemists, at first sight startling hypothesis. How is it that alcoholic solutions of ethyl chloride, ethyl iodide, ethyl sulphide, do not give precipitates of the silver salts when treated with silver nitrate? Why should they not, when solutions of metallic chlorides, iodides, and sulphides give the reaction so readily? Surely KCl, which is so stable a compound, should not break up more easily than one in which Cl is united to carbon? And yet it does; and the explanation now offered is that KCl is *not* a stable compound when treated with solvents, but an exceedingly unstable one, while C_2H_5Cl proves itself to be stable by its refusal to yield Cl to Ag. Chemists must be careful as to the use of that word "stable." They are rightly accustomed to regard inertness at high temperatures—a resistance to the disintegrating influence of heat—as a proof of stability; and yet it is a common thing to speak as if the very opposite quality of great activity—or tendency to decompose under the influence of material agents in solution—were a sign of that same quality. Perhaps this is because the two properties often enough go together. Thus KCN is inert at very high temperatures, but is decomposed in solution by the weakest of acids, while AgCN breaks up easily on heating, and resists the action of acids. Which is the more stable cyanide? I fancy that depends on the special conditions, which must be defined before the answer can be given. According to the new ideas, the strongest acids and bases are the most dissociated in solution, and their *strength* depends on this fact, while weak ones like acetic acid are stable enough. And we are now to conceive that most of the reactions on which we are accustomed to rely in analysis—what may be called double decompositions in the wet way—involve the union of free ions, and not the interaction of compound molecules. Chemists have long recognised that such processes never give us a general test for an element, but only tests for the metals and radicles of salts—and that means the ions of electrolytes. Apparently, we must change our ideas about double decomposition, since the phrase itself is now a misnomer.

A relation between the degree of dissociation and the conductivity of an electrolyte obviously exists, since the strong acids and other much-dissociated compounds (as judged by osmotic phenomena) are the best electrolytes. This question has been investigated with most important results, due chiefly to Arrhenius and Ostwald. The molecular conductivity of a salt was comparatively long since shown by Kohlrausch to be one of those properties which are composed by addition, as I have already mentioned, of two factors due to the two ions. Now, only the dissociated ions contribute to this addition, so that alteration in the molecular conductivity depends entirely on the proportionate amounts of dissociation when different solutions of the same electrolyte are compared. The value of the molecular conductivity is found to increase more or less rapidly, according to the nature of the salt, as more and more dilute solutions are employed; but it attains a maximum, or practically so, within experimental limits. That maximum corresponds to complete dissociation. By comparing, then, the molecular conductivity of a given solution with that obtained for the same electrolyte in (practically) infinite dilution, we get a measure of the extent of the dissociation in the first; for $x = \frac{\mu}{\mu\infty}$, where μ and $\mu\infty$ represent the molecular conductivities of the two solutions, and x the proportion of dissociated molecules in the stronger one. The results obtained by this mode of measurement confirm those arrived at by the osmotic methods; only they are very much more exact.

Finally, Ostwald has shown that from this value of x for any electrolyte can be calculated the coefficient of affinity k, by the formula $k = \frac{x^2}{V(1-x)}$, a value which is constant for all dilutions. This coefficient is of the very utmost importance, for it is found in the case of acids to be practically identical with the coefficients of affinity as determined from Thomsen's thermo-chemical data and by the purely chemical methods. By determinations of conductivity, then, it is possible to ascertain that all-important coefficient of a substance which expresses its chemical activity, which regulates its influence on every chemical action in which it can play a part. And this is so far explained by, and is one of the greatest results of, the hypothesis of the dissociation of electrolytes, which is itself an essential feature of the gaseous theory of solution.

I must not allow myself to convey a false impression. Although this theory, from its power of explaining so many facts consistently, and from the great results it has achieved, has gained much ground with chemists and physicists, there are not wanting advocates of the older hydrate theory of solution, who reject its fundamental doctrines uncompromisingly. They accept the methods of inquiry and many of the facts of the van't Hoff school—how could they do otherwise?—but decline to accept the theory that is advanced to explain them. Most of their arguments appear to me to have but little weight, being based upon misconceptions of the theory they are criticizing; while some of the facts put forward prove, on examination, to tell against themselves. Moreover, we find that the hydrate theory which they advocate leads to an alarming intimacy with such compounds as $100H_2SO_4 . H_2O$ (*i.e.*, a hydrate containing only 0·0018 per cent. of water); and chemists are justified in demanding the very strongest testimonials as to character before they consent to make such acquaintances. On the other hand, it must be confessed that one or two arguments against the gaseous theory appear to be, in the meantime at any rate, real stumbling-blocks, which want removing.

One difficulty has struck me that has not, so far as I am aware, been raised. If it be true that dissolved matter is really in the state of vapour, and that such a salt as KI is dissociated by solution into its ions, K and I, then these ions should obey the gaseous laws, and, among them, Graham's law of gaseous diffusion. Of course the absolute rates of diffusion will be slow, on account of the friction-causing character of the space occupied; but the ratio of these rates should be in accord with the law. There must be, to start with, equal concentrations, equal osmotic pressures, and, of course, equal temperature; but the masses of the two ions will be as 19 to 127. Should not, then, a partial separation by diffusion be possible, which would prove the dissociation in the same way that it has been proved in the case of actual vapours? This is not borne out by experiment. The rates of diffusion of salts are roughly proportional to their molecular conductivities. These are additively composed of the separate ionic values, which represent the rates of migration of the ions during electrolysis—itself a kind of diffusion. Now, these values have been determined, and it has been shown that they are practically equal in the case not merely of K and Cl (which we could understand), but of K and I. It would appear, then, that among the gaseous laws obeyed by dissolved matter Graham's law of diffusion cannot be included. This, probably, admits of explanation; but, as it has puzzled myself, I may be pardoned for stating my difficulty.

I wish now to ask your attention more particularly to the actual process of dissolving, and then to lay before you a hypothesis which, as it seems to me, is a logical consequence of the general theory.

Imagine, then, a soluble solid in contact with water at a fixed temperature. The substance exercises a certain pressure, in right of which it proceeds to dissolve. This pressure is analogous to the vapour-pressure of a volatile body in space, the space being represented by the solvent; and the process of solution is analogous to that of vaporisation. As the concentration increases, the osmotic pressure of the dissolved portion increases and tends to become equal to that of the undissolved portion, just as, during vaporisation in a closed space, the pressure of the accumulating vapour tends to become equal to the vapour-pressure of the liquid. But if there be enough water present the whole of the solid will go into solution, just as the whole of a volatile body will volatilise if the available space be sufficient. Such a solution may be exactly saturated or unsaturated. With excess of the solvent it will be unsaturated; and the dissolved matter will then be in a state comparable to that of an unsaturated vapour, for its osmotic pressure will be less than the possible maximum corresponding to the temperature. On the other hand, if there be not excess of water present during the process of solution, a condition of equilibrium will be arrived at when the osmotic pressure of the dissolved portion becomes equal to the pressure of the undissolved portion, just as equilibrium will be established between the volatile substance and its vapour if the space be insufficient for complete volatilisation. In such a case we get a saturated solution in presence of undissolved solid, just as we may have a saturated vapour in presence of its own liquid or solid.

So far we have supposed the temperature to be stationary; but it may be raised. Now, a rise of temperature will disturb equilibrium in either case alike; for osmotic pressure and vapour-pressure are both increased by this means, and a re-establishment of equilibrium necessitates increased solution or vaporisation, as the case may be.

Now, what will this constantly-increasing solubility with rise of temperature eventually lead to? Will it lead to a maximum of solubility at some definite temperature beyond which increase becomes impossible? Or will it go on in the way it has begun, so that there will always be a definite, though it may be a very great, solubility for every definite temperature? Or will it lead to infinite solubility before infinite temperature is attained? One or other of these things must happen, provided, of course, that chemical change does not intervene.

Well, let us be guided by the analogy that has hitherto held good. Let us see what this leads us to, and afterwards examine the available experimental evidence. We know that a volatile liquid will at last reach a temperature at which it becomes infinitely volatile—a temperature above which the liquid cannot possibly exist in the presence of its own vapour, no matter how great the pressure may be. At this temperature equilibrium of pressure between the liquid and its vapour becomes impossible, and above this point the substance can exist only as a gas. This is the critical temperature. And so it seems to me that, if we carry our analogy to its logical conclusion, we may expect for every substance and its solvent a definite temperature above which equilibrium of osmotic pressure between undissolved and dissolved substance is impossible,—a temperature above which the substance cannot exist in presence of its own solution, or in other words a temperature of infinite solubility. This may be spoken of as the critical solution-temperature.

But a little consideration shows that in one particular we have been somewhat inexact in the pursuance of our analogy. For we have compared the solution of a *solid* body to the vaporisation of a volatile *liquid*. We can, however, do better than this, for volatile solid bodies are not wanting. It is to these, then, that we must look in the first instance. Now, a volatile solid (such as camphor or iodine) will not reach its critical point without having first melted at some lower temperature; and a similar change should be exhibited in the solution process. At some definite temperature, below that of infinite solubility, we may expect the solid to melt. This *solution melting-point* will not be identical with, but lower than, the true melting-point of the solid; and for the following reason: No case is known, and probably no case exists, of two liquids one of which dissolves in the other and yet cannot dissolve any of it in return. Therefore there will be formed, by melting, not the pure liquid substance, but a solution of the solvent in the liquid substance. Hence the actual melting- or freezing-point will be lower than the true one, in right of the laws of which I have spoken when discussing Raoult's methods in the earlier part of this address.

From this solution melting-point upwards, we shall then have to deal with two liquid layers, each containing both substance A and solvent B, but the one being mostly substance A and the other mostly solvent B. These may be spoken of as the *A layer* and the *B layer*. As temperature rises the proportion of A will decrease in the A layer and increase in the B layer; and every gramme of A will occupy an increasing solution-volume in the A layer (B being absorbed there) and a decreasing solution-volume in the B layer. At each temperature the osmotic pressure of A in the two layers must be equal. The whole course of affairs, as thus conceived, now admits of the closest comparison with the changes which accompany gradual rise of temperature in the case of a volatile liquid and its saturated vapour. The liquid is like the substance A in the A layer; the vapour (which is the same matter in another

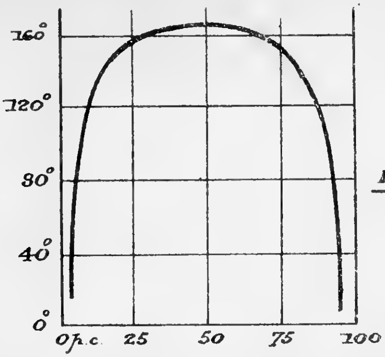

FIG. 1.

Per cent of Aniline in saturated solution.

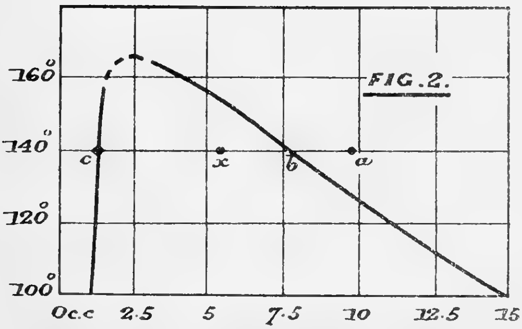

FIG. 2.

Specific solution volumes of Aniline.

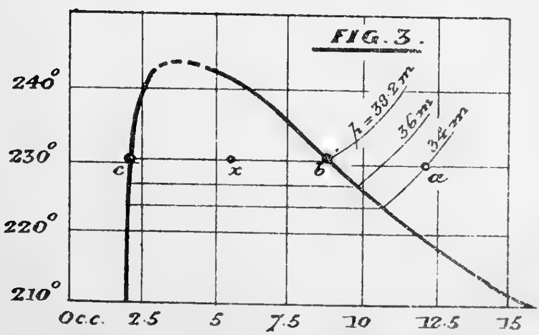

FIG. 3.

Specific volume of Alcohol.

To illustrate Paper by Prof: O. Masson.

state) is like the substance A in the B layer. As temperature rises the liquid diminishes in total quantity, the vapour increasing; but the specific volume of the liquid increases, while that of the vapour decreases. The residual liquid is, in fact, constantly encroaching on the space of its vapour, just as the residual substance A in the A layer is constantly absorbing the solvent B from the B layer. Finally, in either case, the specific volume of the substance will become identical in both layers, which means that the layers themselves will become homogeneous and indistinguishable. Our system will then have reached its critical temperature,—the temperature of infinite volatility in the one case and of infinite solubility in the other.

So much for hypothesis. Are there any facts in support of it? Well, in the first place the hypothesis demands that (in the absence of chemical change) increase of solubility with rise of temperature shall be as general a law as increase of vapour-pressure; and we find that this agrees with the known facts, more especially since Tilden and Shenstone (Phil. Trans., 1884) cleared up certain doubtful cases. Secondly, the hypothesis seems to demand some connection between the true melting-points of salts and the rates of their increase of solubility; and such a relation has, in a general way, been established by the same observers. Thirdly, we have the fact, in complete accordance with the hypothesis, that, while no case is known of a solid body having, as such, infinite solubility in any simple solvent, several cases are known of liquids of infinite solubility and also of *solids which, after they have melted in presence of their own solution, become at some higher temperature infinitely soluble.* This last statement refers to the cases investigated by Alexéeff (Wiedemann's Annalen, 1886), of which I must say a good deal more directly. It would seem to apply also to the case of silver-nitrate, which Tilden and Shenstone described as dissolving in water to the extent of 18·25 parts to 1 at so low a temperature as 130° C. The true melting-point of the salt is 217°; and I have seen it stated (but have been unable to find the published account) that Shenstone has himself shown it to be fusible in water and of infinite solubility at quite reachable temperatures.

With regard to substances that are liquid under ordinary conditions, we have the well-known fact that some pairs are infinitely soluble in one another, while others exhibit the phenomenon of only partial solubility. The hypothesis would draw no hard-and-fast distinction between these cases, except the practically important one that such a mixture as that of ether and alcohol, which belongs to the first class, is usually above its critical solution-point, while such a one as ether and water, which belongs to the second class, is usually below it. It should be possible, according to the hypothesis, to cool mixtures of ether and alcohol sufficiently to cause separation into two layers, similar to those observed at the ordinary temperature in the case of ether and water; but I do not know that this has yet been put to the test of experiment.

Alexéeff's experiments appear to me to be of the very highest importance, and to merit the closest attention in any inquiry into the nature of solution. As already stated, they afford the strongest support to the hypothesis which I have been discussing: indeed, had it not been for this support I should hardly have ventured to discuss it at all. They refer to solutions in water, below and above 100°, of phenol, salicylic acid, benzoic acid, phenylate, and aniline, and to solutions in molten sulphur of chlorobenzene, benzene, toluene, aniline, and mustard-oil. All these afford instances of reciprocal partial solution throughout a considerable range of temperature, leading eventually at a definite temperature to infinite solubility. Several of them afford instances also of solid substances with solution melting-points below their true melting-points.

Alexéeff experimentally determined the temperatures at which different mixtures of the same two liquids are just converted into clear solutions; or, in other words, he ascertained the strengths of the saturated solutions corresponding to different temperatures. For each pair of liquids he found that when a particular strength of mixture is reached the temperature of saturation is lowered by further addition of either ingredient. Thus, a mixture of about 37 parts of aniline to 63 of water requires a temperature of 164·5° to convert it into a homogeneous solution, but one of 21 of aniline to 79 of water assumes this condition at 156°, while one of 74 of aniline to 56 of water does so at 157·5°. He plotted his results in the form of curves, with temperature and percentage strength as the two co-ordinates. The curve for aniline and water is shown in Fig. 1, Pl. IV.; and this may be taken as a fair representative, the general form of all being similar. It is at once apparent that for every temperature up to a certain limit there are two possible saturated solutions—one of water in aniline, and one of aniline in water. The limiting temperature at which there is but one possible saturated solution, and above which saturation becomes impossible, is called by Alexéeff the *Mischungs Temperatur*. It is what I have called the critical solution-temperature. It is, in the case of aniline and water, about 167°, as nearly as one can judge from the curve without a greater number of experimental points in this portion of it than Alexéeff gives us; and the corresponding saturation-strength is about 50 per cent. It is hardly necessary to say that this equality of the two ingredients is an accident which does not characterize all cases.

Now, imagine a 50-per-cent. mixture of aniline and water sealed up in a tube, shaken, and gradually heated. Let us assume that the tube is only large enough to hold the mixture and allow of expansion by heat, so that evaporation may be neglected as too small to materially complicate the result. The course of events will be exactly what I have described with reference to the hypothetical A layer and B layer. There will be formed a saturated solution of water in aniline, which we may call the *aniline layer*, and a saturated solution of aniline in water—the *water layer*. Given the temperature, the percentage strength of each layer may be read off from the curve. As the temperature rises the two layers will effect exchanges in such a way that the aniline layer will become poorer, and the water layer richer, in aniline; and at about 167° the two layers will have attained equal strength and become merged into one. Were we to start with the aniline and water in any other proportions by weight, there would still be formed the two saturated solutions, but their relative amounts would be different, and one or other would be used up and disappear at a lower temperature. To attain the maximum temperature of complete solution you must start with the exact proportions which correspond to that temperature.

But it is possible to learn even more from Alexéeff's work than he himself has made evident. Let me call your attention to the curve shown in Fig. 2,* Pl. IV., the data for which I have calculated in the following manner: From Alexéeff's percentage-figures was deduced the weight of water capable of dissolving, or being dissolved by, one gramme of aniline at each of his experimental temperatures, so as to form a saturated solution. Then, from curves showing the expansion of pure water and pure aniline (the latter drawn from Thorpe's data—Trans. Chem. Soc., 1880), there were read the specific volumes of these substances at each of Alexéeff's temperatures; and from the combined information thus obtained there was calculated the total volume of that quantity of the saturated solution at each temperature which contains one gramme of aniline. This is what I have already called the specific solution-volume. A slight error is involved by the fact that the volume of a solution is not exactly the sum of the volumes of its ingredients; but this error is necessarily small—too small

* In order to save space, only the upper portion of the curve is here represented, as it shows all that is essential to the argument. Of the twelve experimental points, one appears to be somewhat misplaced; but this does not affect that part of the curve which is shown in the figure.

to affect the general character of the curve, or the nature of the lesson to be learned from it.

The specific solution-volumes of the aniline, calculated in this manner, were found to be as follow:—

Temperature.	Specific Solution-volumes of Aniline. In Aniline Layer.	In Water Layer.
8°	1·015	—
16°	—	32·16
25°	1·036	—
39°	1·053	—
55°	—	28·27
68°	1·087	—
77°	—	19·55
137°	1·297	—
142°	—	7·696
156°	—	5·248
157·5°	1·498	—
164·5°	—	3·412

These specific solution-volumes are represented as abscissæ in Fig. 2, with the temperatures as ordinates. For the sake of comparison I have placed side by side with it a specific volume and temperature-curve (Fig. 3, Pl. IV.) for pure alcohol and its saturated vapour, plotted from the experimental data of Ramsay and Young (Phil. Trans., 1886). The reason that alcohol was chosen is simply that the data were convenient to my hand.

The two curves are strikingly similar in form and significance. In Fig. 3 we see the specific volume of liquid alcohol increasing slowly with rise of temperature, while that of the saturated vapour rather rapidly decreases. In Fig. 2 we see the specific solution-volume of the aniline in the aniline layer slowly increasing, while that of the aniline in the water layer decreases more rapidly, with rise of temperature. In Fig. 3 we see that above the critical point the existence of liquid alcohol in presence of its vapour is impossible. In Fig. 2 we see that above the critical solution-point the existence of an aniline layer in presence of a water layer is impossible. In Fig. 3 we see an enclosed area which represents those temperatures and specific volumes which are mutually incompatible. In Fig. 2 we see an enclosed area which represents those temperatures and specific solution-volumes which are mutually incompatible. In Fig. 3 we see that any two points on the curve which correspond to equal temperature also correspond to equal vapour-pressure. In Fig. 2 we see that any two points on the curve which correspond to equal temperature must also, from the nature of the case, correspond to equal osmotic pressure. In Fig. 3 some of the pressures are indicated, as this can be done from Ramsay and Young's data. In Fig. 2 the value of the osmotic pressures cannot be given, as they have not been experimentally determined. In Fig. 3 any point outside of the curve and to the right, as at *a*, corresponds to the state of unsaturated alcohol vapour, whose temperature, specific volume, and pressure are indicated—the last by the isobaric line which passes through the point. In Fig. 2 any point outside the curve and to the right, as at *a*, must correspond to the state of an unsaturated aqueous solution of aniline, whose temperature and specific solution-volume can be read, and whose osmotic pressure could be indicated by an isobaric line had we the data for plotting it. A little thought makes it evident, too, that such isobaric lines would follow the same general course as those shown in the alcohol diagram.

Now consider what must be the effect of gradually decreasing the volume of the unsaturated vapour in the one case and the solution-volume of the aniline in the unsaturated aqueous solution in the other, while temperature is kept constant. In the case of the vapour (Fig. 3) the point *a* will pass to the left across lines of increasing pressure until the vapour becomes saturated at *b*. Then, if the diminution of volume continue, a portion of the vapour will condense to the liquid state, or be transferred to *c*, while the rest remains saturated vapour at *b*. With continued decrease of volume, the proportion condensed will constantly increase, but there can be no alteration of pressure till all is condensed; and after that nothing but a very slight diminution of volume is possible without a lowering of temperature. Well, how are we to diminish the solution-volume of our aniline in the unsaturated aqueous solution? Clearly, by depriving the solution of some of its water, so as to leave the same quantity of aniline distributed throughout a smaller space. And what will be the result of doing this while temperature is kept constant? Evidently, as in the other case, the point *a* (Fig. 2) will travel to the left across lines of increasing osmotic pressure until it reaches *b*—that is, until the solution is a saturated one; and after that, if more water be abstracted, some of the aniline will be thrown out or condensed, not as pure aniline, but as a saturated solution of water in aniline; so that two layers will now co-exist, the aniline in one having the specific solution-volume represented at *b*, and the aniline in the other having that represented at *c*. This transference from *b* to *c* will continue, as water is abstracted, until the ratio of residual water to aniline is just enough to give the whole of the latter the specific solution-volume shown at *c*. At this stage the water layer will disappear, and only a saturated solution of water in aniline will be left; and after this only a very small volume-change can possibly result from further abstraction of water, as the specific solution-volume is already not far from the specific volume of pure aniline itself at the same temperature.

To complete the comparison of the two curves, let me point out that, just as we can from Fig. 3 calculate the distribution of the alcohol between its liquid and vapour layers under given conditions, so can we calculate from Fig. 2 the distribution of the aniline between the aniline layer and the water layer under given conditions. In the former case, if the total volume of a tube containing n grammes of alcohol at, say, 230° be $n \times x$, and if x be marked off between b and c on that line of temperature, then (x, b, and c standing for the volumes which can be read off on the horizontal base-line) $n \cdot \frac{x-c}{b-c}$ is the weight of the alcohol in the vapour layer, and $n \cdot \frac{b-x}{b-c}$ is its weight in the liquid layer, and the volumes of the two layers in cubic centimetres are $n \cdot b \cdot \frac{x-c}{b-c}$ and $n \cdot c \cdot \frac{b-x}{b-c}$ respectively, which are together equal to $n \cdot x$. Just so also with the aniline and water mixture (Fig. 2). If $n \times x$ be the total volume of the mixture (both layers together) containing n grammes of aniline at, say, 140°, and if x be marked off as it was in the other case, then $n \cdot \frac{x-c}{b-c}$ is the weight of aniline in the water layer, and $n \cdot \frac{b-x}{b-c}$ is its weight in the aniline layer, and the total volumes of the two layers are $n \cdot b \cdot \frac{x-c}{b-c}$ and $n \cdot c \cdot \frac{b-x}{b-c}$ respectively, which are together equal to $n \cdot x$. If the actual weights of aniline and water in the mixture be given, the value of x can be calculated with a fair approximation to accuracy in the manner used in plotting the curve ; and so all the facts concerning the distribution at all temperatures become known.

Now, if it be remembered that this case of aniline and water is not an isolated one, but typical of many cases experimented on by Alexéeff, and if it be remembered also that there exists no direct experimental evidence to show that the law which governs these cases is not the general law regulating all simple solutions, it must, I think, be granted that the facts do somewhat strongly support the hypothesis of a critical solution-point, which I deduced in the first instance from the general theory of solution. It may be summed up as follows :—

(1.) In every system of solution which starts with a solid and its simple solvent, there is a solution melting-point for the solid which is lower than its true melting-point. Above this temperature the system consists of two separate liquids, each of which is a saturated solution.

(2.) These two liquids become one homogeneous solution at a temperature which depends on the ratio of the original ingredients. There is one ratio which demands a higher temperature than any other. This is the critical solution-temperature, above which either ingredient is infinitely soluble in the other.

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1. *On Molecular Volumes and Boiling-points in relation to Chemical Character.*

By Orme Masson, M.A., D.Sc.

A very large number of determinations of molecular volumes of liquid compounds at their ordinary boiling-points has been made by various observers since Kopp proclaimed his well-known law. According to this law, the molecular volume of a compound is the sum of the atomic volumes of its constituent atoms. Thus every element has its atomic-volume value, which it carries with it into its compounds. In this sense the property is an additive one; but it is also to some extent a constitutive property, since the facts require that one or two of the elements, at least, should be credited with alternative atomic volumes and a power of entering into combination sometimes with one value and sometimes with another. Later researches proved that isomeric substances have not exactly equal molecular volumes, as they should have if it were entirely an additive property, that the constitutive feature is of general importance, and that it is wrong to regard the atomic volume of an element, as determined by a study of its compounds, as more than a fair approximation to an average value. At a definite boiling-point the molecular volume of each liquid compound is a definite quantity; but any attempt to divide this volume among the constituent atoms can only lead to approximately true results. There is, however, evidence that the atomic volume of an element in the free state (when it is in the liquid condition at its boiling-point under atmospheric pressure) is approximately equal to its average atomic volume in compounds, or to the smaller of its volumes when it possesses two. This has been shown to hold good of bromine, phosphorus, sulphur, and quite lately of chlorine also.

Valuable work has thus been done by attempts to analyse molecular volumes and so study the contributing volumes of the elements as influenced by their modes of combination, or (reversing the problem) by attempts to study the modes of combination by assuming definite contributing volumes to characterize the elements when combined in certain ways. But comparatively few attempts have been made to study the manner in which the molecular volume of a compound, taken as a whole, and considered as one of its characteristic physical properties, may be correlated with other such properties of the same compound. The property which is obviously most likely to have a close connection with the volume at the boiling-point is the temperature of ebullition itself, reckoned, of course, on the absolute scale; and, as this temperature varies with the pressure, that pressure, or (what is the same) the vapour tension of the liquid at its boiling-point, must also be taken into account.

The few records that we yet possess of the variation of the boiling-point, pressure, and molecular volume of a liquid from low pressures up to the critical point, are of great interest and value, but the data have been as yet too few to lead to any very certain general results, such as theoretical considerations point to.

I was lately led to a study of the connection of the molecular volumes and boiling-points with one another and with the chemical characters of liquids by observing a certain regularity in the behaviour of the ethides of the elements. Having determined the molecular volumes of the three closely-related compounds, ethyl chloride, bromide, and iodide, I was struck with the fact that they were directly proportional to the absolute boiling-temperatures. An examination of all the available recorded data proved that this equality of the ratio $\frac{V}{T}$ always characterizes the fluorine, chlorine, bromine, and iodine compounds of the same organic radicle. The actual deviation from perfect equality exceeds 2 per cent. of the total value in only two cases out of the eleven groups of substances examined; but a small variation in each group, after allowance is made for experimental error, does seem to occur in such a way that $\frac{V}{T}$ is greatest for the fluoride and least for the bromide. Practically this variation may be neglected.

The question whether $\frac{V}{T}$ is equal for the compounds of the same organic radicle with any other natural group of elements was one which could not, and cannot yet, be answered by an appeal to direct experiment, as there is a want of data with regard to the molecular volumes. But by using Thorpe's values for the average atomic volumes of the elements it was possible to calculate the molecular volumes with sufficient approximation to the truth, and then, making use of known boiling-points, to calculate the values of $\frac{V}{T}$. This was done, and the result left no doubt at all that the law observed to hold good for compounds of the elements of Group VII. holds good also for the elements of the other natural groups. It was proved, however, that the law, in its present form, cannot be extended to inorganic compounds, but must be confined to the compounds of elements with hydrocarbon radicles. The law, then, fully stated, is as follows:—

If liquid compounds of the elements of the same natural group with the same hydrocarbon radicle be compared at temperatures at which they have equal vapour-pressures, the volumes occupied by unit weights are inversely proportional to the molecular weights and directly proportional to the absolute temperatures.

It is easy to prove as a corollary that *such compounds also undergo equal expansions in changing from liquid into vapour.*

Further, when the above law is considered in connection with a thermo-dynamical relation discovered a few years ago by Ramsay and Young, it follows that *the latent heats of vaporisation of such compounds follow exactly the same law of relation to temperature as do the molecular volumes* themselves. This last generalisation is due to Mr. E. F. J. Love, who called my attention to it.

When different liquid compounds are compared, what determines the equality or inequality of $\frac{V}{T}$? In the case of very nearly-related compounds, as defined in the law, we get equality. That is to say, you can change C_2H_5Cl into C_2H_5I or C_2H_5Br (for example) without materially altering the value of $\frac{V}{T}$; but you cannot change either of them into $(C_2H_5)_2O$ without such alteration; nor can you replace the ethyl by propyl without such alteration. Further, $\frac{V}{T}$ has a different value in the compound CCl_4 (for example) from what it has in the chemically similar compound $SnCl_4$. Hence that kind of chemical similarity which we are accustomed to associate with isomorphism has to do with equality of $\frac{V}{T}$; but it is not the only condition necessary.

Reference to Professor Young's research on the physical constants of benzene and its monohalogen derivatives (Trans. Chem. Soc., 1889)—a research which it would be difficult to praise too highly—afforded a clue to the other essential factor. For in the compounds C_6H_5F, C_6H_5Cl, C_6H_5Br, and C_6H_5I we have a case in point: the value for $\frac{V}{T}$ is constant except for the usual very slight variations already mentioned. Now, these compounds, according to Young, have all the same, or very nearly the same, critical pressure; so that at any equal pressure (*e.g.*, 760mm.) they are at equal fractions of their critical pressure, and are truly comparable. From this and other facts proved by Young, and from the general similarity between his group of compounds and the other groups concerned, I drew the conclusion that, *in all probability, equality of the ratio* $\frac{V}{T}$ *in different compounds at equal pressure depends on a combination of the following: (1) similarity of chemical constitution of a kind akin to that concerned in isomorphism, (2) equality of critical pressure; and implies also (3) constancy of the ratios* $\frac{V}{V'}$ *and* $\frac{T}{T'}$ *at all equal pressures.*

My publication (Phil. Mag., Nov., 1890) of the paper of which I have here given a résumé induced Professor Young to publish (same journal and date) a preliminary account of the conclusions he had drawn from a hypothesis of van der Waals as tested by work of his own. These conclusions, which he only puts forward tentatively in the meantime, are three in number, and relate to the interconnection of volume, temperature, and critical pressure in the case of liquids. His first conclusion is practically identical with that which I have just quoted from my own paper. The second deals with the case of chemically-similar compounds of unequal critical pressure, including such cases as that of CCl_4 and $SnCl_4$, already referred to, and shows that these are comparable at equal fractions of their critical pressures, but not at equal pressures. The third conclusion refers to compounds which are not chemically similar and have not equal critical pressures, in which case no simple law can be at present indicated.

By observations on volumes and boiling-points at atmospheric pressure it is unlikely that any generalisations of interest, beyond those that I have already indicated, will be discovered. Professor Young, who is experimenting on liquids up to their critical points, is on the only safe path to the proper elucidation of the connection between pressure, temperature, and volume, which are the most important physical characters of a liquid, as they are of a gas. I for one shall await with great interest the further developments of his work. In the meantime, I may point out that the generalisation which I ventured to make, and which Professor Young independently arrives at, may be serviceable in this way: If a number of chemically-similar bodies give an equal value for $\frac{V}{T}$ at atmospheric pressure, and if the physical constants of only one of these bodies be known, those of the others can be provisionally and approximately calculated.

2. *Does Magnesium form Alkyl Compounds?*

By Orme Masson, M.A., D.Sc.

Mr. Wilsmore has described fully the many attempts which he has made to prepare magnesium ethide.* Having closely watched his work while it was in progress, I have been fully convinced by the results of these experiments that it is not possible to prepare this compound, at all events by the action of magnesium on ethyl iodide. As this result is in direct antagonism to the statements of all the text-books, which are based on Cahours's work of thirty years ago, some comment seems called for.

Magnesium most certainly does *not* act on ethyl iodide at the ordinary temperature, as stated by Cahours, and also by Hallwachs and Schafarik. At the boiling-point of the liquid its action is slow, but gradually becomes complete; but only magnesium iodide and hydrocarbons are formed. According to Cahours, the action takes place at the ordinary temperature so strongly that artificial cooling has to be resorted to, and at higher temperatures in sealed tubes magnesium ethide is produced. It is an unfortunate fact that this latter statement was not tested more conclusively by analysis. As a matter of fact, no estimation was made of the magnesium, nor can we gather from the original memoir that even a qualitative test was applied to the products of combustion, or of the decomposition by water. The percentages of carbon and hydrogen found were such as might be obtained from an impure specimen of magnesium ethide; but, standing alone, as they do, they are not even an approach to a proof that such a compound had been formed. It seems just possible that Cahours was really dealing with impure zinc ethide, due to his magnesium containing zinc, and this might also account for the action beginning in the cold. However this may be, there is no record, apart from Cahours's, of the actual preparation of magnesium ethide or any other alkyl compound of the metal; and, until there is such a record, Mr. Wilsmore's complete failure to obtain even a trace of the compound appears to me to necessitate an erasure from the text-books.

It was pointed out by Mendeléeff that the power of forming alkyl compounds is characteristic only of certain groups of elements. It, in fact, characterizes those elements which occur on the ascending portions of Lothar Meyer's curve of atomic volumes, but not those on the descending portions. This is true at least of the long periods, but the two short periods have been reckoned exceptional. In these short

* See next paper.

periods, however, a glance at the curve shows that the only elements undoubtedly on descending portions are beryllium and magnesium. The evidence for the existence of alkyl compounds in either case is so slight that one may be pardoned for doubting whether the short periods are exceptional after all. The only evidence of beryllium alkyl compounds comes also from Cahours, and his observations were of a purely qualitative character. About the alkyl compounds of boron and aluminium there is, of course, no uncertainty whatever; but these elements occur at the minima of the curve, and they naturally differ in their properties from the metals of the eighth group, which are at the minima of the long periods.

I believe that magnesium should be classed, as to the power of forming free alkyl compounds, with calcium, strontium, and barium, which do not, rather than with zinc, cadmium, and mercury, which do. This agrees with the arrangement of the elements of Group II., which is suggested by the majority of the chemical, and by at least some of the physical, properties of magnesium. It is still, however, possible, as indicated by Wanklyn's solitary qualitative experiment, that magnesium can form an unstable double ethide with zinc. If so, it resembles sodium more closely than any other element from this point of view; which is likely enough, as sodium is its immediate predecessor in the natural series in which it occurs.

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3. *Unsuccessful Attempts to prepare Magnesium Ethyl.*

By N. T. M. Wilsmore, B.Sc. Melb.

(*Communicated by Orme Masson.*)

This research was undertaken at the instance of Professor Masson, of this University, to whom, and also to Mr. J. B. Kirkland, F.C.S., I am indebted for much valuable help and advice throughout the course of the work.

There are, so far as I am aware, only three notices of magnesium ethyl previously published—namely, Hallwachs and Schafarik, Annalen, 109, p. 206 (1859); Cahours, Ann. de Chim. et Phys., lviii., 3° series, p. 17 (1860); Wanklyn, Journ. Chem. Soc., xix., p. 129 (1866).

Hallwachs and Schafarik heated magnesium filings with ethyl iodide in a sealed tube. The action began at the ordinary temperature, and was completed by heating to 180°. About 5 grammes of ethyl iodide were used up in one day. The metal was then converted into a white mass, no liquid remaining in the tube. There was a strong escape of gas on opening the tube. On heating, the white mass gave a colourless volatile liquid with a penetrating onion odour, which formed white flakes of magnesium oxide on entry of the smallest trace of air, and evolved thick white fumes when warmed in air, but did not spontaneously inflame.

This liquid consisted apparently of free hydrocarbons with traces of magnesium ethide. The greater part of the latter was believed to be combined with magnesium iodide in the white residue, for this possessed the property, even after prolonged and strong heating, of decomposing water with explosive force, evolving heat and a penetrating smelling gas.

Cahours proceeded in a similar way. On adding the ethyl iodide to the magnesium filings, so much heat was evolved that the tube had to be cooled with water. The latter was then sealed, and heated up to 120°—130°, till all the liquid disappeared. The white residue was then transferred to a retort filled with hydrogen, and distilled in a current of that gas, when a liquid was obtained which took fire in the air, and acted strongly on water. This was partially fractionated; and on analysis two fractions gave 54·5 and 55·2 per cent. carbon, and 11·4 and 11·5 per cent. hydrogen (calculated for $Mg\,Et_2$,—carbon 58·53, hydrogen 12·19). The error was attributed to the small amount of material available, which did not admit of sufficient fractionation; and it may be presumed that the same cause accounts for the absence of analytical proof of the presence of magnesium.

Wanklyn treated sodium zinc ethyl with mercury and magnesium wire. A white solid was formed, which was spontaneously inflammable in air, and which contained magnesium and zinc, but only traces of sodium; while on the other hand the mercury was found to be rich in sodium. The white solid was believed to be magnesium zinc ethyl, formed according to the following equation:—

$$Hg + Mg + 2Na\,C_2H_5\,.\,Zn(C_2H_5)_2 = Hg\,Na_2 + Mg(C_2H_5)_2\,Zn(C_2H_5)_2.$$

But the experiment was merely a qualitative one.

The magnesium used by me was the ordinary ribbon of commerce, in which I failed to detect any impurity. In order to get it in a finely divided state, I first tried distilling it in hydrogen. For this purpose an apparatus was constructed, consisting of a 1in. iron tube about 18in. in length, fitted by means of a reducing-socket to a 2in. tube, 6in. in length, to act as a receiver; and to this again another short piece of 1in. tube was attached. To each end of the apparatus about a foot of $\frac{1}{4}$in. iron tube was fitted, for the convenience of connecting the hydrogen generator. The magnesium was placed in the longer 1in. tube, and the apparatus was screwed together, the joints being luted with plaster of Paris. The tube containing the magnesium was then heated to whiteness in a Fletcher's blast combustion furnace for about half an hour, a moderate current of hydrogen being kept up. On cooling and disconnecting, most of the magnesium was found in the form of solid lumps, firmly adhering to the walls of the condenser close to the furnace, the rest (only a small amount) being deposited as dust. These lumps were malleable under the hammer.

It was now decided to use filings. To make them, some ribbon was fused in an iron crucible, under a flux having the composition $3KCl.4MgCl_2$, and containing a little ammonium chloride, as recommended by Matthiessen (Journ. Chem. Soc., viii., p. 107). This flux must not be heated much above the melting-point of magnesium, as it then loses chlorine, and gets gummy. On stirring with an iron rod, the metal ran together into a large globule, after which the crucible was allowed to cool. When the globule had solidified it was taken out with an iron spoon, sufficient flux adhering to it to protect it from oxidation. A curious effervescence was noticed in the flux while the metal was melting. As soon as it was cool the lump of metal was washed, first with water, then with alcohol, and dried at 100°, after which it was filed up with a rasp. A coarse single-cut file would perhaps have been better. The filings so formed contained traces of iron from the file; but it was not thought that this would have any deleterious effect on the experiments.

In this connection I may draw attention to the peculiar action of magnesium on glass. When heated in hydrogen in contact with glass—*e.g.*, in a flask—the glass blackens, where it is hot, just before a red heat is reached, even where there is no metal in contact with it. This phenomenon was also noticed when the magnesium was heated in a platinum boat, placed in a glass tube, through which hydrogen was passing, the glass being blackened above the boat.

This action appears to take place only in hydrogen, as, in conjunction with Mr. J. B. Kirkland, I have repeated the experiment with carbon monoxide, carbon dioxide, sulphur dioxide, air, and hydriodic-acid gas, in all of which the glass was only attacked where it happened to be in contact with the magnesium. Magnesium only acts on these gases (with the exception of air) at a red heat, so that these experiments were strictly comparable with the heating of the metal in hydrogen.

We were hence led to the belief that magnesium must be volatile in hydrogen below its melting-point; which appeared to be confirmed by an experiment conducted by Mr. Kirkland. He heated some magnesium-filings in an iron boat, in a roll of sheet-iron, enclosed in a glass tube, through which a current of hydrogen was made to pass. The glass was blackened opposite the joint of the roll, and on taking out the latter and opening it some of the magnesium was found sublimed in beautiful glistening crystals.

The first four attempts to make magnesium ethyl were modifications of Hallwachs and Schafarik's and Cahours's experiments, depending on the action of magnesium on ethyl iodide, the reaction that was expected to take place being—

$$2Mg + 2C_2H_5I = MgI_2 + Mg(C_2H_5)_2;$$

or

$$\left\{ \begin{array}{l} Mg + C_2H_5I = MgC_2H_5I. \\ 2MgC_2H_5I = MgI_2 + Mg(C_2H_5)_2. \end{array} \right\}$$

Experiment I.

The apparatus for this experiment, as well as for experiments II., III., and V., consisted—first, of a flask of 150cc.–200cc. capacity; secondly, of a condenser, the tube of which was about 5mm. in diameter, and bent at right angles near one end to allow of its being fitted to the flask by means of a cork, through which were also fixed a tube for passing dry hydrogen or carbonic acid, and a thermometer; and, thirdly, of a receiver, which consisted of a small distillation-flask fitted to the distal end of the condenser by a cork. To the side tube of this flask a mercury valve was attached to exclude air. The condenser could thus be used either as a reflux or an ordinary condenser. Great care was taken to have both apparatus and materials thoroughly dry.

Five grams of magnesium-filings were placed in the flask, which was then attached to the condenser; and the whole apparatus was filled with carbon dioxide. Thirty grams of ethyl iodide were now added, the cork being raised to admit it, and a moderately rapid current of carbon dioxide being kept up to prevent entry of air. There was thus slight excess of magnesium. No elevation of temperature was noticeable on contact of the iodide with the magnesium; and no appreciable action took place in the cold.

The flask was heated in an oil-bath to 75°–100°, till no more ethyl iodide was seen to run back. This took thirty hours, during which time a pretty constant slow stream of gas escaped at the mercury valve. This gas burnt with a luminous flame when ignited. At the end of the reaction a white residue remained in the flask. The condenser was then reversed; but nothing except a little unused ethyl iodide came over, although the temperature of the oil-bath was allowed to rise to 250°. An alliaceous smell was, however, noticed. The residue consisted of anhydrous magnesium iodide and unacted-on magnesium, with a trace of organic matter, probably higher hydrocarbons. The reaction was evidently, therefore, principally as follows:—

$$Mg + 2EtI = MgI_2 + C_2H_4 + C_2H_6.$$

As the escaping gas was not analysed, it is not known whether it was a mixture of ethylene and ethane, or an equivalent amount of other hydrocarbons.

Experiment II.

The success of Gladstone and Tribe with zinc–copper couples in the production of zinc ethyl (Journ. Chem. Soc., xxxi., p. 567), led me to try this and the following experiment. The copper appears to take no active part in the reactions, except as playing the part of the negative plate in a galvanic cell.

Five grams of magnesium-filings were treated with sufficient of a 2-per-cent. solution of copper sulphate, rendered alkaline with ammonia, to yield 0·35 gram of metallic copper. As soon as the copper solution was decolorised (which took but one or two minutes), the couple, which acted on water with great energy, was washed rapidly with water, then with alcohol, and finally with anhydrous ether. It was next dried by heating in a current of hydrogen in the flask of the distilling apparatus, which was then attached to the condenser. When the apparatus was full of hydrogen, 20 grams of ethyl iodide were run in. As in I., there was no action in the cold. The flask was heated in a water-bath to about 90° for ten hours, when the condenser was reversed; but nothing except a little ethyl iodide came over. More ethyl iodide containing a little iodine in solution, as recommended by Frankland in the manufacture of zinc ethyl (Roscoe and Schorlemmer, iii., i., p. 460), was added; and the heat was kept up for a further period of twenty-five hours. The colour of the iodine was only slowly removed by the magnesium, which agrees with Wanklyn's observation (Journ. Chem. Soc., xix., p. 144). A white solid was formed, as in I. The condenser was again reversed, and the flask heated in an oil-bath, when a small quantity of ethyl iodide came over. The receiver was then changed. When the inner thermometer was rising from 100° to 120°, a few oily drops distilled over, which were not increased, although the oil-bath went up to 250°, and the inner thermometer registered 170°. These drops volatilised in the current of hydrogen, producing a somewhat alliaceous smell, which nevertheless strongly reminded one of kerosene. This agrees with Hallwachs and Schafarik's account; but, on the other hand, there was no fuming on disconnecting the apparatus. The reaction was apparently the same as in I., the residue being the same, with the addition of the metallic copper.

Experiment III.

This was suggested by Gladstone and Tribe's paper (Journ. Chem. Soc., xxxv., p. 567). It is simply a modification of II.

Three grams of magnesium-filings were heated with 0·5 gram of dry precipitated copper in a current of hydrogen, till the magnesium began to blacken the glass. The couple had much the appearance of the original magnesium-filings, and hence differed markedly from the corresponding copper–zinc couple. The flask was now attached to the condenser, and, when cool, 17 grams of ethyl iodide were added. It was then heated in a water-bath till the ethyl iodide ceased to run back, which took twenty hours.

No gas appeared to come off in this experiment, though the mercury valve indicated a slight excess of pressure within the apparatus. This led to the belief that success was at hand. (I have since noticed that, under certain conditions, such a valve will let a slow current of gas pass through it without any oscillation of the mercury, the gas escaping between the mercury and the glass. Hence, I prefer now to use a sulphuric-acid valve in experiments of this nature.)

The condenser was reversed, and, after the free ethyl iodide had come over, the receiver was changed, and the flask heated in an oil-bath up to 250°. As nothing distilled over, a tin-bath was substituted, and the temperature raised to above 400°, with no result. The residue was the same as in experiment II.

It will thus be seen that the magnesium–copper couple, prepared either by the wet or the dry method, has much the same action on ethyl iodide as magnesium alone. There is no advantage in the addition of iodine to the ethyl iodide.

Experiment IV.

This was a repetition of Cahours's experiment, except that a magnesium–copper couple, prepared as in III., was used instead of pure magnesium. A great deal of gas was evolved on opening the tube, which burnt with a luminous flame when ignited. The residue was the same as in experiments II. and III.

From the results of these experiments it will be seen that I am unable to confirm Cahours's statement.

Experiment V.

Action of Sodium-Magnesium Alloy on Ethyl Iodide.

The reaction looked for was,—

$$Mg + 2Na + 2C_2H_5I = 2NaI + Mg(C_2H_5)_2.$$

Six grams of magnesium filings and 10 grams of sodium were heated together in a hard-glass flask in a current of hydrogen. An alloy appeared to form a little below a red heat, and was then allowed to cool in hydrogen. The flask was fitted to a reflux condenser, as in I., II., &c.; 67·8 grams of ethyl iodide were now added. The sodium and ethyl iodide were thus in equivalent quantities, while the magnesium was in excess, for the above equation. The flask was heated for two hours on the water-bath to 90°–100°; but no apparent action took place. 1cc. of ethyl acetate was then run in, and the water-bath was kept at about 85° for sixty hours, when all the ethyl iodide was used up. On now raising the temperature of the bath the flask cracked, and water got in. A violent action of course ensued; but nothing that would indicate the presence of an ethide was noticeable.

The ethyl acetate was added because it was thought that it might have a catalytic action, as in the formation of mercury ethyl by Frankland and Duppa's method (Journ. Chem. Soc., xvi., p. 415).

Experiment VI.

Study of the Action of Magnesium on Mercury Ethyl.

This was suggested by Frankland and Duppa's method for the preparation of zinc ethyl (Journ. Chem. Soc., xvii., p. 29). The reaction should have been thus:—

$$Mg + Hg(C_2H_5)_2 = Hg + Mg(C_2H_5)_2.$$

20·8 grams of mercury ethyl and 2 grams of magnesium ribbon were heated in a sealed tube to 100°–110° for four hours with no visible result. The temperature was then increased to 130°–140°; but at the end of another four hours the tube exploded. The magnesium ribbon was somewhat attacked where it had been in contact with the liquid mercury ethyl; but the great amount of gas formed seemed to show that this method would not be successful. The mercury ethyl appeared simply to decompose into free mercury and paraffines.

Experiment VII.

The action of magnesium on zinc ethyl was expected to be as follows:—

$$Mg + Zn(C_2H_5)_2 = Zn + Mg(C_2H_5)_2;$$

or, perhaps, from Wanklyn's research,—

$$Mg + 2Zn(C_2H_5)_2 = Zn + Mg(C_2H_5)_2 . Zn(C_2H_5)_2.$$

7·5 grams of zinc ethyl and 3 grams of magnesium-filings were sealed up in a strong glass tube. On heating there was no action till a temperature of 150° was reached, when a slight blackening was noticed. The reaction was completed at 170°. A greyish-black deposit was found in all parts of the tube, even where there was no magnesium, indicating decomposition of the zinc ethyl. There was a great deal of gas on opening the tube. The top part of the tube was then cut off, and a condenser filled with hydrogen was attached, after which the tube was heated in an oil-bath up to 220°. A few drops came over which, on treatment with water, yielded zinc hydroxide; but no trace of magnesium hydroxide was found. The black deposit in the tube was metallic zinc. On adding water to the residue left in the tube there was a copious generation of gas, which was, however, found to be pure hydrogen, due evidently to the action of a zinc–magnesium couple.

Experiment VIII.

was an attempt to make magnesium ethyl by the action of zinc ethyl on anhydrous magnesium iodide according to the equation,—

$$MgI_2 + Zn(C_2H_5)_2 = Mg(C_2H_5)_2 + ZnI_2.$$

11·5 grams of zinc ethyl were sealed up with about 25 grams of magnesium iodide. The action began at 130°, when a slight blackening took place, and appeared to be complete after heating for some time to 150°–160°. On opening the tube there was a moderate rush of gas. The tube was attached to a condenser as in VII., and was heated in an oil-bath up to 200°. A small amount of liquid distilled over, which gave a white precipitate with water. This, however, consisted only of zinc hydroxide. The residue in the tube was metallic zinc, together with the unacted-on magnesium iodide.

Experiment IX.

This was an attempt to obtain the ethide by heating magnesium with anhydrous ethyl-ether, the equation representing the action being,—

$$2Mg + (C_2H_5)_2O = Mg(C_2H_5)_2 + MgO.$$

It was doubted beforehand whether this reaction would take place, as, although magnesium has a great affinity for oxygen, that affinity is not very active till temperatures are reached at which the ethyl groups would be broken up. These doubts were fully borne out by the result.

One gram of magnesium was sealed up with the right amount of anhydrous ether. There was no action, even on heating to 260°. At 290° the tube broke, but no fumes nor ethide smell were noticeable.

The nett result of all my experiments is that I have not found it possible to prepare magnesium ethide.

4. *Note on Magnesium Iodide.*

By N. T. M. Wilsmore, B.Sc.

The best way to prepare this substance in the anhydrous condition is by the method described under experiment I. in the preceding paper, using sufficient ethyl iodide to use up the whole of the metal. The reaction goes best if the metal be first strongly heated (preferably in hydrogen, though air will do). It is then got as a fine amorphous powder, very suitable for studying its behaviour with other bodies. Prepared in this way, however, it always contains a little metallic magnesium, even though considerable excess of ethyl iodide be employed; and also some organic matter, probably paraffines. An analysis gave the following results:—

	Found.	Calculated for MgI_2.
Carbon	0·43 ...	—
Hydrogen ...	0·21 ...	—
Magnesium ...	8·61 ...	8·63
Iodine	90·65 ...	91·37
	99·90	100·00

Magnesium iodide was also made by heating the metal in a current of hydrogen and iodine vapour in a glass tube, and also in hydriodic-acid gas; but the action does not commence till a dull-red heat is reached, and is then so violent that the iodide is formed in a fused state, which solidifies to a hard porcelain mass, very unsuitable for experimenting with.

In hydrogen, magnesium iodide is stable at a red heat. In air, at the ordinary temperature, it turns brown from separation of iodine, and deliquesces; and at a full red heat it loses the whole of its iodine, being converted into magnesium oxide. When prepared by the ethyl-iodide method it acts on water with considerable energy, which might easily be mistaken for the action of an ethide, as was done by Hallwachs and Schafarik; but there is no gas given off, as would be the case with an ethide. This was proved by wrapping up some in a piece of paper, and immersing it under an inverted test-tube full of water. The aqueous solution of the iodide prepared in this way always has a peculiar smell, due probably to the before-mentioned paraffines. Magnesium iodide also dissolves in boiling anhydrous ether, separating out on cooling as colourless crystals, which appear to have the composition $MgI_2 . 2(C_2H_5)_2O$, though this requires further investigation.

5. *The Specific Heat of Gases at Constant Volume.*

By Professor BICKERTON.

It was shown that the specific heat of a rare monatomic gas at constant volume must for many reasons be considered the true specific heat of that atom, for in this state there is neither internal nor external work. It was shown that by taking this as the true specific heat most of the anomalies usually observed disappeared. That it also furnished a standard from which to estimate the proportion of energy that went to increase the velocity of the molecule, and that which was used in overcoming external forces. Thus, for example, in heating water, 40 per cent. (of energy) goes as heat, and 60 per cent. in overcoming molecular attraction.

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6. *Molecular Attraction.*

By Professor BICKERTON.

It was shown that this work, taken in terms of the expansion, furnished a means of estimating the attraction of molecules in terms of their diameter. It was shown that the specific heat of constant pressure depends upon the numbers of atoms of the molecule *plus* the difference between these two ratios in the case of a monatomic gas; and this fact must be taken into consideration in calculating the heat developed by the compression of a gas. It was shown that the attraction of molecules in terms of their diameters might be estimated by comparing the complete isothermals of a gas with a rectangular hyperbola,—assuming the difference to be due to molecular attraction helping the pressure by pulling the molecules together. A third mode of estimating the attraction of molecules is to compress any gas until it ceases to follow the gaseous laws, then allowing it to expand within a calorimeter; thus estimating the work in terms of the reduction of temperature, and from this deducing the molecular attraction.

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7. *Some possible Causes of the Low Temperatures of Partial Dissociation.*

By Professor BICKERTON.

It was shown that in the case of water the molecular attraction had an energy almost exactly equal to a temperature of 1,500° C., and that the attraction of molecules must curve their paths, must increase their probability of impact, and enormously increase the energy of the blows given, so that the probability of dissociation was increased by molecular attraction, by increasing both the frequency and power of molecular encounters. It was also shown that most of the encounters must be of a grazing character, thus tending to knock off single atoms whose inertia was small. These were suggested as the most potent factors in producing dissociation at temperatures so very much lower than the temperatures produced by the combination of the same substances.

Section C.

(GEOLOGY AND PALÆONTOLOGY.)

President of the Section—Reginald A. F. Murray, F.G.S.

ADDRESS BY THE PRESIDENT.

The Past and Future of Mining in Victoria.

The high honour conferred in electing me President of this Section carries with it the obligation of preparing an opening address. An address, like a sermon, requires a text, and that chosen on this occasion is the Past and Future of Mining in Victoria. The subject can only be dealt with in a general way; but, still, a brief retrospect and forecast, coupled with remarks relating to geological investigations in connection with mining in Victoria, may be deemed a fitting initiation of our present meeting on the part of one whose personal experience has been almost wholly limited to that colony. The objects of our Association, as I conceive them, are of a widely cosmopolitan character. Each section of the Association has its particular branches of science to discuss, and each individual his or her taste for a particular line of research, and a laudable ambition to gratify in making known the results; but throughout all runs the dominant object of raising the intellectual standard and increasing the material welfare of the people at large. If, therefore, the treatment of the present subject embraces the practical commercial as well as the scientific element, no apology seems requisite; for, with every respect for pure science, which, like virtue, is its own exceeding great reward, I still maintain that, in young countries especially, it is well that some, at least, of the scientific inquirers should pursue their efforts in directions where results of practical value to the community are most likely to be obtained. That most of the leading geologists in Australasia act on this principle is evinced by the markedly-increased respect of the miner for the opinion of the geologist at the present day, as compared with the thinlyveiled contempt which the former entertained for the latter some twenty or thirty years ago.

Gold-mining naturally takes first place among the mineral industries of Victoria, the yield of gold up to date from the colony having greatly exceeded that from any of the sister States, while its yield of other metallic products has so far been comparatively insignificant.

It is unnecessary to do more than glance at the early history of gold-mining in Victoria. It is known that Sir Roderick Murchison, before any recorded discovery, expressed his belief in the existence of gold in Australia on the evidence of specimens of the Silurian rocks of that continent. Very likely other scientific men arrived at the same opinion, if they did not actually ascertain the existence of the metal.

There are numerous stories as to the finding of gold by shepherds, convict-servants, and others prior to the year 1850; but there appears little room for doubt that the public interest excited by the great discoveries in California led to the systematic search for gold—first in New South Wales and then in Victoria—by men of practical experience; and the marked success achieved was followed by the memorable "rush" of the early fifties.

Every Australian has heard of, if he did not actually participate in, that "rush," and knows that within two or three years there poured into Victoria, by tens of thousands, a body of men the equal of which, for collective enterprise, courage, and vigour, had perhaps never before been congregated within so small an area of the world's surface.

This great prospecting population overspread the land, searching every likely or unlikely locality, with the result that, during the ten years following the first "rush," nearly all the more important alluvial fields, where the metal was easily obtained, were discovered, and, to a large extent, exhausted of their more accessible riches.

Some remarks as to the geological conditions in relation to Victorian goldfields are here requisite, though those conditions are probably familiar enough to most of the present audience. Over about half of the entire area of Victoria the older Palæozoic, Lower and Upper Silurian rocks, metamorphic schists, and granites appear at or close to the surface.

With a few local exceptions these older Palæozoic sedimentary rocks and metamorphic schists have a general northerly-and-southerly strike, and are highly inclined in a series of anticlinal and synclinal foldings across the entire breadth, east-and-west, of their exposure, covering about seven degrees of longitude. They are intersected by lodes, reefs, and veins of quartz, the normal trend of which is closely coincident with their strike; and the quartz reefs are, as a rule, more numerous, more persistent, and larger in the Lower than in the Upper Silurian group. It has been observed that the quartz contained in certain zones or belts of rock-bands is auriferous, while that of adjacent and, apparently, lithologically similar belts is poor or barren, the detrital deposits being rich or poor in gold according to their position in relation to the respective zones. The geological evidence unmistakably indicates an enormous amount of denudation, dating from as far back as Upper Palæozoic times, which has lowered the surface of the Lower Palæozoic rock-foundation by probably thousands of feet. Over by far the greater portion of this Lower Palæozoic area there are no overlying deposits older than Middle Tertiary, except a few occurrences of Devonian and Mesozoic rocks. Any representatives of the great series of rock-groups between Lower Palæozoic and Tertiary have been almost entirely removed from, if they ever existed at all over, the main mountain-system of Victoria, and consequently the Tertiary and Post-tertiary drifts may be regarded as the concentrates which remain from the incalculable denudation referred to.

Naturally the gold disintegrated during that process remained, while most of the material of the degraded rocks was removed, and hence it came about that the Tertiary and Post-tertiary drifts in the vicinity of the auriferous zones were found to contain the detrital gold concentrated from the degradation of mountains of Palæozoic rock, and from the redistribution of the various detrital deposits that had been successively accumulated and removed in pre-tertiary times.

It is no wonder therefore that the easily-accessible, shallow, and exceedingly-rich deposits of auriferous detritus were speedily found and exhausted when the great prospecting army spread itself over the land, and that the concentrates of ages of Nature's work were in a few years appropriated by man.

As the rich shallow drifts became exhausted, the deeper alluvial deposits were eagerly followed up wherever they were found auriferous. Without any particular scientific guidance, and after many blunders, the diggers found out that in numerous localities the deepening channels containing the auriferous drifts passed under layers of basalt, and thither they followed them to depths of several hundreds of feet from the surface, where powerful machinery became requisite and mining took the place of mere digging.

About the same time the gold-bearing quartz reefs outcropping on the ranges of exposed Silurian rock began to attract attention, and the quartz-mining industry was quickly developed. Nevertheless the annual yield of gold began visibly to decrease ; alarm was experienced as to the probable utter exhaustion of the goldfields in a short period, and the opinions of geologists were sought for on the subject. Mr. A. R. C. Selwyn, now Director of the Geological Survey of the Dominion of Canada, was then Government Geologist of Victoria, and between him and the eminent Sir Roderick Murchison arose a friendly controversy as to the future of quartz-mining. Both virtually agreed that, while the yet untouched alluvial deposits might take a long time to work out, their extent was practically within calculable limits, though Mr. Selwyn was strong in regarding their ultimate exhaustion as a thing of the distant future.

With respect to the future of quartz gold-mining the two geologists were not so much in accord. Sir Roderick Murchison, reasoning from experience up to his time in Europe and elsewhere, held that the permanence of auriferous lodes was not to be depended upon for any considerable depth below the surface; and a Commission then inquiring into the subject cited a number of cases in Victoria where at that date (1856–57) quartz reefs rich at the surface had been found to become poor at various shallow depths. Selwyn, though a member of the Commission, maintained his own independent views, which, briefly stated, were that, though possibly there might be a diminution in the quantity of gold in reefs with increasing depth, there was no ground for fear that such diminution would be sufficient to render deep quartz-mining unprofitable, and he further expressed his conviction that this branch of mining would prove as permanent as tin-lode mining in Cornwall. He cited an instance in support of his views of the then deepest quartz-mine, in which, at 400ft., the stone was as rich as at the surface; but, strangely enough, the popular impression obtained that he said the reefs would not be payable below 400ft. Even up to the present time people quote this alleged opinion of Selwyn's as evidence of the unreliability of geologists, and, though the story is now old, I cannot refrain from taking this opportunity of contradicting so utterly untrue an aspersion on the scientific acumen of my former chief.

The sagacity of Selwyn's views has become apparent. True, the annual yield of gold has steadily, and—under the conditions—inevitably, declined: there is not left in Victoria an untried area large enough to contain a new shallow alluvial field of any importance: the yield from quartz has for many years been greater than that from alluvial deposits; but, nevertheless, there are long stretches of deep-lead systems and areas of gravel covered by great thicknesses of basalt and sediments, which, from their positions with respect to the extensions in strike of known auriferous zones, are likely to prove payable for many miles beyond present workings, and will take many years to exhaust, though they can only be worked by means of such powerful and costly machinery as is now essential for this class of mining.

With respect to quartz-mining, however, it may safely be predicted that, though no great augmentation of the annual yield can be expected, the industry will flourish for centuries to come. Quartz reefs have been proved payable and even rich at depths of more than 2,000ft.: they are being worked deep in the Silurian bed-rock beneath the exhausted alluvial deep leads. There are hundreds of known reefs, once proved auriferous, but temporarily abandoned, which will assuredly be reworked and found payable at greater depths. There are great areas of exhausted alluvial workings, the gold in which must have been derived from matrices as yet undiscovered, but which will eventually be sought for and found.

The mining machinery, gold-saving appliances, and methods of working have been, and are still, undergoing constant improvement. Mining, in fact, is becoming a scientific pursuit; and, though the gross annual gold-yield is smaller than heretofore, the amount earned per head by the smaller number actually engaged in mining compares favourably with that of the times when yields were larger and miners more numerous.

Even the gambling form of speculation which has proved so disastrous to legitimate mining has in a great measure become lessened, and people are beginning to recognise the principle that success in mining requires for its achievement as much discretion and judgment as in any mercantile or manufacturing undertaking. As this improvement continues, capital will be more and more confined to legitimate ventures, "paper mining" will decay, and the gold-yield will show a more noticeable profit over expenditure, even though it may continue to slightly decrease.

We may now consider the ways in which the geologist can best apply his knowledge and trained reasoning-powers to the work of assisting the miner and guiding the outlay of the mining capitalist into proper channels. As before remarked, the miner has now a greater respect for the geologist than he had thirty years ago; he no longer regards him as an unpractical dreamer, and at the same time does not err in the opposite extreme of believing him capable of divining-powers. Both geologist and miner recognise, so far as the application of geology to mining is concerned, that the one must base his reasoning on the facts ascertained through the labours of the other. The lines of research proposed in the case of Victoria are probably, with some modifications, applicable to all other gold-bearing countries, and, if worked out to definite results, may wonderfully aid the development of gold-mining. It has already been stated that in Victoria certain reefs or groups of rock-bands contain auriferous-quartz reefs, while in others the reefs are poor or barren, and that the alluvial deposits, whether deep or shallow, are rich or poor according to their position with respect to such zones; and I believe that the same phenomena have been noticed in other parts of the world.

Here, then, are two main lines of investigation: First, with respect to alluvial-gold deposits, to observe the strikes of the auriferous and non-auriferous belts where the rocks are observable at the surface, to learn from such observations the probable trends of these zones in their extensions beneath overlying deposits, and to reason thence as to where the latter, and also the quartz reefs contained in the concealed bedrock, are most likely to prove auriferous. That this is no chimerical view can be shown by means of numerous practical illustrations wherein actual results have demonstrated its correctness.

The second line of investigation involves research of a deeper and more exhaustive character, and applies specially to the zones themselves and the contained gold-matrices. Although in a general way the rich and poor groups of rock-bands can be respectively indicated with tolerable clearness from actual past results, there is as yet no other recognised mode of distinguishing between them. Take, for instance, the Sandhurst and Ballarat goldfields, where we find strips of country, many miles in length and three or four miles wide, running in the direction of strike of the Silurian rocks, and within which the alluvial deposits, deep or shallow, have nearly everywhere been rich, and numerous lines of auriferous-quartz reefs have been proved.

On either side of these strips may be observed apparently the same class of country, the same description of Silurian rocks, and numerous lines of quartz reef, often large and persistent; yet little or no gold can be found.

Exceptions are to be met with in both classes, as within the auriferous belts are many reefs which have not yet proved gold-bearing, while within the poor zones are occasional occurrences of gold in both alluvial and quartz, indicating possibly some minor auriferous groups of bands.

Again, there are, along the known rich lines of reef, intervals where the quartz is barren. The conclusion arising out of all these observations appears to be that, apart from the study of the lodes, reefs, or veins themselves, the mining geologist has a vast field of study before him in the containing rocks, and that the latter are perhaps the more important, and most likely to yield to the student valuable scientific results, which will enable him with far greater accuracy and confidence than at present to guide and assist the miner.

To enumerate in detail all the branches of this inquiry would occupy too much time at present; but in Victoria the principal requirements are—the proper study of the Silurian rocks, the working-out of the sequence and recurrence of the rock-layers in their anticlinal and synclinal foldings, the identification of those groups in which the reefs are rich, poor, or barren, as the case may be, and finally the investigation of the causes of these differences. Briefly, as sketched out here, this means a great field of work for a number of busy brains; but it is work which I believe would lead to great results, and, while as purely scientific as any other branch of natural science, would in a very high degree contribute to the success of mining. If liberally supported by the Governments of the various colonies this work would do far more good to mining than the system of State subsidies to drooping undertakings, for it would assist, while raising the intellectual status of the miner, without debilitating his spirit of enterprise and making a beggar of him, as is too surely the case where these subsidies are given.

Other Branches of Mining.

Gold-mining has been so essentially the chief mineral industry of Victoria, while the results from other branches of mining have hitherto been so small, that it is difficult to get many people to believe in the payable character of any other than gold-mining. Silver-, copper-, and lead-ores have only been found in anything approaching workable quantity in a few places, and have not so far proved payable.

Antimony has been, and no doubt will be again, profitably worked in many localities; but of late tin-mining has given signs of assuming a prominence that a few years ago was wholly unanticipated.

Stream-tin ore was found many years ago in the auriferous-lead gravels of Eldorado, near Beechworth, in such quantity as to render it worth saving when the ground was being worked for gold: it has also been found in many other portions of the colony, but rarely in profitable quantity. Lately, however, stanniferous lodes of great size and richness, with every indication of persistence, have been discovered in the mountainous tract extending from Omeo northwards towards the Murray, and it is pleasurable to state that the discovery was in a great measure due to Mr. James Stirling, Assistant Geological Surveyor, who, in directing the operations of a gold-prospecting party, advised them to search for tin as well.

The principal lodes as yet found are near Mount Wills, a mountain of granite protruding through metamorphic schists; and, from what is known of the district, it is likely—now attention is directed to the search, and scores of active prospectors are becoming expert in recognising the ore—that a very large area in the north-eastern district of Victoria will be proved stanniferous, and will become the Cornwall of Australia as regards tin-mining. The lodes are, properly speaking, dykes of coarse and fine griesen, pegmatite, graphic granite, and allied forms of rock traversing micaceous and nodular schists; they are in places exceedingly rich in tin-ore, masses of which have been found over 50lb. in weight. Crystals are rare, the ore occurring in large and small irregularly-shaped pieces plentifully disseminated through the stone. There are those who, from experience in other parts of Australia, predict that these lodes or dykes will become poor as followed down to depths; but with every wish to avoid undue optimism I cannot share in this view.

Considering that outcrops rich in tin-ore have been found at elevations over 1,000ft. apart, and those exposed in creek-beds or low down on spurs are no poorer than those on the ranges, it does not seem likely that any serious deterioration will be found to occur, though, as a matter of course, it may be expected that the ore-bearing stone will lie in "shoots," separated by poor or barren intervals both longitudinally and downwards.

As active mining operations and the erection of crushing- and dressing-plants are in full progress, a very few months will probably enable it to be determined whether tin-mining in Victoria is likely to become as important as present indications foretell.

Any mention of coal-mining may excite a smile amongst those who know how small, how few, and how dislocated are the Victorian coal-seams compared with those of other Australian colonies. Nevertheless what coal there is possesses good qualities, and is remuneratively workable with proper economy and appliances, and the industry is advancing—perhaps spasmodically, but still with a nearer approach to success at each effort. A dividend—the first, and due certainly to the high prices during the recent strike—has lately been paid from the proceeds of a Victorian coal-mine, and I venture to predict that the colony will yet in a considerable measure supply home requirements independently of fictitious prices.

The brown coal or lignite which occurs in beds of such enormous thickness, unequalled perhaps in the world, has not proved a satisfactory fuel in its raw state, but can with proper appliances be manufactured at a cheap rate into briquettes not much inferior to coal as fuel. It may be expected that this industry will before long assume great proportions, and that the valuable clays which are associated with the lignites will in the presence of so cheap and plentiful a fuel be largely utilised.

Having endeavoured so far to place before you a brief retrospective and prospective view of Victorian mining, let me conclude by expressing the hope that some of the suggestions offered may prove interesting, and serve to induce or stimulate research; and finally accept my heartiest wishes that the best results may attend the labours of this and other sections of the Australasian Association for the Advancement of Science.

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1. *On the Occurrence of Nepheline-bearing Rocks in New Zealand.*

By Professor GEORGE H. F. ULRICH, F.G.S., Director of School of Mines, Dunedin.

Plate V.

IT is not many years ago that species of the interesting group of minerals—viz., nepheline, leucite, hauyne, nosean, and sodalite—called by some petrographers "feldspar-like," and classed by mineralogists either as the Nepheline Group or as the Leucite Group, were considered rather rare—indeed, the four last-mentioned quite absent in the volcanic rocks of countries outside Europe. In recent years this latter supposition has been negatived by the discovery of rocks bearing leucite, accompanied by one or more of its isometric congeners, in isolated localities in Asia, Africa, and America; but of its occurrence in Australasia there was still no record. However, it at last fell to the lot of our energetic co-workers in New South Wales, the Rev. J. Milne Curran, Mr. Edgeworth David, and Mr. William Anderson, to fill the gap by the fortunate discovery of a typical leucite basalt in two isolated localities, Byrock and El Capitan, far in the interior of New South Wales; and an exhaustive description of these occurrences by Messrs. David and Anderson is given in a memoir in Part iii., Vol. i., of "Records of the Geological Survey of New South Wales," 1890. As an occurrence in New Zealand, near Castlepoint, on the east coast of Wellington, a leucite basalt is mentioned, though without description of the rock, by Mr. W. Skey, Colonial Analyst, in Col. Mus. and Lab. Rep. No. 10, p. 48.

Nepheline, both as elæolite in plutonic and as nepheline proper in neo-volcanic rocks, has long been known from countries outside Europe,* still also of rather restricted and isolated

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* An interesting discovery of older and newer nepheline-bearing rocks was made a few years ago in Brazil by Professor O. A. Derby (Q.J.G.S., 1887, xliii., No. 171, pp. 457–473).

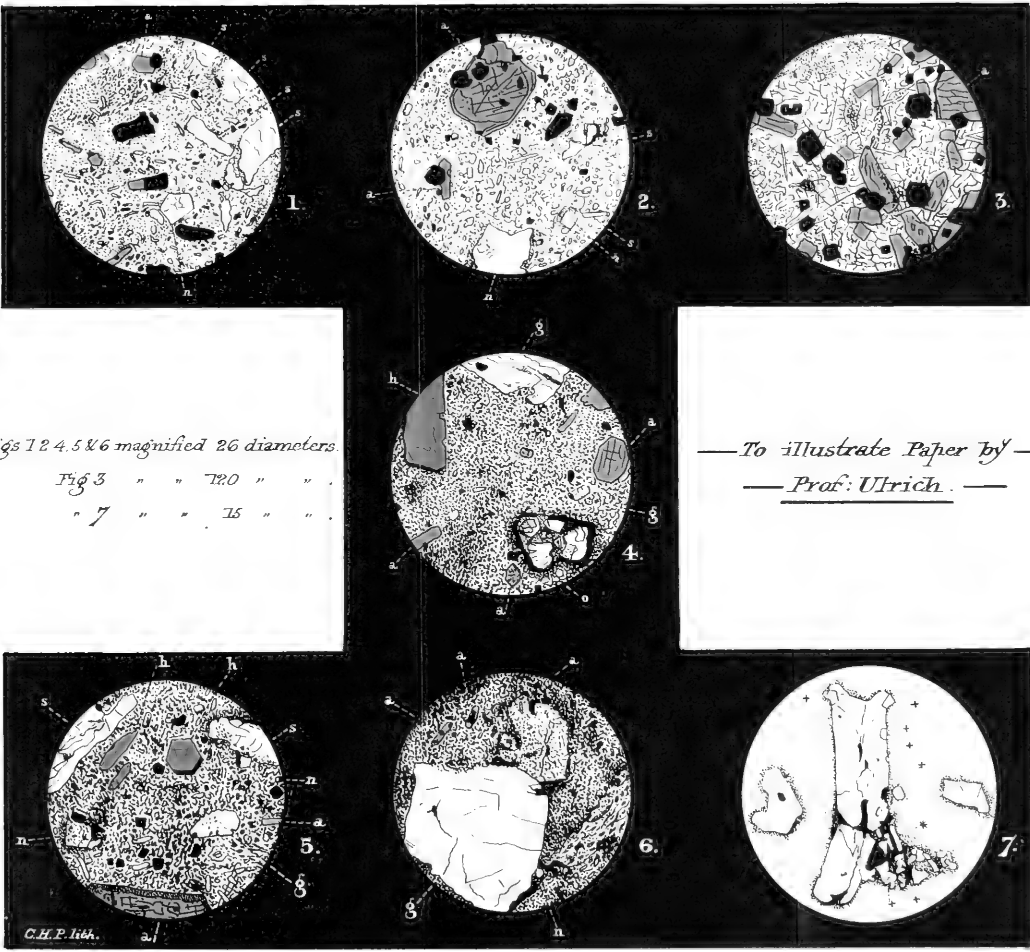
occurrence; and even in European countries, *e.g.*, Great Britain, it has as yet only been identified in a typical phonolite forming the Wolf Rock, near the Land's End.* In Australasia it is, to my knowledge, only known from a single locality—viz., Phillip Island, Bass Strait, Victoria, where it occurs in an older basalt celebrated for its richness in finely crystallized zeolites, especially analcime and natrolite.

Regarding this apparent scarcity of nepheline-bearing rocks in these southern lands, I was therefore much gratified in discovering the mineral about two years ago in an interesting rock occurring on the Peninsula at Portobello, about twelve miles east of Dunedin, and shortly afterwards in a rock of identical character much nearer the city. Since then I have recognised nepheline as a more or less essential constituent in samples of rocks from a number of places close to and in the neighbourhood of Dunedin, the examinations thereby leading to the discovery of some of the rocks being typical *phonolite*, and, in fact, of most belonging to the *phonolite group of rocks*. But, regarding these examinations, I have here to record my great obligations to Mr. A. Purdie, M.A., a student of the Dunedin University School of Mines, who with the greatest zeal made excursions into the high mountainous parts of the district, collected rock-samples, and prepared a large number of thin sections for microscopic examination. Having thus a great variety of nepheline-bearing rock types to choose from for special description, I thought it advisable to select for this purpose the two types structurally the most different from each other—namely, one the most coarsely porphyritic (the one first discovered), the other the most dense or homogeneous-looking; and in illustration of my notes I have prepared by camera seven drawings of thin sections, as seen under the microscope in ordinary light—five with a magnifying power of 26 diameters, one of 15 diameters, and one of 120 diameters. As a complement to this are given short descriptions of a number of sections of nepheline-bearing rocks from different localities, for showing their mutual relations and variations, as well as their respective alliances to some of the other kinds of volcanic rocks occuring in the district.

The Coarsely-porphyritic Rock.

The following are the main facts of the discovery of this type of rock at its two places of occurrence: The existence of gold in a peculiar propylite-like rock at the head of Hooper's Inlet, near Portobello, induced Mr. A. Porterfield, a farmer in the neighbourhood, to prospect about the district with the object of discovering similar gold-bearing rock. Whilst engaged

* J. J. H. Teall's "British Petrography," p. 367.



Figs 1 2 4.5 & 6 magnified 26 diameters.
Fig 3 " " 120 " "
" 7 " " 15 " "

—To illustrate Paper by—
—Prof: Ulrich.—

in this search he occasionally submitted to me specimens of "likely-looking" rocks, as he termed them, because of their showing fine impregnations of pyrite or being traversed by white veins of zeolitic matter. Most of the rock-pieces he brought were unfortunately too decomposed for determining their original character; only so much could with certainty be made out, that they were of volcanic origin. However, on looking more closely through one lot of coarse rock-pieces he left for my inspection, I found, on breaking one of the largest ones, that it contained beneath a thick yellowish-white decomposition-crust a hard nucleus, which, on fracture, revealed the porphyritic rock under notice—a greyish-black base abundantly impregnated with large crystals of two white or, rather, light-coloured minerals. One of these, a feldspar, was found by Szabo's method of flame-reactions (indicating potassium), and from the absence of plagioclastic twin-striation, to be sanidine; whilst the other, by its gelatinising in HCl, flame-reaction for sodium, its oily lustre, and crystal outlines, unmistakably proved to be nepheline—conclusions subsequently confirmed by microscopic examination.

Considering the interest attaching to this discovery, I induced Mr. A. Purdie to journey soon after to Portobello, where, informed by Mr. Porterfield, he soon found the outcrops of the rock; and, on examining these later on in his company, I observed the following: The rock forms two dykes in the small promontory (about 350ft. high at its highest point at the far end) which runs out north into Port Chalmers Harbour, on the eastern side of Portobello Inlet. One dyke (about 12ft. thick) is situated between half and three-quarters of a mile north of Portobello; the other, a good 15ft. in thickness, crops out a quarter of a mile further north near the point, where the shore-line of the promontory turns sharply eastward; and they are both accessible only at low water, being exposed in the nearly vertical line of cliff, from 30ft. to 80ft. in height, facing Quarantine Island. Both dykes traverse decomposed yellowish-white soft rock, the first at a strike of S. 25° E., the second at S. 20° E., with a slight dip to the east; but all traces of them disappear on the smooth slope of the hill above the top-line of the cliffs. Along the foot of the cliffs, at and near about the dyke-outcrops, blocks of the dyke rock are seen of all sizes up to several feet in diameter, resembling at a distance some coarse quartz-breccias, because of the crowded outstanding large sanidine crystals, from between which the nepheline crystals and the dark base have been more or less removed by weathering and sea-action. The soft white rock which the dykes traverse is evidently the result of decomposition of two other kinds of rock—one of greenish-grey colour and dense, the other dark-grey and fine-granular and porphyritic—which show in undecomposed remnants in it at the foot of the cliffs in the neighbourhood of the dykes; the dark-grey rock occurs also in large masses on top of the promontory. Thin sections of both these rock-varieties will be more specially noticed further on.

Regarding the discovery of the second locality of occurrence of the coarsely-porphyritic rock, it happened as follows: At the time the Portobello samples were under examination, Mr. A. C. Purdie, senior, on seeing his son's specimens, affirmed that he had in his possession a specimen of the same kind of rock found on the Pine Hill spur, close north of Dunedin. The specimen was produced, and the identity in character of the rock with that from Portobello seen at a glance. Mr. A. Purdie, junior, thereupon examined the indicated locality where his father had found his specimen, and soon discovered boulders of the rock accumulated in the road that passes up the middle of the Pine Hill spur—the boulders having been collected from the cultivated paddocks on either side of it. On my subsequent examination of the place I found that the area of distribution of the boulders, before cultivation of the paddocks commenced, might have been, perhaps, 15 chains in length by 4 to 5 chains in width over the here rather broad-backed spur. The rock could not, however, be discovered anywhere *in situ* within the indicated area. The Pine Hill spur, it must here be mentioned, terminates about a quarter of a mile south-west of the boulder-locality, falling rather steeply from a height of about 250ft. towards the valley of the Water of Leith, the main watercourse of the district, and forming, for some distance, a vertical cliff at foot. From this terminating point it gradually rises through a distance of about four miles in a north-easterly direction, with several short steep ascents, whilst sending a number of lateral spurs into the valleys on either side, to the Pine Hill, a transversely-extended mountain-ridge about 1,300ft. in height. Near above the boulder-locality there is a massive outcrop of hornblende-augite-andesite—a rock which seems also to prevail in the valleys near around the foot of the spur, with this exception: that in the vertical cliff along the Water of Leith there is an intrusion of common basalt and dolerite which does not extend to the top of the spur. No evidence of any dyke of the nepheline rock traversing the spur and hidden at the boulder-site being thus discoverable, Mr. A. Purdie made several excursions up the spur, but, though carefully searching, could not find any more of the specific rock-boulders, till at last he was successful in discovering massive outcrops of the rock itself on the steep slope of the Pine Hill, facing Dunedin, and he also ascertained that the entire hill is composed of the rock, which, however, becomes more finely porphyritic towards the top. Considering the first-found boulders, it is certainly a curious circumstance that these are preserved within such a limited area, over three miles away from their place of derivation.

The striking feature of the rock is its eminently porphyritic structure, combined with the abundance and large size of the idiomorphic sanidines and nephelines, which shine out in the dark base. The nephelines especially are, as far as records of nepheline rocks go, of quite exceptional dimensions. On the faces of the boulders at Portobello rectangular sections of the mineral can be seen of over $\frac{1}{2}$in. in length and $\frac{1}{4}$in. in width, besides square and hexagonal ones up to $\frac{1}{2}$in. in diameter; but they also go down to the size of a mustard-seed. Their colour on fresh fracture is a light reddish-brown, which changes to dull white by weathering and decomposition, to which they are very liable, as shown by the abundance of cavities left in the greyish-white decomposition-crust of the rock. The generally large size of the sanidines, though not an uncommon occurrence in trachytic rocks, is also a noteworthy feature. The crystals are mostly thin-tabular in the direction of the orthoaxis and largely extended in that of the clinoaxis, in cases to near $1\frac{1}{2}$in. in length, whilst in the line of the vertical axis some sections reach nearly $\frac{3}{4}$in. They very frequently form Carlsbad twins, and are in the average disposed in the base in the same way—*i.e.*, parallel to the clinopinacoid—so that, on fracture of the rock in this direction, one sees mostly the long and broad cleavages of this face—$\infty \underline{P} \infty$ (010)—and at right angles to this the narrow columnar ones of the basal pinacoid—OP(001)—and in these the Carlsbad twinning-line is often plainly observable. About the middle of the faces of some of the large Portobello boulders I observed also some large square sections—one of over $\frac{3}{4}$in. length of side—which seemed to have a diagonal twinning-line, indicating twins of the Baveno type; but as I was not successful in detaching chips of the rock containing them, for closer examination, and found no twins of this type amongst the small crystals in thin sections, I am doubtful on this point. Regarding the relative abundance of the crystals of sanidine and nepheline, it is not easy to determine; in parts of the rock the former, in others the latter, appear in greater number: still, I think that in the average the sanidines are more abundant.

The dark base, which occupies in parts of the rock plainly less space than the crystals of the above two minerals, shows on examination by the unarmed eye numerous inclusions of dark minerals, some of which can be recognised by their cleavage as hornblende; but, as to the character of the remainder, even by using the pocket lens no definite opinion can be formed: one can only see that most have glassy lustre, conchoidal fracture or imperfect cleavage, and are green-translucent on thin edges. Considering the purely macroscopic aspect of the rock, I think the fittest term for it would be "sanidine-nepheline-porphyry."

The real ground-mass of the dark base of the rock is holocrystalline, and, with the exception of scattered, slightly opaque patches, nearly colourless-transparent. Between crossed nicols it is seen to consist of allotriomorphic nepheline, intermixed more or less abundantly with lath-shaped microlites of sanidine. It appears, as it were, broken up into a mass of granules with ill-defined outlines, polarising, on rotation of the stage of the microscope, from bright colourless through light to dark greyish-blue, whilst the feldspar microlites between pass during this operation generally from colourless through yellow to dark alternately. The forms of the granules are quite irregular and undefined, though sometimes they appear to have rudely hexagonal, square, or rectangular outlines. Throughout this ground-mass there are now distributed as porphyritic inclusions sanidine, nepheline, augite, hornblende, olivine, iron-ore, apatite, titanite(?), and particles of clear glass; the special characters of each of which are as follow:—

Sanidine.—Colourless, transparent; sometimes in grains of irregular outline, but generally idiomorphic, appearing frequently in Carlsbad twins. Larger crystals are usually much cracked and filled in the centre with dusty black matter, occasionally also in lines parallel to the sides. The polarisation colours are mostly shades of yellow, rarely deep-orange, light-red, and greyish-blue. Occurs abundantly.

Nepheline.—This appears but rarely in idiomorphic inclusions; smaller than 0·5mm. (*n*, Figs. 2 and 5, Pl V.). It is colourless-transparent, and small crystals are generally very clear and little fractured (*n*, Fig. 2); only occasionally one dimmed by fine dusty matter is observed (*n*, Fig. 5). In moving sections in reflected light in different directions some crystals show a bright bluish opalescence, similar to that of moonstone. Larger crystals, projecting into the dark base, generally have dusty matter and microlitic inclusions zonally arranged parallel to their sides; and a pale-cream-coloured, slightly opaque, and finely-fibrous zone close along the sides indicates doubtless commencing decomposition. Roundish particles of clear glass were also observed in some larger crystals.

Augite.—This is abundantly distributed throughout every thin section in well-developed columnar crystals of fine grass-green colour, the crystals varying in size from over 4mm. long and 2mm. broad to less than 0·02mm. by 0·01mm.; and there occur in profusion still smaller light-greenish and brownish microlites of lath and other shapes, which may possibly belong to the alkaline-bearing varieties of augite—"ægirine" and "acmite." Larger crystals are sometimes light purple-brown in the centre and zoned green around, rarer occurrences are two purple-brown patches with green between and outside, and still rarer ones are green in centre and greenish-purple around. Maximum extinction observed in the prismatic zone, 42°. Sections cut at right angles or nearly so to the vertical axis show the traces of the prism $\infty P(110)$, the orthopinacoid $\infty \bar{P} \infty (100)$, and the clinopinacoid $\infty \breve{P} \infty (010)$ (see *a*, Figs. 2 and 4), and give a fine optic axis at the edge of the field. Pleochroism pretty strong, especially in the latter sections, varying between deep grass-green (*b*) and greenish-yellow (*c*). Amongst the larger crystals, some are zoned quite black around the sides with fine black dust of iron-ore; others contain a number of larger grains of the ore; and there occur cases where the whole crystal is densely filled with such grains throughout. Twins seem rather rare, as only a few (with $\infty \bar{P} \infty (100)$ as twinning-plane) were observed in a number of sections.

Hornblende.—This is in the Portobello rock quite as abundant as, if not more so than, the augite. In the Pine Hill rock it is less frequent. Its colour is light-brown, and it forms slender columnar crystals, varying in size from 3m–4m. long and 1–2mm. broad (*h*, Fig. 4) to very small dimensions, less than 0·05mm. in length. Maximum extinction observed, 10°. Pleochroism very strong, varying between light yellowish-brown (*a*) and deep rust-brown (*c*); absorption $c > b > a$. Sections at right angles to the vertical axis are of hexagonal outline, formed of the traces of the prism ∞P (110), and of the clinopinacoid, $\infty \breve{P} \infty$ (010). (See *h*, Fig. 5.) Twins occur rarely. Like those of augite, the crystals of this mineral are also, though apparently less strongly, invaded by dust and grains of iron-ore; whilst some show but small specks of their brown colour, and others appear quite opaque-black through this invasion, there occur again large crystals (*h*, Fig. 4) which are quite clear throughout—a feature not observed in large crystals of augite.

Olivine.—In the Portobello rock inclusions of this mineral are rather abundant and pretty evenly distributed throughout the dark base, as nearly every thin section shows several of them. This is not the case in the Pine Hill rock, as some sections of this contain not one inclusion, whilst in others there is quite a number. The mineral is transparent and colourless, sometimes with a slight tinge of greenish-yellow, and it occurs in irregularly-outlined grains and more or less perfect crystals, which both go rarely down to less than 0·5mm. in diameter, but generally vary between 1–3mm. in size. They are usually enclosed by a deep-brown or opaque-black ferruginous rim of greater or less width, which probably presents a kind of change of the mineral, as larger grains occasionally occur broken up into a number of larger and smaller fragments, each one surrounded by this rim (*o*, Fig. 4). There is also a slight serpentinous change observable along most of the cracks, though these are not as numerous as usually found in olivine, comparatively large spaces in the inclusions being quite free of them.

Iron-Ore.—Judging from a number of the grains showing square sections, this consists most probably of magnetite. The grains go from 0·5mm. in diameter down to the finest dust, which latter, though very abundant in the base of the rock of both localities, is generally less so in that of the Pine Hill than in that of Portobello, as shown by the comparative clearness of the sections (Figs. 1 and 2; 4 and 5).

Apatite.—To this, no doubt, belong sparingly-distributed long and very thin acicular crystals, which seem to traverse most of the other minerals and extinguish parallel to their own length between crossed nicols. Bright specks of hexagonal outline, sometimes seen in crystals of hornblende and augite, are evidently cross-sections of these needles, as they become dark between crossed nicols, and remain so on complete rotation of the stage of the microscope.

Titanite (?).—This mineral I add with some doubt, though it is a very frequent accessory in rocks of the class under notice in other countries. It seems to me to be represented in the dark base of the Portobello rock by crystals of sharp wedge-like outlines, which occur very sparingly amongst the brown hornblende crystals, and are generally dark throughout, or show only here and there fine specks of brown colour.

Glass.—Particles of this, water-clear, perfectly isotropic, and of all kinds of shapes, occur pretty frequently in the dark base of the Portobello rock (*g*, Figs. 4 and 5); in that of the Pine Hill rock they are more rare. They always contain abundance of larger and smaller gas-cavities, generally arranged in strings. (See further on.)

The Dense Compact Rock.

This forms the so-called Purakanui Cliffs, facing the Pacific Ocean about eighteen miles north of Dunedin, and it no doubt extends into the mountain at the back. The Dunedin–Christchurch railway ran formerly in a cutting along these cliffs; but, owing to frequent landslips, a tunnel has now been driven for it through this rock. Large dykes of the latter, separated by soft, decomposed, clayey rock of light colour, were also passed through in the driving of the Deborah Bay railway-tunnel near Port Chalmers, as shown in a collection of specimens of the rocks met with during this work, made by Mr. W. N. Blair, Chief Engineer of Railways, and preserved in the Dunedin

University Museum. Pebbles picked up in the bed of the Water of Leith, close north of Dunedin, are also of the same character, and indicate the occurrence of the rock *in sitû* within the watershed of that stream.

The rock is quite dense, nearly jaspery in aspect, and breaks with smooth conchoidal fracture. Porphyritic inclusions are small, and very sparingly distributed. Its colour varies in shades of light and dark greyish-green, the lighter-coloured varieties showing generally darker flecks and wavy bands. The rock composing the pebbles found in the Water of Leith is greenish-black, and somewhat resembles Lydian stone.

The appearance of thin sections of the rock, as seen under the microscope, is very difficult to describe. Under a high power there is seen a colourless transparent ground-mass, which between crossed nicols, and on rotation of the stage, proves to be allotriomorphic nepheline, possibly intermixed with a slight percentage of glass and, sparingly, with lath-shaped microlites of sanidine, though these occur in places numerously and closely aggregated. This ground-mass is more or less densely filled with pale-greenish microlites (ægirine ?), their uneven distribution producing light, dim, and nearly opaque portions. They are aggregated in compact groups, arborescent forms, narrower and wider, straight and wavy strings; and such strings also close to form figures of most varied shapes, within which the ground-mass of allotriomorphic nepheline appears sometimes finer, sometimes coarser granulated than the mass around (see Fig. 6). Occasionally tufts and denser strings of these microlites enclose smaller portions of the ground-mass, thereby producing a kind of ocellar structure, as noticed by Rosenbusch in European phonolites, in which, however, the enclosed part consists of idiomorphic nepheline. Larger and smaller brown spots of ferric hydrate, apparently originated through the decomposition of these microlites, are more or less abundant in parts of every section. Solid grains of iron-ore are very scarce. Augite is tolerably abundant in well-formed columnar crystals, from about 1mm. to less than 0·02mm. in length, and of green, occasionally greenish-yellow and light-purple, colour. Most crystals have a broad black margin, composed of dusty iron-ore, and such dusty ore also more or less invests the inside of the crystals; some, especially among the smaller crystals, are rendered quite black-opaque by it. Idiomorphic nephelines and sanidines are rather rare, irregularly-outlined grains of these minerals more common. Needles of apatite seem also rare. Particles of perfectly isotropic water-clear glass, containing abundant gas-cavities usually arranged in lines, occur rather frequently, and are sometimes of considerable size—

3 × 2 mm. and over. They have mostly sharp, straight outlines, forming obtuse-triangular, rhomboidal, trapezoidal, and polygonal figures with unequal angles, and in cases figures closely imitating those of crystals (Fig. 7). I have much hesitated in describing these and the particles mentioned as occurring in the coarse porphyry as *glass*, but the following considerations have decided me to do so:—First: Amongst the considerable number observed in many thin sections there is not a single one with outlines indicating a mineral of the isometric system (for example, nosean, which is hardly ever absent in phonolites), and to consider them all as sections of ill-formed crystals of that system seemed to me unreasonable. Second: They cannot belong to the tetragonal or hexagonal systems under a similar unreasonable supposition of all being ill-formed crystals cut at right angles to the optic axis, because they show no traces of an interference-figure in convergent polarised light. It must also be mentioned that there is not the least indication of their being casts or negative crystals of some pre-existing mineral removed.

The specific gravity of the Purakanui rock is 2·68–2·73; and quantitative analyses of it made by Messrs. F. B. Allen, M.A., B.Sc., and P. Fitzgerald, students of the Dunedin University School of Mines, gave the following results: On treatment of the rock-powder with cold hydrochloric acid, the solution quickly becomes stiff with gelatinous silica, and there are dissolved altogether 54·8 per cent.

		Bulk Analysis of the Rock.		Analysis of Sol. Portion (54·8 per cent.), calculated to 100.
SiO_2	...	51·15	...	44·4
Al_2O_3 } Fe_2O_3 }	...	29·38	Al_2O_3	29·6
FeO	...	—	...	5·8
MnO	...	Trace	...	—
CaO	...	4·59	...	6·0
MgO	...	0·34	...	1·8
Na_2O	...	13·80	...	10·0
K_2O	...	0·95	...	2·4
		100·21		100·0

On comparing these results with those recorded of European phonolites,* a tolerably close agreement is found, and, as the rock under notice also conforms in mineral constitution

* Petrographische Studien an den Phonolithgesteinen Böhmen's, von Dr. Emanuel Boricky. Prag, 1873.

Beiträge zur Petrographie der Plutonischen Gesteine, von Justus Rath. Berlin, 1873.

and general appearance with some varieties of the latter, it is evidently a "phonolite," and specifically a "nepheline-phonolite" (Boricky), or "nephelinitoid phonolite" (Rosenbusch).

Descriptions of Thin Slides of Rock-samples from Various Parts of the District.*

1. *Calder's Quarry, North-east Valley, about One Mile north-east of Dunedin.*

Rock.—Light greenish-grey, very close-grained and compact; not porphyritic. Gives a large amount of gelatinous silica on treatment with cold HCl.

Sections.—Clear ground-mass of allotriomorphic nepheline, densely filled with generally very long, lath-shaped micro-crystals and microlites of sanidine, intermixed in no great abundance with such of plagioclase, all arranged in pronounced fluidal structure. Idiomorphic nephelines scarce, and mostly hidden beneath and between the feldspar laths. Transparency of these minerals more or less impaired through brown coloration by ferric hydrate. Green augite, idiomorphic and in irregular grains, tolerably abundant, but partly converted into chloritic matter, partly and more frequently filled with dusty black iron-ore, which also abundantly occurs in the crevices between the feldspar laths. Solid grains of iron-ore also abundant.

2. *North Quarry, behind the Boys' High School, Dunedin.*

Rock.—Very dark greenish-grey, nearly black; very fine-grained, and slightly porphyritic. Gives a large amount of gelatinous silica with HCl.

Sections.—Allotriomorphic nepheline ground-mass, intermixed with microlites of sanidine and pale-green-coloured augite (probably ægirine). Greenish and brown-coloured augite in sometimes large columnar crystals, idiomorphic nephelines, and sanidines, the latter often in Carlsbad twins, are frequent. Black iron-ore, in larger and smaller grains, abundant; often densely impregnating augite crystals, and forming dark zones around their margins; also scattered and in zonal arrangement within large sanidine crystals. Olivine and brown hornblende scarce, and both having generally broad black margins of dusty iron-ore. Apatite rather rare.

3. *Top of Main Peak, Mount Cargill (2,292ft. high).*

Rock.—Dark greenish-grey, and very slightly porphyritic. Gives a large amount of gelatinous silica on treatment with HCl.

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* Of each rock-sample, at least two,—of some, four or five slides,—have been submitted to microscopic examination.

Sections.—Clear ground-mass of allotriomorphic nepheline, rather scantily mixed with microlites of sanidine; but these occur in places closely aggregated in small streamlike patches with fluidal structure. Tufts and denser aggregates of pale-greenish microlites (ægirine?) very abundantly and evenly distributed throughout the clear ground-mass. Idiomorphic nephelines very scarce. Larger sanidines, partly in Carlsbad twins, also scantily distributed. Augite in columnar crystals of green colour tolerably frequent, and mostly impregnated with grains and dust of iron-ore; some crystals are rendered quite black-opaque by this ore. In the ground-mass the latter is, however, very scarce. Apatite also scarce.

4. *Small Ridge behind Main Peak of Mount Cargill.*

Rock.—Quite similar in aspect to 3, but more strongly porphyritic.

Sections (*a*).—Clear ground-mass of allotriomorphic nepheline, densely filled with microlites of sanidine and greenish ones of ægirine (?), all arranged in fluidal structure. Rather large idiomorphic nephelines abundant, much cracked, and often aggregated in groups. Large sanidines scarce. Green columnar augite and brown columnar hornblende sparingly distributed, the former predominating; both much impregnated with grains and dust of iron-ore, which are also abundant in the clear base, and render the greenish microlites in parts quite black-opaque.

Sections (*b*).—These show the same ground-mass as (*a*); but, besides the greenish microlites, occur others of larger size, which are dark-brown, though mostly rendered black-opaque by dusty iron-ore. They are long-acicular, and cross each other in all directions, whereby an irregular dark network is produced. It is probable they are acmite. The augites are large, and mostly of light-brown and purple colour, green ones being rare; and the brown hornblendes are sometimes very thin and long-columnar. Idiomorphic nephelines same as in (*a*); but there occur more large sanidines, single and in Carlsbad twins. Occasionally observable are large lath-shaped crystals of plagioclase, grains of olivine, and particles of water-clear glass, of irregularly-polygonal shape.

5. *Top of Middle Peak, Mount Cargill.*

Rock.—Greenish-black, dense, and slightly porphyritic. Gives a large amount of gelatinous silica on treatment with HCl.

Sections.—Ground-mass of allotriomorphic nepheline, densely filled with lath-shaped microlites of sanidine and pale-green ones of ægirine (?), all arranged in fluidal structure. Large idiomorphic nephelines and sanidines rather frequent, the latter often in Carlsbad twins. Large columnar augites of purple, light-brown, and green colour abundant; some with broad black margins of iron-ore, but the greater number more or less densely filled with this ore. In the ground-mass the latter is rather sparingly distributed. Olivine is tolerably frequent in irregular grains and crystals, each with margin of black, dusty iron-ore. Apatite scarce.

6. *Range near Mount Cargill.*

Rock.—Dark greenish-grey, with small black spots; close-grained, and slightly porphyritic. Gives a tolerably large amount of gelatinous silica on treatment with HCl.

Sections.—The clear ground-mass consists of a mixture of allotriomorphic nepheline, microlites of sanidine, and also of plagioclase, and is filled with pale-green microlites of ægirine (?). Small idiomorphic nephelines numerous. Large crystals of sanidine and plagioclase frequent, the former apparently predominating. Columnar augites, often of large size, of green and pale-brown colour, abundant, but most are more or less densely filled with grains and dust of black iron-ore. In the ground-mass this ore is also abundant. Apatite scarce.

7. *Range between Pine Hill and Mount Cargill.*

Rock.—Dark greenish-grey, dense, and slightly porphyritic.

Sections.—Clear ground-mass of allotriomorphic nepheline, densely filled with microlites of sanidine and pale-greenish ones of ægirine (?); all showing fluidal structure. The most striking porphyritic inclusion in this is greenish-white olivine in numerous irregular grains and perfect crystals, some of unusual development, consisting in a long narrow columnar extension. One crystal, terminated at both ends by pyramidal planes, measures 1·75mm. in length and 0·25mm. in width: *i.e.*, it is seven times longer than broad. It has a strong black margin of iron-ore, and is zoned inside parallel with the sides by a brown ferruginous streak, while a line of brown iron-spots surrounding small grains of iron-ore runs lengthways through the centre. All the other crystals and grains have also broad rims of black iron-ore, and several are broken up similarly to the grain shown in Fig. 4 (*o*). Augite is abundant in large purple-brown, slightly pleochroic crystals, all with black margins, and more or less densely impregnated with dust and grains of iron-ore, which is also plentifully distributed throughout the base between the inclusions. Idiomorphic nephelines scarce. No large sanidines; no hornblende; very little apatite; a few small particles of water-clear glass. There are, however, a great number of long columnar or acicular crystals, some with blunt or jagged terminations; others, especially larger ones, acutely pointed from one side. Most are quite black-opaque throughout, but some larger ones are faintly deep-brown-translucent. It is probable these inclusions represent acmite.

8. *Pine Hill, near Porphyry Outcrop.*

Rock.—Light and dark greenish-grey, dense, and slightly porphyritic. Gives a large amount of gelatinous silica on treatment with HCl.

Sections of light-coloured rock, colourless transparent ground-mass of allotriomorphic nepheline, with microlites of sanidine in no great abundance. Light- and dark-green microlites (ægirine?) in some parts scantily, in others abundantly, distributed in tufts; also closely aggregated in larger and smaller roundish patches. Idiomorphic nephelines and sanidines numerous, the latter often in Carlsbad twins. Augite in columnar crystals of green colour rather frequent. Hornblende occurs sparingly in large crystals of dark-brown colour. Apatite scarce. Iron-ore grains scantily distributed. There are also observable a few good-sized particles of water-clear glass, showing irregular forms with sharp outlines.

9. *Boulder found with those of the Coarse Porphyry on the Pine Hill Spur (must have come from an Outcrop on Pine Hill).*

Rock.—Dark greyish-green, dense, and rendered porphyritic principally by crystals of sanidine, which are generally disposed parallel to the clinopinacoid.

Sections.—Ground-mass similar to that of No. 8, but the green microlites are of darker shade, in the average larger, and more abundantly and evenly distributed. Idiomorphic nephelines of large and small size abundant, and occasionally aggregated in groups. Sanidines large and numerous, frequently in fine Carlsbad twins. Augites of green colour not plentiful, and in the average rather small. Hornblende in large dark-brown crystals very scarce. Apatite and iron-ore sparingly distributed. Particles of water-clear glass—some of large size—of irregular shapes with sharp outlines, rather abundant.

10. *Top of Flagstaff Hill (2,196ft. high), about Seven Miles north-west of Dunedin.*

Rock.—Very dark greenish-grey, dense base, rendered strongly porphyritic by rather large crystals of sanidine, generally disposed parallel to the clinopinacoid. Gives much gelatinous silica on treatment with HCl.

Sections.—Clear ground-mass of allotriomorphic nepheline, not very abundantly intermixed with microlites of sanidine and rather large, light-green ones of ægirine(?). Idiomorphic nephelines large, very clear, not numerous; some square sections show pronounced parallel cleavage-cracks. Sanidines, partly in Carlsbad twins, numerous, and some very large. They are much cracked, and more or less thickly impregnated with small portions of the ground-mass, dusty matter, green microlites, grains of iron-ore, and roundish particles of glass. These inclusions are rarely distributed evenly throughout, but are mostly confined to the centre parts of crystals, leaving clear zones of greater or less width around; there are also crystals with the centre parts clear and the inclusions forming uneven margins around. One crystal was observed bounded on one side by a jagged rim of water-clear glass. Augite very abundant in large and small columnar crystals, which are, as a rule, more or less abundantly impregnated with grains of iron-ore. Some of the larger crystals are rendered nearly black-opaque by it; others have broad, black margins, leaving only small clear portions in the centre. They are mostly of fine grass-green colour, but there are some amongst the larger ones which are light-brown in the centre and green around. Olivine in large irregular grains and crystals, with broad black margins of dusty iron-ore, is rather frequent. Some crystals are thin and long-columnar like those noticed in No. 7. A number of grains occur sometimes closely grouped together. One large grain was observed showing a broad rim of green microlites so closely aggregated as to look like solid augite. Apatite scarce. Iron-ore abundant in large and small grains.

11. *From Cliffs between Purakanui Cliffs and Hayward's Bluff.*

Rock.—Dark greenish-grey, very fine-granular, rendered strongly porphyritic by crystals of feldspar. Contains scattered large patches of black hornblende; but this mineral, as shown in the thin section, is only sparingly distributed in the base of the rock. Gives a fair amount of gelatinous silica on treatment with HCl.

Sections.—The clear ground-mass is composed of a mixture in about equal proportions of allotriomorphic nepheline and microlites of sanidine, through which are rather scantily distributed the usual pale-green microlites (ægirine?). Idiomorphic nephelines, in the average of small size, are tolerably numerous. Sanidines, some of large size, plentiful, and the large ones are generally full of inclusions of ground-mass, grains of iron-ore, dusty matter, &c., sometimes zonally arranged. Some amongst the sections of the mineral show marginal growth, *i.e.*, a narrow rim, optically of different orientation from the enclosed portion. Large columnar crystals of plagioclase are also present, though in less number than those of sanidine. Both feldspars occur occasionally grown parallel together; and there are sections showing a parallel intergrowth of plagioclase and sanidine: *i.e.*, a large centre portion of the former is surrounded by a narrow zone of the latter, exactly as shown in fig. 1, plate xxiv., H. Rosenbusch's "Physiography of Rock-making Minerals" (translated by J. P. Iddings). Green augite is plentiful in large and small crystals, which are generally impregnated with black grains and dust of iron-ore in greater or less abundance. Some of the larger crystals are brown in the centre and green around. Hornblende occurs very sparingly in good-sized crystals, which are for the greater part black-opaque, only in places deep-brown-translucent. Apatite is tolerably frequent. Iron-ore in large and small grains abundant.

12. *Occurs at the Bottom of the Cliff in the White Decomposed Rock between the Dykes of Coarse Porphyry, Portobello Promontory. (A similar rock crops out on top of the promontory.)*

Rock.—Greenish-grey, fine-granular, and porphyritic. Contains scattered large patches of black hornblende. Gives a fair amount of gelatinous silica on treatment with HCl.

Sections.—As in macroscopic aspect, so also in microscopic character, there exists a marked resemblance between this rock and the one just described (No. 11), though the localities are nearly ten miles distant from each other. It is an analogous case to that of the coarse porphyries of the Portobello promontory and Pine Hill. The ground-mass and microlites of these slides and of No. 11 are quite undistinguishable, and, as regards the porphyritic inclusions, the only differences are that olivine—absent in No. 11—occurs in these slides sparingly in large grains, partially or wholly serpentinised and surrounded by broad black margins; also that the sanidines and plagioclases are larger and more abundantly filled with inclusions (ground-mass, iron-ore, &c.), some showing only a very narrow, clear, marginal zone. Of marginal growth of sanidine and of parallel intergrowth of sanidine and plagioclase, as noticed in No. 11, there occur several fine examples. One large crystal of sanidine shows two narrow marginal zones of different optical orientation, surrounding a differently-orientated centre part. Another large inclusion exhibits a columnar plagioclase surrounded by two differently-orientated broad parallel zones of sanidine.

13. *From Base of Cliffs of White Decomposed Rock between Porphyry Dykes, Portobello Promontory.*

Rock.—Light greyish-green, dense and tough, not porphyritic. Gives much gelatinous silica on treatment with HCl.

Sections.—Clear, though in parts slightly hazy, ground-mass of allotriomorphic nepheline, densely intermixed with long-acicular green microlites (ægirine ?), and rather sparingly with microlites of sanidine. There occur, however, small irregular patches of the nepheline ground-mass nearly free of the green microlites. Idiomorphic nephelines small and not numerous. Sanidines very scarce, and those occurring form mostly Carlsbad twins. Augite thinly scattered in generally small columnar crystals of green colour, which are more or less strongly impregnated with dust and grains of iron-ore. Apatite scarce. Iron-ore in small grains very sparingly distributed throughout the ground-mass. Water-clear, sharp angular particles of glass tolerably frequent.

14. *Quarry at Logan's Point, Dunedin Harbour.*

Rock.—Greenish-grey, dense and compact, not porphyritic. Gives much gelatinous silica on treatment with HCl.

Sections.—The microscopic character of the rock has been described by Professor Hutton, of Christchurch;* but I have here to mention that, in addition to the component minerals he describes (plagioclase, augite, &c.), I found in my sections unmistakable small idiomorphic nephelines and sanidines, some in Carlsbad twins, whilst the large amount of gelatinous silica afforded on treatment of the powdered rock with HCl indicates that a large percentage of the ground-mass consists of allotriomorphic nepheline.

15. *North-East Valley, near Normanby, about Two Miles north-east of Dunedin.*

Rock.—Dark greenish-grey, dense and porphyritic, some of the larger porphyritic inclusions being recognisable by the naked eye as feldspar and nepheline.

Sections.—Clear ground-mass of allotriomorphic nepheline, densely filled with greenish microlites (ægirine ?), and more sparingly with microlites of sanidine. The greenish microlites and dusty matter are in patches so much accumulated as to produce a greyish haziness, imparting to the ground-mass a mottled light and grey appearance. Sometimes only narrow, irregular-veinlike, lighter portions are left between much larger darkened

* The Eruptive Rocks of New Zealand: Trans. Roy. Soc. New South Wales, 1889, p. 134.

ones. Fine crystals and irregular grains of nepheline of large and small size, sometimes several grouped together, are rather numerous, but have suffered more or less through decomposition, as indicated by a light cream-colour, and by their transparency being impaired in varying degree even to opaqueness. Some show these features only round the margin and are clear in the centre, others are cream-coloured and opaque throughout. The clear portions are, as a rule, full of cracks, mostly irregular, but sometimes parallel — indicating cleavage — in square or rectangular sections. They also contain an abundance of microlitic inclusions and vapour-cavities, in some arranged in zones parallel to their outlines, in others in patches; but in the majority they form longer and shorter strings running in all directions. Crystals of green augite, singly or in groups, occur also occasionally as inclusions in the larger nephelines. Porphyritic sanidines are scarce in the ground-mass, and generally form Carlsbad twins. Augite of green and purplish-brown colour, and dichroic in green and brownish-yellow, is very abundant in large and small columnar crystals, which are generally impregnated, in varying degree, with grains and dust of iron-ore; some crystals are rendered quite black-opaque through this impregnation. Larger crystals frequently are purplish-brown in the centre and green around the margin. Olivine occurs rarely in largish grains more or less serpentinised, and with broad black margins of iron-ore. Occasionally several grains are grouped together. Iron-ore is abundantly distributed in larger and smaller grains. Apatite is scarce.

16. *Bell Hill, Dunedin.*

This rock, though greatly resembling in macroscopic character some of the described rock-samples, turned out to be an "augite-andesite." It is dense and compact, of greenish-grey colour, and very slightly and minutely porphyritic. The powder gives no gelatinous silica on treatment with HCl. The sections show a dense, irregular network of small plagioclase laths, probably intermixed with some of sanidine, the interstices between being filled with isotropic, rarely devitrified glass. Porphyritically distributed through this ground-mass occur in moderate abundance larger plagioclases, mostly long and stout-columnar and jagged at the ends; and some showing twinning lamellation according to both the albite and pericline laws; further augite of greyish-green, light-brown to yellow colour, and very slightly dichroic, in great abundance, in large and small crystals and irregular small grains, generally not much impregnated with grains of iron-ore. This ore is, however, plentifully distributed in larger and smaller grains throughout the ground-mass. Apatite is rather scarce.

A quantitative analysis of the rock by Mr. Thomas Butement, an Associate of the Dunedin University School of Mines, gave the following results:—

SiO_2	52·30
Al_2O_3	20·48
FeO	7·01
CaO	7·10
MgO	0·80
Na_2O	6·60
H_2O	4·33*
	98·62

Concluding Remarks.

The foregoing descriptions show that nepheline, both allotriomorphic and idiomorphic, forms an essential component of the volcanic rocks of a large portion of the Dunedin district, and that all those concerned belong to the phonolite group of rocks. Adopting the classification of Rosenbusch, the coarsely-porphyritic rock first described, and 2, 3, 4, 5, 8, 9, 13, 15, belong to "nephelinitoid phonolite;" whilst others (7, 10), through increase of sanidine and corresponding decrease of nepheline, come under his designation of "trachytoid phonolite;" and of the remainder, 1, 6, 11, 14, and 6, 12, through accession of plagioclase, and either absence or presence of olivine, graduate respectively towards tephrite and basanite. The great abundance of hornblende and olivine in some of the rock-varieties described, especially the coarsely-porphyritic ones, though an uncommon occurrence in phonolites, would, I think, not justify applying any special terms to these varieties, such as olivine-phonolite, hornblende-phonolite, olivine-hornblende-phonolite, for the reason that both minerals are generally considered to be only casual accessories. It is certainly, however, a peculiar circumstance that other minerals of the nepheline group, especially nosean, which is so common an accessory—in fact, nearly an essential constituent of European phonolites—is here completely absent, as far, at least, as my observations have gone; and that of the occurrence of tibanite, also an accessory hardly ever absent in those phonolites, only one doubtful instance could be found. Another singular feature in the case of our rocks is the scarcity of zeolites, such as analcime and natrolite—species which are generally so abundant in druse-cavities and fissures of decomposing phonolites,—for only a few small cavities coated with them have so far been discovered in the decomposed rock of the Portobello promontory. It seems, indeed, as if the nepheline-

* 0·05 per cent. at 100° C., 4·28 per cent. on ignition.

silicate, that by molecular change and hydration gives rise to the formation of these minerals, had been leached out too quickly and completely to allow that process to take place; for the white decomposed rock of the promontory gives no gelatinous silica on treatment with HCl. Or it may also be that the nepheline has been converted into kaolin, the same as recorded by Doelter of phonolites in Sardinia.

The degree and manner in which the Dunedin phonolites have been affected by decomposition is very remarkable. Whilst, for instance, the white decomposed rock of the Portobello promontory faces the sea in cliffs up to 80ft. in height, and has not a clayey, but rather a kind of rough, sandstony feel — a rock, in fact, which, were it not for the small undecomposed outcrops at the bottom of the cliffs, nobody would ever suspect to have originated from those dark, hard, and tough rocks before described;—on the contrary, the dense, dark phonolite of the Purakanui cliffs withstands the action of the sea apparently unharmed, as far, at least, as aspect goes, but is beyond its reach much decomposed into brownish clayey matter. And this is the case also with the rock-varieties of the inland localities, only the tops and steep slopes of the mountains (Mount Cargill, Flagstaff Hill, Pine Hill) forming in this respect exceptions. Owing to this strong decomposition, and to extensive denudation having mostly obliterated the original surface-boundaries, the attempt to define its limits, in the case of the nepheline-bearing rock-formation as a whole, would be, I think, a hopeless one; and much more so in that of the special rock-varieties, irrespective of the fact that the similarity in aspect of some of the varieties to other kinds of volcanic rocks they come in contact with — viz., andesite and basalt — requires for their identification both chemical and microscopical examination nearly step by step.

Regarding the questions as to the geological age of the rocks under notice, and of their relative age compared to the other volcanic rocks occurring in the district—viz., andesite, trachyte, and basalt—it can, as answer to the first question, with certainty be stated that all the volcanic eruptions of the Dunedin district took place within the Tertiary period. And, concerning the question of their relative age, certain features in the configuration of the country seem to indicate that the nepheline rocks have broken through the andesites and are therefore more recent, whilst, according to general rule, basalt is the youngest in having broken through both. With the trachyte the nepheline rocks have not as yet been found in contact, and therefore no definite opinion can be formed on the point in question. I am inclined to consider the trachyte younger than the andesite, and as the immediate precursor of the nepheline rocks.

It may in conclusion not be out of place to mention that nepheline-bearing rocks are not confined to the Dunedin volcanic district, but that the similar volcanic area of Banks Peninsula (Province of Canterbury) contains at least one large dyke of a rock which is no doubt a phonolite,* whilst there occurs, in addition to andesite, trachyte, and basalt, an important type of rock, viz., rhyolite, which still awaits discovery in the Dunedin district.

Explanation of Plate V.

Figs. 1, 2, 3, are drawn in ordinary light from thin slides of the dark base of the coarsely-porphyritic rock of the Pine Hill; 1 and 2 are magnified 26 diams.; 3 is magnified 120 diams.

Fig. 1.—Along upper right-hand edge are portions of three crystals of sanidine, marked *s*, the centre one forming a Carlsbad twin, with the twinning-line running through the middle in the direction of the dotted line towards *s*. A fourth sanidine (*s*), of narrow-columnar form, runs upwards from near the broken end of the largest of the three crystals

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* With regard to this assertion, I have to state the following: Some years ago I received from the late Sir Julius von Haast a specimen of rock considered to be trachyte-porphyry, broken from a massive dyke traversing the high andesite range on the eastern side of the Lyttelton Railway tunnel on the Christchurch side of Banks Peninsula. During my examination of the Dunedin rocks I remembered this specimen, and also examined it closely, with the following results: The rock is of a dark greyish-green colour, dense and compact, and rendered strongly porphyritic by small crystals of sanidine, generally disposed parallel to the clinopinacoid, whence results on fracture in a favourable direction a glittering aspect due to the cleavages of that face of the feldspars shining out simultaneously. In fact, the rock very much resembles the green rock, No. 9, described from the Pine Hill, being only more strongly porphyritic. The powder gives a considerable amount of gelatinous silica on treatment with cold HCl; and according to a quantitative analysis by Mr. Thomas Butement the composition of the rock is as follows: SiO_2, 59·87; AlO_3, 21·22; Fe_2O_3, 4·42; FeO, 1·16; MnO, 0·14; CaO, 2·58; MgO, 0·91; K_2O, 4·06; Na_2O, 5·34: total, 99·70.

Microscopic examination of thin sections discloses a clear ground-mass showing all the characters of allotriomorphic nepheline as previously described, but the granulation, so to speak, in light and dark resulting on revolving of the section between crossed nicols is more minute than in the Dunedin rocks. Sparingly distributed through this ground-mass occur lath-shaped microlites of sanidine, and in very great profusion tufts and dense groups of pale-greenish or greenish-grey microlites (ægirine?), imparting to the sections in ordinary light a finely-speckled dark-and-bright appearance, which is rendered more pronounced by an abundant even distribution of rarely large but generally small and even-sized grains of magnetite. Porphyritic sanidines, mostly in Carlsbad twins, are large (up to 4mm. in length and 2mm. in breadth) and numerous, and the larger ones generally show inclusions of microlites and dusty matter. Augite occurs very sparingly in small ill-formed crystals and grains of light-green colour and slightly dichroic. Apatite is also scarce. Idiomorphic nephelines could not be discovered in any of the slides.

Considering these observations in connection with the chemical results, I have no hesitation in calling the rock a "trachytoid phonolite."

just noticed. Near the centre of the lower edge is an ill-formed crystal of nepheline (*n*), with a small crystal of sanidine closely adjoining. The small crystal marked *a*, near the upper edge, with a large grain of black iron-ore penetrating into it, is brownish-green augite; and there are a number of small columnar crystals of this mineral, of fine green colour, scattered throughout the section. The four large black grains—one at the lower edge—represent, no doubt, augite converted into iron-ore, as indicated by the grain above the nepheline crystal having closely attached a particle of green augite, conforming with it in outline. The ground-mass consists of clear allotriomorphic nepheline, densely filled with pale-green microlites (ægirine?) and colourless ones of sanidine, and contains small grains of iron-ore sparingly scattered through it.

Fig. 2.—The ground-mass in this is similar to that of Fig. 1. Near the upper edge is shown a large green augite crystal (*a*), cut at right angles to the vertical axis, but somewhat deformed at the upper and lower corners by two irregular grains of augite breaking into it. A thin black zone of ferruginous matter exists close to, and parallel with, its outlines, and it shows numerous cleavage-cracks parallel to the prism. Included in it are two large and several small grains of magnetite. In convergent polarised light a fine optic axis is seen near the long right-hand edge, which is the trace of the orthopinacoid, while the other outlines represent the traces of the clinopinacoid and prism. There are several smaller augite crystals shown: one (*a*), near left-hand edge, broken into by a large grain of magnetite; *s*, near middle of right-hand edge, is sanidine; and a large, irregularly-contoured nepheline (*n*) is shown near lower edge; a small square one, a little to the right, in conjunction with two small prisms of sanidine (*s*). The small black grains are magnetite, and so is, no doubt, also the large oblong grain, though probably occupying the place of a former augite crystal.

Fig. 3.—This has been drawn under a greater magnifying power, in order to give an idea of the appearance of a part of the allotriomorphic-nepheline ground-mass, which is tolerably free of microlites. It is seen to be traversed by innumerable fine cracks, which do not, however, conform to the granulation in light blue and dark resulting on rotation of the stage of the microscope between crossed nicols. At the right-hand edge near the top is shown part of a large green augite crystal (*a*); and there are a number of smaller, rather ill-formed crystals of this mineral seen in various parts of the section, especially near the lower rim. The black iron-ore grains prove, by their isometric outlines, to be magnetite. Some colourless-transparent, long-acicular microlites, seen here and there in the ground-mass, are doubtless apatite, as they show extinction parallel to their length in polarised light.

Figs. 4 and 5 are drawn in ordinary light from the sides of the dark base of the coarsely-porphyritic rock forming the 15ft. dyke on the promontory at Portobello. Magnified 26 diams.

Fig. 4.—This shows, in the centre of upper part, portion of a large particle of water-clear isotropic glass (*g*), its terminating outlines outside the figured portion being irregular and rounded. With the exception of an included grain of magnetite and a few narrow strings of microlitic inclusions, it is quite clear throughout. Next to it, on the left-hand edge, is part of a large prismatic crystal of rust-brown hornblende (*h*), quite free from inclusions of iron ore. Below this, on same edge, is part of a small prismatic crystal of green augite (*a*); and right opposite to this, close to right-hand edge, is another crystal of green augite cut somewhat obliquely to the vertical crystallographic axis, as indicated by its shape and the prismatic cleavage-cracks. Its outlines represent the traces of the ortho- and clino-pinacoids and the prism. The small clear patch between it and the edge consists of isotropic glass, and so does also the small rectangular clear particle (*g*) below it. At the edge above it, near the large glass-

particle, is shown the end of an augite crystal, so densely filled with magnetite grains that its green colour appears only in small specks; and this is also the case with several smaller crystals and grains of this mineral, distributed with those of hornblende through the section—one (*a*), close to centre of lower edge, appearing nearly black-opaque. Near to this dark crystal is a group of grains of olivine (*o*), transparent, with a slightly greenish tint, seemingly representing a large grain broken up. Each grain has a strong black margin of iron-ore, and around the whole group runs a broader margin of densely-aggregated small grains and dust of this ore, and the crevices between them are filled with it. The larger grains are slightly serpentinised along the cracks. The ground-mass is colourless-transparent, and consists, as in the Pine Hill rock, of allotriomorphic nepheline and microlites of sanidine; but, with the exception of the portion below the hornblende crystal, it is more densely filled with greenish microlites and dust and grains of iron-ore, whence results a darker-speckled aspect.

Fig. 5.—On the left-hand edge, near the upper part of figure, are two large ill-formed sanidines (*s*)—a long thin columnar one overlapped by a shorter and broader one, of which only part is seen. Below this are two prismatic crystals of brown hornblende (*h*), lying parallel to each other and both nearly free of grains of iron-ore. The hexagonal section (*h*) further to the right is also a crystal of brown hornblende, cut at right angles to the vertical axis, its outlines representing the traces of the clinopinacoid and prism. It is quite free of grains of iron-ore, but its two lower sides have strong black ferruginous margins. On the right-hand edge, in line with this crystal, is another large sanidine (*s*), slightly dimmed by inclusions along its lower edge. Attached to this edge is an unusually small square section of nepheline (*n*). A much larger section of nepheline, dimmed by dusty matter, is seen low down near the left-hand edge of figure. The bright, irregularly-outlined grain marked (*g*) near the centre of the figure is water-clear glass; and along the lower edge is shown part of a large prismatic crystal of green augite, much cracked and having a narrow zone of fine grains and dust of iron-ore along the margin. The appearance and constitution of the base is similar to that of Fig. 4. Some of the larger prismatic microcrystals are brown hornblende, some green augite, and the larger black grains are, from their contours, no doubt magnetite.

Fig. 6.—This is drawn in ordinary light from a thin slide of the rock of the Purakanui cliffs. Magnified 26 diams.

The large, irregularly-outlined grain (*g*) is water-clear perfectly isotropic glass, exhibiting under a high magnifying power a multitude of larger and smaller vapour-cavities, mostly arranged in strings. Close to its right-hand edge, near bottom margin of figure, is a very small hexagonal section of nepheline (*n*). There are three small prismatic crystals, marked (*a*), in upper part of figure, of which the two dark ones on the left were once green augite, but are now nearly changed into dusty black iron-ore, only fine specks of green colour denoting their former character; the third and smallest one is still green augite throughout. The ground-mass, consisting of allotriomorphic nepheline, is colourless-transparent, and its peculiar appearance in variously-outlined figures of lighter and darker shade is due to a weaker and denser accumulation of tufts and groups of greenish microlites. Solid grains of iron-ore are sparingly distributed, but dusty iron-ore renders portions of the base quite dim and black-opaque, as at the upper right-hand corner of the large glass-grain and near the small crystal of nepheline.

Fig. 7.—This shows the outlines of three colourless transparent glass particles drawn from same slide as Fig. 6. Magnified 15 diams.

The large centre one is especially interesting, as resembling a long prismatic crystal broken and fractured at one end. The irregularly-outlined small portions marked with crosses along its right-hand and upper margins are doubly refracting, and so are also two of the small fragments that resulted from the fracture; the remainder is perfectly isotropic, with the exception of the small prismatic particle marked with a star, which is doubly refracting in the upper half. Cracks, crevices, and spaces in and between the fragments are filled with dusty black iron-ore, and vapour-cavities are abundant in all the particles.

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2. *On the Occurrence of some Rare Minerals in New Zealand.*

By James Park, F.G.S., Lecturer, Thames School of Mines.

Cotunnite (Lead-chloride).—This mineral came under my notice last May while conducting some experiments on a three-ton parcel of ore from the Golden Gem Mine at Waiomo, a place on the coast about ten miles from the Thames, where a considerable amount of prospecting is being carried on with very encouraging results.

The country rock at Waiomo is a tough greenish-coloured tufaceous sandstone or tufa, which weathers at the surface to a yellowish-brown colour. In places it passes into a harder green and grey-coloured brecciated rock, which contains subordinate beds of soft blue mud-rock, much resembling a fine tufa. On the Thames side of the Waiomo stream the first-named green tufas are intercalated with distinct sheets of hornblende-andesite, locally known as diorite dykes.

The ore from the Golden Gem Mine consisted of rusty-coloured mullocky quartz containing both gold and silver, the latter in the form of kerargyrite (horn silver), and the former as free gold of fine quality.

The ore was crushed wet, and then passed over amalgamated copper plates, in order to ascertain what proportion of the gold could be saved by this means. The tailings were collected in settling-pits, and afterwards treated by pan amalgamation.

During the first operation a yellowish-coloured mineral collected in considerable quantities on the blankets, and on examination it proved to be lead-chloride.

When dry the cotunnite possesses a pale yellowish-green colour, but when wet it assumes a bright-yellow tinge, at a distance resembling that of gold. Streak, white or grey; hardness, about 1·5; specific gravity, 5·32. Slowly soluble in hot water, giving a white precipitate with sulphuric acid.

Tetrahedrite.—A sample of this ore occurs in the mineral collection at the School of Mines, marked as from Koputauahi

Bay, Coromandel. The prevailing rocks in that district, which was examined by me last year, consist of grey and brown decomposed white-speckled tufaceous sandstones, which are traversed in all directions by veins of siliceous hæmatite, and are in places intruded by dykes of augite and hornblende-andesite.

The tetrahedrite is found on the north-west side of Koputauahi Bay, on Mr. Davis's farm, in a soft grey mullocky clay and quartz vein exposed on the beach between high- and low-water marks. The vein trends E.S.E. – W.N.W., with a southerly dip at high angles; and varies from 9in. to 24in. in width.

The tetrahedrite occurs as imperfectly-formed tetrahedrons, on which the faces of the rhombic dodecahedron just appear. The crystals are generally studded with clusters of small but well-developed crystals of pyrites in the form of pentagonal dodecahedrons, and grains of blende. Hardness, about 4; specific gravity, 4·81; lustre, metallic; colour, dark lead-grey; streak, dark; brittle.

The following analysis of a selected sample, by Mr. William Climo, a student of the School of Mines, shows that a large proportion of the copper has been replaced by silver, iron, and zinc, and the antimony by arsenic :—

Sulphur	28·97
Antimony	12·92
Arsenic	9·21
Copper	32·48
Iron	7·92
Zinc	6·55
Silver	1·52
	99·57

This would be represented by the general formula,—

$$[(CuFeZnAg)_2S] + (SbAs)^2S_3.$$

A massive variety of fahl-ore has been described by Mr. William Skey, F.G.S., Colonial Analyst, from Richmond Hill, Collingwood, where it occurs as a narrow segregated vein in a gneiss rock. At that place it is often highly argentiferous; but the sample from Coromandel is poor in silver. The association of the latter with auriferous andesitic lavas, tufas, and breccias is highly interesting.

Nagyagite.—During the past year several specimens of an ore from the Sylvia Mine, Tararu Creek, Thames, rich in lead, gold, and silver, have been analysed at the School of Mines. Careful experiments proved that the gold did not exist in a free state, and a subsequent exhaustive analysis showed the ore to be a telluride and sulphide of lead, gold, and silver, containing 60 parts of lead, 7 parts of gold, and 15 parts of silver in every 100 parts.

The ore is finely granular, with a lustre metallic and splendent; streak and colour lead-grey. Hardness, 1·5 to 2; specific gravity, 7·42. Before the blowpipe it yields a whitish sublimate of tellurate of lead, and copious white fumes of tellurous acid. On charcoal easily reduced to metallic globule with or without soda.

This rare mineral occurs in a quartz vein associated with argentiferous galena, blende, pyrites, chalcopyrite, and antimonite. The rocks at the mine are brown and rusty-coloured tufas or tufaceous sandstones, passing into coarser-grained greenish-coloured tufas and breccias. In the finer tufas, which are often much broken and slickensided, and then possess a somewhat drossy and shaly appearance, have been found a few fragments of black fossil wood, partially silicified, partially carbonised.

Experiments conducted at the School of Mines show that the precious metals contained in the Sylvia ores cannot be saved by ordinary amalgamation, and at the present time extensive dressing-works are being erected at the mine to concentrate the heavy ores for shipment to Europe for treatment.

Petzite.—Rich specimens of this valuable ore are at present being found in a small leader or *dropper* running into the hanging-wall of the main reef in the Nordenfeldt Mine, Thames Goldfield. This mine is situated at the head of Shellback Creek, in the same class of country as the Sylvia Mine, from which it is distant about a mile.

The petzite occurs as a massive dark-blue, almost black, substance, with a black streak. Hardness, about 2; and specific gravity, 8·82. Before the blowpipe it yields a metallic bead with or without soda, emitting abundant fumes of tellurous acid.

A specimen of this ore analysed by Mr. H. Paltridge, of the School of Mines, contained 4·12 per cent. of gold and 2·75 per cent. of silver.

Hexagonal Aragonite.—Among the minerals at the School of Mines there are several examples of the hexagonal form of this mineral, labelled from Cave Valley, Oamaru. The prism is formed by the combination of three individuals about the acute angle. The re-entering angles are generally filled in, thus forming perfect prisms.

Most of the crystals are incrusted with a coating of calcareous sinter; and, judging from the character of the rock adhering to some of them, they would appear to have been found in the Waireka tufaceous greensands of Cretaceo-tertiary age.

The prisms occur in diverging clusters, the largest in the School collection being 4in. long and 1in. in diameter.

Pearl-spar. — This mineral occurs in fine rhombohedral crystals at the Occidental Mine, situated on the western face of Una Hill, Thames district. It is found as a narrow layer in the centre of a quartz leader running into the main lode, which is enclosed in a soft yellowish-white or grey even-grained tufaceous sandstone.

Epsomite.—This mineral is comparatively abundant in the old workings of the Waiotahi and Caledonian Mines, at the Thames Goldfield. It occurs as a fine fibrous efflorescence. The fibres are often over a foot in length, and possess a silky lustre, and pure-white colour. Readily soluble in cold water.

Chalcanthite.—This mineral occurs as stalactitic masses in the old levels of the Caledonian Mine. It has a deep-blue colour and sour taste. Specimens of this mineral were brought from the Champion Copper-mine, Aniseed Valley, Nelson, by Sir James Hector in 1888.

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3. *On Mount Cook Glacier-Motion.*

By J. H. Baker, Commissioner of Crown Lands, Christchurch.

Plate XVII.

In the year 1887, whilst on my first visit to the Mount Cook glaciers, it struck me that the terminal face of the Mueller Glacier occupied a position different from that assigned to it on the map of the explorations of the late Sir Julius von Haast made in 1862, it having evidently materially receded : unfortunately the plan is on so small a scale—viz., four miles to an inch—that no absolute data can be obtained from it to show how much lower a position the terminal face then occupied than that where we find it twenty-seven years later. Therefore, when having the present topographical survey made,—which was necessary to enable an accurate plan to be prepared showing the position and extent of the Mount Cook glaciers,—I determined to leave such permanent marks at the terminal face of each of the glaciers that geologists who may hereafter examine them may have some reliable fixed points from which to decide what changes have taken place between the date of the survey referred to and that of their visit. Similarly, a thought that it might be of some advantage to future observers to know at what rate the glaciers were travelling at a given spot, and on a given time and date, led me to instruct the surveyor, when making his survey of the Hooker Glacier, to range a line across it, setting up rods at equal distances, marking both ends on the permanent lateral moraines or on the side of the adjoining mountain, and to fix, trigonometrically or otherwise, the position of the points so marked that they could at any time be reproduced, to record the distances the rods had moved, and to note the time and date thereof. In like manner I instructed him to paint numbers on certain very large blocks of stone which I had observed on the Mueller Glacier, to fix the position of these blocks trigonometrically, and to record the date on which the observations were made, so that their positions could also at any time be again fixed, and thus the rate at which the glacier was travelling could be accurately determined. I make this explanation of the causes which led to these measurements being made, as it was not my intention to investigate the motion of the New Zealand glaciers myself, for it does not come within the scope of my work; but I deemed that, if properly recorded, such data would be of use to geologists who might wish to do so; therefore these rough notes are put together in the hope that, being, so far as I know, a record of the first actual measurements of glacier-motion in New Zealand, they would be of interest to some of the members of this society.

The Hooker Glacier is situate on the west side of Mount Cook, is seven miles long, and on an average half a mile or a little more in width. The line ranged across it for measuring its velocity was about three-quarters of a mile from its terminal face; and Mr. T. N. Brodrick, who made the survey, reports as follows: "On the 4th of April, at 12 a.m., taking a fixed point on the other side of the glacier, I ranged a line across it on a bearing of 101° 43′ from peg F, setting the rods at fairly regular distances apart in the ice; and again on the 7th April, at 8 a.m., re-ranged the same line, and found the rods had travelled the distances set down below. The rods are numbered from 1 to 5, counting from the west to the east:—

No. 1.	No. 2.	No. 3.	No. 4.	No. 5.
3·3in.	8·2in.	12in.	15·4in.	12·8in.

—thus showing that, although the centre moves the fastest, the eastern side travels more quickly than the west. The old lateral moraine on the east side of the glacier, on which peg E is placed, is very distinctly marked between the shingle slips, as are also the ones between it and the present one now being formed. This seems to show that, after occupying one position for a long time, the glacier had melted away, and then remained stationary for ages before melting again, and so on, until at the present time it is 235ft. below the position it occupied at E. The corresponding old moraine-lines on the west side, although not so distinct, can still be traced: the reason they are not so plain is to be accounted for by the fact that such a quantity of snow accumulates on the Moorhouse Range that avalanches and slips are more numerous, and have swept them away."

These measurements were reduced to give the daily rate at which this glacier was moving at this place at the time they were made, and show,—

No. 1	was moving	1·16in.	per day, or	35ft. 3in.	per year;
2	"	2·90in.	"	88ft. 2in.	"
3	"	4·47in.	"	136ft.	"
4	"	5·42in.	"	165ft.	"
5	"	4·51in.	"	137ft. 2in.	"

—giving an average daily rate of 4·33in., which multiplied by 365 gives the yearly velocity of 131ft. 8in.; but this is only an approximation, as Professor Forbes determined from his observations made in 1842 on the Mer de Glace, Chamouni, that the movement of a glacier differs with the season of the year. But omitting No. 1,—which, being on the side of the glacier, is moving very slightly,—the average is, as I have stated, only 131ft. 8in. a year. I have worked out this average, which, of course, can only be properly done by observations made at various times of the year, to show at what a very different rate the Hooker Glacier, which is comparatively small, travels compared with that of the Mueller or the Great Tasman at the points where these glaciers were measured this season. Owing to a typographical error in the printed copy of Mr. Brodrick's report (see appendix 4 to the Surveyor-General's report for 1889), the rate at which this glacier was moving appears as so many feet and inches, instead of inches and decimals of an inch; and this led Mr. Mannering, who, unfortunately, got hold of an uncorrected copy, to assume, in a paper he read to the Canterbury Institute, that this glacier was travelling very much faster than is the case.

I have stated, you will remember, that I had directed that several large stones should be numbered on the Mueller Glacier, and their positions fixed. This glacier is eight miles long, and half a mile wide at its narrowest point, extending to nearly a mile in other places. Mr. Brodrick at that time reported that "The rocks were well marked in very large characters and on all sides, so that there is every reason to expect that they will not be lost sight of until they are finally discharged from the glacier. Apparently, after leaving the ice and getting on to the river-bed, the action of the water, by washing the loose gravel from underneath them, gradually buries them. This is especially noticeable at the terminal face of the Tasman Glacier, where huge rocks in great numbers may be seen, the more recently discharged ones just beginning to sink, and so on, until at fifty yards from the glacier there is not a large rock to be seen. The circle marked 11 was not painted: it is a singular conical hillock of ice, covered with gravel. Mr. Huddlestone tells me it has kept the same form ever since he went to live at the Hermitage. As there were no conspicuous rocks on that side of the moraine, I fixed its position instead."

These observations were made on the 29th March, 1889; and on the 14th November, 1890—one year and 230 days after —Mr. Brodrick being again in the vicinity, I asked him to re-observe the position of the said stones. He has lately reported,—

"The stones were found again without any trouble. In many cases they had been carried down without displacing the rods which I put on them in 1889, and, as they were only supported on the rocks by piling stones round them, it speaks volumes for the steadiness of the motion. Rock No. 4 has been split by the frost, and each piece has a number on it. No. 7 has slipped down into a large hollow: formerly it was on a ridge of ice; this accounts for its rather erratic motion, and, of course, it must not be used in estimating the rate of the glacier. The average daily rate of the stones is,—

Stations.	Daily Movement.	Yearly Movement.	Difference in Height.
	Inches.	Feet.	Feet.
Station No. 1	4·8	146·0	23·5
" 2	5·5	167·2	18·7
" 4	5·3	161·0	22·8
" 5	7·3	222·0	90·2
" 6	8·0	244·3	38·5
" 7*	12·3	374·0	147·5
" 8	10·2	310·2	48·5
" 9	8·2	249·4	91·8
" 10	7·8	237·2	70·9
" 11	2·9	88·1	10·7
Mean average, excluding Station 7 ..	6·7	203·0	..

* This stone having slipped into a hollow, its movement cannot be relied on.

"I think the relative motions merely confirm what has been already found out by experiments elsewhere, although I do not know whether marks have ever been placed on ice and their positions fixed in the same way that these have been: if not, I would draw attention to the manner in which this method shows the direction as well as the speed of the current. Every care was taken in fixing the positions: different-coloured flags were used when the number was invisible from the observing-station; in some cases the same distance was calculated from two separate bases, and each triangle checked by reducing the stations to the meridian and perpendicular of the trig. station. The changes at the terminal face are principally owing to the Hooker River, which continually alters its course, sometimes running under the ice, as it did in 1889, but more often simply following it round. Whichever way it runs, the effect is the same: the ice is eaten away underneath, especially in flood-time, the upper part falls, and great blocks of ice are carried away by the river. I have found them stranded seven miles lower down. I draw your attention to this, for otherwise it would be difficult to account for the great and constant changes which take place. No doubt a larger amount of snow than usual falling in any particular year would eventually find its way to the terminal face and cause an advance: but the Mueller Glacier on account of the river is unsuitable for any experiments at its terminal face; it is also rough and difficult to traverse, but I have carried out your instructions, and traversed it as closely as I was able. While on this subject I may remark that, accepting the mean annual rate of all the stones as a fair basis for determining the speed of the glacier (that is, twenty-six years to a mile), and allowing that the snow which falls nearer the terminal face than four miles is either melted by the heat or wasted away by surface-streams, and that Mount Sefton contributes nothing to the general stream within three miles of the face, then the snow which forms the most northerly portion of the terminal ice fell eighty years ago, that at the middle might vary between one hundred and two hundred years ago, but none of it would be under one hundred years old. The most southerly portion would be between one hundred and one hundred and thirty years of age. I believe I am correct in saying this, because I take it that, when two glaciers meet, although they join together and form one stream they never mingle. I do not know whether this fact would be disputed, I am too far away to be able to refer to any authority on the subject, but a glance at the tracing of the Murchison Glacier, and a perusal of my description of its moraines, will convince any one that such is the case. As an instance of the magnitude of the ancient glaciers, and the time they must have occupied this valley, it will suffice to say that, at the same rate of speed as the Mueller, the glacier which formed the moraine south of the Pukaki Lake took eight hundred years to carry a stone from the present terminal face of the Tasman to that place. I should say that the average thickness of the moraine lying on the Mueller is about 18in.: it would be possible to calculate approximately how long it took this glacier to build up the large moraines between which it now flows."

As the declivity of the Mueller Glacier at the place where the observations were taken is very much greater (the glacier showing a fall of over 400ft. to the mile) than the bed on which the old glacier rested, of which the old moraine-stones are now found at the south end of Lake Pukaki, it follows that the rate at which it travelled was probably very much less than the velocity of the Mueller Glacier at the present day, and consequently it probably took even a longer period to bring the moraine-stones to the place where they are now found than the time assigned to them.

The survey of the Murchison Glacier was only undertaken this season. Mr. Brodrick reports that—

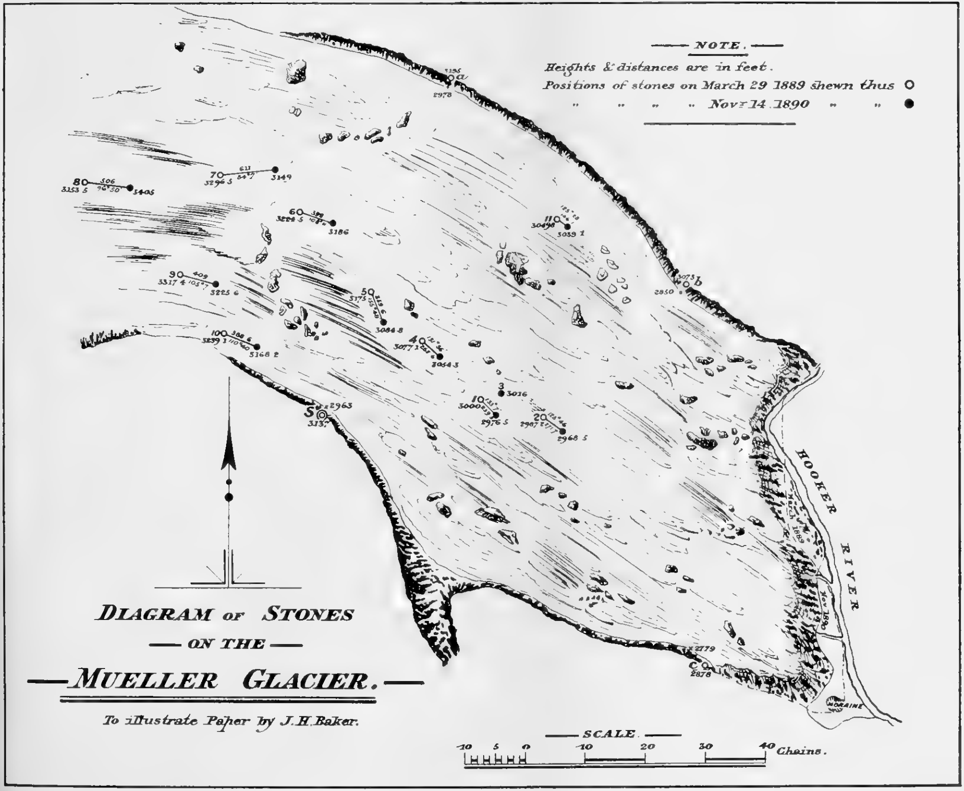
"The terminal face of this glacier is situated about five miles north-east of the lateral moraine of the Tasman Glacier; it is 3,308ft. above sea-level. The ice-face above the outlet of the river is 193ft. high. The Murchison river-bed is a very smooth one, with a fall of about 100ft. to a mile; while the average fall of the Tasman River, of which the Murchison is an affluent, is only 23ft. per mile to the Pukaki Lake. In the valley vegetation grows at an altitude of about 6,000ft., and dense scrub at 4,000ft. In its present state the country, even were it accessible to stock, which it is not, is valueless, though on patches which had been burnt a fine native grass resembling Italian rye was growing luxuriantly. No plants which are not common to other parts of the mountains were to be found except an alpine variety of anise, which I do not remember having seen before. A stratum of bright-red rock crops up in several places along the Liebig Range. I have shown it by a red mark in five different places, the first just opposite the terminal face of the Murchison, the last high on the range nearly in line with the northern portion of the bulge of the Tasman Glacier. It is also visible between Mount Blackburn and Trig. T. The speed of the Murchison was obtained by ranging the line (marked on tracing) from the spur above the Dixon Glacier. The numbers along the line represent the rods set. They were put in on the 29th December, and were reset two days afterwards. The average rate for twenty-four hours was,—

Stations.	Daily Movement.	Yearly Movement.
	Inches.	Feet.
Station No. 78	0·5	15·1
" 79	3·5	106·4
" 80	8·0	238·3
" 81	8·7	264·5
" 82	7·0	213·0
" 83	4·5	136·8
" 92	4·6	140·0
" 93	2·6	79·0
Mean rate	4·92	149·1

"I have now been over all the most important glaciers in Canterbury, and a good many of the smaller ones as well, but I should say that the Murchison, for reasons which I shall try to enumerate, is the best field for scientific research. To begin with, its moraine is composed of different-coloured stones lying in sections, the most conspicuous of which I have drawn on the plan. From the many views I had of the glacier from points on the hills surrounding it, I was always able to distinguish the particular features which I have shown, and they are placed by observations taken with the theodolite from fixed points. We had such bad weather while we were on this glacier that I could not afford to waste any time, or I might have marked the line of larger hillocks forming the medial moraine between the main and the Malte Brun Glaciers as far as the red band. The two semi-crescent-shaped patches shown in red and burnt-sienna are most distinct, and of the form represented on the tracing. The red evidently came from the Cascade Glacier, for its moraine is of the same-coloured rock. The burnt-sienna either came from the same place or from the Baker Glacier—I think the latter, for a small quantity of the same kind of rock is scattered along the northern moraine of the Baker Glacier. The large medial moraine (sepia) is smoother than any I have seen on other glaciers, and from Station 84 to 86 a horse might be ridden along it; the stones are in general small, and there is a large quantity of mud on it; its height is from 60ft. to 90ft.; the general appearance of a section would be like that of a formed road—that is to say, a gradual rise to a slightly flattened crown. Between this moraine and the spur north of the Dixon Glacier a large surface-stream often runs, finding its way under the glacier, but by no fixed opening, just below station 78; there is also a small stream on the other side of the moraine. It is, however, to the first-mentioned that I would draw attention: it is swift, and many perfectly waterworn stones are in its bed. Waterworn stones are to be found throughout the whole length of the main moraine, but, so far as I could see, only on the eastern side: the first pile of them is lying just a little below station 80 on the ranged line; they are not to be found north of that point—at least, I looked for but could not find any. To get from the bed of the creek to the place I have indicated, the stones would have to be lifted about 100ft., yet I believe that is the place they came from, and I think the Dixon Glacier in some manner pushes the ice up. The crevasses marked by blue lines, where the clear ice ends, are drawn in their correct positions. The current of the glacier sets towards the east, and has caused the large landslip shown on plan. The rocks on the glacier, especially along the eastern side, are grooved and scratched in all directions: this is uncommon on

New Zealand glaciers. Many of the marks are deep and at right angles to the grain (if I may use such an expression). I saw some rocks wedged in between the ice and fixed rocks in the lateral moraine; the marks on them were very newly made, and were evidently caused by grinding against the latter. The tributary glaciers differ materially from each other. The Onslow, nearest to the terminal face of the Murchison, is apparently stationary at present. The Cascade and Wheeler contribute nothing to the general stream, and have the appearance of dying out. The Baker and Dixon are, without any question, advancing, especially the former. The Mannering, Harper, and Aida have much the same look as the main glacier. There are one or two small glaciers on the west side of Mount Hutton: these are dying away, and are only worth mentioning because they have complete lateral and terminal moraines, which is unusual for such small glaciers at the altitude they are. The Cass Glacier is only roughly sketched; the length is about right, but the distances estimated. The Classen is also sketched, except between station 91 and Mount Mannering: there it is fairly correct. The Baker and Dixon glaciers have a peculiar ice-formation which I have not seen elsewhere: the dark-blue lines on them represent lateral ridges of ice about 40ft. higher than the rest of the glacier. These ridges are not more thickly covered with moraine than the ice between them and their outside faces, are free from stones, and very steep. At station 71, on the south side of the Baker Glacier, is the best illustration of what I mean; 71 is on the ice-ridge; about 70ft. below it is a new lateral moraine in course of formation: this gradually slopes up to and merges in the ice-ridge. Below this is a hollow; and then at the bottom of the spur, and following it round, comes another small grass-covered moraine, showing that at one time this glacier was about 200ft. lower than it is at present, while three old moraines parallel to the glacier, on the spur to the north, point to the fact that it has also been much higher. The same signs of constant change may be seen near many of the other glaciers, but the Baker is the best example."

The great Tasman Glacier, on the east side of Mount Cook, is by far the largest we have. Its length is seventeen miles and a half, and its breadth varies from one and a quarter to two miles. In a manner similar to that I have narrated of the Hooker Glacier, two lines were ranged across the Tasman Glacier on the 5th December last year, one being situate about five miles from the terminal face of the glacier from a point on the Malte Brun spur near Trig. V., and the other was ranged from the lateral moraine of the Ball Glacier across the Tasman Glacier, about a mile and a quarter higher up:—


NOTE.
Heights & distances are in feet.
Positions of stones on March 29 1889 shewn thus ○
" " " " Novr 14 1890 " " ●
HOOKER RIVER
MORAINE
SCALE.
10 5 0 10 20 30 40 Chains.
DIAGRAM OF STONES
ON THE
MUELLER GLACIER.
To illustrate Paper by J. H. Baker.

Line at Ball Glacier.			Line from Malte Brun Spur.		
Stations.	Daily Movement.	Yearly Movement.	Stations.	Daily Movement.	Yearly Movement.
	In.	Ft.		In.	Ft.
No. 1 ..	9·9	301·0	No. 10 ..	9·2	280·0
„ 2 ..	14·9	453·0	„ 9 ..	10·5	320·0
„ 3 ..	17·3	526·0	„ 8 ..	12·5	380·0
„ 4 ..	17·6	535·0	„ 7 ..	12·3	374·0
„ 5 ..	18·0	547·0	„ 6 ..	13·3	404·0
„ 6 ..	17·0	517·0	„ 5 ..	11·8	359·0
„ 7 ..	16·1	490·0	„ 4 ..	10·4	316·0
„ 8 ..	13·9	423·0	„ 3 ..	9·4	286·0
Mean ..	15·6	474·0	Mean ..	11·1	340·0

The lines were re-ranged on the 7th January, 1891; and the measurements of the latter disclose that at two points only, one mile and a quarter apart, the Tasman Glacier is travelling at the rate of 130ft. per annum faster than at the lower point: thus showing that, as there is no very great difference in the width of the Tasman Glacier at this point, the greater velocity obtained must be owing to the difference in the declivity of the beds on which they move.

The survey of this glacier is still in progress; and Mr. Brodrick, in sending down particulars of the measurements taken, remarks: "In the imperfect state of the survey of this glacier it is perhaps better not to try to describe it; so I will only remark that the widening-out of the glacier into the Murchison valley is very ancient; the lateral moraine there is covered with grass and scrub, and the glacier seems inclined to break through the lateral moraine along its western side in several places."

The information at our disposal, therefore, shows the following are the average rates at the time of year when the observations were made at which the several glaciers were moving at the places where they were measured:—

The Hooker, at the rate of 131ft. 8in. per annum.
The Murchison, „ 149ft. 1in. „
The Mueller, „ 203ft. 0in. „
The Tasman, {At Ball Glacier, 340ft. per annum.
{At Malte Brun Spur, 470ft. „

I have not attempted to draw any conclusions from these figures, for, as I have previously explained, I did not have them made for the purpose of examining the glacier motion myself, but in order that reliable data should be available for any geologist or scientific observer who may wish to study the motion of the New Zealand glaciers; and to any gentleman desiring to do so I shall be happy at any time to supply the measurements made, and all other data that have been recorded

4. *Tongariro, Ngauruhoe, and Ruapehu as Volcanic Cones.*

By H. Hill, B.A., F.G.S.

Plates VI. and VII.

Few places in New Zealand have received greater attention, or, indeed, have demanded more attention, from geologists than what has been appropriately termed the Volcanic Zone of the North Island of New Zealand. Barely five years ago the destruction of the inimitable White and Pink Terraces, the disappearance of the hot lake Rotomahana, and the explosion of Mount Tarawera, drew the eyes of the scientific world of geologists to the spot which Hochstetter had made classic by his exact and interesting description of that portion of the district through which he travelled in the year 1859.

Before the time of Hochstetter, New Zealand had not been traversed by any geologist of eminence, if we except Dieffenbach, nor had there been published any description of the volcanic district which could give to outsiders a true notion as to the wonders to be seen there. But Hochstetter, much as he desired to visit the district to the south of Tokaanu, situated at the south end of Lake Taupo, and much as science would have been benefited had he done so, dared not venture to journey there. Even as Moses of old viewed the Land of Promise he dared not enter, so Hochstetter viewed the Tongariro Range, with the mighty Ruapehu as its furthest limit. But, great pakeha though he was, he dared not disobey the command of Te Heuheu, the chief of Te Kapu, near Tokaanu, whose mana was great and whose word was law. "Ko Tongariro te maunga, ko Taupo te moana, ko Te Heuheu te tangata :" so ran the Native saying, which showed that the power or mana of Te Heuheu extended from Taupo to Tongariro ; and Te Heuheu had said that Tongariro was *tapu*, and that was enough.

Since the date of the Tarawera eruption Sir James Hector, Director of the Geological Survey of this colony, Professors Hutton and Thomas, of the Canterbury and Auckland Colleges respectively, and Mr. Percy Smith, the Surveyor-General, have published descriptive and valuable accounts of what may be appropriately termed the northern portion of the volcanic zone, so that details both descriptive and geological are available for students of vulcanology on the northern portion of the district ; but information respecting the southern division is still meagre and imperfect. Hochstetter, in his volume, describes Tongariro, Ngauruhoe, and Ruapehu, as far as he was able to do so, from a distance, and he also relates an account of the ascent of the active volcano of Ngauruhoe by a Mr. Dyson in

March, 1851, and refers to an ascent of the same mountain by Mr. Bidwill so long ago as March, 1839.

In the "Transactions of the New Zealand Institute," Vol. xix., there are records of the ascent of Ruapehu, by Messrs. Park and Cussen, in the year 1886; and in Vol. xxi. of the Transactions Professor Thomas describes the Tongariro Range, he having visited portions of that district at the beginning of 1888.

It will be seen from these references that the information with respect to some portions of the volcanic country to the south of Lake Taupo is still meagre and incomplete.

In the following paper I propose to add my mite of information to that already collected regarding certain portions of this interesting country, over which I have travelled on three occasions since February, 1887.

The southern limit of the volcanic chain of mountains to the south of Taupo Lake is Mount Ruapehu, which is about twenty-two miles from the place where the Waikato River enters the lake. This chain is known as Tongariro. It consists of three cones, or what once were three cones—viz., Ruapehu, Ngauruhoe, and the Tongariro of our school maps. There are other subsidiary cones which are seen as offshoots from the main chain, especially on the west side in the direction of Ruapehu. This chain of mountains is situated towards the centre of a plateau which varies in height from 4,500ft. in the vicinity of Ruapehu to 2,000ft. near Lake Rotoaira. The volcanic chain runs in the direction of this slope, and it ends towards the north, not at Lake Taupo, but at a much smaller lake known as Rotoaira, which separates the range from the volcanic cone of Pihanga on the south shore of Taupo. The plateau on the west side of the range terminates at Lake Rotoaira, whilst that on the east side may be said to lose itself in a deltalike flat on the borders of Lake Taupo (Pl. VI.).

The northern part of the Tongariro chain, extending from Rotoaira to Ngauruhoe, bears but small resemblance to what was once a single volcanic cone. Denudation has destroyed a large portion of the mountain along the eastern side, and it is only when viewed from Nongo, at the head of Lake Rotoaira, or from Papakai on the north-western side of the mountain, that one sees the shape of what must have been at one time an immense conelike structure. This huge truncated cone has the lower portion of its western and northern slopes comparatively intact, although about midway along its western side the remnant of the cone is broken, but not sufficient to destroy the shape of the slope, which is very well seen in the direction of Ngauruhoe.

The highest portion of this cone is to the north-west, being according to my measurement 6,570ft. above sea-level. The outline of the cone is smooth on the west, somewhat broken and irregular towards the north, and irregular and shapeless on the east. Towards the south there is a lava-flow which unites by a saddle this cone with Ngauruhoe. There is no sign of volcanic activity anywhere around the base or slopes of the cone except at the northern end, just in the same way as the northern slopes of Ngauruhoe give evidence of activity at the present time. The two places where this activity is seen are known as Ketetahi and Te Mari, the former being towards the north-west at a height of 4,800ft., the latter towards the north-east at a height of 5,600ft. Hochstetter, in his account of the district, refers to Ketetahi, from which he saw "large and dense volumes of steam emerging, larger than those from Ngauruhoe." Vast quantities of steam arise to-day just as in 1859 when first viewed by Hochstetter; but, as Professor Thomas has already so well described the spot, it needs no further reference from me. Te Mari, as far as I have been able to discover, is of comparatively recent origin. The place was so called after Te Mari, sister of the chief Matuahu, of Otukou Pa, who died at the end of 1868, just about the time the explosions at Te Mari took place. Te Mari's niece is still living at Moawhango, in the Patea district. No mention is made of Te Mari by Hochstetter, and there is every appearance that the volcanic vents at this place are very recent, and that they broke out at the beginning of 1869, as stated by the Natives. Te Mari is about a mile from Ketetahi. The place is difficult to reach, but the student of vulcanology is provided there with an object-lesson seldom met with. There are three somewhat small and irregular-shaped craters, and at the bottom of each is a shaft of unknown depth, perfectly circular, about 12ft. in diameter, and from which steam is constantly rising. No lava or pumice has been thrown from these vents although smoke has risen from them, and when they broke out in 1869 a bright red flame was seen through the smoke, and as it reached the top of the smoke-cloud it would burst and fall in little parts like snow falling. Such is the account given by an intelligent Native named Aruhe, who was born at Poutou, on Lake Rotoaira, and it is confirmed by two other Natives from the same place.

Within the cone itself are a number of craters, some of which are extremely beautiful, but they are merely the remnants of what must have been at one period a centre of great volcanic activity. They, however, have been so well illustrated by Professor Thomas in the paper already referred to that no further reference to this portion of the chain is necessary, except to say that in what is known as the Red Crater I have seen steam issuing from the walls on each occasion that I have visited the mountain.

Ngauruhoe.

The second cone of the chain is Ngauruhoe, an active volcano from which great clouds of steam are continually rising. It is a mountain-cone of perfect shape, with the portion towards the summit broken off somewhat irregularly. Its longest slope is towards the south, and its shortest towards the north, where a lava-flow joins it to the cone already referred to. The sides slope at an angle of about 40°, but towards the top the slope is greatly increased, and, except in certain places, it would be difficult if not impossible to climb the lip of the crater. Each time that I have ascended the mountain it has been from the west side by way of the Manga-te-popo Stream, the most important tributary of the Wanganui. The valley of the Manga-te-popo is an interesting one from the fact that it is quite filled with lava-flows, one of which is so recent that its black, jagged, and shining surface gives it the appearance of having lately cooled. The material is a heavy black lava, with here and there a feldspar crystal scattered through its mass. Directly at the base of the Ngauruhoe cone, on the west side, the Manga-te-popo Stream takes its rise in a fine bubbling spring of soda-water, which will no doubt become of commercial value in years to come. This spring at the foot of the cone is 5,260ft. above sea-level, and near by the lava-flow at the head of the valley is seen to great advantage. In the course of its progress, the lava, when nearing the base of the cone, divided into two streams, one flowing towards a precipice about 60ft. in height. The lava appears to have cooled on the very edge of the precipice, presenting some very curious and interesting forms.

The cone, which is mostly of cinder and ash, is very difficult to climb; but the top was reached in 2 hours 25 minutes when first ascended by me in March, 1887, and in 2 hours 50 minutes in March last year. At the top the aneroid marked 7,655ft., and the pressure of the atmosphere 23·3in. Thus the height of the cone, as measured from the soda-water spring on the west side, is 2,395ft. Hochstetter estimated the height of the cone at 1,600ft., and the slope at from 30° to 35°; but Hochstetter could only see the height of the cone from the saddle between Ngauruhoe and the northern cone, the lower portion being hidden by another range of mountains. The top of the mountain is very circular, but of irregular height. It is much higher on the eastern than on the western side. The great basinlike hollow at the top is divided into two separate and quite distinct craters, which, for convenience, it will be well to term the major and the minor craters. The lip of the crater is lowest on the north-north-west, from which place it is possible to go inside the major crater for some distance under the almost perpendicular walls forming its north-eastern and eastern sides. The south-western portion of the major crater is in a very active state, and immense clouds of steam are constantly rising from this place. From the spot where the lip is lowest another crater has been formed towards the north-west. It is perfect in shape, and I suppose about 130ft. in depth. Its diameter would be about 130 yards, whilst the diameter of the major crater I estimate to be 250 yards. Towards the centre there is a circular hole 9ft. or 10ft. in diameter, which is the mouth of the shaft from which steam is constantly rising. The walls of this crater when visited by me in 1887 were of a dark colour, with here and there a patch of almost vermilion-red; but in March last year, when I again saw it, the walls were of a primrose-yellow, being covered with sulphur crystals, with here and there a band of red, giving this crater a very beautiful appearance. Steam was rising from the sides at a furious rate, and the crater was much more active than at the date of my first visit. The portion of the major crater which is now the most active part of the mountain is to the south. It is much deeper than the other crater, and is of irregular shape. It seems to have several circular shafts; but the vapour and sulphur-fumes that are constantly rising from the several vents make observation difficult and dangerous. The wall of the crater on the east and south rises in places to 250ft. in height above the floor of the crater on these sides. It is much broken and jagged in appearance, and steam is seen to be issuing from it in many places. The old lava-flows can be clearly seen, and they give a stratified appearance to the walls of the major crater where the fractures have not been extensive. On the north side of the cone, below where the lip is lowest, there is an area several acres in extent which is in a state of activity, as shown by the numerous steam-jets, from which a large deposition of sulphur has taken place. This area showed important changes during the three years that elapsed between my visits to the place. In 1887 there was a slight crater-hole, from which steam issued at a furious rate; but last year the whole area had been covered over apparently with a thin crust, over which it was possible to walk with care. When the crust was broken steam issued, and when a stick was pushed down it was found to be very hot, and to pass through sulphur only. Just before the Tarawera eruption columns of steam were seen to issue from this place; and a similar occurrence took place in 1868, just before Te Mari broke out, as seen by Mr. Batley, of Moawhango, who resided in the vicinity of the mountain at the time. Dieffenbach (vol. i., p. 352) gives Mr. Bidwill's account of his ascent of Ngauruhoe on the 3rd March, 1839. From the description it is evident that Mr. Bidwill ascended the mountain from the Manga-te-popo, as he refers to the lava-flows to which I have made reference. Writing of the crater, he says, "The crater was the most terrific abyss I ever looked into or imagined. The rocks overhung it on all sides, and it was not possible to see above ten yards into it, from the quantity of steam which it was continually discharging. From the distance I measured along its edge I imagine it is at least a quarter of a mile in diameter, and is very deep. The stones I threw in which I could hear strike the bottom did not do so in less than seven or eight seconds; but the greater part of them I could not hear. It was impossible to get on the inside of the crater, as all the sides I saw were, if not quite precipitous, actually overhanging." According to Mr. Bidwill Ngauruhoe was in a state of activity at the time of his visit, as he says that, from indisputable proof, he was able to testify that a stream of hot mud and water had been running from the crater a short time previous to his visit, and that the event had been preceded by a column of black smoke which spread out like a mushroom.

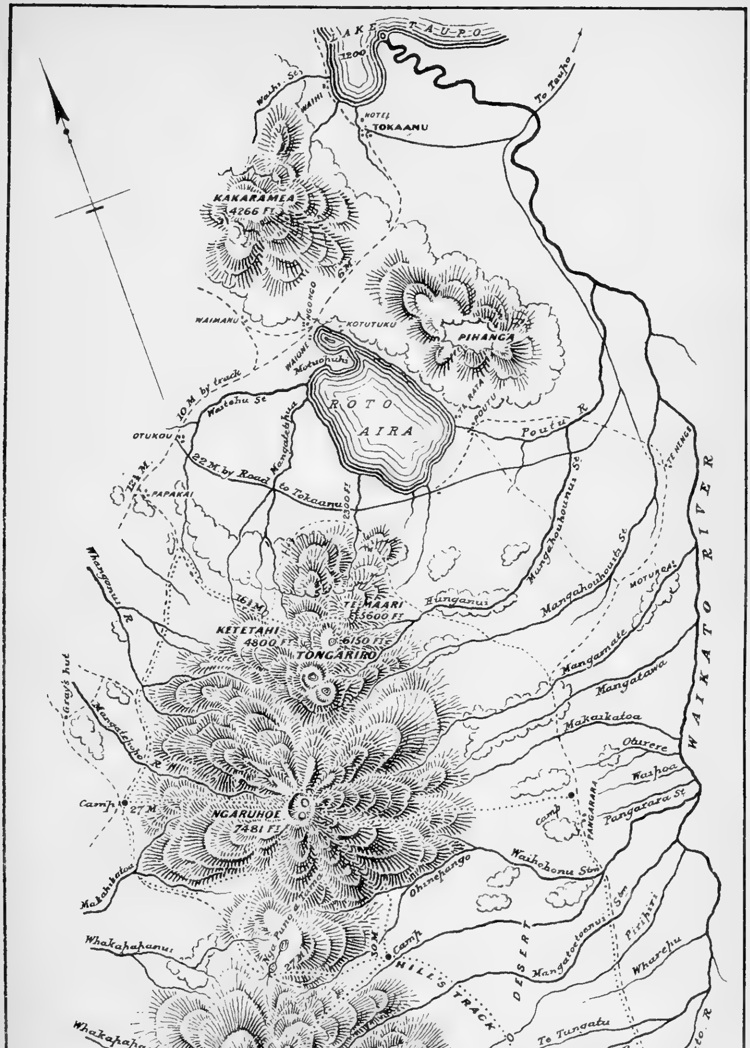
In 1851, or twelve years after Mr. Bidwill had been there, Mr. Dyson succeeded in reaching the top of Ngauruhoe, and this is what he says of it: "The top of the crater was 600 yards in diameter. The lip was sharp. Outside there was almost nothing but loose cinders and ashes; inside the crater there were large overhanging rocks of a pale-yellow colour. The southern side is the highest, and the northern, where I stood, the lowest. There was no possible way of descending the crater. I stretched out my neck and looked down the fearful abyss, but my sight was obstructed by large clouds of steam or vapour. I dropped into the crater several large stones, and it made me shudder to hear some of them resounding, as I supposed, from rock to rock. I saw no lava which had a recent appearance."

It will be observed that these descriptions differ widely from that given by me. The top of Ngauruhoe even so late as 1851 appears to have been a single crater of great depth, which in 1839 acted after the manner of a puia or intermittent boiling-spring. In 1851 it seems to have resembled a ngawha, or a simple boiling-spring; whilst at the present time it may be described as a solfatara. Both Bidwill and Dyson are clearly in error as to the diameter of the crater. It is certainly less than 350 yards in diameter, but the high walls on the eastern side make it appear larger. The smaller or yellow crater is clearly of comparatively recent date, as its shape is perfect, and it is situated north-west beside the place where each observer stood, so that it must have been noticed either by Bidwill or Dyson had it been there at the time of their visits. From the former's description I know the exact direction he took in his ascent, and he must have stood on the western lip of the smaller crater had it been in existence. From appearances I am inclined to the opinion that ashes and bits of sulphur are thrown from one of the craters at intervals. Bits of these are to be found on the rim of the crater towards the west, and there are also several boulders on a small shelving surface between the two craters, which I imagine must have been thrown from the crater at a recent date. On the sides of the cone where the lip of the crater is lowest there is hardly any trace of lava; ashes, cinders, and scoria prevail, but possibly this may arise, as in the case of the north cone of the group, from the fact that denudation is less active towards the south and west than towards the north and east. On the east side, where there are traces of heavy flows of lava, they are deeply guttered in places, and the exposures show a flow of basalt-like lava overlying dust and sand, followed again by cinders, which, in their turn, overlie compact lava. All the lava has crystals of feldspar scattered through it, some of the crystals being more than an inch in diameter. The different rock-materials seen on the mountain were lavas, grey, red, and black, the latter having a pitchy lustre. There was also a bluish-grey lava, which had a metallic ring when struck, not unlike phonolite. I saw no pumice on the mountain nor in its vicinity, intermediate and basic rocks being the only kinds present. In the lower hills at the foot of Ngauruhoe, as at Puke-kaikiore, trachytic rocks are the only ones to be met with, and these trachytic rocks continue from the base of Ngauruhoe to the foot of Ruapehu, between which mountains come the two crater-lakes known as Nga-puna-a-Tama or Tama's Wells. These crater-lakes are situated at a height of 4,350ft. above sea-level, and near the highest part of the plateau-valley which separates Ruapehu from Ngauruhoe. Each crater is about three-eighths of a mile in width and 500ft. in depth. They are nearly circular, and the floor is covered with deep-blue water, towards the centre of which the circular shafts can be seen so characteristic of all the craters on the Tongariro Range.

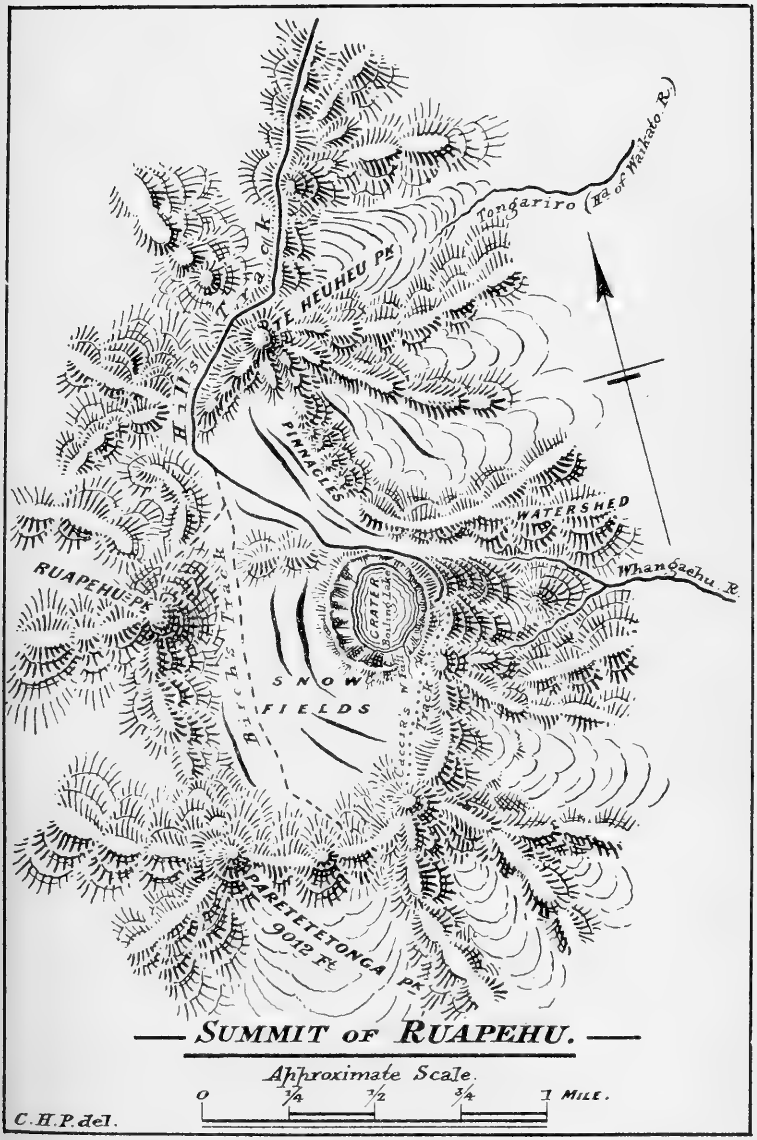
During the breeding-season these lakes are resorted to by hundreds of mutton-birds, but why to these in preference to the other lakes in the district is not known.

Ruapehu.

Ruapehu, the most southern of the volcanoes forming the Tongariro Range, is by far the largest of the three great cones into which the chain naturally divides itself. It is situated on a plateau which, in the vicinity of the mountain, is more than 3,000ft. above sea-level. From north to south it extends for a distance of more than ten miles, and the distance round its base cannot be less than from thirty-five to forty miles. The mountain exceeds 9,000ft. in height, and its slopes for nearly 2,000ft. are always mantled in snow. Towards the south and east the mountain presents a series of steep ridges, whilst several long



To illustrate Paper by H. Hill.



To illustrate Paper by H. Hill.

slopes are seen to run to the north-east, and it is by way of the north-east slope that the easiest ascent of the mountain can be made. When viewing the mountain from the east, three principal peaks can be distinguished—a northern, a western, and a southern—named respectively Te Heuheu, Ruapehu, and Paraetetaitonga, and in the great snow-field between these points the remnants of an old crater can be traced over the snow. To the east of the mountain there is a tract of country known as the Rangipo Desert, and this constitutes the water-parting between the sources of the Waikato and Whangaehu Rivers, one of which runs north and the other south.

At the time when Hochstetter was at Tokaanu no one was known to have visited Ruapehu; nor was it until more than twenty years afterwards that a successful ascent was made to the south peak by Messrs. Maxwell and Beetham. They made no attempt to cross the ice-field, nor does it appear that they saw anything of the boiling lake which is now known to be on the top of the mountain. I have already pointed out that Messrs. Cussen and Park ascended the mountain as far as the southern peak; but only one party ever crossed the ice-field before last year, and that was in 1881, when Mr. and Mrs. Birch, with Messrs. H. H. and H. E. Russell, ascended the mountain by way of the north-east spur, making for Te Heuheu Peak, crossing the ice-field, and passing the crater-lake on its western side. As far as I am aware this was the only time that the mountain had been crossed from the northern to the southern peak previous to 1890.

In 1887, in company with Messrs. Petrie and Hamilton, I followed the Whangaehu River up to its sources far in the mountain on the eastern side. At a height of 7,600ft. we had stood in the centre of a great amphitheatre, the walls of which were hundreds of feet in height. The eastern side had been blown out, otherwise the crater was perfect; and in the centre was a tall mound of lava, which represented the neck of the shaft through which the lava had risen. The waters of the Whangaehu, as they emerged from the mountain-side, were cold, and, though muddy and undrinkable, I concluded that they must have come from the crater-lake, and that the probabilities were against the waters of the crater being warm.

In the course of the year 1889 it was reported that steam had been rising from Ruapehu, and that there must have been an explosion, as the snow in the vicinity of the crater was either melted or covered over with some black substance. Further, it was reported that the Whangaehu River had suddenly risen as much as 6ft. in the course of an hour, although no rain had fallen. In consequence of these reports, I visited Ruapehu for the third time in March last, and, in company with five others, ascended the mountain, crossed the ice-field, and got down to the lip of the crater on the north side. The ice-field at the top of Ruapehu is about one mile in extent—that is, between the northern and southern points. Sharp ridges of rock rise here and there, as may be seen by reference to the plan which is appended to this paper (Pl. VII.). Numerous crevasses are met with, varying from 1ft. to as much as 15ft. in width, and of unknown depth. The crater-lake is situate on the east slope of the mountain, between the three peaks referred to, but much nearer to Paraetetaitonga and Ruapehu than to Te Heuheu: in fact, the ice from these two peaks slopes directly towards the crater. The lake is somewhat irregular in shape, being rather wider from east to west than from north to south. In its widest part I estimate the lake to be 500 yards, whilst its breadth would be 100 yards less. The crater-walls on every side are perpendicular; and to the surface of the water from the lip of the crater the distance must be over 300ft., as I was unable to reach the surface of the water by means of a ball of twine which was more than 100 yards long. The south and west walls of this lake are composed of solid ice, which go down nearly to the surface of the boiling water. Below Ruapehu there is an exposure of black rock in the ice; but nowhere else on the two sides named are there any exposures of rock. On the east and north the crater-walls are made up of scoria and ashes, banded towards the east, and looking like ordinary stratified rocks. The bands are of different colours, and have a gentle slope to the north-north-east. Near the junction of the snow and ashes towards the south there is a small waterfall; but I was unable to find out whether the water was warm or cold. The eastern and northern sides of the crater are hot, and in several places steam was issuing from the sides.

The water in the lake was of a soapy or grey colour, with a pearly lustre showing at times on its surface. It is in constant motion—sometimes from east to west, and sometimes from west to east. At periods of from ten minutes to twelve minutes the surface of the water becomes intensely agitated, and suddenly a great cloud of steam is given off, which hides the surface of the lake for some seconds. This is followed by a brief appearance of stillness on the surface, and a perceptible lowering of the water, when a slow wavelike motion again sets in, as if the water were simmering. This increases in rapidity and intensity until another steam-cloud is given off, and another brief period of repose succeeds. I sat on the rim of this crater-lake for more than an hour, watching every movement of the water and every change in its appearance. Now and then could be heard the falling of ice-blocks into the lake from the cavernous walls which were to be seen towards the western side, and the yawning crevasses on that side of the ice-field showed that there was a gradual movement of ice towards the lake. Whether the size of the lake varies or not I could not say; but according to Mr. Park's account of what he saw from Paraetetaitonga Peak in January, 1886, the lake must undergo some curious changes. On page 71 of the "Reports of Geological Explorations," issued under the authority of Sir James Hector, Mr. Park reports, "At the time of my visit the centre or, rather, the most depressed part of the crater was occupied by a smooth sheet of ice of a greenish-blue colour, which in alpine regions is generally considered characteristic of ice-fields of great depth and permanence." I cannot think, however, that Mr. Park could have seen the position of the crater-lake now described, but that from his vantage-point he simply saw the ice-field between Te Heuheu and Ruapehu, for it is impossible to suppose that the lake could have been frozen over, as the walls of the crater for several hundred yards are simply in the condition of a solfatara. In March, 1881, the lake as seen by Messrs. Birch and Russell was thought to be warm, as they distinctly saw steam rising from its surface by aid of a good glass; and Mr. Cussen, as related by him on page 377 of "Transactions of the New Zealand Institute," Vol. xix., distinctly noticed "clouds of steam rising from the surface of the water," and from the appearance presented he had little doubt that the water was in a boiling state. Mr. Cussen ascended to the south peak of the mountain three months after Mr. Park, and he estimates the lake to be 500ft. or more in diameter, whilst Mr. Birch who saw it in 1881 estimates the diameter at from 600 to 700 yards. Mr. Birch passed across the ice-field under the Peaks Ruapehu and Paraetetaitonga, and had a full view of the lake from the west and south. His estimate of the size of the crater more nearly corresponds to the size as it appeared in March last; but it may be that the ice-wall from the west and south at times is pushed far across the lake, so that to an observer on the east side of Paraetetaitonga the crater-lake would hardly be seen. Regarding the explosion which was reported to have taken place in August, 1889, there can be no doubt whatever that the water from the crater had welled over the lip of the crater at a recent date, as the mark of its rise had been left on the snow exactly in the same way as the waves of the sea leave a ripple-mark on the shore. No large quantity of snow appears to have fallen between the date of the eruption and my visit, and the *débris* and boulders of blue clay were scattered over the ice, and could be traced on the snow-field for about 50 yards from the crater walls. The material that had been ejected was a blue-clay mud, resembling the blue clay thrown out at Rotomahana during the eruption in 1886. It is impossible to say whether the crater now described is the only one on Ruapehu. No doubt it is the only one in activity, but the great ice-field may cover a number of craters the top walls of which are represented by the steep ridges of lava rock which in a measure encircle the ice on the top of the mountain. The great broken-down crater where the Whangaehu River takes its rise adjoins the lake on the eastern side, and it may be that other craters in the direction of Te Heuheu Peak are simply filled with ice, just as the craters in the northern portion of the range are filled with water.

Most of the rocks forming the upper parts of the cones of this range of volcanoes belong to the basic and intermediate lavas, whilst the slopes running from the mountain are all acidic trachytes, and these appear to underlie as a great sheet the whole of the plain extending from Ruapehu to Runanga, on the Napier–Taupo Road. On the west side of Ruapehu there is a very curious line of conical hills running across the plain from Ruapehu in a north-west direction for several miles. These hills are all trachytic in structure, and they appear at intervals of about 200 yards. Their height is from 150ft. to 200ft. There is no trace whatever of a crater on any of them. Probably they are simply the result of blistering on a lava-flow, just as we see blistering take place when melted lead is poured upon a damp and enclosed surface.

Basalt, phonolite, pitchstone, and tachylite are found in abundance in Ruapehu, especially on the east side by way of the Whangaehu River. Extensive flows of phonolite are met with at a height of about 6,000ft., great slabs 5ft. or more in length and varying from an inch to two inches in thickness being common. The pitchstone is well seen in a spot named Waterfall Gully, on the east side of the mountain, and the basalt on the north-east in the direction of Te Heuheu Peak. The tachylite is only found in nodules among the lapilli on the lower spurs of the cone. Along some of the northern slopes there are vast deposits of a heavy pumice of a bouldery character. This, it seems to me, must have come from the crater-lakes of Nga-puna-a-Tama, as the line is traceable in a kind of fan from these lakes in a south-east direction.

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5. *Twisted and Broken Crystals of Tourmaline.*

By Professor Jack.

SECTION D.

(BIOLOGY.)

PRESIDENT OF THE SECTION — Professor WILLIAM A. HASWELL, M.A., D.Sc., F.L.S., Challis Professor of Biology, Sydney University.

ADDRESS BY THE PRESIDENT.

Recent Biological Theories.

I HAVE chosen for the theme of the following address, as likely to be of interest to most of the members of Section D, the subject of recent theories in biology—the new theories or new modifications of old theories that have found the light in the course of the last year or two. To treat such a subject at all adequately and completely would require not a single address, but a long series of lectures; and, without attempting a comprehensive treatment, I purpose merely selecting certain parts of the subject which appear to me the most interesting and the most important.

It is not so very long since the word "theory" was almost *anathema* to the vast majority of the students of plant and animal life. True, there were always theorists; but, with the few brilliant exceptions in which a capacity for theory was combined with a talent for observation, these were looked upon with suspicion, not always untinged with contempt. The naturalist of the old school went plodding along, accumulating his descriptions of species and his records of remarkable and interesting facts, without much thought of theoretical explanation. He was content to take "short views" of things, and found his satisfaction in the indulgence of a passion for the piling-up of concrete particulars—a passion which must ever be one of the mainsprings of activity in the investigation of nature, but which has not been the strongest motive in the cases of those whose names are most likely to be remembered. Theory, in fact, was later in finding its way, as regards the main body of workers, into this than into any other department of science.* It is, it need hardly be said, mainly to the

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* This is true, of course, only as a general statement, and there have been some exceptions. The theorists of the "nature-philosophy" school, for example, at the beginning of the present century, seem not to have been without influence on the scientific workers of their time.

influence of Darwin's writings that in this respect a very important change has come over biological research—a change which has been penetrating further and further year after year, till now it may be said that there is hardly any part of the great domain of biology that it has not reached. This change has been, in great measure, in the nature of an illumination, and the illuminating influence has been theory, and more especially the theories of descent and modification by natural selection. And this illuminating influence, which has lent tenfold interest to the work of every investigator of animated nature, has also shown to him many new lines of study, in following up which he is conscious that, while not leaving his particular corner of the field, he is doing work that is of interest to a comparatively wide circle of thinking men.

The field of biology is so wide, and there are so many problems awaiting solution, that there is a corresponding variety in the subject-matter of the biological theories constantly being put forward. But most of them may, I think, be comprehended in the following main groups:—

1. Theories referring to the ultimate constitution of organized bodies, usually seeking to explain various special properties of living matter—assimilation, growth, reproduction, heredity—by something in the form and mode of grouping of the ultimate elements.

2. Theories aiming at an explanation of the mechanism by which the living world has become evolved, dealing with the shares taken respectively by natural selection, the action of external conditions, and other influences in the process of evolution.

3. Theories which have to do more particularly with the genealogy of the animal and vegetable kingdoms as a whole, or with that of special groups—in other words, with the relationship of living things—with which must be closely connected theories of the homologies of organs.

4. Theories which, assuming the truth of some general theory of evolution, seek to explain individual phenomena in terms of this general theory.

There are many theories that do not come very well under any of the above headings, but these will comprehend at least the main body; and, without attempting to deal with the whole subject comprehensively, I shall direct your attention to recent theories belonging to each of these groups.

As regards the last group, they, for the most part, take natural selection for granted, and aim at showing that some structure is useful to the organism, or is the remnant of a formerly useful part.

Instances of this variety of theory are very numerous. Of cases put forward in the course of the last year or so, may be mentioned the explanation by Stahl of the existence, in the cells of many plants, of very numerous bundles of raphides or needlelike crystals by the experimental proof that the plants in question are thereby protected against the attack of snails; the explanation of the remarkable colour and markings of certain male spiders by the observation that these decorations are prominently displayed during courtship; and the demonstration by Prouho of the defensive function of those problematical organs the pedicellariæ of sea-urchins. So many things have been explained by this principle of utility to the individual or to the race that there can be no doubt that as we know more of the details we shall be able to explain very much more in the same way.

It is the explanation which it affords of the causal connection between the utility of a part and its development that constitutes the main feature of Darwin's theory, as distinguished from such theories as von Naegeli's, which presuppose an internal transforming force. In the struggle for existence, according to Darwin, useful variations in parts are preserved owing to the advantage which the favoured individuals possess over others of the same race in virtue of the variations in question, such useful variations being then transmitted by inheritance, and by-and-by becoming more and more marked by successive repetitions of the same process. It is known as a fact of common observation that variations are constantly arising; and the facts which Darwin brought together regarding the results of the artificial selection of such variations in the case of domestic animals showed how considerable the effects of such a process might be if carried on for a sufficient length of time. And hence Darwin's conclusion that we have in this phenomenon of variation, together with the supposition that Nature (by which is meant the conditions of existence of the organism) selects advantageous variations, the explanation of the progress and improvement of the organism, and eventually of the whole animal and vegetable world.

But how do the variations arise? That they do present themselves is a matter of every-day observation; but the causes to which their appearance is due are very obscure. Darwin himself, in fact, attempted no detailed explanation of this. It is a fact that organisms tend to vary—their instability being in many cases very great—and for the theory of natural selection this is enough. A further question in connection with the development of organisms is the question how far what affects the organism during life—the action of the environment, and the effects of the activities of the organism on the development of special parts—may have a share in the process of evolution. As is well known, Lamarck attributed the whole evolution of organic nature to these influences; and Darwin attaches not a little weight to them in some parts of his work. It is especially on this question—the question of the inheritance of acquired characters,—and on that just mentioned—the question of the mode of origin of variations,—that there has been of late a considerable reawakening of interest in theories of evolution. Ever since the publication of Weismann's Addresses this discussion has been going on, but in English-speaking countries the interest in the matter has become more general since the publication last year of an English translation of Weismann's essays on this and cognate subjects, so that during the last year a large number of papers and articles dealing with Weismann's views have appeared in the various scientific periodicals, as well as in the reviews and magazines.

Weismann, as every one now knows, sets himself in opposition in some points to Darwin, and in all, as far as concerns evolution, to Lamarck. According to the Freiburg professor acquired characters never are, and, from the nature of the case, cannot be, transmitted by inheritance; so that the results of individual experience can have nothing to do with the development of organisms. Any changes, in other words, which arise in the individual as a result of the action of external conditions or of individual effort are incapable of being transmitted to the offspring. This follows as a necessary result from a remarkable dogma which Weismann calls "the continuity of the germ-plasma."

In the egg-cell, as in other cells, the most essential part is the nucleus. The great importance of the nucleus in the life of the cell has long been a matter of deduction from many observed facts. More recently experiments made by Gruber and Nussbaum on the Infusoria have demonstrated that the nucleus is the part in which resides the central controlling force of the cell, and in which resides its capacity for reproduction. In the germ-cell, according to Weismann, the nucleus is the essential part; the protoplasm of the body of the cell is, for the most part, merely nutritive in its functions.* This essential substance then of the germ-cell is, according to Weismann, continuous from generation to generation: that is to say, the essential substance of one generation of germ-cells is derived, and can only be derived, from the essential substance of the germ-cells of the preceding generation. Germ-plasma cannot be formed from the protoplasm of histologically differentiated cells; it must be derived from the plasma of pre-existing germ-cells.

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* This, it is to be noted, is not universally admitted. See a paper by Whitman "On the Seat of Formative and Regenerative Energy" in the "Journal of Morphology," Vol. 2. See also the work of de Vries, referred to further on.

Moreover, the situation of this germ-plasma in relation to other protoplasmic elements of the organism is a special one. The germ-plasma is not capable of being influenced or affected by neighbouring cells except as regards its nutrition. It retains an altogether isolated position, and, however parts of the organism might become modified in the course of the life of the individual, the germ-plasma would be in no way altered.

It follows, as a necessary deduction from these two positions, that the germ-plasma is continuous, and that it is completely isolated,—that acquired characters cannot be transmitted.

But the isolation and continuity of the germ-plasma seem to be at variance with a good many well-known facts; and in the attempts which in some cases Weismann has made to reconcile these facts with his theory, or to modify, as seemed sometimes necessary, the theory to accord with the facts, all that is distinctive in these doctrines of his becomes completely lost.

The whole vegetable kingdom abounds with facts that cannot be reconciled with this view; but the case of certain of the higher plants affords perhaps the most cogent and conclusive evidence. In ordinary higher plants the germ-plasmata must be contained, not merely potentially but actually, in the meristem of the growing-point; and it might thus be traced back from its final situation in the mature pollen-grain or embryo-sac to the germ-plasm of the parent oosphere. It seems difficult to understand how this could take place. The continuous division and differentiation of the cells of the meristem; the discontinuous mode of development of the germ-plasmata, its cessation during long intervals of active vegetative reproduction; and its renewal, the occurrence of which is capable of being determined in many cases by extraneous conditions—all these circumstances make it very difficult to believe in the isolation and continuity of the germ-plasm. Still, it is at least conceivable that in some way or other there is isolation and continuity. But when we come to consider the case of certain of the higher plants, such as the *Begonias*, in which a complete plant with male and female germ-plasmata may be developed from a leaf or a bit of a stem, it is impossible longer to admit Weismann's two fundamental positions. Then there is no growing-point with imperfectly differentiated cells, and a new growing-point or -points has to be formed from the cambium-cells present in the vascular bundles of the leaf; and, if these contain germ-plasma, then the latter must be distributed in the cambium-cells throughout the whole plant.

The series of phenomena here referred to were specially adverted to by Strasburger when criticizing Weismann's theory as it originally appeared; and in the English version of Weismann's essay on heredity is the following comment on the case of *Begonia:* "But I think that this fact only proves that in *Begonia* and similar plants all the cells of the leaves, or perhaps only certain cells, contain a small amount of germ-plasm, and that, consequently, these plants are specially adapted for propagation by leaves." In other words, Weismann here, without seeming to be at all conscious of it, abandons the dogma of the isolation of the germ-plasma. For the case of *Begonia* is by no means an isolated one; and there is abundance of evidence that this diffusion of the germinal matter through the differentiated cells is quite general in the vegetable kingdom, and is by no means rare in animals.

Still more cogent is the evidence afforded by the phenomena of graft-hybrids, phenomena the great significance of which was recognised and insisted upon by Darwin, though they seem to have been entirely overlooked by Weismann. In "The Variation of Animals and Plants under Domestication," Darwin brings together all the cases at that time known. One of these is Adam's Laburnum, which is a form intermediate between *Cytisus laburnum* and *C. purpureus*. To quote Darwin's words, "Throughout Europe, in different soils and under different climates, branches on this tree have repeatedly and suddenly reverted to the two parent species in their flowers and leaves. To behold mixed upon the same tree tufts of dingy-red, bright yellow, and purple flowers, borne on branches having widely-different leaves and manner of growth, is a surprising sight. . . . The most remarkable fact about this tree is that in its intermediate state, even when growing near both parent species, it is quite sterile, but when the flowers become pure yellow or pure purple they yield seeds. . . . We have a clear and distinct account given to Poiteau by M. Adam, who raised the plant, showing that *C. adami* is not an ordinary hybrid, but is what may be called a graft-hybrid—that is, one produced from the united cellular tissue of two distinct species. M. Adam inserted in the usual manner a shield of the bark of *C. purpureus* into a stock of *C. laburnum;* and the bud lay dormant, as often happens, for a year; the shield then produced many buds and shoots, one of which grew more upright and vigorous with larger leaves than the shoots of *C. purpureus*, and was consequently propagated."

Other cases, the particulars of which are given by Darwin, are those of the Bizzarria orange, which is a graft-hybrid between the bitter orange and the citron; graft-hybrids between light- and dark-fruited vines, between bulbs of different kinds of hyacinths, and between different kinds of potatoes—new varieties being produced in this last case by grafting together portions of the tubers of two quite distinct kinds.

In some instances, then, when two nearly-related species are grafted together there are produced flowers, and eventually fruits, which partake in some degree of the characters of both species. Here, germ-plasma, if we are to accept Weismann's view, still remaining isolated, must have travelled up from the cells of the cambium of the lower stock through the cambium-layer of the graft to the growing-point to take part in the formation of the germ-plasmata of the hybrid flowers. In the lower plants this wide distribution of germinal matter reaches a still higher limit. The whole plant in some cases can be pounded up into minute fragments, each of which is capable of giving rise to a fresh plant, and thus of developing new germ-plasmata; so that germ-plasm in such cases must be present in all the ordinary cells of the plant. But how can we assert of a substance which is contained in the protoplasm of all the cells of a plant, or of all the cells of the actively-growing tissues, that it is kept apart from the rest of the organism, and is therefore not liable to be influenced by conditions affecting the ordinary cells?

There is, in fact, absolutely no evidence of the existence of a special germ-plasma handed down in all cases from generation to generation: on the contrary, the germ-plasma may be, and is in a great number of cases, derived not from a special antecedent germ-plasm, but from the contents of somatic cells sometimes displaying a high degree of histological differentiation.

These phenomena of vegetable physiology seem to me to impress on us the conclusion that, in spite of the complexity of structure which it exhibits, all the parts of the higher plant are in close vital continuity, so that no group of its cells is capable of remaining uninfluenced by the condition of the rest.

It is from the vegetable kingdom that we get the strongest evidence against the theory of the continuity of the germ-plasma; but from the animal side there is nothing that can be construed into evidence that a general law of this kind obtains, while, on the other hand, there is a great deal that tends to corroborate and confirm the conclusion to which we are led by the study of the development of plants. True, there are cases in the animal kingdom in which such a continuity actually occurs; there are cases in which, at an earlier or later stage in embryonic life, there are separated off cells which are destined to give origin only to the reproductive elements, and which take no share in the formation of other tissues of the body. But at the other extreme are cases in which the sexual elements make their appearance at a late period in the life-history of the animal, and may be developed from cells which for a considerable time have remained undistinguishable: and between these two extremes there are to be found a continuous series of intermediate gradations.

Moreover, cases analogous to those of *Begonia* and other plants already referred to are to be met with also among animals. It is a well-known fact that in many animals, and in not a few that belong not to the lower but to the higher types, there is the power of regeneration of a lost limb, or tail, or even head. The limbs or tail of some salamanders, for instance, will if removed be replaced by perfect organs developed by a process of budding, and the same holds good of many Arthropods and Molluscs. These phenomena are met by Weismann with the admission that in such cases a certain amount of germ-plasm may be preserved unaltered in the somatic cells. It is, in fact it would now appear, only in the highest forms that the germinal matter is all concentrated in the germ-cells. But it is clear that Weismann's whole argument rests on the postulate that from the beginning of metazoan and metaphytal life the germ-plasma has remained apart from the other protoplasmic elements of the body—so isolated in fact as not to be affected (except, as afterwards admitted, in the case of the ova themselves) by any of the influences affecting the organism as a whole. And, it has already been pointed out, many of the cases in which it is necessary to suppose the presence of germ-plasm in the somatic cells are by no means cases of lowly-organized animals and plants.

But, it might be urged, though to explain these cases it is necessary to suppose the presence of germinal matter in a larger or smaller number of somatic cells, this germinal matter is not in the direct line of descent from ovum to ovum; it has been detached from the main mass of the germinal material and passed to the various parts of the body in order to provide for the possibility of mutilation, or to provide a ready means of multiplication. But such an explanation will not bear a close scrutiny.

In the case of *Begonia*, it is only necessary to point out that complete ova are afterwards developed on plants propagated by leaves, and that the germinal substance of these ova can only have been derived from the particles of germinal matter scattered through the cells of the leaves. And in animals of tolerably high organization the same holds good. Thus regenerated Chætopods develope anew the reproductive elements. But the most cogent examples in the animal kingdom of the formation of ova from material in somatic cells are afforded by the phenomena of budding and regeneration in the Bryozoa* and the colonial Tunicata.

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* *Vide* Seeliger: "Bemerkungen zur Knospenbildung der Bryozoen," "Zeitschr. f. wiss. Zool.," v. Bd. (1890).

It is simply inconceivable that there should be scattered through the nuclei of the leaves of a *Begonia*, or the epidermal cells of a Bryozoan, particles of matter which are at the same time completely cut off from the action of the influences that affect the rest of the substance of the nuclei in which they are lodged; and yet this is the demand which Weismann's theory of the continuity (in an unaltered and unalterable form) of the germ-plasma makes of our credulity. The supposed continuity and unchangeableness of the germ-plasm rests on its presumed isolation. When it is shown that in most of the lower and some of the higher plants and animals there is no such isolation, the whole doctrine, to my mind, necessarily falls to the ground.

Closely connected with his theory of the continuity of the germ-plasma is the explanation which Weismann offers of the occurrence of variation in organisms. This, he holds, is due to two main causes—firstly, differences existing in the mature sexual cells; secondly, differences which result from impregnation. The first set of differences are due to the probable complexity of minute structure in the nuclei of the germ-cells—a complexity so great that it is unlikely that division could take place twice in precisely the same way, so that, to start with, no two ova or spermatozoa are precisely alike. The second cause of difference is the combination of the germ-plasmata of two different individuals; and this Weismann supposes to be the meaning of the process of sexual reproduction: "Sexual reproduction has arisen, and holds its own, as the chief mode of reproduction in both kingdoms of organic nature because by means of it varieties are produced which form the material on which natural selection acts."

That sexual reproduction may be a cause of variation is highly probable; it is difficult to see how it can be the cause of the appearance of an entirely new character, for it can only effect combinations and recombinations of what has already existed. It certainly is not the cause of all variation, as Weismann has himself now acknowledged.

It is a familiar fact that in the case of some of the most widely cultivated garden plants, such as the roses and chrysanthemums, which present almost innumerable variations, and in which new varieties are constantly making their appearance, there is no question of sexual reproduction at all, as propagation of new varieties is effected entirely through the medium of cuttings. Full details of these phenomena of "bud-variation" are given by Darwin in his "Variation of Animals and Plants under Domestication," and it is very singular that these very significant facts should have been completely overlooked by one professing to be a critic of Darwin and his theories. To my mind these phenomena of "bud-variation" are destructive of Weismann's view of the extreme importance to variation of sexual reproduction, since they prove that organisms may develope marked variations of a permanent character when sexual reproduction is altogether suspended. And equally important in this connection, as has been pointed out by Professor Vines,* is the case of the numerous groups of Fungi, presenting innumerable form-varieties, in which there occurs no form of sexual reproduction.

Weismann's ideas are so admirably marshalled and so clearly expressed that his essays form a most interesting contribution to the literature of biology. Moreover, any work which has excited so much discussion of the fundamental problems of biological science can scarcely fail to lead to the attainment of new truths or the elimination of old errors. Perhaps the chief service which the author has rendered to science by the publication of his essays has been in directing attention, by the searching character of his criticism, to the necessity for more conclusive evidence regarding the inheritance of acquired characters.

Written from a very different standpoint is the contribution to the subject of the evolution of organisms recently put forward by Eimer.† His object has been, by the careful study of the variation of certain animals, to endeavour to find a general law of variation. "The Darwinian principle of utility," he writes, "the selection of the useful in the struggle for existence, does not explain the first origin of new characters." "The unreserved study of a single species of animal has led me to the discovery of a whole series of laws which the extension of the investigation to other species showed to hold good generally." "I was able," to quote further from his Introduction, "to demonstrate that variation everywhere takes place in quite definite directions which are few in number; and I was able, on the basis of my observations, to put forward the view that the causes which lead to the formation of new characters in organisms, and, in the last result, to their evolution, consist essentially in the chemico-physiological interaction between the material composition of the body and external influences."

These results he arrived at by a study at first of the variations of the European wall-lizard (*Lacerta muralis*), then afterwards of those of other animals (mammals, birds, and insects), the results being mainly derived from a study of the external markings. His study of the wall-lizard led him to the conclu-

* "An Examination of some Points in Professor Weismann's Theory of Heredity:" *Nature*, Vol. 40 (1889).

† "Organic Evolution."

sion that the markings go through a quite regular series of changes during the life-history of the individual—longitudinal stripes, black spots, black rings, ocelliform markings. The varieties of markings which we find in the adults of the same species are produced by one individual or variety stopping short, as regards its changes of pattern, at one stage, another at another, so that we have striped, dotted, black-ringed, and ocellate varieties. New variations make their appearance mainly in old males, after the ordinary changes have all been gone through, and the males transmit them to their progeny.

Eimer adduces many interesting facts relating to variations of markings, influence of light on colour, instinct and intelligence, and many other topics having a bearing on the question of the evolution of plants and animals. But the support which these give to the wide generalisations above quoted is very small. That external conditions have certain direct effects on organisms is a matter of every-day observation. But these effects, so far as we have evidence, are almost all of a superficial character; and the few cases which Eimer mentions of more profound effects apparently resulting from the action of external conditions—that of the axolotl, and that of the brine-shrimp, for example — are more satisfactorily explained by degeneration and reversion than as instances of evolution *per saltum* brought about by the direct action of external influences.

An important and interesting attempt to explain the phenomena of heredity is that which has been made by de Vries, the botanist of Amsterdam, in a work called "Intracellular Pangenesis," published in 1889. Darwin's theory of pangenesis, which he himself did not put forward with much confidence, has not found many adherents, though it was eminently useful in formulating a problem demanding solution. A modification of this theory by W. K. Brooks avoided some of the difficulties which Darwin's ideas involved, but still has shown itself open to exception on various grounds, as has been well shown among others by Weismann in his essays. According to Darwin's theory the cells of the body under ordinary conditions give off minute particles or gemmules, which find their way to the reproductive cells, and there become collected. It is the presence of these minute particles that endows the reproductive cells with the faculty of reproducing the parent organism: each gemmule is capable of giving rise, when the ovum in which it is contained developes, to that part of the organism from which it originated. But, as has been pointed out by various physicists, the number of such gemmules—each several times larger than a chemical molecule—that can be contained within a minute ovum, though it may be very great, must yet be limited, and Darwin's theory seems to demand an almost infinite number. For not only must each individual character of the animal—anatomical, physiological, histological, psychological—down to the minutest, be thus represented in the ovum by its gemmule, but so must each character of all the phases of its development, and many characters of a remote ancestry. Brooks's modification of Darwin's theory of pangenesis is designed to avoid this difficulty. According to this, the cells of the body are not constantly throwing off gemmules, but only when the part is subjected to unfavourable conditions.

De Vries regards the protoplasm of the cells of an animal or a plant as made up of ultimate elements which he terms *pangenes*. These elements he believes to be much larger than the chemical molecules—each being built up, in fact, of many of the latter, and comparable in size rather to the smallest known organisms. Like Darwin, de Vries believes that each of these particles or pangenes is the bearer of only one single hereditable character; and so in any given organism there must be as many pangenes as there are hereditable characters.

In order to attempt to prove this, it is necessary to trace the genealogy of the egg-cell from one generation to the next. In some plants, as is well known, such as the *Oscillariæ*, there is only a single kind of cell, every cell being capable of acting as a reproductive cell. In most plants, however, and in all the higher forms, there are a variety of sets of cells, some of which —the purely somatic cells—are incapable of giving rise to the reproductive cells, while others are in the direct line from the reproductive cells of the parent plant to those about to be developed. The series formed by the latter lead from egg-cell to egg-cell (or sperm-cell to sperm-cell) either directly—generally within one individual—or indirectly by a roundabout way by vegetative reproduction, the series often passing through a considerable number of individuals before coming back again to the egg-cell. Such a cell-genealogy is unknown in the higher types of the animal kingdom, where the descent from one generation of egg-cells to the next is short and direct. It is very general among plants, however, more particularly among the Thallophyta and Muscineæ, where in some instances every fragment of the plant is capable, when detached, of giving origin to a new individual.

In the higher plants there are found present in increasing numbers genealogical lines of cells which are essentially somatic —*i.e.*, which are destined to give rise to non-productive elements; and in vascular plants there can be no doubt that, at least in the mature condition, tissue-cells can no longer reproduce the species.

But it is to be specially noticed that germ-cells and somatic cells do not stand in fundamental antagonism in the vegetable kingdom; the evidence, in fact, leads us to the conclusion that probably the germinal elements are present to a greater or less extent in all the cells of the plant. As proof of this, de Vries adduces specially the phenomena of galls. A gall which is developed as a result of insect-action on a leaf always contains elements normally only found in the bark of the stem. And quite as cogent proof, it may be added, is afforded by such plants as *Begonia*, in which a new plant containing all the tissue elements may be developed from a part of a leaf.

Now, as shown by the results arrived at by various investigators of cell-structure, it is in the *nucleus* of the reproductive cell that hereditary characters must be conveyed. Further, from the fact that in the act of fertilisation only the nucleus of the sperm-cell fuses with the nucleus of the egg, while yet the whole of the paternal characters pass over, it is not only to be concluded that the paternal characters are represented in the male nucleus, but that after fertilisation germinal elements pass out from the nucleus, and penetrate into other parts of the ovum and its derivative cells, the component parts of which show characters derived from both the male and female germinal cells. Thus, though the nuclei are the bearers of the hereditary characters, the latter pass out from the nuclei in order to become manifested in the body of the cell.

De Vries claims to account for all the known phenomena of heredity by his hypothesis of intracellular pangenesis, which is thus summarised by him: "I call pangenesis (apart from the hypothesis of the transport of the germinal material through the whole body) the view of Darwin that the individual hereditary characters in the living substance of the cells are connected with certain material particles or gemmules. These particles bearing the hereditary characters I name pangenes. Every hereditary character, however many species it may be found to recur in, has its special kind of pangene. In every organism there are many such kinds of pangenes collected together, the more numerous the higher the organization.

"I call intracellular pangenesis the hypothesis that the *entire living protoplasm* is built up of pangenes. In the nucleus are represented *all kinds* of pangenes of the individual in question; the rest of the protoplasm contains in each cell essentially that kind only which should attain to functional activity in it."

"The whole living protoplasm consists of such pangenes which have passed out of the nucleus at various times, with their progeny. It contains no other living substratum."*

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* Not having de Vries's work now at hand, I have been indebted in the compilation of the above brief account to a paper by Bokorn in the "Biol. Centralbl." (1889).

One of the most recent contributions to the theories of evolution is a paper entitled "On the Origin of Sex through Cumulative Integration, and the Relation of Sexuality to the Genesis of Species," by J. A. Ryder,* which has just come to hand.

The writer regards the main end of sexuality as not being merely provision for reproduction or for the occurrence of variations on which natural selection may act, but regards its ultimate end as being protection of the young by the development of viviparity. It has become developed along two quite distinct but parallel lines in the animal and in the vegetable kingdoms respectively.

To quote his own words: "The gradual development of sexuality by slow stages in plants is now so well understood that it is not necessary to enter into the details, which may be found in any standard botanical text-book. It is sufficient to indicate that the transition from asexuality to female macrogonidia and male microgonidia is effected by mere differentiation of cells as respects their size. From naked oospore to carpospore is the next step, with flagellate male elements. Finally, the prothallium appears first with both oospheres and antherozooids; then the prothallia themselves become distinguished as small male and large female ones; then the female prothallium is no longer at once detached, but becomes covered in, while the minor male prothallium still dehisces, but finally becomes partially parasitic upon the stigma, where it vegetates, and throws out a hollow process, which serves to convey the new highly-modified antherozooid to the ovicell. The prolonged adherence of the female prothallium to the parent axis enables the next important step to be taken in the evolution of the seed containing a viviparously-produced embryo, provided with a store of nutriment and suitable envelopes."

"Similar conclusions are borne in upon the zoologist in a study of the reproductive process in the animal world. From asexual fragmentation, and consequent multiplication, the advance to larger and smaller female and male elements was a gradual one, with or without hermaphrodism. Then came hermaphrodism with large female and small male germs; then maleness and femaleness as characterizing distinct individuals of the same species. Finally, protective processes were developed."

The "cumulative integration" of which he is constantly making use is simply "assimilation beyond the needs of the organism," or, in a word, overgrowth; and it is to this overgrowth that Ryder traces sexuality in all the phases of its development.

* Proc. Amer. Philosoph. Soc., vol. xxviii. (1890).

It is generally acknowledged that, in such simple organisms as *Amœba*, reproduction, in the form of fission, is, primarily at least, the direct outcome of overgrowth: the mass becomes too great for the surface, and becomes divided into two. No doubt this process of division, being advantageous for preservation, has become to a considerable extent hereditary, and multiplication may, accordingly, in many instances take place before the necessity for it owing to overgrowth becomes pressing.

Ryder's view is that this cumulative integration acts as a motive force in developing sexuality, not only in its simple forms but in all the phases of its increasing complexity as we ascend the animal and vegetable series. At first, the cleavage which followed from overgrowth, in order that the metabolism of the protoplasm might go on with advantage (the proper ratio of surface to mass being maintained), resulted in the formation of small parts or division-masses, which became completely separated off from one another as independent organisms. In the lowest forms the whole organism consists of a single variety of living substance; but in all above the lowest there are two distinct varieties sharply marked off from one another, and present in very unequal proportions. In the former the process of division is direct; while in the division of the latter there is a reaction between the two kinds of living substance, "which is expressed most strongly as karyokinesis."

The effect of overgrowth in unicellular organisms has been to produce a preponderating quantity of plasma, which invests the primitive nuclear plasma or chromatin with a thick envelope—the cell-body or cytoplasm—and this provides a field for the reaction of the two forms of living matter in the phenomena of karyokinesis.

This increase in the quantity of cytoplasm was due to the rapidity of growth, by which sufficient time was not allowed for conversion into nucleoplasm or chromatin rapidly enough for the division into smaller parts by the direct process of fission. Though at first, as already mentioned, the division-masses produced as a consequence of overgrowth became at once separated from one another, there arose with the increase of cytoplasm a tendency in some cases for the masses to remain in cohesion. There came thus to arise two sorts of division resulting from overgrowth—*disruptive* and *coherent*.

The development of a cell-body led to the production, by divergent evolution, of two sorts of cells. One of these—the most primitive—was poorly provided with cell-protoplasm. This became the male cell. The other was a cell arrested on its way towards disruption into male cells—a cell which, owing to the effects of overgrowth, had lost its tendency to break up into smaller elements like the male cells, this tendency being still represented, however, by the throwing-off of the polar bodies.

Attraction between male and female cells, at first of a chemical nature, led to their fusion, which was favoured by the similarity of their protoplasm, and by the need, on the part of the male cell, for more cytoplasm.

The result of the increase in size of the cytoplasm of the ovum is that, after fusion of male and female cells, a series of segmentations are set up which result in the development of an embryo. This is rendered possible by the large size of the cell-body of the ovum, by which a field was afforded for nuclear motion and growth.

"The principle of continuous growth through cumulative integration; its rhythmical interruption through the 'setting-aside,' or dehiscence, of the useless sexual elements; the evolution of a cytoplasmic field; the direct adaptation to their surroundings of colonial aggregates of cells, resulting from the coherent segmentation of masses of plasma resulting from reciprocal integration; the necessarily cumulative superimposition of adaptations upon one another, have been, in the main, the materials upon which natural selection was dependent in order to become operative in biological evolution."

It is indicative of the very great difficulties which the subject presents that to this day there exist differences of an almost radical character between the views of the minute structure of cell-protoplasm held by different histologists who have devoted attention to this matter. The most generally accepted statement is that there are two kinds of protoplasm present in every cell: a more fluid kind (hyaloplasm), and a kind of a less fluid character (spongioplasm), the latter taking the form of a denser or more open network of threads, between the interstices of which the former lies. There is evidence of this from the appearances presented by many dead and stained cells and a few living ones. According to Bütschli,* however, this is not the true way of viewing the constitution of the cell-protoplasm. The two components are rather to be regarded as mixed together: the one substance—the hyaloplasm—in a state of fine division, and disseminated through the spongioplasm like the oily matter in an emulsion. Bütschli recognises the presence, in many cells, of stiffer trabeculæ and threads in the spongioplasm, which often form networks; but he regards these as not essential to the structure of living protoplasm, since in many cells, *e.g.*, *Amœbæ*, they are not present.

* "Müssen wir ein Wachsthum des Plasmas durch Intussusception annehmen?"—"Biol. Centralblatt." 8 Bd., pp. 161–164.

A theory regarding the nature of the cell which merits some attention from all biologists is that of Altmann. This theory was published by him in a number of detached papers, which, though they have been noticed in various periodicals, have not received a large share of attention. Now he has published the results of his observations, and the theory he has deduced from them, in an independent work, illustrated by a series of fine plates.* Whatever be the value of the deductions of the author regarding the essential character of the cell, he has at least accumulated a number of valuable observations on cell-structure, which form a definite addition to our knowledge.

The fully-formed cell, Altmann points out, is quite a complex structure, and is by no means to be regarded as the simplest organic element. The protoplasm of which a cell consists is composed entirely of a series of minute particles or *granules*, embedded in an intermediate jellylike substance. These granules vary in shape, size, and optical characters in different kinds of cells. In some cases they may be seen in the living state of the cells, but in most they are only brought distinctly into view by certain special methods of treatment. By employing these methods, Altmann has been enabled to make out the arrangement of the granules in a variety of different kinds of cells. In some they lie isolated, embedded in a gelatinous matrix ; in others they are arranged in branching rows to constitute series of fibrils, having various characteristics in different types of cells. Fibrils are not present in every cell ; granules are always present.

The cell-nucleus is to be regarded as the matrix of the whole cell. The connection between the contents of the nucleus and the cell-body is shown not only by the radial structure of the protoplasm, but specially by the phenomena of karyokinesis. By the use of certain methods of staining, the nucleus shows itself to be a mass of granules. The nucleolus usually lies in little conglomerations of the intergranular substance, and the net-formation of the intergranular substance goes out from this.

This netlike intergranular substance also is not homogeneous, but when acted on in certain ways sometimes appears to show symptoms of being made up of yet smaller elements arranged in threads. In the course of indirect division the separation between the substance of the nucleus and that of the body of the cell is totally lost.

While recognising the individual character of the cell, and the all-important *rôle* which it plays in organic structures, our author points out that there are many organized bodies that are not really cells, and attempts to trace the genesis of the

* "Die Elementärorganismen und ihre Beziehungen zu den Zellen." Leipzig, 1890.

latter from the former. The first and simplest stage of cell-genesis would be the *Zooglœa*, where we find colonies of *Schizomycetes* embedded in a jellylike matrix secreted by themselves. A higher stage is represented by the non-nucleated *Cytodes* and *Plasmodia*. In these the granules, according to Altmann, correspond to the micro-organisms of the *Zooglœa;* but the colony has now the property of enclosing, acting chemically on, and assimilating particles of foreign organic matter—a power not possessed by the *Zooglœa* colony.

The passage to nucleated Protozoa, Altmann supposes, may be effected through the process of encystation which is observable in some of the *Cytodes*. In these the protoplasmic body developes an envelope, through pores in which protoplasm passes outwards to form an outer layer, and this outer layer may again develope an envelope. The nucleus may be supposed to be developed from the central mass with its envelope, the cell-body from the outer layer of protoplasm. Thus we have formed a nucleated Protozoan; but this is still the equivalent of a colony of micro-organisms, the individual elements in which are the granules. When the granules, as is the case in many cells, are entirely separate from one another, then we have a condition which is analogous to the *Zooglœa;* when, on the other hand, the granules are arranged end to end so as to form fibrils, then the arrangement is more nearly analogous with that of the colonies of *Schizomycetes*, in which the individual elements are arranged in rows so as to form simple or branching filaments.

Transition-forms between the non-nucleated *Cytodes* and *Plasmodia* and nucleated cells are to be looked for among the *Protista*, in which there must be genetic stages in the formation of true nuclei.

This correspondence between cells and colonies of micro-organisms, Altmann is careful to state emphatically, is only a phylogenetic one; the granules of the cell-protoplasm are not micro-organisms, and are incapable of being cultivated after the manner of Bacteria outside the cell.

The theory that the protoplasm-granules are the elements in organic bodies, and that they correspond to micro-organisms, is not new; similar views have been put forward, among others, by Henle and by Bennett; but this conception has never before been worked out with such thoroughness and supported by such a series of careful observations. Thus presented, the theory is a very striking and suggestive one, and one the thorough discussion of which is very likely to lead to a more intimate knowledge of the constitution of organized bodies.

Two papers which have been published simultaneously in the last number of the "Quarterly Journal of Microscopical

Science" present us with the most interesting examples that have appeared of late of the class of biological theories concerned with the relationships of organisms. Both deal with the vexed question of the origin of vertebrates from invertebrates: one is entitled "On the Origin of Vertebrates from Arachnids," and is by Professor W. Patten, known for his researches on the eyes of Arthropods and Molluscs; the other is "On the Origin of Vertebrates from a Crustacean-like Ancestor," by W. H. Gaskell.

Patten had been impressed by the necessity, in view of the concentration observable in the vertebrate head, of looking in the invertebrate ancestor of the Vertebrata for a similar kind of concentration. This he finds in the cephalothorax of the Arachnida. He then proceeds to point out a series of correspondences between certain parts in living Arachnids, such as the scorpions, and the vertebrates. These comparisons are carefully and ingeniously marked out and illustrated. The cerebral and infra-œsophageal ganglia of the scorpion are shown to present parts corresponding to the fore-, mid-, and hind-brains of vertebrates. The ventral chain, of course, corresponds to the spinal cord. The nerves given off from the anterior ganglia are cranial nerves; those given off from the ventral chain are spinal nerves, and the latter are shown to have dorsal and ventral roots. The sternal cartilage is the primordial cartilaginous cranium of the vertebrate; the pectines are the pectoral limbs; the pulmonary apertures the gill-slits; the sub-neural vessel corresponds to the notochord.

To help out the resemblances between existing forms, Professor Patten presses *Pterichthys* into the service, as an Arachnid which may have been on its way towards the vertebrate type. But this hypothesis seems to have been sufficiently disproved by Mr. Smith-Woodward in a note in the "Annals and Magazine of Natural History" for October, in which he points out that there are features in the dorsal shield of *Pterichthys* which indicate that it covered a vertebrate brain. Thus, on the under-surface of the plate between the eyes is a depression identical in position with one which occurs in *Coccosteus* and other shield-bearing forms proved to have been vertebrates by the discovery of the axial skeleton of the trunk. And, again, as was originally shown by Dr. Traquair, the tail in *Pterichthys* is undoubtedly that of a fish.

Gaskell had announced previously his view that Vertebrata were derived from crustacean-like ancestors, and had sought, and, as he thinks, found, confirmation of this view from the results of a study of the brain of the lowest vertebrate that possesses a brain—viz., the *Ammocœtes* larva of *Petromyzon*. His conclusion is that the brain of the vertebrate is derived from the cephalic stomach of the crustacean, with the wall of which the anterior ganglia have become coalescent, the spinal cord having been similarly developed from the ventral chain of ganglia surrounding and coalescing with the wall of the intestine, the lumen of which is represented by the central canal. A peculiar tissue which surrounds the brain of the *Ammocœtes* is supposed to represent the liver of the crustacean. The mouth and œsophagus of the crustacean were represented by the infundibular passage and a posterior median prolongation from the *saccus vasculosus*.

It will be observed that these two writers, who have arrived at the same general result in very different ways, are at one on one important point—viz., that the vertebrate nervous system is directly descended from that of the Arthropoda.

But it is "a far cry" from the arthropod to the vertebrate, and, though I should not like to be called upon to prove that such a descent has not taken place, I doubt if there are many who will admit that the facts brought forward either by Patten or Gaskell can bear the interpretation which they put upon them.

The great problem of heredity, the problem of the causes and limitations of variation, and that of the influence of external conditions on development seem to be those which at the present time most urgently call for solution. That they will ever all be satisfactorily solved one must be sanguine to hope. The elements and forces concerned in the more subtle phenomena of life seem to be quite beyond our possible ken. Much regarding the grosser phenomena has already been explained by approaching them from the chemical and physical standpoint, and it seems only logical to look for further addition to our knowledge to be obtained by the same means. But whether, when we know all that it is possible for us to know, we shall have any real knowledge of the essential nature of that series of properties which constitute vitality may legitimately be doubted.

Much, however, even in this intricate part of our subject doubtless remains to be discovered; and there are few regions of the domain of biology in which careful and conscientious inquiry, apart from the satisfaction which it brings, will not tend to throw light upon some aspect of these great problems.

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1. *Evolution of the Eye.*

By Professor BICKERTON.

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2. *A Simple Mode of illustrating the Action of the Lungs.*

By Professor Bickerton.

A large bulged lamp-glass is turned upside down, and a three-holed cork fitted into the neck; a small cork stopper is placed in the middle hole, two glass tubes are fitted in the other holes, and a small toy balloon tied to each: these balloons are inside the lamp-glass. The cork is taken out of the central hole, and the lamp-glass pushed some distance into water; the cork is then put in, and on lifting and lowering the glass the balloons fill and empty themselves, the water acting as the diaphragm.

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3. *Suggestions for securing greater Uniformity of Nomenclature in Biology.*

By Professor T. Jeffery Parker, B.Sc., F.R.S.

The author discusses the advantages and disadvantages of the rapidly-increasing terminology of the biological sciences, especially in the department of morphology, and submits the following proposals:—

1. The appointment of a strong international committee to define terms of general and fundamental importance, such as the subdivisions of biological science, terms common to zoology and botany, terms denoting position, &c.
2. The issue of an authoritative historical glossary.
3. The systematic record of new terms.

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4. *On Specific Characters in the Skeleton of Apteryx.*

By Professor T. Jeffery Parker, B.Sc., F.R.S.

The derivation of the various species of *Apteryx* from a common ancestor being assumed, attention was directed to the curious divergence of skeletal characters undergone by them in the course of evolution, such characters being all connected with the degraded sternum, shoulder-girdle, and fore-limb, and all apparently without any physiological significance. The characters referred to are,—

1. The greater proportional length of the sternum in *A. australis* than in *A. bulleri* (*mantelli*) or *A. oweni*, and the fact that in *A. oweni* the bone has a sinuous anterior margin.

2. The fact that the coracoid in the earliest stages yet examined is a solid cartilage in *A. oweni*, while in the other two species it is fenestrated, and has a distinct procoracoid, which may persist, in a ligamentous condition, in the adult.

3. The fact that a radiate is constantly present in the carpus of *A. oweni*, constantly absent in *A. australis*, and occasionally present in *A. bulleri*. In the latter species, moreover, the skeleton of the entire manus is very variable, while in the other two species it is constant in its main features.

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5. *Successful Rabbit-suppression in New Zealand.*

By Coleman Phillips, Wellington.

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6. *Systematic Training of Juvenile Naturalists.*

By A. F. Robin, Adelaide.

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7. *On some Aspects of Acclimatisation in New Zealand.*

By Geo. M. Thomson, F.L.S.

The term "acclimatisation" is defined by A. R. Wallace* as "that constitutional change which enables any organism to become gradually adapted to a different climate from the parent stock." In this colony the term has come to be synonymous with, and really to signify, "naturalisation." But as this word has come to be used in a special sense applicable only to the human subject, we must take the term "acclimatisation" to apply to the passing into the feral state of all those organisms which have been introduced within recent times into these Islands. The popular acceptation of the word is thus seen to be incorrect, but is now sanctioned by usage. In this paper, however, I shall use the preferable term "naturalisation."

* "Darwinism," 2nd ed., 1889, p. 94.

The causes which lead to the establishment of certain forms and the non-establishment of others, the changes brought about on already-existing forms by these new introductions, and the changes which they themselves undergo under the altered conditions, constitute one of the most complicated problems which offer themselves for solution to the naturalist in New Zealand. The questions which arise overlap one another at every turn, and it is a somewhat difficult task to attempt in a brief address to grasp their main features and present them in a clear manner.

In endeavouring to point out a few of the interesting questions which have suggested themselves to me in this connection, I must premise by stating that my own observations have been mainly confined to the southern portion of the South Island. Some of my statements, therefore, which may be strictly accurate as applicable to that limited area, may be found to require modification or alteration as regards other parts of the colony. Stretching as these Islands do between the 34th and 48th parallels of south latitude, it is evident that the range of climate is very great. In the northern portion of the North Island the climate is warm-temperate, so that the plants and animals of the Mediterranean region of Europe thrive there: in the south of the South Island, on the other hand, we find ourselves in a second Scotland, with severe winter frosts, which indeed prevail throughout the interior and eastern portions of this Island.

The humidity also of the Islands is very different in different parts. To take this Island alone: we find that the rainfall on the west coast is very heavy, the saturated winds, in being forced over the Southern Alps, parting with a very large portion of their moisture, and pouring it down on the coast ranges. Probably in no part between Cape Foulwind and Preservation Inlet is the annual rainfall less than 100in., while there is reason to believe that in many localities it may rise even to 300in. On the eastern portions of the Island, especially where intermediate ranges like the Kakanuis in Otago and the Kaikouras in Marlborough still further intercept the rain-carrying clouds, the annual precipitation falls to 30in. and less.

(*a*.) Suitability of New Zealand as a Field for Naturalisation.

New Zealand has always been recognised by naturalists as a distinct zoological and botanical province, one of surpassing interest on account of the long isolation it has undergone, and in consequence of the unique character of its fauna, and, in a less degree, of its flora. It has been colonised by Europeans at an age when questions of scientific interest were beginning to be generally discussed, and we can therefore look back with some degree of certainty almost to the very commencement of the introduction by human beings of foreign forms of life. As far as European forms are concerned, we have the history of the subject still almost within our grasp. Every year that passes, however, makes it more difficult to pick up the ravelled threads of the past, and it is at once the duty and the privilege of the naturalist of to-day to place on record all the facts that he can regarding the introduction and naturalisation of every newly-imported form, so that those who at a later date take up the same line of research may find the problem greatly simplified. Even already, as we know, it frequently proves a difficult matter to arrive at the truth regarding what is indigenous and what is introduced. Witness, for example, the discussion which is embalmed in the volumes of the New Zealand Institute Transactions regarding the claims of *Polygonum aviculare* to rank as an indigenous species; and we have also seen *Gypsophila tubulosa* appearing in Hooker's "Handbook to the New Zealand Flora" as indigenous, as lately as 1868. If such difficulties have arisen with regard to flowering plants, which from the very discovery of the colony have been objects of special attention to naturalists, and towards the collection of which particular heed was given in the very first English expedition which came to these shores, what is to be said about groups of animals, such as insects, which have only received close attention of late years, and what especially about those groups of which representatives are known to occur in these Islands, but regarding which our further knowledge is absolutely *nil?* These considerations point to the importance which attaches to all observations which may be made on introduced forms, and ought to cause naturalists to pay more attention to them than they receive at present.

The remarkable facts that these Islands possess no truly indigenous mammalia, very few song-birds and game-birds, and a poor fresh-water fauna, have led to their being looked upon as a suitable field for experiments in the naturalisation of what are considered by the experimenters desirable types.

Captain Cook started the process when he gave the Natives pigs and various garden vegetables. The former soon became wild in many parts, and have furnished rare sport to the early settlers: the wild cabbage may still be found in abundance near the site of many a Native village now forgotten. The process of introducing new forms of life has been kept up pretty continuously ever since the discovery of the Islands, both publicly and privately. Missionaries, surveyors, and settlers all have tried their hand at it, and perhaps the most remarkable thing about such experiments has been the large amount of failure which has accompanied them. The reasons for such failure are not always explicable; in some cases, however, they are not far to seek, and I shall endeavour to point out a few later on. The desirability of carrying on experiments in naturalisation on a larger scale than could well be attempted by private individuals led ultimately to the formation of acclimatisation societies in the larger centres of population. Some of these experiments have succeeded beyond all expectation, thus bringing about in some respects a completely-altered state of affairs. This has had one unexpected effect—namely, that of causing many of the parent societies to split up into numerous petty branches, each managing its own affairs within a somewhat limited area. At the present time there are no less than twenty-three so-called acclimatisation societies in the colony—namely, twelve in the North Island and eleven in the South Island. Some of these sprung into existence as anglers' associations: the parent societies having stocked the fresh waters of a district with trout and other fish, the local anglers thus acquired the right of controlling the revenues, &c., of these waters. Others originated as farmers' clubs, the primary motive being apparently the protection of the settlers against evils caused by the animals and plants which they have themselves introduced.

(*b.*) Introduction of New Forms of Life by Conscious Human Agency and Accidentally.

New forms of life have been introduced into these Islands not only purposely, but largely also by accident, or, rather, unconsciously. Reference has just been made to the experiments which have been in progress for the last century—experiments which have been carried out in a most systematic manner during the last two decades. Apart, however, from this agency working in definite directions, and oftener making failures than successes, a large naturalisation of organic forms has been taking place accidentally. Seeds of plants introduced for the garden, the pasture-land, or the hedge-row, have in a great number of instances become quite wild. Among interesting examples are the cases of *Eschscholtzia californica*, which has established itself in many parts of the Upper Clutha basin, in spite of the severe winter frosts of that region; and scarlet geranium, which is wild in many parts of the North Island. White clover and many European grasses have spread over wide areas where they were never sown; the broom, the whin, and the dog-rose now cover acres of ground near roads and fences; while vast numbers of weeds of cultivation are to be found in our fields and waste places. This fact impressed itself strongly on Sir J. D. Hooker, who, in an appendix to the "Handbook to the New Zealand Flora," makes the following remarks (p. 757): "The rapidity with which European weeds, and especially the annuals of cultivated grounds, are being introduced into and disseminated throughout New Zealand, is a matter of much surprise to all observers, and not only to professed naturalists. It is a point of very great significance in reference to all inquiries relating to their superior powers of propagating and establishing themselves, which the plants as well as animals of some countries display, as contrasted with those of others; and when, as in the case of New Zealand, the result is the actual displacement and possible extinction of a portion of the native flora by the introduced, the facts may well arouse the interest of the most listless colonist. . . . I can here do no more than again call attention to the fact that now is the time for certifying the dates of the introduction of many plants which, though unknown in the Islands a quarter of a century ago, are already actually driving the native plants out of the country, and will, before long, take their places, and be regarded as the commonest native weeds of New Zealand."

Since these remarks were penned, another quarter of a century has passed, and the state of things they predict has in many parts of the colony been already fulfilled.

An interesting feature in regard to the spread of these weeds is that different species show a remarkable difference in their aggressiveness. Out of a number of different plants introduced, say, from Great Britain, where the conditions have been tolerably uniform for a considerable period of time, and where the struggle for existence has been very keen, it is singular that, on introduction to new conditions such as prevail in these Islands, some should exhibit such superior powers of adaptation to others. Thus, among a score or so of species of British Composites introduced into the southern part of the colony, none, with the single exception of the thistle (*Carduus lanceolatus*), has shown such an aggressive character as the cat's-ear or so-called Cape weed (*Hypochœris radicata*). This plant has spread itself far and wide, but disappears wherever sheep are grazed. The causes for its extensive and rapid spread have never been worked out, but it will probably be found that a number of favourable conditions have combined to bring this about. Its seeds are produced numerously, and are widely spread by means of their pappus; they germinate rapidly; the young plant grows erect among grass, &c., but as it increases in size its leaves broaden and gradually flatten out among the surrounding vegetation, and so smother its immediate neighbours; its powerful tap-root enables it to flourish and grow strong when plants of more superficial growth are suffering from want of moisture; while its hispid surface and abundant latex appear to render it distasteful to most insects. Further, it blooms for many months of the year, and its flowers are apparently (though I am not certain on the point) self-fertilisable, while under favourable conditions of fine weather and sunlight it is visited by many species of insects. Alongside of this plant, the common European dandelion—*Taraxacum dens-leonis*, half-brother to the indigenous form—has been introduced under apparently similar conditions; yet it has never become as widely spread, being confined, as in Britain, to roadsides and waste places. There is no doubt that it is a more highly specialised form in many respects than *Hypochœris*, but to the popular eye this fact is not patent. I instance these two familiar weeds as showing how very difficult it is, at first sight, to assign causes for success or failure in naturalisation. Other instances of remarkable developement among introduced plants are the spread of watercress in the streams on the Canterbury plains, where, however, I am inclined to think that the gigantic development of the first few years is followed by a gradual return to a more normal rate of growth*; the rapid spread of sorrel (*Rumex acetosella*) and *Poa pratensis* as weeds of cultivation, and numerous others.

The use of straw, hay, &c., as bedding and packing material has brought great numbers of plants into the country. I have found various European plants, not found elsewhere in the district, growing near seaports where immigrants' chaff-bedding used to be landed, and in part burned; and it has often struck me as a curious fact how limited the distribution of such plants is, and how slowly they spread. Thus, at Port Chalmers, *Veronica buxbaumii* occurs, but I have not observed it elsewhere in the east part of Otago. Again, *Sherardia arvensis* and *Fumaria capreolata*, var. *muralis*, have been common for many years in one part of the suburbs of Dunedin, but I have not observed them to extend their range. The same remark applies to *Galium aparine*, a plant apparently well fitted for distribution on account of its adhesive fruit. Again, I have watched *Bartsia viscosa* spreading slowly north and east from a point near Abbotsford, in the Green Island district, and in the last nineteen years it has not extended more than six or eight miles, while in the opposite direction (against the prevailing winds) it does not seem to have spread at all.

Many species of insects (and a few molluscs, &c.) have been introduced in the same accidental manner, and in some instances have become readily naturalised. Many of these, like Aphides, some Coccidæ, &c., have been brought into the

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* In this respect the thistle is remarkable. Newly-ploughed land, *e.g.*, in North Otago, is invaded by this plant to such an extent that it becomes an impassable thicket; but this condition does not last more than two or three years, after which the land is found to be unable again to produce such a dense growth of the weed, while its fertility is improved by the accumulation of vegetable mould.

colony along with the plants on which they feed. It will be interesting to watch whether these pests spread to indigenous plants. I have appended a list of introduced insects which Mr. G. V. Hudson, of Wellington, has kindly furnished me with, but which he states is incomplete.

(c.) Examples of Successful Naturalisation.

When we come to consider in detail the numerous forms introduced by societies and individuals with the express purpose of naturalising them in the colony we find that most attention has been devoted, as indeed might have been expected, to animal immigration.

Among successful cases of naturalisation we must give the palm to the rabbit. No one will be found ready to accept the responsibility of having introduced the rabbit; yet various acclimatisation societies, and several private individuals, brought these animals into the colony on their own account, and liberated them at various parts. It is no part of my purpose here to describe the history of the introduction of these animals: my object is to show how they have developed since their liberation. It may be said that they found here no natural enemies, for, though hawks, wekas, and wild cats attacked and destroyed a few young ones, yet the average increase has been prodigious, and natural selection has hardly begun to affect the stock. With a plentiful supply of food, a favourable climate, and absence of enemies, the rabbits would soon have increased to such an extent that all other herbivorous animals would have been exterminated, and then would have ensued a struggle for existence among themselves, which would have resulted in the production of a naturally-selected breed, whose characters, however, it is impossible to predict. Of course such a state has never been reached in these Islands; but it has been approached in certain localities, and, wherever the rodents have increased, means to destroy them have had to be resorted to. The most potent of these is phosphorus, and it is interesting to note that, as no rabbits can escape its poisonous action unless by abstaining from eating the poisoned oats, so the wholesale destruction which it causes cannot in any way affect the developement of the species except in so far as it reduces the number of individuals, and so does away with competition. To obviate the evil effects caused by the increase of the rabbits, various species of Mustelidæ (ferrets, weasels, and stoats) have been introduced, and these are themselves proving such a pest that the last state of this country promises to be worse than the first. Cats, which have been frequently turned out in numbers, keep down young rabbits, rats, mice, and, to a certain extent, small birds; but ferrets and weasels, leaving the rabbits alone, are now exterminating not only introduced species of game-birds, but, worst of all, the unique ground-birds of these Islands, such as kiwis and kakapos. So serious has the danger become, threatening as it does the extinction of these remarkable forms, that efforts are now being made to secure insular areas on which these birds will be strictly preserved.

Hares have spread to a great extent in many parts, but wherever phosphorus poisoning has been resorted to they tend to disappear along with the rabbits.

Australian frogs, which have spread to such an extent throughout three-fourths of the Islands, are strictly limited in their distribution by climatic conditions. All efforts to acclimatise them in southern Otago have failed, no doubt owing to the absence of a long enough warm period in summer. The adult frogs seem unable to survive the winter, and do not reproduce at all.

Of the numerous species of birds which have been introduced, game-birds such as the pheasant, partridge, and Californian quail formerly spread to a great and satisfactory extent, but the introduction of phosphorus poisoning has nearly exterminated them in many parts.

The most remarkable success in bird-naturalisation has been in the case of the starling, which is now found in myriads, and the value of which to the agriculturist must be incalculable. The sparrow, green-linnet, and—to a less degree—the skylark, chaffinch, and hedge-sparrow, are abundant, and, in spite of phosphorus, strychnine, and rewards for heads and eggs, continue to increase and to render the farmer's life a burden to him. It must be granted, however, that the evil that the first two in particular do is very conspicuous, while the enormous amount of good they accomplish is not visible, and hence is usually ignored. Blackbirds and thrushes have increased to an enormous extent in many parts, and, while rendering the groves melodious with song, seriously injure the gardener by eating his small fruit. The goldfinch is another bird which has become extremely common.

The success which has attended the introduction of the trout into New Zealand waters is almost equalled by the rapid increase of golden carp in the North Island. The phenomenal rapidity of growth which characterized the trout first turned out, when the food-supply of the streams was untouched, has not since been sustained, except in the South Island lakes. It has also been found necessary to restock the streams artificially in order to keep up a steady supply of medium-sized fish. The perch is another fish which has made rapid increase in suitable waters.

The common hive-bee, since its first introduction into the colony, has frequently become wild, swarms being continually lost in bush districts. The only other insect whose naturalisation has been attempted is the humble-bee (*Bombus terrestris*), and the experiment, as I have shown elsewhere, has been successful beyond expectation.

(*d.*) Unsuccessful Attempts at Naturalisation.

To the naturalist, the unsuccessful attempts which have been made to introduce animals and plants into a country like this are fully as interesting as the successful cases, and the causes of failure are well worthy of investigation.

I find, for example, that in 1867 and succeeding years the Otago Acclimatisation Society introduced about twenty-three species of foreign birds, of which little or no trace is now to be found. The mistake was made of turning out too few individuals, and even those were not always liberated in the same locality. The chances therefore of their being able to survive to the breeding-season were diminished. This no doubt accounts for the non-appearance of such birds as redpoles, reed-sparrows, English wild-ducks, and numerous Australian birds. Yet some have succeeded in establishing themselves even from very small beginings. Thus, twenty linnets, eight greenfinches, thirty-three chaffinches, eighteen hedge-sparrows, eight yellowhammers, and seven cirl-buntings were the total numbers of individuals of these species turned out by the local society, but all these birds are now to be found in Otago, some of them in vast numbers. No doubt other societies turned them out also, but most of those found locally are almost certainly the descendants of those liberated about Dunedin.

Some introduced birds, which at one time showed signs of increasing, have since disappeared. Thus, Australian magpies formerly bred in and about Dunedin and Balclutha, but they have become extinct of late years; the cause, however, of their disappearance is not known. Similarly, Indian minahs (*Acridotheres tristis*) at one time—about fifteen years ago—began to increase both in Dunedin and Christchurch, but they have since completely disappeared, apparently having been driven away by a more recent introduction, the starling.

The experiences of many of the acclimatisation societies with the salmon—both *Salmo salar* and *S. quinnat*—are well known. Up to within the last three or four years the record has been one of continuous failure. The latest experiments give promise of proving successful. The selection of one river into which the fry are turned by the hundred thousand is much more likely to lead to the ultimate stocking of it than the former mode of distributing the young fish over a number of streams in which it was impossible to watch them. But too little is yet known as to the habits of the salmon after they run down to sea to predict complete success. The temperature of the sea most favourable to them is not known, and in this department of scientific research—namely, the direction and temperature of the ocean-currents round our shores—almost nothing is known. Meanwhile the stage of the experiment when the fish begin to run down to sea has been reached with the large consignments of Scotch salmon imported within the last few years by the Government, and the further result will be watched with interest.

A marked success has been attained at the Otago society's ponds at Clinton, where salmon have been continuously kept in confinement since they were hatched, and are now themselves breeding. These fish commenced to spawn in 1888, and this last winter produced many thousand ova.

Attempts in Canterbury to naturalise whitefish, and in Otago and Southland to introduce medicinal leeches, must be added to the list of unsuccessful experiments.

When we turn to the vegetable kingdom we find a still more remarkable record of failures in systematic attempts to introduce desirable plants. In his "Handbook to the New Zealand Flora" (p. 757), Sir Joseph Hooker says: "I have been informed that the late Mr. Bidwill habitually scattered Australian seeds during his extensive travels in New Zealand: if this be true, it is remarkable how few Australian plants have naturalised themselves in the Islands, considering both this circumstance and the extensive commerce between these countries." But this remark applies to a certain extent to numerous other cases in which the attempt has been made to ornament our woodlands and meadows with many of the favourite flowers of Great Britain by sowing the seeds broadcast. My own observations on this subject lead me to the conclusion that only those plants become naturalised which produce their seed freely. Hence, if from any cause they do not seed, they are not likely to become established. Hitherto many common British plants have failed to seed naturally in the colony, *e.g.*, primroses, cowslips, English blue-bells (*Scilla*), daffodils, harebells or Scotch blue-bells (*Campanula*), heather (*Calluna*), and various heaths (*Erica*), honeysuckle, species of *Lichnis*, *Silene*, *Geranium*, &c., and in consequence these do not spread as wild plants. The reason I believe to be the want of suitable insects to fertilise the flowers. This is singular in some cases, because several of the above-named flowers are visited by hive-bees and are fertilised by them in Europe. But others, as primroses and honeysuckle, depend almost absolutely on various species of Lepidoptera, and in the absence of these insects they have hitherto been infertile. It would now seem, however, as if with the advent of the humble-bee various plants will seed freely which have not done so hitherto, and which even in some cases are not visited by these insects in their native countries. This is just one of those points in connection with naturalisation which want careful and continued observation, and from which we can see how mutually dependent on one another are the various organisms concerned. As an example, I would suggest the following case: *Primula elatior* and *Primula veris*, the parent forms of our common garden polyanthus, are both heterostyled species. If humble-bees visit these flowers for pollen, which is all that I have seen them doing,—the nectar being beyond the reach of their trunks,—only the short-styled flowers will be visited, as in them the anthers are placed at the mouth of the corolla-tube. According to Hermann Müller, humble-bees (in Europe) learn to recognise the long-styled flowers at a distance and avoid them, and if they do visit them they only accomplish self- and not cross-fertilisation. It is more than probable, then, that, by persistent fertilisation of one kind of flower only, a change of form—or, at least, some change in the hetero-styled character—may gradually arise in these introduced Primulas.

(*e*.) Some Changes undergone by or in Process of Occurrence among Introduced Animals.

One of the most interesting points connected with the successful naturalisation of foreign species is the observation of the changes which they undergo under their altered conditions. Nearly all our introduced animals have been brought from lands where the struggle for existence is very keen and where natural enemies abound. In their new home they have been set free from these old trammels, and their enemies have been left behind. Under such circumstances it is not surprising to find that sports in colour, which in Europe would be strictly eliminated as soon as they appeared, owing to their rendering their possessors too conspicuous to their enemies, are here preserved and tend to be reproduced. This is particularly noticeable among rabbits. In the neighbourhood of towns and villages, where cats, dogs, and sportsmen abound, the sober greys and browns of the wild rabbit are the colours commonly seen; but in the country districts, away from all enemies except professional rabbiters and phosphorized oats, neither of which are likely to exert much selective action on their colour, it is as common to see black, white, yellow, and piebald rabbits as the ordinary greys. The same remark applies, but in a less degree, to our introduced birds. Among house-sparrows in particular, variation in colour and especially development of white feathers is extremely common, and is certainly on the increase. From evidence I have collected in Otago, I find that the development of white plumage, usually in the wings and tail, is a very common feature, and by no means confined to sparrows. I have numerous recorded cases of the occurrence of more or less complete albinism, as well as of the development of bright colours, in thrushes, blackbirds, linnets, skylarks, and starlings. Such variations are, of course, not uncommon in the original habitats of all these birds, but it never tends to increase. Here, on the other hand, it is of frequent occurrence, and seems to me to be very decidedly on the increase. My own observations lead me to think that birds with any bizarre or distinctly-abnormal colouring are wilder and more shy than their normally-coloured fellows; but, as I have only watched them in the neighbourhood of towns, where they become objects of interest to passers-by, and especially to those great enemies of birds—the small boys—they are in such localities subjected to an amount of attention and persecution which they do not receive in more sequestered parts.

An instance of change of habit among hares has been mentioned to me since coming to Christchurch. In England I am told that hares seldom produce more than two young at once, while in this country the usual number is three or four. It is also stated that the animals are much larger than in Britain. This, of course, is due to the abundance of food-supply, and is probably only true of those districts where rabbits are almost unknown.

In regard to change of habits among introduced birds, the evidence is very meagre. Sparrows very commonly hawk for moths and other insects here. The habit may not be a new one, but I cannot learn that it is common in Britain. I have been informed recently that in several parts in the North Island sparrows have acquired the habit of burrowing into cliffs, and that they build their nests in the holes and tunnels so made. These birds, together with linnets, greenfinches, and yellowhammers, are all seed-eaters, and are, no doubt, graminivorous when they find other food-supply short. But they never in Britain act as such depredators as they do here. Apparently the insect-supply, mainly through their agency, is extraordinarily reduced in numbers, and they have developed the habit of attacking grain-crops, but especially oats, when the seed is forming and is still in the milky state. The havoc they do is incalculable. Beginning with those portions of the fields which adjoin hedgerows and plantations, they pick out all the grain as it forms, so that by the time the crop—in the ordinary course of maturing—ought to be ready to cut, there is often little left but the straw. Starlings are credited with being very destructive to small fruit (especially currants) in some parts (though the observation is not commonly borne out), and the habit is by some persons considered to be a newly-acquired one. I am informed, however, by a person long resident in the West of England, that there starlings habitually eat small fruit, and the observation is hardly likely to be limited in its application. Several correspondents in Otago and Southland report these birds as eating poisoned grain. The habit of eating grain at all is not common to starlings, and may be due to their own vast numbers and the consequent great reduction in insect-life.

A. R. Wallace, in "Darwinism" (2nd ed., p. 76), has quoted from an article in *Nature* (vol. xxxi., p. 533) an observation made by Mr. Burton, formerly employed in the Colonial Museum, Wellington, regarding the nesting-habits of certain young chaffinches in New Zealand. The following is a quotation from the original paper: "The nest is evidently built in the fork of a branch, and shows very little of that neatness of fabrication for which this bird is noted in England. The materials with which it is made seem very different, too. The cup of the nest is small, loosely put together, apparently lined with feathers, and the walls of the structure are prolonged for about 18in., and hang loosely down the side of the supporting branch. The whole structure bears some resemblance to the nests of the hangnests (Isteridæ), with the exception that the cavity containing the eggs is situated on the top. Clearly, these New Zealand chaffinches were at a loss for a design when fabricating their nest. They had no standard to work by, no nests of their own kind to copy, no older birds to give them any instruction, and the result is the abnormal structure I have described." While this change in the mode of nest-building is one very likely to occur, especially as the materials used are here often necessarily different from those obtainable in Britain, I have not myself been able to note any alteration. Our thrushes always plaster the inside of the nest with mud, as they do in Europe; the chaffinch still commonly makes its nest of moss, neat and compactly arranged, and lined with wool, hair, or feathers; while the goldfinch builds the neatest of cuplike structures, just as its forebears did in England.

If the colours of birds' eggs are, as suggested by Wallace,* adaptive and protective, then in a country like this, where the enemies of the birds are so few in number, we might anticipate that the protective colouring might tend to disappear. I was led to believe that this was actually taking place, and have accordingly made arrangements with more than one of the County Councils in Otago—which purchase large numbers of eggs of sparrows, linnets, greenfinches, &c.—to have extensive series of these handed over to me for examination and comparison. From those already examined, however, I cannot find that any alteration is taking place, unless it be in the case

* "Darwinism," 2nd ed., p. 212.

of the sparrows. There is, however, in these eggs such a very large range of variation already that the question will not be readily decided except by carrying on observations for a considerable length of time. It is certainly, then, premature to speak about a change which has not yet taken place; but it must be borne in mind that it is likely enough to occur, and when it does take place it is also probable that it will be reproduced rapidly and extensively.

I have elsewhere* alluded to the slight alteration in habits, especially of hibernation and of visiting new flowers, shown by humble-bees in this country. These changes may also be expected to develope rapidly, and others may be looked for to arise, all of which will repay close attention.

(*f.*) Changes undergone by Introduced Plants since their Naturalisation.

Reference has already been made to the changes undergone by some of our introduced plants, and their marvellous growth and powers of spreading. Watercress, sheep's-sorrel, thistle, cat's-ear, and meadow poa (*P. pratensis*) have been referred to. But these are only a few examples, and were we to extend the list to the whole colony we should have to name a score of plants which since their introduction seem to have broken free from restraint, and run riot in a style they could not do elsewhere. Comparatively little has been done in the way of observing whether any changes occur in our introduced plants beyond those due to extra-rapid growth and distribution. The following few observations, however, may show a direction in which changes may be looked for.

H. Müller† instances the fact that, in the United States, cultivated species of strawberry (*Fragaria*) tend to diœcism. I am inclined to think the same holds good in this country, although it is difficult to get satisfactory evidence. I have myself observed several cases of infertility among strawberries, and see frequent reference to it in such papers as the *Otago Witness*, where the writers ask for a remedy. It has, of course, to be borne in mind that the so-called "hautbois" varieties in Britain are shy bearers, though the cause of this comparative unproductiveness is not understood, as a rule, by gardeners. I applied for information to various growers near Dunedin, among others to the veteran horticulturist of Otago, Mr. William Martin, of Fairfield. He tells me that the only variety in cultivation in the early days of the settlement was one called the "Chile" (perhaps an American variety), which grew very

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* "New Zealand Journal of Science," January, 1891, p. 16.
† "Fertilisation of Flowers," p. 231.

rankly and flowered well, but gave little or no fruit. As the same variety fruited well in other parts, Mr. Martin attributed the change to the presence or absence of certain constituents in the soil; and this is the explanation commonly given, although, I think, without any justification in actual experience. I am inclined to refer the whole question of fertility and of so-called "shy bearing," not in strawberries alone, but in all other plants cultivated for their fruit or seeds, to the presence or absence of suitable insects. Of all the insects recorded as visiting strawberry flowers in Europe, only the honey-bee is to be found in New Zealand, but I have never seen it or indeed any other insect on these blossoms, nor have I any record of them from other observers who have looked out for them; so that I am of opinion that self-fertilisation is the chief mode by which fruit is obtained in the colony. Diœcious varieties do occur, however, and, unless eradicated, constantly tend to be reproduced by runners, and occasionally, no doubt, by cross-fertilisation by bees, &c.

Other cases of apparent tendency to change are the constant production of self-fertilised (almost cleistogamic) winter flowers of chickweed (*Stellaria media*) and mouse-ear (*Cerastium*), of self-fertilised closed flowers of groundsel (*Senecio vulgaris*), and of absolutely cleistogamic varieties of violets (*V. odorata*). As these peculiarities are, however, all more or less produced in Britain, they cannot be looked upon as being more than intensified here.

As a final example of apparent change in introduced plants, I would instance the remarkable increase of whin or gorse (*Ulex*) in the total absence of fertilising insects. I took particular note of the winter and early-spring flowering of this plant in Otago. In Europe it flowers in February and March, and again in August and September. In Otago it flowers nearly all the year round, reaching its maximum in October and November. I carefully observed a large number of plants in flower during June and July last, looking over them several times every day. The weather was warm, brilliant, and calm, but I never saw an insect of any kind on them (though bees, &c., were abundant enough in the gardens), nor could I find that the flowers were exploded so as to throw out the pollen; yet these plants have produced abundance of seed-pods. No doubt, though I can find no reference to the fact, the early flowers of *Ulex* in Europe are self-fertilisable; but, whether this be the case or not, here the tendency is all towards self-fertilisation. Even the glorious spring and early-summer blossoming of this plant fails to attract insects in most parts of this colony, yet it seeds to such an extent as to cause great expense in its eradication.

(g.) On some Changes induced in the Indigenous Fauna and Flora by Introduced Plants and Animals.

The influence exerted on the indigenous fauna and flora by the advent of Europeans with the accompanying immigration of foreign animals and plants has certainly been very remarkable, and in some cases very destructive. The singular example of the change of habit in the kea (*Nestor notabilis*) has attracted a very large amount of attention just because it is a very conspicuous case. But there are no doubt numerous other examples of the same alteration, to which little or no attention has been drawn. It is, however, extremely difficult to distinguish between the changes caused by direct human agency, especially by fire and firearms, and those due to the imported animals and plants. The whole process of settlement—the burning-down and clearing of the surface vegetation, the ploughing of the land, and the draining of the swamps—all this has brought about radical changes. By this means not only have enormous numbers of indigenous plants and animals been destroyed, but in the case of the latter especially their food-supply and shelter have been removed, so that they have more easily fallen a prey to their enemies. In this way vast numbers of insects have disappeared entirely from the settled districts: sandflies, for example, those pests of the Sounds district, are now almost unknown on the east coast of the South Island. The introduction of insectivorous birds has greatly aided this process of extermination. To such an extent has this work of alteration gone that in all the thickly-settled parts of Otago and Canterbury the facies of the fauna and flora is that of England, and not of New Zealand. This disappearance of insects must greatly affect the native flora. Thus, flies are the principal agents in effecting fertilisation of many of the indigenous flowering plants; but the native forms of Diptera have in many cases become very rare, so that these plants are probably now dependent on introduced flies and bees, or escape fertilisation altogether. Many of the coriaceous and hairy plants of these Islands probably acquired these characteristics as a defence against the numerous grasshoppers and other phytophagous insects which used to abound in the early days of settlement. But these insects are now almost exterminated in many parts, while others with different habits have taken their place, and were it not for the prevalence of fires these now protected plants would probably increase to a very considerable extent, unless, indeed, the same destructive agencies have served to exterminate the insects which fertilise the flowers.

Some plants appear to be dying out without the intervention of fires. This is the case with regard to the spear-grasses (*Aciphylla squarrosa* and *colensoi*) in many parts of Otago. Grazing animals do not touch these plants, and it cannot be due to pigs rooting them out, for wild pigs are not common now compared to what they were thirty years ago. The only explanation I can suggest is that the pistillate flowers frequently fail to be fertilised. This I know sometimes happens. No one has ever recorded what insects fertilise these flowers, and the question is now complicated by the disappearance of insects formerly common, and the abundance of introduced forms.

Some indigenous plants seem quite able to hold their own, under favourable conditions, against introduced forms. Thus, in poor pastures near Dunedin, which have been ploughed and sown down in English grasses, and where only cattle feed, *Haloragis micrantha, Hydrocotyle asiatica,* and other species of the genus, *Wahlenbergia gracilis, Nertera setulosa,* and other small plants abound and form great part of the sward. All these plants, however, and indeed most others which I have found in similar situations, and which show a similar power of holding their own, are not peculiar to New Zealand, but have a wide range outside these Islands. They really, therefore, are species which have already undergone a very severe struggle for existence, and, as shown by their wide geographical distribution, have come victoriously out of it. On the other hand, where neither cattle nor sheep are allowed to graze—in such localities, *e.g.*, as the Town Belt in Dunedin—I find that, while shrubs like manuka (*Leptospermum*), *Rubus, Coriaria, Cassinia,* various scrubby species of *Coprosma,* &c., are able to hold their own, there are very few of the smaller plants which can resist the encroachment of the introduced grasses, especially cocksfoot, dogstail, and sweet-vernal grass. Even in such places, however, a few species—*e.g.*, *Celmisia longifolia*—can hold their own, while, wherever the ground is damp, species of *Ranunculus, Epilobium, Anthericum,* &c., can succeed. This is, no doubt, because few or no marsh plants have been introduced.

As regards insects which seem to have benefited by the introduction of new forms of plants and animals, there is almost no evidence yet collected. I am inclined to think, however, that a few forms have increased decidedly since the settlement of the colony began. Thus the curiously banded and spotted black-and-white moth, *Nyctemera annulata*, seems to be more abundant than of yore. Its larva has taken to feeding on the introduced groundsel (*Senecio vulgaris*), and on a very glabrous ivy-leaved geranium (*Pelargonium* sp.), on either of which plants it may be found in spring in great abundance. Many of the solitary bees of the genus Lamprocolletes seem to be increasing in numbers with the increase of introduced yellow-flowered Composites (*Hypochœris*, &c.), on which they are frequently to be seen. The same is apparently true of the many flower-visiting genera of Diptera, especially *Syrphus*, which find in our introduced flowers a very abundant food-supply.

The disappearance of native birds is probably due more directly to man than to the animals he has introduced. Exception must, however, be made with regard to the animals of the weasel kind, which are of very recent introduction. Many of the larger birds, formerly common, have completely disappeared from the settled districts, having been shot for food by the earlier settlers. Many still survive to find an increased food-supply. Thus, tuis and korimakos are still common in gardens and orchards, finding abundance of nectar in fruit-trees, blue-gums, fuchsias, and other introduced flowers. Parrakeets are very destructive to fruit-gardens and grain-crops; and, in the neighbourhood of bush districts, kakas are fond of raiding the corn both in the stook and after it is stacked. The increase of the rabbits in many parts led to a great increase in the numbers of wekas, which were able to attack and destroy the young ones. Phosphorus, and especially ferrets, have, however, nearly exterminated them within the last few years.

The time which has elapsed since the earliest immigration of European forms may be considered too short to have allowed any marked variations of plants and animals to have arisen. Thirty years ago, Darwin, and those who embraced his views, called in the aid of vast periods of time in which to allow variation to reach specific value. But the accumulated experiences of the intervening period since the publication of the "Origin of Species" show, from the results obtained by breeders of animals and producers of new strains of plants, how very rapidly and in how few generations differences arise which, were we to find them in a state of nature, would be considered to be of specific, if not, indeed, of generic importance.

When once a favourable variation or, as in some of the cases cited, an unsuppressed variation arises, it frequently is reproduced with great rapidity. I have one or two singular instances among domestic animals which show this fact, but shall only advance the following case, which is an interesting one:—

In the district of Strath-Taieri, in Otago, some years ago, certain sheep on one of the runs—probably the progeny of a single ram—were found to be evidently short-winded. Apparently the action of the heart was defective, for when these sheep were driven they would run with the rest of the flock for a short distance, and then lie down panting. The result of this peculiar affection was that, at nearly every mustering, these short-winded sheep used to be left behind, being unable to be driven with the rest. Sometimes they were brought on more slowly afterwards; but, if it happened to be shearing-time, they were simply caught and shorn where they lay.

As a result of this peculiar condition, a form of artificial selection was set up, the vigorous, active sheep being constantly drafted away for sale, &c., while this defective strain increased with great rapidity throughout the district; for, whenever the mobs were mustered for the market, shearing, or drafting, these "cranky" sheep (as they came to be called) were left behind. This defective character appeared in every succeeding generation, and seemed to increase in force, reminding one of the Ancon sheep referred to by Darwin. At first, of course, the character was not recognised as hereditary; but, as the numbers of this "cranky" breed increased to a very serious extent and spread over the district, it came at last to be recognised as a local variety. When the runs on which these sheep were abundant were cut up and sold, or re-leased in smaller areas, a few years ago, the purchasers found it necessary, for the protection of their own interests, to exterminate the variety, of which hundreds were found straggling over the country. This was easily and effectually done in the following manner: As soon as a sheep was observed it was pursued; but, after running for a couple of hundred yards at a great rate of speed, it would drop down panting behind a big stone or other shelter, and seemed incapable for a time of rising and renewing its flight. It was immediately destroyed; and in this manner a useless—but, to the naturalist, a very interesting—variety was eliminated.

Now, cases of variation, preserved in some similarly singular manner, might easily arise among our many introduced forms of plants and animals under the greatly altered conditions in which they are placed in this new field; and the close observation of these forms at present and the changes they undergo will be found to furnish a line of observation which it will always repay the naturalist to follow out.

In concluding these remarks I desire to make one practical suggestion. It is that either our acclimatisation societies should be amalgamated together into one or, at most, two bodies for each Island, or—what in this land of provincial jealousies might prove a better way of overcoming the difficulty—that a representative body, responsible only to the Government, be formed, which should control all attempts at the introduction of new forms of life. At present, any society possesses the power—limited only by its finances—of introducing anything that an active member chooses to suggest. In this way it might be possible to prevent much mischief in the future. But even with this safeguard it is not possible to guard against mistakes. It must be remembered that it is to the Government, acting on the instigation of large landed proprietors, that we owe the introduction of stoats, weasels, and ferrets. And, with all the knowledge in the world, we cannot always foretell whether any introduced form will be able to hold its own, or whether it will succeed so well as to become a pest. But there can be no question that, with more scientific knowledge brought to bear on the whole matter, it may be possible in the future to avoid some of the glaring mistakes of the past.

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8. *On the Botany of the Antarctic Islands.*

By T. Kirk, F.L.S.

The object of this paper is to give a brief but connected account of the chief features of the vascular vegetation of the Snares, the Auckland Islands, Campbell Island, Antipodes Island, and Macquarie Island, so far as known. In a future paper I purpose showing the relationship of the plants of these islands, together with those of the Chatham Islands, and especially of Stewart Island, to the entire flora of New Zealand.

The Auckland Islands and Campbell Island have been visited by three important scientific expeditions; the first of which was the French Antarctic Expedition under Admiral d'Urville in 1839. The botanical collections made by the French naturalists were not large: the Cryptogams were described by MM. Hombron and Jacquinot in the "Voyage au Pôle Sud" in 1845, and the Phanerogams by M. Decaisne at a later date, the descriptions being accompanied by fine illustrations of the more noteworthy forms. In the same year, the American Exploring Expedition under Commodore Wilkes visited the islands; but the botanists do not appear to have collected very largely. In 1840, the British Antarctic Expedition under Sir John Ross arrived in Rendezvous Harbour, now Port Ross, when large collections were made by Sir Joseph Hooker (then Dr. Hooker), assisted by Dr. Lyall, and were described by the former in the first volume of his magnificent work the "Flora Antarctica." The remarkable collections made on this occasion left but scanty gleanings for future travellers.

From Macquarie Island, Mr. C. Fraser, Superintendent of the Botanic Gardens at Sydney, obtained seven or eight species of flowering plants, amongst which was the antarctic *Azorella* *selago*, Hook. f. A few years back the island was visited by Professor Scott, of Dunedin, who published a valuable account of its fauna and flora in the "Transactions of the New Zealand Institute."

Until my recent visit the botany of Antipodes Island and the Snares was entirely unknown. Although the time available for collecting was extremely brief,—in some instances being limited to a few hours,—I succeeded in making a few additions to the plants known from the Auckland and Campbell Islands, and adding to the list of plants common to both. For this success I am largely indebted to the obliging courtesy of Captain Fairchild, in command of the steamer "Hinemoa," who spared no effort to enable me to use my limited opportunities to the greatest advantage, and to whom I desire to render my sincere thanks.

THE SNARES.

The rocky islands known as the Snares are situate on the 48th parallel of south latitude, and within sixty-five miles of the South Cape of Stewart Island. As they lie outside the usual track of vessels, they are but rarely visited, and hitherto nothing has been known of their botany; it was therefore with great pleasure that I found myself on board the Government steamer "Hinemoa" on her southern relief-trip last year, the Snares being usually her first place of call after leaving the Bluff. The group known as the Snares consists of two islands, one much larger than the other, separated by a narrow channel, and by several smaller islets. I was able to land on the largest island only, so that the following notes cannot be considered exhaustive. The island is the abode of numberless penguins, petrels, and other sea-birds, and exhibits numerous indications of their influence on the vegetation.

Several interesting land-birds were observed, the most remarkable being the Auckland Island snipe (*Gallinago aucklandica*), and the grass-bird (*Sphenœacus punctatus*): the latter, which has become very rare on the mainland, was decidedly frequent on this little island. The occurrence of birds of such small power of flight in these lonely islands is very suggestive. Formerly these islands were visited by sealers, who have succeeded in nearly extirpating the seals, only a pair being known to inhabit them at the present time. I was fortunate in seeing one of these, which allowed itself to be stroked on the neck with a long rod by Captain Fairchild, and seemed to enjoy the process rather than otherwise. The visits of sealers serve to account for the presence of a few naturalised plants.

The largest island is of irregular outline, and about a mile and a half in its greatest diameter: in many places the cliffs are steep and lofty, but a good harbour for small craft exists on the north-east side. The rocks are granitic, and the greatest altitude does not exceed 480ft.

The greatest portion of the island is covered with light and occasionally open bush, never exceeding 30ft. in height: in a few places a dense, scrubby growth of *Veronica elliptica*, 5ft. to 8ft. high, requires some exertion to force one's way through: the difficulty is aggravated by the penguins (*Eudyptes pachyrhynchus*), which make vicious snaps at the legs while the explorer is held fast by entangled branches above. Usually a belt of open land covered with tussock occurs between the bush and the edge of the cliff, and a few small open patches are found in the central part of the island. In places where patches of bush have been felled by sealers the ground is covered with a dense growth of *Veronica elliptica* intermixed with tussock.

There is but little fresh water on the island. Two small rills issuing from swampy ground unite before reaching the cliff, but the water is undrinkable, owing to its being polluted by the penguins: and the two or three swamp plants exist under difficulties, being constantly flattened under the broad feet of these birds, which abound everywhere, their numbers being but little reduced by the depredations of the sea-hawks, which swoop down upon unguarded eggs or young birds, and seem almost ready to attack man himself.

Approaching the island in a boat on a fine morning in January, one is struck at once by the peculiar grey or whitish hue of the foliage, flecked here and there with green. On landing this is found to arise from the abundance of *Olearia lyallii*, which is the principal tree on the island and forms the greater portion of the bush. When growing in level situations it is erect, with rather open spreading branches; but when growing on slopes in situations exposed to the wind it is often inclined or with a prostrate trunk, the roots partly torn out of the soil, and the branches rooting at the tips give rise to new trunks, which in their turn are brought to the ground and repeat the process. The short trunks in one or two cases were fully 3ft. in diameter, but the majority were from 1ft. to 2ft., the extreme height rarely exceeding 28ft.

In the description given of this plant in "Flora Antarctica"* it was united with *O. colensoi*, but in the "Flora Novæ-Zelandiæ"† it is treated as a distinct species, although, from insufficient material, the description is necessarily imperfect. Botanically the two species are closely allied, *O. lyallii* differing from *O. colensoi* chiefly in the more open habit, stouter branches, broadly-ovate or orbicular-ovate leaves, which are abruptly acuminate, and especially in the involucral leaves

* Fl. Antarc., ii., p. 543.
† Fl. Nov.-Zel., i., p. 116.

being arranged in from five to eight series. The whole plant is more densely tomentose, newly-formed leaves being white above and below, the tomentum on the upper surface being floccose and falling away during the first winter. The mature leaves on old plants are excessively thick and coriaceous, doubly crenate, with a very short, almost sheathing petiole: on young specimens growing in the shade they were much thinner in texture and very large, some measuring over 7in. in length by 5in. in breadth. The flower-heads are crowded in terminal racemes, 4in. to 7in. long: the rhachis, bracts, peduncles, and outer involucral leaves being alike clothed with dense snow-white pubescence. The remarkable difference in habit and foliage causes it to present an appearance differing widely from that of *O. colensoi,* although the botanical distinctions are almost trivial. It will be a valuable addition to the list of New Zealand plants suitable for the purposes of the cultivator. It appears to be restricted to the Snares and the Auckland Islands, but is rare and local in the latter. The patches of green which showed amongst the white masses of the Olearia were found to be the foliage of another grand plant, *Senecio muelleri,* T. Kirk, a noble species originally described* from specimens collected on Herekopere Island, in January, 1883: but the specimens in the original habitat are not nearly so large as those on the Snares, which attain the extreme height of 26ft., with a short trunk 2ft. in diameter. The branches are somewhat naked, so that the tree has a straggling appearance, but the handsome foliage and large terminal panicles of yellow flowers place it amongst the finest members of a large genus abounding in grand flowers.

Veronica elliptica, to which reference has already been made, completes the short list of ligneous plants. It is, however, of a more robust form than the plant found at Stewart Island and the Bluff, the flowers being larger, with pure-white corollas, which are never pencilled or streaked. The open land is covered with tussocks of the remarkable grass *Poa foliacea,* which produces a vast amount of nutritious herbage. The tussocks are frequently interspersed with *Carex trifida,* the largest of our New Zealand species; and one or two small plants of no great importance are hidden away in the hollows at their base.

One of the most interesting plants is *Colobanthus muscoides,* which is abundant on cliffs at the Auckland and Campbell Islands, but appears to be confined to a patch of swampy ground in this locality, which extends its northern range fully a hundred and fifty miles. It forms rather large dense masses, the inner portion consisting of the partially decomposed stems

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* Trans. N.Z. Inst., xv., p. 359.

and leaves of old plants and the roots of young plants. The seeds often germinate in the capsule, and it was no uncommon thing to find capsules still attached to the stem and with apparently perfect seeds imbedded some 3in. or 4in. below the surface of the mass, the old surface having been covered with a growth of young plants too quickly to allow of the germination of the buried seeds.

Another interesting plant was a new *Ligusticum*, to which I have given the name of *L. acutifolium*: it was only observed in one place, at an altitude of about 350ft. above sea-level; its stems below the leaves were nearly as thick as a man's wrist, and the entire plant was about 4ft. in height. Its nearest allies are *L. intermedium*, Hook. f., and *L. lyallii*, Hook. f., but it is destitute of the viscid milky juice which is so characteristic of those plants in the recent state. The membranous leaves are thrice-pinnate, with large acute segments, and the fruits approach *L. lyallii*.

The most striking plant is undoubtedly the punui, *Aralia lyallii*, var. *robusta*, the large orbicular-reniform leaves of which are sometimes 2ft. in diameter. It differs from the typical form in the absence of the remarkable stolons of that plant, in the petioles being very stout, flat on the upper surface and concave beneath, giving a planoconvex section, and in being solid or nearly so, instead of terete, thin-walled, and fistulose. The flowers also, although forming equally large masses with the type, are individually smaller, and invariably of a dull pale-yellow hue; but there is no structural difference, although it must be admitted that at first sight the plant appears to differ widely from the type.

Lepidium oleraceum was found in one or two places on the cliffs, associated with *Myosotis capitata*, var. *albida*, a form frequent on Stewart Island. *Lomaria dura* was plentiful everywhere close to the sea.

A few naturalised plants have been introduced by the sealers; and the following common New Zealand plants, which appear to be recent immigrants on the Snares, have doubtless been introduced by the same agency: *Sonchus asper, Juncus bufonius, Hierochloe redolens, Deyeuxia forsteri*.

Mosses are exceptionally rare, the only species collected being *Hypnum serpens*. A few Lichens were observed, but no Fungi or Hepaticæ. No opportunity of collecting Algæ was afforded.

The following catalogue of flowering plants and ferns shows a meagre flora even for so small an area. A closer examination of the cliffs than I was able to give might add several species, and a few others might possibly be collected on the smaller islands, but it is unlikely that any material additions could be made:—

SNARES.

Colobanthus muscoides, *Hook. f.*
Lepidium oleraceum, *Banks and Sol.*
Cardamine depressa, *Hook. f.*
Callitriche verna, *L.*
Tillæa moschata, *DC.*
Ligusticum acutifolium, *n.s.*
Aralia lyallii, *T. Kirk, var.* robusta.
Olearia lyallii, *Hook. f.*
Senecio muelleri, *T. Kirk.*
Sonchus asper, *Hoffm.*
Myosotis capitata, *Hook. f., var.* albida.
Veronica elliptica, *Forst.*
Juncus bufonius, *L.*
Scirpus antarcticus, *L.*
" cernua, *Vahl.*
Carex trifida, *Can.*
Hierochloe redolens, *R. and S.*
Deyeuxia forsteri, *Benth.*
Poa foliosa, *Hook. f.*
Festuca scoparia, *Hook. f.*

Lomaria dura, *Moore.*
Asplenium obtusatum, *Forst.*
Aspidium aculeatum, *Swartz.*

Naturalised.

Dactylis glomerata, *L.*
Holcus lanatus, *L.*
Poa annua, *L.*
Lolium perenne, *L.*

THE AUCKLAND ISLANDS.

Port Ross, at the northern extremity of the Auckland Islands, is situated in lat. 50° 32′ S., long. 166° 13′ E. The group was discovered by Captain Bristow in 1806, and was visited by the French Antarctic Expedition under Admiral d'Urville in 1839, and by the American Exploring Expedition under Commodore Wilkes during the same year. But few plants were collected by the members of either. Some of those collected by MM. Hombron and Jacquinot are beautifully represented in the "Voyage au Pôle Sud," the publication of which extended over several years. The botanists of the American expedition also appear to have made but scanty collections. Her Majesty's ships "Erebus" and "Terror" visited the islands in November, 1840, when Dr. Hooker (now Sir Joseph Hooker), assisted by Dr. Lyall, made comprehensive collections, the results of which were described by the former in the first volume of his splendid work, the "Flora Antarctica." At a later date General Bolton visited the group, and added two or three species. There is no record of their having been visited by other botanists; but in 1849 a whaling settlement under Governor Enderby was formed at Port Ross, and abandoned in 1852. The stumps of the felled ratas now afford the only remaining indication of its former existence.

The entire group is about thirty-three miles in length from north to south, its greatest breadth being about fifteen miles, near the southern extremity. In general outline the group is roughly pear-shaped, the narrowest portion being at the northern extremity. It consists of two large islands with several small islands—Enderby Island, Rose Island, Ewing Island, and others still smaller at the extreme north.

Disappointment Island lies off the west coast of the main island. Adams Island is the most southern member of the group, and is separated from the main island by the strait which forms Carnley Harbour, the northern arm of which runs some distance into the widest part of the main island. The hills on the main island nowhere attain the height of 2,000ft., and are for the most part below 1,500ft. Adams Island is remarkably rugged and precipitous; the highest parts probably exceed 2,000ft.

The western coast is steep and unbroken, but the eastern coast is cut up into a number of deep bays or inlets, which afford ready access to all parts of the island.

In many places granite comes to the surface, but is generally overlain with basaltic rocks, which in some places are columnar. The whole is covered with a deep layer of peat, which burns readily when dry.

The small islands at the head of Port Ross are mostly covered with a scrubby growth of *Coprosma fœtidissima*, *Dracophyllum longifolium*, *Metrosideros lucida*, &c., which is so extremely dense that it is difficult to force one's way through. A notable exception occurs on Ewing Island, where a number of grand specimens of *Olearia lyallii* attain the height of nearly 30ft.: most of them are erect and well-grown, but a few exhibit the inclined position so frequent on the Snares.

On the main island a dense belt of shrubs and small trees ascends from the sea-level, usually running out at from 400ft. to 700ft. according to position and exposure. The most important members of this are the rata (*Metrosideros lucida*), *Dracophyllum longifolium*, *Coprosma fœtidissima*, *Myrsine divaricata*, &c., which are often abundant; but in many places the rata is the only tree; it attains the extreme height of 40ft., although in many cases the trunks are short and distorted. The undergrowth was often restricted to *Asplenium obtusatum, Lomaria dura*, &c. In ravines and hollows on the mountain-slopes, the woody vegetation was in many cases restricted to several species of Coprosma—*C. fœtidissima, C. parviflora, C. cuneata*, and *C. ciliata*, the last peculiar to this group: these formed low thickets through which it was almost impossible to force a way. Occasionally the difficulty was aggravated by their being mixed with *Myrsine divaricata*, and stunted rata or *Dracophyllum*. It is, however, less difficult than the belt of *Olearia* scrub mixed with rata and *Dacrydium intermedium*, which is such an unpleasant feature on the mountains of Stewart Island.

The characteristic glory of these islands lies in the fine herbaceous plants which are endemic on their slopes. *Ligusticum latifolium*, with noble foliage and erect stems 4ft. high carrying large umbels of red flowers, is common on the margin of the scrub, and is of sufficiently dense growth to impede progress. *L. antipodum* is a rather smaller species of similar habit, but with the leaves finely divided. The genus *Pleurophyllum* is restricted to these islands, and contains three grand species—*P. speciosum*, the leaves of which form a flat rosette, 3ft. to 4ft. in diameter, from the centre of which rise several stems 1½ft. to 2½ft. high, carrying numerous pedunculate, rayed flower-heads, 1½in. in diameter, with whitish rays and deep rich purple centres. The leaves are grooved longitudinally, and lie perfectly flat: the effect is unique, and, as the plant often covers acres, approaches the magnificent. As the traveller walks amongst them his feet crash through the horizontal leaves as though he were walking on thin ice: *P. criniferum* is of a very different habit; the leaves are usually petioled, and from 1½ft. to 3ft. in length, sub-erect, and spreading, forming a ring round the erect scapes, which are from 3ft. to 4ft. high; the flower-heads resembling large velvet-covered buttons of a deep-brown colour, contrasting well with the snow-white tomentum of the scape and peduncles: the third species, which I have named *P. gilliesianum*,* is much smaller; the leaves are from 4in. to 6in. long, and white on both surfaces; the scape rarely exceeds 2ft. in height, and is usually shorter: it is a plant of considerable interest, although not so attractive as the others. *Celmisia vernicosa* is a beautiful plant with densely-crowded rosulate glossy linear leaves, and numerous erect scapes, 3in. to 12in. high, each carrying a large white rayed flower-head, with deep purple centre. *Bulbinella rossii* is a magnificent liliaceous plant, and well deserved its original name of *Chrysobactron;* its erect flowering stems, from 1ft. to 3ft. high, are most densely packed with diœcious flowers of a bright-orange colour. *Vero-*

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* This is now referred by the author to *P. hookerianum*, J. Buchanan. See Trans. N.Z. Inst., xxiii., pp. 432 and 435.

nica benthami, a small dwarf species, with deep glossy-green foliage and flowers of the deepest blue, is plentiful in situations near the sea. *Myosotis capitata* is also to be found with large deep-blue flowers, which rise above its leaves. Lastly may be mentioned the fine gentians, *G. concinna* and *G. cerina*, with glossy leaves, and waxy flowers of white, purple, or reddish-purple, or white with vertical stripes of red. It may safely be asserted that no other islands of such limited area, outside the tropics, can show such an assemblage of endemic floral splendour: not only are the flowers beautiful in themselves, but, with two exceptions only, they are produced in profusion, the plants covering large areas.

But there are other plants the flowers of which, although less attractive, are of great botanical interest. *Stilbocarpa polaris* is a striking plant, and from the attractions of its foliage might fairly have been included in the list of plants of remarkable beauty. It is a monotypic Araliad with radical reniform leaves, sometimes 1½ft. in diameter, and large compact masses of waxy-looking yellowish flowers. It occurs everywhere at low elevations on these islands, and is of a decidedly antarctic type, extending from Macquarie Island northward to Antipodes Island. It is often associated with a large-leaved nettle, *Urtica australis*, but the nettle is restricted to the immediate vicinity of the sea. *Cotula plumosa* and *C. lanata*, two fine species of great interest, are found on cliffs and in situations exposed to the wash of the spray. *Abrotanella spathulata* grows luxuriantly from sea-level to 1,000ft. Some of the specimens collected were fully 4in. high. *Stellaria decipiens*, a prostrate species bearing a close resemblance to the European *Arenaria trinervia*, occurs in low woods near the sea.

The hillsides, where not clothed with bush, were mostly covered with a growth of coarse sedges and grasses, often forming tussocks. Owing to the heavy rainfall, the spaces between the tussocks, not held together by their roots, had been washed away, so that the grasses were in some places higher than a man, rendering it a work of fatigue to travel amongst them. This state of things was characteristic of nearly all sloping surfaces on these islands. On the tops of the hills progress was but little impeded, the surface-growth being low. It was most interesting to see the tussock-scenery of the interior of Canterbury and Otago largely reproduced here by *Danthonia bromoides*, which occurs in several localities near the sea in the North Island, but rarely exceeds 18in. in stature. In the Auckland Islands it forms tussocks as large as those of *D. raoulii* or *D. flavescens*, but much handsomer than either—a fact which is partly due to the leaves being green, not brown. Its apparent absence from the South

Island is remarkable, and not easily explained. Another grass of much closer growth is *Poa foliosa*, which occurs in all these Islands. *Festuca scoparia*, another valuable economic species, is abundant, especially near the sea. *Carex trifida* formed immense tussocks, and in some places is quite as plentiful as the common form of *C. paniculata;* but the paucity of species of Cyperaceæ is remarkable.

About twenty-five species of ferns are found, none of which call for special remark except perhaps *Schizæa australis*, Gaud., which forms compact masses, 3in. to 6in. across, in the swamps. It can only be considered a variety of *S. fistulosus*, Lab.

The short space of time at my disposal prevented any detailed examination of the summits of the hills, as there was only one occasion on which I could travel to any great distance from the steamer. Rocky places on one of the hills near the western extremity of Carnley Harbour afforded several plants of great interest, such as the typical form of *Ranunculus pinguis*, a plant of different appearance from the mountain plant found on the mainland; *Plantago aucklandica, Juncus antarcticus, Rostkovia gracilis, Luzula crinita, Hierochloe brunonis, Agrostis antarctica, Pozoa reniformis, Cardamine stellata*, and *Cyathodes empetrifolia.*

I was fortunate enough to collect the following plants not hitherto recorded as having been found on the islands:—

Ligusticum latifolium, *var.* angustatum. Perhaps a hybrid between *L. latifolium* and *L. antipodum.*

Pleurophyllum gilliesianum, n.s. Carnley Harbour.

Lagenophora forsteri, *DC.* Port Ross, and other places.

Samolus repens, *Pers.* Carnley Harbour.

Rumex neglectus, *T. Kirk.* Port Ross.

Phormium tenax, *Forst.* Port Ross and Carnley Harbour.

Juncus bufonius, *L.* Port Ross.

Deschampsia gracillima, n.s. A charming little species. Carnley Harbour.

Deschampsia hookeri, *T. Kirk.* (Catabrosa antarctica, *Hook. f.*) Port Ross.

Lomaria dura, *Moore.* Abundant on the margins of woods by the sea. Probably the *L. lanceolata* of Hooker's "Flora Antarctica."

Aspidium cystostegia, *Hook.* Carnley Harbour.

Hymenophyllum villosum, *Col.* Amongst moss, &c.

H. polyanthos, *Sw.* Amongst moss.

H. bivalve, *Sw.* Port Ross, &c.

CAMPBELL ISLAND.

Campbell Island was discovered in 1810, and is situate in lat. 52° 33′ and long. 169° 9′. It is irregularly rhomboidal in shape, and very hilly. Its highest point is the conical peak of Mount Honey, which rises to 1,866ft. on the southern side of Perseverance Harbour. Lyall's Pyramid, on the opposite side, is 1,273ft.; Mount Paris and other points are intermediate. The island is about eight miles from east to west, but rather more from north to south, and is almost divided by Perseverance or Christmas Harbour, which opens on the south-east.

Campbell Island consists chiefly of basaltic rocks with a considerable extent of a compact limestone, which in some places is overlaid by the basalt. In one locality an exposed section shows basalt at the base, overlaid by a bed of limestone 3ft. to 4ft. in thickness; this, again, by roughly columnar basalt, which in its turn is also overlaid by limestone capped with peat. I could not determine on a cursory examination whether the basalt was interjected, or whether its position was due to successive eruptions accompanied by subsidence. The greater portion of the island is seamed with gullies of no great depth, and the surface is covered with a layer of peat of variable thickness; swamps are numerous. *Sphagnum* is plentiful on the crests of the ridges and the slopes of the hills.

The vegetation is less varied than that of the Auckland Islands, and is much less luxuriant. The rata (*Metrosideros lucida*), the characteristic tree of those islands, is extremely rare on Campbell Island, and of very low stature. In fact, the ligneous vegetation is limited to four species of *Coprosma*—*C. fœtidissima*, *C. cuneata*, *C. parviflora*, *C. ciliata*—and *Myrsine divaricata*, which form the bulk of the scrub, with occasional specimens of *Dracophyllum longifolium* and *D. urvilleanum*, *Cassinia vauvilliersii*, and *Veronica elliptica;* the two last, together with the true *Dracophyllum scoparium*, being found only in open places. Usually the twiggy Coprosmas were so interlaced with *Myrsine divaricata* that the scrub was almost impassable, especially on sheltered slopes. *Panax simplex*, which formed a large portion of the woody vegetation on the Auckland Islands, has not been observed on Campbell Island.

All through the island the ligneous vegetation presents a starved and stunted appearance, except in a few sheltered positions. It ceases at low altitudes, in many places not rising above 100ft.; the highest point at which I found it troublesome was under 600ft.; but in all cases it was succeeded by a coarse growth of sedges and grasses of the same general character as that on the Auckland Islands, although less luxuriant except amongst rocks or in other sheltered positions.

The *Sphagnum* swamps on the ridges are often dotted with the dark green of *Phyllachne clavigera* and *Oreobolus pumilio*, Br. In still moister places *Centrolepis pallida* is plentiful, with large masses of *Rostkovia gracilis* and *Astelia linearis*. The endemic *Abrotanella rosulata* occurred sparingly on exposed rocks, but was not observed below 1,000ft. The small-flowered *Pleurophyllum*, with leafless scapes—*P. gilliesianum*—was not unfrequent, and ascended to 800ft.: it appears to be more plentiful than on the Auckland Islands.

The stunted appearance of the ligneous vegetation at low elevations was relieved by most luxuriant specimens of *Ligusticum latifolium*: the large umbels of red flowers and fruit combined with its bold foliage to produce an effect altogether unique amongst New Zealand plants. *L. antipodum* was frequent, as were most of the showy plants of the Auckland Islands: *Stilbocarpa polaris*, *Bulbinella rossii*, *Celmisia vernicosa*, *Myosotis capitata*, *Veronica benthami*, *Pleurophyllum criniferum*, and especially *P. speciosum*. The Campbell Island form of *P. speciosum* shows several points of difference from the Auckland Island plant: the leaves are larger, rather narrower, and usually more or less erect, while they are invariably clothed with jointed or moniliform hairs mixed with the straight tomentum—a character which is rare or entirely absent on the Auckland Island form: the scapes are usually longer, and the flower-head larger, but in these matters there is great variation: the ligulate corollas are of a deep-purple colour, affording a strong contrast with the impure whitish corollas of the Auckland Island plant. It is noteworthy that these differences, although of a trivial character, have proved constant under cultivation during ten years.

In addition to the above, some plants of special interest must be mentioned. *Colobanthus benthami* was collected in two localities on the hills, and *C. muscoides* was common on rocks by the sea. *Ranunculus pinguis* and *Azorella reniformis* were found on dripping rocks, and, like most of the herbaceous plants, exhibited great luxuriance. On the lower slopes of Mount Honey, Mr. F. R. Chapman, Mr. M. Chapman, and myself collected a few plants of a new *Celmisia* closely related to *C. vernicosa*, but with the leaves from ½in. to ⅔in. broad, traversed by several closely parallel nerves: the bracts of the scape are close-set, and the flower-head is similar to that of *C. vernicosa*, but larger. Fewer than a dozen plants, some of which were seedlings, were found, and the whole were restricted to a space less than 300ft. square. It appears to be a robust broad-leaved form of *C. vernicosa*, from which it has doubtless originated within a very recent period indeed, but is evidently able to perpetuate itself. I failed to observe the noble *C. verbascifolia*, of which specimens were collected by Dr. Filhol and Lieutenant Rathoins, of the 'Vire,' so that like other plants on the island it is probably local; but my explorations were limited to a very small portion of its area.

A noticeable instance of this restricted localisation is exhibited by the *Dracophyllum scoparium* figured by Hooker in "Flora Antarctica;" it appears to be confined to a single spot in Perseverance Harbour, and differs widely from the plant to which the name is applied in other parts of New Zealand. It is a compact plant of fastigiate conical habit exactly resembling that of *Cupressus sempervirens*, and quite unlike that of any other species. The plant to which the name is commonly applied was observed on the opposite side of the harbour, and is frequent throughout the colony; botanists are generally agreed in considering it to be a variety of *D. urvilleanum*.

The beautiful gentians of the Auckland Islands are represented by two small forms, which are referred to *G. concinna* by Hooker, one of which is remarkable for its robust stems, and approaches *G. antipoda*, of Antipodes Island.

The ferns and Lycopodiaceæ of Campbell Island are few in number, not more than fifteen species having been noticed, most of which are common throughout the colony, the exceptions being *Lomaria dura*, which is a purely southern species, and the subalpine *Hypolepis millefolium*, which here descends to the sea-level. An undetermined *Hymenophyllum* may possibly prove new: its fronds rarely exceed 1in. in length, and are usually less; the habit closely resembles that of *H. villosum* or *H. polyanthos* when growing amongst moss in exposed places: the rhizomes, however, are densely clothed with short, stiff, imbricating, chaffy scales, differing from those of any other New Zealand species. Unfortunately no capsules were observed.

Mosses are plentiful on the island, but Hepaticæ are less prominent than on the Auckland Islands. A few undescribed Fungi were collected, some of which are of considerable interest.

Only two or three naturalised plants were noticed, although, doubtless, more would be obtained on careful search. Some years back the Maoris of Stewart Island obtained *Calluna vulgaris* on Campbell Island: at least a dozen plants were taken to Stewart Island during seven or eight years. I first saw the plant growing in the garden of the late Mrs. Wesley, a Stewart Island Native, the only Maori known to me who cultivated native plants, of which she had a good collection. She assured me her husband had brought it from Campbell Island when on a sealing expedition. Other plants obtained from the same locality at different periods are still growing in the garden of Mr. C. Traill, of Ulva, and Mr. A. W. Traill, of the Renga. I failed to find the plant, but of the fact of its having occurred on Campbell Island I am unable to entertain the slightest doubt, although by what agency it was established it is impossible to guess.

The total number of species of Phanerogams in the Auckland and Campbell Islands is 112; of ferns, &c., 25.

Considering the flowering plants alone with regard to their New Zealand distribution, they may be classed as under :—

	Species.
Endemic in the Auckland and Campbell Islands ...	30
Extending to the South Island of New Zealand only	27
Extending to both North and South Islands, including naturalised	55
	112

With the exception of *Lomaria dura* and the supposed new species of *Hymenophyllum*, all the ferns are common in both the North and South Islands.

MACQUARIE ISLAND.

Macquarie Island is in 54° 35′ S. lat. and 159° 3′ 45″ E. long. It is nearly twenty miles long and five miles in breadth, and is for the most part hilly; but the hills nowhere rise to more than 800ft. A few plants from this island were sent by Mr. C. Fraser, when Superintendent of the Botanic Gardens at Sydney, to the Kew Herbarium. These were—

Acæna sanguisorbæ, *Vahl.*
„ adscendens, *Vahl.*
Pleurophyllum criniferum, *Hook. f.*
Cotula plumosa, *Hook. f.*
Azorella selago, *Hook. f.*
Luzula crinita, *Hook. f.*
Poa foliosa, *Hook. f.*

Nothing further was learned respecting the botany of this island until Professor J. H. Scott, of Dunedin, visited it in 1880, when he published an excellent account of the fauna and flora in the "Transactions of the New Zealand Institute,"* giving a catalogue of the plants observed by him. He very kindly allowed me to examine his collection before the plants had been identified, when I made a rough list of the species, which differs slightly from that given by him, and is as follows :—

RANUNCULACEÆ.

Ranunculus aucklandicus, *A. Gray.*

This was destitute of flowers, and is the *R. acaulis* of Professor Scott's list.

CARYOPHYLLEÆ.

Colobanthus muscoides, *Hook f.*

Stellaria elatinoides, *Hook. f.*

A small scrap, but unmistakable. Omitted by Professor Scott.

* Trans. N.Z. Inst., vol. xv., p. 484.

ROSACEÆ.

Acæna sanguisorbæ, *Vahl.*
Not in flower; the *A. buchanani* (?) of Professor Scott.
Acæna adscendens, *Vahl.*

CRASSULACEÆ.

Tillæa moschata, *A. DC.*
This is the *T. sinclairii* of Professor Scott.

UMBELLIFERÆ.

Azorella selago, *Hook. f.*
„ lycopodioides, *Hook. f.* (?)
Professor Scott remarks: "Grows in small masses. It has often become confused with *Colobanthus subulatus*; and, as my specimen has neither similar flowers nor fruit, it is named with some diffidence." I did not see anything resembling this plant in the collection. Possibly a form of *C. muscoides* with longer leaves than usual was mistaken for it.

ARALIACEÆ.

Stilbocarpa polaris, *Hook. f.*

RUBIACEÆ.

Coprosma repens, *Hook. f.*

COMPOSITÆ.

Pleurophyllum criniferum, *Hook. f.*
„ gilliesianum, *T. Kirk.*
I did not see the former in Professor Scott's collection; but it is very likely to occur on the island. The latter is omitted from his list.
Cotula plumosa, *Hook. f.*

JUNCEÆ.

Luzula campestris, *A. DC.*
„ crinita, *Hook. f.*

GRAMINEÆ.

Poa foliosa, *Hook. f.*
„ annua, *L.* Naturalised.
Festuca duriuscula, *L.*

FILICES.

Lomaria alpina, *Sprengel.*
Polypodium australe, *Mittenius.*
Aspidium aculeatum, *Sw.*, *var.* vestitum.

ANTIPODES ISLAND.

Antipodes Island is situate in 49° 41′ S. latitude and 178° 43′ E. longitude. It was discovered in the year 1800, but up to the present time nothing has been known of its fauna or flora. The island is somewhat the shape of a ham, its greatest length being two miles and a half from east to west: the eastern extremity, corresponding to the shank of the ham, appears to have been formed by a narrow lava-stream; its greatest width is about a mile and a half from north to south. The island is simply the crater of an extinct volcano, and would be roughly circular in shape were it not for the lava-stream which has been already mentioned. The cliffs are very steep and rugged, rendering the island almost inaccessible except at the north-east corner, where a landing can be effected only in the finest weather. A small stream flows into the sea on this side, and another on the north-west.

The crateriform portion of the island is surrounded by low rounded hills on three sides, broken, however, by the depression formed by the stream which reaches the sea on the north-west side: a small well-defined crater is still visible amongst the hills on the south side, but from want of time I was unable to examine it. Mount Galloway, on the western side of the island, is a bold round-topped hill, and forms the highest point, attaining an altitude of 1,320ft., as determined by Captain Fairchild.

It is not quite certain whether the whole island is volcanic. Some distance from the landing-place I noticed what appeared to be a mass of finely-bedded reddish sandstone, but could not get near enough to determine its precise nature. Most of the rocks observed were basaltic.

Large portions of the interior of the crater are swampy, and the vegetation consists chiefly of coarse sedges and grasses, amongst which numerous small herbs are concealed. There is an almost total absence of ligneous vegetation, the only woody plants being three species of *Coprosma*, two of which are prostrate or nearly so, and the largest, which is confined to the vicinity of Mount Galloway, rarely exceeds the stature of a low-growing bush. Altogether, as seen on a dull day, the island presents a most desolate and unattractive appearance.

In many places this dulness was relieved by the albatross (*Diomedea exulans*), whose nests were dotted over a large part of the island. Some young dark-coloured birds, with down still remaining on the neck and wings, were observed sitting on or constructing nests, but, so far as I observed, only one of these nests contained an egg: in all instances the truncated mound of earth forming the nest was roughly made, loose, and somewhat smaller, presenting a untidy appearance, which formed a remarkable contrast to the nests of the adult birds by which they were surrounded. Sea-hawks were numerous, and constantly on the look-out for unguarded eggs. The small yellow-headed paroquet (*Platycercus novæ-zelandiæ*) was somewhat numerous amongst the *Coprosma* scrub; and a small snipe, probably *Gallinago pusilla*, was not infrequent on the south-eastern portion of the island.

To return to the vegetation: The mass of sedges and grasses was slightly relieved in many places by the large leaves and flower-masses of *Stilbocarpa polaris*, and by a handsome *Senecio*, new to science: although herbaceous, it is of robust growth, and forms large spreading bushes, with fistulose stems, the thickness of a man's finger, and terminal corymbs of yellow, rayless flower-heads. It is related to *S. candicans*, DC., of the Falkland Islands, but the leaves are sessile and much divided: it appears to be of easy cultivation. A curious and pretty gentian (also new to science) was plentiful; it formed rather close masses, sometimes over 1ft. in diameter, of erect stems, procumbent at their base, and from 3in. to 10in. high. The stems and leaves were either of pale-yellow or reddish-purple, with solitary axillary flowers, those on the plants with yellow stems being white, and those on the others being purple vertically streaked with red, the result in each case being that the flowers, notwithstanding their abundance, are not observed until the plant is somewhat closely examined. It is allied to *G. concinna* of the Auckland Islands. *Colobanthus muscoides* was observed on the cliffs, exhibiting a considerable extension of its range eastward. A remarkable form of *Stellaria decipiens*, with the leaves much smaller and capsules much larger than the typical form on the Auckland Islands, was found growing over deserted nests of the albatross. *Ligusticum antipodum* was abundant, although everywhere past flowering, and exhibits a considerable extension of its southern and eastern range. The same may be stated of *Pleurophyllum criniferum*, which was fully as luxuriant as on the Auckland and Campbell Islands. A dwarf nettle with large leaves (*Urtica australis*), of considerable stinging-power, was plentiful, chiefly on the eastern side. It is stated on the authority of Bidwill to occur in the southern extremity of the North Island, but has not been collected of late years in any part of the North or South Island. It now appears to be confined to the Chatham Islands, islands in Foveaux Strait, Antipodes Island, the Auckland Islands, and Campbell Island. Another plant of considerable interest is *Deschampsia hookeri*, a form of the *Catabrosa antarctica* of Campbell Island. The typical form of *Carex paniculata* formed immense tussocks on the north side of the island, and could not be distinguished from the British form: the ordinary New Zealand form, *C. appressa,* was plentiful. About a dozen ferns were collected, but none of them call for special notice here.

The fifty-five species of Phanerogams and ferns in the following list represent nineteen orders — say, 2·8 species for each order—which will allow for the naturalised. This is an exceptionally low average, even for a New Zealand district; especially when it is remembered that the Compositæ, Cyperaceæ, Gramineæ, and Filices comprise over one-half of the total species.

Grouped according to their distribution in New Zealand only, we have the following arrangement:—

Endemic on Antipodes Island	2
Antipodes and other Antarctic Islands ...	9
Antipodes, Antarctic, and Foveaux Strait ...	3
Antipodes, Antarctic, and South Island ...	2
Antipodes, North and South Islands ...	37
Naturalised	2
	55

It must, of course, be understood that this catalogue cannot be considered exhaustive, although it is not probable that any large additions will be made.

Antipodes Island.

Stellaria decipiens, *Hook. f.*
„ *var.* media, *L.* *Naturalised.*
Colobanthus billardieri, *Fenzl.*
„ muscoides, *Hook. f.*
Montia fontana, *L.*
Acæna sanguisorbæ, *Vahl.*
Tillæa moschata, *DC.*
Callitriche verna, *L.*
Epilobium confertifolium, *Hook. f.*
„ alsinoides, *A. Cunn.*
„ linnæoides, *Hook. f.*
Apium australe, *Thouars.*
Ligusticum antipodum, *Hook. f.*
Stilbocarpa polaris, *Decaisne.*
Coprosma ciliata, *Hook. f.*
„ cuneata, *Hook. f.*
„ repens, *Hook. f.*
Pleurophyllum criniferum, *Hook. f.*
Lagenophora forsteri, *DC.*
Cotula plumosa, *Hook. f.*
Gnaphalium bellidioides, *Forst.*
Senecio antipoda, *n.s.*

Sonchus asper, *Vill.*
Pratia angulata, *Hook. f.*, *var.* arenaria.
Gentiana antipoda, *n.s.*
Urtica australis, *Hook. f.*
Corysanthes (?).
Prasophyllum colensoi, *Hook. f.*
Chiloglottis bifolia.
  „ cornuta, *Hook. f.*
Juncus scheuzerioides, *Gaud.*
Luzula crinita, *Hook. f.*
Scirpus cernuus, *Vahl.*
Uncinia rupestris, *Raoul.*
Carex paniculata, *L.*
  „ ternaria, *Forst.*
  „ trifida, *Car.*
Agrostis antarctica, *Hook. f.*
Deschampsia hookeri, *T. Kirk.* (Catabrosa antarctica, *Hook. f.*)
Poa foliosa, *Hook. f.*
  „ anceps, *Forst.*
  „ annua, *L.* *Naturalised.*
Festuca scoparia, *Hook. f.*

Hymenophyllum multifidum, *Sw.*
Hypolepis millefolium, *Hook. f.*
Pteris incisa, *Thunb.*
Lomaria dura, *Moore.*
  „ capensis, *Willd.*
  „ alpina, *Spreng.*
Asplenium obtusatum, *Forst.*
  „ bulbiferum, *Forst.*
Aspidium aculeatum, *Swn.*, *var.* vestitum.
Polypodium australe, *Mitt.*

Lycopodium fastigiatum, *R.Br.*
  „ varium, *R.Br.*

THE BOUNTY ISLANDS.

These consists of numerous islets frequented by penguins, which occur in vast numbers. The rocky surface is totally destitute of all vegetation except a minute green Alga, which occurs on undisturbed avian rejectamenta.

Section E.

(GEOGRAPHY.)

President of the Section—G. S. Griffiths, F.G.S., F.R.G.S., Melbourne.

ADDRESS BY THE PRESIDENT.

In these days, when the great geographical societies of the world issue at short intervals the records of the progress of discovery, and when this information is digested, criticized, and disseminated promptly by a vigilant Press, it is not necessary to recapitulate all the events of the year in the annual addresses delivered to this section. Therefore I shall confine my remarks to such matters of theory or accomplished work as relate to the Australasian region.

On the Australian Continent very little new ground has been broken. The general features of the greater part of the area have long been known, and the surveyors of the back blocks of the several colonies are now slowly filling in the details, which for the most part consist of nothing more sensational than the plotting-down of the courses of insignificant creeks, and the fixing of the positions of the low ranges through which they meander.

On the north-west coast, however, Mr. Alexander McPhee has entered an unexplored region, by travelling inland eastwards from Lagrange Bay. Having made his way for two hundred and forty miles over undulating but badly-watered and lightly-timbered country, he fell in with a camp of blacks, who informed him that in a locality that was two hundred miles further to the south-eastwards there was a tribe which had in its possession a tomahawk, obtained many years before from a party which perished while endeavouring to cross to the west coast. This party was described as consisting of about five persons, two of the number being whites. The Victorian branch of the Royal Geographical Society of Australasia, on learning this news, decided that it would be well to explore the whole region from Lagrange Bay to Lake Macdonald, the more so as Baron von Mueller thought that the persons who perished there might have been a remnant of Leichardt's band. It therefore offered Mr. McPhee £500 to undertake the work; but that gentleman thought that the sum named was insufficient, and the society, having no more funds available for the purpose, has reluctantly abandoned the task for this season.

In March last Mr. Tietkins, F.R.G.S., described an expedition led by himself, which, starting from the overland-telegraph line at Alice Springs, travelled due west for about three hundred and ninety miles. He discovered a salt lake about a hundred square miles in area, which lies directly under the Tropic of Capricorn, and close to the West and South Australian borders. This sheet of water has since been christened Lake Macdonald.

The surrounding country is chiefly a *Spinifex* desert ridged with long, low, flat-topped ranges of red sandstone. From their appearance it is probable that these ranges are the remnants of a sandy Cretaceo-tertiary lake-bed, whose surface, once continuous, is now broken up by the drainage-basins scooped out of it as the waters flowed away to lower levels.

The course of the principal river—the Finke—runs transverse to these ranges, cutting directly through them in deep narrow chasms, and this probably indicates that the present drainage-system is older than the mountain-features of the country. And if the American geologists are justified in their theory that the bed of the Great Salt Lake of Utah was flexed or arched upwards into low hills as it was relieved of the weight of water which once rested upon it, we too may speculate upon similar changes of level having occurred hereabouts to create a synclinorium, or broad regional uplift, in an area which at a still more remote period was the most depressed part of a vast lake-basin. The past history of this part of Australia when it is traced out should shed some additional light upon the interesting subject of the oscillations of the earth's surface, so exhaustively treated of last year by Professor Hutton.

The discovery in the same region of an underground river recently reported by Mr. Brown, Government Geologist, is a fresh indication that the aridity of the region is a modern condition, for it is not easily conceivable that the present rainfall of between 2in. and 10in. per annum could flush the rocks with subterranean waters in quantity copious enough to perforate the limestone rocks with passages which are large enough to rival the Jenolan Caves, or those recently discovered at Waitomo, in New Zealand.

The beautiful map of this region which has been engraved by Stanford for the Royal Geographical Society of Australia is a valuable addition in the cartography of this country. Mr. Tietkins after discovering Lake Macdonald turned back to

Lake Amadeus, and he has fixed the position of its western margin, reducing the size of the lake to one-fourth of the area assigned to it provisionally in the earlier maps.

In New Guinea the energetic enterprise of Sir William Macgregor is rapidly increasing our acquaintance with the river-system and the highlands of the British territory, and with the products of the various zones. His botanical collections, as determined by Baron von Mueller since we last met, show an extraordinary commingling of genera upon such portions of the mountains as lie above the altitude of 11,000ft. In this alpine region he has found representatives of Scandinavian, Himalayan, Bornean, and Antarctic floras. The collocation of these forms upon such isolated peaks, cut off as they now are from their congeners by the tropical climate which invests the bases of the mountains on which they live, adds to the data already accumulated in support of the hypothesis of climatic changes in past epochs.

The torrential character of the rivers is indicated by the fact that, whilst the sources of many of them are situated no further from their mouths than seventy miles as the crow flies, yet they have a fall which is often 13,000ft. As the last part of their courses is through flat swampy land, in parts many miles across, the steepness of the grade is striking. The erosive power of such streams is enormous, and it has fringed the south-eastern end of the island with vast deltas hardly rising above sea-level. These are built up of coarse conglomerates beneath and of fat alluvial soils above, through the jungle-covered surface of which the streams wander to the coast.

The main ranges consist of schists and slates, traversed by numerous quartz-veins, mostly barren of gold. The age of these rocks is reported to be Silurian. The foothills are largely composed of conglomerates, once continuous round the ranges, but now broken up by erosion into isolated raised patches. Volcanic rocks are distributed plentifully in the river-beds, but the vents from which they have been derived have not yet been discovered.

The smaller and more distant islands which dot the Pacific have not been neglected during the period under review, for Mr. C. M. Woodford has returned from his third visit to the Solomon Islands, bringing with him the materials for a work upon the physical features and the fauna and flora, which should be a valuable supplement to Mr. Guppy's recent volumes. Mr. Lindt has also spent some months on the New Hebrides, and brings back with him a series of photographic views of the people and their villages, together with others of the volcanoes, the forest vegetation, the coral-girt shores, and the fishing fleets, which have a considerable value.

There is an important work proceeding in the interior of Australia, which, although undertaken for purely utilitarian purposes, will yield data of considerable scientific interest if the records be carefully kept. I refer to the artesian wells which are being sunk on the back blocks from the centre of Queensland down towards the mouth of the Murray. Urged to great efforts by the disastrous effects of frequent droughts, the squatters are boring in all directions, and with gratifying results in a large number of instances. Step by step the boring-rod tracks out the flow of those great underground streams; and if the Government departments in the several colonies will chart down the data obtained from every bore, whether water be tapped or not, with the depths, and the strata passed through, we shall soon have a mass of valuable material out of which a new geographical feature can be elaborated and added to our maps — namely, the subterranean drainage of the continent, its principal sources, its extension in streams or shoots, its depth from the surface at different points, and any variation that there may be in its volume from year to year.

The chief sources of these water-supplies must be looked for in the great eastern cordillera, which sheds the surface-streams that also cross Riverina. Along its crests the rainfall is of course greatest, being from 20in. to 40in. per annum in the Queensland portion; and it is near to the long ribbon-shaped region of heaviest rainfall—that is, along the sides of the watershed—that the superficial deposits, being largely composed of gravel and rock *débris*, are most pervious. Further, the continuity of the strata of the plains is broken at the hill-foot, where they die out against the outcropping rocks of the main range, and this line of break affords to the water flowing down the hills a ready passage beneath the sediments of the plains.

Under these circumstances a large proportion of the rain caught on the ranges leaks under the subsoil directly it falls, and it flows to the sea slowly indeed, but with its volume undiminished either by the evaporation which lowers the surface-waters of the Riverina 6ft. per annum, or by the demands of vegetation, which are much greater upon river water than the public has any idea of.

As these subterranean waters travel away from their sources they must thin out. Mr. H. G. McKinney, C.E., of the New South Wales Water Commission, estimates that at a distance of a hundred miles from the hills they will have so outspread that the quantity from any one bore would be too small to warrant the expenditure for irrigation purposes. But it appears to me that in every district of any size there must be deeper channels in that ancient land-surface which is now the bed-rock or reef of the miner. These channels are levelled up and masked by the porous and more or less saturated sedimentary beds which compose the undulating surface of the plains. In these leads or channels more copious supplies must have collected, and these will drain away in the direction in which the country falls, which is towards the south-west.

These underground watercourses, or, as the miners would describe them, these wet leads, will run out into the plains for greater distances than a hundred miles. Indeed, when we remember that the streams are undiminished by evaporation or the demands of vegetation, and that they have been the recipients of all the leakage of the hills throughout all the ages that have passed since the sea retired, it appears to me that the deeper leads must be saturated with water right from the mountain-foot to the Australian Bight. For, however slow the circulation of the system may be, as the water has never ceased to run in at the upper ends of the region, and as it does not rise to the surface as springs, it must run out at the lower end into the sea, escaping in the form of submarine springs. As a matter of fact, along the south coast of Australia between Warrnambool and the Murray mouth the sea literally bubbles up with fresh water which has leaked up through the sea-sands. These subterranean streams will be worth tracing, and worth tapping, across the wide dry plains. Mr. McKinney's paper on the rivers of New South Wales, which was contributed to this section in 1888, bears directly on this subject, and is well worthy of consultation in this connection.

I may remind you that the French have ascertained that the terrible Desert of Sahara is underlain by saturated sands, and by means of artesian wells they are creating, artificially, oases in the hungry sandhills, and in this way cultivated fields are steadily invading one of the most sterile districts of the earth. The same result can be effected upon the dry interior plains of Australia. But it will be necessary to record every bore that is put down, to fix the position on the map of the dry as well as of the wet ones, and to note the formations in which the water occurs, and the depths at which it is tapped. In this way we shall gradually acquire an acquaintance with the underground circulation of the continent of great economic as well as scientific value, and we shall add a fresh feature to the geography of Australia.

There is another direction in which work ought to be done; but in this case the onus must rest on New Zealand. Your glaciers require to be systematically gauged as to their lengths, as indicated by their terminal moraines, as well as to their volumes, and rates of motion. And not your glaciers only, but also your mountain-lakes. For both glaciers and lakes are measures of the annual or periodic fluctuations in the temperature of the earth. Large questions connected with the climate of the world are being worked out from such data as I have indicated; but these are, thus far, mainly obtained from the Northern Hemisphere. Similar data from this distant outpost in the Southern Hemisphere would therefore be of great value.

We desire to know if the earth's climate in the present epoch is constant, or, if it be varying, whether it is advancing towards a hotter or colder, a wetter or drier, condition of things. That in the past there have been great secular changes is well established. We have but to examine the drainage-lines of the interior of Australia to learn that they have become dried up in Post-tertiary times; that pasturages have become deserts, and deserts still more desiccated. We now want to know whether this is to go on further or not. Are we in a meteorologically stationary period? Has the climate become fixed for a time? These are interesting questions, and if we can seize on any evidences that, by careful watching, may yield a clue to the answer we ought to grasp the chance.

Now, in the thermometer we have a measure of the minute momentary fluctuations in temperature; in the annual rise and fall of the waters of the mountain-lakes we have a guide to the climate of a season; but in a glacier we have a clue to changes in temperature and precipitation which have operated over longer periods.

Freshfield has reported that the glaciers of the Old World have been advancing for the past five years. For twenty years before that, those of the European Alps were noted to have shrunken. Those of Mexico are said to be diminishing still. Brücker has investigated the weather reports of six hundred stations scattered throughout the globe,—reports spread over a period of many years,—and his conclusion is that there are slow cosmical fluctuations in temperature and rainfall; but he requires still more data to determine whether the climate of the epoch is changing.

I think that I have shown good cause why you should observe these phenomena in New Zealand, and thus contribute new and material facts to the science of geography.

Turning from the past to the coming year, I would desire to remind you that, through the munificence of Sir Thomas Elder, of South Australia, we hope to complete the exploration of Australia during the next twelve months. This gentleman has asked the Geographical Society to formulate a scheme to effect this purpose, and he undertakes to defray its entire cost. Such enlightened liberality deserves to be crowned with success, and I am sure that the enterprise will have your good wishes.

I would now ask you to give me your further attention while I dwell somewhat more fully upon a very important topic—that of Antarctic Exploration.

It is now about four years since Baron von Mueller, in his annual address to the Geographical Society, pointed to the South Polar regions as a neglected field for research. Shortly afterwards I followed up this suggestion with an address upon the same subject; and in June, 1886, an Antarctic Exploration Committee was formed in Melbourne. Through the exertions of this body, information bearing upon the subject has been accumulated. Whalers have been urged to try these seas. The public mind has been gradually educated, and at last its ear has been in some measure secured. These efforts in Australia have aroused attention in Europe and America, and the labour of four years promises to yield fruit at last. For not only has a British shipowner opened negotiations with the Tasmanian Government for the lease of Macquarie Island as a whaling-station and base of operations in the South Polar seas, but we have received from Baron Nordenskiöld, the great polar traveller, an offer to explore the Antarctic.

If Australasia will contribute £5,000, Baron Oscar Dickson will find all the rest of the funds required, and the expedition will be despatched from Stockholm shortly under the supreme command of Nordenskiöld. On getting this noble offer, we in Melbourne started at once to raise the sum asked of us; and, while engaged upon the task, we have heard by telegram from London that Sir Thomas Elder has, for the second time within a few months, shown his enlightened liberality towards science by offering to subscribe the entire £5,000 himself, on certain proper and well-considered conditions. We therefore are justified in believing that this year will see this great expedition starting from the shores of Australia to trace the ice-skirted borders of the mysterious continent that lies abandoned to frost and ice about one week's steaming from our wharves; and I have thought this occasion to be a suitable one for me to remind you of some of the objects that are to be gained by disturbing its solitudes.

My experience during the four years which have elapsed since this project was first mooted in Melbourne is that any reference to the subject is sure to be met with the query, *Cui bono?* What good can it do? What benefit can come from it? What is the object to be served by such an expedition?

In setting myself to the task of answering these questions, let me observe that it would indeed be strange if an unexplored region, eight million square miles in area—twice the size of Europe—and grouped around the axis of rotation and the magnetic pole, could fail to yield to investigators some novel and valuable information. But when we notice that the circle is engirdled without by peculiar physical conditions, which must be correlated to special physical conditions within, speculation is exchanged for a confident belief that an adequate reward must await the skilled explorer. The expected additions to the geography of the region are, of all the knowledge that is to be sought for there, the least valuable. Where so many of the physical features of the country—the hills, the valleys, and the drainage-lines—have been buried beneath the snow of ages, a naked outline, a bare skeleton of a map, is the utmost that can be delineated. Still, even such knowledge as this has a distinct value; and, as it can be acquired by the explorers as they proceed about their more important researches, its relatively small value ought not to be admitted as a complete objection to any enterprise which has other objects of importance. Our present acquaintance with the geography of the region is excessively limited. Ross just viewed the coasts of Victoria Land between 163° E. and 160° W. long.; he trod its barren strand twice, but on each occasion for a few minutes only. From the adjacent gulf he measured the heights of its volcanoes; and from its offing he sketched the walls of its icy barrier. Wilkes traced on our map a shore-line from 97° E. to 167° E. long., and he backed it up with a range of mountains; but he landed nowhere. Subsequently Ross sailed over the site assigned to part of this land, and hove his lead 600 fathoms deep where Wilkes had drawn a mountain. He tells us that the weather was so very clear that had high land been within seventy miles of that position he must have seen it (Ross's Voyage, vol. i., p. 278). More recently, Nares, in the "Challenger," tested another part of Wilkes's coast-line, and with a like result; and these circumstances throw doubts upon the value of his reported discoveries. D'Urville subsequently followed a bold shore for a distance of about three hundred miles from 136° E. to 142° E. long.; whilst in 67° S. lat. and between 45° E. and 60° E. long. are Enderby's and Kemp's lands. Again, there is land to the south of the Horn which trends from 45° to 75° S. lat. These few discontinuous coast-lines comprise all our scanty knowledge of the Antarctic land. It will be seen from these facts that the principal geographical problem awaiting solution in these regions is the interconnection of these scattered shores. The question is, Do they constitute parts of a continent, or are they, like the coast of Greenland, portions of an archipelago, smothered under an overload of frozen snow, which conceals their insularity? Ross inclined to the latter view; and he believed that a wide channel leading towards the Pole existed between North Cape and the Balleny Islands (Ross's Voyage, vol. i., p. 221). This view was also held by the late Sir Wyville Thomson. A series of careful observations upon the local currents might throw some light upon these questions. Ross notes several such in his log. Off Possession Island a current running southward took the ships to windward (Ross's Voyage, vol. i., p. 195). Off Coulman Island another drifted them in the same direction at the rate of eighteen miles a day (Ross's Voyage, vol. i., p. 204). A three-quarter-knot northerly current was felt off the Barrier, and may have issued from beneath some part of it. Such isolated observations are of little value; but were they multiplied, and were the currents correlated with the winds experienced, the information thus obtained might enable us to detect the existence of the straits even where the channels themselves are masked by ice-barriers.

Finally, it is calculated that the centre of the polar ice-cap must be three miles and may be twelve miles deep, and that, the material of this ice mountain being viscous, its base must spread out under the crushing pressure of the weight of its centre. The extrusive movement thus set up is supposed to thrust the ice-cliffs off the land at the rate of a quarter of a mile per annum. These are some of the geographical questions which await settlement.

In the geology of this region we have another subject replete with interest. The lofty volcanoes of Victoria Land must present peculiar features. Nowhere else do fire and frost divide the sway so completely. Ross saw Erebus belching out lava and ashes over the snow and ice which coated its flanks. This circumstance leads us to speculate on the strata that would result from the alternate fall of snow and ashes during long periods and under a low temperature. Volcanoes are built up, as contradistinguished from other mountains, which result from elevation or erosion. They consist of *débris* piled round a vent. Lava and ashes surround the crater in alternate layers. But in this polar region the snow-fall must be taken into account as well as the ash-deposit and the lava-flow. It may be thought that any volcanic ejecta would speedily melt the snow upon which they fell; but this does not by any means necessarily follow. Volcanic ash, the most widespread and most abundant material ejected, falls comparatively cold, cakes, and then forms one of the most effective non-conductors known. When such a layer, a few inches thick, is spread over snow, even molten lava may flow over it without melting the snow beneath. This may seem to be incredible, but it has been observed to occur. In 1828 Lyell saw on the flanks of Etna a glacier sealed up under a crust of lava. Now, the Antarctic is the region of thick-ribbed ice. All exposed surfaces are quickly covered with snow. Snow-falls, ash-falls, and lava-flows must have been heaping themselves up around the craters during unknown ages. What has been the result? Has the viscosity of the ice been modified by the intercalation of beds of rigid lava and of hard-set ash? Does the growing mass tend to pile up, or to settle down and spread out? Is the ice wasted by evaporation, or does the ash-layer preserve it against this mode of dissipation? These interesting questions can be studied round the South Pole, and perhaps nowhere else so well.

Another question of interest, as bearing upon the location of the great Antarctic continent which it is now certain existed in the Secondary period of geologists, is the nature of the rocks upon which the lowest of these lava-beds rest. If they can be discovered, and if they then be found to be sedimentary rocks, such as slates and sandstones, or plutonic rocks, such as granite, they will at once afford us some data to go upon, for the surface exposure of granite signifies that the locality has been part of a continental land sufficiently long for the weathering and removal of the many thousands of feet of sedimentary rocks which of necessity overlie crystalline rocks during their genesis; whilst the presence of sedimentary rocks implies the sometime proximity of a continent, from the surfaces of which alone these sediments, as rainwash, could have been derived.

As ancient slate-rocks have already been discovered in the ice-clad South Georgias, and granite in other islets, and as the drag-nets of the "Erebus" and the "Challenger" have brought up from the beds of these icy seas fragments of sandstones, slates, and granite, as well as the typical blue mud which invariably fringes continental land, there is every reason to expect that such strata will be found.

Wherever the state of the snow will permit the polar mountains should be searched for basaltic dykes, in the hope that masses of specular iron and nickel might be found, similar to those discovered by Nordenskiöld at Ovifak, in North Greenland. The interest taken in these metallic masses arises from the fact that they alone, of all the rocks of the earth, resemble those masses of extra-terrestrial origin which we know as meteorites. Such bodies of unoxidized metal are unknown elsewhere in the mass, and why they are peculiar to the Arctic it is hard to say. Should similar masses be found within the Antarctic a fresh stimulus would be given to speculation. Geologists would have to consider whether the oxidized strata of the earth's crust thin out at the Poles; whether in such a case the thinning is due to severe local erosion, or to the protection against oxygen afforded to the surface of the polar regions by their ice-caps, or to what other cause. Such discoveries would add something to our knowledge of the materials of the interior of our globe and their relation to those of meteorites.

Still looking for fresh knowledge in the same direction, a series of pendulum observations should be taken at points as near as possible to the Pole. Within the Arctic Circle the pendulum makes about 240 more vibrations per day than it does at the equator. The vibrations increase in number there because the force of gravity at the earth's surface is more intense in that area, and this, again, is believed to be due to the oblateness of that part of the earth's figure; but it might be caused by the bodily approach to the surface at the Poles of the masses of dense ultra-basic rocks just referred to. Thus, pendulum experiments may reveal to us the earth's figure, and a series of such observations recorded, from such a vast and untried area, must yield important data for the physicist to work up. We should probably learn from such investigations whether the earth's figure is as much flattened at the Antarctic as it is known to be at the Arctic.

We now know that in the past the North Polar regions have enjoyed a temperate climate more than once. Abundant seams of Palæozoic coal, large deposits of fossiliferous Jurassic rocks, and extensive Eocene beds, containing the remains of evergreen and deciduous trees and flowering plants, occur far within the Arctic Circle. This circumstance leads us to wonder whether the corresponding southern latitudes have ever experienced similar climatic vicissitudes. Conclusive evidence on this point it is difficult to get, but competent biologists who have examined the floras and faunas of South Africa and Australia, of New Zealand, South America, and the isolated islets of the Southern Ocean, find features which absolutely involve the existence of an extensive Antarctic land—a land which must have been clothed with a varied vegetation, and have been alive with beasts, birds, and insects. As it also had its fresh-water fishes, it must have had its rivers flowing and not frost-bound, and in those circumstances we again see indications of a modified Antarctic climate.

Let us briefly consider some of the evidence for the existence of this continent. We are told by Professor Hutton that 44 per cent. of the New Zealand flora is of Antarctic origin. The Auckland, Campbell, and Macquarie Islands all support Antarctic plants, some of which appear never to have reached New Zealand. New Zealand and South America have three flowering plants in common, also two fresh-water fishes, five seaweeds, three marine crustaceans, one marine mollusc, and one marine fish. Similarly, New Zealand and Africa have certain common forms, and the floras and faunas of the Kerguelen, the Crozets, and the Marion Islands are almost identical, although in each case the islands are very small and very isolated from each other, and from the rest of the world. Tristan d'Acunha has fifty-eight species of marine Mollusca, of which number thirteen are also found in South America, six or seven in New Zealand, and four in South Africa (Hutton's "Origin of New Zealand Flora and Fauna"). Temperate South America has seventy-four genera of plants in common with New Zealand, and eleven of its species are identical (Wallace's "Island Life"). Penguins of the genus *Eudyptes* are common to South America and Australia (Wallace: "Distribution of Animals," vol. i., p. 399). Three groups of fresh-water fishes are entirely confined to these two regions. *Aphritis*, a fresh-water genus, has one species in Tasmania and two in Patagonia. Another small group of fishes known as the Haplochitonidæ inhabit Tierra del Fuego, the Falklands, and South Australia, and are not found elsewhere; while the genus *Galaxias* is confined to south temperate America, New Zealand, and Australia. Yet the lands which have these plants and animals in common are so widely separated from each other that they could not now possibly interchange their inhabitants. Certainly towards the equator they approach each other rather more, but even this fact fails to account for the present distribution, for, as Wallace has pointed out, "the heat-loving Reptilia afford hardly any indications of close affinity between the two regions" of South America and Australia, "whilst the cold-enduring amphibia and fresh-water fishes offer them in abundance" (Wallace: "Distribution of Animals," vol. i., p. 400). Thus we see that to the north interchange is prohibited by tropical heat, while it is barred to the south by a nearly shoreless circumpolar sea. Yet there must have been some means of intercommunication in the past, and it appears certain that it took the shape of a common fatherland for the various common forms from which they spread to the Northern Hemisphere. As this fatherland must have been accessible from all these scattered southern lands, its size and its disposition must have been such as would serve the emigrants either as a bridge or as a series of stepping-stones. It must have been either a continent or an archipelago.

But a further and a peculiar interest attaches to this lost continent. Those who have any acquaintance with geology know that the placental Mammalia—that is, animals which are classed with such higher forms of life as apes, cats, dogs, bears, horses, and oxen—appear very abruptly with the incoming of the Tertiary period. Now, judging by analogy, it is not likely that these creatures can have been developed out of Mesozoic forms with anything like the suddenness of their apparent entrance upon the scene. For such changes they must have required a long time and an extensive region of the earth, and it is probable that each of them had a lengthy series of progenitors, which ultimately linked it back to lower forms.

Why, then, it is constantly asked, if this was the sequence of creation, do these missing links never turn up? In reply to this query, it was suggested by Huxley that they may have been developed in some lost continent, the boundaries of which were gradually shifted by the slow elevation of the sea-margin on one side and its simultaneous slow depression upon the other, so that there has always been in existence a large dry area with its live stock. This dry spot, with its fauna and flora, like a great raft or Noah's Ark, moved with great slowness in whatever direction the great earth-undulation travelled. But to-day this area, with its fossil evidence, is a sea-bottom, and Huxley supposes that the continent, which once occupied a part of the Pacific Ocean, is now represented by Asia.

This eastward movement of land-surface translation eventually created a connection between this land and Africa and Europe, and if when this happened the Mammalia spread rapidly over these countries this circumstance would account for the abruptness of their appearance there.

Now, Mr. Blandford, the President of the Geological Society of London, in his annual address recently delivered, advances matters a stage further, for he tells us that a growing acquaintance with the biology of the world leads naturalists to a belief that the placental Mammalia and other of the higher forms of terrestrial life originated during the Mesozoic period still further to the southwards—that is to say, in the lost Antarctic continent, for the traces of which we desire to seek.

But it almost necessarily follows that wherever the Mammalia were developed there also man had his birthplace, and if these speculations should prove to have been well founded we may have to shift the location of the Garden of Eden from the Northern to the Southern Hemisphere.

I need hardly suggest to you that possibilities such as these must add greatly to our interest in the recovery of any traces of this mysterious region. This land appears to have sunk beneath the seas after the close of the Mesozoic. Now, the submergence of any mass of land will disturb the climatic equilibrium of that region, and the disappearance of an Antarctic continent would prove extremely potential in varying the climate of this hemisphere. For to-day the sun's rays fall on the South Polar regions to small purpose. If we accept Croll's hypothesis we must believe that the unstable sea absorbs the heat, and in wide and comparatively warm streams it carries off the caloric to the Northern Hemisphere to raise its temperature at the expense of ours. But when extensive land received those same heat-rays, its rigid surfaces, so to speak, tethered their caloric in this hemisphere, and thus, when there was no mobile current to steal northwards with it, warmth could accumulate and modify the climate.

Under the influence of such changes the icy mantle would be slowly rolled back towards the South Pole, and thus many plants and animals were able to live and multiply in latitudes that to-day are barren. What has undoubtedly occurred in the extreme north is equally possible in the extreme south. But if it did occur—if South Polar lands, now ice-bound, were then as prolific of life as Disco and Spitzbergen once were—then, like Spitzbergen and Disco, the unsubmerged remnants of this continent may still retain organic evidences of the fact in the shape of fossil-bearing beds, and the discovery of such deposits would confirm or confute such speculations as these. The key to the geological problem lies within the Antarctic Circle, and to find it would be to recover some of the past history of the Southern Hemisphere. There is no reason to despair of discovering such evidence, as the late Dr. McCormack, in his account of Ross's voyage, records that portions of Victoria Land were free from snow, and therefore available for investigation; besides which, their surface may still support some living forms, for they cannot be colder or bleaker than the peaks which rise out of the continental ice of North Greenland, and these, long held to be sterile, have recently disclosed the existence upon them of a rich though humble flora.

We have now to consider some important meteorological questions. If we look at the distribution of the atmosphere around the globe we shall see that it is spread unequally. It forms a stratum which is deeper within the tropics than about the Poles and over the Northern than over the Southern Hemisphere, so that the barometer normals fall more as we approach the Antarctic than they do when we near the Arctic. Maury, taking the known isobars as his guide, has calculated that the mean pressure at the North Pole is 29·1°, but that it is only 28° at the South (Maury's Meteorology, p. 259). In other words, the Antarctic Circle is permanently much barer of atmosphere than any other part of the globe. Again, if we consult a wind-chart we shall see that both Poles are marked as calm areas. Each is the dead centre of a perpetual wind-vortex, but the South Polar indraught is the stronger. Polarward winds blow across the 45th degree of north latitude for 189 days in the year, but across the 45th degree of south latitude for 209 days. And while they are drawn in to the North Pole from over a disc-shaped area 5,500 miles in diameter, the South Polar indraught is felt throughout an area 7,000 miles across. Lastly, the winds which circulate about the South Pole are more heavily charged with moisture than are the winds of corresponding parts of the other hemisphere. Now, the extreme degree in which these three conditions of a perpetual grand cyclone, a moist atmosphere, and a low barometer co-operate without the Antarctic ought to produce within it an exceptional meteorological state; and the point to be determined is, what that condition may be.

Maury maintained that the conjunction will make the climate of the South Polar area milder than that of the North. His theory is that the saturated winds, being drawn up to great heights within the Antarctic, must then be eased of their moisture, and that simultaneously they must disengage vast quantities of latent heat; and it is because more heat must be liberated in this manner in the South Polar regions than in the North that he infers a less severe climate for the Antarctic. He estimates that the resultant relative differences between the two polar climates will be greater than that between a Canadian and an English winter (Maury's Meteorology, p. 466). Ross reports that the South Polar summer is rather colder than that of the North; but still the southern winter may be less extreme, and so the mean temperature may be higher. If we examine the weather reports logged by Antarctic voyagers, instead of the temperature merely, the advantage still seems to rest with the south. In the first place, when the voyager enters the Antarctic he sails out of a tempestuous zone into one of calms. To demonstrate the truth of this statement, I have made an abstract of Ross's log for the two months of January and February, 1841, which he spent within the Antarctic Circle. To enable every one to understand it, it may be well to explain that the wind-force is registered in figures from 0, which stands for a dead calm, up to 12, which represents a hurricane. I find that during these sixty days it never once blew with the force 8—that is, a fresh gale; only twice did it blow force 7, and then only for half a day each time. Force 5 to 6—fresh to strong breezes—is logged on twenty-one days. Force 1 to 3—that is, gentle breezes—prevailed on thirty-four days. The mean wind-force registered under the entire sixty days was 3·43—that is, only a four- to five-knot breeze. On thirty-eight days blue sky was logged. They never had a single fog, and on eleven days only was it even misty. On the other hand, snow fell almost every second day. We find such entries as these: "Beautifully clear weather," and "Atmosphere so extraordinarily clear that Mount Herschel, distant ninety miles, looked only thirty miles distant." And, again, "Land seen one hundred and twenty miles distant; sky beautifully clear." Nor was this season exceptional, so far as we can tell, for Dr. McCormack, of the "Erebus," in the third year of the voyage, and after they had left the Antarctic for the third and last time, enters in his diary the following remark: "It is a curious thing that we have always met with the finest weather within the Antarctic Circle; clear, cloudless sky, bright sun, light wind, and a long swell" (McCormack's "Antarctic Voyage," vol. i., p. 345). It would seem as if the stormy westerlies, so familiar to all Australian visitors, had given to the whole Southern Hemisphere a name for bad weather, which as yet, at least, has not been earned by the South Polar regions. It is probable, too, that the almost continuous gloom and fog of the Arctic (Scoresby's "Arctic Regions," pp. 97, 137) July and August have prejudiced seamen against the Antarctic summer. The true character of the climate of this region is one of the problems awaiting solution. Whatever its nature may be, the area is so large and so near to us that its meteorology must have a dominant influence on the climate of Australia, and on this fact the value of a knowledge of the weather of these parts must rest.

To turn to another branch of science, there are several questions relating to the earth's magnetism which require for their solution long-maintained and continuous observations within the Antarctic Circle. The mean or permanent distribution of the world's magnetism is believed to depend upon causes acting in the interior of the earth, while the periodic variations of the needle probably arise from the superficial and subordinate currents produced by the daily and yearly variations in the temperature of the earth's surface. Other variations occur at irregular intervals, and these are supposed to be due to atmospheric electricity. All these different currents are excessively frequent and powerful about the poles, and a sufficient series of observations might enable physicists to differentiate the various kinds of currents, and to trace them to their several sources, whether internal, superficial, or meteoric. To do this properly, at least one land observatory should be established for a period. In it the variation, dip, and intensity of the magnetic currents, as well as the momentary fluctuations of these elements, would all be recorded. Fixed term-days would be agreed on with the observatories of Australia, of the Cape, America, and Europe, and during these terms a concerted continuous watch would be kept up all round the globe to determine which vibrations were local and which general.

The present exact position of the principal South Magnetic Pole has also to be fixed, and data to be obtained from which to calculate the rate of changes in the future; and the same may be said of the foci of magnetic intensity and their movements. In relation to this part of the subject, Captain Craik, R.N., recently reported to the British Association his conclusions in the following terms: "Great advantage to the science of terrestrial magnetism would be derived from a new magnetic survey of the Southern Hemisphere extending from the parallel of 40° S. as far towards the geographical pole as possible."

Intimately connected with terrestrial magnetism are the phenomena of auroras. Their nature is very obscure, but quite recently a distinct advance has been made towards discovering some of the laws which regulate them. Thanks to the labours of Dr. Sophus Tromholdt, who has spent a year within the Arctic Circle studying them, we now know that their movements are not as eccentric as they have hitherto appeared to be. He tells us that the Aurora Borealis, with its crown of many lights, encircles the Pole obliquely, and that it has its lower edge suspended above the earth at a height of from fifty to a hundred miles; the mean of 18 trigonometrical measurements, taken with a base-line of 50 miles, being 75 miles. The aurora forms a ring round the Pole, which changes its latitude four times a year. At the equinoxes it attains its greatest distance from its Pole, and at midsummer and midwinter it approaches it most closely; and it has a zone of maximum intensity which is placed obliquely between the parallels of 60° and 70° N. The length of its meridional excursion varies from year to year, decreasing and increasing through tolerably regular periods, and reaching a maximum about every eleven years, when, also, its appearance simultaneously attains to its greatest brilliancy. Again, it has its regular yearly and daily movements or periods. At the winter solstice it reaches its maximum annual intensity; and it has its daily maximum at from 8 p.m. and 2 a.m., according to the latitude. Thus at Prague, in 50° N. lat., the lights appear at about 8.45 p.m.; at Upsala, 60° N. lat., at 9.30 p.m.; at Bosskop, 70° N. lat., at 1.30 a.m. Now, while these data may be true for the Northern Hemisphere, it remains to be proved how far they apply to the Southern. Indeed, seeing that the atmosphere of the latter region is moister and shallower than that of the former, it is probable that the phenomena would be modified. A systematic observation of the Aurora Australis at a number of stations in high latitudes is therefore desirable.

Whether or not there is any connection between auroral exhibitions and the weather is a disputed point. Tromholdt believes that such a relationship is probable ("Under the Rays," vol. i., p. 283). He says that, "however clear the sky, it always became overcast immediately after a vivid exhibition, and it generally cleared again as quickly" ("Under the Rays," vol. i., p. 235). Payer declares that brilliant auroras were generally succeeded by bad weather ("Voyage of Tegethoff," vol. i., p. 324), but that those which had a low altitude and little mobility appeared to precede calms. Ross remarks of a particular display, "that it was followed by a fall of snow, as usual" (Ross's Voyage, vol. i., p. 312). Scoresby appears to have formed the opinion that there is a relationship indicated by his experience. It is therefore allowable to regard the ultimate establishment of some connection between these two phenomena as a possible contingency. If, then, we look at the eleven-year cycle of auroral intensity from the meteorological point of view, it assumes a new interest, for these periods may coincide with the cycles of wet and dry seasons which some meteorologists have deduced from the records of our Australian climate, and the culmination of the one might be related to some equivalent change in the other. For, if a solitary auroral display be followed by a lowered sky, surely a period of continuous auroras might give rise to a period of continuous cloudy weather, with rain and snow. Fritz considers that he has established this eleven-year cycle upon the strength of auroral records extending from 1583 to 1874, and his deductions have been verified by others.

In January, 1886, we had a widespread and heavy rainfall, and also an auroral display seen only at Hobart, but which was sufficiently powerful to totally suspend communication over all the telegraph lines situated between Tasmania and the China coast. This sensitiveness upon the part of the electric currents to auroral excitation is not novel, for long experience on the telegraph wires of Scandinavia has shown that there is such a delicate sympathy between them that the electric wires there manifest the same daily and yearly periods of activity as those that mark the auroras. The current that reveals itself in fire in the higher regions of the atmosphere is precisely the same current that plagues the operator in his office. Therefore in the records of these troublesome earth-currents now being accumulated we are collecting valuable data, which may possibly enable the physicist to count the unseen auroras of the Antarctic, to calculate their periods of activity and lethargy, and again to check these with our seasons. But it need hardly be said that the observations which may be made in the higher latitudes and directly under the rays of the Aurora Australis will have the greater value, because it is only near the zone of maximum auroral intensity that the phenomena are manifested in all their aspects. In this periodicity of the southern aurora I have named the last scientific problem to which I had to direct your attention, and I would point out that, if its determination should give to us any clue to the changes in the Australian seasons which would enable us to forecast their mutations in any degree, it would give to us, in conducting those great interests of the country which depend for their success upon the annual rainfall, an advantage which would be worth many times over all the cost of the expeditions necessary to establish it.

Finally, there is a commercial object to be served by Antarctic exploration, and it is to be found in the establishment of a whaling-trade between that region and Australia. The price of whalebone has now risen to the large sum of £2,000 a ton, which adds greatly to the possibilities of securing to the whalers a profitable return. Sir James Ross and his officers have left it on record that the whale of commerce was seen by them in these seas, beyond the possibility of a mistake. They have stated that the animals were large and very tame, and that they could have been caught in large numbers. Within the last few years whales have been getting very scarce in the Arctic; and, in consequence of this, two of the most successful of the whaling-masters of the present day—Captains David and John Gray, of Peterhead, Scotland—have devoted some labour to collecting all the data relating to this question, and they have consulted such survivors of Ross's expedition as are still available. They have published the results of their investigations in a pamphlet, in which they urge the establishment of the fishery strongly, and they state their conclusions in the following words: "We think it is established beyond doubt that whales of a species similar to the right or Greenland whale, found in high northern latitudes, exist in great numbers in the Antarctic seas, and that the establishment of a whale fishery within that area would be attended with successful and profitable results." It is not necessary for me to add anything to the opinion of such experts in the business. All I desire to say is that, if such a fishery were created, with its head-quarters in Australasia or New Zealand, it would probably be a material addition to our prosperity, and it would soon increase our population by causing the families of the hardy seamen who would man the fleet to remove from their homes in Shetland and Orkney and the Scotch coasts, and settle here.

In conclusion, I venture to submit that I have been able to point to good and substantial objects, both scientific and commercial, to justify a renewal of Antarctic research, and I feel assured that nothing could bring to us greater distinction in the eyes of the whole civilised world than such an expedition, judiciously planned and skilfully carried out.

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1. *Antarctic Exploration.*

By C. W. Purnell.

The author commenced by remarking that, inasmuch as the subject of Antarctic exploration had already been brought under the notice of the Association by Mr. Griffiths, while an intended expedition under the leadership of Baron Nordenskiöld had been actually announced, the present paper might seem unnecessary. He (Mr. Purnell) had, however, read a paper on the subject before the Otago Institute, so far back as 1878; and, seeing that it appeared doubtful whether Baron Nordenskiöld's project would ever be carried into effect, while, if it were, it was likely to be upon too small a scale to give it a chance of doing any work of real value, the author deemed himself justified in inviting the Association to take some practical steps towards bringing about a solution of the greatest geographical problem which yet remained to tax man's wit and energies. Of the immense region lying within the Antarctic Circle, comprising an area of a little over 8,000,000 square miles, we knew scarcely anything; while, according to Sir Wyville Thomson's calculations, an inner area of 4,700,000 square miles was absolutely unknown to us. Sir James Ross's expedition, which had accomplished more than any other South Polar expedition, was the outcome of the efforts of the British Association for the Advancement of Science; and it would greatly tend to popularise the Australasian Association, and prove that it was of genuine utility, if it could succeed in bringing about a successful Antarctic expedition.

Some of the objects of such an expedition are these:—

The great problem of whether an Antarctic continent existed or not, still remained unsolved. The drift of recent speculations favoured a belief in the existence of an archipelago instead of a continent in the South Polar regions; but when they reflected how many ingenious speculations upon the geography of the Arctic regions had been put to flight upon the results of actual research, they would attach but little weight to these speculations, and it was only by exploration that the question at issue could be determined.

It was of the highest interest to know whether the Antarctic lands were inhabited by man. Probably they were not. But in our present state of ignorance of the conditions of these lands it would be absurd to dogmatize on the subject. The climate of the Antarctic was more trying to mankind than that of the Arctic regions. The temperature was lower in summer and the weather more stormy—in fact, there appeared to be no real summer; but there were substantial grounds for believing that the winters were milder; and sheltered spots might lie concealed within the Antarctic Circle where human beings might contrive to exist. The means of subsistence for man were not absolutely lacking. There was an abundant marine fauna; and, although vegetation had not yet been found at a higher latitude than 64° 12′ S., further research might prove that first impressions in this respect were erroneous.

Important contributions to zoological science might be expected. Ross found the marine fauna abundant in the highest latitudes. Whales and seals were plentiful; and molluscs, crustaceans, corallines, and many other forms (some new) rewarded his dredgings. He landed on Possession Island, in lat. 71° 56′ S. and long. 171° 7′ E., and there met with "inconceivable myriads" of large penguins. The Antarctic regions offered a new world to the naturalist; but negative, as well as positive, evidence was useful, and, even if it were proved that the Antarctic regions contained no fresh forms of animal life beyond those with which we were already acquainted, the knowledge of that fact would help to elucidate the problems connected with the geographical distribution of animals and the whereabouts of the prime origin of life. Light would also be thrown upon the validity or otherwise of the theory that a land-connection formerly existed between New Zealand and South America.

A thorough knowledge of the physical features and meteorology of the Antarctic region would prove of material assistance in enabling us to master the meteorology of Australia and New Zealand and of the adjacent seas. If the Colonial Government subscribed towards the cost of an Antarctic expedition, they would virtually be helping to make their meteorological observatories more efficient. The extension of our present knowledge of ocean-currents, which would arise from a further exploration of the South Polar region, would be a gain of practical as well as scientific value, and we might expect important additions to our knowledge of terrestrial magnetism and the phenomena of auroras. There seemed to be a striking development of volcanic action in the Antarctic lands, and this would offer another interesting field of investigation.

Some commercial advantages—and those not small—would probably flow from an Antarctic expedition. Antarctic voyagers had met with whales and seals in considerable numbers; and Ross discovered an immense guano-bed on Possession Island. Similar deposits might exist in other localities; and the rendering available to commerce of even one extensive guano-bed would of itself almost recoup the cost of an Antarctic expedition.

He felt little sympathy with the projects which had been mooted for a flying survey of what might be termed the outer edge of the Antarctic region, as he was unable to perceive what object of importance was likely to be gained by such a survey. They ought to seek to penetrate into the inner recesses of the Antarctic region. Moreover, an Antarctic expedition upon a large scale would be more likely to gain public support in the colonies; while the Imperial Government, which had already refused to contribute towards the cost of a flying survey, might be willing to aid in a larger expedition, which, if successful, would reflect lustre upon the nation.

The expedition should consist of two auxiliary steamers of from 300 to 350 tons burthen, well manned, and provisioned for a stay in the Antarctic regions of, say, three years. It was of the utmost importance that land-journeys should be made, and the expedition should therefore be thoroughly equipped for that purpose. It would start with enormous advantages over all previous expeditions, since its leaders could utilise the accumulated experiences of the numerous Arctic expeditions which had set out during the past fifty years, while all Antarctic navigators had hitherto made their voyages in sailing-vessels. The exploring ships should, if possible, be manned from the Royal Navy, because thoroughly disciplined men could thus be procured.

The most successful of the attempts which had been made to penetrate into the inner Antarctic region were those of Weddell and Ross. The former attained the latitude of 74° 15′ S. on the 35th meridian of west longitude, and had still a clear sea before him; but neither d'Urville nor Ross, sailing down the same meridian, had been able to reach the 66th parallel of south latitude.

Judging from the experiences of Balleny and Ross the sea to the south of New Zealand was more open. Balleny, on the meridian of 170° E., reached the latitude of 69° S., and there found an open sea. Ross, sailing on the same course, discovered South Victoria Land, and reached a latitude of 78° 10′ S. in longitude 161° 27′ W., when his further progress southward was stopped by the ice-barrier. The route traversed by Ross in his first voyage thus seemed to offer the most practical entrance to the inner Antarctic region, and any exploring expedition which might be despatched should be instructed to follow this route, and endeavour to supplement Ross's discoveries. It would be most important for the expedition to try and find a harbour in which to winter. It might be objected that Ross had failed to find one; but he had only coasted along South Victoria Land once, and in his sailing-vessels he was at the mercy of the winds and the waves, while with steamers a much closer scrutiny could be made, and it was not unreasonable to hope that a coast-line extending over nearly nine degrees of latitude might contain a harbour. Ross had been unable to pierce the ice-barrier, but this did not prove that it was permanent, and material changes might have occurred in the ice-masses since the date of his visit.

The cost of the expedition would depend entirely upon the scale on which it was equipped; but, in any case, it would not exceed the united resources of the Australian and New Zealand Governments, which, the author suggested, should be invited by the Association to co-operate in despatching an expedition to the South Polar regions at their joint expense. If the active support of the Imperial Government could be secured it might be persuaded to lend the requisite ships; but, under any circumstances, it should be asked to lend the services of its naval officers. Possibly public subscriptions could be obtained; but, if all the colonial Governments would contribute, a moderate sum only would be required from each to defray the entire cost of the expedition. And when we consider the splendid revenues which yearly flow into the colonial exchequers,—the enormous sums of money which the Governments of these colonies have squandered at various times for political purposes,—how little Australia and New Zealand have hitherto contributed towards truly national as distinguished from merely colonial enterprises,—how small a fraction of their wealth has been expended upon the advancement of science—this Association might fairly and without hesitation ask the rulers of these colonies to depart for once from their routine work, and engage in a patriotic enterprise worthy of the traditions of a maritime nation, and which would make the names of Australia and New Zealand respected throughout the civilised world.

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2. *Some Account of the Earliest Explorations in New Zealand, &c.*

By Dr. T. M. Hocken.

We may consider that the long list of brilliant voyages and discoveries in the Southern Seas, begun by the renowned Magellan, fitly closed with the splendid record of Captain Cook. Of Captain Cook's great work we have not now to speak, and for the purposes of this paper must be content with referring to that admirable chart which for nearly three-quarters of a century constituted, with few additions, the sole guide to the mariner who sought his path along these unknown coasts. For more than a century prior to Cook's discovery New Zealand's existence upon a map of the Southern Hemisphere was shadowed forth by a mere streak of irregular outline placed there by Tasman, and by him called Staten Land. This streak was considered by Tasman to be a portion of the "Terra Australis Incognita" or great southern continent, and it extended northward along the west coast from about the mouth of the Brunner River to the Three Kings. Cook swept this mist away, and with it the unknown continent which had been so long enveloped in it, and in its place gave us his chart of the Islands of New Zealand, a marvel of accuracy and fidelity. Speaking of it in the last century, Crozet, the French navigator, says, "I found it to possess an exactness and minuteness which astonished me beyond all expression." Nor as a chart was it greatly superseded until 1848, when the Admiralty surveys commenced, under Captains Stokes and Drury, in H.M.SS. "Acheron" and "Pandora." With one of them in his hand the leader of the New Zealand Company's expedition sailed safely into Queen Charlotte Sound, where, in 1839, the practical work of our colonisation began. It is curious that in his chart Captain Cook placed the North Island 30′ and the South Island 40′ too far east, which would place Wellington at the mouth of Tory Channel, and Christchurch at Springfield. These errors of longitude he corrected on his second voyage. We have now to trace the gradual filling-in of those outlines first drawn by Cook's faithful pencil. This is a task of considerable difficulty. There is an *embarras de richesses*, from which, to be just, it is impossible or difficult to select. To compress these within required limits is indeed to give but a mere catalogue of names and dates, or to present with rapid succession a list of explorations divested of all those little incidents which give to travel its very soul and spirit. However, in an evil moment I accepted the task, and, rather than break faith, have now to bespeak your consideration for shortcomings which to me seemed unavoidable.

We may appropriately divide into three periods the history of those discoveries and explorations which have gradually brought our topographical knowledge of this country to its present state of excellence. The year 1839 marked a great epoch in its history, and gave it that vast impulse of progress which has ever since been continuous. In that year the real work of colonisation began under the auspices of the great New Zealand Company, working upon the lines of that system devised by the memorable Edward Gibbon Wakefield. British government was established, and thousands of our countrymen flocked to the almost desolate shores, finding there a congenial home and a new Britain. Prior to this, and from the time of Captain Cook, scanty indeed and slowly gained was the knowledge of New Zealand. Some portions of the coast-line were better known and better laid down; but of the interior an almost complete ignorance prevailed, if we except the northern and narrower portion of the North Island, which, due to the journeyings of the missionaries and of a few other travellers, was fairly well known. But by far the largest part of the Northern Island, and almost the whole of the Southern, lay buried in an obscurity as dark as that of central Africa. A few adventurous whalers fringed the coasts, but neither their interest nor their curiosity tempted them to penetrate the interior, and whatever they knew was known to none besides. Hence that most modern and improved map of 1836, compiled by Lieutenant McDonnell, of Hokianga, and published by Mr. James Wyld, the eminent cartographer of Charing Cross, did not differ very greatly from that drawn by Cook sixty-six years before. It was brought up to date, and comprised all those additions made within our first period. It also comprised several bays and rivers which never existed; soundings also not only incorrect, but which proved disastrous to the first vessel which accepted them. From 1839 onwards the spirit of exploration became necessarily a special feature in the development of the young colony, and marks the second period. The promoters and leaders of the new venture carried with them men of skill, courage, and activity, whose duty it was to search for in all directions, and then to select and survey, lands suitable for the occupancy of those about to follow. The history of these explorations is interesting in the extreme, but so numerous are they that it is impossible within the limits of this paper to give more than a catalogue in the baldest outline of labours worthy of being recounted at full length. We who sit at home at ease enjoying the fruits of such labours fail to associate with them the names of Dieffenbach, Brunner, Heaphy, Tuckett, Stokes, Park, Kettle, Thomas, Fox, and a host of others who passed through all the dangers of mountain, flood, and fell. In the person of Sir James Hector, the distinguished President of this Association, who penetrated the region of the wild West Coast in 1863, we may consider this period fitly to close, and to be followed by the third and last, which extends to the present time. During this the toil of active and extensive exploration has gradually ceased, or at least has altered in character, and has been replaced by the steady continuous work of our admirable Survey Department.

In 1788 was founded the convict settlement of New South Wales, and it was not long before some of the vessels which conveyed the first population to the infant colony spread their sails towards that adjacent country which Captain Cook had invested with so much interest and romance. In its western waters, and ever travelling a little further south, the whaler and the sealer began to develope their industry. Others visited the Thames district, there to procure the magnificent kauri masts and spars so suitable for the King's or the East India Company's navy. At the Bay of Islands, and in various other spots, barter sprang up with the Natives for pigs, potatoes, and flax.

In 1791 Captain Vancouver, then on a voyage round the world, was storm-stayed in Dusky Bay. The further portion of this capacious sound, which had been but partially explored for want of time by Captain Cook, he carefully examined and charted. As an instance of the odd nomenclature of those early-day sailors, it may be mentioned that Vancouver supplanted the name "Nobody-knows-what," given by Cook to a portion of his incomplete survey, by that of "Somebody-knows-what," a name retained in the chart to the present day. He discovered that cluster of rocky islets, lying about sixty miles south-west of Stewart Island, upon which at this moment it is proposed to erect a lighthouse. These he called "The Snares," a name as suitable as that of the "The Traps" given by Cook to those dangerous rocks lying still closer to the mainland and in the fairway of the Melbourne steamers. In the same year Lieutenant Broughton, who in the tender "Chatham" accompanied Vancouver's ship the "Discovery," discovered the Chatham Islands. These he named after the eloquent Pitt, Earl of Chatham, who died on the floor of the House of Lords whilst raising his voice against the injustice of England towards her American colonies. The natives, known to us as Morioris, probably numbered two thousand. He describes them as being of middling size, well limbed and fleshy. Their hair, which was black, was generally worn long, and they were dressed in sealskins or wore mats. Despite their laughing cheerful nature they quarrelled with the sailors, and one of their number was killed.

In 1793 two Natives of New Zealand were, to use plain terms, stolen or kidnapped from their home in Doubtless Bay, and carried to Norfolk Island to teach the convicts how to dress the flax which grows there plentifully. Their names were Tuki and Huru, or, as spelt in the original account, Toogee and Hoodoo. During their captivity there of six months' duration Lieut.-Governor King procured much interesting information from them regarding their country, and induced Tuki to draw with a piece of chalk on the floor of a room a sketch of New Zealand. This was added to and further improved, and was then copied on paper by Captain King. This unique and primitive map was printed in London in 1798, and is contained in Collins's "Account of New South Wales," published the same year. A copy of this is here exhibited. By exercise of faith and stretch of imagination the North Island may be recognised, with Te Reinga and Hokianga River marked thereon, or, as they are there spelt, Terryinga and Chokahanga. But by no faith or imagination is the South Island to be recognised. It is about a fourth the size of the North Island, is of rhomboidal figure, and almost its sole contents is a circular figure marked, "Lake where stones for hatchets are got."

Early in this century the outlying islands of New Zealand were discovered by the masters of the whaling or sealing vessels. In 1806 Captain Bristow fell in with and named the Auckland Islands after Lord Auckland—a group which in 1850 was granted by the British Government to the Messrs.

Enderby for the purpose of founding a large whaling establishment. The scheme was carried out, but in two years came to an untimely end, involving those connected with it in plentiful lawsuits and a loss of £20,000.

In 1809 the master of a sealer discovered the insularity of the southernmost part of New Zealand, thence called after him Stewart Island. The straits dividing the island from the mainland were named after Lieut.-Colonel Foveaux, who in 1808 assisted in the administration of the New South Wales Government during the suspension of the unfortunate Governor Bligh, of the "Bounty." In 1840 this Captain Stewart discharged the duties of pilot on board H.M.S. "Herald," which conveyed Major Bunbury south whilst procuring the chiefs' signatures to the Treaty of Waitangi. His thorough knowledge of the coasts and of the Natives and their language was of the greatest service to Major Bunbury whilst on this difficult mission. He died in 1851 at Poverty Bay, an old and poverty-stricken sailor.

The Campbell Islands were added to the list in 1810 by Captain Hazelburg, of the sealer "Perseverance," and were so named after the well-known Sydney merchant of those days, Robert Campbell.

Macquarie Island, the southernmost of all, was discovered last, and was named after Governor Lachlan Macquarie. Upon it, seventy years ago, was quite an extensive sealing colony, connected by trade chiefly with Hobart Town.

Thus, as might be expected from the nature of their calling, the hardy race of seamen formed the earliest band of discoverers. Some of these, wearied with the dangers of the sea and attracted by the blandishments upon shore, identified themselves with the natives, and, becoming "koumatuas" or "pakehas," transacted for them their simple barter, journeyed with them into the interior, and even participated in their furious tribal warfare, with the consequent delights of cannibalism. Of histories such as these the barest record remains.

In 1805 Mr. Savage, the surgeon of a convict vessel, sailed into the Bay of Islands, which, as we shall see, was a place of increasing repute and resort. He published an account of this visit in 1807, accompanying his directions for entering the bay with drawings of its headlands. This little book is the second written in the English language giving an account of New Zealand, Captain Cook's great journal being the first.

We have now to refer to the Rev. Samuel Marsden, chaplain of the New South Wales colony, who indeed deserves to be ranked as our first explorer. To this remarkable man New Zealand owes much which has never been sufficiently recognised, and much which certainly has been long forgotten. With him the love for New Zealand became a passion. He visited it seven times in the days of small schooners and long voyages, his last voyage being performed in 1837, when an old man of seventy-three. His dying lips closed whilst speaking of the country and the people for which he had done so much. For years he desired in true missionary spirit to introduce the gospel to the Natives, but circumstances with which we have now no concern interfered to prevent this, and it was not until 1814 that, accompanied by his friend Colonel Nicholas, he was enabled to pay his first visit to New Zealand, and so fulfil his heart's desire. A highly-interesting account of this journey was published by Colonel Nicholas in 1817. His services to the infant colony could ill be spared, and Governor Macquarie granted him leave of absence with much unwillingness. However, he was directed to explore as much of the sea-coast and of the interior as his prescribed time would permit. On his return after an absence of four months he addressed an official letter to the Governor, and forwarded a copy of his journal to the Church Missionary Society in London, together with a sketch-map. These are to be found in the "Missionary Register" for 1816. On this excursion he landed at the North Cape, and between land and sea travelled southwards down the Hauraki Gulf almost to the mouth of the river Thames—a distance of two hundred miles—penetrating into the interior at various points. But the chief portion of his time was spent exploring the Bay of Islands, where at Rangihu he planted his first missionary-station. He examined the principal rivers debouching into the bay. By the Natives he was received, as always afterwards, with the utmost friendship; and of their manners and customs, cultivations and fortifications, he gives a valuable account—valuable as the result of an observant, educated man brought into contact with a race in its primitive and unaltered state.

This was the historic district where six-and-twenty years later British government was first founded, and where by the side of Lake Morberrie, as Marsden calls it—Lake Omapere—was fought the Englishman's first battle with the great chief Hone Heke in 1845. It was stated by the Natives that this lake gave origin to a large river which ran through the interior of the Island and opened into the western ocean, and that upon its waters rode many large canoes, and upon its banks were many settlements and pas. Accordingly upon Marsden's map exists a provisional opening for the mouth of this great river, which upon his next visit became known to him as the Shukeehanga, is known to us as the Hokianga, and was indeed the Chokahanga of twenty years before on Tuki's primitive map. Beyond all this nothing whatever was known of the north-west region, which was simply marked "The Desert Coast."

Marsden's second and third visits were paid in quick succession in 1819 and 1820. Now, as on all occasions, the great object of his solicitude was the planting of the gospel amongst the New-Zealanders, and, whilst history has told how faithfully he laboured for that great end, it has failed to place in relief his work as an explorer. In 1820 he sailed from Sydney for the Bay of Islands in H.M. storeship "Dromedary." On this occasion he had as a fellow-passenger Captain Cruise, of the 84th Regiment, author of the fourth English book on New Zealand — "Journal of a Ten Months' Residence." The "Dromedary" was the first vessel to visit the mouth of the Hokianga, but she found the soundings too unsafe to admit of her entrance, so sought elsewhere for a load of kauri spars.

Mr. Marsden now transhipped into the "Coromandel," about to sail for the Thames on a similar search. This vessel gave her name to that well-known district, where thirty-five years afterwards were made the first gold discoveries in New Zealand.

Leaving the "Coromandel," Mr. Marsden, then in his fifty-seventh year, commenced his really marvellous journey into the interior, one which taxed all his courage and endurance. He was absent from his ship between five and six weeks, travelling by foot and canoe fully six hundred miles, through rivers, creeks, swamps, and the roughest tracks. His route was by land to Mercury Bay, famous as the spot where Cook took possession of New Zealand in the name of good King George. Returning, he crossed the Frith of the Thames, traversed intervening country, sailed up the Wairoa and the Waitemata, where from a hill-summit he viewed the Manukau and its heads, and the site of future Auckland. Canoeing up the Kaipara, called by him "Kiperro," and the river Wairoa, which enters its northern portion, he crossed over to Whangarei; then, returning, he traversed the western, the desert, coast to the mouth of the Hokianga, which he ascended, and then walked across to the Bay of Islands. He called the Hokianga River the Gambier after his friend Lord Gambier, President of the Church Missionary Society—a name which it retained for long on old maps.

Marsden's later visits to New Zealand were almost confined to the special purposes of his mission, and his account of them abounds in glimpses of Native life and character, and of the hardships and dangers he endured. Like his great exemplar this apostle of New Zealand in his journeyings suffered shipwreck and hunger, and was in perils in the wilderness and from the Natives.

In 1825, under the modest title of "The New Zealand Flax Society," a company was formed in London for the purpose chiefly of cultivating flax and of collecting various kinds of valuable timber. With this view the ship "Rosanna" was sent out under Captain James Herd, with seventy people on board—stonemasons, carpenters, flaxdressers, shipwrights, and brickmakers—who proposed establishing themselves in some suitable part of New Zealand. Owing to the ferocity of the Natives the expedition proved a failure, and entailed a loss of £20,000 upon its originators. Most of those who accompanied it went to Sydney. A bold and scattered remnant remained, making their way to Horeke, one of the uppermost reaches of the Hokianga, where they established what they were pleased to call a dockyard, giving it the name of Deptford. Almost the last vestige of this ill-fated undertaking is to be found on the map under the name of Herd's Point. But Captain Herd did good service. He very accurately laid down the geographical positions of fifty places he visited whilst voyaging up the east coast of the three Islands, through Cook Strait, and a small portion of the north-west coast. He gives an excellent description of Wanganui-a-te-ra or Port Nicholson Harbour, where, as he says, "all the navies of Europe might ride in perfect security; at the entrance there is 11 and 12 fathoms water." He also carefully surveyed the entrance to the Hokianga River —this time called by the comical name of Jokeehangar—a chart of which he published. Its course for more than twenty miles upwards is also laid down.

At this time the Wesleyan mission-station which had been founded in 1823 at Whangaroa was burnt to the ground by the turbulent Natives; the missionaries were stripped of everything they possessed, and had to fly for their lives. In this terrible juncture they were hospitably received by Captain Herd, who was about to sail for Sydney, and who offered them a passage on his vessel.

Since the time of Marion du Fresne's sad massacre with that of his sailors in 1772, New Zealand had always possessed a mournful interest for his countrymen. In 1824 Lieutenant Duperrey, commanding the French vessel "La Coquille," visited the scene of this catastrophe. By M. de Blosseville, one of his officers, is first recorded our knowledge of Milford Haven, and of "Roto Doua" in the hot-lake district.

In 1827 the celebrated navigator Dumont d'Urville spent three months on the coast of New Zealand in his voyage of discovery round the world. He had previously sailed under Duperrey in the "Coquille," and now he commanded the same vessel, which had been rechristened the "Astrolabe." His expedition was absent from France four years, and on his return its results were published by the French Government in one of the most splendid and elaborate works of travel ever issued. The portion devoted to New Zealand is very extensive, and, apart from D'Urville's personal observations, contains a very full compendium of all previously known and written on the subject. He added much to our topographical knowledge, exploring Blind and Tasman Bays, and, proceeding northerly, accurately laid down portions of the unknown coast, which for ever will be associated with his name on the map. Amongst them are the well-known D'Urville Island, Astrolabe Roads, Croixelles Harbour, and the famous French Pass, through which he was the first to lead the way and to show that by twenty miles was shortened the sailor's passage north. The successful accomplishment of this dangerous feat in seamanship is told by him in a story of dramatic force, and it proves him to have possessed great courage and resource. Sailing up the east coast he explored the Hauraki Gulf and the whole district about and around the future Auckland, inclusive of those lovely islets which lend additional beauty to the waters of the Waitemata. Again he renewed his friendship with those missionary dwellers in the Bay of Islands to whose courtesy and assistance he and Duperrey had been indebted on their previous visit in the "Coquille." Of the brothers Williams's kindness and assistance he speaks in high terms, and he left them and their charming surroundings with lingering regret. Eight years later, and with similar gratitude, did Charles Darwin speak, when, in the "Beagle," he quitted the same oasis.

Again, in 1837–40, did D'Urville conduct a second scientific expedition towards the South Pole, visiting New Zealand by the way. The mode of his death was peculiarly dreadful. After successfully running the gauntlet of every danger found in sea and climate, he was burnt to death with his wife and family whilst travelling in a railway-carriage between Paris and Versailles, and this at the early age of fifty-two years.

In October, 1831, Captain Laplace, commanding "La Favorite," visited the Bay of Islands on his voyage round the world, remaining there a month. During this time he accurately surveyed a large portion of this vast bay, the Kawakawa River, Kororareka, and many of the small inlets. This chart is a monument not only of accuracy, but of exquisite artistic taste.

Thus, in quick succession, did three discovery vessels belonging to the "bloody tribe of Marion" visit and survey these shores. It was, doubtless, this which led the missionaries under the *nom* of the chiefs of New Zealand to address the King, praying that British protection might be extended to the Islands of New Zealand. The prayer was answered by sending, in 1833, Mr. James Busby as British Resident.

In 1834 and 1835 H.M.SS. "Alligator" and "Buffalo" surveyed the harbour of Whangaroa and the Hauraki Gulf, and in 1838 H.M.S. "Pelorus" entered the sound to which she gave her name; and with her ends the first period.

It will be apparent that almost all the topographical additions within this period relate to coast-line. Within these limits it would not be possible to specify the small additions made by the missionaries and a few others to a knowledge of the interior. In 1838 there were but thirteen mission-stations, and these were confined to the northernmost part of the North Island, the most southern being situated at Tauranga and at Rotorua. Between them there was an occasional interchange of visits, with the result of some information gained. There were whispers of mountains called Tonga and Ruapaka, but where they were no one quite knew; and of interior lakes, of which still less was known. That lake, however, which was supposed to give the South Island its name of Tavai Poenammoo ever retained a place on the map, its locality being shifted a little as circumstances demanded. But a new condition of things was at hand, and fair New Zealand was now to unveil the beauties of her mountains and valleys, her lakes and forests.

With Captain Cook's chart in his hand, Colonel Wakefield sailed into Queen Charlotte Sound on the 17th August, 1839, and dropped anchor in Ship Cove, where seventy years before Cook himself had anchored. Colonel Wakefield was leader of the preliminary or pioneer expedition sent out under the New Zealand Company to make plain the way for their colonising operations. His vessel, the "Tory," was commanded by Mr. Chaffers, of the Royal Navy, an accomplished nautical surveyor, and formerly master of the surveying vessel "Beagle," under Captain Fitzroy. His companions, besides Mr. Chaffers, were all men who have left their mark in New Zealand history, and who contributed largely to the early exploration of the country—Drs. Dieffenbach and Dorset, Messrs. Heaphy and Edward Jerningham Wakefield.

Finding that the lands within the sound were quite insufficient for extensive settlement, the pioneers, at the suggestion of Dicky Barrett, the old whaler, proceeded to Port Nicholson, passing through that channel to which the "Tory" gave her name, and which was surveyed by Captain Chaffers.

Port Nicholson, so called after Mr. John Nicholson, Harbourmaster at Sydney, had been but little visited, the line of reef at its entrance warning off vessels from the magnificent haven inside. Captain Chaffers soon showed how groundless were such fears, and very shortly completed an admirable survey of the whole harbour, naming its headlands and other features after persons distinguished by their favour to the Company's scheme.

But interest in this scheme was by no means confined to the Home-country. Barely was it mooted before unusual interest was also taken in it by the adjacent colony of New South Wales, to which, indeed, in some sense New Zealand had been a foster-child. Colonists of various grades, from the mere adventurer to the merchant desirous of pushing the limits of his business, kept themselves in readiness prepared to take advantage of any benefit which the new movement might bring forth. Of the latter class was Mr. Bidwill, who was related to a mercantile house in Sydney, and whose name in connection with New Zealand botany is well known. Six months before the arrival of the "Tory" he visited the North Island, and penetrated further into the interior than any previous European had done, visiting the Thames, the Waikato, the hot springs, and Lakes Rotoaira and Taupo. But his fame rests on the fact of his being the first to ascend the volcano of Tongariro and to gaze into its active crater. He says, "The crater was the most terrific abyss I ever looked into or imagined. The rocks overhung it on all sides, and it was not possible to see above ten yards into it from the quantity of steam it was discharging. The stones I threw in, which I could hear strike the bottom, did not do so in less than seven or eight seconds, but the greater part of them I could not hear." Upon the shoulders of the mountain he collected several new and interesting plants. His ascent was made in the face of great difficulties; the wonder is how it was made at all. Having made the descent in safety, he had to face the fury of another and unexpected volcano—the chief of Taupo, the great Te Heuheu, in a furious outburst of passion, demanding to know how he had dared to pollute the sacred Tongariro, the lofty seat of the great Atua and the tapued sepulchre of his ancestral line. Apparently Mr. Bidwill was not dismayed, and he found that three figs of tobacco quickly appeased the infuriated chief.

For a time Mr. Bidwill cast in his lot with the earliest settlers at Wellington, and some of his relatives are still located on the Wairarapa plains. The second ascent was made twelve years afterwards, secretly and unknown to the Natives, by a Mr. Henry Dyson, whose account is to be found in the *New-Zealander* of the 30th March, 1853.

Having completed his purchase of the lands around Port Nicholson from the Natives, Colonel Wakefield sailed slowly up the west coast, with a view of acquiring further large tracts of land whereon to settle the new immigrants soon to arrive. Dr. Dieffenbach and Dicky Barrett were landed at Taranaki, there to negotiate, if possible, with the Natives, whilst Colonel Wakefield proceeded towards his destination at Hokianga, carefully examining for available rivers and harbours which might lead into good country. The journey was disastrous.

Entering the Kaipara Harbour, the "Tory" took the bar and sprang a leak. With infinite trouble Colonel Wakefield made his way overland to the Bay of Islands, and there chartered a small vessel about to sail for Sydney, in which he retraced his steps to Port Nicholson, to prepare for the arrival of the first band of settlers, then daily expected.

At Taranaki, Dr. Dieffenbach had not been idle, his sojourn there being marked by hardship and perilous adventure. He was joined here by his friends Dr. Dorset and Jerningham Wakefield, who had made the best of their way down from the wreck of the "Tory" in an ancient and tublike vessel, greasy with whale-oil and swarming with cockroaches.

Owing to some fear of a Native outbreak, the party took up their abode on one of the well-known Sugarloaves, very steep and almost inaccessible, and used by the Natives for this reason as a place of security. With young children on their backs, the Natives walked along the dizzy and precipitous heights with the utmost unconcern.

Dr. Dieffenbach's first exploration was the ascent of Mount Egmont, and he was the first European to accomplish this, in company with Hebberly, a pilot. The first attempt was a failure: after three weeks' laborious travel through rain and swamp he only succeeded in reaching the foot of the mountain, and then had to return in rags and half-starved, a potato per diem, washed down with boiled fern-leaves, being latterly their only food. On the second attempt he was quite successful, reaching his home on the rocky island within ten days. The snow commenced at a point about 1,500ft. below the summit. It was very steep and frozen hard, necessitating the cutting of steps. The summit consisted of a field of snow about a square mile in extent. The view was magnificent and extensive, stretching north to the Waikato, and to Cook Strait in the south. Dr. Dieffenbach calculated the height of Egmont at about 8,800ft.—about 500ft. more than the true height.

On his return to Port Nicholson, Dr. Dieffenbach proceeded to the Chatham Islands, which the New Zealand Company, unable to secure recognition by the Government of their land-claims, desired to annex. Here he remained three months, a full account of his explorations being published in the old *New Zealand Gazette* newspaper of 1840. He then made a very extensive series of operations through the North Island, commencing at the North Cape and going south as far as the hot lakes and Taupo. Here he in vain endeavoured to gain permission to ascend Tongariro. The irate chief Te Heuheu was on a war expedition, and had issued his mandate that no pakeha should climb the mysterious mountain.

Dr. Dieffenbach was accompanied on this journey by Captain W. C. Symonds, of the 96th Regiment, agent of the Manukau and Waitemata Land Company, whose head-quarters were in Scotland. This gentleman was somewhat of an explorer, and it was due to his advice and representations made to his friend Governor Hobson that the site on the banks of the Waitemata was selected for Auckland as the seat of Government. He was accidentally drowned in the Manukau three weeks after the arrival of the "Brilliant" in that harbour, the first ship which had ever entered it, and the first emigrant ship sent out by his Scotch company.

Dr. Dieffenbach had for some time been dissatisfied in his relations with the New Zealand Company. He considered that he was hampered in his researches, which were not faithfully reported by them, and that he was expected to present that view alone which was acceptable and favourable to the company. He accordingly applied to Captain Hobson for employment under the Government, to prosecute scientific observations and research through the Islands of New Zealand. The public purse was however too tight to permit the acceptance of this offer, and he returned to England in 1842, where he published his travels.

In January, 1840, the "Cuba" arrived with the survey staff on board, consisting of Captain William Mein Smith, of the Royal Artillery, the Surveyor-General; Messrs. Stokes, Park, and Carrington, assistant surveyors; and twenty-two men.

It may here be said that later Captain Smith became a runholder in the Wairarapa in partnership with Mr. S. Revans, editor of the first paper published in New Zealand. Mr. Stokes afterwards edited the *Wellington Spectator and Cook Straits Guardian*. Mr. Park, who recently died in Christchurch, long continued in the service of the company, performing many of the earlier important surveys; and Mr. Carrington, who died last year, joined his brother in New Plymouth as a surveyor.

Operations commenced without delay, and, after the pressing work of the town sections had been taken in hand, explorations into the interior were vigorously prosecuted. In midwinter of 1840 Dr. Dieffenbach with Mr. Deans and a small party pushed their way up the Eritonga, or Hutt Valley, a distance of fifty miles, until they reached the lower hills of the Tararua Range, whose snow-covered summits were plainly seen. Dr. Dieffenbach got a glimpse of what were afterwards known as the Wairărapa plains, and he had no doubt but that a practicable road could be made through in this direction to Hawke's Bay. His party was absent from Britannia, as Wellington was then called, sixteen days. This Mr. William Deans was a most enterprising settler who came out from Kilmarnock in the first immigrant ship, the "Aurora." Wearied of the endless worry which he and his fellow-settlers suffered in their efforts to gain possession of their land-titles, he quitted Wellington in

1842 for the Port Cooper plains, where he and his brother were the pioneer settlers, founding there their home, and calling it Riccarton.

A well-equipped party under charge of Mr. Stokes started towards the end of August to examine the country between the Hutt and Taranaki, as it was desirable to connect these extremes by road. The expedition completed the journey to the Sugarloaves in exactly a month, making the return journey in less than three weeks. Mr. Stokes gave a glowing description of the land of promise through which he had travelled, the numberless acres of rich soil, and well-watered country so fitted for settlement. He discovered and described many new or barely-known rivers,—amongst them the Manawatu, Rangitikei, and the Wanganui,—proved that three large bays marked on the map had no existence, connected the supposed position of Mount Egmont, and laid down the coast-line for the first time with much approach to accuracy. The Natives were very numerous along the line of route, and everywhere welcomed and assisted the travellers.

The result was in every way satisfactory. Shortly afterwards Mr. Bell, a Scotchman, and his stalwart sons, started overland for Wanganui, becoming the pioneer settlers. Their departure with a team of bullocks, yoked to the heavily-loaded dray, created quite a sensation as they started from the infant settlement on their long and perilous journey. Every one came out to wish them farewell and good luck, and watched the cavalcade upon its solitary journey until it at last disappeared beyond the overhanging hills.

Mr. Stokes next turned his attention to the Wairarapa plains, the lower portion of which he traversed and described. But by far the most complete and interesting exploration of these plains was that of Mr. Kettle and party, who returned by them, having previously made the ascent of the Manawatu River for ninety miles beyond the limit of any previous exploration, and through the gorge or cliffs as they called it. He must, indeed, have reached the position of the present Woodville and then made his way southward by the Mangatainoko River, striking the upper plains by Mauriceville. Mr. Kettle was accompanied by Mr. Wills, then a surveying cadet, and seven Maoris on this expedition, which extended over thirty-three days and was marked by the utmost privation and suffering. The weather was wet and tempestuous; they were more than once a whole day without food, and often under these circumstances without shelter. To add to their misfortunes they were obliged to yield to the extortionate demands of certain Natives who, taking advantage of their necessity, refused to canoe them up a dangerous stretch of water until they had despoiled them of the whole of their spare clothing, and, indeed, of the very shirts they wore. On the last two days of the journey they were reduced to wild cabbage and cold water, sleeping by night in this famished condition round a large fire, and in the morning plunging breakfastless and exhausted into the dense bush. In this most wretched plight they made the Hutt on the thirty-third day, where Mr. Mason, the most outlying settler, received them with every hospitality. Mr. and Mrs. Mason, very old settlers now, still live in the Hutt Valley.

Mr. Kettle brought back full and valuable information of the districts through which he had travelled, besides numerous sketches, and bearings of distant points. In 1846 he was promoted to be the Company's chief surveyor. He superintended the surveys of the new Otago Block, and cast in his lot with the settlers in their principal town—Dunedin—where he died in 1862, at the comparatively early age of forty-two.

In the summer of 1841–42 Mr. Colenso, F.R.S., made—on foot, of course—an excursion of unusual interest, extending from Hicks Bay down the coast to the present site of Gisborne, then inland to the Waikare Lake, over the Whakatane Mountains to the hot lakes and Tauranga, then inland again, canoeing a hundred and fifty miles down the Waikato River to its mouth, which he crossed, proceeding overland to the Kaipara by Mangawai, Whangaruru, and Te Ranga to the Bay of Islands, the seat of the mission, whence he started. The ground thus covered must be between five and six hundred miles. A charming account of this journey was published by the learned author in 1844, in Launceston, Van Diemen's Land. It is written in the freshest manner, and abounds throughout in valuable natural-history notes, principally botanical, and in information of all kinds. Though the pamphlet extends over nearly a hundred octavo pages it is entirely too short. It is a matter of sincere regret that Mr. Colenso is not able to take part in the meetings of this Association, and to lay before it some portion of that rich store of knowledge which he has gathered during the last fifty-five years in New Zealand. His contributions to New Zealand botany are well known, as well as those relating to the Maori race and to subjects connected with our earliest history. Let us hope that he may be spared for many years further to enrich us from the horn of his plenty.

But this by no means exhausts Mr. Colenso's claim to rank as an explorer. He was the first to cross the Ruahine Range, making his way more than forty years ago from Hawke's Bay to Wellington. When, in 1841, Sir Joseph—then Dr. Hooker—visited the Bay of Islands in the Antarctic expedition, his constant companion was Mr. Colenso, who doubtless then became first imbued with the botanical ardour which has since shown no sign of abatement.

So far, as has been said, little knowledge had been gained of the South Island, and of its capabilities as a field for settlement almost nothing was known. With the constantly-increasing tide of settlers, and the necessity of locating them, it became almost imperative to search the *terra incognita* lying unexplored, and full of possibilities. Wellington, Wanganui, and Taranaki or New Plymouth were in process of settlement, and now the Nelson Colony, as it was then called, was about to leave the parent home.

In July, 1841, Captain Daniell and Mr. Duppa together made a short cruise in the schooner "Balley" down the east coast as far as Akaroa. The report was not entirely favourable, though the coast between the Kaikouras and Akaroa was considered to be one continuous field for pasturage. Port Cooper was highly spoken of, having 4 to 7 fathoms of water; there was also a splendid district of flat land between the Peninsula and the snowy mountains—this of course was the Canterbury Plains.

The discovery was now made that the representation on the maps of Banks Peninsula having a low sandy neck was quite incorrect, this being, in fact, part of the mainland covered with luxuriant vegetation. Mr. Duppa went about eight miles up one of the rivers which drain the plain, and he and his fellow-traveller concluded that a more splendid field for colonisation could not be found. It was this high character which induced Mr. Deans shortly afterwards to pitch his tent by the banks of this river.

In September of 1842, Captain Smith, the Company's chief surveyor, himself made a prolonged exploration of the east coast of the South Island in a little cutter of 44 tons. His voyage extended over two months, and he sailed as far south as Ruapuke Island, making accurate surveys of the harbours as he travelled down, obtaining latitudes and longitudes, making sketches of all points likely to be useful to the stranger. He sketched nearly all the coast between Otago and Foveaux Strait, correcting for a hundred and twenty miles the great inaccuracies laid down on the map. He estimated highly the character of this long stretch of country. On his return from the south he entered Akaroa Harbour, and here a terrible calamity befel him. A sudden and furious squall struck the little vessel, turning her on her broadside, and she soon filled and sank. By little short of a miracle, all, with the exception of a Native woman and two children who were drowned, managed to get into the boat and were so saved. All Captain Smith's papers, sketches, records, and instruments were irrecoverably lost, and from memory alone was he able to write his account of this voyage.

With the foundation of the Nelson settlement the realwork of exploration and discovery in the South Island undoubtedly began. The preliminary expedition despatched from England on this service was in all respects better equipped than the first, or what may be termed the Wellington one. Captain Arthur Wakefield, a younger brother of Colonel and Edward Gibbon Wakefield, was in charge, and he had under him a very competent and efficient staff—men whose names, amongst others, will ever be connected with exploration in the South—Tuckett, Brunner, Barnicoat, Monro, Davison, and Pelichet. Their discoveries form an extensive and important feature in the history of early New Zealand—so extensive, indeed, that an effort now to give any note of them would prove a trespass on your patience and an injustice to names and deeds so memorable. I shall therefore conveniently close here, and leave my subject, in the hope of again returning to it.

Whilst engaged in the researches which have resulted in these memoranda, and in others equally interesting, the regret has been very keen that no provision exists for the collection and publication of so many early-history matters which now lie buried and all but unknown. This is not creditable, and I sincerely hope that advantage will be taken of this auspicious occasion to initiate a society of this sort whose branches will extend throughout the colony, and whose object will be to collect and record whilst there is opportunity. Should this happy result accrue I need be under no pains to ask your forbearance for the shortcomings of this paper.

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3. *The Exploration of South-western Otago.*

By F. R. CHAPMAM.

THIS paper embraced a description of the alpine district lying to the west of the Waiau River, and its lake-reservoirs, Manapouri and Te Anau, in the Province of Otago, in the South Island of New Zealand, and a history of the efforts made to explore that region.

The district is alpine, though the mountains are not of sufficient height, or the snowfields are too limited, to produce great glaciers such as occur in the Southern Alps of Canterbury, where the range is twice as high.

The writer denies that there is evidence that a true glacial period ever occurred in New Zealand. The alpine district of Canterbury exhibits ample evidence of more extensive glaciation than now exists, and the region described has been chiselled into its present form by the action of a series of great glaciers.

This great ice-extension might have been produced by greater elevation of the land or by some other cause; but the rest of this great Island from the lake district to the east coast shows no satisfactory signs of glacier-action.

The lakes Manapouri, Te Anau, Hauroto, Wakatipu, &c., on one side of the range, and the thirteen sounds or fjords on the other, are glacier-beds of the most marked description.

The climate is humid, and, as a consequence, the district is a forest region. The rocks are generally granites or similar rocks. The scenery is of the most imposing character, whether visited by land or sea, and as a result attracts great numbers of visitors from the neighbouring colonies.

The flora above the forest-level is alpine, and contains many exquisite flowers which are now finding their way into cultivation.

The purpose of the paper is to urge that attention should be paid to encouraging strangers to visit this region, as New Zealand, like Switzerland, will ultimately derive much benefit financially from the visits of tourists. The Government is urged to take steps to make our alpine and forest flora known through the Chicago Exhibition, as a trade in this class of product is already springing up.

A portion of the paper is taken up with details of exploration, and notably with an account of several expeditions which, since Christmas, 1888, have vainly searched the pass between Lake Manapouri and Smith Sound for traces of the late Mr. Mainwaring Brown, Professor of English at the University of Otago, who was mysteriously lost while exploring there.

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4. *Some Notes on the Meteorology and Steam Routes of the Southern Oceans.*

By Captain Crutchley, R.N., F.R.G.S.

It has been suggested, in consequence of the comparative absence of any detailed information respecting the ice-drifts and currents of the South Pacific Ocean, that any information on this subject, however trifling, is valuable, and it is owing to that belief only that these notes are written, although not without the hope that they may be useful when still further information is obtained to discuss with them.

The Antarctic Circle has not up to the present time received anything approaching the amount of attention which has been bestowed on the Northern Polar regions: not in consequence of its being considered of less interest from a scientific point of view,—for, in fact, the opposite opinion may perhaps be justly formed,—but solely because from a commercial standpoint there is not apparently anything to be gained by the exploration of the frozen south. There is no north-west passage to be discovered which shall open up an easier and shorter route to the East Indies, which was the principal reason primarily for Arctic exploration, and consequently there has been no traditional history handed down to the nineteenth century of the failure of our ancestors to discover the road to the South Pole, which would make it a point of honour with their descendants to endeavour to succeed in similar attempts. But yet men have adventured far on the way to the frozen south; and Ross and Wilkes, and still more recently Nares, in the "Challenger," have all left records which will require to be verified when it shall be considered necessary and of sufficient importance to do so; and it would almost seem as though that task were one imposed specially by Nature for the inhabitants of the New World to accomplish, lying as it does at what may be termed the very doorstep of Australasia. The Old World has combated for centuries with the grim horrors of the North Pole, and even now can claim but a small amount of success. Does it not seem fit that Young Australia and New Zealand should investigate and tell us some of the history and secrets of the Antarctic Circle, which by reason of their own geographical position they have the greatest interest in?

And this interest is not altogether one of sentiment only: it is one which in times past has touched the pockets of various portions of the community, as it occasionally does now. Although Cape Horn has ceased to be the main route for passengers from Australia to England since the opening of the Suez Canal, there is still a very large trade both of steam and sailing vessels from Australia and New Zealand that will never use another route unless the Panama Canal be opened; and it almost seems as though New Zealand should be the more interested of the two countries in doing all that may be done to remove any misconception of a route, which may have arisen from an imperfect knowledge of the borders of an unexplored country and sea, or perhaps even from the adoption of a name for that part of the ocean to which, strictly speaking, it has no title, and which is perhaps misleading, for surely no one will seriously contend that the weather even of New Zealand is such as would justify the word "Pacific" being applied to it, and, that being so, one can scarcely expect the change to be for the better when Cape Horn is mentioned in the place of New Zealand; but they are both equally in the South Pacific, and a comparison of the weather experienced at the two places is not so impossible as may be imagined, for there are times in the higher southern latitudes, more especially during the winter months, when the weather for weeks at a stretch leaves little to be desired, the boisterous days being more commonly reserved for the summer. This statement may appear strange to the ears of those who have always been taught to believe that Cape Horn possessed the monopoly of immense seas and fearful weather; but modern vessels and those of fifty years ago make wonderfully different weather of that which they encounter, and to that fact alone may be attributed the different reports of weather experienced in the same locality; and, if a comparison is instituted between the Pacific and Indian Oceans as to which is the more boisterous of the two, the comparison is decidedly favourable to the first-mentioned one. Still, interesting though the physical features of the two oceans undoubtedly are, they must always be primarily regarded as the highway of vessels, and their various peculiarities studied with a view to simplifying as much as possible the difficulties of navigation, and safeguarding vessels to their destination, if such be possible, by giving them the latest and best information obtained of the route on which they travel.

There is just one remark which must be made on the subject of special observations made by any exploring vessel in the polar regions, and that is that for the year that she happens to be there her observations may be perfect, but that the conditions of one year are perhaps very different from those of another; therefore the necessity arises for series of observations extending over many years, if it is desired to obtain any general rules or principles. For instance, the climate of England this year is not a fair type of its usual weather, for if telegrams are to be trusted it is worse than it has been for thirty years; and it would not be correct if it were assumed to be the usual weather. The data from which the deductions in this paper are derived have all been collected during the past seven years.

From the experience gained during that period of time, which has sufficed to traverse the route twenty times, it will be assumed that the Indian Ocean does not offer any great impediment to navigation inasmuch as icebergs are concerned. It has been so long the fashion to select a comparatively low latitude in which to run the easting down that the quantity of ice reported has been small. Of course the adoption of a low latitude has lengthened the passages, although perhaps they may have been made with greater comfort to the ship's companies; but that is at least problematical, and, except in the vicinity of the Cape of Good Hope and the islands to the southward, which appear to be within the influence of an ice-bearing current which has been deflected to the southward and eastward from the Atlantic Ocean, a fairly-high latitude may be safely maintained, and Maury's remarks on the advantages of a high southern latitude if desirous of making a rapid passage appear to be well founded when considered in relation to that part of the ocean between Kerguelen Land and New Zealand. The winds, also, to the southward of lat. 50° S. are generally such as will insure either a sailing ship or steamer making a rapid passage with no more risk from icebergs than is encountered in an ordinary passage by steam from Liverpool to New York. This point is not one which admits of very serious discussion, the high seas and violent shifts of wind one is warned against by the Admiralty's sailing directions being mostly the records of small and in many cases ill-found sailing vessels, and not by any means to be dreaded in a modern and well-fitted steam vessel; so that, in point of fact, the difficulties of a passage across the Indian Ocean may be regarded as no serious affair.

On the other hand, it must be assumed that between Australia and Cape Horn, in certain years, and at certain seasons of the year, it is not possible to make the passage without the risk of encountering ice in either large or small quantities: not that this is necessarily a great hindrance to safe navigation, because it is not really so; and if a greater knowledge of the subject were universal the risk would be reduced to within very small limits, but with our present knowledge of Antarctic meteorology it is impossible to specify the reasons which make one year better or worse so far as ice is concerned. And it is also certain that for many years past there has been an absence of ice on this route in any such quantity as to seriously impede navigation. Last year was, for instance, much worse as regards icebergs than many which had preceded it; but at the same time there were unmistakable signs to such as would accept them as tended to minimise most materially the risks which of necessity had to be encountered. And it is to be greatly regretted that, beyond the log kept in some instances by ships for the English Meteorological Office, there is no common system of record by all ships of such facts as are or would be of interest to the entire civilised world.

In the chart which accompanies these notes there are marked lines of temperature of the sea for all seasons of the year—not isothermal lines, but a record of temperature taken every thirteen nautical miles; and there is a certain amount of difficulty in displaying them clearly on any one chart, even though different colours have been employed in the endeavour to do so. The principle adopted has been to take the first marked fall of the water-thermometer, and then show its mean variations until the normal temperature, or that experienced off Cape Horn, has been reached. The dates appended to the various lines of temperature show the time occupied in passing from west to east, and the other figures are water-temperatures only. It would have been more satisfactory had the temperatures of the air been also shown on the chart, in addition to those of the water; but, unfortunately, time does not permit of doing so in a satisfactory manner; and it may be considered that, although the question of fog in connection with ice is interesting in many ways, it does not possess the importance which the satisfactory solution of the question as to the best route to Cape Horn assumes. It may be here stated that the temperatures are taken by thermometers that have been tested at Kew Observatory; and to an ordinary observer it would appear to show conclusively that at all seasons of the year, and within certain limits irrespective of latitude, there is between the longitudes of 150° W. and 117° W. always a cold ice-bearing current setting to the north-east; and it may also be noticed that, although more contracted in limits as far as longitude is concerned during the austral winter months, it is yet more clearly defined than during those of the summer, though not carrying with it nearly as much ice. This can be easily understood when one remembers that it is usually during the early spring months that the great proportion of polar ice breaks away from its moorings and sets out on its voyage, to end in dissolution.

As nearly as present information enables one to judge, the breadth of this current varies from four or five hundred to twelve hundred miles, the greater breadth being during the spring and summer months. According to the data from which these remarks are drawn—and they are thoroughly trustworthy—this current cannot be overlooked even in the summer, not because of the ice contained therein only, but also because of its peculiar colour, which in two separate years was a dirty ultramarine, and because it contained large quantities of sea-weed and various kinds of floating matter.

Of course, when it is attempted to frame a theory from imperfect data, even in such a science as geology, it is necessary to look round for collateral evidence sometimes, to prove that of which one may feel perfectly convinced in one's own mind. How much more truly will such a remark apply when reasoning about an element that can hardly even be touched with any instrument to serve in place of the geologist's hammer! but there is collateral evidence to be got even here.

There can be no mistake in the recognition of an Antarctic iceberg that has been recently broken from its birthplace; for, unlike the iceberg of the Northern Hemisphere, it is not a detached piece of glacier-ice, but has always the characteristic of being perfectly flat, or table-topped, and it is a somewhat weird sight at times to see these enormous bergs, extending perhaps two miles in length, with the top of this white wall frequently dimmed by what appears to be mist rising from it. This perfectly flat shape lasts until it has reached warmer weather, and the process of decay commences, when one side will gradually sink and expose the flat surface of the top, like the sloping roof of a house, and then follows the first capsize. When that event has once happened they no longer have any characteristic shape, and the most fantastic imagination could not devise any form they will not assume—in some instances, perhaps, slender pinnacles, or enormous arches through which the largest ships could be taken. In point of fact, upon one occasion an arch was measured more than 250ft. in the clear, and over 400ft. high; and from a spectacular point of view there are few objects in nature more beautiful in the sunlight than a partially-worn iceberg, though it is not, perhaps, appreciated so much when contemplated through the blackness of a dark night.

It will be assumed, therefore, for the purposes of this paper, that the shape of Antarctic ice is direct evidence as to the time it has been afloat; for ice encountered in the lower latitudes during the winter months has seldom the characteristics of freshly-broken-away ice, and one particular instance will be chosen to illustrate this:—

As has been previously mentioned, this ice-bearing current assumes its narrowest limits during the winter months. Last April, position at noon of the observing ship was lat. 55° S., long. 140° W., the vessel steaming thirteen knots. Towards 10 p.m. the temperature of the sea-water fell somewhat suddenly from 40° Fahr. to 34° Fahr., and small pieces or bergs were seen. These gradually increased in size as the centre of the current was neared, until they assumed the flat-topped shape, showing that they had not been in low latitudes long enough to have become dissolved, and later in the day again began to get small, and without any particular shape, as the further side of the current was reached, the water rising in temperature at about the same rate at which it had fallen; after which no more ice was seen.

Now, the existence of Humboldt's current has long been a well-ascertained fact, but Maury distinctly states that all information as to the Antarctic currents of the South Pacific is defective at best. These observations now under discussion go a long way, however, to prove that this branch of the current we are now discussing is not the principal one, but is the one which forms a new Sargasso between the latitudes of 40° and 50° S., and longitudes 140° to 178° W. Mr. Maury also states that this new Sargasso "is less abundantly supplied with drift-matter, less distinct in outline, and less permanent in position than any one of the others;" all of which statements are in entire accordance with the theory of a portion of this branch of Humboldt's current recurring to the north-westward, and varying in force in the different seasons of the year.

It will be observed that the water-temperatures from which these observations are made are mostly taken from about the latitude of 55° S., and also it may be noted that no ice has been seen in the course of the last seven years by observers to the eastward of 117° W. long. Now, the principal ice-drift from the Antarctic Circle is undoubtedly to the eastward of Cape Horn, where by far the greater quantity of ice is always encountered by sailing vessels; and, indeed, it may perhaps be assumed that Humboldt's current expends itself principally in the South Atlantic, and that this portion of it existing between long. 150° and 120° W. is but an offshoot. Furthermore, although this current (Humboldt's) is by no means a sluggish one, it is not considered by Maury to be infested with ice. He concludes that the launching-place of Antarctic ice is too far to the eastward to trouble the route much between New Zealand and Cape Horn, for he says it is rare to see an iceberg in Humboldt's current so far from the Pole as the parallel of 55° S.

Mr. Towson, some fifty years ago, from the best data then at his disposal, calculated that the drift of an iceberg was, under ordinary conditions, towards an east-north-east direction, and its rate of progression was about twelve miles per day. This, of course, is a difficult matter to define, depending, as it must necessarily do, upon current principally; for when the bulk of an iceberg below water is considered, with the small proportion of it shown above and exposed to the wind—about one-eighth—it will be at once seen that all drift to the northward must be accounted for by current, though its progress to the eastward may perhaps be accelerated by the prevailing westerly winds of the vicinity.

Assuming, therefore, that the foregoing premisses are correct, we have the fact that this ice-bearing current, no matter what it may be called, is setting to the northward of east, that icebergs are fairly confined within its limits, and that the further north it reaches the more the ice is scattered, until it is finally dissolved in a low latitude. That it finally recurves to the north-west may perhaps be demonstrated, and that it is clear that the great mass of ice taken up to the eastward of Cape Horn is taken there by an agency other than the current now under discussion; for ice, having once attained the latitude of 55° S. in the middle of the South Pacific, can never be carried round Cape Horn.

There have been many theories started, in connection with ice-navigation, as to the value of the thermometer as a means for its detection, or indicating its immediate vicinity; and these theories, like many others, are some of them capable of interpretation either way. For example, the question may be asked, Will the temperature of the water denote the presence of ice? The answer may be unhesitatingly "No." An iceberg may be fairly closely passed, and the temperature of the water not fall below 45° Fahr. when alongside it. That would be a stray berg that had got into an eddy current from its ice-bearing one. On the other hand, if surface temperature be constantly and carefully taken—say, every hour—and the water is found to drop suddenly five or six degrees, so as to reduce its reading to below 40° Fahr. in two or three hours, it conveys in the clearest manner a warning, which, especially in the night-time or foggy weather, is not to be disregarded with impunity; and thus far the thermometer is a valuable instrument, regarded as a means of detecting ice, by showing that a vessel has entered a polar current which in all probability contains icebergs. But it will be found in practice that a sensitive thermometer exposed to the air, and frequently consulted, will give at least equally reliable information; and a fluctuation of two degrees, even, in a thermometer so exposed below the normal temperature conveys unmistakable information. This, at least, is certain: that the darkest night cannot conceal ice, provided that it be above water and the atmosphere fairly clear. And if the condition of weather does not comply with this one requisite when the warnings of ice are present, the sooner any ship stops the better for all on board her. In even moderately clear weather it can always be seen by a good look-out in time to avoid it.

In clear calm weather, also, ice will give back a distinct echo to the sound of a steam-whistle; but, until it is ascertained beyond doubt that fog does not vitiate this safeguard, it is not worthy of being implicitly trusted.

Therefore, when the question of the best route over this vast tract of sea is under consideration, one is brought to face one of two alternatives: whether will you choose a lower parallel, on which you will run hundreds of extra miles, with the chance of danger not well indicated, supposing it to be present, in the form of ice carried to the northward and distributed over a wide tract by an eddying and weakening current; or will you, by boldly facing the difficulty, cut through that current at a comparatively narrow part, where all the indications of any trifling danger that may exist are well defined, palpable, and to be easily guarded against, whilst by so doing you save some hundreds of miles? The answer can scarcely be doubtful: the difficulty, if fairly met, is conquered at once, and practically is not worth more than fair consideration.

Furthermore, it must be admitted that, considering the data at his disposal nearly forty years ago, Mr. Towson made a wonderfully correct estimate of what the dangers amounted to on this route, and, in fixing upon 57° S. lat. as the proper latitude in which to run for Cape Horn, came to a conclusion which cannot be found fault with, and of which all recent experience has proved the correctness.

There is, however, no necessity why any doubt or uncertainty as to the physical condition of the lower half of the South Pacific Ocean should any longer exist—at least, so far as the route between Australia and Cape Horn is concerned—for this reason:—

It has become the fashion now in the North Atlantic trade to pay special attention to the reports of fast steam-vessels, whether arriving either in England or in America; and to such perfection is this system of reports brought that vessels leaving either America or England for the direct passage across are thoroughly posted before their departure in all the impediments they are likely to meet with on their passage, whether it be ice, or a derelict ship, or a broken-up wood-raft; and their information is seldom more than a week old. Now, there are not many routes in the world where ice plays so important a part as it does in both the North Atlantic and the South Pacific, and therefore, if a system of reporting is found to be of service on one route, it may be fairly asked whether it is not possible to use it with advantage on the other.

And it could be fairly effectively done in a very simple manner by these means: If that part of the ocean lying between New Zealand and Cape Horn were mapped out on a chart into squares, each square with a telegraphic code-word assigned to it, and all steamers leaving New Zealand for Rio de Janeiro were supplied with a copy of this chart, they could, on arriving at Rio, if they had encountered ice, send in their homeward telegram the word or words representing the squares in which ice had been seen; this word or words would be repeated back to New Zealand, and a very simple process of working backwards would give both date and position for the benefit of the next vessel to sail; and the news would probably be not more than fifteen days old. This would be extremely valuable as a warning to vessels to exercise additional precaution when in the vicinity of the reported position; and also they would be able to calculate with fair accuracy where the ice was that had been reported.

When it is remembered that there is a steamer leaving New Zealand for Rio nearly every week, the value of the plan which I propose is apparent.

It may be contended that the expense of such a system of reporting would be more than the absolute risk to shipping justifies. It may perhaps be so; but £300 per annum would be the extreme cost for telegrams, and the work might well come within the scope of the Meteorological Office at Wellington. The insurances of some of the lately missing vessels would pay a number of three hundreds a year; but, irrespective of any such trifling detail, this time would appear to be particularly suitable for the introduction of some such system. Australia, by its co-operation with New Zealand in the matter of the light on the Snares, has frankly admitted its liability to assist in removing any difficulty which exists on the Cape Horn route; and it is an extremely pleasing thing to see: and if, in addition, Australia and New Zealand would co-operate in solving the mysteries of the Antarctic Circle, they would win for their new world a peaceful victory which would outshine in splendour many of the warlike achievements of the old.

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5. *Notes on the Geographical Knowledge of the Polynesians.*

By S. Percy Smith, F.R.G.S.

Part I.

In presenting the following notes for the consideration of Section E, I will preface my remarks by saying that the subject is one which has occupied my spare moments for some years past, and, notwithstanding the fact that I have been, and continue to be, always on the watch for information which will complete our acquaintance with the state of geographical knowledge of the Polynesians, the point at which I have arrived so far leaves a very great deal to be desired. The only excuse which can be offered in bringing the subject forward at this imperfect stage is the hope that many of those who have the opportunity will be induced to supplement the information already collected, or will correct errors which their wider knowledge may enable them to detect. We may thus in the course of time acquire a great deal of knowledge, which will prove of utility in the extensive field of inquiry which is still open to us for the solution of many questions relating to the Polynesian race, its origin, migrations, antiquities, religion, customs, habits, &c.

It is obvious that a full acquaintance with the state of geographical knowledge of the Polynesians will involve that of their origin, and at the same time throw light on their migrations from island to island; and this, again, will elucidate the history of the people in point of time: so that, if ever a history of the South Seas comes to be written, the inquiry which we are entering on should form a very important branch of the subject, supplying, as it were, the framework on which other lines of research must be built up.

The period in the history of the race to which these notes refer is that just prior to the discovery and exploration of the numerous groups of the Pacific by the expeditions sent out by various European nations at the end of the last and the beginning of the present century, or, in other words, before the native traditions had become open to suspicion of being mixed up with a later knowledge of places, acquired from the explorers themselves, or from the visits of the islanders to other lands on board European vessels. The sources of this information are the traditions, chants, and poetry of the people themselves, of which, happily, many have been preserved to us by the care of the early European residents in the various islands. It is to be regretted, however, that this statement can only be applied to some of the groups. Unfortunately, many of those who had opportunities of securing the vast stores of interesting information relating to the ancient state and knowledge of the Polynesians, have not always availed themselves of the chances which were open to them in the early days of intercourse with the islanders; and now the time has passed when much can be secured. The knowledge formerly possessed has passed away with the old priests and chiefs, who were the repositories of their histories. Even in the group which earliest of all became best known to us—I refer to the Society Islands—and about which most has been written, less is known of the ancient chants, traditions, and poetry than of many other islands. Fully as we are acquainted with the customs, religion, language, &c., of Tahiti, the traditions and histories as related by the natives themselves have never been given to the world—we have but brief references to them in the works of Ellis, Moerenhout, De Bovis,* and others. In this respect, perhaps, the Sandwich Islands, the Hervey group, and New Zealand are the only ones where the ancient lore of the people has been preserved in full by the zealous care of a few enlightened individuals, whose names will be for ever honoured for the services they have rendered to science in this respect.

The subject of the geographical knowledge of the Polynesians is, as I have said, intimately connected with the origin of the people, but I do not propose to enter into that question here any further than incidental reference may require. It has already been dealt with very fully from various points of view by several authors, notably by Hale, Quatrefages, Fornander, Fenton,† and others, amongst whom perhaps we ought

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* "Polynesian Researches," by W. Ellis; 2 vols.; London, 1829. "Voyages aux Îles du Grand Océan," par J. A. Moerenhout; 2 vols.; Paris, 1837. "État de la Société Taïtienne," par M. de Bovis, *Revue Coloniale;* 1855.

† "Ethnology and Philology" of the U.S. Exploring Expedition; Philadelphia, 1846. "Les Polynésiens et leurs Migrations," A. Quatrefages; 1 vol. 4to; Paris, 1866. "Les Hommes Fossiles et les Hommes Sauvages," A. Quatrefages; 1 vol. 8vo; Paris, 1884. "The Polynesian Race," A. Fornander; 3 vols. 8vo; London, 1878–85. "Origin and Migrations of the Maori," F. D. Fenton; 1 vol. 8vo; Auckland, 1885.

to class Dr. A. Lesson,* whose peculiar views, however, render his otherwise very valuable work of little direct assistance towards the solution of the question. The consensus of modern opinion is, however, unanimous (with the exception of Dr. Lesson) that the race came from the East Indian Archipelago. Beyond that, and as to where the people came from before their sojourn in that part of the world, opinions differ materially. Perhaps the time has not yet arrived for settling the question definitely.

In attempting to learn something of the geographical knowledge of the Polynesians at the period referred to there are certain difficulties which meet us at the outset, over and above that which has been already mentioned as the want of published works on the traditions, poetry, &c., of some of the groups. The probability is that the people migrated from the Eastern Archipelago in more than one party, or *heke*—to use an expressive Maori term—and at periods separated by several generations the one from the other, and that they came to the islands where we now find them by different routes, which here and there crossed, or for a time were identical. It thus becomes apparent that the names given by the first arrivals to places which they discovered on the route would be unknown to those who followed, and so separate and distinct names would be given to places already known.

We thus have a cause of confusion which it is rarely possible to overcome. Even in the after-intercourse that took place between the first and subsequent *hekes*, when meeting on some of the islands in their voyages, although these differences of nomenclature might for the time have been cleared up to the people themselves, in the process of time each particular *heke* would retain in its own traditions the names originating with it. There is no doubt that some of the *hekes* made lengthened stoppages on such of the islands as suited them for the time, until from various reasons they would be driven further afield. Such reasons, amongst others, would be war, famine, the increase of population, or, perhaps, as much as anything, the love of exploration which has evidently been a characteristic of the Polynesians from the earliest times. Thus, in the process of time the whole Pacific became peopled, the migrations going on from the earliest times, which, if we follow Fornander, would be about the second century of our era, up to the beginning of this century. I would remark *en passant* that Fornander arrives at this date by allowing thirty years to a generation, a number which is, to my mind, too high when applied to the Polynesians, as it is known that they married early. Twenty years seems

* "Les Polynésiens," par Dr. P. A. Lesson. 4 vols. 8vo. Paris, 1885.

to me a more reasonable number to allow, and, if so, then the date at which the people entered the Pacific must be altered to about the beginning of the eighth century—at any rate, so far as the *heke* which first settled at the Sandwich Islands is concerned. Whilst, however, believing that the migrations from island to island have gone on almost uninterruptedly up to within quite recent times, it would appear from the many traditions we possess that there was a period in which, from some cause or other, a very great activity took place, resulting in many of the principal groups becoming settled, or having fresh accessions to their numbers from without, or in which mutual and frequent visits took place. This period, which denotes that at which the race had arrived at its highest powers of navigation, was between the twentieth and thirtieth generations back from the present time, or, in other words, during the fourteenth and fifteenth centuries. Since then the intercourse seems, between many groups, to have ceased.

There is another cause of difficulty in reconciling the names given in the traditions, but it is one that may be overcome as further knowledge is gained; and this is, that the names of islands and places change from time to time, or have additional names given to them. It does not therefore follow that the present names are those by which they were known at the time of some of the migrations, and hence, unless the ancient names are known to the present inhabitants, they would only be retained by the emigrants. The causes of these changes are not always apparent, but are probably due to the well-known custom which obtained amongst all branches of the Polynesians of altering the name of any thing or object when such name entered into that of one of their *tapued* chiefs or *ariki;* or, on the other hand, it may have been due to the occurrence of some notable event in the history of the people.

Frequently these several names are in use at the same time; at others, one becomes more popular, and replaces the older one. As instances of these double names may be cited *Havaii, Ioretea,* and *Raiatea,* all belonging to one of the Society Islands. In New Zealand the North Island is called *Te Ika a Maui,* the South Island *Te Wai Pounamu;* and both are included in the general name of *Aotearoa,* which, however, appears to have been simply *Aotea* originally, for the *Moriori* of the Chatham Islands, who undoubtedly migrated from New Zealand, know it only under the latter form, just as they know the South Island by the name of *Aropaua,* and not *Te Wai Pounamu. Nukuroa* and *Ukurangi* were also ancient names of New Zealand, which have now become quite obsolete. (See note No. 40.)

There is a further difficulty which should be mentioned, due to the changes in the languages—or dialects—themselves since the time of separation of the several branches; so that names which are known in, say, Tahiti in one form have at first sight quite a different appearance when written or sounded in the dialects of other places. For instance, it is not apparent to the casual observer that the name *Tahiti* should be written and pronounced *Kahiki* in the Sandwich Islands; nor that *Rarotoa*, of Tahiti, should be written and pronounced *Rarotonga* by the Hervey-Islanders and Maoris of New Zealand; nor that *Karika*, of Rarotonga, should be written by the Samoans as *Sali'a*. This is, however, a difficulty that is easily overcome by knowing the peculiarities of each dialect. A greater difficulty is found in recognising native names written down by Europeans from what appeared to them to be the sound of the words, and before the Polynesian language had been fixed in their orthography by the excellent system which now prevails. In these dialectic differences, however, we may see in names preserved in different forms a guarantee of their authenticity.

If such differences are in accordance with the genius of the dialect in which they are preserved, they offer a convincing proof against the statement more than once made to the effect that the Polynesian knowledge of countries other than their own has been gained from the Europeans, or from natives who have visited other islands in whalers. To illustrate this: The Rarotongans would not refer to *Upolu*, one of the Samoa Islands, by the name of *Kuporu*, as they do, if they had learned the name in modern times; they would find no difficulty in pronouncing the name as used in Samoa, though the Samoans might find a difficulty in pronouncing the word as in Rarotonga, the former people having lost the "k" in their dialect. Numerous other examples of the same nature might be quoted, some of which will appear in the list of names given further on.

In identifying the names of places, some attention has to be paid to the peculiar consonantal and vowel changes which take place in the Polynesian languages, the laws of which are little known at present, but the study of which will well repay the time devoted to it. The following will illustrate my meaning. Few would recognise at first glance as words absolutely identical the following: *Marino* and *aio*, meaning calm; *karewarewa, kaeaea* (in Maori), or *aeaea* (in Tahitian), meaning a sparrow-hawk—words in which the consonants have disappeared by a process of decay, leaving the vowels and the meaning quite intact.

To any one in these days looking at the class of vessel now employed by the Polynesians all over the Pacific, and considering the distances that separate the various groups, it would appear impossible that the people could ever have made the lengthy passages enabling them to acquire the geographical knowledge with which they must be accredited at the date of their first intercourse with Europeans. But we are too apt to forget that in former times they had a class of canoe—in most islands called a *pahi*—which was immensely superior to those of the present day, and capable of containing a large number of people and abundant provisions. The great double canoe, with its platform extending from vessel to vessel, on which was erected a house, was also suitable for performing long voyages. It was in canoes such as these that the Maoris made the long voyage from the Pacific islands to New Zealand, and no doubt, also, the same style of craft conveyed the Moriori across the boisterous five hundred miles of sea between New Zealand and the Chatham Islands. The Maori traditions make special mention of these double canoes, and, further, state that one—the *Arawa*—had three masts. They have long since disappeared, though in the time of Tasman and of Cook they were plentiful on the coast. The canoe in which *Karika*, of Rarotonga, made his several voyages of discovery is said to have had two masts, and to have been able to carry a hundred and seventy men—the favourite number for a war-party or other expedition—and it must have been a vessel of fair seagoing qualities if, as the Rev. W. Wyatt Gill* relates, he made eight different voyages between Samoa, Rarotonga, and other islands. Mr. Ranken† quotes a voyage made by *Auenga*, of Tahiti—an ancestor of *Tangiia*, the leader of the Tahitian party who finally settled down at Rarotonga with Karika—which was related to him by the Rev. James Chalmers, as follows—which I quote to show the length of voyages the Polynesians could in old times undertake: "Auenga was a chief who sailed amongst other lands. He was from *Avaiki* [read here *Savaii*, of the Samoa group, which the Rarotongans would pronounce *Avaiki*]. He sailed first to *Tonga*, and from *Tonga* to *Vavao*. Thence he tried to return to *Avaiki*, but could not make the land. He was blown about by the winds, and could not make the land; but the god *Rongomatane* took pity on him, and directed him to *Tongareva* (Penrhyn Island). He next visited *Rimatara*, *Rurutu*, and *Tubuai* (Austral group), where he got fire. From *Tubuai* he sailed to *Aka-au* and *Paumotu*, and at last reached Tahiti, where he settled on the lands called *Puna-auia*."

Now, this voyage, undertaken, in a measure, unpreparedly, extended over a length of about four thousand miles. Taking the most direct routes, for the greater part of the way *Auenga* would have to struggle against the trade-winds: indeed, it is

* Vol. ii., Rep. Aust. Assoc. Adv. of Science, p. 634.

† "Mahori Migrations," by W. H. L. Ranken, in vol. i., *New Zealand Magazine*.

obvious, from the course followed, that this was the reason of the long *détour* he made to the south of his proper course.

Even the single canoes of the Maoris were sometimes of great size: the remains of one were still to be seen at Hauraki in 1855, which measured 110ft. long, and was capable of holding a hundred and fifty men and their provisions on a coasting voyage.

The records of these ocean voyages, even in the days of decadence of the people's knowledge of navigation, are so numerous that there is no longer reason to doubt their powers in this respect; whilst, if we go back to the period of twenty to thirty generations ago, which I have indicated, we are forced to the conclusion that they were actually in advance of some nations calling themselves civilised, in their ability to traverse large extents of the ocean, and not only that, but to find their way about with a degree of certainty quite unexpected. The fact that we find this homogeneous race living on almost every known island of the vast Pacific is a sufficient proof of their powers of navigation; for we may, I think, discard the other theory which has been proposed to account for their dispersion, such as enunciated by Dumont d'Urville and Moerenhout—viz., that of a submerged continent, of which the existing islands are but the mountain-tops appearing above the waves, and to which the people retired as the waters gradually arose and swallowed up their former homes. Examples without end might be quoted to show the extent to which the Polynesians were able to navigate their canoes to great distances, and of their ability to find their way about over the ocean without the aid of compass or log, guiding themselves by the sun, the moon, or the stars—for all the principal ones of which they had a name—or in cloudy weather directing their course by the regular roll of the waves before the trade-wind.

One of the captains of the Union Steamship Company told me that he had seen in Fiji a rude chart used in their navigation, in which the constant movements of the seas driven before the trade-wind were shown by parallel strings stretched on a frame, and on these the positions of numbers of islands were indicated in their relative positions by little pieces of wood. The routes from island to island in many of the groups were well known, and the starting-points had characteristic names. For instance, there is a place on the east coast of New Zealand known to the Maoris as the starting-point for *Hawaiki,* their original home from which they immigrated here. In *Atiu,* Williams, in his "Missionary Enterprises,"* tells us there was a starting-point from which departure was taken for Rarotonga; and it was by leaving that place and following

* "A Narrative of Missionary Enterprises," by Rev. John Williams. London, 1846. Page 82.

the directions given by the natives that he discovered the latter island.

In the Sandwich Islands, on the little island of *Kahoolawe*, is a place called to this day *Ke-ala-i-kahiki*, "the road to Tahiti," from which the ancient voyagers started on their long journeys of 2,380 miles to the latter island.

It is well known that in ancient times the teaching of astronomy was an important part of the education of the young men. This knowledge was taught, together with that of other things, in a building set apart, called by the Maoris *wharekura*, which may be looked on as a Polynesian college, where the learned priests acted the parts of professors.* Nor was this cultivation of the knowledge of astronomy confined to New Zealand. I have quite recently come across a short paper written by S. M. Kamakau, a learned native historian of the Sandwich Islands, the translation of which we owe to Professor W. D. Alexander, the Surveyor-General of Hawaii. The paper is a code of instructions for the study of the stars, from which I quote the following extract, as showing the extent to which these people were acquainted with the subject: "If you sail for *Kahiki* you will discover new constellations and strange stars over the deep ocean. When you arrive at the *Piko-o-wakea* (equator) you will lose sight of *Hoku-paa* (the North Star), and then *Newe* will be the southern guiding-star, and the constellation of *Humu* will stand as a guide above you."†

The provisioning of the canoes for these long voyages must have been a matter of difficulty, and especially, perhaps, in the matter of water: indeed, this has been considered by some so serious an objection to the theory of extended voyages as to cause many to doubt, for instance, that the Maoris came to New Zealand in the manner so precisely related in their traditions. But the Polynesians were acquainted with many methods of preserving provisions; and the cocoanut itself would prove an invaluable article of sea-stores on these occasions, inasmuch as it contains both meat and drink. Water was stored in large calabashes, or in specially-made *kumetes*, or wooden bowls, by which means considerable quantities could be carried. Excellent fishermen as all Polynesians are, the sea itself would provide considerable stores on these expeditions, and serve to eke out those the people brought with them from their homes.

From the known length of voyages made, then, there is nothing unreasonable in granting the fact that some generations ago the Polynesians had navigated the greater part of

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* See "Ancient History of the Maori," by John White. Five vols. Wellington, N.Z., 1887–88.

† "Hawaiian Annual" for 1891.

the Pacific. The course taken by the original and different *hekes* from the Eastern Archipelago would bring them, some by the north, some also, doubtless, by the south, of New Guinea (on the south-east end of which some of them remain to this day), to the chain of islands forming the Solomon and other groups in that neighbourhood; and, although they do not appear to have made a lengthened stay in these groups—the islands being already occupied by the Melanesian race—some signs of their sojourn are still traceable, such as in the Stewart Islands, Leveneva or Ontong-Java, and other places. From Fiji—where the people are believed to have made a longer stay —from Samoa, and from Tonga, they explored the surrounding seas to the east and south-east, discovering fresh lands, on which they settled, and from which, again, other expeditions in various directions from time to time departed on further exploring voyages. The course of their voyages having been so far constantly tending towards the east, and the continued discovery of new lands as they progressed in that direction, naturally led them onward in the hopes of making fresh discoveries. A time would come, however, in their easterly course, when the south-east extremity of the Paumotu archipelago would be reached.

Did they extend their explorations further to the east? It would seem reasonable to suppose that they would do so. Up to this point there had been no break in the continuity of islands, and, led on by the hope of fresh discoveries, they would push out into that great solitary stretch of water which, with few breaks, reaches to the shores of South America. Tradition is silent as to whether they reached this great land. The space of ocean may have been too great for them, hardy navigators as they were, and many a brave crew must have perished in the attempt. The distance of the south-east Paumotu Islands from the American continent is about four thousand miles; and, although the Polynesians have gained Easter Island, a good third of the way across, there is nothing to show positively that they reached the mainland. On the other hand, there are some things which render it not impossible that they did so. It has been frequently noted that the garment called *tiputa* in Tahiti and some other islands is an exact copy of the poncho of the ancient South Americans; and many have seen in the shape of the Polynesian *marae* evidence of intercourse with the people who built the *teocali* of Mexico and Peru. Again, the question of the origin of the *kumara* or sweet potato (*Convolvulus batatus*) is still one, I believe, on which botanists have some doubts as to whether it is a native of South America or of eastern Asia. In the former case, its wide distribution all over Polynesia as a cultivated plant testifies to a connection with America in very early days, or the plant may have been carried by the Polynesians to America. The fact that some of the native races of Peru call the plant by the name *umar*, which is very like *kumara*, or, as it is called in some of the islands, *umara*, is either an extraordinary coincidence or indication of a common source from whence the name was derived.* In the Rev. R. Taylor's "Ika-a-maui," he relates the following tradition, which he learned from an old Maori of the Rarawa: "In a neighbouring island from whence they [the Rarawa Tribe] came were beasts which carried men on their backs; and in some of the islands were axes having holes in them, through which the handles were thrust; and in one island, men who wore no clothing and were perfectly black; in another, men with sandy hair, who had nuts with oil in them." Mr. Taylor is not always quite safe to quote—at any rate, as to the deductions he draws; but we possibly have here a confused tradition of the *llama* of South America, besides a reference to the Melanesians with black skins, and to the cocoanut of Polynesia. Sufficient proof, however, is yet wanting to decide the question as to whether the Polynesians ever reached America. Long as the voyage of four thousand miles may seem, and against the trade-winds too, that performed by *Tukuiho* and the people of Rapa Island when they sailed in the same direction from their island home twenty-four generations ago, and discovered *Rapa-nui*, or Easter Island, does not fall so very far short of it, the distance being about 2,520 miles, without any intervening resting-places.

The well-authenticated voyages between the Sandwich Islands and Tahiti, a distance of 2,380 miles, as related by Fornander, show also the extent to which this people were masters of the sea. In this latter case, however, there are a few little islands on the route, which the voyagers would no doubt know of—a fact which is proved by finding remains of native occupancy in the shape of stone axes, graves, and other things.

Again, to the north of the Paumotu archipelago lies the Marquesas group, which was discovered and settled early in

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* Quatrefages, in his "Les Hommes Fossiles et les Hommes Sauvages," page 411, in writing of the plants in common use in Polynesia, says, "The *kumara* has been regarded at different times as originating in Asia or in America, but not a botanist has assigned Polynesia for its birthplace; and De Candolle is inclined to think that it is indigenous to both continents. At the same time he admits that it has been described in a Chinese work of the second or third century. It was therefore known in China before the Buddhist missions, which have taken the Asiatics to America, and of which the reality, a long time discussed, seems to me to have been placed beyond doubt at the present day. (See 'Fusang, or the Discovery of America by Chinese Buddhist Priests in the Fifth Century.' By Ch. Leland.)"

the history of the migrations, if we may believe the more than usually minute account of their voyage given by Fornander, and the lengthy genealogy preserved by the people.

In this account of the two expeditions the names are given of fourteen different resting-places by one account and eighteen by the other. Of these, only two, or perhaps three, can be identified with certainty, and this well illustrates the remarks made previously, to the effect that the names of places change, and the ancient ones come to be known only to the emigrants. No doubt this long list of islands at which the people stayed for a longer or shorter time carries back the history of their voyage to far-distant lands in the Eastern Archipelago, but at the same time it clearly indicates the route taken during the latter part of it, which was through Fiji, Tonga, and probably Samoa. From Marquesas—or *Aoma'ama,** as the natives call it—the explorations extended northwards to the Sandwich Islands, or *Hawaii*, a distance of some 2,400 miles, for there is to be found in the traditions of the latter islands mention of names of islands in the former group: indeed, it is known by tradition that voyages to and fro were occasionally made by both peoples during the golden age of their knowledge of navigation and seamanship—*i.e.*, about from twenty to thirty generations ago. At this period, also, voyages were frequently made between the Sandwich Islands, Tahiti, Samoa, and the other groups: indeed, many of the Hawaiians trace their descent from settlers arriving from the southern isles at this time. It would be also at that period that the Maoris of New Zealand acquired a knowledge of people's names who were also known to the Hawaiians, and whose exploits have been handed down in the traditions of both races. This knowledge was acquired at their common meeting-ground of Tahiti and the neighbouring islands.

To the southward of Tahiti, at some six hundred miles distance, lies the Hervey group, the principal island of which is Rarotonga, which was discovered, according to the tradition related to the Rev. J. Williams in 1823, and since often verified, by *Karika*, who, sailing from *Manu'a*, in the Samoan group, twenty-nine generations before Williams's visit, found the island, and took possession of it. On his way northward Karika fell in with *Tangiia*, a chief of Tahiti, who, like Karika, was on an exploring expedition to find a new home for himself and followers, he having been expelled from Tahiti by his brother *Tu-tapu-aru-roa*, on account of a quarrel about land.

These two *hekes* settled down together at Rarotonga. It is from these same people, a few generations later, that some of

* The apostrophe here indicates the dropping of the "r," common to the Marquesans. In Maori, the word *Aomarama* is of common use, and means "the world," or "the light world," or "daylight," in contradistinction to "Po," or "night," or Hades.

the Maoris of New Zealand derive their origin, if we may believe their traditions, which are supported by the remarkable similarity there is in their languages and customs. The Rev. W. Wyatt Gill, in the volume of Transactions of the Association for last year, says that the number of generations since the time of Karika should be twenty-five, and not twenty-nine. If so, then Karika discovered Rarotonga about the year 1380, if we adopt twenty years to a generation, which I believe to be about the right length when applied to the Polynesians.

Hitherto we have seen that the explorations have generally taken an easterly, northerly, or southerly direction; but the next voyages of discovery to which I shall refer are in a backward direction, towards the south-west. The Maori traditions, as currently reported, say that New Zealand was discovered by *Kupe* and by *Ngahue* at different times, but before the great migration which took place twenty-one generations ago, and that both of these navigators came to the islands for reasons which, if read literally, appear childish. There is little doubt in my mind, however, that the islands were known and inhabited long before the time of either of these voyagers, and that both of them came with the express object of obtaining the *pounamu*, or green jade, of which they had heard from others, and which was looked on as an article of great value in some of the islands. Kupe is said to have sailed from *Wawau-atea*, and, after coasting round the shores of New Zealand, finally returned to his own country, his place of departure being still called *Te Hokianga o Kupe*, or "The Returning of Kupe;" in which name we easily recognise the harbour in the North called Hokianga. For reasons which are quite too lengthy to quote here, I believe this *Wawau-atea* to be Bolabola, in the Society group. If so, our voyager must have sailed about 2,500 miles, both going and coming. The great migration which followed these two voyagers is well known: it took place about twenty-one generations previous to 1850, or, if we allow twenty years to a generation, which, from knowing that the Polynesians married early in life, I think to be a fairer number than the thirty years usually assigned as the length of a generation, would make the date about the year 1430. But these people were following in the wake of voyagers who had already discovered the country, and who had given them the direction in which to sail. They came fully prepared to occupy a new country, and brought their wives, families, attendants, and several plants which they acclimatised here, such as the *kumara*, *taro*, *hue*, *aute*, &c., besides dogs, and, as some traditions say, certain birds and plants which are known to be natives of the country. This latter statement has frequently been used as an argument to discredit the traditional account of the origin of the Maoris, as given by themselves; but it is capable of a probable explanation as follows: The introduced plant about which most discussion has taken place is the *karaka*-tree (*Corynocarpus lævigata*), and the birds are the *pukeko* (*Porphyrio melanotus*) and the little green paroquet called *kakariki*. These things are said to have been brought in the canoe *Aotea*, commanded by *Turi*, who, as the tradition states, stayed on his way here for some time at an island called by him *Rangi-tahua*. This name cannot now be identified, but it is not impossible that it may be Sunday Island, which lies just in the course Turi should have followed. If so, then, the *karaka*-tree, the green paroquet, and the *pukeko* are all found in that island, and are natives of it. It is quite probable, all of them being new to Turi, that he brought some of the birds and the seed of the *karaka* with him, and the tradition of his having introduced them to New Zealand may be quite true, notwithstanding that all of them are natives of this country. But Turi was not the only one to introduce the *kumara*. There are very circumstantial accounts of others having done so, and also of voyages made back again to Hawaiki specially to obtain supplies of this useful root.

This migration found a race already in occupation of the country, of which mention is made in the traditions, and from whom many of the chiefs now living trace their descent. I believe this original people to have been of the same Polynesian race as the Maori, speaking the same language, and having much the same customs, but that they were inferior mentally and physically. They became gradually absorbed in the later migrations, by whom they were in a great measure ignored. The Maoris—properly so called—came from a place called *Hawaiki*—a name which was brought by the Polynesians from the Eastern Archipelago, and which, under slightly different forms, is found in most of the groups of the Pacific, either as the name of one of the islands, or as that of a place from which they trace their common origin in the far-distant past. In the case of the Maoris, I feel little doubt that during the later generations they had come to look on this name as a general one applied to the islands of the Pacific known to them; but the particular Hawaiki to which I trace their immediate origin before their migration here is that of Havaii,* or Raiatea, in the Society group, from whence, it will be remembered, the Rarotongans also trace their origin in part. The connection of this name of Hawaiki with the Society group will be shown later on. Here I will merely say that I believe the Maoris to have migrated from both Rarotonga and the Society Islands, their connection with Samoa, which has

* Havaii, of the Tahitian dialect, would be pronounced by the Maoris Hawaiki. The Tahitians have lost the hard sound of "k," and also the nasal "ng."

often been contended for, being merely that of some of their ancestors through Karika and his people, the discoverers of Rarotonga.

I have already made mention of the discovery of the Chatham Islands—the native name of which is *Rekohua*—situated about five hundred miles to the south-east of Cook Strait. At present we have not information sufficiently precise to indicate the period when this group was discovered, though it evidently had been colonised long before the great *heke* to New Zealand in about the year 1430. It is to be hoped, however, that its original discoverer may be known before long, when Mr. A. Shand publishes his work on the Moriori people and their traditions. At about twenty-seven generations ago the Chatham Islands were visited by three canoes, which came, as the Morioris say, from Hawaiki; but previous to that *Kahu* had explored the group, and he found people living there even then. Kahu returned to New Zealand, not liking the islands. (See note No. 37.) The date of this voyage has yet to be settled, and the genealogy which gives the name of the ruling chief at the time of his visit will require correction. It is obviously wrong in some particulars. In its present form it goes back for 154 generations, with, in addition, thirty-one gods before man appeared on the scene—a longer roll than can be counted by any of the Polynesians. It is related in the tradition respecting the three canoes mentioned above as having come from Hawaiki that two of the captains, *Maruroa* and *Rananga*, visited the land of *Tahiri* and *Irea*, from whence they obtained the information about *Rekohua*, or Chatham Islands; and, as the visit of these canoes would be, according to my method of computing dates, about the year 1300, it is obvious that the islands were known at a comparatively early period in Polynesian history. I feel little doubt that the Moriori originally emigrated from New Zealand, a voyage requiring a considerable amount of skill and seamanship when we consider the prevailing boisterous weather that obtains between the two places.

To voyages leading to the discovery of many of the other islands of the Pacific it would be tedious to refer, though many might be quoted, but rarely with the minuteness of detail preserved in the Maori traditions. I have given sufficient examples to show that the Polynesians were a maritime people even before the nations of Europe had passed the stage of mere coasting voyages. They had pretty well explored all the Pacific before Columbus discovered America, and had made voyages quite as adventurous as his, and were possessed of vessels perhaps better able to cope with the dangers of the sea than the old Spanish caravels. It is not at all improbable that they anticipated Columbus in the discovery of America, as they almost certainly did Cook in the discovery of the east coast of Australia, where — I am informed by my friend Dr. Carroll, of Sydney—traces of the Polynesian language are to be found, and where their descendants yet have a tradition of the arrival of canoes from the eastward, the occupants of which settled down there. The fact of the existence of a colony of Polynesians on the east side of Yorke Peninsula is also mentioned by Quatrefages in his "Les Hommes Fossiles et les Hommes Sauvages."

Their voyages must have extended occasionally to the westward of the Fiji group, and probably to New Caledonia and the New Hebrides, where, indeed, a colony of them has been found.* With the exception of New Zealand, the green jade is believed only to be found in these groups, and yet the early European voyagers saw it in the possession of the Polynesians in many of the islands. Allowing that some of it came from New Zealand during the later periods, it would also be obtained from the other islands named. It is known that one of the Loyalty Islands is at present inhabited by Polynesians who arrived there five or six generations ago in one of their own canoes, and that there are also colonies of them in some of the other Melanesian islands to the north. It is even probable that such an isolated little spot as Norfolk Island was first discovered by these old sea-kings in their westerly voyages, for a stone hatchet has been dug up there of the usual Polynesian pattern—a fact which has been verified by Mr. John White, the author of "The Ancient History of the Maori," who saw the implement at Norfolk Island many years ago.

When we come to consider that the Polynesians had a knowledge of the geography of the Pacific extending from the Chatham Islands in the south-west to the Sandwich Islands in the north, from the Solomon Islands in the north-west to Easter Island in the south-east — distances respectively of 4,400 and 6,000 miles—we cannot but wonder that a people apparently in so early a stage of advancement, and without the aid of other instruments to guide them than their own acute senses, should have been able to make such lengthened voyages, or that they could find the same islands twice after voyages extending over days, and sometimes weeks. Like all savage peoples, their perceptions of the signs of nature, whether on the land, the sea, or in the air, were far keener than those of civilised beings. The neighbourhood of land would become to them a certainty long before our duller senses would ever have suspected its existence. The flight of birds, the drift of wood, the fragrance of the land, were all signs full

* "Samoa a Hundred Years ago," by the Rev. G. Turner, LL.D. 8vo. London, 1884. Page 331.

of meaning, and telling their own tale to them, whilst we should not have perceived them.

Many of the discoveries were no doubt made involuntarily, such as in cases where canoes have been blown out of their courses, or driven off the land whilst fishing, &c.; but all the greater discoveries were made by expeditions fitted out for exploring purposes, generally with a view of finding new lands on which to settle, and in which the people carried with them animals and plants to acclimatise in their new homes. The causes of these expeditions were, in general, wars, quarrels about land, supremacy, or over-population, in which the defeated or weaker party left their old homes to find new ones in places of safety from their enemies. Their traditions make frequent mention of these causes, and some give quite minute particulars respecting them.

It has not been my purpose to enter more than incidentally into the question of the dates at which the various groups were discovered or became settled, though the information exists for doing so with some degree of certainty—that is, if we allow to the genealogies of the people the weight that is assuredly their due. The information is not yet complete, but it may be made so, and it is to be hoped that all those who have the opportunity of collecting such information will do so before it is too late. When we come to remember that these genealogies are the only sources from whence the approximate dates of events in the history of the Pacific can ever be fixed, their importance becomes evident. Many of them from each island are required as a check before reliable deductions can be drawn. It is thus, from the mean of a very large number of genealogies, I have been able to assign twenty-one as the number of generations which have elapsed since the great *heke* arrived, and New Zealand was colonised by the Maoris.* It has often been said by those who have paid little attention to the matter that these genealogies are of little value, and that they could not be retained in the memory; but on this subject only those who have studied and compared them can form an opinion. Without going into particulars, for which this is not the place, let me give one instance which will show that by their aid, and by their aid alone, it will be possible to arrive at the relative date of events in Polynesian history. The Maori and the Hawaiian, like many other islanders, have ancestors in common. Tracing the descent from one of their great heroes of old by the genealogies preserved by each of

* Though twenty-one is the mean number of generations since the Maoris settled in New Zealand, it is right to say that such mean is derived from genealogies belonging to the descendants of all the known original canoes. It is more than probable that the arrival of some of the canoes took place several generations after the first ones recorded.

these people, I find that the numbers of generations are as follows: By the Maoris, thirty-three; by the Hawaiians, thirty-four; and there is some reason for believing that this same person was known to the Tongans, thirty-four generations ago. This remarkable agreement shows that there is a value to be attached to these genealogies that might have been unexpected.

I have referred to this subject here, though not immediately connected with that of my paper, as evidence of the authenticity of the oral traditions on which is based the extent of geographical knowledge of the Polynesians. If their genealogies can be shown to be correct within certain limits, their other traditions will be equally so, preserved as they have been with the greatest care, handed down from father to son by a priesthood often specially set apart for this particular purpose. No one doubts that the Iliad was thus handed down from generation to generation long before it became finally fixed in writing, nor should there be any more difficulty in believing that the Polynesian traditions could be preserved in poetry and song in the same manner.

In the foregoing remarks I have confined myself to Polynesia generally—properly so called—and have not touched on the geographical knowledge which obtained amongst the kindred peoples of Micronesia or of Melanesia; nor have I even hinted at the voyages which must have been made by the race which there are strong reasons for believing preceded the Polynesians in the Pacific. Information as to this race is almost entirely wanting. We can, indeed, only surmise that there was such a race from the remains which are found scattered from the Caroline Archipelago to Easter Island. These antiquities are so foreign to the genius of the Polynesian that we are forced to conclude that they had no hand in their construction—a fact which is borne out by their entire ignorance of the meaning of them; nor are they able to give any account of the origin of them. Their presence in so many of the islands occupied by the Polynesians and Micronesians merely serves to excite our curiosity without satisfying it. Let us hope that before too late efforts will be made to preserve all that can be ascertained about them, and thus in process of time we may be able to add another and more interesting chapter to the History of Discoveries in the South Seas.

In the notes which follow I have given the names of places recorded in such of the Polynesian traditions as I have had access to, and as known to each group or island, and I have included amongst them some names the identification of which has not yet been accomplished, in the hope that those who may care to read them will be able to fill up the gap. I am indebted to a large number of authors for the data, besides, so far as New Zealand is concerned, my own notes acquired from the Maoris during the last thirty-five years. The authorities are quoted under each heading.

Places known to the Maoris of New Zealand.

1. *Hawaiki.*—This is the name of the place from which the people derive their origin; it is of very frequent occurrence in their traditions, songs, and poems. The particular Hawaiki to which the Maoris refer I believe to be Raiatea, in the Society group, for the following reasons (among many others):—

The ancient name of Raiatea was Havaii, according to Ellis, and also according to De Bovis, and Mr. James L. Young, of Tahiti.

2. *Rangiatea.*—In 1859 an old Maori of the Puketapu hapu of Ngatiawa, living on the west coast of the North Island, told me that the name of the place his ancestors came from in Hawaiki was *Rangiatea.* Now, if we recollect that the Tahitians do not sound the *ng* of the Maori, the above word becomes at once Raiatea, and it has the same meaning both in Tahitian and Maori. The name does not occur frequently in Maori traditions, the older name of Havaii or Hawaiki taking its place; but in one tradition it is mentioned as the home of *Tinirau,* one of the Polynesian deified chiefs, and the brother-in-law of *Maui.*

It is also referred to in Mr. John White's "Lectures" (Auckland, 1860) as the name of a temple in Hawaiki. This temple, no doubt, has some reference to the very celebrated *marae* at *Opoa,* in Raiatea, which was the scene of so many ceremonies, and the fame of which had reached most of the other groups. It was looked on as a very sacred spot.

There is a Maori proverb which also contains the name —"Te Karaka i ruia mai i runga o Rangiatea," which the Rev. R. Taylor refers to as "a mountain in Hawaiki; too high to be overlooked." This was the motto of one of the tribes.

But to complete the identification would lead me into other lines of reasoning, for which this is not the place.

3. *Wawau.*—A place mentioned in the remarkable voyage made by Whiro and Tura, given in Mr. John White's "Ancient History of the Maori," vol. ii., p. 7, where Whiro is described as leaving his own island for *Wawau.* Whiro, under the name of Hiro, was a deified chief of Raiatea, and has the same thievish attributes as the New Zealand hero, together with the credit of having made some remarkable voyages.

4. *Wawau-atea* is the name of the place from which *Kupe* sailed on his voyage to New Zealand (see several Maori traditions; also Trans. N.Z. Inst., vol. i., p. 23). Wawau

is also mentioned in the celebrated tradition of *Tawhake* ("Ancient History of the Maori," vol. i., p. 108); but in the connection in which it is there used there is little doubt that *Vavao* in the Tonga group is meant. It was also mentioned to me in 1860 as the place from whence came the ancestors of the Ngatiwhatua Tribe, some of whom crossed the seas in the canoe called *Takitumu*; others, it is believed, in the *Mamari.* There are other mentions of the place in the old songs. Taken altogether, this place must be identified with *Vavau,* or Bolabola, of the Society group (Vavau being its ancient name), which is but a few miles from Raiatea. Vavao in the Friendly group was equally known to the Maoris, as mentioned above.

Vavau, like Havaiki, is no doubt one of the names brought by the people from the original home in the Indian Archipelago. Fornander seeks to identify it with *Babao,* the ancient name of a bay in Timor. In the Rev. J. Chalmers's paper on the *Toaripi* tribe of New Guinea, published in the last volume of the Association's Transactions, we find, at page 316, that *Lavau* was the name of the place to which the spirits of the dead departed, and that it was in the west, as usual amongst the Polynesians.

5. *Tawhiti-nui-a-Rua.* 6. *Tawhiti-nui.* 7. *Tawhiti.*—In the story of Pungarehu it is related that he and his companions were blown out to sea, finally landing on a strange land. When asked where they came from, they replied, "We two came from Hawaiki — from *Tawhiti-nui-a-Rua*" ("Ancient History of the Maori," vol. ii., p. 31). It would be interesting to ascertain whether the Tahitians have any tradition of Tahiti ever having been called Tahiti-nui-a-Rua, or Great Tahiti of Rua — Rua no doubt being a man's name, quite possibly Ruanu'u (or, in Maori, Ruanuku), who was one of their gods, or deified ancestors. Tawhiti, or Tawhiti-nui, occurs in several of the Maori poems, where it implies "distance," and is often also given as the name of a place. (See, for instance, "Nga Moteatea me nga Hakirara," by Sir George Grey, p. 21, where it occurs with reference to ancient names of people and places.) Although the word means "at a distance" in Maori, many of the references in the old songs are to the name of a place—such place being Tahiti, of the Society group.

8. *Ta-porapora.*—In "Te Ika a Maui," page 110, is given the following genesis of several lands:—

Ko te rangi e tu nei
Ka noho i a Hawaiki.
Ka puta ki waho ko Ta-porapora,
Ko Tauwhare-nikau, ko Kukuparu,
Ko Wawau-atea, ko Whiwhi-te-Rangiora.

The translation of which is,—

> The sky which stands above
> Dwelt with Hawaiki.
> There came forth Ta-porapora,
> And Tauwhare-nikau, and Upolu,
> And Wawau-atea, and Whiwhi-te-Rangiora.

From the connection here with Hawaiki, possibly this name is meant for Bolabola, of the Society Islands. Wawau-a-tea is certainly the same referred to above, which I have identified with Bolabola.

9. *Morea.*—In the legend of *Hine-i-te-puwha* ("Ancient History of the Maori," vol. ii., p. 159), in one of the incantations, occurs this name. It is possibly identical with *Moorea*, or *Eimeo*, of the Society group. The legend itself bears some resemblance to that published in the first volume of the Association's Transactions, "The Genealogy of the Sun." The man's name, *Rakuru*, is identical with the *La'ulu* of the Rev. G. Pratt. I do not place much reliance, however, on this identification, for possibly the Tahitian *Moorea* should be in Maori *Mokorea*.

10. *Arowhena.*—This is described in the legends of Uenuku (An. Hist. Maori, vol. iii., p. 8, &c.) as a mountain. The highest mountain in Tahiti is Orofena, spelt also by Ellis Orowhena, and by Wilkes Orohena. From the tradition, it was situated on some island distant from the home of Uenuku, which I believe from many things to have been Rarotonga.

11. *Motutapu* is frequently mentioned in tradition and song, especially in connection with *Hine-te-iwa-iwa* and *Tinirau*, whose place of residence was at *Motutapu*. *Rangiatea (Raiatea)* is also mentioned as his home. Within the reef at Raiatea is a small island called Motutapu, and possibly this is the one mentioned in Maori tradition, but the name is such a common one that the identification is uncertain. The name is also mentioned in connection with Tinirau in "Myths and Songs of the South Pacific."

12. *Mata-te-ra*. 13. *Maa-te-ra.*—*Mata-te-ra* is the name of a place in Hawaiki that the *Rarawa* tribe say they came from. In "Ancient History of the Maori," vol. ii., page 182, it is stated that the canoe *Uaki-rere* left Hawaiki and went to *Mata-te-ra* to obtain the taro root, and returned thence to Hawaiki without coming to New Zealand. In "Transactions of the New Zealand Institute," vol. xii., page 161, is a reference to *Maa-te-ra*, no doubt the same place. This latter reference is in an incantation, and there it states that the place was at Hawaiki ("at *Maatera*, at Hawaiki"). I have been unable to identify this name.

14. *Otea.*—This is mentioned in the legend of *Whiro* as the place where *Tura* jumped ashore to avoid destruction, whilst

Whiro continued his voyage to *Wawau,* which we have already identified as Bolabola. On the shores of Bolabola, the chart shows a place called *Otea-vanua,* to which possibly the tradition may relate.

15. *Pape-aia.*—This occurs in one of the legends of *Tawhake,* and is given as that of the village in which he was then residing (An. Hist. Maori, vol. i., pp. 61 and 65). It is probable that the scene of the *Tawhake* legends is laid in Raiatea—at any rate, the Maori version of it leaves that impression—the reasons for which statement are too lengthy to give here. The word *pape,* in Tahiti, means "water," and is found in numbers of cases as forming part of the names of places there. The word is not known in Maori. The similarity to Tahitian names makes it probable that the place was situated in the Society group.

In the list of fifteen names given above, some are certainly identical with those in the Society group, whilst others have only a possible connection. I wish to draw special attention to Hawaiki, Wawau, Rangiatea, Wawau-atea, and Arowhena, which seem to me to be identified with the greatest amount of probability, because, if true, they show an origin for the Maoris not previously hinted at, and clear up doubts that have long been expressed as to the particular Hawaiki from whence they came. There is abundant evidence from other lines of research, all leading up to the same conclusion; but we are limited here to the geographical aspect of the question. I will merely add that two very eminent leaders in the migration to New Zealand—*Turi* and *Ngatoro-i-rangi*—are both known to Tahitian traditions, and, so far as I can learn, to those of no other islands. I will now proceed to show the connection with one of the other groups:—

16. *Rarotonga.*—This name occurs very frequently indeed in Maori traditions and poetry, and it has been applied constantly, also, to places in New Zealand, no doubt in recollection of the Polynesian island of that name. It is expressly stated in the appendix to "Nga Moteatea," page lxix., that it was a sacred spot where was the resting-place (*nohoanga*) of certain gods, some of whom were stolen and brought to New Zealand. In another tradition it is related that some of the celebrated canoes in which the Maoris came here were built at Rarotonga. The following quotation from Sir George Grey's work (already referred to above) shows the knowledge of this island, and of some others: "Otira, ko nga ingoa o nga kainga i haere mai ai i Hawaiki enei tupuna: Ko Hawaiki te tino ingoa nui o aua motu; nga kainga i roto koia enei, *Ko Waerota, Ko Rarotonga, Ko Waeroti, Ko Parima, Ko Manono;*" which may be translated, "But the names of the places in Hawaiki from which these ancestors came are these: Hawaiki

was the principal (or general) name of those islands; the places comprised in it were *Waerota, Rarotonga, Waeroti, Parima*, and *Manono*."

17. *Ahu-ahu.*—This name occurs in the legend of *Paikea*, who is stated to have swum from the Pacific islands to New Zealand. It has quite erroneously been identified with Ahu-ahu, or Great Mercury Island, on the east coast of New Zealand.

Now, the upsetting of the canoe, which gave rise to Paikea's long swim, took place, as related in the *Uenuku* legends, at some of the islands before the migration here; and for very many reasons I believe the scene of Uenuku's adventures, and his place of residence, to have been Rarotonga. Paikea, therefore, in his long swim, did not land at Mercury Island, but at Mangaia, one of the Hervey group situated not far from Rarotonga, the ancient name of which was *Au-au*. Knowing that the Maoris introduce an "h" where the Hervey-Islanders leave it out, we have in Ahu-ahu the exact equivalent of Au-au, or Mangaia. In Sir George Grey's "Nga Mahinga a nga Tupuna," page 40, will be found a lament by *Apakura* for her son *Tuwhakararo*, who had been killed, in which is a reference to this same Ahu-ahu. The incidents related in this tradition took place before the *heke* to New Zealand.

18. *Hikurangi* is mentioned in the traditions, and, as the name implies, is a mountain. In "Nga Moteatea" there are several references to it, and many of them show that they do not relate to places in New Zealand, where, however, the name is a very common one. In the history of *Turi's* voyage to New Zealand is found a mention of Hikurangi, but there is nothing to show where it was beyond the fact that it was some place not far from *Turi's* course, and that he—inferentially—must pass it long before reaching New Zealand. In one of the Uenuku legends *Ruatapu* admonishes *Paikea* when he gets ashore to tell the people of the coming of a great disaster, and advises them to flee to Hikurangi for safety, or they would be drowned in the rising waters. Taken in conjunction with other matters, I identify *Hikurangi* with *Ikurangi*, a high hill in Rarotonga.

19. *Nukuroa.*—In "The Ancient History of the Maori," page 140, mention is made of this place. It may be identical with *Nukuroa*, the ancient name of Mitiaro, one of the Hervey group ("Myths and Songs," page 17); but from the context of the tradition I should be inclined to believe it refers to some place far away in the Eastern Archipelago. Under the various forms of *Nusa, Nuha, Nuhu, Nuka, Nuku, Nu'a, Nu'u*, we find this word extended from the coasts of Asia to the Marquesas, and in all cases it means "an island," or "land," or "the earth." The lesser of the two larger islands of the Ke group,

near the west of New Guinea, is called *Nuhuroa*. It has already been stated that *Nukuroa* is one of the ancient names of New Zealand.

20. *Rangi-riri* is often referred to as a place in "Hawaiki," and, according to Maori story, it is a spring in the sea, the source of all fish. It occurs in many fishing-songs, and in one of the incantations used at the separation of heaven and earth, thus showing it to be a very old name. In one of the Uenuku legends (An. Hist. Maori, vol. iii., p. 42) it is mentioned as the name of a country, and, as I have reason to believe that Uenuku lived at Rarotonga, I think this place is probably identical with Rangiriri in that island, mentioned in "Myths and Songs," page 97, in this quotation: "I te moana i Rangiriri," "In [or At] the sea at Rangiriri." The name, however, is a very common one in New Zealand, and no great weight can be placed on this identification.

21. *Waerota.*—Waerota has already been referred to in note No. 16, wherein it is stated to have been one of the places from whence the Maoris came. In the celebrated chart of *Tupaea*, drawn by him under the eye of Foster and Cook, and which furnishes such an admirable illustration of the geographical knowledge of the Polynesians, I find an island called, in the clumsy orthography of these two great men, *Oirotah*, which has a very great similarity, if not identity, of sound with *Waerota*. If this place, known to Tupaea, was the name of an island it cannot now be identified, and is perhaps an example of what I have already referred to as the changes in names of places that sometimes occur. But I am inclined to identify it with a place in Rarotonga. Thus: In "Nga Moteatea," page 325, in the "Lament of Turaukawa,"—that old poem so full of references to the ancient knowledge of the Maoris,—occur the following lines :—

Pukai rawa atu ki te aroaro o *Matariki*,
O *Herekikini*, o *Heremomotu-kai*,
Momotu tangata ki runga ki *Waerota*,
Nekea e *Puanga* ki runga o *Rarotonga*.

Which, notwithstanding the difficulty and obscurity of Maori poetry, I venture to translate as,—

Were laid in heaps before *Matariki* (the Pleiades),
Before *Herekikini*, before *Here the divider of food*,
Men were cut up [and offered ?] on *Waerota*.
Let *Puanga* remove them to Rarotonga.

Now, *Vairota* is the name of a *marae* in Rarotonga, according to Williams (Miss. Ent., p. 182). It is mentioned as follows, the language being Rarotongan :—

Tera rau kura ui i te atua a Karavai, e !
Kua ki a Vairota, e,
Karo i tutuki tika ia Oromea, e
Te koto ua ra i te Tuporo i Te Manga, e.

What a carrying of bread-fruit leaves is Karavai's to his gods, oh!
He has filled Vairota,
But has not killed completely Oromea,
For he is now drumming and dancing merrily at Te Manga.

In a note Williams mentions that *Vairota* is the name of a *marae*. According to the rules of vowel-changes "e" should not change into "i;" but it is possible Williams may not have caught the delicate difference there is in the diphthongs "ae" and "ai."

In the five names which I have here sought to identify, the two first are almost certainly correct. About the others there is more doubt; but, considering the striking similarity between the Maori and Rarotongan dialects, the express mention of the ancestors of the former having come from the latter place, and the identity of many of their customs, we are warranted in concluding that the Hervey group was formerly well known to the Maoris. There are names of places in both Rarotonga and Mangaia which are common to those islands and New Zealand; and, moreover, one of the Maori ancestors was named Makea, which is the family name of the reigning kings of Rarotonga, and of whom Karika (Makea-Karika) was the first that we know of.

I now proceed to show the knowledge the ancient Maori had of another group—namely, Samoa.

22. *Hawaiki.*—I again refer to this widely-expanded name, but merely to say that the Maoris certainly had a knowledge of *Savaii*, the Samoan representative of the name. It is probable that in some of their traditions where "Hawaiki" occurs Savaii is referred to. Under various forms this name may be traced far back towards the eastern home of the people. It occurs under the following variations:—

Ava, the Kingdom of Ava (?).
Java, the island of that name.
Sawa-i, in the Island of Seran, Ceran, Celam, or Ceram.
Jawa, the Bugis name of the Moluccas (J. R. Logan).
Hawaiki and Kowaiki, west end of New Guinea (Dr. Carroll).
Habai, one of the Tonga group (uncertain if this is identical).
Savaii, the principal island of the Samoa group.
Havaii, ancient name of Raiatea, Society group.
Hawaiki, a place known to the Paumotu-Islanders.
Havaiki, a place known to the Mangareva- or Gambier-Islanders.
Hawaiki, a place known to the Maoris of New Zealand.
Avaiki, a place known to the Rarotongans and Mangaians.

Savaiki, a place known to the Tongareva- or Penrhyn-Islanders.

Hawaii, the principal island of the Sandwich group.

Avaiki, a place known to the Aitutake-Islanders.

Havaiki, a place known to the Marquesas-Islanders.

Havaiki, a place known to the Easter-Islanders.

Hawaiki, a place known to the Chatham-Islanders.

23. *Kuparu.*—There are not many references to this name in Maori traditions or poetry, but in one of the *Tawhake* legends (An. Hist. Maori, vol. i., p. 108) we find it, and, as it is there connected with the names *Tutuhira*, *Vavao*, and *Rarohenga*, of which the first is obviously Tutuila, this must be identified with Upolu, the second island in size of the Samoa group. If we remember that "a" and "o" belong to that series of vowels which mutually and frequently interchange in Polynesia, and that the Samoans cannot pronounce the "k," we have the exact word Uporu in Maori, the "l" of Samoa being always rendered by "r" in Maori.

In Rarotonga the word is *Kuporu* or *Kupolu*. By referring to note No. 8 it will be seen that the word appears as *Kukuparu*. The word *Kuparu* also occurs in a *karakia* given at page 373 of "Nga Moteatea," and these are, with the exception of a song in my own collection, the only cases where I have met with it.

24. *Tutuhira* is found in the quotation above given. It is obviously Tutuila, the third in size of the Samoan Islands.

25. *Manono* occurs very frequently in both traditions and song, and principally as the site of a strong fortress or town which was burnt by Whakatau, a minute account of which has been preserved by the Maoris. It is often called the *Uru-o-Manono*, "the top, or summit, of Manono." Probably the little island of *Manono*, off the coast of Upolu, Samoa, is referred to, which has played such an important part in the history of that group. At the same time, it should be mentioned that there is a Manono in Moorea, Society group, the site of a celebrated *marae* called *Hau-rua-o-Tama* (de Bovis); another in Mangaia; and, again, another in Hawaii.

26. *Parima.*—This is mentioned in appendix to "Nga Moteatea," amongst other places, as one of those comprised in the general name of Hawaiki; and from its position with regard to the word *Manono* I identify it with the celebrated little island-fortress near Manono, off the coast of Upolu, named Apolima. This is the only reference to the name I am acquainted with. Possibly the name *Aparima*, in Southland, New Zealand, is derived from it.

27. *Rarohenga and Rorohenga.*—This name will be found in the traditions of Tawhake, where it occurs in conjunction with Upolu, Tutuila, and Vavao. From this connection, and

from the similarity of sound, I identify it with *Olosenga*, one of the smaller islands of the Ta'u group, at the east end of Samoa. The dropping of the "r" in the Samoan rendering of the name I take to be an illustration of that decay of the consonants so frequently met with in the Polynesian language. "H" is the Maori equivalent of the Samoan "s."

28. *Manuka.*—I only know of one mention of this name as an ancient one, and that occurs in the "*Waiata a Tamangori*" amongst my own collection, where, from the context, and from the mention of Rarotonga, Kuparu, and other old names, I am inclined to identify it with Manu'a of the Ta'u group, Samoa, from which Karika sailed when he discovered Rarotonga.

29. *Whangara.*—Mention is often made of this place, after which Whangara, near Gisborne, New Zealand, was named. It is said to be the place which the canoes from New Zealand returned to in Hawaiki, to fetch the *kumara* root. This may be the Fangala in Upolu, or it may also be Fa(ng)ara, in Raiatea. It would be interesting to ascertain whether in either of these places the *kumara* grows in a semi-wild state; for such is the account of it given by the Maoris.

In these eight names of places in the Samoan Islands, the first five are almost certainly correct as to identity. The Maoris have a great deal in common with the Samoans, as they have with other branches; but there are at the same time such great differences in many of their customs, language, and traditions that there can be no reasonable doubt that they did not migrate from there to New Zealand directly, as has so often been contended.

The next group which I shall consider will be that of Tonga, together with Fiji.

30. *Tonga.*—This name is frequently mentioned in song and chant, and often in connection with *Whiti*. There can be little doubt that it refers to Tonga of the Friendly Isles.

31. *Wawau.*—I have already pointed out in note No. 4 the probability of one or more references to the Island of Vavao, of the Tonga group.

32. *Tuhua.*—This has commonly been referred to Tuhua, or Mayor Island, on the east coast of New Zealand; but from the stories with which it is connected it is much more likely to be *Tofua*, in the Tonga group. There is an old volcano in Samoa also called *Tofua*. In Samoa, in Tonga, and in New Zealand the name is in each case applied to a volcano, either extinct or active. In New Zealand it is also the name for obsidian, or volcanic glass.

33. *Whiti* is frequently named in the old poetry, and refers with little doubt to the Fiji group. *Whiti-reia* is also a

place mentioned—probably intended for one of the Fiji Islands. It is found also with the following adjectives, implying probably that there were several islands: *Whiti-haua*, *Whiti-nuku*, *Whiti-raki*, and sometimes *Tonga-whiti*. I do not, however, place much reliance on these four latter names, as they have also a meaning not applicable to names of lands.

In the notes which immediately follow, I have gathered together a few names of places mentioned in Maori traditions and poems which cannot easily be recognised, or about which there is considerable doubt. I do so in the express hope that some one will be able to throw light on their identification.

34. *Ulimaroa.*—When Captain Cook was at Doubtless Bay, near the north of New Zealand, the Tahitian Tupaea, who accompanied him, asked the Maoris if they knew of any country but their own; to which they replied that their ancestors had told them of a country of great extent lying to the north-west by north, or north-north-west, to which they gave the name of —according to Cook's orthography—*Ulimaroa*, and they added that some of their ancestors had visited it in a very large canoe, that only part of them returned, and reported that after a passage of a month they had seen a country where the people ate hogs. Tupaea thought that the story was false because they did not bring any of the hogs back with them. Cook very pertinently remarks, however, that the Maoris called the hogs *booah*, the name common in the islands, and if the animal had been wholly unknown to them, and they had had no communication with a people to whom it was known, they could not possibly have been acquainted with the name.

Now, if this was the mere recollection of the hog brought with them at the time of the *heke*, the Maoris would not have called the animal *puaa*, but *puaka*, or *poaka*, as they do at the present day; but if they learnt the name some generations after the *heke*, and when the Polynesians had lost the "k" sound, they would pronounce the word just as here given—viz., *puaa*.

The only Polynesian name I know of at all like this is *Rimaroa*, mentioned on Tupaca's chart, and there shown as one of the Paumotu group. But we cannot identify this with the Ulimaroa of the Maori, even if we bear in mind the error in the chart pointed out by Hale, which would make the island to lie somewhere to the south-west of Tahiti instead of in Paumotu.

Cook also tells us that the Maoris of Queen Charlotte Sound, in the South Island, mentioned this same name to him as that of a distant country, and in this instance pointed to the north as the direction of it. Cook adds that Tupaea seemed to have some knowledge of such a place, derived from a confused traditionary account.

So far as I am aware, the name has not been heard since Cook's time—since when, it must be remembered, much of the ancient knowledge of the Maori has been lost.

35. *Hiwa* is found in Maori songs, often in conjunction with other words referring to ancient people, gods, and lands, sometimes with adjectives added, as, *Hiwa-nui* and *Hiwa-roa*. It is possibly a recollection of one of the islands of the Marquesas—*i.e.*, *Hiwa-oa* or *Nuku-hiwa*. In the Hervey group the name *Iva* is supposed by the Rev. Wyatt Gill to refer to Nuku-hiva, of the Marquesas.

36. *Rurutu* occurs in one of the laments given in "Nga Moteatea" in connection with several ancient names—"Ki te takutai o Rurutu," "On the seashore of Rurutu." Can this be Rurutu, one of the Austral group, near the Hervey group?

37. *Taranga*.—From the fact of this name occurring in the tradition of the Creation (An. Hist. Maori), it is evidently very old indeed. If we remember that in Hawaii the "k" replaces the Maori "t," and that the people of the former place use "n" for "ng," we shall recognise *Karana*, of the Hawaii traditions, one of the original homes of the people on the far-distant shores of Asia.

38. *Nuku-te-rea* occurs in the tradition of *Tu-taka-hinahina* (An. Hist. Maori, vol. ii., p. 51), with two other lands or islands (*Nuku-te-iki*, *Nuku-muru*). In Fornander, vol. i., p. 175, the original home of the *Take*, or Marquesans, is called *Take-hee-hee*, in which was a place called *Nu'u-teea*. The Marquesans do not pronounce the "r;" consequently *Nu'u-te'ea* becomes *Nuku-terea*, identical with this Maori name. The Maori tradition, however, is probably of later origin than their migration from the Eastern Archipelago, and the locality must be looked for in nearer lands. At the same time the incidents related have a very archaic tone about them; some of them clearly relate to a great volcanic outburst.

The notes above given—which are, I acknowledge, of unequal value—taken altogether, show that the Maori had an extensive knowledge of the Pacific islands, inasmuch as it included Fiji, Tonga, Samoa, Tahiti, Rarotonga, and possibly the Marquesas, and some lands in the Indian Archipelago. From other lines of reasoning it may be shown that they were acquainted with the Hawaii Islands; but, as the evidence is not in its nature geographical, I do not refer to it here.

Places known to the Moriori of the Chatham Islands.

In what follows I am indebted almost entirely to information supplied me by Mr. Alexander Shand, of Whangamarino, Chatham Islands. The references are very few, but they will, let us hope, be greatly supplemented by Mr. Shand's own work which he is now engaged on. Having resided on the islands myself for twelve months in 1868–69, I obtained some acquaintance with this ancient branch of the Polynesian race; but, not having the present inquiry in view, I omitted to obtain the information which would now be to me so valuable. The study of this people will prove of great interest when their traditions and knowledge become known, for it is believed with strong reason that they represent that branch of the race which occupied New Zealand before the migration of the Maoris in 1430. There are very considerable differences in their physique, appearance, customs, habits, and language, which separate them from the other Polynesians by a wide gulf—so much so as to render the result of Quatrefages' study of their craniology quite probable, and in keeping with his theory that they have a taint of Melanesian blood in their veins. The greater interest attaches to this people from the melancholy fact that they will be extinct within the next few years. In 1862, when a census of them was taken, they numbered 160. Last year Mr. Edward Tregear, of Wellington, was able to find only twenty-seven alive. Like all Polynesians, they had a large collection of traditions, many of which have been secured by Mr. Shand, a gentleman who has devoted many years to their study, and who, perhaps, alone is able to speak with authority concerning them.

39. *Hawaiki.*—The Moriori have a knowledge of this widely-distributed name, and mention is made in their traditions that three canoes arrived from there in the time of *Rongopapa,* who lived twenty-seven generations ago, which would make the date about the year 1300. As previously mentioned, this was not the date of discovery of the group, about which there is at present a good deal of uncertainty. The Moriori has had more than once intercourse with the outer world, as the following brief history will show, which I translate from *Te Korimako,* a newspaper published in Maori (No. 14, of April, 1883):—

"This is the line of descent of the ancestors of this island of *Wharekauri* (the Maori name of Chatham Island; *Rekohua* was the Moriori name, and, according to what the Morioris told me, *Rangi-kohua* also):—

"First, *Rangi.* His wife was *Papa.* These were the first people made by God. Their child was *Rangi-tokona.* His child was *Te Ao-marama.* His wife was *Rutake-whenua.* Their children were,—

"*Rongo-mai-whenua* (whose wife was *Tu-whenua*) and *Rongo-mai-tere.* The children of the former were,—

"*Rangipokia, Tangoro-mapunawai,* and *Tahi-wata.*"

40. *Aotea.*—"The first canoe which came to this island belonged to *Kahu.* It came from *Aotea* (New Zealand). When *Kahu* came to the island he found it drifting about. It was he

who closed it (fixed it in position), even unto *Rangiauria* (Pitt Island). Kahu stayed at *Wharekauri*. It was the seed of the *kumara* that he brought, and he planted it at *Okahu* and at *Waiteki*; but the *kumara* did not grow. *Kahu* found on his arrival men living on the island—that is, the men whose names are given above. But it was not very long that *Kahu* stayed here. *Kahu* spoke his word, and said, 'It is a bad land—a land of peat and swamp.' This was the word of *Kahu;* and he returned to *Aotea*."

"After *Kahu* had left there were born *Tane*, *Tumu-nui*, *Tumu-rarapa*, *Rangi-wahia*, *Tangiwharau*, and *Maru-mamake:* these were all younger brothers of *Tahi-wata* above. The offspring of *Nuku*, *Maru-mamake's* son, was *Marupuku*."

"In the days of *Marupuku* there came two canoes. The canoe of *Mahiti* landed at *Te Awa-patiki*. [Note: Te Awa-patiki is on the *east* side of the island.] The name of the canoe was *Rangimata*, and the names of the clans who came in that canoe were *Weteina*, *Makao*, and *Tara*."

"This was the word asked by *Marupuku* of *Mahiti:* 'Whariu ko tere?' (Whence, or, What are you?) *Mahiti* answered, 'Ko au, ko Mahiti' (It is I, Mahiti). Then asked *Mahiti* of *Marupuku*, 'Whariu ko whenua?' (What land is this?) Then answered *Marupuku*, 'Ko au, ko Marupuku' (It is I, Marupuku; meaning, It is mine). This canoe is in the fresh-water lagoon, still standing, at Te Whanga."*

"It was the canoe of *Rakeirou* that landed at Te Aunui. The name of the canoe was *Rangihoua*. There was one clan came in that canoe, *Makao-auha*.""

"The fourth canoe landed on the other side of the island. *Orepuke* was the name of the canoe. The man on board was *Moe;* he was the chief. His clan was *Rauru*."

"In the days of the descendants of Marupuku came the migration of *Pomare*," &c. This migration of *Pomare* was that of the Ngatiawa Tribe of Maoris who chartered a vessel and conquered the islands in the year 1835. I have given the translation in full (so far as relates to the voyagers), because I believe it has not been published before.

41. *Aropaua*.—This is the name of one of several places which the Moriori say were in Hawaiki; but it is evidently meant for the island in Cook Strait, the name of which was frequently applied to the South Island. The other names are: *Tongepu*, *Tongerei*, *Tonge-haka*, *Ru* (*te*) *Korokoro*, *Tanatea*, *Ohuru*, *Ru* (*te*) *Ngere*, *Tauao*, *Tohu-a-Tane* (*Tu-a-Tane*). It is supposed that seals came to the Chatham Islands from these places. I hesitate to identify any of these names.

* The meaning here is, that the representation of the canoe, in solid limestone rock, is still to be seen.

42. *Hukurangi.*—This name occurs in Moriori traditions as the residence of *Tahiri* and *Irea*, to whose place *Maruroa* and *Rananga*, who went to the Chatham Islands in the *Rangimata* canoe, paid a visit prior to their voyage, and from whence they obtained the direction in which to sail for Rekohua or Chatham Islands. It was at *Hukurangi* that they were taught the knowledge of the names of the months, and where they heard of the *pohutukawa* and *mawhai* trees. There are several very interesting questions raised by this tradition, but, as I am limited to the geographical points at issue, I will merely call attention to what I have already stated—namely, that *Ukurangi* was one of the ancient names for New Zealand.

End of Part I.

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6. *A Natural Method of teaching the Elements of Geography and Map-drawing.*

By Professor A. W. Bickerton.

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7. *On the Relation between Rainfall and Forest.*

By J. T. Meeson, B.A., of the Inner Temple, Barrister-at-law, Christchurch.

Captain Campbell-Walker, in his able and exhaustive paper (Appendix to Trans. N.Z. Inst., Vol. ix.) "On the Climatic and Financial Aspect of Forest Conservancy as applicable to New Zealand," after enumerating and illustrating many ways in which the presence of forests undoubtedly tends to ameliorate the climate of a country, as well as to increase and conserve its water-supply, and therefore its productivity, "records his opinion that so far nothing has been found to establish the theory that extensive denudation will of itself cause a marked decrease in the rainfall" (Par. xxviii.), "although the facts as he has seen and compared them in this colony almost convince him that forests have a direct influence on the amount of it." However—he significantly goes on to ask—"May not the presence of the trees be the effect of the rainfall, and not the cause of it?" and confesses that he feels no kind of certainty one way or the other, but takes comfort from the fact that Dr. Brundis, the Inspector-General of Forests in India,—no mean authority,—and doubtless many others, have like himself failed to make up their minds about the matter. He even avers "that statistics in this colony tend to prove that the rainfall has increased at stations in the neighbourhood of which woods have been extensively cut down."

Now, I firmly believe that this attitude of mind on the important subject in question is precisely that of many thoughtful people. They feel that there is an intimate relationship between rainfall and forest, but are not prepared to assign priority of existence to either. Nevertheless the usual opinion originated by those who clearly perceive the beneficial effects of an arboreous covering, and the evils resulting from the wanton destruction of such covering, in most newly-settled countries, has been that rainfall will be very seriously affected by deforestation and largely increased by reforestation. To this dictum quite lately more than one authority much more competent to form an opinion than myself has demurred. I follow on the same side, and venture to discuss the question in a somewhat novel fashion.

I have prepared, and have now before me, two maps of New Zealand—the one showing approximately by degrees of shading the average annual rainfall in the different parts of the colony; the other showing, also approximately, from the information supplied by Captain Walker while acting as Conservator of Forests in New Zealand (Report on Forests: C.–3, Appendix to Journals H. of R., 1877), where the great forest-areas principally lie, and the comparative extent of them. The similarity between the two maps is evident at a glance, so much so indeed that, with some trifling exceptions, principally on the eastern side of the Islands—in Cook County and the Province of Marlborough, *e.g.*—it may be said that the more darkly shaded areas in the two are nearly coincident; and it is impossible to do otherwise than conclude that between rainfall and forest there is, in some way, the connection of cause and effect.

To construct, even roughly, a map of the forests of New Zealand is no easy matter: no authentic map of that character is in existence; and the materials for constructing one, as supplied by the source already indicated, are neither precise nor adequate. There is pretty accurate information as to the amount of forest which was in the hands of our Government in 1877; but at that time very much had already been alienated, especially of kauri, totara, and other commercially valuable timber, and of course a large quantity still remained in the possession of the Natives.

The total area of forest at the disposition of the State in 1877 was as follows:—

	Acres.	Acres.
Auckland	960,000	
Napier	138,000	
Taranaki	1,027,000	
Wellington	773,305	
		2,898,305
Nelson	2,682,000	
Marlborough	500,000	
Westland	2,623,550	
Canterbury	207,700	
Otago	2,000,000	
Southland	800,000	
		8,813,250
Total		11,711,555

That is to say, besides the acreage already alienated to private individuals or still remaining in the hands of the Maoris, there would seem to have been at the date in question over eleven and a half millions of acres of forest out of a total area of sixty-four millions. Captain Walker quotes Sir J. Hector as giving the total area of forest in New Zealand as 12,130,000 acres, but considers that it is probably much more than that; and so it apparently is, for in the "Handbook of New Zealand" for 1886 the estimated proportion of forest-land—that is, the percentage of the entire area in each provincial district—is given as under:—

			Total Area of Province. Acres.		Acres in Forest.
Auckland..	9·449	per cent. of	16,650,000	=	1,573,258
Hawke's Bay	11·803	"	2,137,000	=	252,230
Taranaki	83·003	"	3,050,000	=	2,521,896
Wellington	57·142	"	7,200,000	=	4,114,224
Nelson	14·434	"	6,700,000	=	967,278
Marlborough	19·301	"	3,000,000	=	579,030
Canterbury	4·306	"	8,693,027	=	374,320
Westland..	62·809	"	3,045,700	=	1,912,973
Otago and Southland ..	8·729	"	15,038,300	=	1,312,693
Total					13,607,902

There are marked discrepancies between these figures of 1886 and the ones previously quoted from Captain Walker's report of 1877. In some cases those of the later date are much larger than those of the earlier. This might arise from the the former including forest-lands already alienated by the Crown and also those areas of woodland still possessed by the Natives. The discrepancy, however, in the case of Nelson is too great to be accounted for in this way. I have no means whatever of explaining it. In any case the figures are very large, and clearly show that there is a vast area of forest still left in the colony, which certainly deserves the credit that it possesses of being, as regards arboreous vegetation, one of the richest portions of the globe; but the destruction that has gone on since European settlement began must have been enormous if we may judge from an estimate made by Sir J. Hector, and quoted in the "Encyclopædia Britannica," to the effect that in 1830 there were probably 20,370,000 acres of forest in New Zealand. That the area should have diminished by at least one-third in less than fifty years shows the immediate necessity of steps being taken towards forest-conservation. This, however, by the way.

The above figures, and the map drawn in accordance therewith, show us pretty clearly that the great forest-areas in New Zealand are on the western side of the Islands—*on the western slopes*—and, if they are below 4,500ft. in height, on the *summits* of the mountain-chains. The densest forests, as far as the North Island is concerned, would seem to be in the Taranaki Province, of which more than four-fifths is forest-clad, and in the Wellington Province (on the Tararua and Ruahine Ranges), of which more than half the surface is so covered; and, as regards the South Island, the Province of Westland has proportionately and absolutely the greatest amount of forest-area, as much as three-fifths of its surface being forest. There are vast areas of wooded country also at the extremities of the colony—that is, in the Provinces of Auckland, and Otago and Southland. In Nelson and Marlborough the mountain-ranges are less elevated generally, and more broken, and the forest spreads over the land extensively, but with large bare areas intervening, so that the proportion of area forest-covered is not so large as in the districts previously named. Canterbury and Hawke's Bay, with their naked plains and comparatively sparsely-timbered hills, and a very extensive bare area in the interior of Otago, are absolutely and relatively the poorest in forest of all the provinces, and these are precisely the areas which are most subject to warm north-westers and have least rainfall, being most protected by mountain-chains against the prevalent rain-bringing or equatorial winds.

Similarly, a rainfall map prepared on the basis of authentic statistics shows that the greatest rainfall in New Zealand occurs on the western slopes of the Southern Alps and the mountain-ranges in Taranaki; and, generally speaking, the colony has its heaviest precipitation on its western side—as so frequently occurs elsewhere in corresponding latitudes—and there is less and less as the eastern shores are approached. Heavy rains also occur over the extreme northern and southern areas; and local circumstances bring about exceptionally-heavy rainfalls in various other districts of limited area, particularly in the Provinces of Nelson and Wellington, and on the east coast of Southland. The conclusion is inevitable. Rainfall and forest must, as a general rule, be related to one another as cause and effect; and, though the two may have reacted on one another to a limited extent, yet for the most part the rainfall has brought about the forest, rather than the reverse.

Mountain-ranges as a rule are, as is well known, better covered with forests than level country. I do not think this arises, as Darwin supposed, because plains are in themselves less favourable to the development of arboreous growth than broken and hilly country; for some of the most extensive and dense forests in the world extend over areas level as a table. Mountain slopes and summits—particularly if at all formidable —are little interfered with by man or cattle, and there growth goes on more or less comparatively undisturbed; and, as good drainage and various aspects and different kinds of soil in such situations are sure to be found, there various forms of vegetable life, suitable to the climate, through the instrumentality of birds and winds spring into existence. But the main cause why woods thrive on mountains better than on plains is that rainfall increases, within certain limits, 3 or 4 per cent. for every 100ft. of elevation.

Captain Walker, as if arguing desperately against his own convictions, asks, if forests follow rainfall, "Why should not rain have fallen and forests been created on the eastern slopes of the mountains on which the clouds laden with moisture from the Pacific first impinge?" The answer is conveyed in the question. Rain has *not* fallen on the eastern slopes of our Alps, because in this latitude the rain-bringing winds are western, and comparatively little rain comes from the east at all. The rain from the west has been intercepted by the mountains, and, as there has been little rain, forests have not been called into existence on the eastern slopes, except in a few places where low passes have permitted the moisture to cross to the leeward side.

That woods do undoubtedly tend to the equalisation of temperature, screen the soil from the sun, check evaporation (which in open country is five times as great as in woods) particularly from pools and streams, render the air about them to some extent cooler and moister than it would be otherwise through the immense surface that the leaves expose to radiation and copious evaporation, and mechanically bind the soil and check the running-off of moisture from its surface—all this, in addition to their grace and beauty of form and colour, —for I share all Lord Beaconsfield's enthusiasm about trees,— must be granted. I will even go further and say that, in consequence of some of the effects herein just enumerated, there would be a slight increase of the rainfall in a country if forests could be grown to occupy a large area previously bare. In France it has been computed that 5 per cent. more rain falls over woodland than in the open; but one would like to examine this calculation closely and see if here also effect has not been put for cause, and cause for effect.

Besides, all kinds of trees are certainly not equally beneficial as regards conserving moisture or giving shade or cooling the air. Some plants—sunflower, *e.g.*—pump water out of the ground enormously; and the drying capacity of the Eucalyptus, as far as the ground around it is concerned, is considered one of its special and peculiar virtues. Even in the case of other trees, the amount of moisture which they draw up from the ground by their sometimes far-reaching spongioles is really enormous. True it is that transpiration and consequent evaporation are constantly going on during growth, and sometimes are so copious that an individual tree will perspire its own weight of water in twenty-four hours; and this undoubtedly does render the air around cooler and moister, though it must be remembered the ground is proportionately robbed of its moisture. According to some people, trees are as good as artesian wells, and will draw water from heaven as Franklin's kite drew electricity from the clouds. They certainly do draw water in large quantities, but it is rather from the earth than from the sky.

That forests, in a wide sense, operate to materially change the climate of a country, as many have contended, I believe therefore to be a serious mistake, resulting from the confounding of cause and effect. The power attributed to trees of drawing rain from heaven is a matter indeed on which many people have held the most extreme views. James Brown, in "The Forester," says, "It is in the power of man to alter, modify, and regulate the climate in which he lives to suit the various kinds of crops he cultivates." One gentleman I know —a well-known *littérateur* of a city in Australia, and the editor of its leading journal—who always entertained the idea that the miraculous virtue of drawing rain lay especially in the *Melia azedarach* or white cedar. This, therefore, he largely planted in the grounds attached to his house, but it is needless to say that the rainfall over his few acres was not sensibly larger than that of the locality generally. Such notions remind one of the old story of King Canute and his courtiers on the sea-shore. Professor Tate, of Adelaide, who holds views similar to my own, in a lecture delivered by him some years ago went so far as to say that "European experience based on records kept since 1688, and extending up to the present day, failed to prove that the rainfall had decreased as the trees had been destroyed, and that a similar remark might be applied to the United States, covering a period of sixty-six years." *Per contra*, our later visitor, Mr. David Christie Murray, told me a short time ago that in the Ardennes, where he had lived for many years, it had been observed that the rainfall had been seriously affected by the destruction of the indigenous forest.

There is a good deal of evidence—much of it more or less untrustworthy—on both sides of the question; but I believe the balance falls on the side of the views which I have expressed, and this is what we should expect from *a priori* considerations. The powers of nature which determine general weather are too Titanic for man to hope to overcome. He does not even thoroughly understand them yet, for meteorology is the newest of the sciences. But what knowledge we do possess goes to show that nine-tenths of the rain that falls is cyclonic, and thus general weather depends on widely-operating physical laws, which man will best recognise his own interests by bowing to as inevitable. In India, where at one time they largely held the notion that they could by reforestation modify an extremely hot and, considering their requirements, dry climate, after large experience in this kind of work they have entirely changed their views, and no longer struggle to avert the inevitable or accomplish the impossible. Some of the British colonies, however, still attempt this feat. They have so long repeated the ordinary phrases about forests causing rain that they have come to believe them eternal verities.

As long as the configuration of New Zealand has been what it is, the prevailing western winds have deposited their precious burden on the western sides and summits of the Southern Alps, and on those portions of their eastern flanks and the country beyond to which they could travel without mounting more than, say, 4,000ft. This is one of those wide and general features of climate depending on our latitude (the "roaring forties"), our insular position, and the existence of a high range of mountains running from north to south near the western shores. To alter this feature in any material way whatever, man is perfectly impotent; and, where the rain falls heavily, there the forest heavily covers the land; where less heavily, there the trees grow in patches; where very lightly, there the shady woods are wanting, and the plains are treeless. Above, say, 4,500ft. forest-growth ceases, and stunted vegetation only is found; for at that height cold checks growth, and, instead of rain, for the most part snow falls.

Of course, the nature of the soil and other circumstances are factors of the greatest importance; but, generally speaking, in a country unoccupied by civilised man the forest-areas will be the areas of heavy rainfall. A good map showing clearly the forests of New Zealand, if we took into account the woods destroyed by settlers and accidental fires, would exhibit the main features of the annual rainfall. In countries that have been long settled and cultivated it is impossible to determine what were the areas of virgin forest. It is only in a country such as ours, just placed in the hands of civilised man, and where the aboriginal inhabitants have not been given to felling and clearing on an extensive scale, that such an inquiry becomes possible; and, as to determining or helping to determine what are or have been the areas of greatest precipitation, it may surely be considered, next to exact meteorological statistics, as of paramount importance.

Certainly different kinds of trees require different degrees and amounts of moisture, as of heat, light, and elevation, to develope them. Some, indeed, seem specially adapted by nature for dry climates and positions: they have hairs covering their leaves, which thus attract a larger proportion of dew, or their leaves are needlelike, or set on edge, so that during a drought the sun has less effect on them. It would almost appear as if the Eucalyptus when grown in a moister climate than that in which it is indigenous alters its habit of growth. In New Zealand here, its leaves grow less edgewise, more open and flat to the sky, as if they felt they could safely expose themselves to a less powerful sun in a climate where moisture is happily so plentiful as to temper materially his ardent rays. But all these are quite exceptional characteristics of particular species, and are instances of modification of form to protect life and accommodate it to its environment.

It would be quite possible to bring out the truth of the proposition submitted as to the relationship between rainfall and forest by a survey of the surface of the earth generally. Some instances could be given which pointedly confirm the theory: *e.g.*, the northern and eastern portions of the Island of Madagascar, where the climate is moist, are clothed with magnificent forest, whereas elsewhere in the island the vegetation is remarkably scanty, there being only a narrow arboreous belt along the shores. But it is very difficult to conduct the inquiry as to the earth generally with precision, because there are large areas in the world over which the extent of woodland is very imperfectly mapped out, or, indeed, known; and unfortunately, too, these are precisely the regions where the rainfall is conjectured rather than measured. Moreover, where the forest-area and the mean annual average of rain are well known and duly recorded, there the condition precedent that the forest be indigenous and virgin does not obtain; for the countries referred to have been so long settled that few spots, if any, are left in true primitive wildness. Similar uncertainty, indeed, may exist as to the reading of such cases as Makatu Island, in the Fijis, where the windward and presumably rainy side is densely wooded, while the leeward side is timberless. Moseley, the naturalist of the "Challenger" expedition, thinks the forests there are owing to heavier rainfall; but we have no meteorological statistics from the island, and, as the windward side is the steeper of the two, it may be that the natives, though barbarian, in bygone days have cleared the leeward side for cultivation. The Island of Madeira, as the name implies, was once entirely timber-covered: now, however, through ruthless destruction by Zargo and others, the island is bare except on one side, and that is the windward and rainy. Fire is powerless in a land of incessant rain, or, if it temporarily succeeds, the damage done is speedily repaired.

It is believed that before human inhabitants became numerous in the world its surface was almost entirely covered with forest. Possibly at that remote period—and the latest inquiries into the question of the antiquity of man show that it must have been very remote indeed—the mean annual rainall on the earth was everywhere considerably greater than it is now. Whether that was so or not, in our own day the most extensive natural forests in the world would seem to be generally, though not exclusively, in those parts where the rainfall is known or conjectured to be heavy, if not the heaviest.

For example, the greatest and most productive forests on earth are in America; and that Continent, as a whole, has undoubtedly a humid climate. British America has 900,000,000 acres of valuable timber. British Columbia and the Washington and Oregon Territories of the United States are densely timbered, and the immense *Sequoia* (*Wellingtonia*) *gigantea*, is only found where the western slopes of the Nevada Range intercept the heavy western rains from the Pacific. Passing to South America, we find in the silvas of the western portion of the great plain of the Amazon an area of nearly a million English square miles covered with impenetrable forest and jungle (Brown's "Forester"). In all these lands the rainfall is heavy, in some parts very heavy. Loomis (map, Amer. Jour. of Science, 1882) shades them so as to show a mean annual average of at least 50in., and often over 75in. In Neeah Bay, Washington Territory, the amount is 123in.; in Blockhouse, Oregon, 96in.; in Halifax, N.S., 54in.; in New Westminster, 58in. What it is in the forests of Brazil, particularly in the uplands towards the Andes, I cannot discover, but it must be very large, for, the latitude being tropical, the trade-wind striking against the eastern flanks of the mountains must cause immense precipitation. The Andes are clothed with forest along their entire length either on one side or both sides, because the mountains catch the eastern rains in one latitude and the western in another. Contrast with this luxuriant arboreous vegetation—resulting, as I contend, from heavy rainfall—the barrenness of Peru and northern Chili, the treeless condition of the pampas of La Plata, Banda Oriental, and Patagonia, and the deserts of Utah and Nevada, in all of which countries the mean annual rainfall is less than 10in. (6in. at Fort Bridger, Utah; 5in. at Fort Churchill, Nevada; 4in. at Mendoza, La Plata; and 0in. at Lima).

Darwin, in his "Journal of Researches" (p. 46), *à propos* of the entire absence of trees in Banda Oriental, notices many of the above facts respecting South America, and discusses the question with which we are engaged at some length. He thinks, as I have already remarked, that extremely level countries such as the pampas seldom appear favourable to the growth of trees, and that this may be possibly attributed to the force of wind or kind of drainage. The fact is, however, that quite recently the *Eucalyptus globulus* has been extensively planted in different parts of the pampas, and, being a tree that can stand drought well, it succeeds despite the pampero, even better than in Australia, becoming both richer and denser in foliage. But, apart from this experimental proof that Darwin was in error on this point, it must be observed that the most extensive tracts of level country with which we are acquainted are flanked on their western sides by mountain-chains cutting off the oceanic winds and rains (Guyot's "Earth and Man"); and this factor, from the point of view of one who believes that rainfall determines forest, is not to be lost sight of. I confess I do not see that the argument as to force of wind and drainage in level tracts is very cogent. Darwin himself subsequently records that he found little or no vegetation whatever on the Sierra de la Ventana—a group or chain of hills 3,000ft. high on the eastern side of the Patagonian plain and at no great distance from the South Atlantic. Now, the treeless uniformity of Patagonia ought to have been broken by this elevated ground, if Darwin's reasoning was conclusive; for shelter would be found either on one side or another of the chain, and drainage would be generally good on its slopes. Darwin refers to Maclaren's article in the "Encyclopædia Britannica" as "inferring with much probability that the presence of woodland is determined by the annual amount of moisture," and emphatically says that, confining our view to South America, we should certainly be tempted to believe that trees flourished only under a very humid climate, for the limit of the forest-land follows in a most remarkable manner that of the damp winds. He seems, however, to attach importance to the fact that the Falkland Isles can boast of few plants deserving even the title of bushes. Such carefulness about making wide generalisations is eminently characteristic of the great naturalist. A trifling exception like this, however,—and even though many more might be given,—could be probably accounted for by quite exceptional circumstances, such as being swept by cold and stormy oceanic winds, which accounts similarly for the stunted vegetation of our own Chatham Islands, and does not appear to justify hesitancy about accepting a law which is widely and generally observable. Forest argues heavy rainfall, but heavy precipitation of rain must be accompanied by other circumstances to result in the growth of wide areas of timber.

Of the Dark Continent and its forests our information—though, thanks to the attention which this part of the world has of late been receiving, not by any means meagre—is as yet only general. Of exact statistics we have scarcely any; but the explorations of recent travellers—particularly the indefatigable and indomitable Stanley—show us that almost impenetrable woods fill up the heart of the land, more or less from the Atlantic Ocean to the Indian; and Loomis's map gives us a rainfall of over 75in. for the whole of this wide tropical belt. Northward of it stretches from the Atlantic to the eastward of Central Asia—only broken by the Hindoo Coosh and the Himaleh Mountains—a vast treeless desert, almost rainless.

In India, owing to the beneficial action of the monsoons, a copious rainfall of above 75in. is found along the coasts and at the base of the stupendous chain to the northward, with very excessive precipitation in certain limited areas—Cherapungi, *e.g.*, in Assam, where the fall is over 600in. in the year. The valuable forests of pine, box, sal, teak, ebony, and deodar therefore here are very extensive, and now all are most carefully conserved—not so much with the view of securing a continuance of the rainfall as for the sake of preserving and economizing national wealth. As regards teak (*Tectonia grandis*) it is well known that it grows best where the rainfall is heaviest. Burmah, Java, Sumatra, and Borneo, as regards rain and forest, are equally liberally endowed by nature. All have a truly tropical average of over 75in. (213in. at Sandonay, Burmah; 220in. at Buitenzorg, in Java; and 181in. at Padang, Sumatra); and all are remarkably well wooded. Siberia, north and north-east of the Altai Mountains, is one enormous forest. It has, however, only a moderate rainfall of from 10in. to 50in. according to locality. The forest here, therefore, does not cause heavy precipitation. But it must be remembered that this is a high latitude, and evaporation is comparatively small. A little rain, therefore, under such circumstances is very effective. The same remarks apply to a large part of Russia in Europe. Japan, again, is well wooded and has a rainfall of over 65in. On the other hand, the steppes of Tartary and Mongolia are nearly treeless, and have less than 10in. of rain in the year.

In Europe, man's action has been powerful enough to completely alter the face of the land, but we know from history that till comparatively recent times it was covered with forest, and this may be presumed to have been the effect of the rainfall with which the Continent is blessed, through its latitude, its being intersected by great oceanic areas, and the action of the Gulf Stream and the Return Trades bringing copious moisture from the Southern Hemisphere—a rainfall coming more or less throughout the year, very heavy in particular spots, but not tropically heavy anywhere, yet quite sufficient, considering the high latitude, to promote vigorous arboreous growth almost in every corner.

Australia has a poor mean average of rainfall throughout its vast interior (5in. at Alice Springs, 6in. at Charlotte Waters), the greater part of which lies within an anticyclonic region of high pressure and the dry south-east trades. This is a land, therefore, subject to very severe droughts, periodically blighting the face of nature from the 18th to the 30th parallel of latitude, and occasionally embracing the whole continent; and as a consequence — though Darwin ("Journal of Researches," p. 47), with scantier information than we possess, speaks of the whole of Australia in spite of its arid climate as being covered by lofty trees—I believe we should be correct in saying that the interior for many thousands—yes, even hundreds of thousands—of square miles is nearly absolutely treeless. Along the eastern coasts and mountains the rainfall is heavier (48in. at Brisbane, 49in. at Sydney: compare 20in. at Adelaide and 25in. at Melbourne), and the arboreous vegetation is more profuse; while the Australian Alps in the south-eastern corner, being within the area and influence of the cyclonic depressions that pass along the southern coast in regular succession, are covered with Eucalyptus woods, and there the massive *E. amygdalina* attains its gigantic size.

This review is too cursory and sketchy, but, when taken in conjunction with the more careful examination of the rainfall and forest of New Zealand, previously given, it may perhaps be considered enough to give semblance of truth to the proposition that *the native forests of a country are located in those districts blessed with abundant rainfall, and by the said rainfall are mainly brought into existence.* That a reflex action of forest in producing rain also may exist to a limited extent, I quite believe; but, as I have implied, I think it is a power supposed by most people to be much greater than it actually is. Of course, also, what constitutes sufficient abundance of rain for arboreal development depends on latitude and several other circumstances.

A notice in *Research* of the 1st October, 1889, states that Dr. Hamberg, of the Central Meteorological Institute of Stockholm, has been detailing in a public address the results of his thirteen years' experience and investigations on the influence of forests upon climate. These were carried on at numerous stations—some on free open land, some on forest-clearings, and some in the depths of woods—and related more especially to temperature, humidity of air, and rainfall. He found that temperature was more equable under trees than on free land, and on free land than in clearings; and that, while forests afforded shelter against cold and cutting winds, they did harm on the whole in respect to the sun's heat by depriving the earth of it, and fostering frost through lowering the temperature on the ground on clear nights. As regards the moisture of the air and the rainfall, his researches went to show that in Sweden, at all events, forests are simply *without influence*. In Gothland, *e.g.*, the new forests, presumably extensive, had not increased the rainfall in the least. He concluded that climate rested on a more solid basis than that of forests, and that forests deserved preservation for more weighty reasons than their influence on climate. At the meeting where this address was given, Baron von Kroemer agreed with the views of Dr. Hamberg, and went so much further as to say that even as regards protection trees were not always desirable, for in Scania, *e.g.*, corn dried much more quickly after rain on free land than in clearings. There is no doubt that in a cold country like Sweden the beneficial effects of forests would be less than in a tropical country like Ceylon, *e.g.*, where Colonel Clarke, after many years of observations, came to the conclusion that "forests make climate more equable, increase the relative humidity of the air, and *perhaps increase the rainfall*," and also regulate the water-supply, making springs more sustained and rivers more continuous; giving besides protection against strong winds, and preventing the soil from being washed away by heavy rains (*Nature*, 18th October, 1888). This is pithy testimony given by an authority who commands attention; but there is nothing in that testimony which militates against my views, herein expressed.

The proposition which I have endeavoured to establish is one which some people will be disposed to regard as so self-evident as to need no demonstration. It is one which, nevertheless, is frequently lost sight of when the relationship between rainfall and forest is discussed; and it can be maintained quite consistently by those who hold, as I do, that the wholesale destruction of the forests of a country must be, as a rule, prejudicial in various ways to its future interests; though in the process of settlement such destruction, or at all events a large part of it, is inevitable. Indeed, I often think that, even for the sake of preserving old types of the fauna and flora of the land, it would be well if blocks of country here and there, not necessarily very extensive, were, like the Suli lands of Timor, held inviolably sacred as against axe or gun, or destructive instrument of any kind. To deny, however, that reforestation would materially increase rainfall is quite a different thing from denying that deforestation must in some respects prove calamitous. Let us plant trees by all means where the ground cannot otherwise be more profitably employed. By so doing we shall clothe the earth with beauty, and shelter it alike from the bitter blast and the fiery sun, and conserve its refreshing moisture for the benefit of plants and animals. But *we shall not materially affect the mean annual rainfall*, for that is determined by the operation of cosmic laws which neither the wisdom nor the will of man can change.

Section F.

(ECONOMIC AND SOCIAL SCIENCE.)

President of the Section—The Hon. G. W. Cotton, M.L.C., South Australia.

ADDRESS BY THE PRESIDENT.

A State Bank of Issue the only Solution of the Domestic-currency Question.

That I decidedly recognise the high honour conferred upon me by the Australasian Association for the Advancement of Science by appointing me President of this Section F, is testified by my travelling two thousand miles to take part in the proceedings of this meeting in New Zealand. That the subject I have taken would be acceptable I was glad to be assured by Professor Hutton when he so courteously acknowledged my acceptance of the position assigned to me early in last year. I have done my best to make the study as simple as possible, that the general public who are most affected by the want of a State bank of issue should to some extent understand the practical bearing of this most important economic question. The very able and conscientious gentleman who last year filled the chair that I am called upon to occupy to-day closed his presidential address with the following deeply-significant words: "Popular favour is a terrible task-mistress, for she refuses bread to those who fail to work her pleasure: but the evil time draws too near for delusive teaching. It is now necessary that those who see the rocks ahead should speak out faithfully." Most of us have heard of the "rocks ahead" referred to by the late Mr. W. R. Gregg, but Mr. Johnston was more far-seeing in his treatment of his subject than Mr. Gregg. In dealing with the very difficult but eminently practical subject that I have chosen, I do not propose to defend "pleasant delusions," upheld, as the well-known Mr. Matthew Macfie alleges, by reason of the "credulity and ignorance" of the public mind on the little-studied subject of finance. It was announced the other day that on the 20th November a meeting would be held at the London University, presided over by the Chancellor of the Exchequer, with a view to the foundation of a British Economic Association. The notice alleged that "it was rather an anomaly that no organized scientific body exists in Great Britain to promote that most important branch of knowledge in which we have made more advance than all the rest of the world—Economics." That newly-to-be-formed association will scarcely say of this antipodean institution, *Sequamur, sed non æquis passibus*. We hope, when the great British foundation has advanced beyond our more humble achievements, that we shall keep it well in sight.

The question constantly recurring, and not to be put down till it is satisfactorily answered, is: Does the direction given to labour by capitalists and other non-workers under present conditions induce greater production, in its broadest sense, than if labour had free and direct access to the soil, combined with an organized co-operative system of its own? We cannot dissociate the various branches or classes of society. An American publication says, "In these days of labour-trouble, society is tempted to forget, in the duty of saving itself, that the poor are also society." A Leipsic journalist wrote, "The working people are forced to fatten the more fortunate one who by accident, bad laws, or by unscrupulous spoliation of his fellow-man, has possessed himself of the means necessary for the production of capital." The object of economics is first to discover if such testimony is true, and, if so, to correct the cause of the wrong. Every individual is a member of the same commonwealth, and, if any one class suffers, all others suffer with it till the wrong is removed. From such premisses I conclude that we are all here for the purposes of considering how the good of the whole community may be promoted, our care being that none are left to want. It must not be supposed that the shortcomings of social and political relations can be rectified at once. Those enamoured of a Fabian policy adopt the ancient dictum, *Natura non facit saltum*. However, during the current century, Nature, aided by the skill of man, has, at his suggestion, made astonishing leaps and bounds. Instead of taking six months to convey by the breath of Æolus the voice of science to the antipodes, the lightning speed of the telegraph relates what took place the instant before. So we may not altogether accept the voice of the classic legend. I venture to state that this subject of high finance, when not obscured by long-lived prejudice and the mental vision torted by self-interests, after all is not so hard to be comprehended, for, as a Home writer remarks, "there is a way of looking at the question which will enable every person of average capacity and knowledge to form a practical conclusion upon it." I submit as true the proposition that "general suggestions are nebulæ, out of which detailed schemes are formed," or, as the classic legend, transferred to the entablature of a gasworks in England, runs, *ex fumo dare lucem.* From the smoke that I endeavour to raise to-day I encourage myself to believe that some light may be evolved.

I ask at this stage of the proceedings to be allowed to overlook the huckstering process of money-changing, sometimes called "money-making," in which the uppermost, and so often the only, question is, "How much shall I gain in this transaction from the labour of others?" I propose to consider, briefly as I must, and as clearly as I can, that essential question in social economics, the dynamic agency of money, as contributing to the comfort and well-being of "all sorts and conditions of men." With this view, I must not raise myself, as if to the apex of the social pyramid, by means of a balloon, only to descend more quickly than I went up; but begin where the builders do—on the bed-rock—and, by a steady aim, raise the superstructure. I must discover where the use of money first comes in as an aid to labour and in the necessary distribution of the products of labour. It goes without saying that the sole source of human activity is the food-supply, and the maximum of result is obtained when every member of the human family is usefully employed, each one according to his ability—a quantity continually to be increased by the exercise of proper technical instruction. I ask that the total food-supply of the population of the world shall be taken as a unit, and that the sources whence it is obtained shall be noted. This total supply is gained from the soil and from the sea by no other means than by the output of human labour, and ought, from year to year, to be equal to the sustenance of each individual for the entire period. If each individual were so located that he planted upon and gathered from the land or gained from the sea his own food and no more, and was content to make his own clothing and construct his own dwelling from materials raised or gathered by himself, there would be no place for money, as no exchange of commodities would be needed. But the instant any one, A, of the millions of human beings desires to have something—say the product of a day's labour—of another, he begins to bargain for exchange by offering something that he can spare for the article that he wishes to have. It may happen that his neighbour, B, does not want the proffered article in exchange for what A desires. Notwithstanding, B supplies A with the commodity he asks for, and receives a token, bearing the value of a day's labour on its face, as representing the cost of the article that B has given to A. By-and-by B desires to have from C something that cost him a similar outlay of labour, and he passes over to C the token he had received from A in payment. It is a recognised doctrine that the transfer of debt may be made *ad infinitum*. The only condition is that it was an honest debt to begin with. In the case supposed the exchange was a token for a day's labour for some commodity that took the same time to create.

Referring to the token itself, money, it is of no consequence of what material it is made, provided (1) that the supply is easily procurable, (2) that it is durable, (3) that it can be easily carried, and (4) that it cannot be counterfeited. In itself money is only the tangible sign of some article of use or desire in terms of the labour put forth in its creation. What, then, of a golden sovereign? This trinket has cost at least the putting-forth of from twice to ten times its value in labour to produce it. Little wonder is it that a gold-mining country is always recognised as being a poor country. Manifestly, to raise gold as a medium of exchange is a great waste of capital—*i.e.*, of labour, the basis of all capital. True economy consists in expending as little labour as possible in producing any article desired for a given use. Hence the advantage of so-called labour-saving machines. The article under consideration for the moment is the medium of exchange —money. In the passing from hand to hand of this medial agency there is the danger that some person possessing a token, say, for a day's labour may take it into his head that it would be easy to foist a money-token into circulation for which he had not expended an honest day's labour, so he starts in the evil business of a counterfeiter or forger of money. The value of gold as coin, if any, is that, in consequence of its costing a good deal more in labour to get from the earth than it will represent as money, it is not likely to be over-issued. Whether there is enough of it to afford a regular supply is not often thought of. If the revived doctrine of the alchemists should prove to be practicable—viz., that "indications point to the near discovery by scientists of methods by which to transform the two sole forms of atoms into any substance that may be desired"—then perhaps the "superstition that gold may be made a standard of value" will become patent to the most credulous believer in the "intrinsic" worth of gold as a money-token. But, in the meantime, may not gold be looked upon as representing the remorseless sacrifice of human life, the agony of ill-requited and desperate toil, of needless suffering, cruel bloodshed, and savage rapine? If we knew the history of a piece of gold and its transition down through the ages it might make us shudder as at the fire of hell. Of this more hereafter.

We left A's acknowledgment of the indebtedness of a day's labour passing from hand to hand: at length it may be presented to him for the equivalent that B would not accept because he did not want it. A may have removed, or have nothing, or have died. It must be said of the issuer of money, as is said of the kingly office, "The King never dies," and that the State never becomes insolvent. The issue of representative value cannot be intrusted to any person or any body of people whose shoulders are less broad than the State itself. Money, as the representative of food—the support of labour as it passes from hand to hand—must be sure of conjoined food and labour being given in exchange for it whenever it is presented. This leads to the question that the issues must be adequate to the requirements of the State—*i.e.*, of each person within its limits. Mr. Del Mar crystallizes what I think no one will doubt the truth of into these words: "An expanding traffic needs an expanding money, one that by *regulation* can be made to keep even pace with increasing exchanges;" but must not be liable to "increases, without regulation, either from the adventitious production of mines, the obtaining of the money-metal by conquest, the unlimited emission of Government notes, the license of private coiners, or the greed of private banks of issue." In another place Mr. Del Mar says, "Pieces of money only need a mark of authority impressed upon them, and a Government virtuous enough to restrict their issue and strong enough to prevent the money mark being counterfeited." Some persons allege that such a Government cannot exist in Australasia. Then, shall we put ourselves in the hands of associated banks and their outside confederates—shareholders and other traders in money? As your late Mr. Bathgate remarked, "We have put our head into a noose, and let the banks turn the twitch-stick."

As an illustration of the working of a medium of exchange let a single instance be given, going back thousands of years. It is allowed that the term *nummus*, once used by the Romans for money, came from the Greek νόμος (law), in this case meaning the exact science of numbers; so that number and not "intrinsic" value is the synonym of the circulating medium of exchange—money. On the banks of the Nile are found small pebbles, flat and thin like money, giving sizes from a sixpence to a crown-piece: these are believed to have been used by the Kings of Egypt for money: hence the scientists have dubbed these nodules of limestone *nummulites*. Now, as there was an unlimited number of these ready-made pebbles, any one might easily get a stock and offer them in exchange for whatever he wanted, without having expended as much labour for each pebble as the commodity he proposed to purchase with it had cost the producer of that article for use. It is thus seen at once that the pebble-money must be restricted in its number, as the original form of *nummus* from νόμος (law) implies; else, like the over-issued paper money in Argentina, it would become greatly depreciated in its representative value: in other words, it would take a great deal of the over-issued currency to purchase a very small quantity of goods. As the Pharaoh was the only person who was entitled to be supplied with food without having worked for it, he had the right to decree a fixed value upon each white stone. He caused a certain number to be branded with the royal mark, which none might imitate: this therefore became the pebble currency of the land of Egypt. The Pharaoh gathered his tribute or labour-tax of food by the emission of his marked pebbles, and thus provisioned he maintained his court, his army, and his employés in public works as other Governments have done, each in its own particular way. The pebbles thus emitted became the currency of the country, and enabled exchanges to be made among his subjects. If, as was likely to happen, the Pharaoh wanted further supplies he would make a new issue of marked pebbles, "watered stock"—a process which would depreciate the currency; or he would make an enforced levy upon his subjects for some of the previously-issued pebbles, and thus "corner" the money-market, by which means the price of the food that he wanted to purchase would be rendered more favourable to the buyer. Judging from the financial tactics of later ages, if Pharaoh had surplus stores that he wanted to sell, he would emit his newly-branded pebbles freely, so that he might sell at a profit. This latter course might be State jobbery; but the Kings of Egypt, like the bank associations, had not the terror of the ballot-box before their eyes: that may follow later on, as far as the banks are concerned. Passing along to the time of David, King of Israel, we read that by his victories he amassed so much gold and silver in Jerusalem—afterwards added to by the glamour of his son's wisdom—that it is said, "Silver was not anything accounted of in the days of Solomon;" plainly showing the absurdity of gold, or gold and silver—bimetallism—being reckoned as a "standard of value."

From what has been said, I hope it has been made plain that an honest Pharaoh could, by regulating the issue of his ear-marked white-stone currency, produce greater stability in finance than could be contrived by any uncertain influx of silver or gold. Food may be cheap for either one of two reasons: Because there is more of it than can be consumed (in which case no one ought to go short of it); or money may be so scarce that there is not enough in circulation to enable many would-be consumers to purchase as much as they require for their sustenance. In both instances the growers of wheat equally suffer, but it is in the latter case that nobody benefits: the cause of the whole misfortune rests with those who have permitted a deficient money-circulation to exist. These are the two peas that the thimble-riggers of finance will continue to play in the game of picking the pockets of the public, and of keeping bread from the mouths of the poor, until the regulation of the currency passes out of the hands of private persons and becomes a matter of public policy.

I will now refer to the dynamics of money, as exemplified in modern times by "moving" food, as the Americans call it. In 1847–48 there was a famine of potatoes in Ireland; but was no food produced there? Certainly there was. Why, then, did it not reach the famishing Irish poor? Because the power of the marked pebbles was exercised by a class who "toil not, neither do they spin." By making a levy called "rent," the oatmeal, and the pork, and the butter raised in Ireland went to feed absentees and their dependents, while the producers at home were left to starve. The co-operation of labour to-day is effected by means of money moving wheat from the elevators of Chicago, from the grain heaps of India, and from the ports of the Baltic and Black Seas, to wherever it is wanted to keep labour going. This result is accomplished by what is known as "capital"—the dynamics of money in the hands of a comparatively few persons. If universal labour had a sufficiently developed organization, the year's production of food might be delivered in rations, like the supplies of an army, so that each worker, having done the task allotted to him for the day, would have no other concern than to take his ration and spend the rest of his time as was most agreeable to his inclination.

At present, *capital* means that amount of the result that labour has gained from the soil, as food, which has been exacted from the toilers by middlemen, who, while distributing that product, not only kept food enough for themselves and their immediate helpers, but who retained enough of food-value in their own hands to create a new class of persons to produce food specially for the advantage of themselves. These persons are known as tenants—borrowers of the very money that the lenders had abstracted from employés in the exchange of commodities placed in their hands, &c. They thus practically say to themselves and their children, by their accumulations, "Take your ease; eat, drink, and be merry; for, by the eternal fitness of things, you have provided for yourselves an income of food for all generations to come." Nemesis is not, however, to be evaded. To escape ennui, the child of luxury, by etiquette and custom, has invented for himself toils peculiarly his own. Science itself cannot escape the never-ceasing contagion of custom. That cynical woman of genius, "Ouida"—who, by her satire, preserved that interesting relic of the past, the Cathedral of Venice—in turn twits the devotees of science with the keen eye that they keep upon the "main chance"—the salary they must receive for their labours; "not for love alone," but "because there is money with it."

Capital may be said to be the system of dynamics which rules in this world of individualism, and is an agency by means of which the few are able to augment their possessions at the expense of the labour of the many, in contradistinction to the energy that should be begotten of the perfect organization of the labour of the whole community. It may not be supposed that the present state of social existence can at one bound leap into the improved condition shadowed forth in this paper. We have to do with a period of transition. What I have undertaken is to show that one portion of the machinery by which progress is to be achieved is by the State taking entire control of the currency of the country. With the more advanced thinkers of the age, I cannot overlook the circumstance that Mr. Del Mar points out—namely, that, though "reform in the institution of money would remove many causes of popular discontent, it is never referred to by land reformers, because the subject is one usually beyond the scope of popular agitators, and who, besides, may fear to risk the popularity of their own remedy by acknowledging the existence of another." He sums up his contention by stating, what all ought to know, that "money"—*i.e.*, the whole system of the currency—"unheard, unfelt, almost unseen, has the *power* to so distribute the burdens, gratifications, and opportunities of life that each individual shall enjoy that share of them to which his merits entitle him, or to dispense them with so partial a hand as to violate every principle of justice, and perpetuate a succession of social slaveries to the end of time."

Which track is our course of social life travelling upon? Few persons will, I apprehend, take objection to the abstract lines I have so far laid down. The self-conscious dishonesty of those who possess ill-gotten booty always apologizes for itself that it has by its own acts prevented greater wrong being done; and we teach ourselves to look upon the mass of moral and physical human degradation, induced by the glare of what we call civilisation, as a better position of affairs than that which preceded it. If this progression exists, there may be hope. Probably, few doubt that the present condition of France is better than that which obtained under the *ancien régime*. Then let us not talk about finality. Again I refer to the history of the past to show how ready human nature is to take the shadow for the reality. A block of wood has been prayed to as if it were the divinity it is supposed to represent. A king is treated as reverentially as if he were the "all sorts and conditions of men" whose interests he is pledged to conserve, till at length, not being unconscious like the idol, he forgets that the homage addressed to himself is only respect paid through him to the millions over whom he reigns. Nor are democratic rulers free from the danger of a similar misconception. In like manner, money, instead of being thought of and treated as the representative of labour, passing from hand to hand, is looked upon as something possessing intrinsic value of its own. Money itself is not a sacred thing at all. It is the labour for the life-sustaining food that it represents: that is the holy thing which, sanctified by inspiration and intelligence, is brought into practical usefulness by "the sweat of the brow"—a type and a precedent of that labour which is unto life eternal, and the issue of which is encysted in the words, "Give us this day our daily bread."

This misapprehension of the nature of money has caused the greater part of the troubles of human existence, because the overwhelming fact that "a man's life consisteth not in the abundance of the things which he possesseth" has been lost sight of. As a consequence, war, rapine, murder, aggression, dishonesty by strategy and by overt action, have prevailed, till the doctrine that might makes right is accepted far and near, the frequency of the wrong having obscured its enormity not only in the eyes of those who inflict it, but also of those who suffer from it. It was found that to toil, though healthy, was tedious; and the results of toil, however honest, were too tardy to satisfy the ambitions of those who, forgetting the thing signified—the labour—fell down and worshipped the *eidolon*—the money—so that he was a true witness who summarised "covetousness" as "idolatry." Whether this fact were written in the Bible or no, it is as the frontlet on every eyebrow emblazoned by the wealth begotten of the ill-requited labour of others, till at length a Huxley could with truth aver that "it was better to have been born in heathen Fiji than in the slums of Christian London." The ethics of the misuse of money are graphically set forth in the story of the unjust steward. That worthy, unwilling to avail himself of the fair distribution of food by labour, alleged that he could not dig; that it was beneath the ambition of a thief to beg: he therefore introduced the still-practised "division of the spoils" between himself and those who became his willing tools.

We have before us the food and the pebbles—the one the prime factor of life, the other the agent of distribution—each awaiting the performance of its office. Food is more heavy to move; pebbles less so, especially when their number is certified on a strip of papyrus, similar in effect to the silver-certificates of to-day. Let it be supposed that when the Pharaoh had, by means of the pebbles, taxed out of his fellaheen the corn that he wanted for himself and his retainers—such as public works, civil service, army and navy, &c.—then these pebbles became the currency of Egypt, by means of which symbols his subjects might distribute the remainder of the food among themselves more readily than by direct barter. It has pleased the money-changers of the age to pass into slang, for the use of those unacquainted with the methods of commerce, that "Barter would be a relapse into barbarism." When the masses of the people are better informed they will remember that all the business of the world is transacted by one kind of barter or another. There is not a politician here to-day, whether a Protectionist or a Freetrader, who does not hinge his arguments on the relative proportions of the exports and imports of this colony of New Zealand; and what is that but casting his language in the time-honoured mould of barter? Then, when does barter become inconvenient? First, in dealing with comparatively insignificant quantities of a commodity, on account of the difficulty of dividing and moving such small quantities over considerable distances; and, second, because the exchange of goods in kind does not admit of their being so easily sweated by their distributors as by the intervention of the token—money.

Silver and silver-certificates have been referred to. The silver-men of America know what was understood in King Solomon's time—that immense quantities of available silver cause its purchasing-power to diminish. Hence they have set all their ingenuity to work, aided by all the political influence they can command by bribery and other means, to persuade the public into the belief that, in spite of the vast quantity of silver that is now being raised in excess of its economic uses, it is possible to maintain for it the same purchasing-power —which means, from their standpoint, the same selling-price —that it formerly possessed. To this end, the general taxpayer of the United States pays for all the labour of the persons engaged in silver-mining, in fabricating the machinery engaged therein, down to the last person who earns his living from the industry of striking silver coinage, instead of these hosts of workers being engaged in the production of some useful article of food or commerce. But these silver-men conjure up for justification the immensely over-issued paper currency of Argentina. The over-value these men put upon their silver stands on no better basis than the inflated price put upon copper by the French syndicate, or the over-issued face-value of the Argentine paper. The worth of gold, silver, copper, paper, as money depends solely on its total volume, and on the rapidity with which it circulates. This great dynamic fact has been purposely kept in the background till those who ought to know better have come to overlook its existence, in order that the public might, through not understanding the true doctrine of the currency, more easily become the victims of the money-changers. Hence the cry was put forth not long ago in New Zealand, with respect to the financial project of the late Mr. James Macandrew, and which doubtless was repeated with parrotlike satisfaction by an uninstructed public, "that Mr. Macandrew would put everything right with a bale of paper and a printing press."

I need hardly say at this stage of my paper that I advocate what is called the quantity or numerary theory of the currency. Countries without a Government strong enough or sufficiently intelligent to curb the avarice of those who set up what is called a "standard of intrinsic value," whether of gold or silver or both combined—bimetallism—as the only means by which an over-issue of a non-intrinsic value currency can be prevented, usually lose sight of the fact that an inadequate issue of money may be as disastrous as an over-issue. This circumstance may not be so patent to the public, but writers on finance agree that "the influence which the contraction or expansion of the currency has upon prices and upon commerce has been rarely suspected by those among whom the events have taken place, who have usually been content to discover other causes than this for prosperity or adversity." When a financial crash comes the man with a sovereign in his hand triumphantly laughs at his neighbour who possesses a note of the collapsed bank; but the man with the gold does not reflect how many pounds he has been done out of in his business by the fluctuations in the value of his property caused by the seesawing of the financial wire-pullers when they have alternately expanded and contracted the currency for their profit and his loss. It is asserted that Sparta, the first Roman Republic, Carthage, and every country while working under a numerary system of the currency has been prosperous. A purely numerary system is incompatible with a despotism, whether the tyrant be a king or an oligarchy. The Roman Emperor Octavius, it is said, wished to return to the numerary system of the first republic; but who was to control the emission of the currency? "To intrust the Senate with the tremendous powers would be to deliver up the government to them. The power would probably be abused. To regulate the currency himself would expose him to the attack of every dissatisfied class." No Government in Australasia has yet arisen that can affix a sign on every money-token sent into circulation equivalent to the brand S.C. of the Roman Republic. The numerary brand of the famed iron currency of Lycurgus was, it is believed, the secret of its value. The famous William Pitt, like Augustus, quailed before the capitalists of his age, who were the masters of the Government debt. Mr. Pitt, with the Roman Emperor, saw that a numerary paper emission was a system of taxation equable in its incidence—the very thing the capitalists dislike. Thwarted in his object of fair-play, he petulantly exclaimed that a national paper currency was to the bankers what a policeman was to a thief. I find that your Mr. Verrall, like Augustus Cæsar, has found how dangerous it is to propound an honest currency. The Roman was wise before attempting the deed, and thereby saved his political position; Mr. Verrall made the discovery at the expense of his place in the Legislature—but, still, *magna est veritas et prævalebit.* The present system, backed up by the gold and silver delusion, will die hard, because it appeals right along the gamut of human covetousness, from the shrill scream of the cheap-jack to the guttural base of the millionaire, offering to each and every a means of overreaching his less-informed neighbour.

I have already indicated that I propose to relegate gold and silver to the position of commodities, to be bought and sold for what they are worth, as men, women, and horses still continue to be. I would like the civilisation of to-day—not by proxy of its members, but in a grand procession—every now and then to pass along the slums and into the dens of each abode of poverty in these islands; this done, that afterwards every outcast because of his poverty, with his wife and his children in their garments soiled by labour, or tattered for the want of its wages, there being nothing for them to do, should proceed along your gayest thoroughfares and into your wealthiest churches, that civilisation might become better acquainted with the totality of its present outcome. This better acquaintance with the state of the case might lead to the aggregate of the people taking the management of their affairs out of the hands of the few into their own. Is it a hopeless task for these colonies, in the freshness of their youth and in the honesty of their purpose, to form a Government that shall emit such an amount of representative value as shall be adequate to the need of the country?

This emission by the Government once established and understood by the masses, the *descensus Averni* of over-issue would be checked by the knowledge gained from observing the financial effect of each succeeding issue on the trade, commerce, and agriculture of the country. In half a generation the public danger of being harmed by the jugglery of bankers' associations, with closed doors, assisted by their confederates outside, capitalists of every grade, would have passed away, because the people would have become sufficiently enlightened to testify their wishes through the ballot-box. I may be told that I am very dogmatic on a subject that is very deep. Permit me to reply that among students of other schools of finance I might not be listened to unless I had the assurance that comes of conviction. A legislator the other day in your Assembly alleged that "an hour had been wasted and the honourable member fooled" during which this subject had been advocated by Mr. Verrall. Shades of Bathgate and Macandrew, fortunate that you are no longer in the presence of such a Solomon!

To the question of State issue of notes is related the twin subject of land-monopoly, to which I can in this connection make but little reference, save to note that the influence of land-monopoly in Victoria was so potent that my paper on "Small Holdings of Land the Mainstay of Individuals and Nations" was only noticed in the just-published "Transactions" of this Association by its title. I freely admit the feebleness of my attempt to deal with such a great question; the importance of the subject was the same, nevertheless. Often has my attention been directed to the progress of assisted settlement on small holdings in your beautiful islands, inaugurated, I think, by Sir Robert Stout and the Hon. John Ballance.

The profound theorists who prosper under the present condition of finance may ask, How is the State to discover what is an adequate emission of State paper? These querists will desire elaborate calculations and bewildering columns of figures. These are often the receptacles of dust that they ever have at hand to blind the eyes of the public. But is not this the section for statistics? Not long ago a banker before a meeting in Melbourne, at the Bankers' Institute of Australasia, broadly asserted that banks' elaborate figures were not to be trusted; while long before that an English financier had stated that public opinion has been proved by results to be more reliable than the arguments of experts trained to think in particular grooves. Of this the operation of Sir Robert Peel's Act of 1844 may be cited as an instance. Living in London till 1848, I heard it popularly said that this Act "was calculated to make rich men richer and the poor poorer." There are few that will now deny this view of the case.

I submit a plan to illustrate how the proposed new system of a State bank of issue may be tested. Let an extensive plain which it is desired to irrigate be thought of. The question arises, How many millions of gallons will it take to cover the plain a foot deep in the shallowest place? The mathematicians have measured its superficial area, and calculated the inequalities of its surface; they have allowed for the supposed differences of the soil in respect to soakage; but, after all, the only exact test of quantity of water required is to open the sluices from the reservoir and let the meter through which the water passes register the quantity till the desired level is attained. So let the Government cautiously ascertain what volume of currency will meet the expanding requirements of the country by carefully recording the issues and checking the results upon the business and productive energy of the country. It may be asked how it is that, of the three systems of money that have obtained during the historical period—viz., the *ponderata*, the *moneta*, and the *numerata*, or the weighed, the minted, and the numbered — at the present period the nations of the world have harked back to the system of *Juno moneta*, the minted, with all its vagaries of haphazard. My reply is, Chiefly because, as the late Mr. Walter Bagehot remarked, "those who best know many of the facts of banking will not tell them or hint at them." I presume he meant they were trade secrets. Science now disclaims these tricks of the dark ages. In the history of the world it is recorded that human power had too often exulted over those lying at its mercy. The victors left off eating their captives when they found it was to their advantage to employ or sell them as slaves. Under a partially-enlightened national conscience, those in political or social power took advantage of the ignorance of those less informed than themselves, and do up to this hour propose that capital should have the balance of might on its side, and the food of the world within its grasp with which to enforce its power. Thus, to-day, no matter at what expense in labour any property real or personal has been brought together, if merely one-half of its cost has been pledged for money the mortgagee takes the whole of it and leaves the unfortunate borrower penniless. So glaring is this hardship that even the *Law Times* awhile ago revolted against its infliction, and said, "The notion of sanctity of contract is outside the question, when the enforcement of the contract is practically impossible, or only attainable at vastly exceptional cost." The heaviest part of the indictment is that by tampering with the currency of the country the bankers bring about the very catastrophes that place the borrower at the mercy of the lender. It was given as a *jeu d'esprit*, in an American paper, that Johnny was pondering over his copy-book sentence, "Honesty is the best policy," and submitted to his money-lending father whether it was so. "Yes, sonny," the senior affectionately replied; "if people had not been honest, how should I have got on as I have done?" The contention of the near future is between the reign of utter dishonesty in finance, disguised though it may be as an angel of mercy, and of common fair-play.

In my opinion the establishment of a State bank of issue somewhat upon the lines of the Bill carried in the Lower House of New Zealand by the late Mr. Macandrew is the thing to be done. Then, *moneta*, the minted money of the usurer, will give place to the counted volume of the *numerata* under the regulated control as to its emission by the Government of the people who have to get their living under its potent influence. But, this being so, how is it that the vast

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edifice of progress has been reared during little more than a century? Certainly by means of co-operation, of which up to now money—*i.e.*, capital—has been the only efficient agent. The despotism of a single mind could build a pyramid or found an empire. This power having passed away, on its ruins has arisen capitalism—that is, the concentration of the results of other men's labour in the hands of a few. This oligarchy by the use of the lever of wages has exacted from the labourer a large proportion of the reward of his work. Then, if capital ceases to be the bond for co-operation of labour, some power must take its place. Economists look to the combined action of a State bank of issue and the organization of labour to replace the iron hand of the taskmasters' wage-power. The progress will be slow; but the reason why a Government which is said to be of the people, for the people, and by the people should not begin to be welded into a great co-operative power, by the aid of a State bank of issue, it is difficult to pronounce. Because the management of State finance falls into the power of money-forgers like the late President Celman of Argentina, the robbery perpetrated, or the financial ruin brought about, though not peculiar to paper money, is laid at its door. The supposed reserve of gold in the Bank of Amsterdam, when looked for, was found to have been spirited away; and, when the disturbing ideas attaching to the importance of gold and silver coinage are banished for good and all, we may expect to have a currency founded on a true basis, and one that, as knowledge extends, will be "understanded of the people."

Referring again to paper money, because its excessive issue brought about financial disaster, we might as well repudiate the use of either fire or water because of the destruction wrought by a conflagration, or the devastation caused by an extensive inundation. Then, what of the constant practice of these colonies borrowing foreign capital? Mr. Bagehot averred that what will be the effect on incipient civilisations by the facility with which these loans are asked for and granted "no untutored mind can say." There are not wanting men of great political insight in these colonies who say that the refusal of loans from outside capitalists would be one of the best things that could happen to the public; but, then, what would become of the money-brokers at Home and abroad? Why the Australian Colonies, unlike most other countries, should have no internal debt of their own, whose bonds should be a convenient mode of investment and opportunity for mild speculation, it is difficult to divine. The Chief Justice of South Australia the other day, in a State correspondence, recognised the want of a "local market for Government stock." If the insatiable bent for borrowing outside capital were checked, we might set about discovering how we might help ourselves, and probably should find that a measure similar to the Bill of Mr. Macandrew, passed in the Lower House of New Zealand, for an Act to be entitled "The Public Advances on Land Act, 1886," would meet the case, provided that the bonds were open to be purchased by the savings of the people.

It is a frequent remark that the French are more patriotic than the English are—and for a very good reason. A Frenchman can purchase Government bonds called *rentes* for as small a sum as £4 each, upon which he receives interest: he therefore feels that he is somebody, and that he has a stake in the progress of his country. In 1886 a £20,000,000 French loan was called for—it was subscribed twenty-one times over; there were, in all, 247,000 subscribers, the greater number of whom were for 100fr.—£4—all of whom received their full allotment. It is small wonder that the French are patriotic when over five millions are small landholders, and many millions hold the bonds of their country.

Fancy what Australian workers might become if thus recognised by a supercilious oligarchy! The notes issued by the Government would form the currency of the country, and, as agents in production, like the marked pebbles of the Pharaohs, they would distribute the rewards of labour to him who had earned them. Mr. Macandrew's Bill provided for the conversion, on demand, of interest-bearing bonds into notes not receiving interest and *vice versâ*. Mr. Verrall, on the other hand, proposed that the Government should pay a percentage on the note currency in the hands of the public; but as this seems to be paying away revenue with one hand, to be collected from the general taxpayer—identically the same party—with the other, the abstract advantage is not apparent. Practically, it might, as an inducement, smooth the way for the introduction of the system into public favour. A well-regulated State bank of issue should so far minimise the fluctuation of value as to assure a borrower of money that the interest agreed upon, as it became due, and the principal sum, when to be repaid, should be met by the sale of about the same quantity of produce of live or dead stock that the money borrowed would have purchased at the time of the loan. Everybody will know that under the existing system of a forced expansion of the currency at one time, and the violent contraction of it at another, the borrower of £1,000 at 5 per cent. when money is abundant may, when money is scarce, have to sell 50 per cent. in quantity more produce in order to pay the interest, or repay the loan, than the money would have purchased when he borrowed it. Of course I shall be told that this "arises from financial depression," or a "visitation of Providence." This is the very thing I am trying to get at—

the Providence that sits in bank parlours—and I want to see God's good Providence, as of old, turn the money-changers out of His temple of justice and fair-play, which shall no longer remain "a den of thieves."

To learn how just my contention is, let any one refer to a paper read by Mr. Matthew Macfie, on the 14th November, 1888, before the Bankers' Institute in Melbourne, when he stated that the Bank of England adopted the policy of keeping its supply of the currency inadequate that the bank might have occasion to demand a famine price for accommodation to its customers; that the bank had been known to force its official minimum to 10 per cent., while French traders, at the very time, were only paying 3½ per cent. "It is time," Mr. Macfie said, "to put an end to abuses whose maintenance for so long a period is alone due to credulity and ignorance." If I have succeeded in shaking this false confidence of "credulity" and expelling this ignorance in any degree, I submit that I have, in however humble a manner, aided in forwarding the objects of this Association.

To summarise briefly, my contention is—(1.) That a condition essential to the currency of any country is that it must be of such a character that, by regulation, its total numerary volume may be adequate to the business requirements of the community. (2.) That a so-called metallic basis for a currency is a delusion and a snare, and only plays into the hands of those who seek to avail themselves unduly of the results of other people's labour. (3.) That for the social and political welfare of any country it is indispensable that the emission of its circulating medium, money, must be in the hands of one party only, and that party must be the State. (4.) That, as the power of capital at present is the only efficient bond of co-operation, there must be substituted for it the united force of organized labour, and of a State bank of issue, before any permanent change for the better is possible. (5.) That, while this change is being effected, the increase of knowledge in social science afforded by the correlated facts of statistics will hasten on, I hope peacefully, the revolution that I have tried to briefly set forth in this paper.

It will doubtless be conceded that the true province of science is to utilise the lessons afforded by the study of the past, whether in time nearer or more remote, in order that we may profit both the present generation and the generation in the nearer future; while more gifted spirits will forecast the achievements of human discovery when "all things shall work together for good," because the fruits and fallible science of man shall more nearly run co-ordinate with the infinite and not fallible purpose of the Supreme Mind. This cannot be while civilisation and science leave out of their calculation "the least of those who bear the human form." If I am correctly informed, even the Maoris surpass ourselves in caring for every individual in their community. As I think, it is time that money, the means of the distribution of wealth, should be made to more efficiently perform the office that pertains to it—viz., that "he who gathered much had nothing over," while "he who gathered little had no lack." Political and social science may be considered as being the object and end of all discovery. "Gather up the fragments, that nothing be lost," surely applies not less to humanity and each of its units than to objects whose main title to our attention is that they minister to man's sustentation and well-being. As noticed in the address of the distinguished President of this Association last evening, scientists should teach us, in the prospect of a vastly-increasing population in these Islands, that the means for their support should not be deported without practical science providing for a renewed supply of the elements of plant-food. It is to be hoped that no considerable portion of the surface of this beautiful and picturesque New Zealand will be rendered useless for all time, like vast tracts in Nubia, California, and elsewhere, when the "disinherited" classes become the special wards of science, and when the civilisation of the future may boast, as did the Incas of Peru in a past age, that not a single person of all their subjects was unprovided for.

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1. *Australian Political Achievements and Aspirations.*
By E. Nesbit.

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2. *A Plea for Woman's Rights.*
By Mary A. Clark.

Section G.

(ANTHROPOLOGY.)

President of the Section—A. W. Howitt, F.G.S.

ADDRESS BY THE PRESIDENT.

It becomes the pleasing duty of my office as President of Section G of this meeting of the Australasian Association for the Advancement of Science to direct attention to a branch of anthropology connected with savage custom to which little attention has been given, but which, when diligently studied, will, I feel convinced, amply repay whatever labour may be bestowed. Such a study will reveal many peeps into the inner social life of savages, and will also throw an unexpected light on the most obscure practices of antiquity—namely, on the mysteries of classical times whose origin has only been a matter for conjecture.

Very little has been done in this direction by those who are competent to pursue it by reason of their sufficient knowledge of savage custom and the mental status of savages. First, it is necessary that the investigator must be himself, so to say, among the initiated before he will be in a position to consider the bearing of the scraps of evidence which he may gather from those who have mentioned more or less fully the ceremonies of savages. When all that is as yet known about existing mysteries has been gathered together and subjected to critical examination, it will then be necessary that the further comparison with ancient mysteries shall be made by one able to do so by reason of competent acquaintance with classical literature.

The first steps only have, so far, been taken. Something is known now authoritatively as to the practice of the initiation ceremonies of the Australian tribes extending over a considerable area in south-eastern Australia. Not only is the procedure known, but the intention of the ceremonies is explained, and it is seen that, as might have been anticipated, they have been established and are maintained with the object of insuring that the youths of the tribe shall, in assuming the privileges of manhood, only be permitted to do so when the assembled elder men are satisfied that they are able to take their share in the common liabilities of the community.

In memoirs which I have communicated on these subjects to the Anthropological Institute of Great Britain will be found details of the ceremonies of two tribes, in which I personally participated, and as to which I can therefore speak with confidence. The Rev. Mr. Fisin, my valued *confrère*, has also rendered most interesting particulars as to the ceremonies among some tribes of Fiji; particulars have been given as to the *dukduk* ceremonies in New Britain; and, finally, in very numerous works of various authors, details more or less full, partly from observation, partly from hearsay, are given concerning the ceremonies of Australian tribes. When all these statements are carefully considered, digested, and completed, we shall find that there is far more to be said on this subject in its Australasian aspect than is as yet suspected.

I may note here the most interesting and valuable information given as to the ceremonies of North American tribes by Mr. Cushing, especially of those of the Zuni Tribe. In the annual reports of the Bureau of Ethnology will be found much bearing on the subject. The field for inquiry is world-wide. Wherever there are savage races in existence, and where they are disappearing before the white man, no time should be lost in recording all that can be learned about their ceremonies before the knowledge of them is lost for ever.

So far as is at present known, the Australian ceremonies of initiation are to be classed under two types, and, broadly speaking, they may be distinguished from each other by the presence or absence of circumcision, or possibly even by that of the incision, which has been termed by the late Mr. Curr the "terrible rite," but for which I think the Dieri term *kulpe* might be appropriately used.

In the present state of knowledge on this subject it may be said that the two types of ceremonies are characteristic respectively of the eastern and western halves of the continent. Approximately the western boundary of New South Wales and of Queensland may be taken to mark the dividing-line, although in Queensland the practice of circumcision and of *kulpe* extends within that colony more or less.

A further rough definition may be made by noting the range of the two types of class-system. On the eastern side of the boundary indicated there is found, more or less universally, some form of the well-known *kamilaroi* class organization, in which there are two primary class names, four sub-class names, and corresponding groups of totems, and with descent either in the female or male line. On the western side of the boundary the prevailing class-system is marked by some form of that of which I have taken the Dieri classes as the type—namely, two primary class names without any sub-classes but with groups of totems.

Whichever type the ceremonies may follow, the underlying principles are the same, and as an illustration I will shortly note the main features attending the initiations of the tribes in the southern parts of New South Wales, which are practically the same as those which are practised at least from the eastern coast to Wentworth, and from the southern coast far into the Riverina district.

It is always convenient to have some term which may be used to define some custom which is general over wide areas, irrespective of the different local names which are given to it. The initiation ceremonies to which I refer are termed in different tribes *bora*, *burbung*, *kuringal*, *bunau*, *jeraeil*, &c. The first-named term, *bora*, applies especially to the ceremonies of the Kameleri tribes. It is a well-known term, having a generally-accepted meaning—and in that sense I propose to use it—as indicating certain ceremonies, just as the word "totem" is now accepted for a certain organization for which each Australian tribe has its own term. With this understanding, the use of the word *bora* will be convenient without being misleading. I shall use it in describing, for example, the ceremonies of the Muring tribes of southern New South Wales, with which I have a personal acquaintance. The *bora* is held when, by the direction of the principal head-man of one section of the tribe, the whole community is collected together. I use the term "community" as comprising those tribes between which there was connubium.

The tribe, regarded as a community, is divided into two intermarrying moieties, which are each composed of either an aggregate of totem or an aggregate of local class—the former in cases where the archaic structure of the tribe with maternal descent is still vigorous, the latter where the old organization has broken down and paternal descent has become established. For the former I instance the Wirajuri Tribe in New South Wales, and for the latter the Kumai Tribe in Victoria. The Wirajuri Tribe is divided into two principal classes, with subclasses and totems having descent in the female line. In the Kumai Tribe the classes and totem have disappeared, leaving no more than traces behind, while the tribe is organized in strongly-marked local classes, which are perpetuated in the male line. In both of these tribes the *bora* was held at the instance of the head-man of one of the two moieties of the tribe. In the former the head-man sent his mandate by a messenger of his own totem to the head-man of the same totem in the adjoining horde* or adjoining tribe. The message was transmitted through one particular totem, which, in fact,

* I use the term "horde" when there is maternal descent, and "clan" when descent is in the male line.

represented one of the two principal classes. This totem made the other totem aware of the order given, and it and its sister totems were aided in carrying out the ceremonies by the aggregate totems of the other moiety.

One primary class thus initiated the youths of the other class, and this is easily understood when it is remembered that it would afterwards give its daughters or sisters to these men as wives. In the Kumai Tribe the message originated with the head-man of one of the moieties of the tribe, which in this case were entirely local. The messenger was most commonly a relative of the head-man, and probably of the same local clan. The message was conveyed to the head-man of the other moiety, and, as in this instance there were no totems, it has one moiety of the tribe composed of local classes, which aided the other moiety to initiate the youths of the tribe. The Kumai had no connubium with surrounding tribes, and therefore the "community" was confined to themselves alone.*

The principles on which the *bora* ceremonies are formed may be stated as follows—for all tribes, so far as my knowledge extends, whatever variation there may be in practice. The youth in initiation passes from boyhood to manhood, and assumes or is invested thereby with the privileges of the latter, but with its responsibilities as a member of the tribe.

With the Wirajuri the novice is taken from the assembled women—*i.e.*, out of the maternal control—by the initiated men of that moiety of the tribe to which belongs his future wife, or, to state the case with more precision, to which belong the women as regards whom he has inherited potential marital rights. The men who especially instruct him and watch over him during the ceremonies are the brothers—own or tribal—of those women.

It is, *mutatis mutandis*, the same with the Kumai. With them the men who stand in the fraternal relation to the women from among whom the novice might in the future legally obtain a wife are the sponsors of the novice. It is, therefore, in all cases the one moiety of the tribe which initiate the youths being the sons of the other moiety, and the initiated youths take each other's sisters—own or tribal—to wife.

The ceremonies themselves impress upon the novice the necessity of abandoning for ever childish habits, and of behaving themselves with the gravity and decorum due to manhood. This is impressed upon them by the instructions of

* There may possibly have been an exception as regards the south-western clan—the Bratana—to whose ceremonies some of the western Kulin came; but, as these ceremonies were held after the settlement of the country by the whites, I think it open to question whether this was originally the practice.

their "sponsors," if this term may be used, by the direct injunctions of the old men who conduct the ceremonies, and by some of the spectacular games which are performed for their instruction as well as for their amusement.

During the course of *bora* certain principles for their guidance during life are impressed upon them: for instance, to listen to and obey the old men; to generously share the fruits of the chase, &c., with others, especially their kindred; not to interfere with the women of the tribe, especially as regards those related to them; not to injure others by witchcraft.

The sacred traditions of the tribe are imparted to them under the obligation of secrecy, for breach of which the penalty of death may be inflicted, either by violence at the hands of the initiated or by supernatural means by the wizards. They are told how the *bora* was in the first instance instituted by the Great Being, whose representation is now for the first time shown to them moulded life-size in earth upon the ground, whose presence is believed to inspire the wizards during the ceremonies, and whose voice is heard in the roaring noise of the sacred instrument, which is the central mystery in the ceremonies of the tribes. In some tribes one or more teeth are knocked out as a visible sign of initiation to all whom it may concern.

The qualification of the novice to take his place as a warrior is in many tribes tested by a combat in which he takes part. As a hunter, he is sent out when initiated to earn his own living, often for several months; and, under the custom of the *bora*, the novice is, by the strict rules of prohibition as to certain food-animals, placed practically in a state of privation, while possibly surrounded by plentiful but forbidden game. The extraordinary restrictive power of these rules, and the wonderful effect of the teaching at the *bora*, has been often shown by serious, nay, even fatal effects produced by "conscience" in novices who have broken the rule and have eaten of forbidden food.

At the close of the initiation the youth is clothed with the garb of manhood: he is invested with the belt, the kilt, the armlets, the forehead band; he is painted with the tribal markings, and he is armed with the proper weapons of offence and defence.

Finally, having been initiated, instructed in what he may justly speak of as the sacred religion of the tribe in its moral code, having satisfied the elders that he is fitted as a warrior and as a hunter to be received as a "full man" in the community, he is permitted to take his promised wife where infant betrothal is practised, or to obtain one under such conditions as obtain in that particular tribe.

One of the most remarkable facts brought out by the comparison of initiation ceremonies is the universality of the use in them, or in connection with them, of a wooden instrument, which is a child's toy in England, and which is there known as the "bullroarer." As I remember to have made and used one as a child, it is about 8in. in length by 3in. in width, and, when whirled round at the end of a cord, caused a loud humming or roaring sound. Throughout Australia, so far as my investigations have extended, it is one of the most sacred and secret objects appertaining to the ceremonies. It is not permitted to women and children—I may say, to the uninitiated generally—to see it, under pain of death. The novices were told that if they made it known to women and children their punishment would be death, either by actual violence or by magic. So secret was this object kept among the Kumai that, intimately as I was acquainted with them, it was not exhibited to me at their *bora* until the old men had been fully satisfied that I had been present at one of their neighbours'—the Murring—and that I had there seen it, had become acquainted with its use, and, more convincingly, that I had possession of one which had been used in their ceremonies. The reverential awe with which one of these sacred objects is viewed by the initiated, when carried round to authenticate the message calling a ceremonial assembly, is most striking. I have observed it not merely once but many times, and cannot feel any doubt about the depth of the feeling of reverence in the minds of the aborigines in regard to it. A peculiar sacredness is attached to it for several reasons, among which the principal are that it is taught that the first one was made by the supernatural being who first instistituted the ceremonies, and the roar emitted by it when in use is his voice calling upon those assembled to perform the rites. It is the voice of Baiame, Daramulgun, Mungan, however he may be called in the several languages, but in those tribes with whose ceremonies I have acquaintance he is also more familiarly called "our Father." The universality of its use, and under the same conditions, in world-wide localities, is one of the most puzzling questions in this branch of anthropology, and can only, as it seems to me, point to the extreme antiquity of its use. As I have said, it is universally used in Australia. Its use is recorded at the native courts of Africa, where it is called "the voice of Oro." The Maoris, the Zulus, the Navajoes use it in their ceremonies, and it has been pointed out by Andrew Lang that its use in the Dionysian mysteries is clearly indicated by a passage in the scholiast to Clemens of Alexandria. In his interesting chapter on the bullroarer in "Custom and Myth," Mr. Lang well says that in all probability the presence of this implement in Greek mysteries was a survival from the time "when the Greeks were in the social condition of Australians." I feel inclined to go somewhat beyond this, and to say that it is a survival of the time when the ancestors of the Aryan peoples were in that condition. If so, he might possibly say that its earliest use may be assigned to a time still more remote, for it is found in the ceremonies of savage races wide apart and of diverse stocks. I am not satisfied that its use under precisely similar circumstances is sufficiently explained by the supposition that it was independently discovered by the early savages.

The ancient mysteries of classical times have had a great fascination for numbers of writers, and have exercised their ingenuity in reconstructing their course and explaining their object. I cannot feel any doubt, taking Greece as an example, that the most venerated of the mysteries has been handed down to historic times from a period which was then completely lost to view in the obscurity of the past, their extreme antiquity causing their origin to be attributed to heroic and divine authors.

To draw any parallel between the *boras* of the Australians and the mysteries of Greece may seem to be entirely far-fetched and unreasonable; but the use of the "bullroarer" as a sacred object shows that there is, in so far as concerns it, a connection, or at least a striking parallel in practice. There was extreme secrecy as to the mysteries, with a death-penalty for its breach. Their origin was attributed to a heroic or divine being. The conduct of the mysteries was in the hands of men who were of a sacred character, by reason of their sometimes hereditary office. The ceremonies were calculated to elevate the initiated in the moral sentiments according to the spirit of the times. The circumstances attending the mysteries were such as to produce a highly-strung mental state, which rendered the novices extremely susceptible to impressions, which became indelible. The teaching of the sacred myths was by means of impressive spectacular representations. Such statements as these may be made as to the Eleusinian mysteries, and they apply variously to the *boras* of the tribe with which I have personal acquaintance, and I have little doubt that they represent those of other tribes.

The instruction given to the novices at the *boras* is clearly intended to elevate them in their conception of duty towards the elder men, towards their fellow tribesmen, and in their feelings of reverence for Baiame or Daramulgun, the "All-father" and instructor of the tribe. Among the striking spectacular representations which are given during the night for the instruction and amusement of the novice there are some which might become developed into such representations as those which are believed to have been made at Eleusis. Among these, I may note the passage across the carefully-cleared space which serves as a style of a mystic Ngalabbie, the two wives of Daramulgun "coming from afar," and the exhibition to the novice of the representation of Daramulgun moulded life-size in the ground, with examples dispersed round his figure of all the weapons and implements invented by him for man's use, and surrounded by the wizard, who invokes his name in a magical chant. When we add to this the striking and suggestive representation of the reviving of a dead and buried wizard, of the magical chanting of one of the synonyms of Daramulgun, it must be admitted that the conception is reached that the teachings of the *bora* indicate a rude form of religion, which is taught to the youthful Australian savage in a manner and under circumstances which leave an indelible impression in his after-life. Glimpses of these matters have been but barely seen by observers, who have obtained garbled accounts from men who would regard them as being of the uninitiated, to reveal to whom the sacred secrets would be an impious act.

There is a marked distinction to be drawn between the men of the past generation in all Australian tribes, who were born and brought up under their ancestral laws, and the younger men who have been raised up under the influences of our civilisation. Those who have had the best opportunities of judging will certainly arrive at the conclusion that many of the old men, with all their savage faults, had also some admirable qualities. This has been my experience. I have known men among them who, according to their lights, were right-minded, honourable, trustworthy fellows, who would not be guilty of a mean action. I cannot put this distinction between the past and the present generations better than by quoting an expression from Mr. McG——, a missionary who had a lifelong experience. He said, "The old people were reliable, but the young people are all rascals." I attribute the good qualities which those old men possessed to the teachings imparted to them not only during childhood, but especially then at the *boras*.

I have quoted the opinion of a missionary, and I can compare with it the opinion of one of the worthy old blackfellows I have mentioned. He said to me, when we were discussing the holding of our *bora*, "I am glad it will be held, for our boys are all going wild since they have gone to the white people; we have no longer any control over them."

It is much to be regretted that so little has been recorded authentically as to the *bora* ceremonies, by persons properly qualified to describe them. There have been accounts given by various writers, mostly at second hand, and other accounts, generally as magazine or newspaper articles, which profess to be descriptions from personal observation, but which are evidently dressed up to suit the mode of publication, and the authenticity of which is not guaranteed by the names of the authors, and the facts stated are not capable of verification.

The earliest authentic account with which I am acquainted is that given by Collins in his account of the first settlement of New South Wales. There can be no doubt that he was present at one of the *boras*, for his descriptions and the illustrations in his book are sufficiently accurate, and delineate parts of ceremonies which I have myself witnessed. Collins was, however, absent from them during the night, at which time some of the impressive spectacular performances take place. Collins's account is, however, a most valuable testimony of the existence of these *bora* ceremonies in the form in which they occurred before the white men settled in Australia, and also of the teachings imparted in them.

There were, and no doubt still are, white men who have been duly admitted to the *boras*, and were quite capable of giving most important evidence regarding their ceremonial in distant parts of Australia, but it is remarkable that two at least within my knowledge have absolutely refused to describe them. No doubt these men were at the time they were admitted bound down under a solemn promise to secrecy and silence, and honourably keep it. We must regret that they are tongue-tied, but we must admire their constancy. Fortunately, in my own case no such promise was exacted, for I attended under circumstances in the first instance which caused those who conducted the *bora* to receive me as one having already acquired the status of one of themselves.

It seems singular that Buckley makes no remark upon the *bora*, for in his character of resuscitated blackfellow he would undoubtedly have been held to have been "made a young man" in whatever way that ceremony was practised in his tribe. But it seems that the *bora* among the Kulin tribes of the Yarra River and of Western Port district was reduced to a mere semblance of the full, picturesque, and impressive *burbung* of the more northern tribes, and it is probable that the neighbours of these Kulins with whom Buckley lived so long had ceremonies equally simple. If so, there would have been little to attract his attention, or to cause him to specially mention it to the biographer who recorded his adventures.

Morell and Davis, who also lived with the aborigines in Queensland for years, have, so far as I know, not given any account of the *boras* held there. In South Australia, Gason, who is well known as having been accepted by the Dieri Tribe as one of their tribesmen, has given an account of the several ceremonies through which the boy ascends to perfect manhood in that tribe. But these accounts are wanting in those details and descriptions which are necessary to enable the anthropologist to ascertain the principles on which the ceremonies are founded, and the objects which they are intended to gain.

It may be possible, on careful examination of the various works of travellers and other writers on Australian subjects, to discover passages which bear upon the initiation ceremonies, and from them by a process of comparison to arrive at slight conclusions at least as to their character in the tribe described. It is also to be hoped that, while there are tribes which are so far unbroken as to maintain their ceremonies, some one may have the opportunity or may make the opportunity of witnessing them, and by a record of the proceedings add to the scanty literature of a subject which is one of those having very great interest to the anthropologist, and also, from having undoubtedly a bearing by comparison upon the history of races which are now civilised, is of interest to the historical and classical student.

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1. *Old Stories of Polynesia.*

By E. Tregear, F.R.G.S.

The author commenced by pointing out that in some of his earlier writings he had stated that the study of the New Zealand and other Polynesian peoples was of value to the ethnologist mainly because it enabled him to see our own ancestors during the stone age, and thus to enter more fully into the discussion of the conditions out of which modern civilisation had evolved itself. He stated that he had not altered his opinion as to the valuable light which many of the usages of the modern savage throw upon the customs of the ancient savage; but he had modified his views in consideration of the great danger to which investigators exposed themselves by hasty generalisation and by conclusions based on perhaps false analysis. The result of his researches had been, philologically, that he was very strongly impressed with the fact that the language of Polynesia bore strong internal evidence of a far higher culture, of a far higher civilisation, than anything now to be found amongst the natives of the Pacific Islands. After dealing with the question whether a nation once in possession of a high state of civilisation ever lost this, and showing that instances of this fact had occurred (notably the case of the Portuguese at Malacca), the paper went on to point out the remarkable fact that the Maori-Polynesians did not use pottery, and also that wherever the Papuan held sway there was a pottery-making people, and that they also used the most mighty of ancient weapons, the bow, which was rejected by the Polynesians. Reference was also made to the fact that when Tasman first saw the Maoris two hundred years ago they used double canoes, and when Cook visited New Zealand double canoes were plentiful; but a modern Maori of thirty years of age did not know that his ancestors used such a vessel. The paper then went on to recite a number of old Polynesian stories, and to point out the striking coincidence between the customs related therein and those existing in ancient Europe. This was most particularly illustrated with reference to Milton's description in "Paradise Lost" of the war in heaven, and it was pointed out that this story, almost word for word, was orally transmitted in Polynesia, centuries before Milton lived, in the Maori legend of Tane and Rangi. The similarity of the well-known legend of Maui catching the sun with a flax rope to some told by the Ojibbeway Indians and the Dogrib Indians was next commented on. The Polynesian deluge-myths—viz., the deluges by water and by fire—were next referred to, and the striking similarity between the Chaldean account of the deluge and that of the Polynesians was noted; then was noted the identity of the legends of the American Indians, the Indians of Brazil, and numerous others concerning the deluge of fire. Indeed, as it was put in the paper, the legend came from the great continents as Keltic, Greek, Egyptian, and American. It was also found in Polynesia, the Maori sages speaking of some mighty conflagration in the past. In concluding, the author said, "I think the question may well be asked as to the scientific value of these old stories; and the answer is as follows: If the chronology taught us in our youth allows of no expansion, the benefit we should derive from the study of these old legends would be small indeed. I do not fear, however, to shock even the most orthodox by claiming for the human race an antiquity upon this earth almost inconceivable, since Professor Sayce, the champion of Biblical archæology, is not afraid to state that he considers human beings have communicated with each other by means of articulate language for at least forty thousand years—nothing being said as to the duration of the inarticulate period. That people separated by vast distances of sea and land, divided also now into races apparently distinct in blood and speech, should hold possession of the same primitive legends argues, if not a common origin, at least an intercommunication in a past so infinitely remote that the mind is filled with awe, and there is opened up a vast field for inquiry into the period antecedent to our oldest history. Races which spoke Sanscrit, Greek, and Latin, the cultivated peoples of our histories, have left us a few writings which help to illume the near past as a candle glimmers in some dark mine; but what can we gather concerning the lives and thoughts of those ancient forefathers of ours who transmitted to us the blood which runs in our veins to-day? Their personalities lie deep in the abysses of that ocean of time where the histories of Greek, Egyptian, Babylonian, Persian, Roman, Kelt, and Saxon, are but reflections visible on its topmost surface. What we shall ever know of our most ancient progenitors lies embalmed in these apparently foolish but priceless and almost indestructible traditions passed on from 'mouth to ear' through innumerable centuries."

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2. *Graphic Symbols.*

By R. Coupland Harding, Wellington.

The tendency of English grammarians of the present century, and more especially in recent years, has been towards the restriction of the use of arbitrary symbols in writing and printing; and, professedly, towards the exclusive use of those twenty-six signs which may (by a figure of speech) be called phonetic. It is my purpose to show that arbitrary signs, though unsystematic and habitually misused, have a more important place in written language than is generally conceded; that in fact they hold at least an equal place in modern English with the so-called phonetic signs; and that to an appreciable extent they have exerted and still exert a reflex influence on the language itself.

The objection to arbitrary signs is in certain respects well founded, and might even be carried to much greater lengths with advantage. It becomes necessary therefore at the outset to discriminate between the classes of arbitrary signs. The result will show that, while one class is falling into disfavour, and may in time even become obsolete, another class is becoming more widely used, and its value better appreciated.

For convenience, arbitrary signs may be divided into three classes: (1.) Those which express definite ideas, simple or complex, apart from the words of any given language. Such are the ten digits, and the familiar arithmetical and astronomical signs. (2.) Signs of punctuation, accents, and other diacritical marks. (3.) Grammatical and rhetorical marks. These are peculiarly arbitrary, and vary not only in each language, but with the usage of every individual writer. In this class are comprised not only signs like the note of exclamation, but the whole usage of italics, small capitals, and of capitalisation.

It is true that the latter distinctions, though they are set forth more or less minutely in every grammar, are not usually placed in this category: nevertheless they rightfully belong to it. When we look into the forms of our alphabetical symbols, we find that at least half of them are arbitrary, having a certain loose grammatical application instead of their primary phonetic use. We have not, like certain Semitic tongues, a triple alphabet, of initial, medial, and terminal forms—a clumsy system, probably devised when it was not customary to space between words, and continued after its original purpose was forgotten,—but we have, in our distinction between capitals and the so-called "small" letters, a purely arbitrary and equally clumsy and unnecessary device.

I need say nothing of the imperfection of our alphabet, considered as a phonetic system. To represent forty simple sounds, we have an alphabet nominally containing twenty-six signs, though really, as I will show, a much greater number. By overlapping and combining,—by adopting in part the orthography of every known tongue in which the same signs are used,—we have a mass of phonetic symbols which no man can number, and which run into hundreds, if not thousands. Phonetically considered, our twenty-six letters, then, are exceedingly arbitrary signs—far more so than such characters as + and −, which have a fixed and definite meaning.

I have said that we have more than twenty-six phonetic characters, and that the arbitrary signs outnumber the letters. This is sufficiently proved by a printer's ordinary "body-fount" of type for newspaper- or book-work. Reduced to its lowest term, including the necessary punctuation-marks, a fount contains twenty-nine characters; or, including the notes of admiration and interrogation abhorred by the late Dean Alford, thirty-one. With these, any word, sentence, or collection of sentences in English may be correctly and legibly represented. All outside these may be classed as arbitrary signs. Many founts in actual use by printers contain thirty-four characters, all told. But this scheme shuts out the ten figures, which are certainly arbitrary signs. It makes no provision for parentheses, reference-marks, and the numerous sundries used in ordinary printed text. And it excludes "small" letters, "small capitals," and the large and small italic letters. Hence, an ordinary newspaper- or book-fount, without what are technically called "peculiars," instead of consisting of twenty-nine characters, runs into about four hundred.

But to the book-printer this is but the beginning. He requires mathematical signs, astronomical signs, fractional marks, "superior" and "inferior" letters and figures, accented letters capital and small, which may easily swell the number to one thousand, or even fifteen hundred. Some of these symbols are rarely used, but, as they have a recognised place, the book-printer must keep them, and the educated reader is expected to understand them. So that, judged by the typographical standard, the arbitrary signs in English work outnumber the purely alphabetical symbols in the proportion of 50 to 1.

I leave out of consideration forms like script and black-letter, which all educated persons are required to learn, and which still further multiply the methods in which a given character may be written, or printed. I pass over the innumerable "fancy" styles now fashionable, by which the standard forms are tortured almost into illegibility. I take the four alphabets—roman and italic, large and small—and I find (excluding trifling changes of form) forty-nine separate and distinct characters to represent twenty-six letters. Only seven of the small letters are the same in form as the corresponding capitals; for the other nineteen, entirely different symbols are used. In the italic, four more appear. Sixteen letters have two distinct symbols, four have three. It is no doubt demonstrable that the A, a, and *a*, for example, are all modifications of the same primitive character—the fact remains that they have diverged into quite distinct forms.

It is clear that we must seek in the alphabet of capitals the true standard forms. This is demonstrated by the fact that entire pages of books, monumental inscriptions, &c., may be printed in these characters without infringing any grammatical rule. In many such cases the use of the small letters is excluded. It is not possible to reverse the rule: a page without capitals would be considered a grammatical absurdity. The great mass of printing and writing, then, is done in characters deviating from the standard. The question arises: Why are these two forms retained? The answer is that the small letters are not in the true sense letters at all, but arbitrary signs. They have a negative value, as distinguished from the positive value of the capitals. When we write the second "a" in "Aaron" differently from the first, it implies that it is not the initial. The word is as legibly and quite as correctly written entirely in capitals (in the leading article of an English newspaper it would be so printed—in the text it would not). In fact, the device is equivalent to that by which in Greek a final *sigma*, or in Hebrew a final *mem*, is distinguished by a complete difference in form from the same letter used as an initial or medial.

Much of the space of every grammar is occupied in defining rules of capitalisation; but the whole subject is still unsettled. Formerly every noun was distinguished by a capital, and every proper noun by italic. Now the capital is reserved (generally speaking) for the proper noun, but names of books, of ships, and of stage characters are still commonly represented by italics. The usage in regard to nouns derived from proper nouns is quite unsettled. Some writers capitalise certain pronouns to convey the idea of dignity; others so distinguish words of any denomination which it is desired to emphasize. In the best English newspapers, one system is adopted for the editorial articles, a second for the news columns, and a third for the advertisements. The distinction between capital and small letters, then, is arbitrary, of no phonetic value, and of very uncertain value in any other respect. Therefore, of our forty-nine alphabetic characters, twenty-three must be regarded as belonging to the category of arbitrary signs, and placed in the third of the three classes enumerated at the beginning of this paper.

We have only to compare any printed book of the present day with one a century old, to see how the tendency is towards the restriction of use of these signs. The proper name in capitals in a *Times* leader; the italicising of the name of a ship—are survivals from a bygone period of literature. Italics have been characterized as distinctively feminine. It would be more correct to say that they belong to the infantile period. The fact is that the whole system of signs of the third category is in the nature of stage-directions incorporated with the text, and is to some extent a reflection upon the intelligence of the reader. If *Punch* to-day printed his jests in the same manner as those of Peter Pindar,—or even, to fix a later date, those of Thomas Hood,—with every play upon words italicised, and a plentiful supply of exclamation-signs to mark off the points, no one would have patience with him. Good writers now use italics very sparingly. The unnecessary brackets, dashes, asterisks, and other elliptical marks so much in vogue a hundred years ago no longer disfigure the text; and in the best works small capitals are rarely to be found, and the use of capitals is reduced to a minimum. Unfortunately in this latter case it is the standard form of letter that is gradually being superseded. It is time to raise the question whether it is right that the intelligent reader should have his own language partially parsed for him as he reads, and whether he should be asked to submit longer to have his ordinary reading decorated or disfigured (like certain modern hymnals) with expression-marks: especially when the system adopted is extremely inaccurate and inefficient,—perhaps the worst and most cumbrous system of arbitrary signs that has yet been devised.

Of the second section of signs—those of punctuation—I have little to say. A radical reformer in the United States has been advocating their entire disuse; but I do not think he has made out his case. Our experience with unpunctuated Acts of Parliament in this colony some years ago is alone sufficient to condemn such a proposal. If we could revert to an ancient Greek system, and display our lines as on monuments and title-pages, points would be quite superfluous; but such is not the case. It is curious, however, to note how the colon is passing into the region of superannuated signs. It is obsolete, except for the single purpose of introducing a quotation, and then, nine times out of ten, it is supplemented with the dash.

Turning now to the first division—that of the arbitrary signs proper—we enter a region where there is some degree of system and accuracy. The Arabic figures are the typical example of the economy and value of this method of expression. Imagine the cumbrousness of calculation in words spelled out at length! Imagine the task of performing an intricate mathematical operation with the aid of Roman numerals, in which the same number may be represented in two or more ways, and in which the symbols may represent a minus as well as a plus value! The whole system is full of pitfalls for the unwary. In an excellent book of reference a table of this notation gives CM as representing 100,000, when in reality it is the symbol of 900.

Next in value to the figures come the familiar mathematical signs. And, whatever grammarians may say, mathematicians will appreciate their importance. They are above and beyond any phonetic or grammatical symbols, because they can be read at sight by men of any language. So with the astronomical signs. The old symbols of the heavenly bodies and of their aspects have an appropriateness and beauty by which they have long survived the lore that gave them birth. At first applied to occult astrological purposes, they are to-day the shorthand of the astronomer. And I may here remark the curious fact that, of astronomical signs proper, as distinguished from astrological, we have none, and that they would be a boon. (A few Greek initials, like δ for declination, can scarcely rank as such.) While there are symbols for all apparent positions—as conjunction, opposition, sextile, quadrature, and trine—there are none for real relations. Consequently a column of phenomena in a modern almanac presents a strange mixture of symbols and text. Signs representing greatest distance and closest approximation, for example, would do away with the necessity of writing in full the words "perigee," "apogee," "perihelion," and "aphelion."

In the devising of new signs, however, philosophers have shown a sad lack of invention. Take, for example, the sign for Uranus—the initial of the discoverer with a circle pendent—a sign, by the way, which is not recognised on the Continent. The signs for the four planetoids first discovered were tolerable, but those afterwards devised and now happily abolished reached the lowest depths of symbolical absurdity. As, for example, Iris—"a semicircle representing the rainbow with a star within it and a base-line for the horizon;" Flora—"the rose of England;" Metis—"an eye and a star—sagacity and prudence;" Egeria—"a star and a plate;" Irene—"a dove carrying an olive-branch and having a star on its head," with an alternative, "an olive-branch, a flag of truce, and a star." And these clumsy and inartistic conceptions had to be typographically represented in a space the twelfth of an inch square. When more than one symbol is used for the same idea, the object of symbolic writing is frustrated (as it is in alphabetic writing, only we are accustomed to the anomaly). For example, there are three astronomical signs for the earth —a circle surmounted by a small cross, ♁, a cross within a circle, ⊕, and a horizontal line within a circle, ⊖.

An interesting aspect of the question is the interchange between literal and arbitrary signs. The physician's ℞, supposed to signify Recipe, is, as is well known, a corrupted form of the symbol of Jupiter, the benignant planet, whose good offices were thereby invoked. On the other hand, the radical symbol √, apparently arbitrary, is a cursive modification of the initial of Radix. These are typical instances out of many others.

Akin to this is the actual derivation of words from graphic symbols—a process still in operation, and of which some notable instances occur in literature. The Italian proverb, "Round as the O of Giotto," is a case in point, the reference being to an inscribed circle having no literal significance whatever. So in *King Henry V.*, Shakspeare writes,—

—or may we cram
Within this wooden O the very casques
That did affright the air at Agincourt.

Sometimes written "oe" by old writers. "Em" and "en" are recognised terms of measurement in printing, representing the space supposed to be occupied respectively by a capital M and small n. The D of a saddle, the T of a wharf (sometimes superfluously written "tee"), a T-hinge, and a T-square are all instances of this kind of word-formation, of which we have a typical and early instance in the geographical term Delta. L and Y come into the same category in the compounds L-shaped and Y-shaped. The "comma bacillus" of Koch is a recent instance in point. The symbol and the thing signified, the symbol and the form of the symbol, become confounded, and, ideas having first been expressed in arbitrary forms, the forms themselves react both upon ideas and language.

I have said enough to show the important place occupied by arbitrary signs. In some cases, as in the signs of equality, =, and parallelism, ‖, they possess remarkable fitness and beauty. As regards precision and accuracy, so far as the English language is concerned they have the advantage over the phonetic signs, besides being in most cases internationally used. I am no advocate of a Mongolian system of writing by symbolism —it is foreign to the genius of European peoples; but in ordinary text certain signs might be used with advantage. Why not revert to the old Saxon sign for "and"? (The familiar & or &, though suitable to French work, is inappropriate in English, being really a monogram of the letters "et"). The perpetually-recurring definite article might advantageously be represented, as in shorthand, by a sign. And in the signs used in scientific work, greater economy and efficiency might easily be introduced: as for example, in astronomical work distinguishing inferior and superior conjunction by inverting the sign, ☌, a plan adopted by myself in almanac-work for years past, and which required no more than to be set forth in the key at the beginning of the book.

It is possible to carry the use of signs to excess, and where, as in the case of botanical symbols, they are in complete muddle, two or three being in use for any given subject, and scarcely two writers observing the same system, they are useless. Arbitrary signs must be highly appreciated by German philosophers, for German writers use an enormous number unknown in English work. One German typefounder exhibits nearly two hundred separate mathematical signs, besides astronomical, pharmaceutical, military, and many others.

I have sometimes wondered why Pitman, in his revolutionary reconstruction of the alphabet for typography on a phonetic basis, did not revert to first principles, and give us a single series of signs. Instead of this, he fell into the traditional groove, and reproduced the fundamental defects of the present system—its stage-directions, parsing-signs, and expression-marks, its small letters and italics with their variations of form—a plurality of symbols for a single sound. Perhaps this is one reason why his reform—while its value is almost universally admitted—is so slow in meeting with acceptance.

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3. *A Chapter from Maori Mythology.*

By John White.

Thomas Carlyle puts into the mouth of one of his characters the questions: Who am I? What is this me? Whence? How? Whereto? Thousands of other great minds, Pagan and Christian, have been exercised with these same questions, and, in one way or other, have published the results of their researches, and found eager listeners or readers. The Maori, though far removed from the civilisations of the rest of the world, held opinions on these important questions too, and, if unable to answer them as satisfactorily as more highly favoured members of the human family, possibly such answers as they were able to give had no less influence on their lives and general character.

To give some idea of these views on these universally important matters is the object of this paper.

Amongst the Maori generally, the universe was held to be divided into three great states—namely, Rangi (or the heavens), Papa (or the earth), and Te-po (or darkness). Rangi comprised twenty minor divisions, each having its presiding deity, with attendant spirits (or gods). That most remote from the earth, called Te-rangi-a-mai-waho, was deemed to be the abode of To, or A, the great creator of all things. Here, they believed, was the great temple called by some Nahe-rangi, and by others Tu-warea. Hither ascended all the spirits of the offerings of gratitude or praise, and all petitions for aid; and hence were dispensed blessings to the upright, and punishment to the disobedient, to the spirits of the other regions of Rangi, or to men of Papa. Each successive region below, counting from twenty to one, was the abode of beings diminished in perfection and excellences in proportion to its distance from Te-rangi-a-mai-waho. These successive regions were respectively called—

Rangi-whakaka, or Wairua.
Tama-he-rangi, or Au-kumea.
Tama-rau-tu, or Au-toia.
Rangi-whaka-ipi-pu, or Nga-atua.
Tama-nui-a-te-ra, or Nga-tauira.
Tama-nui-a-rangi, or Hau-ora, or Wai-ora-a-tane.
Haumia, or Nga-roto.
Maru-tawhiti, or Wakamaru.
Moehau, or Kiko-rangi.
Te-rangi-whaka-upoko.
Rangi-ma-kawekawe.
Te-rangi-o-nga, or Te-rakanga.
Tihinga.
Rangi-nanao.
Rangi-pua-kaka.
Pou-tu-te-rangi, or Rangi-a-whai-tu-tahi-a-iwa.
Taketake-nui-a-rangi, or Rangi-o-tama-i-te-oko-tahi.
Whiti-rangi, or Rangi-o-tane, or Rangi-pohutu-kawa.
Rangi-o-tane, or Ure-nui-o-rangi, or Te-rangi-o-rehua.

The soul of man was generally believed to be a ray from the mana (power, or glory) of A, or, as he is sometimes called, To, which became detached, as it were, in the heaven Tama-rau-tu or Au-toia, or Te-rangi-whaka-ipi-pu or Nga-atua; and, after an existence there equal in duration to the average life of man on earth, to have reached a state of development which fitted it for the next lower, thus descending through the other heavens until it reached Te-rangi-o-tane. The uninhabited space containing stars, moon, and clouds, was called by respective tribes Whiti-nuku, or Te-pu-taku-o-roko, or Papa-tu-a-nuku, or Tau-arai-o-te-ao, and was crossed by each soul to take its abode in the body of an infant of man, its arrival being indicated at the time of "quickening."

Below this would come Te-reinga, or Te-po (the world of shades); it also was believed to comprise twenty regions, counting from one downwards. These regions were respectively named—

Te-po-a-wawau-te-rangi, and Tu-mo-rahia-te-rau-o-te-aki.
Uranga-o-te-ra, or Paerau.
Karokaro, or Hine-a-te-ao.
Te-ana-a-toko-meha.
Tau-arai-o-te-ao, or Hine-a-te-po.
Tawiti-o-wawao-te-rangi, or Hine-maki-moa.
Tau-arai-o-te-po.
Riringa-te-po.
Nanao-te-po.
Wha-iti-te-po, or Whare-o-tu-kai-nanapia.
Kai-namu-te-po.
Po-tahuri-atu.
Po-tahuri-mai.
Po-take.
Ka-rea-te-po, or Te-po-a-hine-maki-moa, or Ka-tu-moa.
Kou-awha-roropua.
Toke.

These were the abodes of the spirits which, for rebellion against To or A, were hurled from the region of Rangi, never to return.

Into these shades some of the souls of men descended after the death of the body on earth. Whether this came about naturally, by accident, or in battle, it was believed the soul set out at once to Muri-whenua, a point at the extreme north of New Zealand. There, on the edge of a precipice, grew a large pohutukawa tree. One of the roots of this tree hung over the precipice and reached to the bottom. There was a cave: at the opening of the cave was a large growth of seaweed, moved to and fro by every wave which broke against the cliff. The assembly at the tree kept on chanting farewell songs to the tribes, the spirits of dogs joining in chorus. Then the spirits of the men danced a war-dance and made the wildest noises and gesticulations, and then one by one they descended the cliff by the overhanging root and glided into the cave leading to Uranga-o-te-ra, or the first region of the shades. The period of existence in each region of shades—Te-po—was also supposed to be for the average period of man's life on earth; and as they descended the darkness deepened and the powers and faculties of the soul diminished until at Toke the darkness was complete, and the soul assumed the shape of a worm and came back to this earth and died and ceased to exist. But all souls did not so pass on, for the chiefs and priests were believed to be the offspring of certain gods who came down from the temple Nahe-rangi and co-habited with the daughters of Tiki, and the souls of their descendants were supposed to go up to the heavens, there to exist eternally.

The souls of children still-born were supposed to be of a particularly malevolent character, and, in revenge for loss of life on earth, they remained there and became plagues of blight, pains, accidents, misery, disease, and death.

It will therefore be observed that the Maoris believed in eternal life for the souls of their priests and chiefs, and annihilation for those of the common people. In their ceremonies for the dead this is more particularly noticeable; for the body of the priest or chief was laid out with its feet towards the north before it was taken to the place of burial, and all the blood-relations of the deceased, men, women, and children, assembled round the corpse, the men standing with the boys on the right or east of the dead, the men being nearest to the head of the corpse and all in a line; the women and girls on the left or west of the corpse, all in a line, with the girls next to the feet of the dead. The priest, standing at the head of the corpse, between the rows of the people, then chanted,—

It is Pi and Pa.
The day dawns;
Food is eaten
At the settlement
Where the parents
Cultivate, and where
They left some food
In this world.

And this incantation is also chanted by the priest:—

Climb up Tawhaki,
To the first heaven,
To the second heaven,
To the highest heaven,
To the host of Tawhaki—
The Tawhaki of Hema;
And cry in Whare-toreke
Toreke (poreke—all gone).

This incantation was supposed to assist the soul to ascend. The priest then put a taro-bulb into the left hand of the corpse, and again chanted,—

It is Pi and Pa.
Dawn has come;
Food is eaten.

The food of
The thousands
To whom thou goest,
To the many above,
To the thousands above ;
And all is calm.

Flax cords were then tied with a slip-knot to a tassel of the mat in which the body was enshrouded, and one cord was placed in the hand of each child of the boys and girls, and the priest again chanted,—

The gods draw near,
The gods come towards ;
But, Kinokino, do not
Thou come to my side
With the art of Hia
The god.

And, as the last word of the chant was uttered by the priest, each child pulled the flax cord with a jerk, to disconnect the soul from the body, lest it should remain and afflict the relatives.

When the body was buried the priest went back to the pa (stockade, fort, the home of the people) ; and the bearers of the body went to the nearest swamp, and when they had had caught a matata, or swamp-sparrow, they sent word to the priest, who forthwith went to them. Each person was then provided with a stick to which certain of the feathers of the bird were tied. The bearers, with a stick thus dressed in each hand, sat on their heels in line, facing the priest, who stood facing the east, with a stick similarly dressed in his left hand. He then moved to the south end of the row of men, and chanted,—

Oh ! here am I.
Oh !
Oh ! then, son here,
Here, here, oh, oh !
O son ! here,
Here, here. Oh, oh !
Here am I ;
Oh !
O son ! oh !
I did search for
You here. Oh, oh !
Here am I. Oh !
O son ! Oh, oh !

And as he chanted he gradually raised his stick, and all with sticks extended at arm's length gradually raised them in perfect harmony and as though it were the action of one, also their bodies, until as the priest concluded his chant they were all erect with extended arms. The priest then collected the sticks and threw them down in front of the mua.

The dead of common people were tied tightly in a rough mat and placed in a sitting posture. The priest put a taro-bulb into each hand, and chanted,—

There is the seed,
The seed lifted up;
The seed by which you go
To your many,
To your thousands,
To your sole lord.
Clear the path
To Pae-rau.

This was supposed to aid the soul in its descent to the Po (shades).

The departing spirit was supposed to see the spirits of the dead below, and, on its arrival at the Uranga-o-te-ra, to be asked where it came from and what work it had done; to which it replied by giving a history of its life.

In the first Po was a river called Karokaro-pounamu, where was a ferrywoman named Rohe. All who required her services went down to annihilation. All who recovered from insensibility caused by a blow, or fit, or trance, were supposed to be refused a passage by Rohe and sent back to life.

They appear to have believed also in regions for the spirits of dogs, rats, and other animals; also one for fish. They had gods of light and beneficence, and gods of darkness and malevolence, and of both there were many.

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4. *A Song from Mangaia, Hervey Group, South Pacific.*

By the Rev. William Wyatt Gill, LL.D.

In the early part of the year 1815, Enuataurere, the eldest daughter of the warrior chief Rakoia, was accidentally drowned at Tamarua, on the southern part of the island of Mangaia, in the Hervey group. A few months afterwards my worthy old friend—according to the custom of the ruling families—solaced himself by chanting her praises in a song composed by himself at a grand *fête* in honour of the deceased. Enuataurere was at the time of her death about fifteen years of age.

Long years afterwards Rakoia named my only daughter Enuataurere, after his own lost child. On this occasion the venerable chief chanted this song in the presence of the elders of the clan, as a formal adoption of the child. At various times Rakoia crossed the island, spear in hand (not for battle, but as a support to his failing limbs), to bring presents of food to his adopted daughter, invariably chanting this song in praise of Enuataurere.

Rakoia, at the period of his death in 1865, was about eighty years of age. He had, ere Christianity had been introduced, fought in four pitched battles, besides several minor engagements. He was accounted the best poet of his day. The following is the song, written down from his lips :—

THE PRAISES OF ENUATAURERE.

By Rakoia; circa A.D. 1815.

Taû tama nei! Eaa rai ē!
Uri mai koe i te inangaro kimikimi,
Kia akataataa, e taû ariki.
E au maiku teia ē!

Ua kau koe ia maveiiti
I te tapu o te ariki.
O piri tau o ange karetu o te vao:
E tiere rau kokovi ē!

Tei ia oki tooku inangaro,
Tei pau atu na iaau.
E korero tuku na te metua;
Akairi ake i reira ē!

Na ara puātou, na ara kakea;
E motu ai to aerenga 'tu i te avatea.
E uu maire, eaa mai o te rā ē!

E apinga ua i pukea mai,
Ka apai na te ao roi toka piri.
Ua puipui te puka 'i—
Ei iaaku koe, naaku rava,
I tu ake taû inangaro ē!

Manea metua i te tupu-anga i te tama ē!
O Enuataurere! O Enuataurere!

E kaura nga Tapairu:
Ei matareka no Enuataurere ē!

Ua mataano te tangata e,
Ei iaku koe ē!

O Enuataurere i te tai kura i te moana.
Te nunga koe i te uru o te kare i tai ē!

Aue ē! Enuataurere ē!
Enuataurerere ē!

My first-born! Where art thou?
Oh, that my wild grief for thee,
Pet daughter, could be assuaged!
Snatched away in time of peace.

Thy delight was to swim,
Thy head encircled with flowers,
Interwoven with fragrant laurel
And the spotted-leaved jessamine.

Whither is my pet gone—
She who absorbed all my love—
She whom I had hoped
To fill with ancestral wisdom?

Red and yellow pandanus drupes
Were sought out in thy morning rambles,
Nor was the sweet-scented myrtle forgotten.

Sometimes thou didst seek out
Fugitives perishing in rocks and caves.
Perchance one said to thee,
"Be mine, be mine for ever;
For my love to thee is great."

Happy the parent of such a child!
Alas for Enuataurere! Alas for Enuataurere!

Thou wert lovely as a fairy!
A husband for Enuataurere!

Each envious youth exclaims,
"Would that she were mine!"

Enuataurere now trips o'er the ruddy ocean.
Thy path is the foaming crest of the billow.

Weep for Enuataurere—
For Enuataurere.

The most interesting stanza is the last but one—

Enuataurere now trips o'er the ruddy ocean.
Thy path is the foaming crest of the billow.

The spirit of the girl is believed to follow the sun, tripping lightly over the crest of the billows, and sinking with the sun into the underworld (Avaiki), the home of disembodied spirits.

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5. *Notes on "Maori Literature."*

By the Rev. JAMES W. STACK, Christchurch.

THE Maoris of New Zealand had no literature in the ordinary acceptation of the word, the art of writing being unknown till it was introduced by the missionaries about the year 1820. It was by the advice of Professor Lee, of Cambridge, that Roman letters were employed to represent the sounds of the language, and a phonetic system of spelling adopted in forming the words.

Notwithstanding that the language was unwritten, the Maoris were found to possess a vast amount of knowledge on a variety of subjects, which they had preserved and handed down from generation to generation by oral tradition. The possibility of their being able to transmit knowledge in such a way is placed beyond all doubt by what we know of the Druids, who possessed no literature, and yet attained to a high state of mental culture, through knowledge orally transmitted. We are told that even at the present day many Asiatic nations who possess alphabets from olden time nevertheless still transmit their history by oral tradition. And the story of the greatest epic in the world shows how perfectly long poems of the most complex metrical structure may be transmitted by oral tradition for centuries. There is no reason, therefore, to discredit the claim put forward on behalf of Maori traditions to be recognised as a national literature, in which lie embedded the thoughts of the wisest and best of the race for centuries past, especially when we consider the method adopted to secure their correct transmission from generation to generation, which involved a systematic course of instruction extending over several years, and conducted by teachers whose knowledge of the subjects they taught was beyond question.

In every tribe there existed classes for instruction in the various subjects of knowledge cultivated by the people. These classes were opened with great ceremony at the beginning of winter, the date being fixed by the rising of Puaka (Rigel), a star in the constellation of Orion, which took place between May and June. The classes were held in a building specially set apart for the purpose, called the Whare-kura, or Red-house; or Whare-pu-rakau, the Spear Armoury (those weapons being stored there). The classes were kept open for about three months. The hours of instruction were from sunset till midnight. The pupils consisted of a picked number of boys chosen from the best families in the tribe. Instruction was imparted by a band of *tohungas*, or skilled persons, the object of having several of them to teach at once being that they might correct one another's mistakes, and so prevent erroneous instruction being given. The subjects taught comprised the myths relating to the origin of all things, and to the gods and demi-gods; the religious belief of the race, charms, incantations; the rules of *tapu*; legends and fables; history, national and tribal; laws, genealogies, treatment of diseases, astronomy, agriculture, &c. The most proficient of the pupils trained in this way afterwards became in their turn the instructors of others, and formed the *tohunga*, or learned class.

Besides this method of instructing, the *tohungas'* instruction was given on winter evenings in every chief's house to all members of the tribe who chose to attend, and in this way the whole population became well informed in tribal history, social laws, mythology, legends, and other subjects of general interest.

What helped to insure correctness and exactness in imparting the traditional knowledge of the Maoris was the belief that a serious mistake made while teaching was an omen of disaster or death. The Maoris were a highly sensitive people, and preferred death to being the subject of ridicule, and a professor of history or mythology who publicly exposed his ignorance on any point would probably either commit suicide or die of vexation. Only those who were quite confident of the correctness of their knowledge of the subjects they taught ever ventured to act as public instructors.

One of the precautions taken to prevent the transmission of incorrect statements was the practice of publicly rehearing at the tribal or national gatherings the various traditions of the people. This practice, while it helped to diffuse the knowledge which the learned possessed, gave them an opportunity of comparing notes with one another, and lessened the risk of any serious departure from the received traditions of the race.

To Europeans whose memories have not been exercised and trained to the same extent that the Maoris' memories were, it seems almost impossible to believe that so large an amount of knowledge on such a variety of subjects as they possessed could have been preserved for any length of time by oral tradition. But we have evidence of the exceptional powers of memory possessed by the Maoris, furnished by some of the earliest travellers in this country, one of whom states that he was accompanied on one occasion by a young chief on a visit to a distant tribe. While there the young Maori heard for the first time a poem of about fifty lines, which he correctly recited on his return for the amusement of his friends. I have often been twitted myself by Maori chiefs for consulting books of reference, "You white men," they said, "keep your knowledge on your book-shelves; we keep it all in our memories."

On comparing the traditions of the Maoris of New Zealand with the traditions of other branches of their race scattered over the Pacific, from all intercourse with whom they have been cut off for many centuries, it is very satisfactory to find that they are substantially the same. (*Vide* Appendix.)

These facts encourage the students of Maori traditions to prosecute their investigations with a full persuasion that they contain much that is of considerable antiquity, in spite of their having so recently been collected into their present form.

What Professor Max Müller thinks of these Polynesian traditions we learn from the preface to the Rev. Wyatt Gill's "Myths and Songs of the South Pacific," where he says, "Now, what are these myths and songs but antiquities, preserved for hundreds—it may be for thousands of years, showing us far better than any stone weapons or stone idols the growth ofhe human mind during a period which is as yet full of the most perplexing problems to the psychologist, the historian, and the theologian! They contain much that will deeply interest all those who have learned to sympathize with the childhood of the world, and have not forgotten that the child is the father of the man; much that will startle those who think that metaphysical conceptions are incompatible with downright savagery; much also that will comfort those who hold that God has not left Himself without a witness even amongst the lowest outcasts of the human race."

The language spoken by the New-Zealanders is a dialect of the language spoken by the various branches of the Maori race scattered over the Pacific from the Sandwich Islands in the north to New Zealand in the south, and from Easter Island in the east to Rotuma in the west; and is probably one of the oldest living languages in the world. Mr. Abraham Fornander, of Hawaii, believes it to be of Aryan origin, but Aryan of a pre-Vedic and pre-Iranian era, and that its identity with the pre-Malay dialects still existing in Malaysia is now fully established; and not only so, but that it is manifestly the older surviving form of a once common language. Thanks to its isolation for long ages, it has preserved the ancient simplicity of its structure. The rudimentary simplicity of its alphabet attests the early age at which it separated from its kindred in the Asiatic Archipelago.

To express the sounds of the dialect spoken by the New-Zealanders only fourteen letters are used—five vowels and nine consonants—none of which are sibilants; this is a noticeable peculiarity, as sibilants do exist in the Samoan, Rarotongan, and Hawaiian dialects. Except in forming the sound *nga*, no two consonants ever come together, and every syllable and every word ends in a vowel, which renders the language, when spoken, soft and euphonious.

The local differences of dialect, though in Maori estimation important, appear to us very slight, and not equal to the differences which exist between the dialects of the northern and western or southern counties of England. The most marked peculiarities are found amongst the Ngatiawa, who occupy the west coast of the North Island, and the Natives of the South Island. The former have a peculiar mode of expressing the letter "h," by a kind of guttural catch in the breath, which disposes of it in much the same way that our cockneys get rid of it. The South-Islanders substitute "k" for "ng," in the same way that the Hawaiian and other Polynesians do.

The grammar is peculiar as compared with the ancient and modern languages of Europe.* Nouns are not inflected nor the verbs conjugated in the same way. To form the cases or the plurals of nouns, or the mood, tense, or person of a verb, all that is required is to put a particle before or after the word. There is no auxiliary verb "to be," but its place is supplied by a particle. Every regular verb has a causative as well as an active and passive meaning. The pronouns are very complete, and possess double duals and double plurals. One peculiarity of the language is that the same word may be used as a noun, a verb, a verbal noun, and an adjective, requiring merely the addition of one or more particles to alter its meaning.

The vocabulary is wanting in words to express abstract ideas, but full of terms to describe outward objects. But there

* *Vide* Colenso, in Vol. i., Trans. N.Z. Inst.

are here and there terms which seem to indicate that abstract ideas were once more common to the minds of the race than now. But, while the language is defective for the purpose of argumentative discourse, it is peculiarly well adapted for the purpose of narration, and the peculiar style of oratory cultivated by the people.

To Sir George Grey, K.C.B., formerly Governor of New Zealand, is justly due the credit of rescuing Maori literature from oblivion. For, although many writers have published specimens of Maori compositions, Sir George Grey was the first to compile and publish anything like a complete collection of the literature of the people, though even his work is far from being exhaustive. It is satisfactory, therefore, to find that other competent Maori scholars, like Dr. Shortland, Mr. Colenso, F.R.S., and Mr. White, have added largely to the valuable collection of Maori traditions which we now possess in book-form.

It is a curious fact that the same misfortune attended Sir George Grey's first effort to compile the literature of the Maoris which attended the Rev. Dr. Maunsell's attempt to compile a lexicon of the language—the materials in both instances, after many years of labour, were totally destroyed by fire. In the case of the lexicon the loss was irreparable, as Dr. Maunsell has never attempted to rewrite the work; but, fortunately, Sir George Grey, undaunted by the loss, renewed his efforts and carried them to a successful issue. What a monument of patient industry the completed work was may be best understood by reference to the author's preface, where he tells his readers, "For more than eight years I devoted a great part of my available time to acquaint myself with the ancient language of the country, to collect its traditional poems and legends, to induce the priests to impart to me their mythology, and to study their proverbs. When I had with great pains collected a large mass of materials Government House was destroyed by fire, and with it were burnt the materials to aid me in my studies; and thus I was left to commence again my difficult and wearying task." How successfully he overcame the difficulties thrown in his way, and accomplished his task, his published works testify.

Mythology.

I shall commence my notes on the literature of that portion of the Maori race which inhabits these Islands by briefly reviewing the mythological traditions compiled by Sir George Grey and others.

It is surprising to find a people sunk in such barbarism as the Maoris at the time they first came into contact with

Europeans, possessing such elaborate theories about the origin of all things—theories which contain traces of a philosophy which evidently belonged to a period of higher mental culture. They conceived of the lapse of countless ages before the dawn of light upon the earth. Commencing with Te Kore, or Nothingness, to which they assign an unlimited period, they approach the dawn of Life and Consciousness on earth through eighteen stages, each stage being a period of myriads of years. "Then began the first Seeking and Searching." Hence the saying of antiquity,—

> Darkness, Darkness;
> Light, Light;
> The Seeking, the Searching,
> In Chaos, in Chaos.

This was the seeking for a consciousness of existence and freedom of action.

In the order of existence, the Maoris believed that Thought came first, then Spirit, and last of all Matter.

Living beings existed from an inconceivably distant past, when everything was wrapped in darkness. Heaven, or Sky, was the father, and Earth the mother of all. In order to deepen the impression in men's minds of the vast length of the period preceding the dawn of creation, instead of stating the fact in so many words, the traditions enumerate the several periods, counting from the first to the tenth, and from the tenth to the hundredth, and from the hundredth to the thousandth, and from the thousandth to myriads. And this was repeated eighteen times while describing the slow progress from a past eternity to the dawn of light, and the creation of animal and vegetable life.

How light reached the Earth is thus told: After countless ages, during which Heaven and Earth adhered to one another, their offspring, weary of the darkness in which they were enveloped, conspired to rend them asunder. Five of the boldest undertook, each in turn, the task; Tane alone was successful. Planting his head firmly on his mother's body, he raised his feet upwards and pressed them against his father, and by a mighty effort he rent his parents apart, in spite of their shrieks and cries. The legend concludes with a very beautiful conception of the origin of mists and dewdrops. "The vast Heaven has still ever remained separated from his spouse the Earth. Yet their mutual love still continues—the soft warm sighs of her loving bosom still ever rise up to him, ascending from the woody mountains and valleys, and men call these mists; and the vast Heaven, as he mourns through the long nights his separation from his beloved, drops frequent tears upon her bosom, and men, seeing these, term them dewdrops." (Sir G. Grey, Poly. Myth., p. 15.)

It is a noticeable fact that, with the exception of Mother Earth, no female deities are spoken of amongst the chief gods in connection with the beginning of things, though they appear later on in the history of the world. During the period between the separation of earth and sky and the appearance of man, this world was occupied by the race of demi-gods, whose existence was discovered at the time of the separation. It is to this period that the exploits of such heroes as Maui and Tawhaki relate. It is from what is told about them we learn that the Maoris conceived of an under and upper world, earth lying between them. When Maui sought to discover who his father was he resolved to follow his mother Taranga, who nightly visited her children on earth, but vanished again before dawn. To discover the path by which she went, Maui determined to detain her till it was light enough to watch her movements; so he carefully closed every crevice through which light could enter the building where his mother slept, and, on her waking and wondering at the prolonged darkness, he quieted her by the assurance that it was still night. But when the sun rose high in the heavens a sunbeam shot in through a chink, and Taranga with a shriek sprang out of the house. Maui watched her seize a tuft of grass, and descend an opening beneath it. By magic he changed himself into a pigeon, and followed his mother. After a long flight down a narrow cavern he emerged into open space, and saw before him a party of people seated under a grove of trees, and amongst them his mother, and beside her a man who he at once surmised was his father. Eventually he was recognised, and the mother told how she had prematurely given birth to him by the sea-shore, when she cut off her long tresses, and, having bound him in them, cast him into the foam of the sea, where he was found by a sea-god, and reared up by him. The father thereupon acknowledged him, and proceeded to baptize him; but, owing to the omission of some part of the rite, Maui became subject to death, the Great Lady of Night.

Besides believing in an inhabited under world the Maoris believed in an inhabited upper world, consisting of ten planes, one above the other. In the highest resided Rehua, the Aged One, with flowing locks, and lightning flashing from his armpits. He was the eldest son of Rangi, and supreme lord of the gods who ruled the world. He was the Lord of Kindness, and dispersed gloom and sadness. He was opposed to war and bloodshed. "The darting lightning," says an ancient poem, "gleams above, and Rehua commands where all that sacred is." (White, vol. i., p. 37.) The descriptions of Rehua continually recall to mind the Olympian Jove, "Father of gods and men."

That the Maoris conceived of the gods as something more than embodiments of power—as beings taking an interest in human affairs, and able to see and hear from the highest of the heavens what took place on earth—is indicated by the story of Maui's elder brother going in search of his favourite sister Hinauri. In the course of his search he ascended the heavens, to consult Rehua and get the clue to her whereabouts. On reaching the first heaven he asked the dwellers there, "Are the heavens above this inhabited?" They answered, "They are." He again forced his way upwards, and found an inhabited place, and he asked those he met whether the heavens above them were inhabited. They said, "Yes." He continued his ascent, asking the same question and receiving the same answer, till he reached the Tenth Heaven, the abode of the God Rehua. "Rupe feared the Man of Ancient Days, and at length ventured to say, 'O Rehua! has a confused murmur of voices from the world below reached you upon any subject regarding which I am interested?' The god answered, 'Yes, such a murmuring of distant voices has reached me from the Sacred Isle Motutapu in the world below.'" When Rupe heard this he immediately changed himself into a pigeon, and took flight downwards towards the island of Motutapu, where he found his beloved sister.

Sometimes the inhabitants of the upper world, who were superior in beauty and acquirements to those who dwelt on earth, fell in love with men; and some very charming stories are told of these attachments, reminding the reader of the Eastern legends of the loves of the angels, so beautifully told by the poet Thomas Moore. The fame of the hero Tawhaki's courage and manly beauty chanced to reach the ears of a young maiden of the heavenly race who lived above in the skies. One night she descended to judge for herself. She found him lying asleep. After gazing at him she stole to his side, but before dawn she went back to the heavens. She repeated her visits night after night till love forced her to disclose herself fully, and for her lover's sake she forsook her friends and her home in the sky. After a time a daughter was born to them. Tawhaki, shortly after its birth, made some disparaging remark about the child, which pained the mother so deeply that she seized the babe, and took flight upwards. Tawhaki tried to seize her, and prevent her going, crying out, "Mother of my child, oh! return once more to me." But as she soared upwards she replied, "No, no, I shall never return to you again." "At least, then, leave me some parting token of remembrance," he cried. "My parting words," she said, "are, Lay fast hold on that creeper which, hanging down from on high, has again struck its fibres into the earth." Tawhaki was plunged in grief, his heart torn by regrets for his wife and little girl. Unable to endure their loss, he went in search of them, accompanied by his younger brother. They journeyed on till they reached the spot where the ends of the tendrils, which hung down from heaven, reached the earth, and there they found an old ancestress, quite blind, named the Face of Night. She was the keeper of the tendrils which hung from above, and sat at the spot where they touched the earth, and held the end of one of them in her hands. The two brothers adopted a curious device to obtain from the old lady the information they wanted; and, having succeeded, the younger brother was the first to attempt the ascent. He sprang into the air, but seized by mistake a loose tendril, and away he swung to the very edge of the horizon, but a blast of wind drove him in an opposite direction, and so he swung backwards and forwards till, his feet touching the earth again, he let go his hold and gave up the attempt. Tawhaki then seized a firmly-rooted tendril, and began to climb. By direction of his old relative, the Face of Night, he kept on repeating powerful incantations, and so escaped the dangers of that difficult and terrible road, and reached the sky. Then the legend describes how he transformed himself into an ugly old man, and joined a party of people who were making canoes, who pressed him into their service, and made him carry their tools and firewood, and how he horrified them all, when they reached the village, by seating himself beside the sacred person of the chief lady of the place, who was no other than his celestial wife. After exciting the wonder and curiosity of all the inhabitants of the place, he made himself known to his wife, and resumed his natural appearance. He never returned to earth again, and was worshipped by the Maoris as the God of Thunder and Lightning.

How mankind learnt to ignite fire is told in a curious legend common to all Polynesians. The Maori Prometheus, Maui, who was a great practical joker, having extinguished all existing fires, his mother directed the servants to go and ask the goddess Mahuika to give them fire to cook with, but they were all too terrified to obey her. Maui then offered to go himself. His parents warned him not to play any tricks on the old lady, and he promised to be careful. But on reaching the abode of the Goddess of Fire, and obtaining what he asked for, he went aside and extinguished it, and presented himself again. The fire was obtained by the goddess from the root of her nails, which she tore out to obtain it. Maui kept on extinguishing the fire given, and asking for more, till he thoroughly exasperated the Fire Goddess, who, when reduced to her last toenail, pulled it out and dashed it on the ground, when everything caught fire. Maui changed himself into a hawk, and flew with rapid flight; but the earth and sea caught fire, and Maui narrowly escaped destruction. The fire was extinguished by the aid of the God of Storms. But before the fire was all lost the

Fire Goddess saved some sparks, which she threw into the kaikomako and a few other trees, where they are still cherished. Hence men rub portions of the wood of these trees together when they wish to ignite a fire.

The inhabitants of earth became subject to death through Maui's failure to overcome the Great Lady of Night. Maui, having overcome every labour he undertook, asked his father whether there was any undertaking beyond his power. He replied, "It is impossible for you to overcome your ancestress, the Great Lady of Night." Maui replied, "Lay aside such idle thoughts, and let us both fearlessly seek whether men are to die or live for ever." Boasting of the great feats he had accomplished, Maui went forth, full of confidence, to attempt the conquest of the devourer of all living. Accompanied by a crowd of companions disguised as little birds, he reached the dwelling of the old lady in the evening. She was asleep, with her mouth wide open. Divesting himself of his clothing, and armed with a weapon, he entered the old woman's mouth. The little birds tried hard to suppress their laughter at the ridiculous figure he cut. At last the tiwakawaka (fantail) could keep his merriment in no longer, and laughed out loudly. This woke the old woman, who, discovering her danger, closed her mouth on Maui, who never returned to this world again. And in consequence of his failure death prevailed over all beings on earth.

The labours of Maui were,—

1. The search for and discovery of his father in the underworld.
2. Obtaining his ancestress Murirangawhenua's jaw-bone.
3. Noosing and beating the sun, so that mankind might have longer days.
4. Fishing up the land.
5. Fetching fire from the goddess Mahuika.
6. Changing his sister Hinauri's husband into a dog.
7. His encounter with the Great Lady of Night, in which he lost his life.

To quote Judge Fornander's remarks upon similar myths in Hawaii, "They point to a period of the human mind when the thoughts of sages still lingered and laboured on the borderland between material facts and metaphysical abstractions; when Atea was still half the sun springing forth from and succeeding to and dispelling the gloom and darkness of night, and half the deified impersonation of creative power; when Atea was still the mere dawn in the result of the apparent contest between darkness and light, encircling the neck of the sun as well as his goddess-wife."

Historical Traditions.

The historical traditions of the Maoris date from a period antecedent to their arrival in this country, and are full of very interesting information. Many of them relate to voyages undertaken by ancient navigators; and the description given by them of the seas through which they sailed points to the early migrations of the race in tropical latitudes.

It would occupy too much time to trace in detail the history as told in these traditions, but there are a few interesting facts contained in them which may be mentioned because they throw some light upon the origin of this remarkable people.

When asked where they came from, the Maoris of New Zealand always replied "Hawaiki." For a long time it was thought that the Hawaiki to which they referred was one of the Sandwich Islands; but when the Pacific became better known it was discovered that every group occupied by Polynesians possessed an island of that name, and that Savaii, in the Samoan group, Avaiki, in the Hervey group, Habai, of Tonga, Hawaii, of the Sandwich Islands, all bore the same name, which meant Little Hawa. Judge Fornander has taken great pains to find out the reason for the constant recurrence of this name, and I venture to think that his theory about it is correct. Tracing the course by which the Maori race reached its present home in the Pacific, he discovered that at one time it occupied the large island we call Java, a name which he thinks the Maoris brought with them from the cradle of their race in the Cushite Empire of Saba or Zaba, and gave to their island home, just as we have given Old-World names to our new homes in these southern seas. On being driven out of Java by a Malay invasion the Maoris migrated eastward in search of new lands, and when settling in the islands they found they invariably named one Hawa, after their last home, but, to distinguish it from the original, added the adjective "iti," and called it Hawa-iti or -iki, Little Saba or Java.

It adds to our interest in the Maori people to think that they come of a race which had attained to a high state of civilisation a thousand years before our era. Their long isolation from other nations has helped them to preserve in their myths and legends, and in their religious rites and social customs, much that may assist ethnologists to solve the questions raised by the discovery of monuments and remains in the countries once occupied by Cushite civilisation, but about which the present inhabitants of those countries know nothing at all.

Emerging from the region of myths and legends, and approaching actual history, the traditions contain narratives of several voyages made by Maori explorers to New Zealand before the final migration of the present inhabitants took place.

Of these navigators the most celebrated were Ngahue, the original discoverer of New Zealand, Kupe, and Tamateapokaiwhenua. Ngahue is said to have discovered greenstone on the west coast of the South Island, and to have taken a quantity of it back with him to Hawaiki. Kupe afterwards circumnavigated the North Island, and Tamatea the South. The principal migration to these shores took place about the year A.D. 1400, or about the time when Henry V. of England gained the Battle of Agincourt.

The causes which led to the present inhabitants abandoning their former home and coming here are variously related; but the most probable tale is that, a civil war having broken out, the weaker party determined to seek refuge in the new country about which such favourable reports had been brought back to them by Ngahue, Kupe, and others. The chief body of emigrants embarked in a fleet of six or seven canoes, each capable of containing 140 men. One of these vessels, the "Arawa," is described as being formed of two canoes lashed together, a deckhouse occupying the platform which joined them. They appear to have been similar in all respects to the canoes seen by Captain Cook in the Pacific, and said to be very suitable for long voyages.

The traditions furnish internal evidence of their general correctness. For one thing, we learn from them the season of the year when the canoes reached this country. The rata was then in bloom, and one of the crew was so struck with the brilliant colour of the flowers that he threw his soiled red-feather head-dress overboard, intending to get a fresh one from the woods on landing. This tradition shows that the migration took place at the only season of the year when the prevailing winds were fair for voyagers from the north-west to the south-east. Many other details might in like manner be cited to prove the correctness of the narrative.

Besides the first fleet, other canoes appear from time to time to have arrived from Hawaiki, bringing fresh settlers to the country. And there are accounts of return-voyages being made in search of sweet-potato seed, and the secret of its successful culture and storage.

Some idea may be formed of the mass of traditions which had accumulated in the course of centuries (and the mental effort it must have cost the people to hand down to our time even such portions as we have been able to rescue from oblivion) when we consider the voluminous nature of one class alone—namely, those relating to tribal history, and biographical records of notable men and women.

On arriving in New Zealand, or Ao-tea-roa, the crews of the colonising fleet dispersed themselves over the length and breadth of these Islands, and formed independent tribes or nations, each of which was subdivided into *hapus*, and the *hapus* into families. Each family, *hapu*, and *iwi* carefully preserved their genealogies and the record of their doings. Every free man amongst the Maoris was required to know by what title the land claimed by his tribe was held—whether by right of original occupation, conquest, purchase, or gift—and thus it happened that traditions relating to the same transactions were preserved by tribes whose interests were antagonistic. Several opportunities have been afforded in recent times through the Native Land Court of comparing these accounts which have been transmitted for several generations through separate and independent channels, and they have almost invariably been found to agree—a fact which adds to our confidence in accepting other traditions preserved in the same way, but the accuracy of which cannot be proved in the same manner. The laws by which the Maoris regulated their social and civil relationships were embodied in the historical traditions, which served at the same time to show how these laws originated, and to illustrate their application.

Although the greater part of the annals handed down relate to intertribal wars, we must not read them by the light of our knowledge of the state of things which existed when firearms were first introduced. Those weapons revolutionised Maori warfare, and encouraged ambitious men to prosecute devastating wars, which produced a reign of terror throughout the country. During the centuries which preceded our occupation, the ordinary life of the people in times of peace was pleasant and agreeable. The people possessed abundance of food, and agreeable and healthy occupation for mind and body. Each season of the year and each part of the day had its allotted work or amusement both for men, women, and children. The women, besides such household duties as the preparation of food and cleansing their houses, made the clothing and bedding required for their families. They gathered the flax and ti-palm fibres used, and prepared and worked them up into a variety of garments, some of which took months to complete, and when finished were beautiful specimens of handiwork. The children played a variety of games with tops, balls, kites, and swings. The youths engaged in wrestling and running, leaping with poles, skipping in squads of ten or a dozen together, and foot- and canoe-races. The men gathered the food and stored it in *whatas* or storerooms, which were attached to every chief's compound, and built on tall posts to protect the contents from damp and rats. Besides such natural products of the soil as fern-root, ti-palm stems, convolvulus-roots, and the berries of the karaka and hinau, the Maoris cultivated the kumara, hue, and taro. Fish of various kinds were caught during the proper season, and cured in vast quantities by drying in the sun, just as the Caribs of the Mexican Gulf cured their boucan. Wild pigeons, kakas, koko, tui, Paradise ducks, wekas, and mutton-birds were cooked and preserved in their own fat, in vessels made out of large kelp-leaves. Netting, carving, and the grinding and fitting of stone implements and weapons occupied the old men, and much of the leisure time of the young. They beguiled the long winter evenings by reciting historical traditions and tribal genealogies, by repeating poetry and fairy tales, and by songs, dances, flute-playing, and round games.

"In their social and domestic relations," to quote Mr. Colenso, "much harmony and good feeling prevailed. They were courteous in their behaviour towards each other, and so unwilling to hurt the feelings of others that in conveying bad and startling news they employed a song or quoted a saying of well-known meaning. They avoided wantonly hurting any one's feelings, and were scrupulously careful not to cause offence to visitors by look, word, or gesture. Any one guilty of rude behaviour was spoken of as one who had had no parents—one hatched from a cuckoo's egg. If they met an enemy in the company of one of their own friends and allies, no matter how deadly the feud between them might be, they would be quite civil to the enemy, and do nothing to harm him while with their friend, for fear of giving him pain, though, once separated from the friend's protection, they would not hesitate to kill and eat him.

Their chivalrous conduct on some occasions towards their foes was very remarkable—perhaps unparalleled except in the age of knighthood. Instances are recorded of a besieging party, when informed that their enemies were in want of food or weapons, sending a supply.

The story of Tutewaimate's encounter with the robber-chieftain Moko illustrates this pleasing trait in the Maori character.

Tutewaimate, a powerful chief who ruled the tribe inhabiting the Canterbury Plains about the year 1550, was subjected to considerable annoyance by a robber-chieftain named Moko, who waylaid the convoys of provisions and goods being brought to him, and killed the porters. But, as the latter were slaves, Tu did not think them worth avenging; but when Moko, in the course of these predatory attacks, killed a relative of his the great chief resolved to avenge his kinsman, and, accompanied by a large army, proceeded to attack Moko. Leaving the bulk of his forces at Kapukariki (Cust), Tutewaimate pushed on early one morning with a few chosen warriors to Moko's stronghold. He found the place quite unprepared, all the men except the chief being away. Having ascertained from a woman he met that the robber was asleep in a cave close by, he quietly approached the spot, and found him lying asleep, quite unconscious of his danger. But, like a true knight, he scorned to strike his sleeping foe, and, raising his voice, he uttered the following challenge:—

> I, Tutewaimate,
> Tutewaimate, son of Popotahi,
> Swift as the wind from the Rakaia Gorge,
> I have forestalled the drying of the morning dew.

The startled robber, raising himself to a sitting posture, replied,—

> Ho, Moko,
> Moko, son of Hautere,
> The wind rushing down from Mount Tere,
> The man fed upon uncooked shark.

As he uttered the last word the treacherous Moko, by a sudden and unexpected thrust, killed his generous foe.

The courage and endurance of Maori warriors is abundantly illustrated, and, though the record of ferocity, cruelty, and treachery found in the traditions is often appalling, it is sometimes relieved by deeds of generosity and mercifulness. While one dying chief bequeaths to his tribe the prosecution of a blood-feud, another implores those he is leaving behind him to forgive the wrongs they have suffered, and to promote peace. Again and again we hear the echo in succeeding generations of the words uttered by a venerable father of the people as they were leaving the shores of Hawaiki: "O my children! hearken to these my words. Depart in peace, and, when you reach the place you are going to, do not follow after the deeds of Tu, the god of war, but rather follow quiet and useful occupations, and then you will die a tranquil and natural death. Leave war and strife behind you; dwell in peace; conduct yourselves like men; let there be no quarrelling amongst you, but build up a great people."

It is in the biographical records of noted individuals that we meet with the most pleasing presentations of Maori character and customs. There we find the mask of ferocity and heartless cruelty which the tyranny of custom obliged the Maori to wear in his public intercourse with his fellow-men laid aside, and the real man, with his human sympathies and feelings, revealed to us. There we find the domestic life of the people stripped of its repulsive features, and presenting a picture which civilised men can look upon with pleasure. One of the most charming specimens of this kind of literature is the story of Hinemoa, the maiden of Rotorua. The story tells how the beautiful maiden, who lived on the shores of Lake Rotorua, and the young chief Tutanekai, who lived on an island in the lake, fell in love with each other; how for a long time each suffered from the secret fear that the other might not share the affection felt. It describes the joy which followed the discovery that it was mutual, and the precautions taken by the young lady's friends to prevent her escape. It tells how the youth nightly serenaded his lady-love from a tower on his island-home, and how the sounds of his flute borne over the water so affected her that she could not endure separation from him, and on a dark night, guided by the sound of her lover's flute, she swam across to Mokoia. At the spot where Hinemoa landed was a hot spring. She got into it to warm herself, for she was trembling all over, partly from the cold after swimming across the lake, and partly from modesty at the thought of meeting Tutanekai. Whilst warming herself a slave came close to her to draw water from the lake. The maiden, who was very frightened, called out in an assumed voice, "Whom is that water for?" "Tutanekai," was the reply. This was a good omen for her, and she bethought herself of a device to bring her lover to her side. Calling to the servant, she said, "Give me a drink." When the calabash was handed to her she purposely let it fall on a rock, and broke it. The servant returned for another, but he had no sooner filled it than she again asked for a drink, and when the calabash was handed to her she dropped it on the rock, and broke it. This was repeated several times. The slave thought it best to report the matter to his master, who on hearing what had happened seized a weapon and hurried down to the bath, where he shouted, "Where is that fellow who broke my calabashes?"

The charming simplicity and naturalness with which the conflicting feelings of modesty and love surging in the maiden's bosom are described in this concluding part of the story invest it with singular beauty. There is an entire absence of anything indelicate, or calculated to wound in the slightest degree the susceptibilities of the most sensitive and refined. Hinemoa (says the story) knew the voice; the sound of it was that of the beloved of her heart; and she hid herself under the overhanging rocks of the hot spring. But her hiding was hardly a real hiding, but rather a bashful concealing of herself from Tutanekai. He went feeling about along the banks of the hot spring, searching everywhere, while she coyly hid under the ledges of the rock, peeping out, wondering when she would be found. At last he caught hold of her hand, and cried out, "Ah! who is this?" And Hinemoa answered, "It is I, Tutanekai." But he said, "But who are you? Who is 'I'?" "It is I; it is Hinemoa." And he said, "Ho! ho! ho! Can such, in very truth, be the case!" And she answered, "Yes." And

She rose up in the water
As beautiful as the wild white hawk,
And stepped on the edge of the bath
As graceful as the shy white crane.

"And he threw his garment over her, and they proceeded to his home, and she became his wife."

The chief who committed this tradition to writing winds it up with the following words: "Never yet have the lips of the offspring of Hinemoa forgotten to repeat the tale of the great beauty of their renowned ancestress, and her brave deed in swimming over the lake to Mokoia." And, we may add, nor will the race that has succeeded to their inheritance at Rotorua cease to cherish the memory of that romantic story, which will for ever grace the pages of this country's history.

Another charming story is that of Te Ponga's love for Puhihuia:—

The tribes of Waikato were at war with the tribes who occupied the country around Auckland Harbour. Battle after battle was fought without any advantage being secured by either side. Wearied out at last, they mutually agreed to make peace, and one of the fiercest of the Waikato warriors undertook to arrange the terms. Accompanied by a large force he entered the enemy's fortress, which occupied the summit and slopes of Mount Eden. He was welcomed in the usual manner, and after the complimentary speeches were over a great feast was held. In the evening the residents entertained their visitors by dancing and singing before them. The young daughter of the chief of the town, watching a good opportunity, bounded forward to display her skill in dancing. The strangers were overpowered by her beauty, and Te Ponga, their leader, "felt his heart grow wild with emotion when he saw so much loveliness before him." The visitors, in their turn, gave an exhibition of their skill, on which occasion Te Ponga acquitted himself with such grace as to win Puhihuia's admiration. A passionate attachment sprang up between the two. Te Ponga, unable to sleep for his great love for the maiden, lay tossing all night from side to side, devising scheme after scheme by which he might secure a private interview with the maiden and disclose to her his love. His slave, noticing his restlessness, sought the cause; and, on being told, made the following suggestion: "To-morrow, at nightfall, as you sit in the court-yard of your host, feign to be very thirsty, and call loudly for me to fetch you some water. I will keep well away; and do you continue to shout angrily to me, 'I want water. Fetch me water.' Call so that the father of the young girl may hear, and he will certainly tell her to fetch you some. Then, rise and follow her as if in search of me." Te Ponga carried out his servant's suggestion, which resulted as he had anticipated. Pretending to search for his servant, that he might administer a beating for his prolonged absence, Te Ponga followed the maiden. He had no knowledge of the path to the spring; but, directed by the voice of the maiden, who tripped along singing merrily, he reached the fountain just as she was dipping her calabash into it. Hearing footsteps behind her, Puhihuia turned quickly round, and there stood Te Ponga himself. She was too startled and astonished to speak for some moments, and when she recovered herself she asked, "What can have brought you here?" "I came," he said, "for a draught of water." But the girl replied, "Indeed! did I not come here to draw water for you? Why, then, did you not stay at my father's house until I brought the water to you?" Then Te Ponga answered, "O maiden! you—you are the water that I thirst for." This confession led to a mutual exchange of vows. But they felt that, in consequence of late hostilities between their respective tribes, it would be useless to make their intentions publicly known. It was arranged between them that Puhihuia should elope with Te Ponga on his return. To prevent pursuit, Te Ponga ordered his followers to secretly disable all the war-canoes belonging to their hosts by cutting the lashings of the topsides. On the morning the visitors took their departure Puhihuia left the pa with a number of her female companions, and wandered along the path the visitors were returning by; and, as they came up, she began joking and laughing with them. Her father, seeing his daughter and her companions going so far, called out, "Children, come back here." All but the chief's daughter at once turned back; but she had only one thought in her heart—how to escape with her beloved. Gliding behind some large scoria rocks, which hid her movements from the fortress, she redoubled her speed. Te Ponga, seeing her running in this hurried manner, called aloud to his men to follow. Then began a swift flight indeed—of Te Ponga, and his warriors, and the young girl. Rapidly they flew, like feathers drifting before the gale, or as runs the weka which has broken loose from the fowler's snare. When the chief of Maungawhau saw that his daughter would be lost, he called upon his people to pursue her. There was a wild rushing to and fro for weapons, which delayed the pursuers, who reached the beach at Manukau just as Te Ponga had embarked with the maiden in his war-canoe. His men dashed their paddles into the water, and shot away swift as a dart from a sling; and, like Lord Ullin, the father of Puhihuia was left on the shore lamenting.

Besides these tales of love of which I have just given specimens, there are many fairy tales, and tales of magic and sorcery—tales of monsters that dwelt in deep pools, and in caves and forests.

Sir George Grey has preserved two specimens of Maori fairy tales which bear a strong family likeness to similar stories found in Europe and elsewhere. The first tells how the art of netting was discovered by a certain chief, who found the fairies one night drawing their fishing-nets on the coast near the North Cape. He joined them, and, by delaying their departure till dawn, secured their nets, and so learnt the stitch, and taught his descendants. The other story relates how a hunting-party on the Waikato were terrified by fairies, who swarmed all round their camp-fire, climbing over the roots of the trees to peep at Te Kanawa, who, to propitiate their good-will, presented his greenstone and other ornaments. The fairies, contenting themselves with the shadows of the ornaments, retired before dawn.

The fairies are described as a numerous people, merry, cheerful, and always singing, diminutive in person, with fair hair and skin. Upwards of forty years ago I used to hear the Maoris continually talking about the doings of the fairies, and often met persons who declared they had seen them. One man described how he saw the fairies building a pa on the summit of a hill enveloped in mist. From the way he told his story I felt sure he had actually seen what he was describing, but that probably what he took to be fairies were the shadows of men building a pa at some distance, thrown upon the curtain of mist.

Some of the stories of sorcery and magic are very curious. On Banks Peninsula, near Gough's Bay, the trees were thought to be enchanted men, and able at times to move about. Sorcerers were said to have the power of striking people dead by a look, and withering up trees and shrubs. Persons of ignoble birth or unskilled in magic were warned never to look upon any enchanted object for fear of losing their sight or their lives.

The legend of the magical wooden head explains how sorcerers accomplished their ends. The story throws some light upon the ideas prevalent amongst the Maoris regarding the manner in which supernatural aid was to be obtained, to enable men to accomplish what was beyond the ordinary power of mortals. A sorcerer possessed of a magical wooden head caused the death of all who came within a certain distance of it. A brave warrior renowned for skill in magic resolved to rid the country of the pest. To gain his object he enlisted by the agency of powerful charms and incantations the services of thousands of spirits kindly disposed to mankind, to fight the malignant spirits who guarded the head. A battle ensued, the evil spirits were defeated, the fortress was taken, and the cruel sorcerer and owner of the magical head was put to death.

Maori fables (says Mr. Colenso, in his able paper, Vol. i., Trans. N.Z. Inst.) are very natural and correct, and mostly conversational, between animals or natural objects, such as between the large rock-lizard and the red gurnet, the codfish and the fresh-water eel, the rat and the green paroquet, the sweet potato and the fern-root. Had they more and larger animals they might have had a volume of fables rivalling those of Æsop.

Their legends of ogres and monsters are very like the stories that still linger in European nurseries. They are said to have been the first occupants of this country. They are described as giants who could stride from mountain-range to mountain range, swallow rivers, and transform themselves into anything, animate or inanimate, that they chose.

But there is a still more remarkable class of legends, relating to the existence of huge reptiles of the saurian order, which are said to have infested various parts of this country, and to have proved very destructive to the inhabitants. The descriptions given of the appearance of these huge reptiles, and their habits, and the manner in which they were captured, are so minute and exact that it is hard to believe that the accounts relating to them are of such great antiquity as the evidence we possess proves them to be. For it appears that these legends are common to all branches of the Maori race. Judge Fornander, referring to these *taniwha* stories, in the first volume of his interesting work on the Polynesian race, says, "The Hawaiian legends frequently speak of reptiles of extraordinary size, living in caverns, amphibious in their nature, and being the terror of the inhabitants. Now, when it is taken into consideration that throughout the Polynesian groups no reptiles are found much larger than the common lizard, it is evident that these tales of monster reptiles must have been an heirloom from the time when the people lived in other habitats, where such large reptiles abounded."

For at least a thousand years these stories have been handed down from generation to generation, and are now told with such minuteness of detail that if we knew nothing about their antiquity we should accept them as descriptions of what happened a comparatively short time ago. The fact of their preservation for so long a period adds greatly to our assurance of the value of such of the Maori traditions as the people themselves assert to be of great antiquity.

Poetry.

The largest collection of Maori poetry is contained in a work, extending over four hundred pages, published in 1853 by Sir George Grey. But this work contains only a portion of the traditional native poetry stored, till Europeans came, in the memories of the people; still, there is quite enough to show how much poetical feeling may coexist with the most revolting usages of a barbarous life. These poems comprise specimens of the various compositions which may be classed under the headings of incantations, visions, and charms; war songs or chants; love songs; canoe songs; historical ballads; dirges, laments; children's songs, lullabies.

Mr. Colenso, remarking upon the poetry of the New-Zealanders, says, "The people frequently beguiled the monotonous drudgery of some of their heavier work, performed together in company, by songs with suitable choruses. Such songs were sung when dragging or paddling their canoes, or digging in their cultivations. Their war songs and defiances contain horrible curses, and breathe a spirit of ferocity; while their love songs are full of the tenderest feeling, expressed sometimes in the most touching and beautiful language. Their sentimental songs, expressive of abandonment, loneliness, and despair, contain much pathos, and, sung as they always were in a minor key, were often very affecting. The whole of their poetry, though abounding in poetical images, is destitute of rhyme and metre, a deficiency their poets got over by lengthening and shortening vowels and words; proving that the Maoris, like ourselves, conceive of poetry as something far higher than mere versification."

Translators have found great difficulty in getting at the real meaning of many of the compositions, not only owing to the presence in them of obsolete words of great antiquity, but to the extraordinary license allowed to poets in dealing with the words they used. Owing to the peculiar character of the language the omission of a letter might entirely alter the meaning of a word. Take the word "*hanga*," for instance, which means "to make;" omit the "h," and it means "turn," or "facing."

I may be excused for referring here to a note by the Rev. Dr. Maunsell, one of the most learned Maori scholars New Zealand possesses, on the peculiarities of Maori poetry. Dr. Maunsell says,—

"The construction of Maori poetry was not only abrupt and elliptical to an excess not allowed in English poetry, but it also carries its license so far as to disregard rules of grammar that are strictly observed in prose; alters words so as to make them sound more poetically; deals more arbitrarily with the length of syllables, and sometimes even inverts their order or adds other syllables. It is true that these irregularities help much to invest Maori poetry with that deep shade which none can penetrate without close study of each particular piece; but it must be remembered that by far the largest measure of the difficulty arises from the peculiarly local circumstances, and from the remote and vague allusions so wrought into the piece that even one tribe will often be unable to understand the song of another, especially if it be one of any antiquity.

"To follow the Maori poet through all the wild irregularities of his flight would be far from the intention of these notes. . . . They will be found for the most part to consist of omissions of the nominative case, of the objective, often of the verb and verbal particles, omissions of the prepositions, changes of one preposition into another, unusual words introduced, and words sometimes inverted, exceedingly wild and abrupt metaphors, and transitions unexpected and rapid."

After reading Dr. Maunsell's statement it will not surprise any one to find that much of the Maori poetry baffles all attempts made by Europeans to translate it into intelligible language. The poetry of any language suffers by translation, and in no case is this so apparent as with Maori poetry. Its excellence in the original may be gathered from the fact that, poor as our attempts at translation are, they will be found to contain much that is beautiful in sentiment and expression.

The following is a translation of part of an ancient lament by the chief Ika-here-mutu for his children, some of whom died in battle, others of disease. (For original, see Sir G. Grey's "Poetry of the New-Zealanders," page 9.)

Here I sit, while my throbbing heart
Mourns for my loved children.
Here, like Tane's offspring,
Drooping yonder in the inland forest,
I bend like the fronds of the tree-fern
Over my lost children.
Where art thou, O my son!
Thou whom thy people were wont to greet
With the welcome cry, "Draw near! Draw near!"
Thou art gone, alas!
Borne by the strong ebbing tide
[That bears all men away].
O my friends! here I sit alone
Upon the plot where my flock gathered—
A slippery plot,* swept so clean
That nothing now remains to greet mine eyes.
I cannot bear to gaze upon the sun
Now shining down on me.
[Its bright light mocks the darkness of my soul.]
I cannot bear to gaze on Taranaki's snowy peak,
Nor to feel the warm inland breeze blow upon my cheek,
For they only serve to wake the memory of my loss.

Trees were called the offspring of Tane, as he was father of all vegetation. The shape and appearance of the tree-fern affords a beautiful and appropriate simile to describe the

* The slippery plot, literally—the spots where sea-birds flock together.

attitude of the broken-hearted father, with bowed head and extended arms, bending over the remains of his children, after Maori custom.

*Hinewhe's Lament for her Father Te Rauparaha, when carried off by Man-of-war Crew.**

[Te Rauparaha, the celebrated northern chief, who was residing with his family on the shores of Porirua Harbour, was unexpectedly seized and carried off one night by a man-of-war crew, as he was suspected of treacherous intentions towards the settlers at Wellington. His daughter is very satirical in her allusions to those who preached peace and practised treachery.]

Love no longer burns within the breasts
[Of your once-famed warrior tribe].
Kapiti's summit stands alone,
For thou, the famous of the land,
Art snatched away.
Sleep, warrior, sleep on shipboard,
And then you may be bound, spirit of the deep.

* * * * * *

The rata-tree that grew beside me,
That sheltered me with its spreading boughs,
Is gone—torn from the midst of Toa's sons—
Of Toa the brave.
Why were you not snatched away
When the eyes were bloodshot in battle ?
From the mouth of the loaded gun
You might then have cried,
" Comrades, farewell,
Night's shadows close around."
But who can turn life's stream,
Or fetch its waters back!
'Tis past, 'tis past.
Revenge alone remains.
Your grandsons, they shall seek it;
For your own sons and followers lie
Like lazy kokopu in darkling pools asleep.
Farewell, my father,
Offering made by Tamihana and Matene to the god of peace.
Alas! from realms below was brought this treacherous law.
The law they promised us was one of peace.
My faults alone have ruined you.

Kapiti was Te Rauparaha's stronghold. His son Tamihana and his nephew Matene introduced Christianity to the tribe called Toa, or the "brave." Trusting to the peaceful professions of the English, Te Rauparaha took no precautions to protect himself, and was easily taken prisoner. The news of his capture roused the indignation of his daughter, who is unsparing in her ridicule of the cowardice of Toa's sons, and the treachery of the English under the guise of peace.

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* See Sir G. Grey's "Poetry of the New-Zealanders," page 12.

An Exile's Lament for his Native Land.

Afar the tide of Kawhia laps the shore.
Alas! we are parted now.
Over the well-known hills
The clouds are creeping slowly up to me,
To pass over me, and join me to thee.
    Land of my childhood,
    Here, from afar, I greet thee.

The Lament of One forsaken in her Old Age by her Husband.

Sink, O sun! Descend to thy cave,
And carry tidings there.
            Alas! Alas!
Like the flood-tide returning ever,
The tears rise in my eyelids,
But thou repliest not.
            Alas! Alas!
The smoke is just now rising from the south.
'Tis there Ngawhare dwells, the man I love.
Why didst thou lead me thus far,
To fling me, like rejected food, aside?
'Twas thou, with smooth, deceitful words,
Didst lure me from my home.
With lightsome step I followed thee.
    * * * *
Oh! why did I scorn Te Wheoro,
Betrothed in infancy to me?
    * * * *
'Tis now the seventh moon,
The time when
The white flowers of the "toe" bloom [on me]:
The eighth month comes, and they are blown away.
            Alas! Alas!
The rainbow stands above, the lightnings flash,
And I depart.
            Alas! Alas!

A Lover's Lament.

The mists still hang on Pukehina.
Along its slopes my lover wends his way.
Turn, love, once more,
That I may pour forth my tears to thee.
I was not the first to speak of love.
You deceived me, your inferior;
And now my foolish heart
Is beside itself
When my eyes rest, love, on thee.

The following translation is taken from Mr. Colenso's paper in Vol. xiii., Trans. N.Z. Inst., p. 75:—

A Love Chant.

Rain on, O thou rain! Continue to rain down without there. Here am I within the hut deploring my distress, and comparing [this with that]; for my eyes are as if supplied with water from a flowing spring. It is the great love I bear to the fond one of my affection that causes these fiery, convulsive pains—the dear one, who is so greatly desired and longed-for.

Now, alas! thou art separated far off to a distance, who will return thee hither to me? . . . . I will go forth to look at the fleecy clouds sailing hither, coming this way over the mountain. Alas! the boundary that parts us, dear young lady, is as a great ocean-depth to thee. Notwithstanding, in that one direction — towards thee — my eyes are dim with steady gazing; for thou alone art the only one of my deepest affection. . . . .

A Love Song by a Widow for her Deceased Husband.

After the evening hours
I recline upon my bed.
Thy own spirit-like form
Comes towards me,
Creeping stealthily along.
Alas! I mistake,
Thinking thou art here with me,
Enjoying the light of day.
Then, the affectionate remembrances
Of the many days of old
Keep on rising within my heart.
This, however, loved one—
This thou must do:
Recite the potent call to Rakahua,
And the strong cry to Rikiriki,
That thou mayest return.
For thou wast ever more than a common husband—
Thou wast my best-beloved, my chosen,
My treasured possession. Alas!

A Love Song.

Rise up quickly, O thou moon!
Make haste to get above me,
That I may give vent to my sighing
And utter my laments.
Now, indeed, for the first time
I feel the pangs of love.
It is as if a demon or a lizard
Were within me gnawing.
* * * *

O ye light, fleecy clouds flitting above!
Fly on, fly away, and carry tidings,
That my beloved one may hear of me in her anxiety.
* * * *

Alas! alas! my very eyesight
Is fast failing me:
When I look at the distant headlands
They quiver, and are dim.

PROVERBS.

The proverbs were very numerous, and afford abundant evidence of the wit and shrewdness of the people. Nothing pleased a Maori audience better than to hear them aptly quoted. Unfortunately, some of the best would be almost unintelligible to English people; but the following specimens will be understood and appreciated:—

How often does the weka escape the snare! (Equivalent to our proverb, "A burnt child dreads the fire.")

The white crane, whose flight is seen but once. (Equivalent to "Angels' visits, few and far between.")

The road to Hawaiki is cut off. The tide fills the Cave of Death of the Hundred Sea-monsters. (Equivalent to "The Rubicon is passed.")

Black and red united can do it. (The red-ochred chief and charcoal-smeared slave united can do anything.)

Food given by another person is only a throat-tickler; but food gained by the labour of one's own hand is the food which satisfies.

A man fond of sleep and a man fond of idleness will never obtain wealth.

The passing clouds can be seen; but passing thoughts cannot be seen.

Great is your going forth (to war); small your return. (Equivalent to Ahab saying to Benhadad—1 Kings, xx., 2—"Let not him that girdeth on his armour boast.")

Deep throat; shallow muscle. (An idle glutton.)

He who goes before gathers treasures; he who lags behind looks for them in vain.

Sir, bale the water out of your mouth. (Equivalent to vulgar colonialism, "Dry up.")

Dropping water wears away the soil; so frequent slander a good name.

Perhaps thou camest hither from the village of Mr. Falseways. Perhaps thou and Take-up-talk travelled hither together.

One day's beauty, a short-lived pleasure. (Sometimes used of a girl's countenance.)

Show yourself a true man, never be disobedient.

Food underdone is your own; fully cooked goes to others. (A warning to dawdlers.)

Totara forehead. (Equivalent to "Brazen-face.")

The following specimen of epistolary composition, which came accidentally into my possession, shows how naturally Maoris express their thoughts in poetical language. The writer is a very commonplace-looking old man, who came from the North Island to reside at Kaiapoi some years ago. He is the last person any European would imagine capable of expressing himself in the way he does here: "Nau mai haere atu ra e taku karere aroha i runga i nga huamo nunui o nga ngaru nunui o te moana tutuki atu ki nga Roma kino o Raukawa. Ma 'Te Anau' koe e mau atu ki Kihipone. Ma te mera koe e hari atu ki te poutapeta i Tokomaru. Ma tetahi tangata koe e mau atu kia Tamara rana ko Heni, me nga tamariki hoki. E hika ma, tena koutou." [Come hither, and go, my messenger of love, on the great rearing crests of the mighty heaving billows of the ocean, that meet the angry waves of the stormy Straits of Raukawa (Cook Strait). The "Te Anau" will convey you to Gisborne. The mail will carry you to the post-office at Tokomaru, and some person will carry you to Damaris and Jane, and to their children. Ladies, I salute you and your children!]

Conclusion.

Even the brief and superficial survey of Maori traditions which is all that could be attempted in a paper of this kind furnishes sufficient evidence to prove that they are something more than mere literary curiosities, and that in proportion as they become better known to ethnologists their value will be more fully realised and understood.

The fact that they contain myths relating to the origin of all things corresponding in details and in chronological order with those of the Homeric age, must tend to remove doubts as to the possibility of knowledge being transmitted for ages by oral tradition; for in no other way have the Maoris preserved those myths which they possess in common with races from whom they have been separated for probably not less than two thousand years, and which were evidently derived from a common source.

In the poetry and proverbs of this long-isolated people we find the same ideas and the same similes employed that the poets and sages of the Old World used to describe human passions and emotions, and to sum up the thoughts of the wise; and we find their orators giving utterance in their public speeches to lofty ideas, in strange contrast with their sordid surroundings. But, as beseems an antipodean literature, some of the ideas are found to be topsy-turvy. In place of Aphrodite, it is the hero Maui who rises from the foam of the sea; it is Hinemoa who swims the strait, and not Leander; and, instead of the angels falling in love with female beauty, it is the manly beauty of Tawhaki that attracts the celestial fair one from her heavenly home.

So far from being ignorant savages, we find that a large proportion of the people possessed cultivated minds, and were well instructed in subjects which only highly-educated Europeans think of acquiring any exact knowledge about. They were familiar with the flora and fauna of their country, to every object of which they gave distinctive names,* precise enough to prove that they were keen and intelligent observers of all natural objects. They scanned the stars and named the various constellations, and took such note of their movements as to mark the seasons by them. Their sense of beauty was so correct that, simple as their clothing, and utensils, and weapons

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* See "Forest Flora," by Kirk; and Buller's "Birds;" and Colenso's papers in Trans. N.Z. Inst.

were, they designed the forms of them in such a way as to render them objects of beauty. With such inferior tools as sharp fragments of stone and shells, their artists executed with finished workmanship carvings of complicated pattern and beautiful design. Possessing that subtle faculty which enables people to discern at once the fitness of things, the Maoris preserved in their formal intercourse with each other the utmost propriety of conduct, and always behaved with dignified self-possession in the presence of civilised men, however exalted in station.

Those who only fix their eyes upon the defective side of the Maori's character and acquirements; who think only of his cruel behaviour towards his foes and inferiors, and forget his courtesy and generosity to his friends and equals; who think only of the things in which he comes behind the ordinary civilised man, instead of the things in which he excelled him, will find in these traditions a rebuke administered to that spirit of race-pride which leads the European to look with feelings akin to contempt on all coloured men, as if they were all alike infinitely beneath him; and they will also learn how it is that most of those Europeans who have taken pains to acquire accurate knowledge of the first inhabitants of this country have formed such a high opinion of the Maori race.

Appendix.

Table showing that the Mythological Traditions brought by the Maoris from Hawaiki were accurately preserved up to the Time of the English Occupation of their Country, as proved by their Correspondence with similar Traditions in other Parts of Polynesia, from which the Maoris have been separated for Centuries.

Mangaian and Hawaiian (*Vide* Gill and Fornander).	*Maori* (*Vide* Grey, Shortland, White, &c.).
Chaos begat Papa, or Earth. Papa, the wife of Awatea = day-time.	Chaos begat Papa. Papa, the wife of Rangi = day.
The children of Papa and Awatea were— Tangaroa, god of the sea; Rongo, a cruel god, leader of war among mortals; Tane, the generative principle.	The children of Papa and Rangi were— Tangaroa, god of the sea; Rongo, a cruel god, leader of a rebellion in heaven; Tane, begetter of trees and men. There were other sons besides.
The sky pressed on the earth and confined the inhabitants, who were in darkness.	The sky pressed upon the earth and confined the inhabitants, who were in darkness.
The sky was raised to where it is now by *Maui*.	The sky was raised to where it is now by *Tane*.
Ra, the Sun, captured by Maui, who compelled him to go more slowly—snared with a noose.	Ra, captured by Maui—snared with a noose. Beaten to make him go more slowly.
Maui, son of Taranga, visits his parents in the underworld in the form of a pigeon.	Maui, son of Taranga, visits his friends in the underworld in the form of a pigeon.

Mangaian and Hawaiian.	*Maori.*
Maui's sister Ina drifted to Sacred Isle (Motutapu). Married Tinirau, chief of Motutapu.	Maui's sister Hina-uri drifted to Sacred Isle (Motutapu). Married Tinirau, chief of Motutapu.
Maui assumed form of pigeon, and sought his sister, and brought back tidings of her.	Maui the elder assumed form of a pigeon, and sought his sister, and brought back tidings of her.
Maui visits fire-*god* Mahuika in the form of a linnet.	Maui visits fire-*goddess* Mahuika in the form of a hawk.
Maui tries to get the secret of the origin of fire; extinguishes the brands given him by the god; provokes him till in anger he sets the underworld on fire.	Maui tries to get the secret of the origin of fire from Mahuika; extinguishes again and again the fire given to him, and so enrages the goddess that she sets the underworld on fire.
Maui barely escapes in the form of a linnet.	Maui barely escapes in the form of a hawk.
Maui brings the secret back.	Maui brings the secret back that it is hidden in the wood of certain trees.
Maui fishes up the island Rakaanga. Natives there show spot where his hook caught in the fish.	Maui fishes up New Zealand. Maoris show spot on East Coast where his hook caught.
The enchanted forests:— Rata builds a canoe. Fells a suitable tree. Next day finds it standing again. Fells it second time. Following day finds it standing again. Rata seeks the aid of the presiding divinity, who gets canoe made and carried to the ocean.	The enchanted forests:— Rata builds a canoe. Fells a suitable tree. Next day finds it standing again. Fells it second time. Following day finds it standing again. Rata blamed by the offspring of Tane for destroying trees without permission. They agree to make the canoe for him. He returns and finds it completed. Takes it to the ocean.
The Sacred Crane and Serpent.	The Sacred Bittern, the *Poua-hao-kai*.
Rata takes a passenger on board his canoe, who is seeking the remains of his father, Vaiaroa.	Rata seeks the bones of his father Wahieroa.
Tane, in search of a wife. Married Ina.	Tane in search of a wife. Married—Hine-hauone. Hine-titama.
Tane, husband, or generative principle in nature.	Tane, husband, father of vegetation and men.
The beginning of the new year indicated by the appearance of the stars Puaka and Matariki on the horizon in the morning.	The beginning of the year fixed by the appearance of Puaka and Matariki at dawn.
Human sacrifices taken from particular families.	Human sacrifices taken from particular families.
Ten heavens, the upper world.	Ten heavens, the upper world. Some say more.
Several divisions of the under world. Last, Roe, threadworm.	Several divisions of the under world. Last, Toke, earthworm.
The water of life of Tane.	The water of life of Tane.
The Deluge, lasting. Men, women, and animals saved in a building erected on a raft.	The Deluge, lasting eight months. Men, women, and animals saved in a building erected on a raft.

Section H.

(SANITARY SCIENCE AND HYGIENE.)

President of the Section—Dr. Allan Campbell, Adelaide.

ADDRESS BY THE PRESIDENT.

The Advancement of Sanitation among the People.

If I understand the position of a president of a section of this Association, his address has a latitude in the direction of popular treatment not allowable in a strictly scientific paper. All the more so may such latitude be permitted in a subject with such popular bearings as sanitation. It is on this ground that I have selected "The Advancement of Sanitation among the People" as the title of the present short address.

All who have had any experience of a really practical nature with the administration of Health Acts must have found that they could go but a little distance before there cropped up in their path a series of difficulties calculated at every step to defeat their object. These difficulties seem to come in every direction. They not unfrequently lie in the Acts themselves, which seem to have been purposely passed in a form which only gives the semblance of power to constituted authorities. They lie sometimes in these very constituted authorities, who, although they possess the power, from motives of popularity-hunting or self-interest passively decline to put their power in operation. Or the difficulties may remain with the public, who, from ignorance and inertia, refuse to be directed, or disturbed in their crude naturalism.

On this sea of difficulties the enthusiastic sanitary reformer looks out with some dismay, and strains his eyes to catch some encouraging signs of progress. Something depends on the colony from which the outlook is made. A comparative glance at the colonies shows that advancement in sanitation has been unequal among them; still, all through, progress is being made, and in several lines have been laid which must lead some day to a much better state of things than now exists.

To discover the direction in which future advancement lies it becomes us to weigh the spirit of the age, and also to see clearly that sanitary science must submit itself to that spirit, and heartily co-operate with it. We are all prone to regard our pet science as something distinct from the ordinary run of knowledge, and to get ourselves to believe that in order that it may reach the community means of a special nature are necessary. This is specially the case with a science which has a popular aspect, and admits of being brought into active operation by a public enactment. Legislative authority is eagerly grasped at as the way out of many difficulties. In this the fact is apt to be forgotten that a just conception of this very spirit of the times makes it clear that legislation is not only required, but the higher sanction of popular conviction has to be secured as well. I hold that blank ignorance and its attendant inertia is the dead-wall that withstands all sanitary progress—ignorance, too, that envelopes legislators, Boards of Health, and people alike.

The spirit of the times is the diffusion of knowledge among the people, and the birth, through this agency, of social and political advancement. The communities of this Southern Hemisphere are self-controlling, and no unimportant feature of their national character is their readiness to resent what they regard as an interference with the rights of the individual. The people refuse to be governed by autocratic boards and bureaux, and it seems to me they will continue to assume the same attitude unless they come to possess the knowledge that is needful to secure their acquiescence. It is perfectly plain to those who know anything of the working of our political institutions that legislators will only go a very limited length in the direction of compulsion, so long as the people generally are unprepared to see intelligently its necessity.

As sanitary reformers, it therefore behoves us to catch the trend of the popular movement, and work directly on its lines. We must move forward on those lines which open out the prospect of final success—that is, we must go with the rising tide of public education, and graft the practical side of our science upon it.

"We must educate our masters" is the watchword of to-day. Political power is in the hands of the people, and all legislative advance is the expression of their will. If, then, as the phrase goes, the government of the country be "by and for" the people, no proposition is clearer than this: that all social progress that has its root in legislative enactment, such as sanitation, must be preceded by the enlightenment of the people. Any enactment will fail to possess efficiency unless the education of the public mind on the subject reaches a proper standard.

My hearers will bear with me while I say, further, that manhood-suffrage and vote by ballot are imperial agencies. And every day sees arising more acutely the demand that no effort must be spared to educate the people and bring them up to a truer perception than they now exhibit of the requirements and laws of social existence. I am encouraged to believe that, as time goes on, our national school-systems will bear their due results. Much, however, must necessarily depend on that education being directed in channels which are soundly practical, whether or not the object be secured of making the people more plastic to those needful reforms which find their base in legislative enactments.

There are two lines, so far as sanitation is concerned, on which the ideas of the public ought to be made to run, and upon which an intellectual habit should be formed. The first is to regard society as an organic whole; and the second, to obtain intelligent notions of natural sanitary laws. There are few directions in which it is more important to view our social relations as an organized whole than in that of sanitation. Society has a life of its own, which is yet dependent on the health and vigour of its individual members. This is strikingly so, so far as the social body in its sanitary aspects is concerned. Diseases of the severest type have their hunting-ground in the social organism. As individuals living apart or in isolation men would be practically free from them, but as units in close social relations diseases of the most formidable nature afflict us. In several aspects of public health, sanitary reformers have risen to the conception of a national life; and what I contend is that the people who constitute the social organism, and who in these colonies seek to govern themselves, must also rise to the perception of the same great truth, The idea of a "national life" must not be limited merely to influences that arise out of our modern complex industrial system, but take in every condition arising out of all phases of the social relationship. If such a conception once gained an entrance to the public mind, and became a conscious precept of the public understanding, many of the difficulties which now surround sanitary legislation, and bar the way to a higher sanitary standard, would speedily disappear.

The second broad line on which reform should run is through the instrumentality of our national school-systems. It is in the school where the seeds of knowledge must be sown. And it is an assuring fact that the knowledge which sanitary reformers desiderate so seriously in the public generally can be taught amid other school subjects to the young. We find the kindred topics of elementary physiology, chemistry, and physics now taking their place in the school curriculum, and the way is ready for hygiene and sanitation to receive a share of attention. Independently, however, of the fact just pointed out, that the elementary subjects of physiology, chemistry, and physics are already taught in our national schools, there is the broader fact to be remembered that early years form the only period of receptivity to the masses. The vast majority of men do not pass much beyond the stage of early manhood before the channels of access to their understanding become practically closed, and as middle life is reached the numbers who are found capable of accepting fresh or larger views of any question like sanitation are few indeed. The knowledge must be imparted to the young, and in as practical and every-day character as it is possible to make it.

While preparing this paper, I communicated with Mr. Hartley, the Inspector-General of Schools in South Australia —a gentleman, I may say, fully alive to the progress of public opinion as well as education. As he is at present one of an intercolonial committee preparing a series of school-books for common use, I deemed it advisable to suggest to him the desirableness of incorporating a series of lessons on hygiene and sanitation in the new series. He communicated the suggestion to the head of the Education Department in Victoria, when it was found that the suggestion had been anticipated, and Victoria had entered upon the preparation of a school-book on the subject. The scope of that book, which will be issued to the public schools of Victoria in a few months, may be seen by the following headings of chapters which it discusses: (1) Introductory chapter; (2) Air; (3) Food; (4) Drink; (5) Clothing; (6) Dwellings; (7) Water; (8) Exercise, rest, recreation; (10) Violation of the laws of health; (11) Ambulance. This outline is admirable, and evidently, while the treatise may be fitted to be a textbook to the most advanced pupils, much of it may be imparted to the younger children.

In my original communication with the Inspector-General of Schools in South Australia, I submitted, at his request, an outline of elementary lessons, which he would in all probability have adopted had the Victorian Education Department not already entered the field. The lessons were divided into six chapters, with a series of subsections.

Lesson I.

Hygiene.—Its meaning. Care of the person: (1) Skin, physiology; (2) baths; (3) care of the mouth, hands, hair, &c.; (4) clothing; (5) clothing and infection; (6) disinfection; (7) exercise, rest, recreation.

Lesson II.

Food.—(1) Kinds of food; (2) elements; (3) outline of digestion; (4) preparation; (5) adulteration; (6) diseased food; (7) evils of insufficient and bad food.

Lesson III.

Water.—(1) General qualities; (2) sources of supply; (3) impurities; (4) dangers of bad water; (5) its purification.

Lesson IV.

Air.—(1) Composition; (2) deterioration; (3) preservation; (4) effects of vitiated air; (5) ventilation; (6) air a medium of infection.

Lesson V.

Sanitation.—(1) Houses—site, &c.; (2) soils; (3) preservation of soil; (4) drainage—principles, &c.; (5) diseases from impure soils and drains.

Lesson VI.

Public Health.—(1) What it is; (2) its preservation; (3) nuisances; (4) trades; (5) filth diseases; (6) Health Acts and administration; (7) advantages of following sanitary laws.

An exceedingly practical chapter on ambulance is added in the Victorian forthcoming book, and I can testify, from practical experience, to the deep interest children take in this subject.

I see in this movement hope for the future of sanitary work. It may, no doubt, take years to leaven the public mind, but, now that sanitary reformers have been able, in many communities, to overtake the cruder insanitary conditions by legislation, by dint of this further movement of instructing the young we may secure that additional hold which will not only do away with the constant struggle that now goes on between sanitary enactments and the fulfilment of their requirements by the people, but also bring about what we all so much desire to see—the people of themselves, either by legislation or otherwise, aiming to secure a higher sanitary condition for its own sake.

1. *House Sanitation in Sydney.*

By W. E. Cook, M.C.E. (Melbourne).

Before the year 1880 no properly-defined and well-considered system of sewerage was carried out in Sydney, but from time to time, as the growth of the city demanded, sewers of all sorts and sizes, from 10ft. by 5ft. stone sewers to pipe-drains of 9in. diameter, were constructed in almost every street running down to the Harbour of Port Jackson. These sewers served to carry off both the stormwater and the foul-water sewerage from the houses. In most cases they are still in existence as stormwater sewers, and in many instances they still act as foul-water sewers, pending the construction of the low-level main sewers.

In the year 1876 it was decided to construct a system of sewers of such sizes and at such depths as to carry the foul-water sewerage of the city and eastern suburbs into the ocean near Bondi, and that of the southern suburbs on to a sewerage-farm, where the foul water is purified by filtration through sand, and the clean water effluent empties into Botany Bay.

The main outfall-works of both the eastern and southern systems were begun in 1880, under the late Mr. W. C. Bennett, M.Inst.C.E., as Engineer-in-Chief for Sewerage. Upon the death of this gentleman, Mr. R. Hickson, M.Inst.C.E., succeeded to the position, and all the works both on the main and reticulation sewers were carried out under his supervision until November, 1889, when, by the provisions of the Metropolitan Water and Sewerage Act Amendment Act, the maintenance of the main sewers, and the construction and maintenance of the reticulation sewers, including house-connections, came under the control of the Board of Water-supply and Sewerage. Mr. J. M. Smail, M.Inst.C.E., who had for a number of years been engaged upon the construction of the main southern outfall and branch sewers, was then appointed Engineer for Sewerage under the Board.

When Mr. Smail took over the control of the sewerage works under the Board, fourteen thousand houses had been connected with the sewers (principally the old city ones), and since then, up to the end of 1890, four thousand additional houses have been connected. While designing and constructing the reticulation sewers, it was also necessary to initiate and carry into effect a thorough system of house-connection, and provide for the ventilation of the house-drain and its various branches. Certain well-defined regulations have been laid down for securing the thorough construction and ventilation of the house-drains and branches, and these are strictly enforced. It can readily be imagined that the ignorance of some householders and the greed of others would, under ordinary circumstances, cause considerable trouble in carrying these regulations into effect; but, fortunately, the Sewerage Act, above referred to, places very large powers in the hands of the Board and its officers, so that but little difficulty is really experienced.

[Here followed a description in minute detail of the various sanitary appliances which have been adopted in Sydney.]

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2. *Remarks on the Christchurch District in connection with its Drainage and the Disposal of the Sewage.*

By Courtney Nedwill, M.D., and Edwin Cuthbert, M.Inst.C.E., Engineer to the Christchurch Drainage Board.

The Christchurch District is distant from the sea about five miles, above which, at high water, it stands only 16ft. The area included in the city and suburbs consists of 2,800 acres, having a population of about thirty-five thousand. The ground is composed of a series of strata of clay, sand, and shingle, interspersed with water above large water-carrying beds, which lie at a distance of from 80ft. to 280ft. from the surface. Springs derived from this source issue in several places over the district; and at Avon Head, four miles from Christchurch, some large ones form the head-waters of the river which flows through the town. Through Christchurch the fall is fairly good, but thence in its course to the sea is very slight, the tide affecting it within two miles of the eastern boundary of the city.

Before the drainage-works were put in hand the subsoil water was generally to be found within from 2ft. to 3ft. of the surface, while in some places it frequently covered the land. The almost uninterrupted flow from the numerous artesian wells had a considerable influence in helping to make the district a waterlogged one. At this period Christchurch was undoubtedly very unhealthy. Slop-water, added to subsoil-water, saturated the ground, and common cesspits were then to be found in almost every quarter of the district. In the year 1875—the date we are now speaking of—the population of the city itself was only 10,611, yet there were no less than 49 deaths from typhoid fever and 21 from phthisis; while the infant mortality-rate, calculated by proportion of deaths under one year to 1,000 births, had reached the high figure of 184·2, the general death-rate itself being 30·4.

If we compare the mortality bill of 1889 with this bad record we see at once the improvement that has taken place. From a town dangerous to live in, Christchurch has been converted into a very healthy city. So soon as the effects of the works were felt the death-rate dropped. In the year 1882 it was 13·7; in the year 1888, 11·36; and in 1889, the latest year for which we have the returns, it was 9·77. In this last year the deaths registered from fever were only five, those from phthisis only eight, while the population had in the meantime increased from 10,611 to 16,785. It is to be regretted that reliable statistics cannot be obtained for the suburbs, so that we might deal with the larger population of thirty-five thousand, but there is every reason for believing that they have fully participated in the general improvement that has been so manifest in the city.

The following is a short description of the works undertaken for the drainage of the district:—

The sewers have been constructed by and are vested in the Christchurch Drainage Board, a corporate body constituted by a special Act of Parliament in the year 1875 "to provide for the drainage of the City of Christchurch and the surrounding districts."

The surface-drainage is connected by side-channels, constructed by and under the control of the various local bodies in the district. They are for the most part of concrete, and consequently watertight, although many in the outlying portions are merely cuts in the ground. These channels discharge into natural creeks, the River Avon, and into sewers specially provided for stormwater, which discharge into the Avon and Heathcote Rivers. It is much to be regretted that, while the primary object of these sewers was the carriage of stormwater only, they are in some cases rendered very foul owing to the nature of the contents of the side-channels; and this is a matter over which the Drainage Board has practically no control. The length of these sewers, which were constructed and are maintained by the Board, is 10 miles 15 chains, and the cost of construction £57,000. They vary in size from 4ft. 8in. to 12in. diameter.

In abnormal rainfalls, which are of somewhat rare occurrence, small low-lying portions of the district become flooded, but this is owing to the rise in the rivers, which prevents a free discharge from the sewers. On the cessation of the rain the water is quickly run off, so that it is not probable that the health of the district is thereby affected.

The system of sewers for the removal of sewage proper was designed by the late Mr. W. Clark, M.Inst.C.E., and has proved most successful. The separate system has been adopted —*i.e.*, rain-water, so far as possible, is excluded. This enables a very large percentage of the total length to be laid with sewers of small diameter. They are thus much more easily flushed, and there are not the same facilities for the generation of sewer-gas as in larger sewers. We think it is now generally admitted that, both from an economic and a sanitary point of view, the separate system is beyond question the most suitable.

The following table shows the different sizes of sewers, with their respective lengths :—

	Ml.	ch.
Concrete egg-shaped sewers with brick arch, varying in size from 1ft. 6in. by 2ft. 3in. to 3ft. 8in. by 4ft. 9in. ...	4	10
18in. diameter pipes	0	10
15in. "	2	47
12in. "	3	38
9in. "	25	22
Total length	35	47

Owing to the topographical features of the district it was found impossible (even had it been desirable) to obtain a natural outfall, so that pumping has had to be resorted to for the removal of the sewage to the irrigation farm.

The sewers vary in depth from 3ft. to 13ft. below the surface. The pipes are jointed with cement mortar, and are laid on concrete, which is brought half-way up the pipe. Manholes and ventilators are provided at frequent intervals. As a general rule, the gradients are so arranged as to obtain a velocity of 150ft. per minute. House-connections are laid with pipes of 4in. diameter, and soil-pipes of 3in. diameter.

The area served is about 2,800 acres in extent, and consists of the City of Christchurch and surrounding suburbs of Sydenham, St. Albans, Linwood, and a portion of the Heathcote, Riccarton, and Spreydon districts, with a population of, say, thirty-five thousand. There is ample margin, however, for a very large increase in the population without involving any extra outlay in the existing sewers or pumping-station.

The hours worked at the pumping-station for the year 1889 averaged 10·4 hours per diem, and the amount pumped per diem to 6,256 tons. Of this, a proportion of, say, 80 per cent. is subsoil-water, which, of course, will not materially increase for all time. From this it will be at once seen to what extent further connections can be made before extra power will be required.

The expenditure incurred for these sewers, machinery, buildings, tank, iron main to sand-hills, land, and contingencies was £127,000. In several localities the quicksands proved to be very troublesome, and special and costly provision had to be made to overcome the consequent dangers and difficulties. Had it not been for this fact, the cost would have been considerably less than as before stated.

Flushing is regularly and systematically attended to, the water being derived from artesian wells and collected in tanks, which are placed in the most suitable positions. The pipes are as clear and free from obstruction as when first laid. The system is well ventilated by openings in the centre of the streets, and very few, if any, complaints are made on account of smells at these ventilators.

That all-important portion of the scheme—house-connections and internal and external sanitary appliances—receives every care. The work is done by plumbers and pipelayers licensed by the Board for the purpose, and is subject to the inspection and approval of the Board's engineer. A code of sanitary rules and regulations for the guidance of licensees and the public, based on the most approved methods for work of this nature, has been in force for some years with the most satisfactory results, and licensees are bound by such rules and the conditions contained therein.

The whole of the sewers on the north side of the river are collected at a point on its northern bank, and passed through a cast-iron siphon under its bed. On the south side they are collected by the main intercepting sewers (which of course also take the northern sewage) and discharge into the tank at the pumping-station. During the night the main sewers do duty as reservoirs, for the sake of economy, but it is hoped that the Board will soon be in a more prosperous condition financially, when this system will give way to continuous pumping.

In addition to these sewers there is a length of 1 mile 26 chains of duplex sewers in the suburb of Richmond, which take both stormwater and liquid sewage: these discharge into the River Avon, about one mile below the city.

The total length of covered sewers under the Board's control is 47 miles 8 chains, and the number of houses connected to 31st December last was 1,291. As each house is connected a survey is made of the premises, showing the exact position of the service-pipe, siphons, junctions, &c. These details are plotted on block plans kept for the purpose, and all particulars are periodically entered up in the Connection Register.

The collecting-tank is 30ft. diameter by 21ft. deep. It is built of brick in cement, with a concrete invert, and was constructed under most unfavourable circumstances in a boiling quicksand. It is, however, of a most substantial character, and is not in the least likely to cause trouble by settlement or otherwise. From this tank the sewage is pumped.

The pumping plant consists of two compound surface-condensing horizontal engines, fitted with expansion-gear of forty-eight indicated horse-power each. They are run with a consumption of about 3lb. of coal per I.H.P. per hour. The pumps are four in number (two to each engine). They are double-acting, and of the usual type for sewage-pumping. Each pair is capable of throwing 3,500 gallons per minute. The boilers are three in number, of the usual Lancashire type, and fitted with Galloway tubes. It is usual to work only one engine and one boiler at a time. The working pressure is 50lb., and the vacuum generally stands at 27in. The cost of working, including coals, general stores, wages, and repairs, is, say, £730 per annum.

In times of excessive floods the sewage is sometimes pumped to the estuary direct, for the sake of economy. It is then, of course, largely diluted with subsoil-water and rainwater, which gets in through the ventilators and house-connections in low-lying localities.

The iron main to the sandhills is a mile and three quarters long, of 24in. diameter. It has been laid with turned and bored joints, which have never shown any sign of leakage. The mean lift is 30ft.

At the end of the rising main the sewage enters a wooden flume for a short distance, and thence goes into a settling-pond; thence along an open carrier, about a mile in length, and through a second settling-pond, before it is distributed in the branch carriers and applied to the land. A large quantity of sewage sludge, which proves injurious to the land by choking the pores, is caught in the settling-ponds. These are cleaned out periodically.

Having arrived at the farm, the sewage is distributed by carriers over seventeen paddocks laid down with English and Italian rye-grasses, and there treated by surface irrigation. The liquid has not only to pass over the surface, but must percolate through the land before it is caught by the effluent-water drains, through which it is discharged into the estuary. The area of land prepared for irrigation is at present only 36 acres, and consists of a very sandy loam. It has not been found necessary as yet to provide subsoil drains, owing to the extremely porous nature of the soil. The growth of grass is very prolific. Only two cuttings of hay are made each year, as it is found more profitable to feed cattle and dispose of them in the shape of beef.

None of the grass paddocks have as yet been ploughed since they were formed; but this may shortly be found necessary in some of those at first laid down, owing to a tendency to rankness in the grass and the presence of Yorkshire fog. They are formed level on their longitudinal section, and slope each way from the branch carrier, with a fall of 1 in 150. Each paddock contains about two acres.

The operations at the farm for the last year show a profit of £54 5s. 8d., and it is expected that better results will be obtained when the supply of sewage increases, and more land is prepared for treatment.

Of all modes of disposing of sewage in a healthy and profitable manner, none can compare with filtration through and irrigation over the land. As each year passes the tendency seems more and more to favour this method. It is only necessary to refer to the recent Sanitary Congress at Brighton, and the able paper on the purifying qualities of the earth, read at it by Dr. Vivian Poore, to be convinced of this fact.

Charges have been made against sewage farms as being injurious to health; but when the sewage is delivered in moderate quantities, and before important putrefactive changes have occurred, no danger need be feared. The milk and butter from cows fed on sewage-raised food compare favourably with other samples, while vegetables grown on sewage farms are of excellent quality. When the members of the Association visit our farm they will see for themselves that cattle thrive amazingly on the grass raised by sewage off common sandhills. These sandhills, which were perfectly worthless, will in time produce large quantities of excellent crops, although at present it cannot be contended that the filtration is as effectively performed as would be the case in good mould.

The following analysis, made for us at the Colonial Laboratory, Wellington, by Mr. Skey, shows that in the passage of the sewage through the sand a certain amount of ammonia has escaped conversion, which would not have happened in better land:—

Analysis.

1. Sewage.—Colourless and turbid, with the odour of putrefaction.

2. Effluent water after No. 1 had been passed through the paddocks, and as discharged into the estuary.

The following results were obtained upon them as computed in grains per gallon:—

	No. 1.	No. 2.
Ammonia	0·16	0·02
Organic matter*	10·21	4·21
Mineral salts†	10·81	10·12
	21·18	14·35

* No. 1 containing nitrogen 0·51gr.; No. 2, 0·16gr.

† No. 1 contains 0·21gr. of phosphoric acid and 0·76gr. of potash; No. 2 contains traces of this acid only, and 0·31gr. of potash.

The precise nature of the rest of the mineral substances in these waters has not been determined, but as far as was shown by qualitative analysis they appeared to consist in each case mainly of alkaline chlorides and sulphates.

These results show that the sewage has been very largely deprived of its more valuable constituents, and that the soil through which it has been passed has gained those substances that were most deficient in it, after having been exhausted by cropping.

In conclusion, we can unhesitatingly assert that the sewage system has so far been an unqualified success. Its benefits are directly felt owing to the large amount of sewage which is daily removed from the district, and indirectly from the lowering of the level of saturation, which has conduced so largely to the health of the people. As houses are more freely connected with the sewers, so will the direct benefit be more appreciated and felt, and we can only express the hope that the ratepayers at large will be sensible of this fact.

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3. *On the Registration of Disease.*

By Isaiah de Zouche, M.D.

The object of this paper was to urge the official registration of disease, both on scientific and practical grounds, and the value of a State record of disease as regards its prevention was pointed out. The medical officers of health should be notified of the outbreak of any disease, with all the surrounding circumstances,—locality, temperature, rainfall, sewage, ventilation,—and these records would then be of value in dealing with subsequent epidemics. Notification should be made in the first place to the medical officer of health, so that preventive measures might be taken. The difficulty of stamping out was acknowledged; but at least isolation and disinfection could be practised, and public attention called to the presence of infectious disease by registration and publication. The author referred to the ignorance of the public as regards the danger (to others) of "mild" typhoid and "mild" scarlatina; to the importance of inquiry as to the origin of each case of disease; and to the question of compensation for loss of business through registration of any house in which zymotic disease occurs. He said that zymotic diseases may be exterminated, and recommended the registration of architects and builders, and showed the desirability of their being qualified in hygiene. The author spoke at length on the unwisdom of allowing unqualified persons to treat cases of zymotic disease; on the possible spread of disease owing to their ignorance of hygiene; the results which would ensue from registration of disease; the Improvement of Houses Acts; the periodical official inspection of houses, public buildings, &c.; and the registration of diseases non-zymotic. He gave an account of what has already been done as to registration and stamping out disease, and referred to the law of Holland, British legislation, the Public Health Act, the Local Improvement Acts, and the Prevention of Diseases Act. He drew attention to the fact that, owing to improved sanitary measures, there had been a decline of 45 per cent. in mortality from typhoid during the last ten years; and mentioned the defects of the Public Health Act of New Zealand owing to its permissive character, and to the non-appointment of medical officers of health. Scientific questions which could be settled by the registration of disease—the change of type of disease, &c.—were also dealt with.

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4. *On the Sanitary Defence of New Zealand.*

By W. E. Hacon, L.R.C.P. Lond.

The author points out that the present Health Act is inoperative, and that many more medical officers of health require to be appointed. Further, that these medical officers, instead of being under the control of public bodies, should be under the direct control of a Minister of Public Health. The institution of a well-organized society for the discussion and publication of information bearing upon national health would also be of equal service, especially if at the same time instruction in physiology and the laws of health were made a recognised department of the educational system of the country.

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5. *Demography of South Australia.*

By Thomas Borthwick, M.B. Edin.

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6. *On the Sewerage Question, and the Desirability of introducing the Pneumatic System invented by Captain Liernur.*

By Benjamin Backhouse, H.A.R.I.B.A., Chairman of the the City of Sydney Improvement Board.

Though to some the subject of this paper may appear unsavoury and uninteresting, thoughtful people, we are persuaded, will gladly learn how dirt can literally be blown out of every house, unnoticed by the inmates, and be conveyed to the country in such a form that agriculturists shall eagerly compete for the possession of it. We are evidently on the point of arriving at the conclusion that waterclosets and sewer-drainage are too costly and too dangerous to be longer tolerated.

The cost of such a system in cities like London, Liverpool, and Glasgow, is enormous; and, after it has been incurred, we are forced to acknowledge that the objects which should be arrived at by a rational system of drainage have not been attained. Medical science teaches that human excreta should not be permitted to accumulate in the vicinity of our houses, or be so disposed of as to pollute the atmosphere or destroy the amenity of our coasts or rivers. What we do is this: We construct cesspools close to our dwellings, and fill them with the most dangerous impurities; we intersect our streets with sewers, which generate noxious gases; we saturate our rivers with filth, so that they are fishless and their waters undrinkable; and now, when air, earth, and water have been rendered pestiferous, we are at our wits' end, and see no escape from our position of growing jeopardy. We cannot cleanse our drains by the more abundant use of water without incurring intolerable expenditure. For instance, the remedy for the offensiveness of the London sewers is said to be an additional daily supply of 42,000,000 gallons of water, costing £383,250 a year; whereas the existing water companies can only supply 5,000,000 gallons per day. This was the state of things many years ago, and it must be infinitely worse now. The costliness of the water system is thus strikingly put by Captain Liernur: "The average amount of water used per day per individual is 4 cubic feet, or, say, 250lb., while his fæcal products weigh but 2lb.; so that the water-carriage men, in order to move handily 1lb., add 125lb. to it. Strange engineering this!"

Besides all this, we are now being forced to the conclusion that our expensive and dangerous mode of dealing with sewage is an absurd plan for throwing away matter the preservation of which is essential to the productiveness of agriculture. While so treating it as to convert it into a prolific source of disease we have been practising what Liebig calls "robbery culture." And, in order to give back to the soil that which it needs, we are annually expending incredible sums in the purchase of bone, guano, and artificial manures.

I desire to bring under notice one or two opinions of only a few men of some note who have made exhaustive studies of the whole question. T. Hawksley, C.E., of Great George Street, Westminster, writing in favour of the Liernur system, but referring more particularly at the time to the general scheme of sewerage as conducted in the United Kingdom, says: "We have gone incurably mad on the water-carriage system, to the exclusion not only of all other systems, but even of all ideas with respect to them. In sanitary matters we have become so packed with false doctrines that what ought to be countervailing facts cannot be got into them."

[The remainder of the paper gives extracts from the opinions of other eminent men, and their conclusions are in favour of the Liernur system.]

Section I.

(*LITERATURE AND FINE ARTS.*)

President of the Section—R. H. Roe, M.A., Brisbane.

ADDRESS BY THE PRESIDENT.

It is with much diffidence that I enter on the duties of the office to which the Council of the Association, wishing to pay a compliment to my colony, have graciously appointed me, and this diffidence springs not only from my previous inexperience of such gatherings as the present, but also from the feeling that a sixteen years' sojourn away from the centres of productive activity in literature and art is likely to render me an unfitting exponent of the most prominent ideas now current in these departments of human knowledge.

I shall not presume, then, to attempt a survey of Australasian art or Australasian literature, appropriate as such a subject would be in the hands of a chairman fully conversant with either, but, realising that a man is most likely to have something worth saying in connection with the problems with which he has been brought face to face in his daily work during the best years of his life, I shall take advantage of my position to-day to ventilate my views as to the place which literature ought to occupy in modern education.

The subject is not new, but is one upon which all of us, teachers and the general public alike, ought to hold definite views unbiassed by the prejudices of early training or present surroundings.

Education ought to have two main aims—the development of all our powers of body, mind, and soul, and the supplying of facts and accomplishments which may be useful for the battle of life or for the full enjoyment of its leisure-hours.

Personally, I feel that the most serious responsibility of education is the development of character; for it is character that moulds the shape of our after-lives, making them deformed or fair to look upon, and it is to character therefore that all education should pay the first and highest attention. Now, a master's greatest power over his pupils' character lies probably in his own personality. His own example, his power of making them look at right and wrong with proper enthusiasm or scorn, are as powerful factors in the growth of their characters as are rain and sunshine to the plant. But he must have tools to work the ground, and, of all tools, the best in my judgment is literature. In it you are dealing with moral ideas—that is, with ideas which show the motives and consequences of men's actions, ideas which help to render our sympathies more tender, to open our eyes to the great life-problems of the past and present, and to give us examples and principles of conduct which may serve as chart and compass through the troublesome seas of our own life's voyage.

I do not wish to depreciate unnecessarily the other subjects which with bewildering multiplicity claim admission into our schools. We are expected nowadays, while knowledge is advancing and accumulating its riches in a manner even more marvellous than the accumulation of capital in civilised countries, to turn out our pupils as completely versed in the sum total of human knowledge as in the days when classics were the only literature, and arithmetic and Euclid the only mathematics. Yet examinations tend more and more to give their best prizes to specialists, to those who, neglecting the rudiments of a good general education, have made themselves masters in some branch of knowledge, however unfitted this branch may be by itself for the full development of our moral and intellectual powers. So that we have now to beware of two dangers—the danger, on the one hand, of intròducing too many subjects, and so causing either superficiality or overstrain from the attempt to cover too much ground; and, on the other hand, the danger of spoiling a boy's education and robbing him of knowledge which no one ought to be without, in order that he may, by specialising, gain some university scholarship or prize. The awarding of entrance scholarships at the university for proficiency in one subject only drives schools to specialisation; whereas school education should be kept as far as possible general, and specialisation should begin at the university.

You cannot educate a human soul on mathematics only. Their great defect, to my mind, as a predominent element in education, is that they contain no moral ideas; they do not touch character except indirectly by teaching perseverance and exactness. Yet this is not their only shortcoming: they give no vocabulary, no power of expression; words are reduced to a minimum; the process of argument is made as mechanical as possible, symbols being used for ideas; and the whole mental exercise is as free from humanising influences as is half an hour's exercise with dumb-bells. Nor are they perfect as instruments of reasoning, since they accustom men to deal only with certainties, whereas life's problems consist of probabilities and experiences. Socrates, in "The Republic," says to Glaucon, "In all my experience I have hardly ever known a mathematician who could reason." He had not the advantage of knowing the eminent mathematicians of this century, or he would probably have expressed himself in less general terms; but, still, his meaning is clear. Mathematics can only deal effectively with absolute truth and limited conditions; they do not give the power of balancing arguments, or analysing ideas, or dealing with problems which proceed from complex premisses; they produce a narrow and positive frame of mind, which, when confronted with the difficulties of social, political, or theological problems, falls back in despair on earthly prejudices.

Science has, in my opinion, a higher value than mathematics in school education. It is more literary; it deals with the phenomena of nature around us, and gives us an intelligent interest in the wonders of the universe; it teaches the habit of observation and experiment, and impresses on us all a belief in the reign of Law, through the lowest as well as the highest works of creation. Science-teaching at schools should not be made mere memory-work—the learning by heart of lists of orders, and atomic weights and chemical formulæ,—nor mere mathematical work, as it often is in physics; but it should be kept as literary and practical as possible; it should train the mind to watch for and explain clearly causes and effects, instead of merely tabulating results; it should deal with the simpler phenomena rather than with the more complex, for only a specialist can follow the reasoning in the higher problems. At school, we should be content to teach the elements of many sciences—that is to say, the outlines of chemistry, physics, botany, physiology, geology, and astronomy: there we can teach "something about everything" in science, and later on the "everything of something" can be learnt, when the pupil has discovered which branch is most attractive to him. The main defect of science as the dominant element of education lies in this: that, while it deals with the past of the physical world, and shows us what has happened to the stones and elements, it tells us but little of what has happened to man, and nothing of what has been done by individual men. It therefore lacks what I have called humanising power; it does not make the heart more tender and sympathetic, nor the soul more strong by contact with the souls of the best and noblest that have lived, as does literature; it does not help us in the political and social problems of the day, by showing the rise and fall of nations in the past; it does not fill us with hope and confidence for the future, by unfolding the moral and spiritual growth of mankind through the ages of history. Literature alone does this, and therefore on account of its character-forming power, *because* it purifies and strengthens the emotions, *because* it gives us the highest motives for right action and the rules for life, it ought, in my judgment, to be the main foundation of any educational system. Literature, no doubt, has other claims for admission into that system, as giving facility, elegance, and accuracy in the expression of thought; but it is by reason of its influence on character that I would assign it a supremacy over all other subjects.

The next question is, What literature? Fifty years ago the answer, without hesitation, would have been, Latin and Greek; now probably it would be, Latin, Greek, German, French, and English. Fifty years hence I believe it will be, English and French or German. I have no wish to disparage the classics. No one who honestly considers what Greek and Latin thought have done and are still doing for the education of the world can speak of the classics with anything but gratitude and respect; but we cannot fail to realise that even amongst the most conservative champions of classical education, even in the centres where classics and classics only have been the most cherished tradition, opinion has been much modified of late as to their suitability to meet our present needs. If the new knowledge that the world has been gathering since the Renascence in literature, in natural and social science, and in mathematics is to be admitted to a reasonable share in our education, either classics must go altogether or the time given to them must be materially reduced. Can we teach the classics effectually with two or three hours a week for them in the time-table? Undoubtedly, no. Such a restriction of time would make the study of them worse than useless. Some wish to throw overboard Greek and retain Latin; but nearly all the classical literature worth keeping is Greek, and nearly all our scientific terms, whose meaning is not plain to us from kindred words in our own tongue, are Greek. Latin is no doubt the key to the Romance languages, a point I will speak of more fully hereafter, but any other arguments which can be advanced for or against Latin apply equally to Greek, and the two, in my opinion, must stand or fall together; and, if they are read at all, they must be read accurately. Much as grammars and methods have improved of late years it would be impossible to attain a precise knowledge of the accidence and syntax and a wide acquaintance with the literature of Latin and Greek with a few hours' work per week. Such study would only result in slipshod work, destructive of all mental accuracy. At present this defect, at any rate, cannot be laid to the charge of classical study. Therefore I maintain boldly that either the study of the classics ought to be maintained in its full supremacy as at present, or it should be abandoned altogether; and I believe that the time is not far distant when the latter alternative will be insisted upon, when it will be joyfully accepted even by those who cling tenaciously to the old system from the recollection that the only literature teaching which they have received, all the love they may have for poetry and noble thoughts, came to them through the old classics.

What should we lose by giving up classics? It is worth while to look carefully into this question. The teaching of classics as at present pursued has, it is maintained, a high linguistic value; and in good hands, when they are treated as history and as literature, they become the best instrument that we have for training both the imagination and the character.

Let us consider the linguistic value first. It is urged that they teach us the rules of syntax as no analytic languages can teach us; that they show us the true meaning, through derivation, of the vocabulary that we use; that Latin, at all events, is the best foundation for the study of most modern languages, and that the masterpieces of the ancients are literary models for elegance of expression more perfect than the world has since produced. Now, on these points I confess that, before English grammar was started as a distinct subject, any ideas which men had in syntax came from their classical training; but I believe also that much of the confusion that now reigns in English grammar arises from the attempt to force into classical moulds, and tabulate under classical headings, the methods of expression current in an analytical language like our own.

The subtleties of the subjunctive in Latin, and of subordinate moods and negatives in Greek, even the eccentricities of accents (though the Greeks themselves did not use them), are excellent material for teaching mental accuracy; but I am one of those who feel deeply grateful to our forefathers for abolishing genders from English, for reducing inflexions to a minimum, and for practically getting rid of the subjunctive altogether. It is this sensible simplicity in its syntax and accidence which to my mind forms the great strength of the claim of English to become the universal language of the future; and surely it is unprofitable to spend our time in mastering the refinements of the ancients on these distinctions, when English itself shows how well thought can be expressed without any of them. We should aim at simplicity of thought and ease of expression, and, without being pedants, should try to make grammatical usage and logical accuracy agree in our structure of sentences; whereas in the study of the classics any inaccuracy in the laws of thought like the Attic attraction of the relative is highly commended as an idiom, and we actually imitate the grammatical blunders of classical authors provided that they occur often enough to constitute an idiomatic usage.

If we want merely to teach clearness and precision of thought we ought rather to go direct to the study of the laws of thought and inference as taught in logic. I am afraid schoolmasters are not without blame in this matter; we have been trained to teach Greek and Latin grammar in a certain way, and we find it easiest to go on in the same groove. Boys and girls, my experience tells me (strange as the statement may seem), like to learn by heart in preference to being made to think; and the learning of the lists of gender rules and the syntax is not altogether distasteful to the majority. Undoubtedly there is no lesson so easy for an ordinary schoolmaster as the old-fashioned grammar and construing lesson—none that requires less originality and less preparation; and therefore our prejudices are all in favour of the retention of this method of teaching. Personally, I believe in the study of the thought rather than of the rules for the expression of the thought; and, though I know it is a question how far young minds can grasp the full meaning of beautiful thoughts in language, still we ought to remember that the ancients themselves knew little of grammar rules; they read their Homer for the sake of the story and the poetry; they learnt accuracy of syntax from constant usage rather than from conscious application of rule: and I believe that we are too much inclined to spend our time in teaching how to express thought before we furnish our young minds with thoughts to express; we pay too much attention to grammar and analysis, instead of realising that the best means of attaining accuracy of expression in our own language is constant practice in the use of it.

Again, in the matter of vocabulary, Latin and Greek are the key to the scientific terms of all Aryan languages, not of English only; and a knowledge of classics no doubt helps to save us from slight inaccuracies in the employment of words, as well as from their gross misuse after the manner of Mrs. Malaprop. Still, though we may know something more about a word if we can trace its derivation, we do not therefore understand its present meaning better. We assign, for instance, just as definite a meaning to the word "sleep" as we do to "somnolence," even though the derivation of "sleep" may be unknown to us, while we can trace "somnolence" back through Latin, Greek, and possibly Sanskrit. It is undeniable that too close an adherence to the etymology will often lead us astray in the pronunciation of words like "theatre," "orator," "senator," "relative," "ablative;" and in the meaning of others like "security," "indifferent," "censure," which have drifted away from their original force. It is certainly desirable to know the historical development of the present meaning of the words we use.

If Latin and Greek were taken from us we could still use a majority of the beautiful lessons in etymology contained in a book like Trench's "Study of Words;" but, after all, the main point for us is to have a precise conception of the present force of our words, and I fancy this would be obtained by constant practice in comparison of each word with its nearest synonyms quite as fully and much less laboriously than by the present system of classical derivation. Many of our greatest masters in prose and verse, whose use of our tongue is unrivalled for richness and purity of vocabulary, have had, like Shakespeare, but little acquaintance with the classics; and certainly the diction of many whom we venerate—Milton, Dryden, Johnson, Gray—has been (I say it with all humility) marred and encumbered by the overloading burden of obscure mythological allusions and classic conceits. We want precision in our use of words, but freedom from all conventionality and from slavish imitation.

Next, considering the classics as the key to other languages, we must acknowledge the utility of Latin more especially for this purpose; but how very few ever use this key to effect an entrance into any language but French, and how many neglect, even when learning French, to find out the commonest truths that Latin teaches them about that language! I certainly should not advocate the addition of Spanish and Italian to the burdens of the modern schoolboy—there is no literature in either that would justify the labour; and to insist on Latin for the sake of understanding French is about as reasonable as to begin with Sanskrit in order to understand Latin. Latin no doubt gives a fuller knowledge both of French and English, but it is by no means necessary for either, and the labour involved in the acquisition of Latin could be more profitably expended elsewhere.

That one language besides our own is desirable will, I think, be generally acknowledged. A foreign language opens the eye of the mind, suggests comparisons, and shakes off prejudices very much after the manner that foreign travel affects us for our good. German has certainly the richest literature, and German, as the parent of our own tongue, would probably be considered by most to have the greater claim, though many would still stand by French because of its importance in European intercourse. To us in the colonies both French and German have mainly a literary value. The number of those who would use either of them for the purposes of travel or trade correspondence is so small that it would not be justifiable to introduce the study of either of them into our schools on these counts. We study them for the sake of their literature, for exercise of our linguistic faculties, and for comparative grammar. They are to be preferred to the classics, first, because they are living languages, dealing with the thoughts which stir the world now; and, secondly, because they do not demand for their mastery anything like so large a portion of our available time.

But to return to the classics: Let us consider them lastly with reference to their subject-matter. Let it be granted that we use the study of them in the best way—that is, not only as an exercise-ground in grammatical subtlety or in etymology, but as an introduction to the best specimens of good literary style; that we gather from them the life and manners of the two races to whom modern Europe owes its present intellectual and political development; that we trace in them the working of the principles, political, social, and moral, which face us in the difficulties of modern life: the question remains whether we could not get all these lessons without the laborious entrance into the languages which prevents any but the most gifted from ever getting beyond the grammar stage. The value of the study of the subject-matter of the classics is beyond dispute. The perfect symmetry and simplicity of the Greek drama is unrivalled. The boldness of outline with which the virtues and the vices of the Greek and Roman heroes are depicted by the historians makes ancient history as unique for character-lessons as are the models which Greek sculpture has left us for lessons in art. The eloquence and patriotism of Demosthenes, the noble idealism of Plato's dialogues, cannot be taken without serious loss from any system of a liberal education. Yet I believe that all present advantages could be secured by treating these authors as part of English literature, and reading them in good translations. No one has grasped the main features of Roman character better than Shakespeare, who had only inferior translations to draw upon. No one has formed a more accurate conception than he of the feelings which the rise of Cæsar created in the hearts of the old Roman aristocracy.

I think the time has come when the best scholars of our day might be authorised by the universities to produce a standard English version of all the classics, with the same care as our forefathers translated the Bible. Our Bible is in no way inferior to the original; and, though probably the masterpieces of ancient thought would not so readily pass into our tongue, still works like Jowett's Plato and Browning's translations of the "Alcestis" have shown us what even individuals can accomplish. Now is the time to make a combined attempt, while scholarship and criticism are in their prime, and translation, combining accuracy and grace, has reached an unprecedented excellence. I am certain that a large majority of boys, and of university students too, would form a better conception of the grandeur and beauty of Greek tragedy, and a better knowledge of all that is worth learning about the thought and life of the Greeks and Romans, by reading the best poets, philosophers, and historians quickly in good translations than they now can do by the piecemeal study of single plays and historical extracts.

The classics have done noble work in the past in dispelling the intellectual darkness of the Middle Ages, in kindling again the fires of imagination, and in giving birth to the critical and historical faculties which have grown to manhood under their care since the Renascence. But it is time now to give the signal for a general advance. I think our age may yet hope to be regarded as the age of a second Renascence, in which men, bursting the shackles of the past, will joyfully enter into fellowship with the new learning which now stands claiming admission. Formerly the world awakening from its long sleep rushed eagerly into the new knowledge, casting aside somewhat rudely and scornfully the barren disputations of the Schoolmen. The hair-splitting problems over which men had wrangled for centuries were by no means solved; they were simply put aside as being of inferior interest and unprofitable. Printing had then thrown upon the western world the new wealth of ancient literature; the habit of foreign travel, whether from desire of knowledge, or of gain, or adventure, set men thinking, and made them progressive not only in their manners and customs, but in their thoughts and literature.

Our own age is probably the most progressive that the world has seen. The inventions of science have introduced into the progress of thought the same rapidity of onward movement as is to be found in the progress of our material comforts. Men travel abroad as they have travelled in no previous age; the best literature of all countries is circulated at a price which is within the reach of all students, and public libraries offer it gratis to those unable or unwilling to buy. New discoveries and theories are flashed by telegraph from one side of the world to the other, instead of creeping at snail's pace from country to country in the course of centuries. A master mind like Lord Bacon, a century after Copernicus, only alludes to the new theory of the earth's motion round the sun in order to treat it with scorn, and the majority of Englishmen of his time had probably never heard of it, while in our day discoveries of Professor Koch are in every man's mouth in Australia before he has published the details of them in Berlin. A little book like Bellamy's "Looking Backward," published in America, within a year furnishes subject for discussion in every house and debating club in Australia. A vast conception like Darwin's, incapable of absolute demonstration, triumphs over prejudices, and in a generation becomes the working hypothesis of all the rising devotees of science.

Nor have we stood still in education. Every year sees the introduction of new subjects, improvement in the method of teaching the old, new editions and new books in all branches of school work. Yet I have slowly come to the conviction that the greatest advance of all has still to be made—namely, the dropping of those languages whose grammar consumes a disproportionate amount of our school-time, and whose literature, beautiful as it is, does not deserve to engross our attention as it has hitherto done. Huxley, in his "Lay Sermons," complains that we teach the young to think that everything which is of importance in the world happened some two thousand years ago; and certainly we have neglected and do neglect unwarrantably the literature and history of our own country. If I were asked what lesson in the whole school course, in my experience, did most good in stimulating the intelligence of a class, I should say, Undoubtedly the Shakespeare lesson. Boys are there dealing with sentences which often require much thought for comprehension, but which, being in their own tongue, can be understood without that constant use of dictionary which bewilders and disheartens a beginner in Æschylus. They feel, too, that Shakespeare is real; that he looks at life's problems as we look at them, and has something to teach us about them all, since he paints every variety of human passion; they realise alike the majesty of his tragedy and the humour of his comedy, and recognise the unrivalled vigour and appropriateness of his diction.

We ought, then, to use our Shakespeare much more freely than we do, and to turn out our boys as conversant with the details of all his plays as are the best boys of an English public school now with their Sophocles or Æschylus. Compared with Shakespeare, Greek tragedy is poverty-stricken in its subject-matter, dealing as it does only with a few heroic legends, and wearisome in its iteration of the doctrines about Nemesis and the resistless power of fate, neither of which is of any value to us except as an historic curiosity.

Nor would I confine English literature to Shakespeare. A careful study of some of our best lyrics, such as Shelley's Ode to a Skylark, would, I believe, teach a class more of the melody of verse, more of the power of metaphor, more of the transcendent flights of the highest poetic thought, than any Greek chorus or Latin ode that has been written. In prose, for teaching beauty of style and richness of illustration, no author can surpass Macaulay; for teaching conciseness, nothing could be much better than Bacon's Essays. For literature, then, let us have as much as we can of our own tongue, and, in order to retain the best of the ancients, let us make them pass into our own language by adoption, that is, by scholarly translation.

I know that I am laying myself open to the retort, Why have you not begun in your own school if these are your views? My answer is, Schoolmasters are powerless until the reform has begun at the universities. So long as the classics have the lion's share of the honours and prizes at the universities, so long as the classics are necessary for matriculation, for degrees, for admission to the law and all the learned professions, so long must they remain the chief work of the schools. Any school neglecting them would lose rank and sink into obscurity. The schools have done what they can by the introduction of a modern side, in which no classics are taught; but whilst all the best boys, looking forward to the universities and professions, are driven perforce into the classical side, the modern side is encumbered with backward boys, and cannot be taken as a fair sample of what the extended study of English literature would do in our schools. Let the universities give to English a fair trial; let them award to English literature the same prizes and scholarships, in value and number, as they do now to Latin and Greek; let them allow English language and literature to be done as an alternative for the classics in any university examination; and I have no doubt whatever of the final result. We should soon have the majority of our boys and girls trained, as were the ancients, in the best writings of their own tongue, conversant with the best thoughts that have moved the world in the past, and not absolutely ignorant, as they too often are now, of the great problems which face us in our life's journey to-day. We should have a far larger proportion of them who on leaving school would prize literature as the treasure-house of the world's knowledge, who would turn to her for comfort in time of trouble and despondency, who would love her as the friend to hold converse with in leisure-hours, would honour her as the ever-present artist that interprets to us alike the beauties and the secrets of nature, and would reverence her as the prophet and priest that fills our souls with noble ideals and high aspirations. It can hardly be claimed that our present system produces this effect. Any love of literature that we may possess is not the result of our school training: it is an aftergrowth which has sprung up in spite of early neglect. We see now everywhere in the numerous societies for home-reading which have been started in all English-speaking communities a growing sense of the value of our literature, and also a protest against our present system of education, which feeds us during the most acquisitive years of our lives, when the memory is freshest and the heart warmest, not upon the true fruits of the tree of knowledge, but upon the husks of obsolete declensions and the dry straws of grammar. I confess that a sense of shame often comes over me, when young souls eager to learn are asking as it were for bread, and I feel that I am giving them but a stone.

I know that literature is not all that is needed in education, though I maintain it should be the main element because of the riches which it contains, because of its all-powerful influence in teaching the expression of ideas and in forming character. If we drop the burden of the dead languages we shall be free to move; so long as we keep them we are in danger of breaking our backs with too heavy a load if we add much else. Freed from the dead languages we should have time not only for more literature, but for more science and art; and we could then hope that these subjects would be taught and learnt in the right spirit; that science would be learnt not as a catalogue of tables and classifications, but as the philosophic interpretation of the mysteries of the universe and of the physical conditions of life; and that art would be studied with leisure and love, as being the poetry of form and colour, which presents to us the ideal, the beautiful, and the sublime, where words fail us and the mind is moved through the eye and through the heart.

Many points have been discussed in this address; perhaps a brief restatement of my main contention will make it clearer. A truly liberal education is what we want to frame: one which shall give real culture to all who will go through its course, instead of cultivating only a few, as does the present system; one which shall prove attractive to the majority of our pupils, instead of burdensome and repulsive because it deals mainly with barren knowledge. In such a system, as I have tried to point out, Modern Literature should hold the chief place, though Science and Art should have far more cultivation than they can get at present; and such a system cannot be formed merely by adding new subjects, one after the other, to the old; we can only escape from confusion on the one side, and stagnation on the other, by letting go the burden of the dead languages. It is the universities who must lead the reform, and it is to them that we must appeal for help. They are too apt to consider themselves simply as the depositories of the old learning, and that the maintenance of this is their sacred charge. The outside world, however, demands that they should be the centres of light from which the illumination of the age radiates. It is for them to open the way for reform by allowing Modern Literature to serve invariably as a substitute for the classics, and by turning out men rich in the knowledge of modern writings. At present few university men can teach well except on the old lines. Modern Literature will then only need its fair proportion of prizes and scholarships to enable it to compete successfully with the classics. Nowadays there can be no fair contest, for classics have, so to speak, all the arms and ammunition. Most of those engaged in teaching feel that reform is needed; that our modern education is becoming more and more burdensome, and in some respects even less effective than the old; and we look to the universities to move forward with the times, and to be not the drag upon the chariot-wheels of progress, but our guide and leader in the march against ignorance and blind tradition.

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1. *National Art as applied to the Colony.*

By Kenneth Watkins.

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2. *The Horse in connection with Art.*

By J. Thistlethwaite.

Section J.

(ARCHITECTURE AND ENGINEERING.)

President of the Section—John Sulman, F.R.I.B.A.

ADDRESS BY THE PRESIDENT.

The Architecture of Towns.

Every one has heard of Nuremberg—that quaint old German city, famed in art and song—and may possess some vague idea that it is one of the many picturesque survivals of the Middle Ages in which the Fatherland is so rich. But, as a matter of fact, it is perhaps in western Europe the most perfect example yet remaining to us of a mediæval town, and as such presents a striking contrast to the cities of to-day. Imagine, then, a narrow, swiftly-flowing river passing through the midst, bridge-spanned, and even house-covered in parts. On either hand pile up the houses in apparently the wildest confusion, with no one dwelling like its neighbour, but each as varied in design and picturesque in outline as the fancy can depict. The streets, with a few notable exceptions, are winding and narrow, and only relieved by occasional large open spaces, near which tower up the churches and other public buildings. And then surround the whole by the original wall, with its bastions and gate-towers, gateways and portcullises, posterns and ditch, and you have a faint idea of what Nuremberg is like. A walk through its streets, notwithstanding the tide of modern life in full flow, carries one irresistibly back to the past, and it is easy to people them with the sturdy burghers in doublet and hose, the strings of packhorses arriving and departing laden with goods, and all the busy hum of outdoor life. Then, every citizen carried on his business in the lower floors of his own house, and stored his goods in the high-pitched and dormer-lighted roofs, of which so many still remain, with their projecting beams and pulleys. Little space was wasted, for land within the walls in the city's palmy days was valuable; and so we find odd corners utilised, narrow lanes spanned, and every house with its projecting turret or oriel, to gain some space within or afford a better outlook. Of building regulations as we know them there appear to have been none, and every man did what seemed right in his own eyes; with a result that one cannot but admire, but which it would be unwise to imitate. Though the sense of vision is still charmed by the relics of the past, the odours of the roughly-cobbled or unpaved street, with its central gutter (the only drain), need not be recalled. Fortunately for the visitor and inhabitant alike, they have been replaced by well-paved roadways and modern sewers, but not before they had taken toll century by century of thousands of valuable lives prematurely cut off by the scourge of ever-present disease and periodical epidemics.

Such is Nuremberg the ancient, and such was the type of city prevalent all over northern and western Europe prior to the Reformation. With the Renaissance came a great change in architectural treatment; but the widening and straightening of city streets, and the general improvement of the conditions of healthy life, was a work of time, in which even yet in many quarters little progress has been made. But the modern spirit is permeating even the most backward communities, and it is as impossible to return to the condition of the Nuremberg of the past as to turn back the tide, or stop the earth in her course.

In the old cities of Europe congested quarters are being opened up, narrow winding ways made straight, and sun and light are beginning to penetrate even the most unwholesome of the slums. At the best it is, however, a work of palliation, and not of reconstruction. To new countries alone, like Australia and America, is it permitted to form their own surroundings, and embody therein the knowledge we now possess. Of air and space in our streets we in Australasia lack but little; but its better disposal was the theme of my paper last year on "The Laying-out of Towns." In that I advocated a new mode of planning, based on the spider's web, and incidentally pointed out the opportunities thereby afforded for grouping, variety, and picturesqueness in the architecture of the buildings, and on these points I now propose somewhat to enlarge.

But before doing so it is well to recall the conditions and limitations, approved by experience, to which the architecture of a modern city must conform, and thus prevent a useless chase after a mere will-o'-the-wisp, such as some writers have advocated in seeking to revive the haphazard picturesqueness of a mediæval city. And in the first place the wide and straight streets of modern towns demand the regulation of frontage-lines; and little by little old encroachments are being pared away, and a uniform line of frontage enforced, to the benefit, no doubt, of the general community, but to the detriment of individual expression in the buildings. Then, owing to the abnormal values city properties have attained in the central portions, a tendency to excessive height has of late years become a marked feature, rendering a limitation in this direction also advisable for the public good. What it should be will depend on various circumstances, such as climate, width of street, density of population, character of water-supply, and liability to spread of fire. In Paris it has been fixed for private buildings at seven stories, or 65ft. 6in., in streets of that width, with a less height for streets of less width. Above this height (which is that of the front wall), the roofs may be raised to any point within a semicircle having half the width of the street, or not more than 27ft. 6in., for its radius. The working of this rigid rule is very evident in the architecture of the city, for, the height being moderate, every foot of space within the permitted lines is utilised, and great sameness and uniformity is the result. In London the new County Council Bill proposes a limit of 90ft. to the parapet, with permissive regulations as to gables and roofs; and this, if passed, gives ample height for ordinary purposes, without meddlesome restriction of terminal features.

Special regulations against the spread of fire are, of course, necessary, but these are not of such a character (except in prohibiting wooden buildings) as to much affect external architectural treatment. The great safeguard is the limitation of the size of blocks of closely-packed buildings, and their subdivision by wide open streets. Where such dangerous blocks exist it is the duty of the city authorities to resume sufficient property to form a new street or streets, and compensate the owners at the general expense. Such subdivision is a gain not only in safety, but in health, convenience, and architectural effect. A striking example in point is the proposed continuation of Post Office Street, Sydney, which may now be regarded as an accomplished fact. But for the late disastrous fire it would most probably never have been seriously considered.

There is, however, another class of regulations, dealing in the most minute way with the architectural features of a building, against which I would enter my earnest protest. Every projection is limited, window-frames must be fixed in an allotted position, and generally the designers' hands are so tied that he has no freedom of treatment, and is condemned to the monotony of a flat front. The London Building Act is the parent of these vexatious restrictions, which have been copied into those of many a colonial city. Their absurdity has, however, become so patent that of late years it has been quite the custom in London to apply to the Superintending Architect for a special exemption, and to obtain it almost as a matter of course. I wish that our local authorities would do likewise;

or, better still, abrogate these clauses, and, in lieu thereof, make one or two simple rules such as the following: No projection from the face of a building abutting on a public way of not less than 66ft. in width to exceed, say, 4ft.; such projection not to commence within a height of 12ft. from the pavement. Every projection to be included within an angle of 45° in plan drawn from the centre of the party-wall. The former would give all the liberty required, and, if, owing to bad construction, any accident occurred and damage ensued, the owner is already liable at law; while the latter would sufficiently protect adjoining owners from injury to light, air, and prospect.

The regulation of buildings is, however, not the only work within the scope of Governments and City Councils, for they of necessity have to erect some of the most prominent structures in every city. It therefore becomes a matter of the utmost importance that these should be as good in quality and design as can be obtained. That this is the case it would be rash of me to assert, though the general average throughout the colonies is of a high order. Nothing less than the best should, however, be satisfactory, and with this end in view the Minister for Works in New South Wales has announced that, in future, designs for all Government buildings of over £5,000 in value will be open to public competition. The result of this move will be watched with much interest, and, if successful, it will no doubt spread to the other colonies of the group. But, even when Governments or Councils are not to be relied on for setting an example, they might at least be trusted to preserve us from actual detriment by the multitudinous wires that disfigure our streets. These have been placed underground in London and many other cities; and why not here? Besides being a disfigurement, they are actually a danger in case of fire, as fire-escapes cannot be raised in front of buildings where they exist.

The duty of the Government to encourage a love of art amongst the people is not by any means overlooked in one direction—namely, that of painting—as witness the small but excellent galleries in the chief cities; and if these, visited only occasionally, are important as a means of education, how much more so are the architectural compositions of the streets—the ever-open gallery of the people! Every encouragement that Government can give to the improvement of city streets should therefore be given; but at the same time the fullest liberty consistent with respect for the rights of others should be allowed to individuals, for it is mainly through the individual that any advance is made.

The foregoing gives a brief outline of some of the features that limit and give direction to the architecture of a modern town. The result, as we see it, is too often dull and prosaic;

but need this be so? I think not; and will therefore endeavour to indicate the lines on which improvement seems most feasible. In the first place, as set forth in my paper on "The Laying-out of Towns," wherever possible the principal Government, municipal, and public buildings should be grouped in the centre around an open reserve from which the main streets radiate. If the "spider's-web" plan of town is not adopted, then an arrangement of the public buildings as nearly approaching the above as possible would be desirable; for an aggregation of such structures would be to a modern town what the Acropolis was to Athens—namely, the nucleus, or centre, around which the whole of the city life revolves. On these buildings the best in art might well be lavished, as no others would be so much in public view or typify so well the city's character. It is, perhaps, needless to add that each building should be absolutely detached, and thus seen on all four sides. To give an example of what might be done in an existing city, I will instance Sydney, which in the Outer Domain possesses an unrivalled reserve almost in the centre of the community. On the Macquarie Street side it is occupied by various Government and private buildings of no architectural merit. Let these be cleared away as occasion demands, and a series of structures be erected for public purposes, each detached, thus showing off whatever beauty they may possess to the best advantage, and affording vistas into the Domain beyond. On the other side of the Domain the Art Gallery is already commenced; and if another public building were erected between this and the gates a complete semicircle would be formed, which, if well designed, would make a combination scarcely to be excelled for stateliness and beauty.

The next point to consider is the treatment of streets or avenues leading up to the central reserve, or of main streets with a definite and important terminal point. And here difference of opinion is sure to arise. One school will advocate a symmetrical and uniform design, such as we see in the avenues of Paris, while another will urge the claims of individual treatment and picturesque diversity; and there is much to be said on both sides. For the symmetrical, it is urged that greater dignity and power is obtained by the subordination of the units of the design to the general lines of the composition; and, especially where a fine building, object, or outlook is the terminal point, the enhancement of this so adds to the general effect as to more than compensate for the loss of individuality in the separate buildings of the group. On the other hand, the advocates of the picturesque school point out that, at any rate in the present condition of Australasian society, such ordered design can only be accomplished by undue interference with the rights of the individual, and that as a race we would not submit to such restrictions of our liberty as the Parisians suffered under Napoleon III. and his Prefect Baron Hausmann, and which, indeed, remain in force till the present time. For, as a rule, city properties, owing to their great value, are held in small blocks, and every owner not only reasonably wishes to make the most of his own, but also to build in such a way as to best suit his requirements, which it is scarcely likely would be exactly the same as those of a score or more of adjoining owners. On the positive side it is also urged that diversity of treatment is more pleasing to the eye, and palls less quickly, than ordered symmetry; but on this point there is no likelihood of agreement. It is entirely a matter of personal idiosyncrasy. For my part, I would unhesitatingly give it as my opinion that, of the two, the individual treatment is the most suited to our habits, and that on the whole it will produce the most artistic results. But, of course, this must be taken with limitations: where no restriction exists as to height of buildings it is quite possible that the whole effect of a street may be ruined by the overpowering altitude of one or two mammoth piles. This is especially noticeable in some American cities, and may be seen to a less extent both in Melbourne and Sydney. The limit of height should be that which the majority of buildings are likely to attain; and a municipal regulation is therefore desirable not only on practical, but also on artistic grounds. On this, however, let me make a suggestion. To avoid the uniformity which such a limit would foster I would allow the maximum height to be the average of the whole front, and not that of any specific part. It would thus be possible to keep one part of the building lower and the other higher than the fixed line, and so afford more liberty of internal planning and external design. And whenever such a special feature as a tower, spire, turret, dome, or other terminal is introduced, easy exemption should be made in its favour, as adding to the beauty and general interest of the city.

But there is one very prominent feature of the streets of these sunny southern lands that cannot be ignored when considering their architectural treatment. Whatever the improvement in the upper portions of the buildings, it goes for nought so long as we have to endure the shed-like shelter known as a street-verandah. It is a veritable *bête noire* to the architectural reformer. In the first place, it is only permissive, as it is erected over the public way, and hence City Councils ordain that it shall be of the slightest materials, such as iron and wood. Then, it is not every building in a street which requires one, and so, added to flimsiness, we have loss of continuity. And, lastly, it is rarely of the same height for many houses together. The result is utterly mean, and absolutely ruinous to architectural effect. In its present form, the only improvement possible is "off the face of the earth." But what shall we substitute? To arrive at a just conclusion, its *raison d'être* must be considered. Many buildings, especially shops, require a screen from the blazing rays of the sun; others, as hotels, theatres, and places of public resort, a covered shelter from the rain, extending from the building to the kerb, for the convenience of carriage traffic. In the former case, the recessing of the shop-front, as in Farmer's large drapery establishment, in Sydney, meets every need, with the added advantages of non-interference with the light and rights of adjoining premises, and the non-obstruction of the ordinary traffic of the footpath by loiterers at the windows. Architecturally, also, such treatment is an infinite gain, as there is nothing flimsy or unsubstantial to mar the unity of the design, and in capable hands the varying treatment of the arcades (not necessarily composed of strutted arches, like Farmer's) would be a source of unexpected beauty, and the contrast of light and shadow, solid and void, would add immensely to the effect of any ordinary street. On a large scale, the arcades of the Melbourne and Sydney Post Offices show what power and grandeur of design such a treatment affords; and, if generally applied, our streets, instead of being a reproach for meanness, would vie with those of any of the older cities of the world. The majority of the pavement verandahs being thus abolished, it would cause little obstruction and no inconvenience to allow rain-shelters to the entrances of public and other buildings to be erected in solid materials, harmonizing with the structures to which they belong. For permission to erect these, an adequate rent should be charged, as I see no reason why the public property should be used by special individuals without payment. It would otherwise be unfair to those who do not require the same facilities. Architecturally, an occasional projection of this kind, instead of being a defect, is a distinct gain to any street view, in the relief it gives to the unavoidable monotony of the frontage-line. One striking example to which I may refer is the portico of the Town Hall at Adelaide; and though rather heavy, its value in enhancing the pictorial effect of King William Street is patent to every visitor to that well-planned city.

But there is another alternative—viz., the erection of continuous verandahs of the same design all round a special block in which every building required such an addition. This would only be feasible to a very limited extent, but might be introduced in the case of street-improvements involving the clearing of a considerable area of ground, as in the widening of Post Office Street, Sydney. It would also necessitate unity of design in the buildings to be erected. And, as it is intimated that such is the intention of the Government in the instance just referred to, the experiment will be watched with some degree of interest. If a verandah should form part of the scheme it is to be hoped that it will be of solid materials, in harmony with the buildings, and not a repetition of that horrible monstrosity, the cast-iron frieze, which ruins one side of George Street. There are many examples of what such arcades should be—to wit, those of the Rue de Rivoli, &c., in Paris, and that around Her Majesty's Theatre in London, though they are rather heavy; or, preferably, the lighter and more handsome arcades of the old City of Bologna in Italy. But, as I have before intimated, the combined design of street-frontages is not generally applicable to our present conditions, and therefore, for general purposes, the recessed shelter for those who require it seems to be the only satisfactory architectural solution of a very difficult problem.

And now as to the treatment of the ordinary buildings of which a town or city is mainly composed. The public structures may give the key-note, but it is the every-day buildings that make the complete harmony, and whether this shall be full and rich or flat and insipid will depend on every single architectural note. The importance of well-designed private structures is therefore great; and if every citizen could be made to feel that in each new building he erects he is helping to make or mar his city, and so reacting on the value of his own property, one little step in advance would be gained. To the credit of Australians be it said that this feeling is at least as well developed as amongst the citizens of the Old Country, who have enjoyed for centuries the inspiration of fine examples at their own doors. There is, however, great room for improvement both here and in England. The quality in which such is most needed seems to be that of individual expression. There is a terrible sameness about an ordinary modern street. The houses, offices, or shops all look as if they had been cast in two or three stock patterns, and a length cut off as required. There are, of course, many exceptions, especially among the larger buildings, but sameness is the rule. Warehouses and offices are often so much alike that it is hard to tell from the appearance of the building which is which; and the same applies, to a greater or less extent, in all kinds of edifices. I would therefore advocate the individualising as much as possible of every class of structure. Let the warehouse be as like a warehouse as it is possible to make it. Stability and strength should be the leading note of a store for heavy goods, and a special feature be made of the access and appliances for receiving and delivering merchandise. On the other hand, in a set of offices a good entrance for foot-passengers, and abundant window lighting, should at once differentiate it from the store; while in a shop the large ground-floor window is a *sine quâ non*, but as yet is rarely treated in a satisfactory manner in combination with the superimposed structure. As a rule every inch of frontage is used for glass, and an ordinary heavy brick or stone front is piled on top, apparently resting on nothing. The requirements of modern trade prohibit large and obstructive piers, therefore the upper stories must be lightened to combine and harmonize with the void below. If this be done effectively, a distinct type of elevation is evolved, that at once proclaims the class to which it belongs. And in this way I might enlarge on all the different kinds of city buildings. The hotel for residence requires abundant balconies, while street dwellings, instead of being stereotyped in two or three stock patterns, might be as various as their occupants. But these are points of detail on which I cannot enlarge on the present occasion. Nor shall I allude to the question of "style," otherwise than to state my conviction that by following the hints I have given, and so meeting as perfectly as possible the practical needs of every-day life, we shall more surely evolve a style of architecture suitable to our habits and climate than in any other way.

The proper use of materials is another section of the subject on which much could be said; while public monuments, sculpture, and external colour decoration are themes that demand a separate paper. It must, however, suffice for the present that I have simply referred to them.

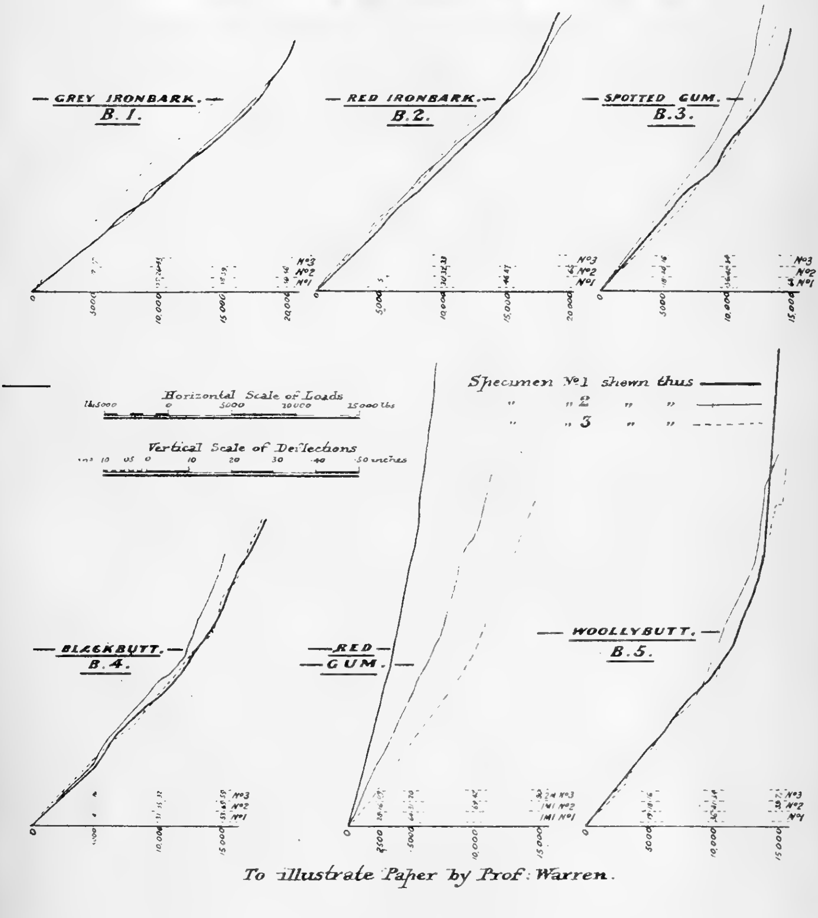
In order to carry out some of the suggestions made in this address, a competent guiding authority, possessed of initiative powers, is a necessity. This at present does not exist in any Australian city. The City Councils, through an official, see that their Building Acts are adhered to; but these are restrictive in scope, and purely regulative. Something is required like the General Council for buildings and improvements that has existed in Paris for upwards of two centuries, nominated by the Government, and composed of the best specialists the country can boast; but unfettered by the severe restrictions of the Parisian Building Act. A similar Council has been suggested for London by the President of the Royal Institute of British Architects, in the *New Review* for October, 1890. Such a body should be empowered to reserve sites for future public buildings, and initiate city improvements, not piecemeal, but as part of a complete scheme to be realised section by section in the course of years. The saving in outlay by prevision would be immense, and the value of individual properties would be proportionally increased. Is it too much to hope that some day the suggestion may be realised?

It is, however, well to have an ideal; and in my paper on "The Laying-out of Towns," and in this address, I have

N.S.W. TIMBERS.

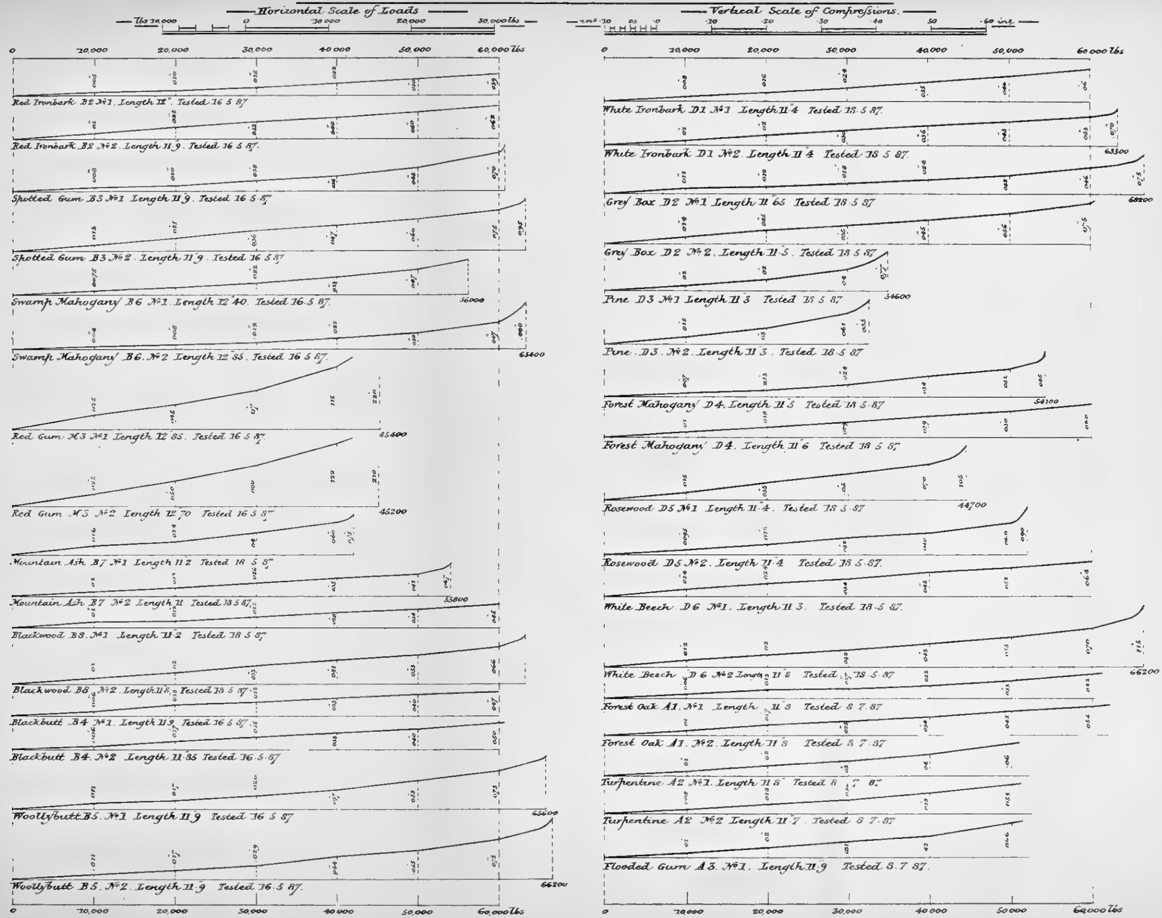
CROSS BREAKING.

DIAGRAMS SHEWING LOADS & DEFLECTIONS.



To illustrate Paper by Prof: Warren.

N. S. W. TIMBERS. DIAGRAMS SHEWING LOADS & COMPRESSIONS.



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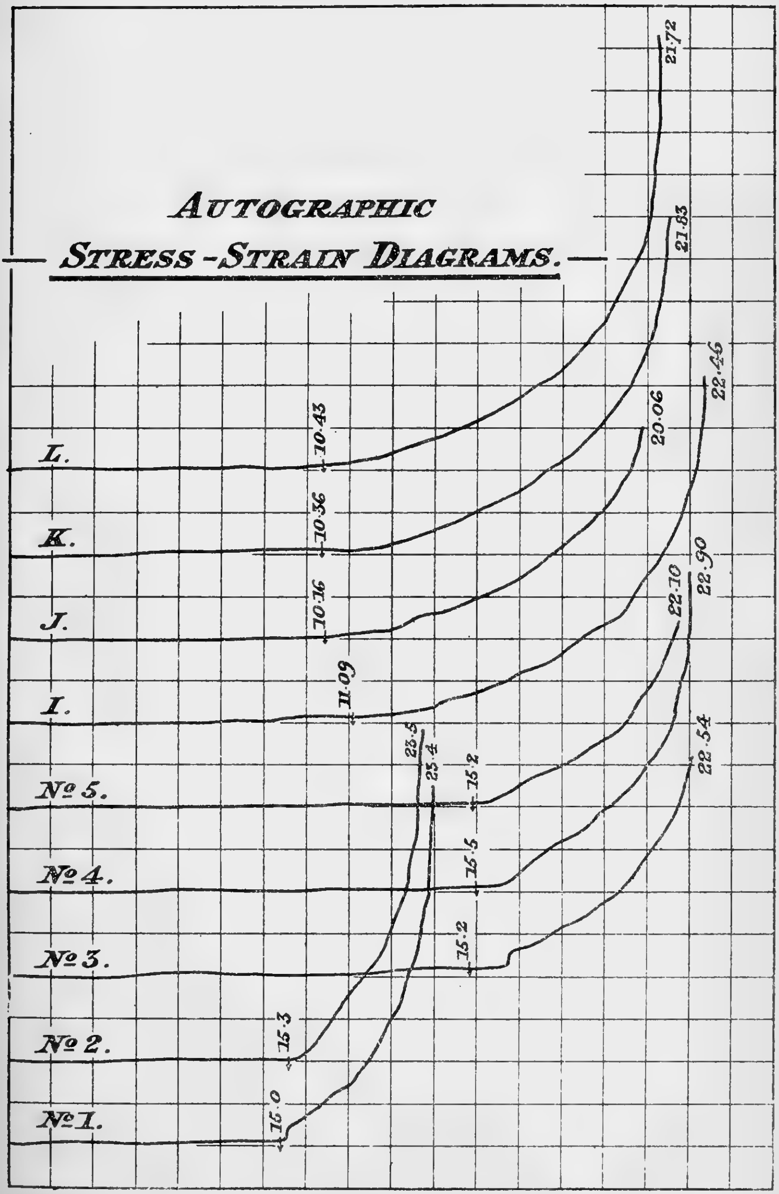

C.H.P. del.

To illustrate Paper by Prof: Warren.

endeavoured to set forth a few points that have occurred to me as likely to excite thought in the minds of those who are engaged in building up our Australian cities. They may not be realisable at once, or in the exact form indicated, but of this I am certain: that, if carefully weighed and considered, and in due time acted upon, they cannot fail to effect a great improvement, and help to produce cities in the future which, if not as wildly picturesque as the Nuremberg of the past, will be more useful, healthy, beautiful, and pleasant to live in than any this quarter of the word knows at present. Some may say this is only a dream; but, if we compare the present with the past, we may safely forecast the future. I cannot better conclude than by quoting the words of Ruskin, that "it is only possible to answer for the final truth of principles, not for the direct success of plans, and that in the best of these last what can be immediately accomplished is always questionable, and what can be finally accomplished inconceivable."

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1. *Description of the Apparatus used in testing Materials, with especial reference to Cast-iron, Wrought-iron, and Steel. Tests to secure a Suitable Material. Safe Working-stresses, Fatigue, and Factors of Safety.*

By W. H. Warren, Whitworth Scholar; M.Inst.C.E.; M.Am.Soc.C.E.; Challis Professor of Civil and Mechanical Engineering in the University of Sydney.

Plates VIII.–XIV.

The strength of a structure, such as a girder, a roof, or a bridge, depends not only upon the form and dimensions of the structure, but also upon the materials used in its manufacture. The load or loads which a structure is designed to carry produce stresses in the various members, which may be tensile, compressive, shearing, and occasionally torsional; the stresses develope resistances in the material, which are generally accompanied by slight alterations in form, such as an elongation or a shortening of the member in question. The elongation or compression, as the case may be, is termed the "strain," which must not be confounded with the "stress" producing it.

The stresses which are produced in the various parts of a structure depend entirely upon the form and dimensions of the structure, and are independent of the materials used in its manufacture; but, in arranging the areas of the various parts to resist the stresses produced in them, it is necessary to know the physical properties of the materials, such as the tenacity, ductility, elasticity, and their rate of expansion by heat, their power to resist compressive, torsional, and shearing stresses, &c.

The science of construction is partly an exact science and partly an inexact science. It is exact in so far as it consists in the determination of the stresses in structures, but it is inexact with regard to materials, although, by means of the modern appliances for testing materials, it is possible to arrive at results the accuracy of which, as far as the requirements of the architect and engineer are concerned, leave little to be desired.

Testing Appliances.

The most important testing-machines used in the laboratories in England and Europe are based on the constructive principle first adopted by Mr. David Kirkaldy, M.Inst.C.E., —that, namely, of applying the load by water-pressure, and measuring it by dead-weight. In some of the larger testing-machines used in America, and generally in smaller machines, spur-gearing and screws are used to apply the load. It should, however, be mentioned that a large and accurate testing-machine was designed by Mr. A. H. Emery for the Watertown Arsenal, in which the power is applied by means of an hydraulic press supplied by a set of pumps driven by a steam-engine through an accumulator. The stresses are measured by scale-beams, to which they are transmitted through a set of diaphragms and cells containing a mixture of alcohol and glycerine, and which operate as a frictionless reducing mechanism. The machine, once standardised, is said to be almost absolutely accurate. Its capability of recording accurately large and small stresses was shown when it was first used for breaking a bar of iron 5in. in diameter, and afterwards a single horse-hair. It has been since used for a variety of most valuable tests, which are recorded in the reports published each year by the United States Government.

The machine used at the University of Sydney, and also at the University of Melbourne, consists of a force-pump and hydraulic press for applying the load, and two levers for measuring it. It is proposed to add an accumulator to the Sydney machine. There is a knee-lever, 5:1; and a steelyard, 20:1; the total leverage being 100:1. The poise-weight may be varied from 50lb. to 1,000lb.; so that the maximum load that can be applied is 100,000lb. There are also appliances for testing in tension, compression, cross-breaking, and torsion up to this load.

In using the machine to test a piece of iron or steel in tension, it must be prepared to one of the forms shown on Plate XI.; it is then fixed in the machine, and the load applied gradually, which is balanced while pumping goes on by winding the poise-weight along the steelyard until fracture occurs. To test a piece of iron or steel in compression, it should be prepared to a uniform size, parallel throughout, and square at the ends. To test a rolled girder, a bull-iron, or a rail, &c., it is merely necessary to support it across the knife-edges of the cross-head, and apply the load with a knife-edge in the centre.

If it is desired to test the tensile strength, the elasticity, and the ductility of a piece of steel or iron, a light lever multiplying 100:1 is attached to the specimen, which is capable of measuring small elongations. This apparatus will be subsequently referred to. The load is applied, and the movement of the long arm of the lever shows that the specimen stretches, and that up to a certain point, by no means easy to determine exactly, but generally about 11 or 12 tons per square inch of the sectional area of the specimen, the stretching is uniform and regular: thus, with a load of 1 ton per square inch, the specimen will stretch about $\frac{1}{12000}$ part of its length, which, for a length of 10in. under test, will be $\frac{1}{1200}$in. With a load of 2 tons per square inch, the elongation will be $\frac{2}{1200}$in. or $\frac{1}{600}$in.; and with 3, 4, 5, 6, 7, &c., tons per square inch, the elongations will be 3, 4, 5, 6, 7 times $\frac{1}{1200}$in. respectively, and generally the elongations are practically proportional to the loads producing them. In other words, the specimen is said to be perfectly elastic for these loads; which is shown by releasing the pressure, when the specimen practically springs back to its original length of 10in. But this so-called elasticity has a limit, which in wrought-iron is generally about 11 or 12 tons per square inch, and in mild boiler steel about 18 tons per square inch, after which the elongations increase much more rapidly than the loads producing them, and the material behaves as if it were plastic, until the specimen fractures, which generally occurs at from 20 to 24 tons per square inch for wrought-iron, and from 24 to 30 tons for mild boiler steel; the elongations at the point where the material ceases to be "elastic" (the so-called limit of elasticity) being for an area of one square inch about $\frac{1}{100}$in., whereas the total elongation at fracture will be from 1in. to $1\frac{1}{2}$in. for ordinary iron, and 2in. to $3\frac{1}{2}$in. for steel, on a length of 10in.

Again, it will be observed that the area of the specimen at the fracture is smaller than the original area. The elongation is generally expressed in terms of the length of the specimen tested, and the contraction of area in terms of the original area: thus, we say the percentage of elongation in ordinary iron is about 10 per cent.; its contraction of area is about 12 per cent.

The elongations and contractions so expressed are measures of the ductility of the material. The term "modulus of elasticity" is used to denote the result found by multiplying the stress per square inch by the original length of the specimen, and dividing by the elongation. Thus, we have seen that a stress of 1 ton per square inch will produce an elongation of $\frac{1}{12000}$ part of the length of a piece of iron, or for a length of 10in. $\frac{1}{1200}$ in.: this gives the modulus of elasticity as 26,880,000lb. per square inch. The modulus of elasticity may also be defined as the ideal stress which would be capable of stretching a perfectly elastic bar to double its length; it may be calculated from the following formula: $E = \frac{WL}{kl}$, where E = the modulus of elasticity, W = the load producing elongation l, k = area in square inches, L = original length of specimen.

The modulus of elasticity is an important factor in all calculations where the stress is determined from the strain, as, for example, in the deflection of beams; and it should be noted that an error in measurement of the elongation of the specimen of $\frac{1}{10000}$in., with a load gradually increasing up to 10 tons per square inch, would mean an error of 2 per cent. in the modulus of elasticity; and, in trying to determine the extensions from ton to ton, an error of $\frac{1}{10000}$in. would mean an error of 20 per cent. in the extension per ton. It is therefore evident that very delicate instruments are necessary in order to measure these minute elongations. Several ingenious pieces of apparatus have been devised from time to time, among the best of which are those used by Professors Unwin and Kennedy.

Professor Kennedy's apparatus consists of a light lever multiplying the elongations of the specimen from a hundred to two hundred times, according to the degree of accuracy desired. These extensions are measured between two small holes in the test-piece, which are generally 10in. apart. Two steel points fit into these holes, one of which is fixed, and the other movable by the stretching of the specimen. The whole apparatus is slung on the test-piece, and is totally unaffected by its motions as a whole, and, of course, by any change of form in the frame of the machine. The instrument can be easily calibrated from time to time by means of Vernier callipers. This apparatus has been in use for the last five years at the University of Sydney. Professor Unwin uses a screw micrometer extensometer, also a roller and mirror extensometer; while Professor Bauschinger uses still more delicate appliances.

The foregoing considerations show that delicate instruments are necessary in order to determine accurately the elastic limit and modulus of elasticity; but other difficulties exist, which will now be considered more closely. The method described for determining the elastic limit is that usually adopted in the commercial testing of materials; what is really found is better defined as the "yield-point." It is well known that the yield-point can be raised by mechanical means, that the application of a stress greater than the yield-point raises the yield-point, and that it may be artificially raised almost to the breaking-point.

With very delicate instruments a permanent set is observable with stresses well within the yield-point, and the stress fixed upon as the elastic limit depends upon the delicacy of the instruments used in determining it. The stretching of a bar within the yield-point consists partly of an elastic extension and partly of a permanent set; and it is this permanent set which makes it so extremely difficult to determine the true elastic limit.

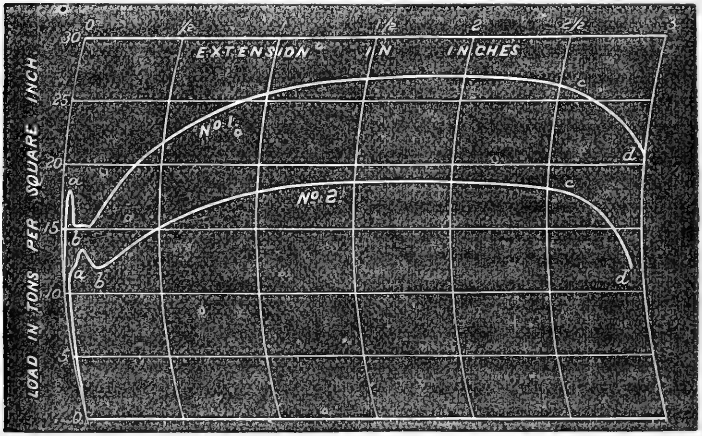
Professor Bauschinger has shown that these artificially-raised yield-points are entremely unstable, and may be lowered considerably by hammering the test-bar on the end and reloading it, and that, moreover, the yield-point cannot be raised in tension without at the same time lowering the yield-point in compression. When a bar is subjected to stresses alternating between tension and compression the elastic limit cannot be raised, and the yield-point settles down to the true limit of elasticity.

Professor Bauschinger further points out that ordinary materials of construction have their yield-points artificially raised in the process of manufacture, and proves by a most elaborate series of experiments that the true elastic limit—which he still defines as the stress beyond which the strains cease to be proportional to the stresses producing them—can be correctly ascertained by first subjecting the bar to a series of stresses alternating between tension and compression; the limit then decreases to a value not differing appreciably in tension and compression, and below the initial elastic limit or yield-point. The elastic limit found in this way is about 8 tons for wrought-iron and 9½ tons for mild steel. The stretching which occurs at the yield-point for hard and soft steels does not differ materially, from which it is inferred that hard and soft material may be relied upon to work together in a built-up structure, under ordinary working-stresses. The same has also been observed in the case of iron.

It is very desirable in all important tests of materials to have a record automatically registered by the machine itself: such an apparatus is called an autographic stress-strain apparatus, because it draws a diagram which shows the strain produced by stresses which vary from nothing to that required to break the bar. The author possesses one designed by Professor Kennedy, and made for the University of Sydney in his laboratory.

The form of the diagram for a piece of mild steel is shown in the woodcut, from which it will be seen that the extension produced by a given load is represented as an abscissa, while the load itself is represented as a curved ordinate. The diagram represents the behaviour of the specimen during the test, and shows clearly the limit of elasticity, the maximum load, and the elongation. The curve not only indicates the

Diagrams taken with Professor Kennedy's Apparatus.



No. 1. Landore Rivet-steel: Yield-point, 17·39 tons per sq. in. Max. load = 27·29 tons.

No. 2. Swedish Bar-iron: Yield-point, 12·67 tons per sq. in. Max. load = 18·85 tons.

yield-point, and the amount of extension which occurs at this point, but it is seen by inspection that the local extension which occurs at the breaking-point is measured by drawing ordinates at the commencement and termination of the curve drawn during the time the specimen is undergoing local extension. Again, the area of the diagram represents the gross mechanical value of the material, as it represents the work done in breaking the bar, which of course depends upon its breaking-strength and ductility.

The principle of the apparatus is as follows: The test-piece is placed in the machine with a stronger bar, which is called a spring-piece. The material of this bar must be ascertained by previous experiments to be perfectly elastic, so that its extensions are strictly proportional to the pull on the test-piece; and, moreover, it should be of such an area that its limit of elasticity occurs only at a load greater than that which will break the test-piece. By a simple arrangement a very light pointer is made to swing about an axis through an angle proportional to the pull on the test-bar. The end of this pointer in its motion always touches a piece of smoked glass, to which is given a travel in its own plane proportional to the extension of the test-piece. In this way the diagram is drawn. After the test the glass is varnished to fix the black, and the necessary particulars about the test are written on it with a scriber. The glass is then used as a negative, and copies produced by photography.

Professor Unwin's autographic stress-strain apparatus consists of a revolving drum, whose angular displacement is proportional to the position of the poise-weight which denotes the load on the specimen. The extension produced by the load is recorded by means of a wire passing over pulleys and connected with the test-piece; a pencil attached to this wire draws the diagram.

Mr. Aspinall and Professor Hele Shaw have each devised apparatus on the same principle as that adopted by Professor Unwin. In Mr. Wickstead's apparatus the stress is measured by the compression of a spiral spring, acted upon by a small auxiliary ram in a cylinder, in which the pressure is the same as that in the main hydraulic cylinder. This auxiliary ram is kept in constant rotation, to reduce the friction of the cup-leather to an exceedingly small amount. A pencil attached to a rod moved by the auxiliary ram draws a line on a drum whose angular displacement is proportional to the stretching of the test-piece.

The limit of elasticity, ultimate strength, and total extension are perfectly recorded by the apparatus above described; but the portion of the diagram from *a* to *b* and from *c* to *d* on the diagrams recorded by Professor Kennedy's apparatus, as shown in previous woodcut, are much more perfectly shown than in any of the others.

Mr. J. A. McDonald, M.Inst.C.E. and M.Am.Soc.C.E., and the author devised an apparatus which was made at the University, and used in drawing the stress-strain diagrams shown in the author's pamphlet on "New South Wales Timbers of Commercial Value." These diagrams are for compression and cross-breaking, but an arrangement has since been added which enables diagrams to be drawn for tension-tests of iron and steel. The apparatus can be best understood by inspecting it at work in the testing-machine. It has been in constant use for the last four years, and has proved to be very convenient. A few of the diagrams obtained from it are shown in Plates VIII., IX., and X. The following tables, Nos. I. to V., illustrate the method of recording the results of testing at the University of Sydney for ordinary commercial tests. More complete information on the timber-tests may be obtained from the author's pamphlets on this subject.

FORM AND DIMENSIONS OF TEST-PIECES.

The forms and proportions adopted by the author are illustrated on Plate XI., in order that the results obtained might be comparable with the greatest number of English, German, and French results.

It is well known, however, that the form and dimensions of the test-piece have a very marked effect upon the results obtained in testing. See Hackney, "Forms of Test-pieces," Proc. Inst. of Civ. Eng., vol. lxxvi. High percentages of elongations may be obtained from short or thick test-pieces: long and thin test-pieces give much lower percentages of elongation for the same material.

The tests intended to govern the quality of the material for a particular purpose will next be considered.

In testing wrought-iron and steel intended to be used in engineering construction it is at least necessary to determine the strength and ductility. The ductility is usually ascertained by measuring the percentage of elongation in the manner already described, or by the percentage of contraction of the fractured area. The contracted area is measured most conveniently by means of micrometer callipers. The strength alone, as first pointed out by Mr. Kirkaldy, is no indication of the quality of the material. "A high breaking-strength may be due to the iron being of a superior quality, dense, fine, and moderately soft, or simply to its being hard and unyielding. A low breaking-strength may be due to looseness and coarseness in the texture, or to extreme softness, although very close and fine in quality. The contraction of area at fracture forms an essential element in estimating the quality of the specimen, and by comparing the breaking-strength with the contraction of area at fracture the respective merits of various specimens can be correctly ascertained."

The contraction of area can generally be measured with sufficient accuracy in round specimens, but in the case of flat specimens, especially very broad, thin strips, it cannot be measured with sufficient accuracy; and when the fracture is oblique, as is often the case, the difficulty is increased. The contraction of area is also largely influenced, as stated by Professor Unwin, by local conditions of hardness and homogeneity at point of fracture.

It is in consequence of the difficulty in measuring accurately the contraction of area at fracture that many competent authorities have advocated its omission in specifications of tests of materials, in favour of elongation; but here, also, a difficulty exists. The elongation consists of two parts—namely, general and local. The general extension in a specimen continues so long as it offers increased resistance to the force producing it, and is proportional to the length of the specimen; but the local extension commences after the general extension has ceased, and is most decided in all ductile materials, such as steel. It is confined to the portion immediately adjacent to the fractured area. The local extension is, in fact, proportional to the area of the specimen.

Although it is usual to measure the total extension on a specimen, and to express it in percentage of length, the more scientific way, which has been suggested by Professors Unwin, Barba, and Wickstead, is to separate the general extension from the local.

Mr. Wickstead described, at the last meeting of the British Association, a method of doing this from the autographic record, and recommended a column in the test-sheet of "Percentage of General Extension," in addition to the usual columns —namely, "Percentage of Contraction of Area," and "Percentage of Total Extension." The local extension can then be expressed by subtracting the "General Extension" from the "Total Extension."

The local extension is seen by dividing the test-piece before testing, over the length of, say, 10in., into ten equal parts, each 1in. long: the elongations remeasured after testing will be much greater on the 2in. or 3in. which include the fracture than over equal lengths measured on the remaining portion of the 10in.

Plate XII. shows a bar 30in. long, divided into thirty equal parts, with the remeasured lengths after testing. Here the local extension is very decided.

In autographic stress-strain diagrams, such as those produced by means of Professor Kennedy's apparatus, the local extension is easily separated from the general extension; and when this is done it is possible to eliminate the effect of different proportions in regard to length and area of cross-section, on the percentage of total extension.

The ductility of a specimen can also be ascertained by bending round a bar of given radius. But here, again, the proportions of the test-piece exercise a decided influence on the angle bent through before fracture, which measures the ductility.

When steel is required for boiler-construction it is usual to specify, in addition to the ordinary tests referred to, that strips of the plate shall be heated to a cherry-red heat, and cooled in water at 80° Fahr., after which they should bend double without signs of fracture.

In order to secure a suitable material for railway-axles it is usual to specify, in addition to the ordinary tests for tensile strength and ductility made on specimens cut from the axle, that the axle itself should be tested to destruction by a series of blows produced by a falling weight, the axle being reversed after each blow. The results of the drop-test—which this test is called—on axles, when the experiments are carefully conducted, give a fairly close approximation to the endurance which may be expected from similar axles under the conditions existing in ordinary railway practice. The French make use of the drop-test not only for axles, but for small samples of the materials used in the construction of guns.

In general it may be stated that the conditions under which a given material is tested should conform as nearly as possible with those existing in the structure, machine, rail, tire, axle, or gun of which it forms a part.

It is rarely necessary to test wrought-iron and steel in compression or torsion in order to determine its suitability for constructive purposes, as the tensile tests generally show all that is necessary with regard to the quality of the materials.

The tensile strength of cast-iron varies from 7 tons to 10 tons per square inch, its modulus of tensile elasticity from 10,000,000lb. to 15,000,000lb. per square inch, while the compressive strength varies from 30 tons to 40 tons per square inch. It is usual to test sample-bars of cast-iron as beams loaded in the centre and supported at each end. The span is usually 36in., and the cross-section of the test-bar 1in. wide by 2in. deep. The breaking central weight varies from 24cwt. to 30cwt.

Working-stress and Factor of Safety.

Working-stress signifies the intensity of stress—generally expressed in tons per square inch—to which a piece of material may be subjected without ceasing to fulfil its purpose efficiently under the conditions on which the stresses are applied.

The factor of safety is the ratio of the ultimate strength to the working-load. Sir William Fairbairn proved that a riveted girder loaded to one-third of the load which would have broken it if applied gradually, failed after 313,000 applications of this load.

The experiments of Herr Wöhler and Professor Spangenberg demonstrate the following law, known as "Wöhler's law:" "Rupture may be caused not only by a steady load which exceeds the carrying-strength, but also by repeated applications of stresses none of which are equal to this carrying-strength. The differences of these stresses are measures of the disturbance of the continuity, in so far as by their increase the maximum stress which is still necessary for rupture diminishes." Professor Bauschinger has made a long series of experiments which confirm those made by Herr Wöhler. Professor Bauschinger's experiments are the most valuable on this subject which have ever been made, and the results are summarised in Table VIII.

In England, Sir B. Baker has made various experiments which also confirm Wöhler's original experiments. For example, he found that when a shaft is loaded with one-half its gradually-applied breaking-weight, and set rotating, about five thousand reversals of stress produced fracture. He mentions an experiment with a bar of cast-iron loaded with a weight which, according to Fairbairn's experiments, it should have carried for a long series of years, broken in two minutes when set gently rotating; also, a bar of fine tough steel so changed in constitution at fracture after a few months' rotation as to offer no advantage over a new cast-iron bar of the same section. Sir B. Baker has proved by experimenting on flat bars of steel by repeatedly bending them, that, after subsequent testing in direct tension, and direct crushing, the effect of repeated stresses is more prejudicial in tension than in compression.

The change which a piece of material undergoes when subjected to repeated stresses is termed "fatigue." It is most marked in the case of stresses alternating between tension and an equal compression, as seen in the fracture of railway-axles.

The strength of a piece of material when subjected to a gradually-applied load, as in a testing-machine, is termed its "statical strength." When subjected to a load which is entirely removed before being reapplied, the load which will ultimately break the piece is termed its "primitive strength." When subjected to stresses which alternate between tension and an equal compression, the ultimate breaking-stress is termed its "vibrating strength." Approximately, the vibrating strength is to the primitive is to the statical as 1 is to 2 is to 3. The values of these strengths for a variety of materials are recorded in Table VIII.

Several methods have been proposed which have for their object the representation of the results of the experiments made by Wöhler and Bauschinger, and their extension to the various ranges of stress which occur in engineering practice; among which may be noticed Gerber's parabola. If the ranges of stress given in Table VIII. are plotted as ordinates, and the minimum stress as abscissæ, the points fall on a parabolic curve, which Professor Unwin expresses thus:—

Let f *max.* and f *min.* denote the limits of stress, and Δ the range of stress; then—

$$\Delta = f\,max. \mp f\,min.$$

The upper sign is to be taken when the stresses are of like kind, and the lower sign when of opposite kind, as in alternating stresses. Let f denote the statical breaking-strength; then the equation to Gerber's parabola is,—

$$\left(f\,min. + \frac{\Delta}{2}\right)^2 + k\,\Delta = f^2.$$

If the statical strength f is known, and the value of f *min.* and f *max.* for any range of stress at which the bar stands a practically unlimited number of repetitions before breaking, then k can be determined, and the limits of stress for all conditions of loading can be calculated. The parabolas drawn from the above equation, using the results recorded in Table VI., are represented in Plate XIII.

Soon after Wöhler's results were published, Professor

Launhardt published a formula which applies to the cases in which the stresses are either tensile or compressive, which may be represented as follows:—

Let b denote the breaking-strength,
s " statical strength,
p " primitive strength.

Then, $$b = p + (s - p)\frac{f\ min.}{f\ max.}$$

If in the end lattice-bar of a bridge the stress produced by the live load were nine times the dead load, then—

$$\frac{f\ min.}{f\ max.} = \tfrac{1}{10};$$

and, using the results given in Table VIII. for wrought-iron, we have—

$$b = 13{\cdot}10 + (22{\cdot}8 - 13{\cdot}1)\tfrac{1}{10} = 14{\cdot}07 \text{ tons};$$

so that 14·07 tons is the actual breaking-strength of the bar; and, if the working stress is taken at 4·69 tons per square inch, the factor of safety is,—

$$\frac{14{\cdot}07}{4{\cdot}69} = 3 \quad \left(\text{not } \frac{22{\cdot}8}{4{\cdot}69} = 4{\cdot}6\right).$$

In order to meet the cases which include stresses alternating between tension and compression, Professor Weyrauch proposed the following formula, in which the vibrating strength is denoted by v:—

$$b = p - (p - v)\frac{max\ B}{max\ B_1}.$$

If the greatest tension on a bar is 5 tons, and the greatest compression 10 tons, then—

$$\frac{max\ B}{max\ B_1} = \tfrac{5}{10} = \tfrac{1}{2};$$

and, using the same material as before, we have—

$$b = 13{\cdot}10 - (13{\cdot}10 - 7{\cdot}15)\tfrac{1}{2} = 10{\cdot}125 \text{ tons};$$

and the factor of safety, with a working-stress of 3·375 tons per square inch, is—

$$\frac{10{\cdot}125}{3{\cdot}375} = 3 \quad \left(\text{not } \frac{22{\cdot}8}{3{\cdot}375} = 6{\cdot}4\right).$$

The effect of "fatigue" is considered to be purely local, as it is not possible to discover any change in strength, elasticity, or ductility in material which has been fractured in this way, by retesting it in the ordinary way by means of the testing-machine.

There is no difference in the results obtained from testing specimens cut from an axle broken in ordinary use, or by means of the drop-test, than would be obtained from testing specimens cut from the axle when new. Retesting specimens cut from old structures does not show any measurable change in the material. It is known, however, that the fracture of specimens by repeated stresses in Wöhler's machines, and that of railway-axles from the fatigue occurring in ordinary work, are short and crystalline, showing no signs of ductility; hence the reason given by Professor Unwin that fatigue is primarily a loss of power of yielding in the particles near the plane of weakness at which fracture occurs. Whatever the cause, the facts shown in Table VIII. remain, and must be accepted as the true basis of the determination of the safe working-stresses in materials.

The rule which still exists in the regulations of the British Board of Trade for iron railway-bridges is simply to limit the working-stresses to 5 tons for tension and 4 tons for compression. For steel the limiting stress is 6½ tons. No account is taken of the variable range of stress. The rule obviously gives excessive strength for those parts of bridges where the range of stress is small, as in plate web box-girders of 150ft. span, while it would be dangerous if applied to those parts of structures where the range of stress is large, as in the longitudinals and bracing of modern bridges.

It may be stated, without fear of contradiction, that no properly-trained engineer would use the British Board of Trade rules in railway-bridges. In America and in Europe the practice has long been to make the working-stress depend upon the range of stress. Thus, in the elevated railway at New York, the flanges of the girders were designed for a stress of 3·6 tons per square inch, the web-bracing for 3·4 tons per square inch, and for members subjected to alternating stress 2 tons per square inch.

In the numerous elaborate specifications which have been written by American engineers to govern the design of important railway-bridges, rules are given for limiting the intensity of working-stresses in various parts of the structure more or less in accordance with the results given in Table VIII. In the Roads and Bridges Department, New South Wales, Mr. J. A. McDonald, M.Inst.C.E., M.Am.Soc.C.E., Engineer for Bridges, has for some years limited the intensity of working-stress in the various parts of the structures designed by him in strict accordance with the results recorded in Table VIII. Mr. McDonald has prepared Table VII. for general office use, which gives the ultimate breaking-strength for various ranges of stress as given by Launhardt's and Weyrauch's formulas. Plate XIV. has been prepared to show the practice of the Roads and Bridges Department for fixing the intensity of working-stress, compared with that sanctioned by the Board of Trade. The stresses given on Plate XIV. are found from TableVII. by dividing by the factor of safety, which is 3.

Table No. I.

Transverse Strength of New South Wales Timbers.

Local Name.	Number and Letter.	Size of Specimen, in Inches. Length.	Breadth.	Thickness	Weight, in Pounds per Cubic Foot.	Breaking Load, in Pounds.	Modulus of Rupture, in Pounds per Sq. In.	Modulus of Elasticity, in Pounds per Square Inch.	Number of Days seasoning.	Deflection, in Inches. 2,500 lb.	5,000 lb.	10,000 lb.	12,500 lb.	15,000 lb.	17,500 lb.	20,000 lb.
Red ironbark	B_2 1	54·00	6·00	4·00		21,500	16,125	2,400,000	58	0·075	0·15	0·30	..	0·46	0·617	..
"	B_2 2	54·20	5·90	3·90	76·5	20,500	16,448	2,306,572	121	0·090	0·18	0·32	..	0·47	..	0·66
"	B_2 3	54·10	5·91	3·92		20,500	16,253	2,318,836	121	0·085	0·17	0·33	0·423	..	..	..
"	B_{16} 1	53·25	5·60	3·77		22,000	19,901	2,775,300		0·083	0·165	0·34	..	0·505	..	0·72
"	B_{16} 2	52·50	5·60	3·77	72·6	21,500	19,949	2,559,400	554	0·090	0·178	0·36	..	0·54	0·66	..
"	B_{16} 3	52·75	5·65	3·80		22,750	20,042	2,662,900		0·085	0·17	0·333	..	0·52	0·63	..
"	P_4 1	52·50	5·51	3·67		24,125	23,406	3,715,100		0·088	0·17	0·335	..	0·505	..	0·722
"	P_4 2	52·50	5·51	3·69	72·9	23,687	22,732	2,838,800	671	0·090	0·172	0·336	..	0·50	..	0·705
"	P_4 3*	52·25	5·61	3·80		17,125	15,220	2,703,200		0·085	0·165	0·315	..	0·47	..	..
Grey ironbark	B_1 1	54·00	6·03	4·10		25,000	17,758	2,716,499	117	0·060	0·120	0·250	..	0·38	..	0·56
"	B_1 2	54·00	6·10	4·14	73·9	25,000	17,216	2,559,107	121	0·060	0·120	0·260	..	0·39	..	0·56
"	B_1 3	53·90	5·92	4·00		24,500	18,623	2,179,791	197	0·085	0·170	0·330	0·402	..	..	..
"	B_{17} 1	52·875	5·66	3·80	74·7	22,750	20,042	2,781,950	675	0·080	0·150	0·300	..	0·455	..	0·66
"	B_{17} 2	53·125	5·56	3·80		25,000	22,420	2,832,000		0·080	0·140	0·303	..	0·453	..	0·628
White ironbark	D_1 1	53·95	5·98	3·84		19,625	16,024	2,916,157		0·070	0·140	0·295	..	0·465	0·603	..
"	D_1 2	54·50	5·99	3·86	73·5	21,250	17,143	2,994,610	51	0·077	0·154	0·285	..	0·434	..	0·640
"	D_1 3	53·80	5·96	3·97		23,000	17,629	2,471,295		0·075	0·150	0·304	..	0·440	..	0·629
"	P_5 1	56·62	5·75	3·92		25,000	20,370	2,722,800		0·075	0·150	0·285	..	0·415	..	0·565
"	P_5 2	52·25	5·57	3·88	69·6	24,125	20,715	3,601,100	682	0·076	0·156	0·290	..	0·426	..	0·592
"	P_5 3	52·00	5·64	3·88		23,375	19,822	2,788,300		0·077	0·157	0·297	..	0·428	..	0·596

* Faulty specimen.

TABLE No. II.

COMPRESSIVE STRENGTH OF NEW SOUTH WALES TIMBERS.

Local Name.	Number and Letter.	Size of Specimen, in Inches.			Area, in Sq. In.	Total Breaking Load, in Pounds.	Breaking Load, in Pounds per Sq. In.	Modulus of Elasticity, in Pounds per Sq. In.	Number of Days seasoning.	Compressions, in Inches.								
		Length.	Breadth.	Thickness.						10,000 lb.	20,000 lb.	30,000 lb.	40,000 lb.	50,000 lb.	60,000 lb.	70,000 lb.	80,000 lb.	90,000 lb.
Red ironbark*	B_2 1	12·00	3·00	3·00	9·00	86,400	9,600	2,666,666	159	0·005	0·010	0·015	0·022	0·030	0·039	..	..	..
"	B_2 2	11·90	3·06	3·03	9·27	83,100	8,963	1,092,802	142	0·010	0·023	0·032	0·040	0·050	0·062	..	..	..
"	B_{16} 1	11·87	2·84	2·81	7·98	97,250	12,186	2,976,000	848	0·005	0·010	0·015	0·021	0·028	0·033	0·040	0·048	0·067
"	B_{16} 2	11·87	2·81	2·81	7·20	90,750	12,429	2,355,700	848	0·007	0·014	0·022	0·031	0·038	0·047	0·054	0·067	0·107
"	P_4 1	11·50	3·00	2·91	8·73	100,000	11,454	1,646,650	832	0·008	0·016	0·024	0·033	0·043	0·048	0·056	0·064	0·075
"	P_4 2	11·75	2·82	2·82	7·95	100,000	12,572	2,462,000	832	0·006	0·012	0·019	0·025	0·031	0·038	0·044	0·051	0·061
Grey ironbark†	B_1 1	11·80	3·10	3·03	9·39	99,200	10,558	1,033,732	218	..	..	..	..	..	..	..	..	..
"	B_1 2	11·90	3·09	3·08	9·52	93,000	9,772	..	218	..	..	..	..	..	..	..	..	..
"	B_{17} 1	12·00	2·91	2·90	8·44	77,250	9,154	1,422,000	848	0·009	0·018	0·025	0·033	0·040	0·052	0·064	..	..
"	B_{17} 2	11·87	2·80	2·82	7·89	90,200	11,423	1,671,300	848	0·009	0·015	0·023	0·030	0·037	0·044	0·051	0·062	0·085
White ironbark†	D_1 1	11·40	2·85	2·84	8·09	74,700	9,227	1,760,564	21	0·008	0·016	0·024	0·035	0·046	0·060	..	..	..
"	D_1 2	11·40	2·79	2·79	7·78	63,300	8,132	1,464,524	21	0·010	0·020	0·030	0·036	0·043	0·053	..	..	..
"	P_5 1	11·63	2·83	2·92	8·26	90,000	10,892	1,563,100	833	0·008	0·016	0·023	0·030	0·036	0·043	0·050	0·060	0·086
"	P_5 2	11·75	2·92	2·94	8·58	100,000	11,648	2,737,400	833	0·006	0·012	0·019	0·024	0·031	0·039	0·046	0·051	0·061

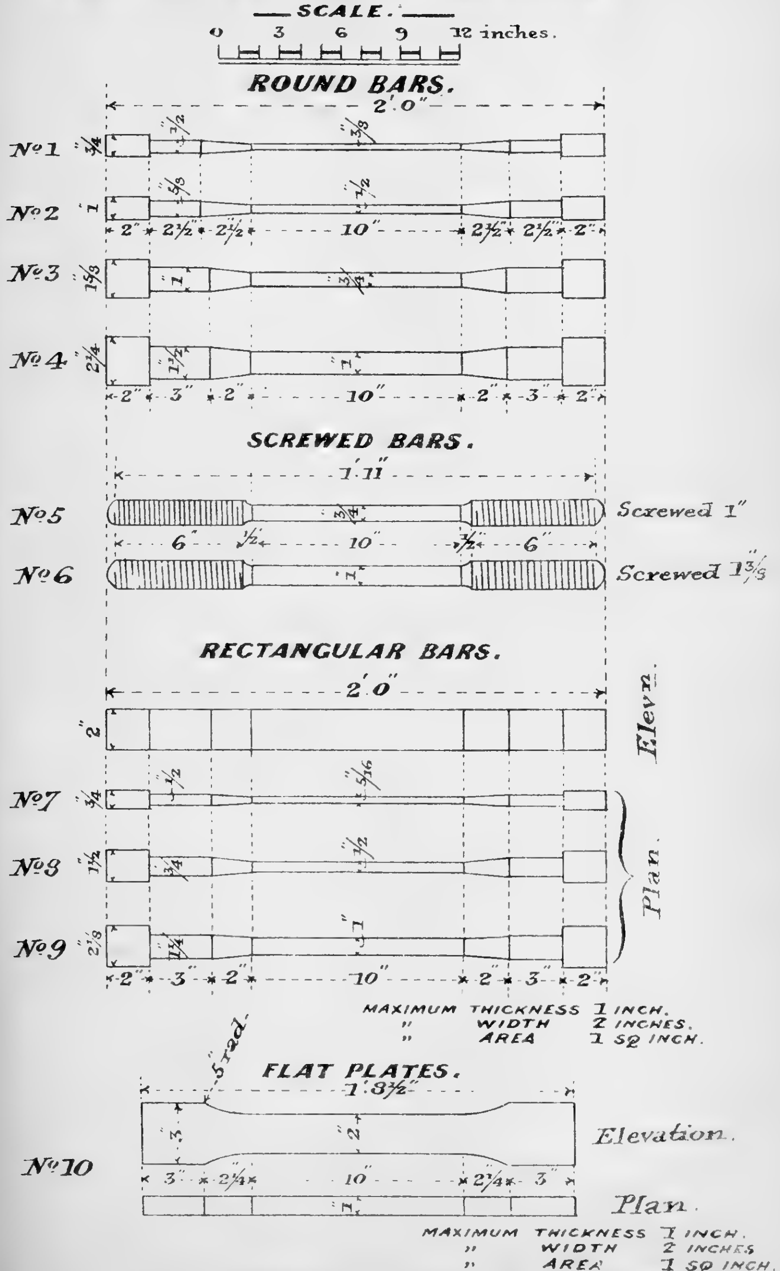
* Eucalyptus leucoxylon. † Eucalyptus crebra.

Tables Nos. III., IV., and V.

Test Number.	Description.	Original Dimensions.			Strain, in Pounds.		Strain, in Tons.	Limit of Elasticity.	Contracted Dimensions.			Contraction of Area per Cent.	Elongation per Cent.
		Breadth.	Thickness.	Area.	Total.	Per Sq. In.	Per Sq. In.		Breadth.	Thickness.	Area.		
	Table No. III.—Specimens of Steel.												
1	Mulwala Bridge, New South Wales[1] ..	2·071	0·325	0·67307	45,000	67,036	29·97	19·48	1·562	0·2125	0·33282	50·55	21·5
2	" " [2] ..	2·073	0·269	0·55763	55,763	61,421	27·42	17·45	1·534	0·1920	0·29453	47·18	22·5
3	Dalziel boiler steel[3]	2·315	0·448	1·037	65,000	62,777	28·02	15·00	1·84	0·34	0·6256	39·00	24·0
4	Krupp steel, shell of boiler	1·83	0·635	1·035	65,700	63,478	28·33	15·58	1·27	0·418	0·528	48·9	21·0
5	Hawkesbury Bridge pins, Dalziel steel[4] ..	0·87 diam.		0·5944	31,000	52,147	28·50	..	0·52 diam.		0·2123	64·0	28·5
6	Tire steel[5]	1·01	1·01	1·02	89,000	87,254	38·9	..	0·70	0·70	0·49	51·9	32·0
	Table No. IV.—Specimens of Iron for Roof over Centennial Hall, Sydney.												
1	Tie-rod[6]	0·898 diam.		0·633	33,250	52,527	23·40	15·0	0·745 diam.		0·4359	31·0	21·5
2	" [6]	0·886 diam.		0·616	32,500	52,759	23·50	15·3	0·740 diam.		0·430	30·0	19·5
3	Wind-bracing[7]	2·2	0·486	1·0692	54,000	50,505	22·54	15·2	1·92	0·432	0·8294	22·4	13·0
4	" [7]	2·2	0·486	1·0692	54,900	51,346	22·90	15·5	1·91	0·443	0·8461	20·8	19·0
5	" [7]	2·2	0·486	1·0692	53,000	49,569	22·10	15·2	1·91	0·440	0·8404	21·4	11·0
	Table No. V.—Specimens of Iron.												
I	Cut from broad gauge[8]	1·185 diam.		1·10288	55,500	50,323	22·46	11·09	1·04 diam.		0·84949	22·9	20·5
J	Axles sent from South Australia[9]	1·184 diam.		1·10179	50,800	46,139	20·6	10·16	1·06 diam.		0·91609	17·6	12·5
K	" " [10]	1·178 diam.		1·0899	53,200	49,905	21·83	10·36	1·0375 diam.		0·84541	22·43	20·0
L	" " [11]	1·172 diam.		1·0788	5,250	48,664	21·72	10·43	0·9225 diam.		0·68830	30·04	25·75

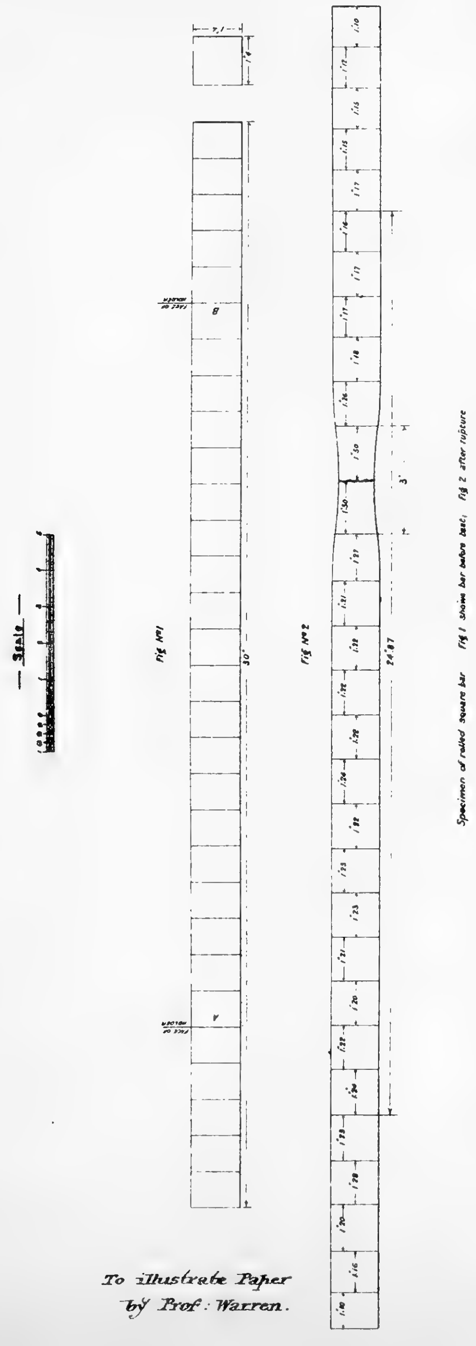
[1] Cut from L bar, 6in. by 3in. by $\frac{5}{16}$in. [2] Cut from boom-plate, 27ft. by 12in. by $\frac{5}{16}$in. [3] From furnace. [4] Cut from $7\frac{1}{2}$in. sq. ingot. [5] Elongation measured on 3in. = 0·96in. [6] Good fracture. [7] Slightly crystalline. [8] Fracture 90 per cent. crystal. [9] Fracture 55 per cent. crystal. [10] Fracture 40 per cent. crystal. [11] Fracture fairly good.

DETAILS OF TEST BARS
TO SUIT
UNIVERSITY TESTING MACHINE.

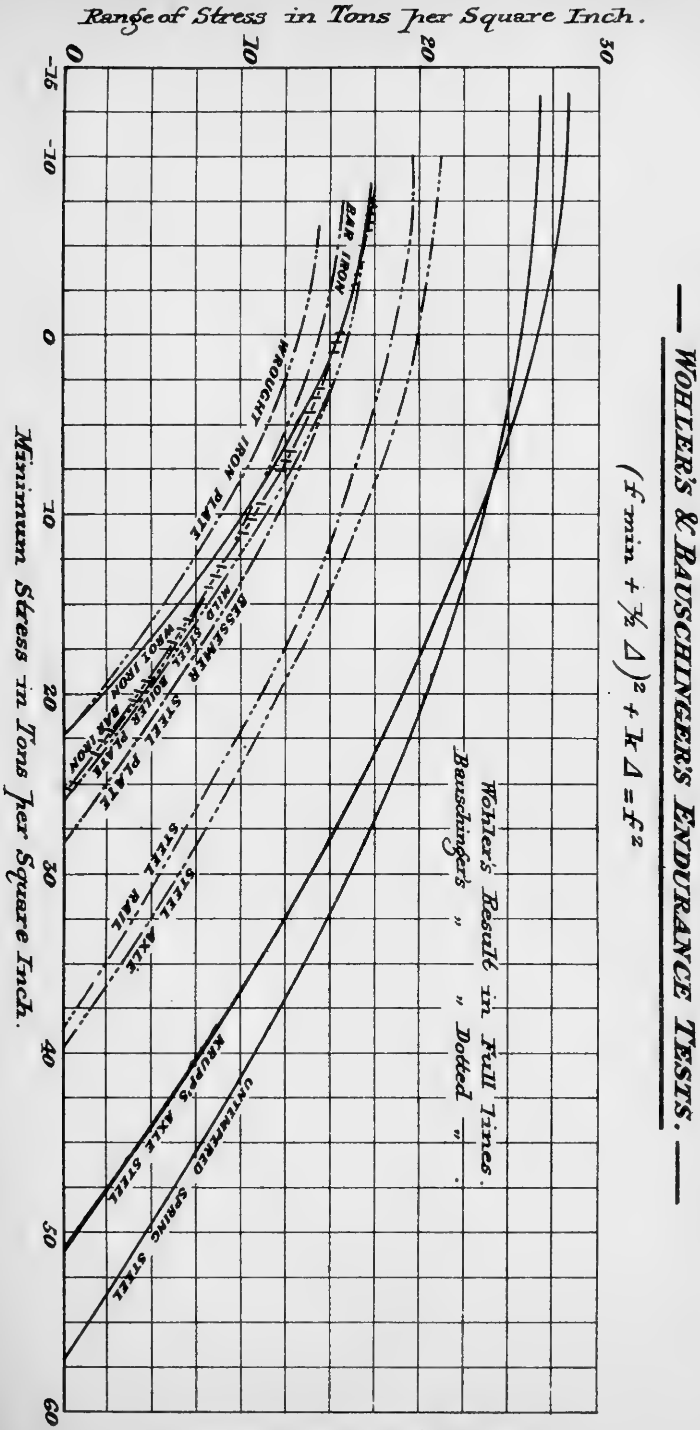


To illustrate Paper by Prof. Warren.

PLATE XII.



*To illustrate Paper
by Prof: Warren.*



To illustrate Paper by Prof: Warren.

COMPARATIVE DIAGRAM OF WEYRAUCH'S & BOARD OF TRADE RULES

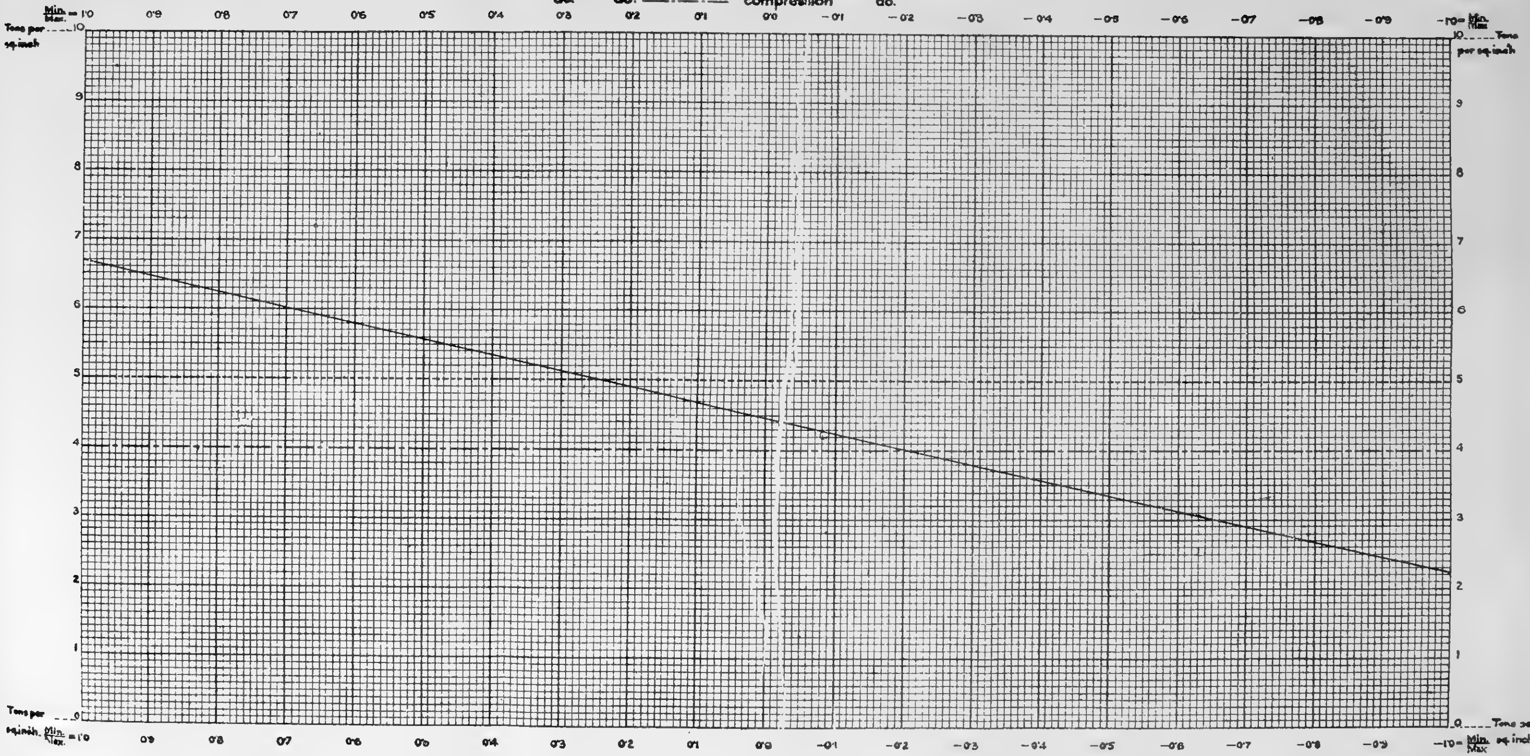
FOR THE

SAFE LOADS ON IRON

Black line gives safe loads for intermittent & alternating stresses for wrought iron giving an ultimate strength of 21 tons per sq. in. (Weyrauch)

Line dotted thus -------- tension (Board of Trade)

do. do. —·—·— compression do.



A. H. M. del.

NOTE. Factor of safety for black line taken as ⅓

To illustrate Paper by Prof: Warren.

[signature] Engineer for Bridges 24/12/90

Table No. VII.

(Roads and Bridges Department, N.S.W.)

Strength of Wrought Iron under Varying Stresses.

[Calculated from Weyrauch's Formula for Breaking-strength of 21 tons.]

	$\frac{min.}{max.}$			
When	= 1·0,	ultimate strength =	20·1	tons per square inch.
„	0·9	„	19·4	„
„	0·8	„	18·7	„
„	0·7	„	18·1	„
„	0·6	„	17·4	„
„	0·5	„	16·7	„
„	0·4	„	16·1	„
„	0·3	„	15·4	„
„	0·2	„	14·7	„
„	0·1	„	14·1	„
„	0·0	„	13·4	„
„	−0·1	„	12·7	„
„	−0·2	„	12·0	„
„	−0·3	„	11·4	„
„	−0·4	„	10·7	„
„	−0·5	„	10·0	„
„	−0·6	„	9·4	„
„	−0·7	„	8·7	„
„	−0·8	„	8·0	„
„	−0·9	„	7·4	„
„	−1·0	„	6·7	„

Note.—Ordinary factor of safety = $\frac{1}{3}$.

John A. McDonald,
Engineer for Bridges.

8/4/90.

Table No. VIII.

Material.	Opposite Stresses.		One Stress Zero.		Similar Stresses.		Range Zero. Ultimate Statical Strength.
	Least.	Greatest.	Least.	Greatest.	Least.	Greatest.	
Bauschinger's Endurance-Tests. Stresses requiring 5 to 10 million repetitions to cause fracture. Tons per square inch.							
Wrought-iron plate	− 7·15	+ 7·15	0	13·10	11·4	19·2	22·8
Bar iron ..	− 7·85	+ 7·85	0	14·4	13·3	22·02	26·6
Bar iron ..	− 8·65	+ 8·65	0	15·75	13·2	21·92	26·4
Bessemer mild-steel plate	− 8·55	+ 8·55	0	15·70	14·3	23·8	28·6
Steel axle ..	−10·5	+10·5	0	19·7	20·0	32·1	40·0
Steel rail ..	− 9·7	+ 9·7	0	18·4	19·5	30·85	39·0
Mild-steel boiler-plate	− 8·65	+ 8·65	6	15·8	13·3	22·55	26·6
Limits of Stress from Wöhler's Endurance-Test. Stresses in tons per square inch for which fracture occurs only after an indefinitely large number of repetitions.							
Wrought-iron plate	− 8·6	+ 8·6	0	15·25	12·0	20·5	22 8
Krupp's axle steel	−14·05	+14·05	0	26·5	17·5	37·75	52·0
Untempered spring steel	−13·38	+13·38	0	25·5	12·5	34·75	57·5

2. *On working Narrow-gauge Railways with Light Traffic in New Zealand.*

By J. P. Maxwell, M.I.C.E., Commissioner for Railways in New Zealand.

The peculiar conditions under which the New Zealand Government railways are situated in many respects, make it of interest to examine the expenses attending the transit of goods and passengers thereon, and to compare the results of working the principal groups. The large mileage of railway in proportion to the population, the location of the population along the coast-line mainly, the active competition of water-carriage against the railways at many points, the very short distances over which traffic can be carried, the importation by sea of the great proportion of mercantile products which are used by the population, the extension of the railways inland to mountainous and pastoral districts almost devoid of population, form a combination of circumstances adverse to the railway system such as probably has no parallel in any other country.

The comparison of the working results of different systems of railways, without any precise knowledge of the conditions under which they have been attained, or of the manner in which accounts have been compiled, is a common error, and one which leads to many erroneous inferences.

The conditions affecting railway operations are so complex that it is often difficult to draw correct inferences from data, even from results obtained from railways working in the same country and climate. Where the systems are in different countries, where nearly all the conditions differ widely, the difficulties are much increased. The rates of wages, the physical features of the roads, the durability of materials, the cost and economic value of fuel, the climate, risks from storms and floods, density of population, competition, the extent class and direction of traffic, the age of the lines, and many other factors affect results.

In Europe, where unskilled labour earns from 1s. 6d. to 2s. 6d. per day of ten or twelve hours, the population is very dense, distances traversed are short, and fuel and iron are cheap, the practice and results should be expected to differ widely from those in the United States, where unskilled labour earns a dollar a day of ten hours, fuel and iron are dearer, population is less dense, and the distances traversed are much greater. Still more widely must the practice and results be expected to differ from both these in our own colony, where unskilled labour earns still higher wages, and the working-day is eight hours, the population is very sparse and mostly located on the coast, while the lines terminate inland, mostly in mountainous pastoral districts almost devoid of population.

It is, however, quite common to see comparisons drawn between the practice and results in railway working in these countries, without consideration of the different conditions.

The United States railways are probably lower in the average expenses of working at per ton per mile than any other country, India excepted. It is probable that on the Indian railways goods results are lower; the Indian expenses per passenger per mile are certainly much lower. Great volumes of traffic, and great average distances of carriage, tend chiefly to give these low results per ton- and passenger-mile.

In order to contrast the differences between one of the great American railways and those of New Zealand, the following particulars of the New York Central Railway are quoted. This line extends from New York to Buffalo, on Lake Erie, 440 miles. The Port of Buffalo in one year passed through its grain-elevators 80,000,000 bushels of grain, four times the quantity produced in all New Zealand. A large proportion of this would be conveyed thence by rail:—

(1.) Miles of railway, 1,329.
(2.) Ton-miles moved, 2,155,000,000.
(3.) Average goods-train load, 177 tons.
(4.) Average distance per ton, 189 miles.
(5.) Tons of goods, 11,418,000.
(6.) Passenger-journeys, 14,662,000.
(7.) Passenger-miles, 476,000,000.
(8.) Average distance per passenger, 32 miles.
(9.) Average expenses per ton-mile, 0·26d.
(10.) Average expenses per passenger-mile, 0·61d.

In New Zealand we have as follows:—

(1.) Miles of railway, 1,726.
(2.) Ton-miles moved, 46,359,000.
(3.) Average goods-train load, 17 tons.
(4.) Average distance per ton, 28 miles.
(5.) Tons of goods, 1,645,000.
(6.) Passenger-journeys, 5,000,000.
(7.) Passenger-miles, 56,605,000.
(8.) Average distance per passenger, 11 miles.
(9.) Average expenses per ton-mile, 2·14d.
(10.) Average expenses per passenger-mile, 0·86d.

This is a sufficiently startling contrast, and will serve to show the enormous difference there is between such light-traffic railways as those we have to deal with, with our population of 600,000, and the railways which serve the great Continent of America.

As another example we may instance the Ohio and Chesapeake Railway, which carries nearly 1,000,000 tons of coal an average distance of nearly 298 miles, while it also carries 600,000 tons of through freight an average distance of 424 miles.

Now, we have no traffic in any way resembling this, nor are the physical conditions of the country such that a business like this is ever likely to arise, so far as we can judge at present.

What the United States railways pay in interest on their cost we cannot learn from any published statistics. So many millions of capital have been lost by investors in railways which have gone bankrupt, and have been sold for a fraction of their cost, that the present capital does not indicate anything like the whole cost. Large land-endowments and large subsidies have been granted to many companies, which further interfere with correct estimates being arrived at. The watering of stock also affects the question.

Where the State builds the railways it has to pay the interest on the whole cost. In many countries, where they have been done by private enterprise, private capital is sunk, and the State has not to bear the burden of unprofitable speculations. The United States railroads, on the average, earned 3 per cent. on present capital in 1889. The New Zealand railways shown in the tables earned 3 per cent. on their cost for 1889, but, for the foregoing reasons, we cannot compare these results on the same basis.

There are other material points connected with compilation of accounts which prevent comparisons on a common basis in many respects.

The "express traffic" in America, which covers parcels, small lots of goods, and perishable freight, is transported by the railways in bulk. Express companies generally receive, pack, despatch, and deliver such traffic. The cost of these operations is thus usually excluded from United States railroad statistics, while in our practice the work forms a material part of the railway service. Although express companies do business of this kind on a small scale here, the greater part of New Zealand merchandise-traffic is such as in America is done by the express companies.

The live-stock traffic in the United States is enormous. The practice in many cases is to waybill at a fixed weight per truck-load, which is largely in excess of the actual weight of live-stock carried. Tonnage quantities are thus swelled, and the cost per ton-mile appears correspondingly lower.

The ton used in United States computations is 2,000lb., and not the English standard.

It is the practice in many American companies' accounts to state the passenger and goods expenses separately. The apportionment is to a large extent arbitrary. Each railway has until recently followed its own method of computation. The labours of the Inter-State Commerce Commission during the past three years have resulted in more uniform methods of apportionment being adopted, so that among the American managers those persons who are intimate with the conditions under which different lines are worked, and the methods of computation of accounts, will be in a position to judge of results.

Sleeping- and saloon-cars are largely run in the United States, for which independent charges are made by separate companies who own them. The revenues and expenses of such companies are really railway revenues and expenses, but they do not appear in the railway accounts.

The terms "ton-mile," "passenger-mile," and "train-mile" indicate merely the distance moved in each case; they give no indication of the work performed due to overcoming the resistances of gravity or friction.

The English railway companies give no data such as the American. The utility of such details does not seem to be generally admitted among English managers.

Those who are interested in such matters will find Mr. E. B. Dorsey's book on English and American railways compared an admirable and interesting work. Mr. Dorsey is compelled to resort to laborious estimates of English working results in order to compare with American statistics. The careful student of such subjects will be impressed with the fact that no sufficiently-accurate data about English working are recorded to allow of very reliable inferences being drawn from the comparisons.

The primary object of railway working statistics is to enable the professional men in charge of the operations to judge of and control the expenses of working and the operation of the traffic.

As an instance of the error into which capable writers are liable to fall when unacquainted with the details of their subject, a recent article in the *Nineteenth Century* by Mr. Jeans may be quoted. This writer quotes from statistics the total tonnage carried on American railways by all the companies, divides it by the population, and deduces the "tons per head." Now, it is well known that there are numerous companies in America, and that the volume of through traffic is counted by millions of tons. Each company counts each ton of its through traffic as its own quite properly. But if we erroneously take all the companies' tonnages and add them together we get an exaggerated view of the aggregate traffic of the railways which is useless as a measure of the whole business. Similarly the "through traffic" prevents our knowing the average distance which goods are hauled in the aggregate. Each separate railway is correct in stating its own average, but no correct average can be stated for the United States railways as a whole. Similar errors have occurred in the local Press about Victorian statistics. Victoria divides its railways into four systems in accounting. If a ton of goods or a passenger passes over two or more systems in transit it would be reckoned as many times. Out of a total tonnage of 4,000,000 shown in the Victorian statistics 1,000,000 tons are shown to be reckoned more than once for the year 1889–90, and 12,000,000 out of 71,000,000 passengers are similarly treated.

A high cost per ton-mile is inseparable from a light short-distance traffic. It is interesting to consider the causes which lead to this result. On railways with large enough traffic, continuous working throughout the twenty-four hours prevails — every part of the railway machinery is fairly well utilised; while with a light traffic and population, such as we have, the trains are run on the busiest parts only about sixteen hours a day, and on the remotest parts once a week only. These lines, then, are not, on the average, a fourth part utilised. On the average, the running-time of a truck is not more than one hour in twenty-four. The small number of trains which the light traffic and population admits of conduce to this. The excessively short average distances also make the expenses due to shunting relatively very high.

Owing to the direction of the traffic, the average non-paying load per waggon in New Zealand in proportion to the paying load is as 2 to 1; on the great American railways it is stated to be as 2 to $1\frac{3}{4}$.

The low average paying-load obtained in New Zealand is because all the heavy traffic—namely, timber, grain, coal, firewood, live-stock, meat, &c.—is towards the ports, where the population is concentrated. A very moderate traffic in small lots of goods of a few hundredweight each forms the greater part of the return traffic. A business which takes full train-loads of goods hundreds of miles, so that the running-time of its rolling-stock is probably half or three-quarters of its life, results in excessively low expenses for trucks per ton-mile. Similar remarks apply to locomotives. Running light loads, with long standing hours, leads to very high expenses compared with cases where continuous work, with full loads, is obtainable.

A locomotive capable of taking a 100-ton load costs as much in running-wages as one which will draw a 500-ton load.

When the traffic and population are very small, so as to warrant purchasing and working the smaller locomotive only, other things being equal, the traffic in 100-ton loads will cost five times as much per ton-mile for locomotive-running wages as a traffic carried with the larger engine.

The illustration previously given will serve our purpose here. The New York Central Railway carries loads on the average ten times greater than the New Zealand railways. Other things being equal, the expense of locomotive-running wages per ton per mile will be ten times greater on the latter than on the former: other things are, however, not equal; the average distance on the former is for goods carried eight times that of the latter, so that the New York Central would have other advantages, through the more continuous use of its locomotive-power and railway. Other running-wages are similarly affected.

Station, terminal, and fixed expenses, when averaged at per ton per mile on so short an average run as twenty-eight miles, are very high. The terminal expenses on account of stations, trucks, locomotives, labour, machinery, management, &c., on the average amount to 2s. per ton for New Zealand; they thus average nearly 1d. per ton per mile on the average haul. Such expenses, therefore, when compared on the ton-mileage basis with the operations of railways which do a long haulage traffic, present an unfavourable appearance, though they are not high in the total amount.

Having corrected the figures for the difference between the American ton and the English standard, we have obtained an approximate idea of the relative loads carried; but there remain discrepancies which we cannot eliminate, owing to rule-of-thumb practices in counting truck-load weights of live-stock and lumber.

In distances we get a fairly approximate result in both cases. With passengers the same difficulties do not prevail, and we get a fair comparison of the passenger-mileage and the average distance carried by each separate railway; but the average distance carried for the American railways in the aggregate cannot be stated, owing to "through" traffic.

There are many difficulties attaching to the apportionment of expenses per ton-mile and per passenger-mile. The practice now followed by the advice of the Inter-State Commerce Commission in America cannot be followed here, because, owing to our very light traffic, nearly all the New Zealand trains run mixed, and the staff for the most part performs mixed duties. In dealing with this point the author has adopted the plan of apportionment based upon the gross load carried per ton of goods and per passenger, which has been arrived at after a careful consideration of the truck- and carriage-mileage and the quantities of traffic.

The divergencies in passenger-traffic between the New Zealand railways and the American example quoted are small relatively to those of the goods-traffic. Our passenger-traffic is large for our small and scattered population. The passenger-mileage is greater than the ton-mileage, while on the American roads it is only from one-seventh to one-twelfth. The New Zealand expenses do not differ materially from the American per passenger-mile. The average fare is also much the same.

One object of this paper is to draw attention to the character and extent of our light railway traffic in contrast with that of other railways, where the population and traffic are very large, or where the distances carried are considerable, so that the subject may be considered on its proper level. It is very difficult for those of the general public who are familiar with railways in the older countries to understand why the refinements, luxuries, speeds, and cheap services obtainable there are not also attainable here. English and American railway-managers are sometimes startled to find a system of over seventeen hundred miles of railway on which trains do not run continuously through the twenty-four hours, and they do not appreciate the lightness of traffic, which makes such a practice out of the question.

The economies in all processes of working and in accommodation which are essential in a colony, such as this, where the mileage of the railways has in many parts outrun the capacity of the population, to utilise them profitably, are unknown to the workers of railways in the older countries, where the denser population and great manufacturing industries demand an entirely different treatment. High speeds, gas and electric carriage-lighting, continuous brakes, separation of traffic, carriage-warming, baggage-checks, and many other luxuries, must be foregone where population is very sparse, grades are steep, and rails are light, and where at least one-half of the stations are without any resident clerk or other officer, on account of the traffic being insufficient to justify the payment of one man's wages per annum. It is not difficult to realise that the traffic must be very light if it is considered that the population only averages six per square mile, and in many parts where railways have been built there is probably not one inhabitant to the square mile over large areas.

Private investors would not venture to build railways where one train per week is more than is needful for the traffic, or where two or three very small trains a week are all that the traffic of the district warrants.

Some years since the author introduced in New Zealand the practice of recording the ton- and passenger-mileage and the average distances and loads on the five chief sections of the New Zealand railways for professional purposes, and, as the accounts and other operations are conducted upon the same basis, fairly accurate comparisons may be made, and the results explained.

The character of the rolling-stock is now tolerably uniform. The carriages, for the most part, in use are of American type. The goods-stock is mostly four-wheeled, that being best adapted generally to the light traffic. A certain proportion is of American type. A capacity of 6 tons to a non-paying load of 3½ tons is general, and in the American types a capacity of 16 tons to a non-paying load of 7 tons. All the stock has oil-boxes.

The locomotives, for the most part, are small types of engines, fit for light traffic on steep gradients, with sharp curves from 5 chains radius upwards. As a rule, they have under 20 tons on the coupled wheels. The heavier types are eight-wheel coupled tender-engines, with as high as 27 tons on the coupled wheels, suitable for minimum curves of 7½ chains radius. The use of bogies, compensating levers, balanced slide-valves, and sight-feed lubricators has been generally introduced. American or Russian oils are chiefly used for lubricants. The average mileage per engine is about 14,000 miles per annum—a very low result, due to short services and long-standing hours. The average cost per engine-mile for all locomotive expenses is 9·55d. This average includes the Fell engine services on the Rimutaka incline of 1 in 15, which has a centre rail for about two miles and a half. The Fell engines weigh 36 tons, and draw a gross load, exclusive of their own weight, of 70 tons up 1 in 15 at about five miles an hour. These engines ran 17,900 miles in one year, being 624 days in steam, and costing 3s. 10d. per engine-mile.

Methods of working are uniform throughout the colony. Unskilled wages cost 6s. 6d. and skilled wages 8s. to 10s. 6d. per day of eight working hours.

The extreme speed of trains between stations is fixed at thirty-six miles per hour.

The Winter block-system is in use on certain parts of the lines where the traffic and other circumstances make it necessary.

The rails are, for the most part, of 40lb. iron and 53lb. steel. Some 30lb. rails have been used on branch lines. All renewals are made in 53lb. steel.

Structures and buildings are chiefly of wood. Combined wood and iron bridge-trusses are largely used. The bridging is very extensive in some instances, as in the Rakaia, Rangitata, and Waitaki, the river-beds being nearly a mile in width.

There are no difficulties from frost or snow, but extensive floods have to be dealt with occasionally.

The cost of improvements in renewing iron rails with 53lb. steel rails, in reconstructing improved types of rolling-stock, and more permanent structures is borne by the working-expenses. This makes the expenses appear heavier than they otherwise would do.

The average age of the lines is a little over twelve years. The full average cost of renewals will not therefore be reached under three or four years more. The cost of renewals of rails and sleepers and new works is about one-third of the whole cost of the maintenance of way and works.

The expenses of maintenance of the railways under consideration, of £127 per mile, must be considered very low under these circumstances.

The average number of hands employed is two and a third per mile in all departments. The stations are very numerous, more so than the traffic justifies; about one-half of them only are manned.

We can now proceed to consider the particulars of sections separately.

The Napier line is fairly straight, and it has no gradient steeper than 1 in 45. It penetrates into a fertile country, in which settlement is rapidly extending. There is no water-competition, and there are no non-paying branches. The climate and country are such that it does not suffer from storms or floods. The products of the country are timber, firewood, wool, live-stock, meat, and dairy-produce. There is no mineral traffic. Coals are sea-borne. Good steam-coal is delivered at Napier at about £1 4s. per ton. This line, which has cost £6,760 a mile, has earned 5 per cent. on its cost. It presents an example of the results obtainable from a line fairly located in a good country, and not placed in direct competition with water-carriage, nor burdened with short branches which cannot be worked to advantage. Its goods-traffic is carried a long average mileage, and its locomotive-power and rolling-stock are thus advantageously utilised.

The Wanganui Section has many steep gradients and sharp curves; the maximum gradient is 1 in 33. They are so situated as to form a considerable barrier to rapid transit, and to make the locomotive charges high. It traverses a district as fertile and productive as the Napier line does, but it follows the coast closely, and has numerous small ports, which introduce water-competition, a condition which, while advantageous to the settlers, does not conduce to the prosperity of the railway. The population is mostly concentrated near the ports. As a consequence, the average distances of the traffic and the loads obtainable are very small. The traffic consists of timber, wool, firewood, live-stock, meat, and dairy-produce. There are no minerals. Coals are delivered at the ports at about £1 4s. per ton. It is separated from the chief seaport, Wellington, by the intervention of a private railway. All the conditions tend to make the traffic small, the distances carried short, and, consequently, the expenses per ton high. It was at one time contemplated to make this line the main railway route between Napier, Wellington, Wanganui, and Auckland, but the colony has, fortunately, otherwise decided. The unfavourable character of the line, and the additional distance, would have effectually prevented its being of service in this capacity. A central route has been selected in preference.

The Auckland Section has a large proportion of its length in unsettled country, with little or no traffic upon it, and it has some water-competition in addition. There is a mineral traffic in brown-coals, which form the local fuel-supply, and are used for locomotive purposes, but they are very little used for steamers. There is a light traffic in agricultural and pastoral products. The maximum gradients are 1 in 40. Were it not that the line extends so far into unsettled districts, the expenses per ton- and per passenger-mile would not be higher on the average than they are on the Napier Section.

The Wellington line has a traffic similar to Napier and Wanganui. It crosses a mountain-range in a distance of about eighteen miles, with gradients of 1 in 33 and 1 in 40 on the port side, and 1-in-15 gradient, worked on the Fell system, on the inland side, and against the chief traffic. This part of the line has 5-chain curves. The high rate of the expenses is chiefly due to this feature, which entails a great expense in locomotive-power, and, in a lesser degree, to the working of a four-mile branch. There is no mineral traffic. Coals are delivered by sea at Wellington at about £1 per ton.

The Hurunui-Bluff Section has flat gradients in the northern and southern portions, and maximum gradients of 1 in 50 with 7½-chain curves in the central part. It has several brown-coal and lignite mines. The brown-coals are used for locomotive purposes largely. They cost from 7s. 6d. to 8s. 6d. at the pit-mouth. The traffic is chiefly in grain, wool, live-stock, timber, firewood, meat, and dairy-produce. It has numerous short branches, on which the traffic is very light generally, due to the fact that the inland country they penetrate is, for the most part, pastoral and but very sparsely populated. It has several ports, around which the population is chiefly concentrated, and, as a consequence, the distances that traffic is carried are, on the average, very short, being below the general average. The maintenance charges, due to the long and expensive bridges, are somewhat heavy, and they are also increased by the liability of parts of the line to damage from floods.

Although there has been a gradual decrease in the expenses per ton-mile and per passenger-mile for some years past, this improvement is slow, because of the continual further extension of the railways into unsettled or pastoral country almost devoid of population, the expenses of which neutralise the economies elsewhere.

That railways with such light traffic as we have in New Zealand can be profitably worked is shown by the results obtained on the Napier line. If lines are intended to be financially successful they must be so located, both with regard to the class of country they are to serve and the competition they are to face, as to allow of a reasonable traffic being obtainable. Lines connecting seaports at short intervals apart, and serving only very limited areas of country, are not likely to prove financially successful; neither is any line entering a country which cannot furnish traffic to give one train-load a day.

Railways have been pushed on rather in accordance with a popular sentiment that it is a good thing to do for the settlement and development of the country than on the ground that any present direct profit is to be got from them. On most of the extensions which have been carried out of late years no profit in working could be looked for in the immediate future.

As railways continue to be extended into unpopulated country, the expenses measured at per ton-mile and passenger-mile must be high, even with the most parsimonious administration and the curtailment of conveniences and luxuries.

A practical cessation from railway building until the colony has largely increased its population would lead to a lower rate of expenses on the larger volume of traffic which would be obtained. A larger population would command a lower rate of expenses, lower charges, and greater conveniences, without necessarily impairing the financial results.

The following tables give a summary of the cost of construction, revenue, working-expenses, and statistics of the different sections of the New Zealand railways:—

TABLE 1.

Section.	Miles open.	Train-miles.	Mixed Passenger and Goods. Ton-miles.	Expenses. Way and Works.	Per Ton-mile.	Loco-motive-power.	Per Ton-mile.	Carriages and Waggons.	Per Ton-mile.	Traffic.	Per Ton-mile.	General Charges and Sundries.	Per Ton-mile.	Total.	Per Ton-mile.
				£	d.	£	d.	£	d.	£	d.	£	d.	£	d.
Auckland	254	341,113	8,177,770	29,242	·86	15,243	·44	7,092	·21	19,153	·56	3,025	·09	73,755	2·16
Napier	97	209,028	4,963,864	12,178	·59	8,463	·41	3,450	·16	8,277	·40	1,840	·09	34,208	1·65
Wellington ..	91	229,396	4,516,965	12,225	·65	15,748	·84	5,659	·30	9,533	·50	2,400	·13	45,565	2·42
Wanganui ..	215	255,208	4,553,668	24,001	1·27	14,247	·75	6,284	·33	11,426	·60	2,458	·13	58,416	3·08
Hurunui-Bluff ..	1,069	1,637,396	46,789,728	142,145	·73	91,457	·47	36,651	·19	117,107	·60	16,933	·08	404,293	2·07
Totals ..	1,726	2,672,141	69,001,995	219,791	·76	145,158	·50	59,136	·20	165,496	·58	26,656	·09	616,237	2·14

Section.	Goods. Tonnage.	Goods. Ton-miles.	Goods. Average Distance carried, in Miles.	Goods. Average Load per Train-mile, Tons.	Number of Passenger-journeys.	Passenger-miles.	Passenger-journeys. Average Distance in Miles.	Expenses per Passenger per Mile.
								d.
Auckland	133,677	5,630,732	42·12	16·51	600,834	6,367,594	10·59	·86
Napier..	81,263	3,283,926	40·41	15·71	322,010	4,199,847	13·04	·66
Wellington	93,280	2,587,093	27·73	11·28	524,759	4,824,681	9·19	·97
Wanganui	91,613	2,238,309	24·43	8·77	292,918	5,788,397	19·76	1·23
Hurunui-Bluff	1,245,473	32,619,576	26·19	19·92	3,260,341	35,425,380	10·86	·83
Totals	1,645,306	46,359,636	28·17	17·35	5,500,862	56,605,899	11·31	·86

TABLE 2.

Section.	Miles open.	Cost of Construction.	Net Revenue.	Rate of Interest.	Per Cent. Expenses to Gross Revenue.
		£	£	£ s. d.	
Auckland ...	254	1,898,964	28,351	1 9 10	72·77
Napier ...	97	656,164	34,214	5 4 3	50·17
Wellington ...	91	1,050,095	25,623	2 8 10	65·02
Wanganui ...	215	1,512,352	23,919	1 11 7	71·98
Hurunui-Bluff	1,069	7,805,935	276,016	3 10 9	59·11
Totals ...	1,726	12,923,510	388,123	3 0 0	62·88

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3. *Steep-grade Inclines on Mountain Railways.*

By ROBERT WILSON, F.R.S.E., M.Inst.C.E.

THE study of physical geography shows that, with few exceptions, plains or valleys, with a more or less varying rise from the sea-coast, penetrate into the heart of the wildest hill-country, the inclination of the ground becoming steeper as the recesses of the range are penetrated. The rise of the ground is most abrupt, often ending in precipitous faces of rock, or steep bluffs of softer material, when nearing the saddles or dividing-lines of the watershed at which these valleys culminate. This almost universal feature is taken advantage of in laying out roads and railways through a mountain country: the solid, or sound ground, which is to be usually found on the banks of the rivers traversing these valleys is naturally chosen for the location of such works, and, in the instance of a road, this permanent ground may be sometimes adhered to even to crossing the highest point on the saddles.

But this is rarely possible in locating a railway-line, as the satisfactory limit of grade is about 1 in 40 for any ordinary locomotive engine depending for its haulage-power on the adhesion between the driving-wheels and the rails. As the declivity of the valley increases beyond this grade, which is usually the case some miles from the dividing-ridge of the watershed, the location of the railway must of necessity leave the bottom of the valley and be taken on to the side of the hills rising from it; otherwise the line would run to earth at a point which would necessitate a tunnel of abnormal length and cost, such as to render the construction financially impossible.

The disadvantage of locating a line on the hillside instead of on the river-flats is obvious, as in one case spurs often break up the line of the hill, which have to be curved round, cut, or tunnelled through; tributary streams fork out as they traverse the hill-slopes, necessitating more numerous culverts or bridges; and the larger tributary streams often cut deep ravines in the hillsides, which must be crossed by means of long, high, and costly viaducts, or by high earth embankments over expensive culverts. Further difficulties may be met with in the form of loose unstable ground, such as is seen on the mountain-sides in New Zealand, forming the well known "shingle-slides," which may have to be crossed by bridging, or, better, tunnelled under in the sound ground behind.

The line on the hillside, from the nature of its position, is liable to heavy slips of rock or other material loosening from the hillside above. These slips may carry away important works, or block the line, and entail heavy charges for maintenance and loss from stoppage of traffic. The line constructed on the river-flats is free from many of these dangers, and experience shows that the cost of construction is, together with the charges for maintenance, much less in proportion.

Such important differences affecting the financial prospects of a mountain railway have met with due consideration, and have led to the introduction of steep inclines worked with special auxiliary power, the location of the purely adhesion line being in this case on the low sound ground as long as possible, thus concentrating the difficulties of construction and haulage into certain sections, which can be treated specially. This system of location is becoming more generally accepted as the rational method in which to construct railways passing through and over a mountainous district.

One of the earliest and most successful examples of the use of steep grades, with auxiliary power, for surmounting exceptional heights, is the San Paulo railway in Brazil. In this instance the steep grades are worked by means of a rope actuated by fixed engines. The trucks are attached to the rope, and are thus drawn over the steep-graded portion of the line, and are afterwards hauled on their further journey by the ordinary adhesion locomotive engine.

The San Paulo incline has a gradient of 1 in 9·75, and mounts a height of 2,650ft. in five miles; it has been in work for twenty years without the loss of a single life; during this time 2,600,000 passengers and 4,000,000 tons of goods have been carried up and down the incline, giving a yearly average of 130,000 passengers and 200,000 tons of goods. The line has been equally successful financially.

There are objections to rope-haulage, as it necessitates a line with curves of large radius, and when these are obligatory in a hilly country considerable additional cost is incurred in construction. Again, the ropes can only haul a given number of trucks in a given time, and the stationary engines are a fixed power, limiting the amount of traffic which can be carried over such a road; and, if development of future traffic is provided for, it means an increased first outlay in the plant put down, without an equivalent return until the anticipated development is attained.

The Fell system of engine to work on steep grades was introduced some years ago, and in a measure overcomes the objections of the rope-traction system in so far that the development of traffic can be met by additional rolling-stock; and, moreover, the curves employed need not widely differ from those of the ordinary adhesion lines. These engines have been at work some years on the Rimutaka incline, in the North Island of New Zealand, being a part of the Wellington and Masterton railway. This incline has done good service, although subjected to much adverse criticism by many not fully conversant with the theory and practice of the system of traction. The Fell engine has, as an auxiliary power, two cylinders which work horizontal driving-wheels fixed under the engines. These wheels are held in contact with a special centre-rail by the adjustable pressure of springs. The engines have their haulage-power augmented by this further adhesion due to the pressure of these horizontal driving-wheels, and are thus enabled to take a greater load up the steep gradient of 1 in 15 than they could otherwise do. The Rimutaka incline has been called by some a costly toy, but this statement is refuted by the actual cost of working the section.

On referring to a report made by the author—then Joint Consulting Engineer to the Government of New Zealand in London—on the proposed Abt system for Arthur's Pass, on the New Zealand Midland Railway, it is therein shown that by the Public Works Statement of 1888, Return 44, the cost of working the Wellington and Masterton section, with the Rimutaka incline included, was 49·37d. per train-mile; and the average cost per train-mile throughout the colony, by Return No. 8, was 56·02d. per train-mile; 13·02d. being the locomotive-cost, as against 44·14d. the locomotive-cost on the incline. To get a fair comparison, the height surmounted by the different grades in a given length must be taken into account; so that, if a 1-in-60 grade had been adopted instead of the 1-in-15 on the incline, the development, or increased length, required to reach the same height would be four times as great.

Take, for argument, 13·02d. as the engine-cost per train-mile on the 1-in-60 (and it must be remembered that 13·02d. is given as the average cost throughout the five chief sections of railway in New Zealand, and no doubt the average grade would be much below this—probably under 1 in 120): to reduce the cost of working the Fell engine per train-mile to the average cost of the ordinary engines per train-mile on the five chief sections, on the assumption that they work throughout on an average of 1-in-60 grade, 44·14d., the engine-cost per train-mile of the Fell engines, must be divided by 4, which equals 11·035d. per train-mile, as against 13·02d., the average cost per train-mile as before stated.

Reducing the problem of a long easy-grade line *versus* short steep grades and low-grade approaches down to first principles, it will be remembered that the mechanical energy which must be expended in raising a weight through a given height is equal in amount if the weight is raised by means of a long inclined plane, or lifted directly through the given vertical height equal to that reached by the inclined plane. This fact eliminates any question of total energy expended in the two systems, beyond that of increased friction due to distance, which is in favour of steep inclines, and reduces the question to one of efficient application of working details and the cost of construction and maintenance, by the two methods of locating and working a mountain railway.

Since the introduction of the Fell system, which has the defect of being, like the ordinary locomotive, dependent entirely on adhesion for its haulage-power, and therefore suffers in efficiency from climatic changes, there has been a great stride made in working steep-grade inclines. These improvements are embodied in the Abt system, of central rack, and rack-engine. This motive-power has long passed the period of doubt or theory, having stood the test of some years' practical working. This special method of traction for inclines is the invention of Mr. Roman Abt, of Switzerland.

Briefly, the leading features of the system are, the form of rack-rail, which is fixed between the ordinary carrying-rails, and is built up of a number of individual elementary racks placed side by side. Each one of these is of the simplest form, being a bar of steel with teeth cut in one edge. Each rack can bear safely a certain strain, and the number is increased in proportion to the duty required.

These individual racks are laid so that the pitch of the teeth is stepped, or what is technically termed "staggered," the teeth of one bar being slightly in advance of the teeth of the next, and so on. The teeth in the engine-pinion are made to correspond to those in the rack-bars, and are also stepped, producing a simultaneous contact of several teeth, which increases the security against fracture of an individual tooth; and, even if this should arise, from any exceptional cause, it would not be followed by any serious consequences.

The component bars of the Abt rack are laid with broken joints, and in this way the rack-rail becomes practically one continuous structure, there always being one or more whole bars at the point of junction between the ends of any two lengths in one line of bars. Moreover, the breaking of joint in the rack allows of equalising throughout the length the influences of expansion and contraction through variations of temperature. These racks are secured to chairs which keep them in a fixed position, but allow of any individual bar being taken out and replaced in a few minutes.

The pinions of the engine are constructed with as many separate discs as there are separate rack-bars, each disc corresponding to one line of these. They are provided with teeth corresponding to the pitch of the racks, and they are stepped in relation to the teeth in each to correspond with the broken pitch of those in the rack. These pinion-discs are in elastic contact with the shaft actuating them. This is obtained by means of springs, through which each of these discs obtains a small relative motion to each other, allowing of any slight adjustment in case of irregularity of pitch in the teeth of the rack-rails, thus producing a perfectly automatic contact of the teeth. Curves of any radius within the limits of application to railway-construction can be laid with the rack. The same bars are used on the straight as on the curved line. The auxiliary power is in the form of pinions driven by separate cylinders worked independently of those moving the ordinary adhesion driving-wheels with which the engines are fitted; so that, whatever the condition of the road may be, or however much the adhesion wheels may slip from climatic changes, the pinions work steadily on, and raise the load by means of the fixed racks. This is one of the important features of this system: as the pinions are working in the rack, thus the motive-force becomes a given power working against a fixed resistance, and is in no way influenced by the condition of the atmosphere, as is the case with the ordinary engines, in which the adhesion varies according to the state of the rails.

Rack-rail locomotives can be built of specially large tractive power by coupling two or more driving-pinions one behind the other; and experience shows that, by placing one of these coupled pinions a little in advance in reference to the time of contact with the teeth of the rack, coupling heightens the uniformity and smoothness of motion.

One of the most ingenious features of the Abt system is the arrangement by which the engine-pinions enter or leave the rack sections of line without entailing any stoppage of the train.

This is a necessary feature, as these engines run over the ordinary road by means of their adhesion wheels, and only bring into use the auxiliary power on the steep-grade sections.

This entering-tongue is built up of a series of bars corresponding to those in the rack, about 10ft. long, hinged at the end which joins the continuous rack, and rests upon strong springs, usually of the volute form. The teeth in the portion at the hinged end are the same as in the permanent rack, but are gradually diminished in height towards the outer end, by planing the top of the teeth away in a taper form, giving the tongue a wedge shape; so that, when the pinion passes on to the movable portion, the teeth of the pinion or pinions slide into the increasing depth of teeth, the bar yielding until true contact is obtained. This arrangement, as might be expected from its simplicity, never fails in action, and the train enters the rack section, at five or six miles an hour, without any apparent blow or noise. The pinions are caused to revolve in the direction the engine is travelling at a slow speed before the entering-tongue is reached.

On entering the rack sections the adhesion machinery continues to work as before; the driver, having already started the auxiliary engines, has only to adjust the regulator to meet the required power. On leaving the rack sections steam is shut off from the auxiliary cylinders, and the adhesion wheels once more become the only motive-force employed.

On these steep-grade sections the engine developes the full power by adhesion and by the rack pinion; there are therefore four beats of the exhaust in place of the usual two, and this has the effect of increasing the draught through the fire-grate, and thereby increases the steam-raising power of the boilers at the time when a large quantity of steam is required. The ordinary engine going up a bank has its speed reduced by the increased resistance, and, the blast from the exhaust being less frequent than when running on low grades at a higher speed, the boiler is less capable of maintaining the steam-pressure when it is most required.

The descent of long adhesion grades is a source of danger in weather producing greasy rails, and to meet this condition powerful brakes must control the descending train. The brake arrangements on the Abt engines are most efficient, reducing the danger of the descent of steep grades below that of descending on ordinary long adhesion grades. There are first the ordinary steam-brakes on the adhesion driving-wheels of the engine, and the vehicles are fitted with one of the continuous brakes now largely used on most railway systems in Europe. In addition, there are the brake-discs on the pinion-shaft, by which the pinion can be completely locked, and the train held stationary at will.

The braking on the down-grades, to allow the train to descend at the required velocity, is done by using all the four steam-cylinders as air-compressors by reversing the engines, there being a special provision of valves for this purpose, similar to the Chatelier arrangement; and, to quote the words of the late well-known American engineer, Mr. W. W. Evans, "this is the most perfect brake imaginable." The wear-and-tear is greatly reduced, as the sliding and rolling of the teeth of the pinions, which in the descent act mainly as the controlling power, work against the smooth, well-greased surface of the rack-rail. The racks and pinions, being, as before remarked, a fixed resistance and fixed power, give absolute control of the train. By this means it can be stopped in its descent at any point, or its motion reversed, on the steepest gradients, reducing the risk of accidents to a minimum; and passengers may travel up and down the steep inclines feeling assured that there is less danger on these sections fitted with the Abt system than on an ordinary gradient.

This Abt system is employed on the Hartz Mountain railway, the rack gradients being 1 in 16·67; on the Oertelsbruch and Lehesten line, rack section 1 in 12½; Oertelsbruch quarry line, 1 in 7·3; on the line from Eisenerz to Vordenburg, in Styria, 1 in 13·3, with an annual traffic of 320,000 tons of heavy goods, besides passengers; also on the Visp–Zermatt railway, in Switzerland, 1 in 8·33 (this line carries passengers exclusively, and has six different rack sections); the Puerto Cabello and Valencia railway, in Venezuela, incline 1 in 12½. The Transandine railway, in South America, under construction, will have about eighteen miles of rack upon it, divided into several sections. I have received information by the last English mail that the Japanese Government have decided to use the Abt system for an incline of five miles in length on the Warin Togë railway, and also that the Neilgherry railway, in India, is to be built with a gradient of 1 in 15.

The history of the Puerto Cabello–Valencia line is a practical proof of the success of the application of a steep grade in conjunction with low through-grades. The original survey for this line from the seaport to Valencia was laid out as an ordinary adhesion railway, and to obtain the required grades the line followed the contour of the hills, gradually rising to the table-land upon which the city is situated.

The estimates for the adhesion line reached such a figure that it was deemed financially impracticable, and attention was turned to adopting the valley route and the Abt incline. The surveys were made for the new route; and the difference on the estimated costs was so great that the capital was at once forthcoming, and the line was constructed under the personal supervision of Mr. Carruthers, then the author's partner. The length of the line is thirty-four miles, rising to a summit of 1,950ft. from sea-level at Puerto Cabello. The first nine miles from the port are practically level; the valley continues to rise, and the grade for the next seven miles is about 1 in 100; the ground then rises sharply, necessitating grades of 1 in 29 for three miles; reduced again to 1 in $43\frac{1}{2}$ for about two miles; rising finally on the incline from this point to the summit on a grade of 1 in $12\frac{1}{2}$; afterwards falling on an easy grade for the next nine miles into the city of Valencia. The results have been most satisfactory, the line proving equal to the heaviest traffic, notwithstanding that the Abt incline has a grade of 1 in $12\frac{1}{2}$ for two miles. The company's stock and debentures are in good repute on the London market, and traffic is improving year by year. But for the existence of the Abt system of incline-railways Valencia would probably be to-day without railway-communication.

The Hartz Mountain railway was the first line constructed upon the Abt system, and connects the town of Blankenburg with the town of Taane, in the Hartz Mountains, a distance of nineteen miles. The line has a rise of 1,495ft. outward from Blankenburg, giving an aggregate rise on the round trip of 2,130·6ft. The ruling gradient on the rack sections is 6 per cent., or 1 in 16·67; and on the adhesion 2·5 per cent., or 1 in 40. The minimum radius of curve on the rack is 820ft., and on the adhesion line 590ft. The locomotives employed have an average service-weight of 51·2 tons; and they take a train-load of 118·1 tons, exclusive of their own weight, at seven miles an hour, up 1 in 16·67, but at times work trains weighing 135 tons. The racks on these steep sections show no wear, and the maintenance does not cost any more than the ordinary line. The wear of the pinions is very slight, a flank adjustment being necessary once in twelve months; and the life of the pinion is estimated to be about ten years. Upon the Hartz railway there are eleven separate rack sections; so that every train passes twenty-two entrance-tongues in one journey.

The traffic on the Hartz railway in 1888, according to the last returns in possession of the author, was as follows:—

Passengers	58,550	Increase from 1887	..	5,050
Goods (tons)	146,250	„ „	..	26,250
Mileage	57,256	Decrease „	..	1,652
Average weight per train (tons)	105	Increase „	..	8
Maximum „ „ (tons)	135	„ „	..	15

The maximum load consisted of nine loaded waggons, the gross weight of which was 15 tons each. The total number were fitted with three friction-brakes. The heavy traffic on this line consists principally of ironstone for the smelting-furnaces at Blankenburg. The working-expenses for 1888 were,—

	£	s.	d.
Salaries and wages	4,372	10	0
General expenses	6,665	15	10
Maintenance	728	15	0
Fuel	1,506	1	8
Repairs of engines and waggons ..	874	6	10
Hire of waggons	437	3	5
Total	£8,584	12	9

—giving a cost per train-mile of 2s. 10·9d.

The cost of transport was—

	£	s.	d.		
Wages	815	13	8;	equal to	27·8 per cent.
Fuel	1,179	5	3	"	40·2 "
Stores	244	7	8	"	8·3 "
Water	17	1	3	"	0·6 "
Loco. repairs ..	677	12	6	"	23·1 "
Total ..	2,934	0	4		100·0

Cost per train-mile, 1·019s.

For comparison, the working-expenses of the railways of Germany and Austria from the latest statistics obtainable —1885—are as follow: Germany, 3s. 8·7d.; Austria-Hungary, 3s. 6d. The cost of transport in Germany per train-mile is 10·1d.; Austria-Hungary, 12·7d.

To arrive at a more equitable comparison between the cost of working the Hartz line, the author, in a paper read before the Institute of Civil Engineers, London, reduced the cost of working this railway to the basis of work performed as the product of weight and height, and compared it on this same basis to the cost of working the Semmering railway, a mountain section of the Austrian Southern railway, which has an adhesion grade of 1 in 40 for twenty-six miles, with an aggregate rise of 1,505·9ft., and on the through trip 2,221·2ft., the average train-load being 129·7 tons. The results show the expenses of the Hartz railway for transportation and locomotive-power to be 1·05s. per train-mile on the data of 1887, and the cost of raising 1,000 foot-tons 2·3d. On the Semmering incline the cost of transportation and locomotive-power was 1s. 4·9d., and the cost of raising 1,000 foot-tons was 3d. Therefore the cost of raising 1,000 foot-tons of train-weight to a height of 1ft. on the Hartz railway is only 76·6 per cent. of the cost at the Semmering. This gives a very fair comparison of the two systems—when certain allowances are made for the greater proportion of the heavy traffic being down the longest grade on the Hartz line—one with steep grades worked by special means, and the other a long adhesion gradient worked by the ordinary engine. The coal-consumption on the Hartz Railway was 9lb. per 1,000 foot-tons of train-weight, or 3·898lb. per indicated horse-power. In Germany the average consumption of fuel in the locomotives per indicated horse-power is given at 5·253lb.

The author is able to speak with some authority on the use of steep grades on mountain railways, as he was associated with Mr. Carruthers when the application of the principle to the Puerto Cabello and Valencia railway was under discussion, and then made several visits of inspection and research to Blankenburg, and saw the practical working of the Abt system under favourable and unfavourable conditions, and he made further investigations before recommending the change of location on the New Zealand Midland railway at Arthur's Pass, and also with the view of drawing up a report on the same question in 1888, as Joint Consulting Engineer in London to the New Zealand Government. The changes made by the author in the location of the New Zealand Midland Railway Company's line at Arthur's Pass have been criticized by many in the colony; and, as the question is of some local interest, a few leading particulars and reasons which have induced the author to advise the change of location from the summit tunnel of three miles and a quarter in length to an incline with grades of 1 in 15 may be of some interest. Most of the following particulars were included in the report to the New Zealand Government.

To form a comparison between the Abt incline and the tunnel line as originally surveyed, it is necessary not only to take into consideration the tunnel and the incline, but also the section of railway affected by the substitution of the incline for the tunnel. The length of line on the original survey constituting the affected section is about 24 miles 16 chains, made up of the tunnel, 3 miles 16·5 chains, 14 miles 18 chains of 1-in-50 grade, 6 miles 16·3 chains of lighter grades, including the level bridge over the Teremakau River, to the West Coast termination of the survey made for the Government by Mr. Napier-Bell, now an esteemed member of the author's personal staff. Going westward the line has a down-grade through the tunnel of 1 in 44; on leaving the tunnel it is located, with a grade of 1 in 50, on the hillside overlooking the valley of the Rolleston Creek, the Otira and Teremakau Rivers; there are two short tunnels, as well as the longer one through the summit, and several very high and costly viaducts, crossing deep gullies formed by the tributary streams of these rivers. The line for about fourteen miles is on the sidling ground of the hills, and in many places shows a heavy section for construction, and, moreover, crosses many shingle-slides, some of them of great magnitude, which would require special works to render the line stable, and in some cases the solution of the difficulty would be tunnelling behind these ever-shifting masses of loose rock. If the line had been constructed as surveyed, it is difficult to estimate the annual cost to maintain it on such unstable ground, constantly liable to slips produced by the heavy rainfall of the West Coast. The section of railway described was originally estimated to cost, for the tunnel, £92,166 per mile, equal to £307,600; and for the remainder, £22,046 per mile, equal to £458,024: making a total of £765,624 for this section. The approximate estimate of cost —the surveys not being completed—of the same section with the incline, instead of the tunnel, is—nineteen miles close under the hills or on the river-flats of the Teremakau and Otira Rivers, with heavy rock protection-work, at £11,500 per mile, equal to £184,000; six miles of incline at £25,000 per mile, equal to £150,000: total, £334,000; giving an estimated saving in cost of construction in favour of the incline of £431,624, which, at 5 per cent., is equal to £21,581 as the saving in interest on the cost of construction alone per annum. The surveys, so far as they are completed, for the incline, show exceptionally favourable results, and the author anticipates that the estimated figures now given will, at any rate, not be much exceeded. The country to be passed through by the incline is of a comparatively solid and rocky nature, which will greatly reduce the original estimated cost of maintenance on the incline itself.

The surveys have been difficult and costly, owing to the rugged character of the country. The author's staff have shown great skill, courage, and perseverance. Laying out the incline is near completion, and, so far, without serious accident to any of those engaged on the work, which has required the nerve and coolness of practised alpine climbers, combined with great technical skill, to overcome the difficulties of survey and final location of the line.

The comparative estimated cost of working the tunnel section and the incline section may prove of interest, being based upon statistics obtained in working the Government railways of New Zealand. The New Zealand Public Works Statement for 1888—Return No. 4—gives the average cost of working the railways at 56·02d. per train-mile, made up as follows (the author takes the returns of this year, as the original report to the Government was based upon figures obtained therefrom):—

	d.
A.—Maintenance	20·08
Locomotives	13·02
Carriages	5·30
Traffic expenses	14·18
General charges	3·01
Sundries	0·43
	56·02

As the cost of working either the tunnel or the incline will be affected by the extra expenses of working on the West Coast, due to the climate and higher wages, a new figure must be estimated of the cost per train-mile, which will be as follows:—

		d.	
B.—Maintenance	..	28·71,	being 43 per cent. more than A.
Locomotives	..	17·32	" 33 " "
Carriages	..	7·05	" 33 " "
Traffic expenses	..	18·86	" 33 " "
General charges	..	3·01;	assumed unaffected.
Sundries ..	..	0·43	"
		75·38	

The cost of working a long bank of 1 in 50 would be increased by extra maintenance and locomotive and waggon expenses over the working of a level line. This, again, modifies the cost per train-mile on this portion of the line to 85·01d., made up as follows:—

		d.	
C.—Maintenance	..	34·45;	increase of 20 per cent on B.
Locomotives	..	19·8	" 13·2 "
Carriages ..	..	8·46	" 20 "
Traffic expenses	..	18·86;	assumed unaffected.
General charges	..	3·01	"
Sundries ..	..	0·43	"
		85·01	

The estimated cost of working the Abt incline, allowing extra for maintenance, locomotives, and waggon charges, is 98·5d. per train-mile:—

		d.	
D.—Maintenance	..	39·32,	being 30 per cent. more than B.
Locomotives	..	27·72	" 65·5 " "
Carriages and waggons		9·16	" 30 " "
Traffic expenses	..	18·86;	unaffected.
General charges	..	3·01	"
Sundries ..	..	0·43	"
		98·5	

Return No. 3 of the Public Works Statement, 1888, shows that the cost of working the Fell engines, in pence per train-mile, is 44·14, including—

		d.
Repairs	.. ..	19·67
Stores	.. ..	0·57
Fuel	.. ..	10·68
Wages	.. ..	13·22
		44·14

These figures, modified to meet the differences in cost of fuel and wages at Arthur's Pass, must in the case of fuel be reduced by half, as coal can be procured on the West Coast at, say, 15s., as against £1 10s. per ton on the Rimutaka, while wages must be increased in the ratio of about 8 to 6. These new figures give—

	d.
Material and repairs	19·67
Stores	0·57
Fuel	5·34
Wages—increase 8 to 6	17·62
	43·2

The cost for repairs is based on the assumption that these would be done on the East Coast.

Substituting this for locomotive-cost in D gives the cost of working the incline at 113·98d., made up as follows:—

	d.
E.—Maintenance	39·32
Locomotives	43·20
Carriages and waggons	9·16
Traffic expenses	18·86
General charges	3·01
Sundries	0·43
	113·98

The engines used on the adhesion portion of the section may be assumed to take a nett load of 69 tons up a gradient of 1 in 50, at ten miles per hour, while the average load taken up the Hartz railway on the incline is 95·5 tons; but, as the loads may have to be taken through, and the trains may run in conjunction, take this load of 69 tons as the same in both cases. The cost per train-mile, reduced to the cost per ton, is as follows:—

	d.
A.—Average of New Zealand railways ..	0·812
B.—Increased cost for the West Coast ..	1·094
C.—Cost of working a long bank	1·23
D.—Cost of working the Abt incline	1·43
E.— " " " assuming the Abt-engine cost as the Fell engines ..	1·65

On the assumption that the cost of transport is the same both ways over the pass, and taking for traffic the figures which have been mentioned on several occasions by Mr. Maxwell—150,000 tons per annum—upon the basis of the various costs per ton arrived at under letters A, B, C, D, and E, an estimate of the relative cost of working the two sections may be arrived at. Consider, first, the incline section: take the cost per ton, under B, for the line on the river-flat, and D for the incline section. Then, for the tunnel line, take cost B for the first seven miles from the Teremakau, C for a long bank of 14·18 miles, and B for the tunnel. But, in taking B as the cost of working the tunnel, it is on the assumption that it would be possible to work this without the aid of artificial ventilation, which is an open question.

Then, the estimate of cost on the incline will be—six miles of incline, multiplied by 1·43d. per ton, multiplied by 150,000, equals 1,287,000d.; nineteen miles of flats × 1·09d. × 150,000 = 3,110,500d.: total, 4,397,500d. = £18,322. Tunnel section, seven miles of usual grades × 1·09d. × 150,000 = 1,144,500d.; 14·18 miles of 1 in 50 × 1·23d. × 150,000 = 2,619,000d.; 3·2 miles of tunnel × 1·09d. × 150,000 = 523,200d.: total, 4,286,700d., or £17,861; showing a difference in favour of cost of working the tunnel line of £461 per annum.

Comparing the two sections on the basis E, of 1·65d. per ton for the incline as the present Fell incline, the balance in favour of the tunnel is increased to £1,287 per annum.

If the tunnel and Abt incline are compared without considering the nature of the sections dependent on them—but which is inadmissible in practice—the balance of cost in working would be about £4,000 per annum in favour of the tunnel, on account of the greater height through which the load is lifted on the incline.

Mr. Maxwell reported to the Government on this question during the time the New Zealand Midland railway contract was before the House, and this report was printed as Parliamentary Paper D.–8, 1888. He gives £6,000 in favour of the cost of working the tunnel. But this may be accounted for by the difference of data used in this instance, Mr. Maxwell taking ½d. per ton per mile for locomotive charges, as on the ordinary lines with 1-in-50 grade, and the ordinary average wages; but this, as shown, must be modified in considering railway work on the West Coast, and over exceptional country this must be increased, and also charges for maintenance must be materially increased for working a long bank on the sidling ground down to the Otira and Teremakau Rivers. According to the estimate of cost of working the tunnel section on basis A, which is £18,360, and the cost of working the incline on basis D throughout the average cost of the New Zealand railways, instead of on the combined bases B and C, as before compared, this becomes £12,250, which new figure would leave a balance of £6,110 in favour of the tunnel, which is practically the same figure as that given by Mr. Maxwell, and arrived at by separate reasoning, but which is reduced, as before stated, to £461 when the true conditions of working the sections are compared.

The result of the comparison made shows that the estimated difference in cost of constructing this section with an incline instead of a tunnel, and locating the adhesion line on the river-flats, against a summit tunnel of three miles and a quarter, and the greater part of the line located on the hillsides, is £431,624, thereby reducing interest-charges by £21,581; and if it is assumed that the author's estimate of cost of working proved incorrect—which cannot be admitted—and the difference in cost amounted to £6,000, there would still remain a balance on interest account of £15,581 per annum in favour of the Abt incline, which gives a railway of practically unlimited capacity, as will be shown, and a perfectly safe method of working the traffic. And, further, it is self-evident that this reduction in cost of construction means an advantage not only to the company, but also to the colony, and that the incline, far from being a "makeshift," as some have stated, is the safe and permanent method of location, having the advantages of important reduction in cost, as well as a great saving in the time required to construct and open the line for traffic.

The question is naturally raised, Is such an incline, as surveyed and located over Arthur's Pass, capable of dealing with the estimated traffic on the line, and the future increase due to the development of the West Coast districts? This is conclusively answered in the affirmative, and is proved by the following details, derived from a graphic time-table on which this section can be worked.

The incline as located has provision for four passing-places upon it. These, of course, will not necessarily be worked in the first instance, but by so doing it would allow of five trains being on the incline at the same time. Provision has also been made in the length of these sidings so that, instead of two trains only being able to pass each other, four can do so, by two trains each way being run close behind one another loosely coupled, this being a preferable plan on this system to a train double the length, with two engines at one end. The proposed engines to work the incline are estimated to haul 118 tons of gross weight, excluding the weight of engine; but, in calculating the capacity of the incline, the gross load is taken at 100 tons, including the weight of waggons, which would give 60 tons of nett weight. For purposes of estimation, take first a single train only on each of these passing-places. Thus, nineteen journeys can be made each way in twelve hours, which is equal to thirty-eight journeys; this is equivalent to 3,800 tons of gross load per day of twelve hours; and, excluding Sundays, there are 313 working-days in the year, which gives a gross load of 1,189,400 tons per annum, or a nett paying-load of 713,640 tons in the same period. The traffic which is likely to be obtained on opening the East and West Coast line has been estimated as under 200,000 tons per annum. As two trains can go over the incline close behind each other, in place of the single train, this at once doubles the capacity, giving a gross load of 2,378,800 tons, and nett load of 1,427,280 tons, per annum. Further, as this system can be worked, like any other railway, during the night, there is no reason why the whole twenty-four hours should not be taken into account instead of twelve. On this basis the full capacity of the incline becomes 4,757,600 tons gross, and 2,854,560 tons nett, per annum.

These figures alone may convey very little meaning to many, but by comparison the capacity of such an incline is made apparent, and it becomes markedly so on referring to the New Zealand Government returns of 1890, which show a total tonnage of 2,112,734 as the amount of traffic hauled on the whole of the New Zealand Government railways. It is thus evident that the incline as laid out will not be the limiting factor of the traffic between the East and West Coasts; and if such figures were approached it is palpable that it would pay not only to double the incline line, but also the whole system across the Island.

It is the intention of the author to use engines to work the incline sufficiently powerful to take the same load over this section as the ordinary adhesion engine can bring to the point of interchange of loads.

It is anticipated that the ruling gradient of the adhesion line on the section between Brunnerton and Otira will be reduced from 1 in 44 to 1 in 60; the speed can therefore be increased on this section over and above the speed on the 1-in-50 grade as originally laid out on the long bank; therefore the time of transit by the introduction of the incline will not be increased, as the loads can be carried over this section at from six to eight miles an hour, the reduction of speed on the short incline being made up on the long adhesion section with the reduced ruling gradient.

It has been stated that the snow during the winter season on Arthur's Pass will cause stoppages of traffic. It can be shown from statistics that snow only lies in small quantities on the Pass, and only for a few days at a time, even during the most severe seasons. On the other hand, the Hartz line passes over high plateau-lands exposed to heavy falls of snow, often forming deep local drifts. The author visited the Hartz Mountain railway during very severe weather. Snow was lying on the ground to the depth of between 5ft. and 6ft., the drifts being in some places 10ft. and 15ft. deep. Moreover, these masses of snow lay for weeks; but during this time traffic on the line was never stopped, and the entire delays amounted to only a few hours, when first clearing the heavy snow on local parts of the track. The amount of snowfall on Arthur's Pass is therefore not at all likely to produce any delays or difficulty in conveying traffic over this portion of the company's line.

It has been questioned in the colony whether the East and West Coast Railway, as originally surveyed, could possibly be remunerative, owing to the first cost of construction and the heavy charges for maintenance on a line located on the shifting hillsides of the Otira and Teremakau; but the author ventures to think that, in the face of the demonstrated saving in the cost of construction, and also in the cost of maintaining the line on the permanent ground now chosen, the most sceptical must now form a different estimate of the prospects of the East and West Coast Railway.

The advantage of adopting the system of locating mountain railways on the low ground of the valleys or plains as long as possible, and concentrating the difficulties of construction and heavy grades on special sections, is fully appreciated by engineers whose practice has given them experience in constructing and working mountain railways. Their convictions as to the advantage of inclines in mountain locations have been many times forcibly expressed; and in evidence the following extract is given from a work of the well-known American engineer, and member of the Institution of Civil Engineers in London, Mr. A. W. Wellington. Writing on the subject of steep inclines and low approach-grades, his conclusions are, that "by this method of location we get the cheapest line, we get the lowest through grades, and, more than all else, we concentrate the resistance into the remaining more difficult sections, so that the motive-power on the line can be accurately adapted to the work required, and kept fully at work over the distance where it is used; thus making it almost a matter of indifference what rate of ascent we adopt on our more difficult sections—a fact which powerfully tends to still further reduce the cost of construction for these more difficult sections."

Again, quoting from a paper on the Abt system of railway on steep inclines by another well-known American engineer, the late Mr. Walton W. Evans, he states: "The lower the gradient to which the engineer is limited the longer will be the line, the greater the call for artificial structures, the deeper the cuttings, the higher and costlier the embankments, the more numerous the bridges, and the longer and more frequent the tunnels. Any system which admits an extension of the limit of gradients will greatly reduce the cost of construction of new roads. But a system, like that of Mr. Abt, which combines at once an extensive range of gradients with perfect safety and economy of operation, will prove a perfect boon—one of the most valuable gifts to our modern means of transportation. A very important point in favour of this new system, when compared with mountain lines of usual gradients, is the materially-increased safety in working the line. The general operating expenses are lower with the Abt system than with the equivalent adhesion system."

These quotations prove that the advantages of inclines on mountain railways worked by special systems of traction are, in the opinion of experienced engineers, no longer a question of doubt, but are methods of locating correct both in theory and in practice; and, as the construction of railways will yearly extend into districts more and more inaccessible by nature of the country to be passed over, so must special means be adopted by the engineer to surmount such difficulties, and reduce the cost of construction and maintenance to a point which will make such mountain lines not only possible to construct and maintain, but also financially successful. Experience seems to show that the solution of this problem is the application of steep-grade inclines on mountain railways.

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4. *Drift-material of New Zealand Beaches, and their Effect on Harbour-works and Rivers.*

By C. Napier Bell.

The question of what becomes of the material denuded from the mountains by the frosts and rains is nowhere so forcibly brought to mind as in New Zealand, where, from the peculiar structure of the main mountains, composed of hard metamorphic slates and sandstones, shivered and fractured in every direction, the quantity of boulders and gravel brought by the rivers from the mountains to the sea is not exceeded in any part of the world. The mountains are crumbling away with amazing rapidity, and the rivers and torrents are burdened with a vast amount of work in removing this material to its resting-place in the sea. Figuratively speaking its resting-place is the sea, but actually the materials from the mountains find no rest there: arrived at the sea-beach they have before them a long and toilsome journey, far more restless and wearying than that just accomplished down the river-beds.

The subject of the travel of sea-beaches has been extensively discussed, and there is a considerable amount of literature on the subject in the Proceedings of the Institute of Civil Engineers; but the travel of the New Zealand beaches, especially those of the South Island, shows this peculiarity in which they differ from those of most other countries which have been brought under notice: that the travel is invariably in one direction, and that is towards the north. If this in the meantime be taken for granted, one is confronted with the question of what becomes of the vast quantities of sand, gravel, and boulders which are yearly brought by the rivers from the crumbling mountains to the sea.

The problem is not quite similar to such cases as that of great rivers like the Amazon, Mississippi, Rhine, the River Plate, in which for hundreds of miles before reaching the sea the river-beds are very flat, and the currents in the strongest floods have a moderate velocity. Such rivers carry only silt and the finest of sand, which is dispersed by the sea over great areas of its bed, and carried, it may be, hundreds of miles away. The heavy gravels, boulders, and coarse sand brought down by the torrential streams of New Zealand are never carried far out from the beach, and the waves soon heap them on the shore, where they commence their voyage toward the north. One would suppose that the effects of such a stream of materials must leave evidences of some change in the aspect of the shores; and the apparent absence of any such changes causes many persons to conclude that no such travel is taking place. It is often however forgotten that changes in the grand features of nature which are to be seen at a glance are out of the question. If in the short lives of men changes were everywhere apparent, nature would assume the instability of human affairs, and that permanence which is her most striking feature would not exist. The changes, however, do exist, but it would take a Methuselah to see them, and for want of any such long-lived men they can only be detected by the reason, and the careful observation of practical observers.

The materials from the mountains may be disposed of by the sea in several ways: they may be employed in widening the beaches so as to cause the sea-shore to retire seaward; they may be swept along the shore and gradually ground fine, to ultimately cause shoals and new land to be formed at the end of their journey; or they may be ground up to the finest sand, and dispersed over the sea-bottom for some miles seaward: and it is most reasonable to suppose that all of these methods of disposal are made use of by the sea.

Whether the beaches are widening and driving the sea back is difficult to prove, because the process is so very slow, but there seems to be some evidence that at one time at least this operation was at work on our beaches. Besides the enormous accumulations of shingle and boulders that everywhere encumber the base of the mountains, in many places, if not everywhere, there are found great deposits of blue clay and soft sandstone filled with sea-shells and bones of fish. These deposits in many places extend inland almost to the base of the great mountains; they are covered with enormous deposits of shingle, which is often found to be composed of rock not now found among the mountains. This would seem to show that the mountains were higher than they are now, and that their tops were formerly covered with a softer and more shaly rock than the hard crystalline slates and sandstones of the present time.

As the land rose out of the sea the rivers cut through the blue clay, and, their beds becoming flatter as the sea retired and the mountains were reduced in height, the former rocky gorges were filled with the wide deposits of shingle which form the present river-beds. At the same time all the deep bays and hollows between rocky hills were filled up with the accumulation, and the present features of the coast-lines were defined, showing now the blue clay and other sea-deposits separated from the sea-shore by a more or less wide strip of gravel, boulders, silt, and sand of comparatively recent origin. It would not be prudent to pursue this theory further, as it may incur the denunciations of the geologists.

In speculating on what becomes of the gravel brought down by the rivers, the enormous power of the sea in grinding up the hardest material must never be forgotten. The scrubbing by the waves on the beach never ceases day or night, and the hardest stone is reduced to sand in a very short time. I have noticed large rocks of basalt, placed to protect the railway at Timaru, in a few years not only rounded and polished, but reduced to half their original size; and on many beaches it is seen that the size of the shingle diminishes the farther it travels—it has only to travel far enough to become reduced to the finest sand. I assume therefore that there is sufficient evidence to show that the shingle on the west coast constantly travels northwards, and before reaching Cape Farewell it is ground to sand; what is not dispersed over the sea-bottom or blown ashore arrives at the west entrance to Cook Strait, where it meets a total change of condition in opposing currents, it is driven into the mouth of the strait by the easterly tidal currents and the prevailing westerly winds, and forms that remarkable feature called Farewell Spit, which is about eighteen miles long, enclosing part of Golden Bay. It is always extending, as shown by the great extent of shallow water in front of its end, and it will most likely enclose the entire bay and form a lagoon of it.

Following up this speculation to the "bitter end," the inference is that the shingle of the east coast of the South Island also travels north, and is finally ground to sand; what is not blown ashore is first of all deposited on the sea-bottom at the east entrance to Cook Strait. From that position it is drifted into the strait by the stronger westerly tidal currents, and, after being shifted backward and forward by opposing tide-rips, it finally emerges at the west end of the strait. Here it mingles with the fine sand and other deposits which the northerly currents have brought up the west coast, travelling in deep water, and the whole is deposited, and forms that great bank of shallow water contained in the wide bay between Capes Farewell and Egmont.

But the northerly currents and the waves of west and south-west gales slowly drag this deposit towards the land around Kapiti, Foxton, and Wanganui, and, mixing with sand from the rivers of that coast, together they resume their northerly journey until, as the currents get feebler, and the land trends more and more at right angles to the direction of the prevailing winds, an increasing proportion of the sand gets blown on shore, and is piled up in sandhills. This may account for the vast accumulation of sand on the west coast of the North Island, shown by the enormous sandhills north and south of the Manukau, and extending to the North Cape, where the phenomenon culminates in the whole of the northern extremity of the Island for 40 miles being composed of sandhills 200ft. and 300ft. high.

Any one who examines the charts of New Zealand with this theory in view will see evidences in support of it. All up the east coast of the South Island there is a more or less wide belt of shallow water of 50 fathoms and less. From Foveaux Strait to Dunedin Peninsula the coast is rocky and straight, and the shallow water along this coast-line is narrow, but it takes a straight line from the peninsula to a point about ten miles seaward of Banks Peninsula, and from this point makes another straight cut to the rocky coast under the Kaikoura hills. It hugs the shore along that coast to Cape Campbell, and then spreads out to form the great bank of deposit at the east entrance to Cook Strait. The same shallow bank of deposit hugs the south shore of the strait, filling all the bays, but leaving deep channels through it, where the tides rush in and out of the sounds, and leaving a narrow channel in the centre of the strait with 120 to 150 fathoms of water.

The great bight formed between Capes Farewell and Egmont is entirely shallow water of about 50 fathoms. At the east end of the strait the 50-fathom line is close to the entrance; on the west end it is 120 miles away from the entrance. This seems to show that the waves and currents bring the wear-and-tear from the east and west coasts of the South Island to form the vast deposits at the west entrance of Cook Strait.

On the west coast (South Island) the 50-fathom line is much nearer the shore, as the coast-line is straighter, and probably the sea was originally much deeper on this coast, but the shallow water, in a manner similar to the east coast, fills the bays and hugs the headlands.

The charts also show that on both coasts the general set of currents is towards the north. The prevailing direction of the winds on the east coast is south-east, and on the west coast south-west. Also, engineering works and observations prove that the material of the beaches is continually travelling towards the north on both coasts.

I must now fortify the weakest position in this line of argument by showing sufficient reason for assuming that the material drifted up the east coast ultimately passes through Cook Strait.

The charts show the same range of tide at either end of the strait. At Cape Campbell and Port Underwood spring-tides rise 8ft., and neap-tides 6ft.; at Queen Charlotte Sound, Porirua, and Kapiti, springs 8ft., neaps 6ft. Nevertheless, as the tides come from the south-east, it is fair to suppose that they run through the strait for a longer time, if not with a stronger current, than the return tide flowing from the west to the east, because the tidal wave, the return eddy of which creates the tide on the west coast, is continually retreating away towards the west at the rate of a thousand miles an hour.

There is about four hours' difference in the time of high water between the east and west sides of Cook Strait, and a very strong current is set up through the strait with the rising tide.

If any material at all is carried by these currents, it will be carried farthest by the tide which lasts longest, and will be spread and deposited where the current is checked by the open sea—that is, in the great bight between Capes Farewell and Egmont. There can be little doubt that the tide-rips carry great quantities of material from the wear of the land; otherwise it would be impossible that the extraordinarily deep channel through that part of the strait where the current is strongest could be prevented from silting up to the depth of the banks that surround each entrance.

I assume, therefore, that the drift-material of the east coast finds its way at last to Cook Strait, and then works its way through to the west by the preponderance of the westerly tidal currents.

I have thus driven this problem into a corner, and found that all the wear-and-tear of the mountains of the South Island goes to extend New Zealand towards Samoa at its extreme north point. This is a grand deduction, and I hope the critics will make shipwreck of any attempt to disprove it.

But the fact of the shingle and sand travelling continuously in one direction may be disputed, and I must endeavour to set this point on a firm foundation. In the Minutes of Proceedings of the Institution of Civil Engineers there is much writing and discussion on the subject of the travel of material along beaches. It is acknowledged that it does travel, but the extent and causes are the subject of much difference of opinion. Thus, in one of these discussions, Mr. J. T. Harrison, C.E., notices the drift of shingle by the south-east winds which are the prevailing winds in that part of the Mediterranean, which drive towards the west the shingle and sand from the mouth of the Rhone, and from cliffs of gravel abraded by the sea, and that in its travel it forms spits across estuaries and bays, enclosing them to form extensive lagoons, which are so marked a feature of the coast near the mouth of the Rhone.

Professor Ansted, on the contrary, thinks storms bring sand from the bottom of the sea, and in that way form these singular lagoons. Vol. lvii., page 365, says that observations have shown that all along the coast of Portugal detritus is carried from north to south by the action of the sea, and, being checked at the mouth of the rivers by the outcoming stream and south-west winds, it is first deposited on the north bank, then drifted into the river, forming innumerable bars and shoals; but it is scoured out by floods, and drifted along clear of the rivers. Vol. lviii., page 272, notices the influence of the littoral wave-currents at Genoa, which drift the sediment of the River Bisagno towards the port. Vol. lviii., page 281: Mr. Kinahan, C.E., on the subject of the lagoons on the south coast of Ireland, asserts that the tidal flow and its eddies carry the beaches with them; that ordinary wind-waves assist the tide-currents when in the same direction; that if these waves strike the beach at right angles they pile up the shingle, and form what are called "full beaches"—if the waves are against the tide-currents they cut out the beach, churn it, and draw the shingle into deep water; that heavy winds with the tide-currents completely sweep the windward portion of the beaches, and fill up the leeward portion; that ground-swells strike the beaches at right angles, and draw the shingle into deep water. He notices the singular fact that stones of 2cwt. and 3cwt. travel in water of 15 to 20 fathoms, greatly helped by the floatage of great masses of seaweed that lift them along with the slight impulse of each wave.

Professor Ansted's opinion that sand is brought by storms from the bottom of the sea has also been supported by others in discussions on the bars of rivers; but, besides being improbable, it is disproved by the fact that the sea-bottom a few miles from shore is covered by mud, not sand, and I think it cannot be disputed that all sand of the seashore comes from the land.

There are innumerable instances of lagoons enclosed by spits of shingle in this Island, some of which are on a very large scale, and they all show unmistakable evidence of the effect of waves and currents in conveying the material of the beaches.

Whatever part the tidal currents may take in transporting the material of beaches, I think it is greatly exceeded by the shore- or wave-currents, caused by the directions in which the waves strike the beach; and, as far as I have observed, the gravel and heavy sand only travel in shallow water, but the finer the sand the deeper the water it may travel in. On the coast of this Island both tidal and wave currents combine to carry the material of the beaches towards the north.

On the east coast the prevailing currents from the Antarctic Sea sweep up the coast until they reach the neighbourhood of Poverty Bay, where, meeting the tropical currents driven by the influence of the trade winds southwards, they pass away to the eastward. On the west coast the prevailing northerly currents are a sort of gulf-stream from the tropical currents which, flowing down the east coast of Australia, are turned round by the Antarctic, and eddy back to the north along the west coast of both Islands of New Zealand. This accounts for the genial climate of the west coast of the South Island, on which the sea has a temperature of 8° to 10° warmer than on the east coast.

From many observations I am convinced that if the waves strike the coast in an oblique direction they create a current in the same direction; this current keeps close to the shore, and usually only extends a few hundred yards beyond the breakers. Where a great stretch of coast is under the influence of such oblique waves, the current they create flows along the coast regardless of the opposing direction of headlands or deep bays; a cape may project at right angles or in any direction to the general coast-line, and the current will sweep round it with undiminished strength. Deep bays also fail to influence the current, but on the contrary the form of bays is generally modified, where such currents prevail, into long sweeping curves. It is in the progress of these modifications that deeply-indented inlets containing rivers, or into which the current cannot enter, are enclosed by boulder-banks, or spits of sand, and the rougher outlines corrected to a uniform curved shore.

I have made many observations which go to prove the existence of such currents, and the consequent travel of beaches continually in one direction.

On the beach at Greymouth, a very moderate surf striking the beach at an angle of about 20° from the perpendicular, on wading up to the breast in the sea it is found impossible to keep your feet against the current flowing towards the north, and at the breakwater it flows out to the end of the stonework directly against the waves. Also at Westport, in moderate weather, with the waves from west-south-west, a powerful current sweeps round the end of the breakwater towards the north. A ship stranded near Cape Foulwind was carried by the current, bumping along the beach, into the Buller River mouth. A piece of ship's hawser thrown into the sea at Hokitika is picked up on the Greymouth side of the Teremakau, sixteen miles to the north of Hokitika. The bodies of persons drowned in the Grey and Buller are always found on the beach to the north. I have noticed the characteristic red-granite shingle of the Buller River on the beach near Mokihinui, twenty-five miles to the north. The slate and granite shingle of the Grey River is found on the beach many miles beyond Point Elizabeth, where neither the rocks nor the creeks contain this kind of stone. A ship with coals was wrecked at Napier, and very soon afterwards fragments of coal were found by the late Mr. Webber at Mahia, nearly seventy miles to the north. At Timaru, bricks thrown into the sea were observed to travel north at the rate of a mile a day. At Greymouth, limestone rocks washed out of the south breakwater into the river were swept by the flood out to sea, but soon appeared on the north beach, travelling north. At Timaru I found basalt stones which had been deposited to protect the railway drifted along the beach three miles to the north.

There are two methods by which the waves convey material along the beach: First, the oblique waves wash shingle and sand obliquely up the beach, and the recoil draws it down at right angles. This method is made use of to convey boulders, gravel, and heavy sand. The second method has a greater effect, which consists in the surf stirring up the sand of the bottom, which is then transported by the currents.

The waves continually sift the sand from the shingle, and keep the shingle exposed to the grinding action of the waves, for it is observed that the heavier material is driven up to low-water mark, while the recoil of each wave draws the finer sand into deep water, where the currents carry it away.

For instance, when the breakwater was built at Timaru it was at once observed that shingle accumulated on the south side, while the beach to the north was laid bare of its shingle and sand to such an extent that the sea commenced to undermine the clay cliffs now unprotected, and the coast-line for several miles north suffered considerable alterations. As the breakwater extended, shingle accumulated in an enormous quantity, but did not go round the end of the breakwater: divers, however, reported a strong current round the end, carrying clouds of sand; and after some years the beach on the north, which had been swept bare, became covered with sand, which has since increased greatly. At Macquarie Harbour I noticed clouds of sand drifting with a strong current between South Head and Entrance Island, in 70ft. of water; and on the bar of the same harbour, the water being beautifully clear, I noticed, as every wave passed, the sand at the bottom was suddenly raised and carried seaward by the current in 12ft. of water. We also anchored off the beach some miles north of this harbour, in 3½ fathoms of water; just outside the breakers the water was quite clear, but as every wave curled over to break I saw that it was discoloured with sand, which the strong shore-current carried towards the north. These waves, which were 8ft. high, were breaking in about 18ft. of water.

Some people think that a rocky headland projecting far out to sea must stop the travel of sand and shingle. I do not think this is the case; it may, and sometimes does, stop the shingle, but the sand travels round it. The obstruction often keeps the shingle and coarser sand in a bay formed by its base, where it remains until it is ground to fine sand, in which condition it is able to travel round the obstructing headland.

At the projecting end of such headlands the waves dash with violence against the rocks and the steep shore, disturbing the bottom to considerable depths, thus keeping the sand "alive;" and the shore-current, which nothing checks, carries it round the rocks, at the same time filling all quiet bays and recesses in them.

In positions where the supply of shingle is great, and the waves act at a favourable angle, the shingle-beach is able to advance so as to surround the headland, in which case it must follow that the water in front of the headland is sufficiently shoaled to allow the shingle to travel.

Dunedin and Banks Peninsulas are cases where only sand can travel round the headland, and, the distance being great, and the water deep, it may be inferred that only very fine sand can travel round. Cape Foulwind is a case where coarse sand and very fine shingle are able to get round the rocks. The bluff of Napier and Point Elizabeth are cases where shingle travels round them.

Thus a succession of projecting headlands at a distance from the source of supply of the shingle may completely stop it, as it is either all ground to sand before it can reach the obstruction, or, having reached it, it is detained in a hollow bight at the base of the headland, where it is exposed to the grinding action of the waves until it is reduced to sand, which, as it is formed, is sifted from the shingle, and carried on its travels. Should, however, the sand be too coarse to travel in the depth of water existing at the rocky point, it is cast ashore in the coves and bays, and there further "treated" until it has acquired the requisite fineness for locomotion in the required depth of water.

Were it not for the constant supply of fresh material to be acted upon, the sea would wear the land away with alarming rapidity. The hardest rocks where exposed to be scrubbed by the waves are worn away in a very short time, but usually the rocks are protected at foot by small beaches of shingle or sand, constantly renewed.

From the above it may be imagined that most artificial harbours are surrounded by many perils, and a person designing one who does not recognise the striking peculiarity of the New Zealand coasts lays himself open to serious risks of failure. Similarly, any engineer carrying New Zealand experience and applying it to another country without further investigation would be liable to grievous error. Thus the only positions in New Zealand where harbour-works could be constructed without risk from drifting materials would, on this theory, be the ends of each Island projecting in the direction whence the currents and prevailing winds come; but in another country under different conditions of prevailing winds and waves the favourable positions for such structures would be quite different.

Persons who have not studied these phenomena are very apt to misinterpret the conditions which they observe, and draw wrong conclusions from them. Thus, some persons think that there being deep water in front of a headland is sufficient evidence that it stops the travel of the beaches: they argue that if sand or shingle did pass round there must necessarily be a beach round the bluffs, and all the bays on the lea side would be filled up, whereas no changes are observed. They forget that the material carried away is always equal to the supply, therefore all things remain as they were; no effect can be seen unless you follow the stream to some place where there is a total change of conditions, and there a vast deposit will probably be revealed.

I have known people suggesting various positions for breakwaters or harbours: one position was to keep the material entirely back, another would have the effect of "shooting it off" to some place of safety, and so on. But the fact remains that if there is an obstruction to the travel of the beaches the material will travel round it regardless of the direction in which it is placed. Sooner or later the stream will lap round it and fill up the sheltered space.

In this perplexing condition of things the only means which appears to offer a chance of safety is to imitate nature as closely as possible—that is, to place the entrance of the artificial harbour so that it may be swept by the full force of the wave, and give every facility for the sand and shingle which travels past the entrance to continue its journey. To have the entrance swept by the waves requires that it should be at right angles to their prevailing direction, and that the side of the enclosure in which the entrance is be in the direction of the prevailing heaviest waves. This may make a dangerous entrance, but there is no other way out of the difficulty that I know of.

Another way to deal with the travel of beaches is to enclose a space so large that the tide rushing in and out would have sufficient power to keep a channel open of the required depth. On a low sandy coast this will only have the desired effect if the tidal current is confined between walls projecting into the sea, so as to create a sort of artificial rocky headland, so that the violence of the waves against the stones may disturb the bottom, which enables the shore-currents to carry away the material. Of course there must be a free get-away for the material after it has contended with the entrance and travelled past, and in this generally lies the secret of success in such structures.

A harbour in the form of an island off the coast is another method of dealing with the difficulty of travelling beaches, and, if well designed and placed, it is no doubt the best solution of it; but such harbours are necessarily costly, and on that account cannot always be adopted. One of this description was built at Callao, in Peru, about fifteen years ago, and has served its purpose, and stood well in spite of the earthquake-wave which passed over it during its construction. Sir John Coode is building one of this description on the coast of Natal, but I have not yet heard of its success or failure.

In many parts of the world, as well as in New Zealand, rivers have been furnished with breakwaters and training-walls with the object of enabling them to maintain deeper water than they carried in their natural condition. In most cases such works have been successful, sometimes very much so, as in Greymouth and Westport, the Sulina mouth of the Danube, and the South Pass of the Mississippi. Where such artificial mouths to rivers have been constructed, opposing the drift-material of the beaches, they are seen to act very like natural headlands of rock. The commotion of the waves disturbs the bottom round about the projecting ends of the breakwaters, and the shore-currents carry away the disturbed material, whether it comes drifting along the beach or is brought down the river; consequently the success of such structures will be subject to the same laws which determine whether a rocky point shall continue to stand in the sea with deep water round it, or shall be surrounded with a shingle or sand beach. If the supply of drift-material be very large and composed of heavy shingle, while the currents out of the river are feeble, such a work will probably be a failure; but if the supply be moderate, the material light, and the river-currents strong, the work will be successful. In any case success will depend on the unobstructed get-away of all material which has accomplished the ordeal of passing the entrance, and any structure on the lee side which interferes with the travel of the material will be injurious to the principal structure. Of course river harbours have the additional disadvantage of bringing down material from the interior, and this would be a difficulty which would make success in such structures very uncertain, were it not that in the New Zealand rivers which have been furnished with these improvements prevailing currents and waves are always in one direction, and the frequent floods are so powerful as to sweep the shingle brought down the river quite outside the breakwater, where the waves carry it on to the leeward beach, and it travels on as it has always done.

It appears to be evident that the farther seaward such training or guiding breakwaters project the more certain will be their effect in maintaining deep water, partly because on the weather side heavy material will find considerable difficulty in advancing against the waves to the end of the projecting wall, and consequently it will undergo a large amount of rough usage and grinding-down before it gets so fine as to be able to travel with the shore- or wave-currents, which must flow on in whichever direction they are forced to go; but the finer the material the deeper the water will be in the neighbourhood of projecting rocks, and among currents passing round them. Also, the farther the breakwater projects the farther will the beach be from the end of the leeward breakwater; and as the supply of material is not increased, and under the supposition that the get-away is unobstructed, the leeward beach should suffer no alteration, and as a consequence the leeward breakwater will maintain its original depth of water, into which as into a pit all accumulations drifted round the windward breakwater or out of the river will fall and will be washed on to the beach by the waves and carried on their accustomed journey.

Such prognostigations and reasonings as the above will often be found verified in actual experience; they will also sometimes be found to fail, for there is always much uncertainty as to what will or will not happen in the construction of artificial harbours, and after a failure has disappointed the most careful observation and long experience it will be discovered that some back current or unlooked-for eddy was not noticed, the disturbing effect of some opposing waves was not thought of, or the force of such and such a current as compared with the quantity or weight of the material it had to deal with was neglected, and then the poor engineer finds the sweet fruit of all his thought and care turned to bitter ashes just as he hoped to enjoy his long-expected repast.

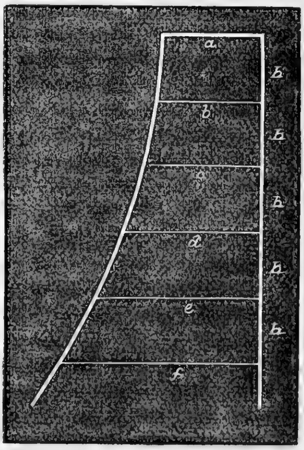
5. *A Graphical Method for the Design of Reservoir-walls.*

By R. W. Chapman, M.A., B.C.E.

Plates XV. and XVI.

The problem of the design of a masonry reservoir-wall, in which there shall be no waste of material, may be shortly stated thus: We have to so vary the thickness of the wall from top to bottom that, if we consider any horizontal section, that portion of the wall above that must have sufficient stability, due to its own weight, to resist the overturning influence of the hydrostatic pressure. It is usually considered advisable to neglect in calculation the strength which the wall receives from the adhesion of the cement, and consequently, as it is a question of stability only, no factor of safety is required. Moreover, the pressure must be so distributed over the base of the wall that there is always some pressure at the face, and consequently the centre of pressure on the base must never be at a greater distance from the face of the wall than two-thirds of the base. Such are the conditions under which reservoir-walls are designed by most writers on the subject.

I propose in this paper to give an account of a method by which the proper width of the wall may be directly determined at intervals by a simple graphical construction. I shall suppose that the face of the wall exposed to the hydrostatic pressure is vertical, as the slight inclination usual at the lower portion of the face is not sufficient to change the direction of the resultant fluid pressure much from the horizontal, and by neglecting the slight deviation we make our wall really a little stronger than theory requires.



As in the figure, which represents a section of the wall, suppose that the top width is a, and b, c, d, e, f, &c., denote the widths at intervals of h feet, proceeding from the top to the bottom. These measurements are all supposed to be made in feet.

The top width of the wall, a, has to be decided upon at the start. For still water there is no pressure on the wall right at the top, but impact of wind and wave necessitate of course some thickness being fixed upon. The width b is then determined from the condition that the portion of the wall above b must satisfy the conditions for stability. Then the widths c, d, e, &c., are determined in order, from similar considerations. Since the section of the wall will be independent of the length of the wall, to simplify calculations the wall may be supposed to be of unit length.

An easy calculation in statics shows that the distance from the face of the wall of the centre of gravity of the top segment of the wall, included between a and b, is given by the formula,

$$\frac{b^2 + a^2 + ab}{3\,(a + b)}.$$

Similarly, the distance of the centre of gravity of the next segment from the face of the wall is—

$$\frac{b^2 + c^2 + bc}{3\,(b + c)},$$

and similarly for every other segment.

Also, the moment of overturning in foot-pounds for the top segment, due to the water-pressure, is $\frac{62{\cdot}5}{6}\,.\,h^3$; the moment of overturning for the first two segments is $\frac{62{\cdot}5}{6}\,.\,2^3\,.\,h^3$; for the first three segments, $\frac{62{\cdot}5}{6}\,.\,3^3\,.\,h^3$, &c.

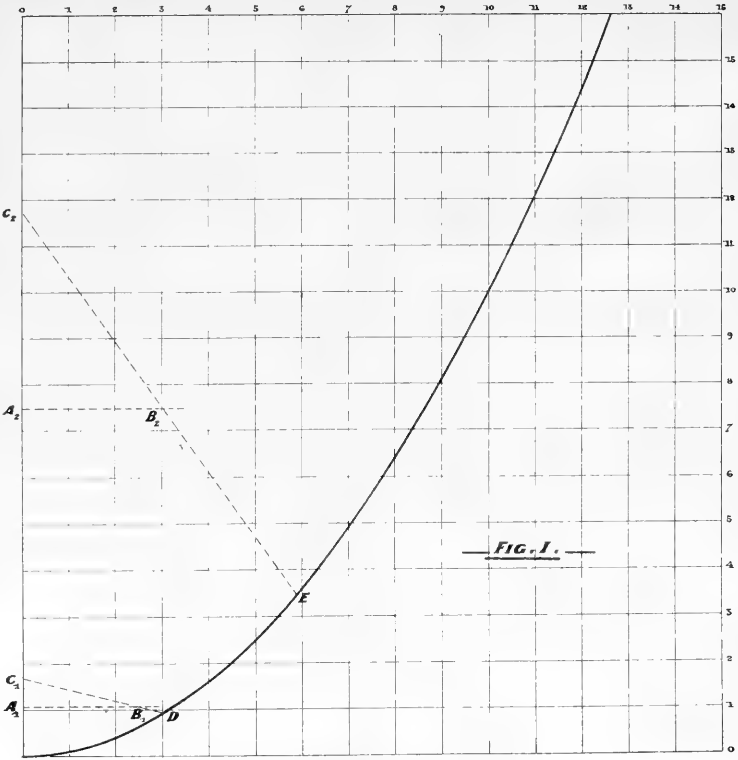
Let us suppose that by some means the first four widths, a, b, c, d, have been correctly determined, and we wish to find the next width, e. Since the centre of pressure on the base is at the extremity of the middle third, taking moments about that point, the condition for stability will give us the following equation to determine e:—

$$\frac{a+b}{2}\left\{\frac{2e}{3} - \frac{b^2+a^2+ab}{3\,(a+b)}\right\}hw + \frac{b+c}{2}\left\{\frac{2e}{3} - \frac{b^2+c^2+bc}{3\,(b+c)}\right\}hw +$$
$$+ \frac{d+c}{2}\left\{\frac{2e}{3} - \frac{d^2+c^2+dc}{3\,(d+c)}\right\}hw + \frac{d+e}{2}\left\{\frac{2e}{3} - \frac{e^2+d^2+ed}{3\,(d+e)}\right\}hw =$$
$$= 4^3\,.\,\frac{62{\cdot}5}{6}\,.\,h^3,$$

where w denotes the weight of a cubic foot of masonry.

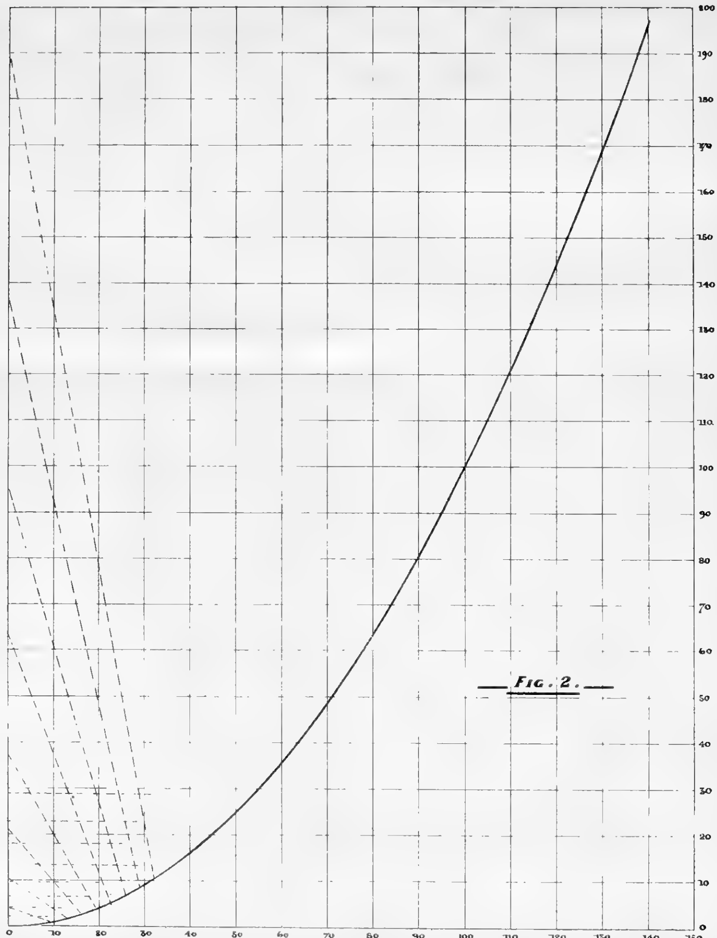
Now, the previous width, d, would be determined by a precisely similar equation, *i.e.*,—

$$\frac{a+b}{2}\left\{\frac{2d}{3} - \frac{b^2+a^2+ab}{3\,(a+b)}\right\}hw + \frac{b+c}{2}\left\{\frac{2d}{3} - \frac{b^2+c^2+bc}{3\,(c+b)}\right\}hw +$$
$$+ \frac{d+c}{2}\left\{\frac{2d}{3} - \frac{d^2+c^2+dc}{3\,(d+c)}\right\}hw = 3^3\,.\,\frac{62{\cdot}5}{6}\,.\,h^3.$$



C.H.P. del.

To illustrate Paper by R. Chapman.



To illustrate Paper by R. Chapman.

On subtracting these two equations and simplifying, we get

$$e^2 + (e - d)\ (2a + 4b + 4c + 3d) = (4^3 - 3^3)\ \frac{62{\cdot}5\ h^2}{w}.$$

Similarly, to determine d, we have—

$$d^2 + (d - c)\ (2a + 4b + 3c) = (3^3 - 2^3)\ \frac{62{\cdot}5\ h^2}{w},$$

and similarly for the other widths.

Thus, writing x for the unknown quantity in each case, we have the following equations to solve in order to determine the proper widths of the wall at each point in succession, starting from the top:—

$$x^2 + (x - a)\,a = 62{\cdot}5\ \frac{h^2}{w} \quad \ldots \quad \ldots \quad \ldots \quad (1.)$$

The solution of this equation determines b. Then, we have, to determine c,—

$$x^2 + (x - b)\ (2a + 3b) = 62{\cdot}5\ (2^3 - 1^3)\ \frac{h^2}{w} \quad \ldots \quad (2.)$$

To determine d,—

$$x^2 + (x - c)\ (2a + 4b + 3c) = 62{\cdot}5\ (3^3 - 2^3)\ \frac{h^2}{w} \quad \ldots \quad (3.)$$

To determine e,—

$$x^2 + (x - d)\ (2a + 4b + 4c + 3d) = 62{\cdot}5\ (4^3 - 3^3)\ \frac{h^2}{w} \quad (4.)$$

&c.

The equations when put into this form lend themselves very easily to a graphical solution. The typical form of the equation is,—

$$x^2 + (x - p)\ q = r.$$

The positive root of this equation is the same as the positive value of x, which satisfies the two simultaneous equations,—

$$\left.\begin{aligned} 10y &= x^2 - r. \\ 10y + (x - p)\,q &= o. \end{aligned}\right\}$$

The first of these equations represents a parabolic curve. The curve $10y = x^2$ is very easily set off, as in Plate XV. This curve, once plotted, answers for all the equations, as the equation $10y = x^2 - r$ represents the same curve with the axis of x moved upwards to a distance $\frac{r}{10}$, as represented by one of the red lines in the plate. The equation $10y + (x - p)\,q = o$ represents a straight line which passes through the points $x = o, y = \frac{pq}{10}$ and $x = p, y = o$. The abscissa of the point of intersection of the curve and straight line gives the positive value of x, which satisfies both equations, and consequently gives the value of x required.

The process of design is illustrated in the drawings appended by an application to the design of a wall 50ft. high, 2ft. 6in. wide at the top, and composed of masonry whose weight is 144lb. per cubic foot. The width of the wall is determined at intervals of 5ft.

The first equation to be solved is thus—

$$x^2 + (x - a)\, a = 62{\cdot}5\, \frac{h^2}{w} = 10{\cdot}85.$$

We proceed accordingly to measure off $OA_1 = 1{\cdot}085$. $A_1B_1 = a = 2{\cdot}5$, and $A_1C_1 = \frac{1}{10}a^2 = 0{\cdot}625$. The line C_1B_1 is then drawn; and the point where it intersects the curve, *i.e.*, D in figure, gives 3·03 as the value of b, the width of the wall 5ft. from the top.

Next OA_2 is measured off $= (2^3 - 1^3) 62{\cdot}5 \frac{h^2}{w} = 7{\cdot}59$; $A_2B_2 = 3{\cdot}03$; and $A_2C_2 = \frac{1}{10}\, 3{\cdot}03 \times (2a + 3b) = 4{\cdot}26$. The line C_2B_2 then intersects the curve at E, which gives 5·86 as the next width of the wall.

The distances to be measured off in order are thus—

$$OA_1 = \tfrac{1}{10} \,.\, 62{\cdot}5\, \frac{h^2}{w}.$$

$$A_1B_1 = a. \qquad A_1C_1 = \tfrac{1}{10}\, a^2.$$

$$OA_2 = \tfrac{1}{10}\, (2^3 - 1^3) \,.\, 62{\cdot}5\, \frac{h^2}{w}.$$

$$A_2B_2 = b. \qquad A_2C_2 = \tfrac{1}{10}\, b\, (2a + 3b).$$

$$OA_3 = \tfrac{1}{10}\, (3^3 - 2^3) \,.\, 62{\cdot}5\, \frac{h^2}{w}.$$

$$A_3B_3 = c. \qquad A_3C_3 = \tfrac{1}{10}\, c\, (2a + 4b + 3c).$$

&c. &c. $A_4C_4 = \frac{1}{10}\, d\, (2a + 4b + 4c + 3d)$.
&c.

I found it convenient in making the drawing to change the scale of the curve at this point, and consider the typical equation, $x^2 + (x - p)\, q = r$, as the resultant of the two equations,—

$$\left.\begin{array}{l} 100y = x^2 - r \\ 100y + (x - p)\, q = o \end{array}\right\}$$

but otherwise the process is exactly the same.

In making the drawings, the distances OA_1, OA_2, &c., are measured off first of all, and red lines drawn through these. In calculating the value of A_3C_3 we have to add on $b + 3c$ to the previously-calculated value of $2a+3b$ in order to get the required $2a+4b+3c$: this is then multiplied by c. Similarly in the next we add on $c+3d$ to the previously-calculated $2a+4b+3c$, and multiply the result by d. The whole thing can be done in a very short time, and is a great saving on any methods of calculation.

The following are the results of the wall worked out:—

Width of Wall.			Distance from Top of Wall.
2·5 feet	...	...	0 feet.
3·03 "	...	...	5 "
5·86 "	...	...	10 "
9·40 "	...	...	15 "
12·70 "	...	...	20 "
15·90 "	...	...	25 "
19·20 "	...	...	30 "
22·50 "	...	...	35 "
25·70 "	...	...	40 "
29·00 "	...	...	45 "
32·30 "	...	...	50 "

Plate XVI. shows the necessary construction to obtain the last seven widths.

---

6. *On Railway Gauge as a Factor in the Profitable Working of Locomotive Railways.*

By E. Dobson, M.Inst.C.E.

The subject of this paper is an inquiry into the extent to which the gauge of a railway affects its constructive cost, its working expenses, and its capacity for traffic.

For obvious reasons, no notice will be taken of lines worked by electricity or by rope traction; nor is it thought necessary to allude to gauges narrower than 3ft. 6in., or wider than 5ft. 6in., such extreme gauges being recognised as only suitable for special conditions of traffic. Practically, however, the inquiry will be confined to the consideration of three gauges only—viz., 3ft. 6in., 4ft. 8½in., and 5ft. 3in.—which, for the purpose of this paper, will be called respectively narrow, standard, and broad gauges. The 5ft. 6in. gauge may be dismissed from the inquiry simply with the remark that it embraces the advantages of the 5ft. 3in. gauge, but with additional weight of axles, extra length of sleepers, and greater distance from switch-rail to crossing-point, without sufficient compensating advantages in the speed of the trains, or the more economical maintenance of the road.

Let us consider the narrow gauge under the following heads, viz.:—

Economy of construction.
Maintenance of the road.
Cost of rolling-stock.
Expense of working the traffic.

First as to constructive cost:—

Grades.

The economy in earthwork at distance that may be effected by the introduction of steep grades is dependent on the power of the engines to be used.

It is unnecessary here to argue that the reduction of the gauge to 3ft. 6in. cripples the engine-power, or that, on the other hand, the increase to 5ft. 3in. gives facilities for the use of inside cylinders of larger diameter than can be used on the standard gauge without altering the usual position of the valve-chest, and introducing a consequent elaboration of the valve-gear.

Whilst therefore, in level country, light lines, whether of standard or smaller gauges, may bring good results, the crippling of the engine-power by reducing the gauge will often, in the case of mountain roads, cause a great increase in constructive cost to obtain grades that can be worked with paying loads by the lighter class of engines.

Earthwork.

Apart from the question of grades, it may be said, generally, that the cost of the road depends not on the width between the rails, but upon the weight of the engines, and the speed at which the trains are to be driven. The margin of safety in the width of the embankments depends on the weight to be supported, and the stability required to stand without injury the vibration of the trains. Whatever the weight of the engine, the wider the platform by which that weight is distributed over the top of the bank the more regular will be the settlement of the earthwork, and the less the injury from vibration. Hence, if a bank be narrow and weak, the evil will be increased, not lessened, by reducing the width between the rails.

The width of cuttings with sloping banks depends more upon the width required for drainage, and for provision against the track being blocked by slips, than upon the gauge; but in favourable ground the reduction in gauge will be followed by a corresponding reduction in the cubic contents of the excavation. On the other hand, an increase of gauge will require a corresponding increase in the contents of the cuttings.

The width of cuttings protected by retaining-walls, the breadth of tunnels, and the clearance required at bridges, all depend on the width and construction of the rolling-stock, not on the gauge.

Carriages with side-doors require greater clearance than those opening only at the ends.

Purchase of Land.

Taking into consideration the many advantages arising from reserving a wide strip of ground on each side of the actual track, and the difficulty of obtaining any such additional width after the line has become hemmed in by the progress of settlement, it seems hardly worth while to discuss the saving which might be effected in the cost of land for the construction of a railway in a new country by the reduction of a foot or two in the gauge, although in taking a line through the heart of either London or Paris such a consideration might have some weight.

Permanent-way.

The length of sleeper and width of ballast will be reduced with the gauge, but with a given weight of engine this must be made up for by an increase in the number of sleepers and depth of ballast, to give equal support on the 3ft. 6in. and on the standard gauges.

With the reduction of the gauge, the greater the injury to the rail from the beat of the engine, the speed remaining the same. Hence, to produce equal results with the 3ft. 6in. and the standard gauge, a stronger rail must be used on the narrow gauge.

The conclusion to be drawn from these premisses is as follows: that nothing is to be gained in constructive cost by the reduction of the gauge except in the earthwork of the cuttings, whilst on the other hand the cost of the earthworks may be greatly increased by the limitation to engine-power caused by this reduction, and the necessity of obtaining flatter grades than would be required with more powerful engines.

Maintenance.

We next come to the cost of maintenance. Here at once the voice of experience speaks with no uncertain sound. The cost of maintaining the road in order rises rapidly with the reduction of the gauge ; and this is easily understood. Not only does the decrease in stability render it more necessary to keep the levels of the rails in perfect adjustment, but the greater overhang of the rolling-stock exerts a pounding action upon the road, the relative damage to the road increasing with the very necessity for keeping it more perfectly in level than would be required with wider gauges.

An illustration of this came under the author's notice when the 5ft. 3in. gauge of the railways in Canterbury, New Zealand, was reduced to 3ft. 6in., the platelayers' wages rising at once to nearly double their previous amount. It may be mentioned that the ballast was weak, being merely round shingle, and could only be kept in place at the curves by boxing it up with earth—in fact, burying it in the formation—a precaution which however has been found necessary on many lines of standard gauge, especially since the flange-rail came extensively into use in place of the double-headed rail commonly used on English lines.

With regard to renewal of material, it cannot be said that the gauge has any relation to the durability of rails and sleepers, except that there is more wear upon the rails with the narrow gauge than with the broader gauges, the speed and the work done remaining the same.

Rolling-stock.

The next question we come to is that of rolling-stock, and here we really arrive at the consideration by which the question of gauge is practically governed.

First, let it be here repeated, if need be, for the hundredth time, that "light" and "narrow gauge" are not convertible terms as applied to railways. Light railways may be worked with greater advantage on wide than on narrow gauges, whilst narrow-gauge railways, if required to carry heavy traffic, will involve as heavy works and as great, if not greater, constructive cost, than if made to the standard gauge.

Let us consider the question of rolling-stock under the two great divisions of engines and carriages.

And first with regard to engines:—

Engines.

Now, what are the characteristics of engines on the broad and narrow gauges, as compared with those built for the standard gauge?

The 5ft. 3in. gauge affords room for the simplest arrangement of the valve-gear with inside cylinders of large diameter, and of large outside cylinders without objectionable overhang, whilst with tank engines the extra 6in. adds a considerable mileage to the length of the trip between the visits to the watertanks.

The 3ft. 6in. gauge involves reduced area of firegrate and diameter of boiler, whilst the diminished width of base involves reduction of stability, the bringing-down of the centre of gravity of the engine, and consequently the reduction of the size of the driving-wheels, and, as a necessary result, however great the haulage-power of these engines, there is a serious diminution of speed as compared with engines built for wider gauges.

On the other hand, the cost of light engines is but little increased by building them on wide gauges, and the size of the driving-wheels then enables them to develcpe speeds equal to those of heavier engines.

An engine with 6ft. driving-wheels will be propelled the same distance as one with 3ft. wheels with only half the number of piston-strokes, and, although piston-speed depends on the length of the stroke as well as upon the number of the revolutions of the driving-wheel per minute, this illustration gives a clear idea of the causes which govern the relative speeds of engines on the narrow and on wider gauges.

Now let us consider how far the question of speed affects the cost of the rolling-stock.

Putting aside the question whether the day's work of an engine is to be reckoned by the time under steam or by a maximum of mileage run, and the consideration of the extent to which the number of engines required to work a given traffic is reduced by increasing the speed at which they run, what is the effect of raising the ordinary narrow-gauge speed of fifteen miles an hour to the ordinary broad-gauge speed of thirty, with express speeds of forty and fifty, stoppages being, of course, included in all cases?

Simply, so far as passenger traffic is concerned, that nearly double the amount of mileage can be covered in a given time with the same number of carriages, and the same number of hours' wages paid to drivers, firemen, and guards. Broadly speaking, the passenger-traffic on the broad gauge may be carried on with little more than half the number of carriages required on the narrow gauge, with a corresponding saving in lengths of sidings and carriage-sheds—a matter of great importance in metropolitan stations.

A similar saving will result in the number of trucks, but not nearly in the same proportion, as the time occupied in loading and unloading is not affected by the speed of transit.

Carriages.

Next, how does the gauge affect the construction of carriages and trucks?

Narrow-gauge passenger-carriages with longitudinal seats and end-doors are very convenient; but, with the narrow gauge, sleeping- and dining-cars cannot be made of sufficient width without a dangerous overhang.

Ordinary goods trucks may be made of any gauge, but for cattle-trucks and horse-boxes the narrow gauge is inconveniently narrow.

In general, also, it may be remarked that narrow-gauge carriages, cattle-trucks, and horse-boxes are necessarily deficient in lateral stability, and are easily derailed when travelling at high speed over lines the levels of which are not in perfect adjustment—a circumstance often occurring with heavy goods traffic after a downpour of rain. The somewhat recent occurrence of a train being blown over by the wind is a striking illustration of the instability of narrow-gauge rolling-stock.

And, lastly, it may be remarked that cranes mounted on narrow-gauge trucks cannot be used without the trucks being first bolted to the rails to keep them from tipping over even when lifting a very moderate weight.

Inefficiency of Narrow-gauge Stock.

The conclusions drawn by the author from the above considerations are two: first, that the diminution of speed greatly increases the number of engines, carriages, and trucks, as well as the cost of labour, required to carry on a given traffic; second, that the reduction of the gauge diminishes the efficiency of the rolling-stock in every important particular.

Mode of dealing with Sharp Curves.

It may be and often has been argued that railways have sometimes to be constructed in situations where the curves must be so sharp that they cannot be worked on the standard gauge.

In these exceptional cases the author would suggest that, rather than set out a line to wriggle like an eel on a narrow ledge notched out for miles on a precipitous mountain-side, it will generally be better to take a bolder route, although involving steeper grades and a different system of traction; and that, when these circuitous routes are unavoidable, it is a mistake by narrowing the gauge to cripple the engine-power in places where above all others it is most wanted, and that it is best to use engines working with toothed wheels on a central rack, or with horizontal drivers gripping a raised central rail.

Working-expenses.

The study of the above-named considerations leaves little to be said about the working-expenses of narrow-gauge lines. The extra maintenance of the road, and the maintenance and renewal of a larger quantity of rolling-stock, added to the increase of the wages bill on account of the greater number of persons employed to conduct a given traffic, all combine to make the working-expenses on narrow-gauge lines much greater than on those of the standard or broad gauge from the moment the traffic reaches the point at which the construction of a railway might be made to yield a profitable return.

General Conclusions.

The conclusions at which the author arrives from the foregoing considerations are as follow :—

1. That the supposed economy in the construction and furnishing of narrow-gauge lines is simply a delusion.
2. That the working-expenses will be practically the same on the standard and broad gauges, but will be greatly increased on the narrow gauge.
3. That the capacity for traffic will be greatly reduced on the narrow gauge, whilst its cost is proportionately increased, thus, in level country, excluding a large amount of traffic which can be carried as expeditiously and more economically by horse-teams.

It therefore appears to the author a matter for the deepest regret that, after the New Zealand railways had been started on a gauge which, without an appreciable increase of constructive cost, not only gives great stability at high speeds, but affords ample facilities for the development of locomotive-power, this gauge should have been abandoned for a narrow-gauge fad which, without seriously diminishing constructive cost, has crippled the efficiency of our railway system.

One single example of the mischief done may suffice: had the south line been constructed to the 5ft. 3in. gauge, on which it was originally commenced, the Dunedin express would have been run in five hours, and passengers leaving Christchurch at 8 a.m. might have had two hours in Dunedin for the transaction of business, and have returned by the afternoon express, reaching Christchurch at 8 p.m. Comment is needless.

Is it yet too late to retrace our steps, and to reform our railway system so as to make it efficient and self-supporting, if not a valuable source of revenue?

7. *On the Barometric Determination of Altitudes.*

By E. Dobson, M.Inst.C.E.

The object of this paper is to explain a method of obtaining altitudes from barometric observations to a close degree of accuracy by reference to a couple of bench-marks of which the height above the sea has been determined by the spirit-level, without the necessity of making any correction for temperature, wind, or moisture.

The tables to be used have been calculated by the formula,

$$x = 60235 \times \frac{30}{b'}$$

(in which

x = altitude in feet above the sea of the upper station;
30 = height of the mercurial column in inches at the sea-level;
b' = barometer reading in inches at the upper station;

the mean temperature of the atmosphere being assumed as 32° Fahr.),

and then corrected for temperature to show the heights corresponding to a temperature of 32° Fahr. at the sea-level, but decreasing at the rate of 1° for every 300ft. of elevation.

So long as the deviations of the synchronous barometer readings from the normal readings in the tables decrease in an ascending scale at the rate of $\frac{1}{30}$ for every inch of barometric pressure, the altitudes will be correctly given by the following equation:—

$$C = \frac{(B - A) \times (c - a)}{(b - a)} + A,$$

in which

a = tabular height corresp. to barom. reading at lower B.M.
b = " " " upper "
c = " " " intermediate station.

A = height above sea-level of the lower B.M.
B = " " upper "
C = " " intermediate station.

If the differences from the normal barometer readings vary in any other ratio than the above, a correction must be applied, the mode of calculating which is shown in the paper, which also contains tables for the altitudes corresponding to every hundredth of an inch of normal barometer pressure from 30in. to 26in., with a temperature of 32° Fahr. at the sea-level.

8. *On the Construction of Hypsometrical Tables.*

By C. W. Adams, Chief Surveyor of Otago.

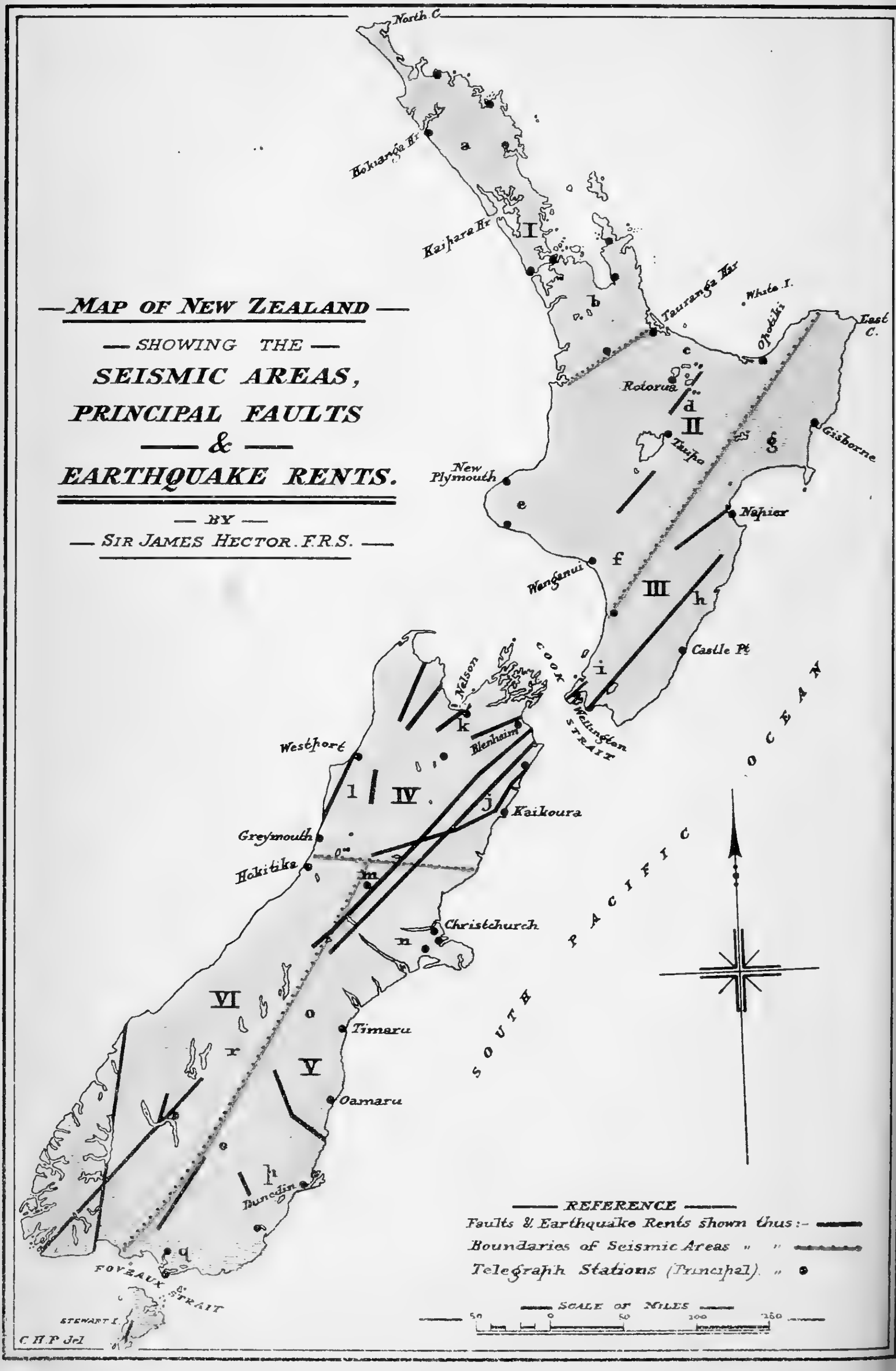
The object of this paper is to facilitate the calculation of heights from observations taken with an aneroid barometer.

Most of the tables in common use adopt a fixed barometric constant, requiring a tedious correction for every variation in temperature. They are also framed on the erroneous assumption that moist air has a constant coefficient of expansion—viz., $\frac{1}{450}$ for each degree Fahrenheit.

It is well known that air at a low temperature is much nearer saturation than it is at a high temperature, say about 75 to 80 per cent. at 32°, and 50 to 60 per cent. at 80° Fahr.; and this variation in the hygrometric state of the air should be taken into account in any formula for the calculation of heights.

So far as the author is aware, Mr. Arthur Beverly, of Dunedin, is the first mathematician who has attempted to construct barometrical tables on this assumption, and his tables are undoubtedly a great improvement on all other tables previously used. His object in writing this paper is to go a step further still—viz., to advocate the construction of a special table for each variation of climate.

The author has constructed such a table for Otago, New Zealand, from data giving the hygrometric state of the air for all ordinary temperatures recorded twice a day for a period of three years, which, he states, is reduced to the utmost simplicity. The corrections for temperature, and for the average hygrometric state of the air at different temperatures, are provided for in the table; so all that is required is to take out the tabular number corresponding to the sum of the temperatures, and one small multiplication gives the resulting height (as he maintains) with greater accuracy, and with less labour, than any of the tables at present in use.


MAP OF NEW ZEALAND
SHOWING THE
SEISMIC AREAS,
PRINCIPAL FAULTS
&
EARTHQUAKE RENTS.
BY
SIR JAMES HECTOR. F.R.S.
North C.
Hokianga Hr
Kaipara Hr
Tauranga Har
White I.
Opotiki
East C.
Rotorua
Taupo
Gisborne
New Plymouth
Napier
Wanganui
Castle Pt
COOK STRAIT
Wellington
Nelson
Blenheim
Westport
Kaikoura
Greymouth
Hokitika
Christchurch
Timaru
Oamaru
Dunedin
FOVEAUX STRAIT
STEWART I.
SOUTH PACIFIC OCEAN
I
II
III
IV
V
VI
REFERENCE
Faults & Earthquake Rents shown thus:-
Boundaries of Seismic Areas " "
Telegraph Stations (Principal) "
SCALE OF MILES
50 0 50 100 150
C.H.P. del

REPORTS OF RESEARCH COMMITTEES.

Report of the Committee, consisting of Mr. A. BIGGS, Mr. R. L. J. ELLERY, Sir JAMES HECTOR (*Secretary*), Mr. H. C. RUSSELL, Professor THRELFALL, *and* Mr. C. TODD, *appointed to investigate and report upon Seismological Phenomena in Australasia.*

Plate XVIII.

THE members of this Committee not having had an opportunity of conferring, the following report, relative to New Zealand only, has been drawn up by the Secretary:—

All the early records are necessarily very incomplete, and commence with the earthquake felt near D'Urville Island by Captain Furneaux on the 11th May, 1773.

Subsequently, only prominent shocks are referred to until from the beginning of 1846. The record is therefore very imperfect; but since 1868, when the present Meteorological Department was organized, and the telegraph brought into operation, the record has been tolerably complete for the whole of the inhabited parts of the colony. The earthquakes during the last twenty-two years have therefore been scheduled, the colony being divided into six districts, each having a characteristic structural peculiarity, as shown on the map exhibited (Pl. XVIII.).

An analysis of this schedule shows that during the period 537 earthquakes have been recorded, of which only 2 were recorded in the northern district of Auckland, 184 in the central district of the North Island, 183 on the east coast of the North Island, 88 on the west coast of the South Island, 98 on the east coast, and 30 in the extreme south.

But, of the above number, 142 were felt only in the middle section of the North Island, between the South Taranaki Bight and the Bay of Plenty; 147 only in the district between the East Cape and Wellington; and 145 were confined to the east and south coasts of the South Island. Of the whole number, only 7 could be identified as having been felt in places outside the colony.

District I. includes (*a*) Hokianga–Kaipara, (*b*) Kaipara–Cambridge.

District II. includes (*c*) Tauranga–Opotiki, (*d*) Hot Lakes–Taupo, (*e*) Taranaki, (*f*) Manawatu–Wanganui.

District III. includes (*g*) Gisborne–Napier, (*h*) Napier–Castlepoint, (*i*) Wellington–Wairarapa.

District IV. includes (*j*) Marlborough, (*k*) Nelson, (*l*) Buller–Grey.

District V. includes (*m*) Bealey, (*n*) Christchurch, &c., (*o*) South Canterbury, (*p*) Dunedin, (*q*) Southland.

District VI. includes (*r*) Central Otago.

Earthquakes in New Zealand Districts.

1. Total number of earthquakes in New Zealand between 1868 and 1890 537
2. Total in each district—

I.	Hokianga–Kaipara–Cambridge ...	2
II.	Tauranga–Taupo–Taranaki–Manawatu...	184
III.	Gisborne–Napier–Wellington	183
IV.	Marlborough–Nelson–Grey	88
V.	Bealey–Christchurch–South Canterbury–Dunedin–Southland	98
VI.	Central Otago	30

3. Percentage of total number of earthquakes in each month:—

	Per Cent.		Per Cent.
January	8	July	8
February	11	August	10
March	10·4	September	8·4
April	7·4	October	6·5
May	6·9	November	7·4
June	8·4	December	7

4. Number and percentage in each district for each month:—

Month.	Dist. I.		Dist. II.		Dist. III.		Dist. IV.		Dist. V.		Dist. VI.	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
January ..	..	..	12	6·5	19	10	5	5·6	8	8	3	10
February ..	..	..	19	10	15	8·2	5	5·6	10	10	1	3·3
March	..	..	26	14	19	7·6	7	7·6	9	9	0	0
April	..	..	17	9·2	16	8·6	7	7·6	7	7	6	20
May	..	..	10	5·4	11	6	8	9	7	7	2	7
June	..	..	12	6·5	17	9·2	5	5·6	10	10	2	7
July	..	..	20	11	18	10	10	11·3	3	3	0	0
August ..	..	..	14	7·6	20	11	10	11·3	11	11	5	16
September ..	..	..	13	7	18	10	10	11·3	9	9	1	3·3
October ..	2	100	19	10	6	3·4	10	11·3	11	11	3	10
November ..	..	..	11	6	14	7·6	4	5	5	5	5	16
December ..	..	..	11	6	15	8	7	7·6	8	8	2	7

Number of Earthquakes (537) felt in various Districts.

Anywhere in the colony, and outside	4
In Districts II., III., IV., V., VI., and outside the colony	3
Districts II., III., IV., V., VI. only	7
Districts II., III., IV.	13
Districts III., IV., V.	3
Districts II., IV., V.	2
Districts II., III.	17
Districts III., IV.	15
Districts IV. and V. or VI.	11
Districts V. or VI.	115
Districts II., IV.	6
Districts II. and V. or VI.	2
Districts III. and V. or VI.	4
District II. only	142
District III. only...	147
District IV. only	46

SCHEDULE OF EARTHQUAKES recorded in New Zealand, 1868–1890.

NOTE.—The letters in the columns refer to the subdistricts named above; the asterisks to the letters in the columns indicate smart and severe shocks.

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1868.								
Jan. 29	..	..	..	*e*	*i**	..	..	..
Feb. 1	..	8 a.m.	..	*e**	*i**	..	..	..
Mar. 12	..	..	..	*e*	..	..	..	..
July 16	..	0.30 a.m.	..	..	*i*	..	..	..
" 30	..	..	..	..	..	*k*	..	..
Aug. 11	..	5.30 a.m.	..	*e*	..	..	..	..
" 15(a)	..	..	..	..	..	..	*n*	..
" 17(b)	..	10 a.m.	..	*e**	*g*,* *i**	*l*,* *k*,* *j**	*n**	..
Sept. 21	..	4.10 p.m.	..	..	*i**	..	..	..
Oct. 19	..	0.10 a.m.	*b*	*c*, *e**, *f*	*g*, *h*, *i**	*k*,* *l**	*n*	..
" 19	..	4 a.m.	..	..	..	*k*	..	..
" 25	..	..	..	*e*	..	..	..	..
" 26	..	2.40 p.m.	..	*e**	..	..	..	..
" 29	..	..	..	*e*	..	..	..	..
" 30	..	..	..	*e*	..	..	..	..
" 31	..	0.30 p.m.	..	*e**	..	..	..	..
Nov. 1	..	..	..	*e*	..	..	..	..
" 6	..	..	..	*e*	..	..	..	..
" 8	..	..	..	*e**	..	..	..	..
" 9	..	..	..	*e*	..	..	..	..
" 18	..	..	..	*e*	..	..	..	..
Dec. 2	..	3 a.m.	..	..	*i*	..	..	..
" 15	..	4 p.m.	..	*e*	..	..	..	..
" 21	..	..	..	..	*i*	..	..	..

(a) Great tidal wave in New Zealand, Chatham Islands, Australia, Sandwich Islands, South America, and throughout Pacific (see Trans. N.Z. Inst., vol. i.); also on 17th. (b) Very severe at Taranaki, where much damage was done.

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1869.							
Jan. 9 ..	..	..	*e*	*i*	..	..	..
„ 10 ..	..	..	*e*	..	..	..	..
„ 14 ..	..	..	..	..	..	*q*	..
Feb. 10 ..	3 a.m.	..	..	..	..	*q*	..
„ 11 ..	10.13, 10.30, a.m.	..	..	*g*, *i*	*k*,* *l*	*n*	..
„ 22 ..	..	..	*e*	..	..	..	..
„ 23 ..	..	..	*e*	..	..	..	..
„ 27 ..	11 p.m.	..	..	*g*	..	..	..
Mar. 4 ..	..	..	*e*	..	..	..	..
„ 10 ..	..	..	*e*	..	..	..	..
„ 13 ..	..	..	..	..	*k**	..	..
„ 15 ..	..	..	*e*	..	..	..	..
April 20 ..	Night	..	*e*	..	..	..	..
May 24 ..	8.27 p.m.	..	..	..	*k**	..	..
June 1 ..	6.23 p.m.	..	..	*i**	..	..	..
„ 1 ..	7.30 p.m.	..	..	*i*	..	..	..
„ 5 ..	7.53, 8.2 a.m.	..	..	*i*	..	*n**	..
„ 5 ..	7.19 p.m.	..	..	..	..	*n*	..
„ 6 ..	2.21 p.m.	..	..	..	..	*n*	..
„ 24 ..	11 a.m.	..	..	..	..	*q*, *o*	..
July 16 ..	7.20 p.m.	..	*e**	..	..	..	..
„ 23 ..	10 a.m.	..	..	..	..	*n**	..
Aug. 4 ..	0·30, 2.25 a.m.	..	..	*i**	*k**	..	..
„ 26 ..	7.15 a.m.	..	..	*i*	..	..	..
Sept. 30 ..	9 p.m.	..	..	*i*	..	..	..
Oct. 11 ..	1.30 a.m.	..	..	..	..	*q*	..
Nov. 3 ..	0.50 a.m.	..	..	..	..	*n*	..
„ 15 ..	Night	..	..	..	..	*n*	..
„ 26 ..	2 a.m.	..	*f**	*i**	..	..	..
„ 28 ..	1.30 a.m.	..	..	..	*k**	*q**	..
Dec. 25 ..	5 p.m.	..	..	..	..	*q**	*r**
„ 29 ..	3.45 a.m.	..	*f*	..	..	..	..
1870.							
Jan. 8 ..	3 a.m.	..	..	*g*	..	..	..
„ 15 ..	2 a.m.	..	..	*g*	..	..	..
„ 17 ..	..	..	..	*g*	..	..	..
Feb. 10 ..	9.40 a.m.	..	..	..	..	*m*	..
„ 12 ..	..	..	..	*g**	..	..	..
Mar. 17 ..	11.25 p.m.	..	..	..	..	*n**	..
April 4 ..	4 p.m.	..	*e*	..	..	..	..
May 3 ..	10 p.m.	..	..	*i*	..	..	..
„ 14 ..	7 a.m.	..	..	..	*l*	..	..
„ 21 ..	6.24 a.m.	..	..	..	..	*m*	..
„ 25 ..	8.32 a.m.	..	..	*i*	..	..	..
June 13 ..	2.29 a.m.	..	..	..	..	*m*	..
„ 25 ..	10 p.m.	..	..	*g**	..	..	..
„ 26 ..	2 a.m.	..	..	*g*	..	..	..
July 7 ..	2.30 a.m.	..	*e**	*i**	*k**	..	..
„ 8 ..	2.30 p.m.	..	*e*	..	*k**	..	..
Aug. 11 ..	3.54 a.m.	..	..	*i*	..	..	..
„ 22 ..	2.28 p.m.	..	..	..	*k*	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1870.								
Aug. 24	..	11.42 a.m.	..	..	..	..	*m**	..
„ 31	..	6.25 p.m.	..	..	..	*l, p, q*	*m,* n**	..
Sept. 1	..	6.20 p.m.	..	..	..	*l*	..	..
„ 29	..	..	..	*e*	..	..	..	..
„ 30	..	Morning	..	..	*i*	..	..	..
Oct. 3	..	2.15 p.m.	..	*c*	*i*	*k*	..	..
„ 23	..	..	..	*e*	..	..	..	..
Nov. 2	..	1 p.m.	..	..	*g*	..	..	..
„ 10	..	..	..	..	*i*	..	..	..
„ 19	..	..	..	..	*i*	*j*	..	..
Dec. 18	..	7.38 p.m.	..	..	*i*	..	..	..
1871.								
Jan. 1	..	0.30 a.m.	..	..	*i*	*k, j*	..	..
„ 8	..	..	..	..	..	*l*	..	..
„ 20	..	8.35 a.m.	..	..	*i*	..	..	..
„ 30	..	2.30 p.m.	..	..	*i*	..	..	..
Feb. 14	..	..	..	*e*	..	..	..	..
Mar. 13	..	10.30 a.m.	..	..	*g*	..	..	..
„ 16	..	11.45 p.m.	..	..	*i*	..	..	..
„ 19	..	9.5 p.m.	..	..	..	..	*m**	..
„ 28	..	8 a.m.	..	..	..	..	*n*	..
April 19	..	1.30 a.m.	..	..	*g**	..	..	..
„ 19	..	4 p.m.	..	..	..	..	*q**	..
„ 20	..	..	..	..	..	*l*	*p*	..
„ 20	..	1.15 a.m.	..	..	..	..	*q*	..
June 28	..	Night	..	..	*i*	..	..	..
July 25	..	10 a.m.	..	..	*g*	..	..	..
Aug. 1	..	8.52 p.m.	..	..	..	..	..	*r*
„ 16	..	0.25 a.m.	..	*c*	..	..	..	..
„ 16	..	9.30 p.m.	..	*c*	..	..	..	..
„ 22	..	7.45 a.m.	..	*c*	..	..	..	..
„ 27	..	..	..	..	..	..	*n*	..
„ 31	..	..	..	..	..	*j, k*	*n*	..
Sept. 1	..	6.30 a.m.	..	..	..	*l*	..	..
„ 26	..	5.30 a.m.	..	*f*	*i*	*j*	..	..
Oct. 1	..	11.22 p.m.	..	..	*i*	..	..	..
Nov. 10	..	..	..	..	*i*	..	*n*	..
„ 23	..	..	..	*f*	*i*	..	..	..
„ 25	..	1.45 p.m.	..	*f**	*i**	*j**	..	..
„ 26	..	..	..	..	..	*k*	..	..
Dec. 4	..	6.15 a.m.	..	..	*i*	..	..	..
„ 5	..	9.27 a.m.	..	..	..	..	..	*r*
„ 7	..	7.4 a.m.	..	..	*i*	..	..	..
1872.								
Jan. 15	..	10.30, 10.33, 11.19 a.m.	..	*c**	..	..	..	..
„ 26	..	6.7 p.m.	..	..	..	..	*o*	..
Feb. 9	..	1.37 a.m.	..	..	..	..	..	*r**
„ 10	..	..	..	..	..	*k*	..	..
„ 14	..	0.30 p.m.	..	*f*	..	..	..	..
„ 15	..	3.31 p.m.	..	..	..	*k*	..	..
Mar. 3	..	..	..	..	*i*	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1872.							
Mar. 6	..	..	..	..	..	..	*r*
〃 14	..	..	..	*g*	..	..	..
April 10	2.22 p.m.	..	..	*i*	..	..	..
June 6	..	..	*d**	..	..	..	..
〃 7	..	..	..	*g**	..	..	..
〃 11	1.30 p.m.	..	..	..	*k*	..	..
〃 18	0.38 p.m.	..	..	*g**	..	..	..
July 2	0.30 a.m.	..	*f**	*i*	..	..	..
〃 29	..	..	..	..	..	..	*r*
Aug. 2	..	..	*f*	*h*	..	..	..
〃 4	..	..	..	*i*	..	..	..
Sept. 5	10.45 p.m.	..	*f*	..	..	..	..
〃 6	3 p.m.	..	..	..	..	..	*r*
〃 10	8.15 a.m.	..	*f*	..	..	..	..
〃 20	5.7 p.m.	..	*f,* e**	*i**	*j,* k**	..	..
〃 24	9.17 a.m.	..	..	*i*	..	..	..
Oct. 4	4·14 a.m.	..	*f*	..	..	..	..
〃 10	4.19 a.m.	..	*f*	..	..	..	..
〃 14	9.58 p.m.	..	..	*i*	*k**	..	..
Nov. 1	8 p.m.	..	..	*i*	..	..	..
〃 20	1.25 p.m.	..	..	..	..	*p**	..
〃 20	0.30 p.m.	..	..	..	..	*p*	..
Dec. 1	3.30 a.m.	..	..	*i*	..	..	..
〃 13	1.51 p.m.	..	..	*i*	..	..	..
〃 16	1.30 p.m.	..	..	..	..	*q*	..
〃 26	5.3, 5.20 p.m.	..	*e*	..	*k,* j**	..	..
1873.							
Jan. 4	8.30 p.m.	..	..	..	*l*	..	..
〃 6	6.30 p.m.	..	*f**	..	..	..	..
〃 26	6.7 p.m.	..	..	..	*k*	*n**	..
〃 31	8.50 p.m.	..	..	..	..	..	*r*
Feb. 5	6.30 a.m.	..	*f*	..	..	..	..
〃 10	5.51 p.m.	..	*f*	..	..	..	..
〃 10	10.50 p.m.	..	*f*	..	..	..	..
〃 16	6.51 p.m.	..	*f*	..	..	..	..
〃 18	6.15 p.m.	..	*f*	..	..	..	..
〃 22	5.30 p.m.	..	*f*	..	..	..	..
〃 24	Early	..	*f*	..	..	..	..
〃 25	9.30 a.m.	..	*f*	..	..	..	..
Mar. 13	4.30 p.m.	..	*f*	..	..	..	..
〃 16	10.30 p.m.	..	*f*	..	..	..	..
〃 17	0·5 a.m.	..	..	*i*	..	..	..
〃 18	Night	..	..	*i*	..	..	..
〃 22	11.50 p.m.	..	..	*i*	..	..	..
〃 23	0.10 a.m.	..	*f*	..	..	..	..
〃 23	11.50 p.m.	..	*f*	..	..	..	..
〃 26	11.18 p.m.	..	..	..	*k*	..	..
〃 26	11.55 p.m.	..	..	*i**	..	..	..
〃 27	5 p.m.	..	..	*i*	..	..	..
〃 31	4.30 a.m.	..	*f*	..	..	..	..
April 1	3.55 p.m.	..	..	*i**	*k**	*n*	..
〃 5	11.30 p.m.	..	*f*	..	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1873.								
April 14	..	..	..	..	*i*	..	..	..
" 17	..	11, 11.30 p.m.	..	..	*i**	..	..	..
May 17	..	..	..	*f*	..	..	..	..
" 19	..	..	..	*f*	..	..	..	..
June 4	..	0.40 a.m.	..	..	*g*	..	..	..
" 8	..	0.7 a.m.	..	*f**	..	..	..	..
" 12	..	7.30–7.40 p.m.	..	*f, e*	*i*	*j*	..	..
" 13	..	8.15 a.m.	..	*f*	..	..	..	..
" 18	..	5.15 p.m.	..	*f**	..	..	..	..
" 22	..	11.45 a.m.	..	*f**	..	..	..	..
" 29	..	9 p.m.	..	*f**	..	..	..	..
July 4	..	..	..	*f*	..	..	..	..
" 5	..	3 a.m.	..	*e*	..	..	..	..
" 5	..	2 a.m.	..	*f*	..	..	..	..
" 5	..	Midnight	..	*f**	..	..	..	..
Aug. 24	..	1.47 a.m.	..	..	..	..	*m*	..
" 29	..	1.20 p.m.	..	*f**	*i*	*j,* k*	..	..
" 29	..	1 p.m.	..	..	..	..	*n*	..
Sept. 11	..	1.49 p.m.	..	*f**	..	..	..	..
" 18	..	10.23 p.m.	..	..	*g*	..	..	..
" 21	..	2.45 p.m.	..	*f*	..	..	..	..
Oct. 18	..	4 a.m.	..	*f*	..	..	..	..
" 18	..	2.20–4 a.m.	..	*f**	..	*k**	..	..
" 23	..	11.30 a.m.	..	..	..	..	*n*	..
Dec. 6	..	5.15 p.m.	..	*e*	..	..	..	..
" 8	..	2.23, 3.45 p.m.	..	*e, f*	*i*	*k**	..	..
" 16	..	0.10 p.m.	..	*f**	*i**	..	..	..
" 29	..	0.40 p.m.	..	..	*i*	..	..	..
1874.								
Jan. 21	..	7 a.m., 6 p.m.	..	*c**	..	..	..	..
" 23	..	..	..	*c*	..	..	..	..
" 24	..	6–8 a.m.	..	*c**	..	..	..	..
" 29	..	9.15 p.m.	..	..	*g*	..	..	..
Feb. 1	..	..	..	..	..	..	*p*	*r*
" 2	..	Night	..	..	..	..	*q*	..
" 4	..	..	..	..	..	..	*p*	..
" 8	..	..	..	..	..	..	*q**	..
" 28	..	5 a.m.	..	*c**	..	..	*n**	..
Mar. 1	..	0.10 p.m.	..	..	*i*	..	..	..
" 4	..	Midnight	..	*f**	..	..	..	..
" 7	..	10.27 a.m.	..	..	*g*	..	..	..
" 9	..	Midnight	..	*f,* e*	..	..	..	..
" 11	..	Night	..	*f*	..	..	..	..
" 17	..	11.30 a.m.	..	..	*i*	..	..	..
" 25	..	0.3 a.m.	..	..	..	..	*n**	..
April 24	..	11 p.m.	..	..	*i*	..	..	..
June 6	..	8.45 a.m.	..	..	..	..	*n*	..
" 9	..	..	..	*d*	..	..	..	..
" 20	..	6 a.m.	..	..	..	..	*q,* p**	*r**
" 23	..	11.30 p.m.	..	*f*	..	..	..	..
July 4	..	9.35 p.m.	..	*e**	..	..	..	..
" 28	..	4.37 p.m.	..	*f,* e*	..	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1874.								
Aug. 3	..	4.16 a.m.	..	..	*g**	..	..	..
" 4	..	0.15 p.m.	..	..	*i*	..	..	..
" 5	..	7.20 a.m.	..	..	*i*	..	..	..
" 6	..	5.10 p.m.	..	..	*i*	..	..	..
" 9	..	p.m.	..	..	*i*	..	..	..
" 15	..	2.15 a.m.	..	..	*i*	..	..	..
" 18	..	2 p.m.	..	*f*	..	..	..	..
Sept. 14	..	..	..	*e*	..	..	..	..
Oct. 18	..	5.21 p.m.	..	..	..	..	..	*r*
" 28	..	..	*b*	..	..	..	..	..
Nov. 14	..	1.30 p.m.	..	..	*g*	..	..	..
" 27	..	9.30 p.m.	..	..	..	*j*	..	..
Dec. 1	..	..	..	..	..	..	*n*	..
" 15	..	8 a.m.	..	*e*	..	..	..	..
1875.								
Jan. 18	..	1 a.m.	..	..	*g*	..	..	..
" 4	..	6.30 p.m.	..	..	*i*	..	..	..
Mar. 7	..	5.18 a.m.	..	*f**	*g*,* *i**	*k**	*n**	..
" 13	..	5.13 p.m.	..	..	*i**	..	..	..
April 14	..	2.30 a.m.	..	*c**	..	..	..	..
" 17	..	7.15 a.m.	..	..	*g**	..	..	..
" 19	..	5 a.m.	..	..	*i*	..	..	..
" 25	..	11.5 p.m.	..	*f**	..	..	..	..
May 12	..	10.30 a.m.	..	..	*i*	..	..	..
" 24	..	4.45, 5 p.m.	..	..	*i*	*j**	..	..
1876.								
Jan. 10	..	..	..	..	..	*l*	..	..
" 13	..	4.13, 4.20 p.m.	..	*f*	*g**	..	..	..
Feb. 25	..	3.20 a.m.	..	..	..	..	..	*r*
" 26	..	8.50 a.m.	..	..	..	..	*o**, *p*	*r*
" 26	..	8.40 p.m.	..	..	..	..	*o**	..
" 29	..	..	..	..	*i**	*j**	..	..
Mar. 7	..	1.20 a.m.	..	*f**	..	..	..	..
" 9	..	10.40 p.m.	..	..	..	..	*o**	..
" 10	..	5.25 a.m.	..	..	..	..	*o**	..
" 26	..	4.20 a.m.	..	..	..	*k*	..	..
" 27	..	10.10 p.m.	..	*e**	..	..	..	..
April 11	..	11.40 a.m.	..	..	..	..	*p*, *o**	*r*
" 13	..	6.10 p.m.	..	*f*	..	..	..	..
May 3	..	6.30 p.m.	..	..	..	..	*q*	..
" 3	..	7.54 a.m.	..	*f*	..	..	..	..
" 5	..	6, 6.10 a.m.	..	*f*	*i*	*j*	..	..
" 6	..	6.30 a.m.	..	..	..	..	*n*	..
" 14	..	5.50 p.m.	..	..	..	..	..	*r*
" 20	..	4.17 a.m.	..	..	..	..	*p**	..
" 20	..	5.30 a.m.	..	..	..	..	*o**	..
" 31	..	3 a.m.	..	..	*i**	..	..	..
" 31	..	5.20 p.m.	..	..	..	..	*o*	..
June 28	..	..	..	..	*i*	..	..	..
July 19	..	4.15 a.m.	..	*e*,* *f*,*	*g*,* *i**	*j*,* *l**	*n**	..
" 20	..	..	..	..	*g*	..	..	..
Aug. 7	..	3 a.m.	..	..	*i*	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1876.							
Aug. 14 ..	8.4 p.m.	..	..	..	..	*m**	..
Sept. 3 ..	0.16 a.m.	..	..	*i*	..	..	..
„ 3 ..	5 a.m.	..	..	*i*	..	..	..
„ 13 ..	2 a.m.	..	..	*i*	..	..	..
„ 23 ..	8.2 p.m.	..	*e**	..	..	..	..
„ 28 ..	6 a.m.	..	..	..	*k*	..	..
„ 28 ..	6 p.m.	..	..	*g**	..	..	..
Oct. 24 ..	2.3 a.m.	..	..	..	..	..	*r*
Nov. 21 ..	6.45 a.m.	..	..	..	..	..	*r*
Dec. 7 ..	0.45 p.m.	..	..	*g*	..	..	..
„ 7 ..	11.30 p.m.	..	*f*	..	..	..	..
1877.							
Jan. 10 ..	9.58 p.m.	..	..	*i**	..	..	..
Feb. 2 ..	10.10 p.m.	..	..	..	..	*n*	..
„ 5 ..	10.24 p.m.	..	*f**	..	..	..	..
„ 7 ..	Night	..	*f*	..	..	..	..
„ 9 ..	6.49 p.m.	..	..	*i*	..	..	..
„ 10 ..	8.49 a.m.	..	..	*i*	..	..	..
April 13 ..	..	..	..	..	..	..	*r**
May 2 ..	..	..	..	..	..	*q*	..
„ 8 ..	7.20 a.m.	..	*e*	..	..	..	..
„ 11(a) ..	..	..	..	..	..	..	..
July 4 ..	3.30 p.m.	..	..	*i*	*l*	..	..
„ 16 ..	10 p.m.	..	..	*i*	..	..	..
Aug. 11 ..	6.30 a.m.	..	*f*	*i*	..	..	..
„ 14 ..	6 a.m.	..	..	..	..	..	*r*
Sept. 15 ..	8 a.m.	..	..	*i*	..	..	..
„ 16 ..	..	..	..	..	..	*n*	..
„ 22 ..	4.40 p.m.	..	..	*i**	..	..	..
„ 29 ..	1.50 a.m.	..	..	*i*	..	..	..
Oct. 9 ..	..	..	..	..	..	*p*	..
„ 10 ..	8.53 p.m.	..	..	*i*	..	..	..
„ 10 ..	Night	..	..	..	..	*o*	..
„ 25 ..	8.40 p.m.	..	..	*g*	..	..	..
Nov. 6 ..	9.10 a.m.	..	..	*i*	..	..	..
„ 7 ..	8.21 p.m.	..	..	*i*	..	..	..
„ 21 ..	..	..	..	..	..	*n*	..
Dec. 8 ..	4.15 a.m.	..	*d**	..	..	..	..
1878.							
Jan. 15 ..	8.45 p.m.	..	..	..	..	..	*r*
Feb. 12 ..	3 a.m.	..	..	..	..	..	*r*
Mar. 11 ..	9.35 p.m.	..	..	..	*l*	..	..
April 4 ..	Midnight	..	*f*	..	..	..	..
„ 11 ..	8.55 a.m.	..	..	..	*j**	..	..
„ 25 ..	3.30 a.m.	..	..	..	..	..	*r*
„ 28 ..	6.25 p.m.	..	..	*i*	..	..	..
June 3 ..	0.15 a.m.	..	..	..	*j**	..	..
„ 5 ..	11.15 p.m.	..	..	*g**	..	..	..
„ 23 ..	7.38 a.m.	..	..	*i*	..	..	..
„ 23 ..	3.15 p.m.	..	..	*g*	..	..	..

(a) Tidal isturbance on east coast.

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1878.							
June 24 ..	8.30 a.m.	..	..	..	*k*	..	..
July 5 ..	10.17 p.m.	..	*f**	*i**	..	..	..
„ 20 ..	11.39 p.m.	..	*f**	*i**	..	..	..
„ 21 ..	3 a.m.	..	..	*i*	..	..	..
Aug. 8 ..	7.53, 8.10 a.m.	..	*e*, *f**	*i*	..	..	..
„ 23 ..	7.35 p.m.	..	..	..	..	..	*r*
„ 24 ..	2.38 p.m.	..	..	..	..	..	*r**
„ 25 ..	2.40 p.m.	..	..	..	..	*q*	..
Sept. 14 ..	4.30, 5 a.m.	..	..	*i*	*j**	*n**	..
„ 30 ..	..	..	..	..	..	*n*	..
Oct. 21 ..	10.55, 11.45 p.m.	..	*f*	*i**	*j*,* *k*,* *l*	*n*	*r*
„ 27 ..	3.30 a.m.	..	..	..	*j*	..	..
Nov. 8 ..	3.20 a.m.	..	..	..	..	..	*r*
„ 14 ..	0.8 p.m.	..	..	..	..	..	*r**
„ 27 ..	6.40 p.m.	..	..	..	..	..	*r*
Dec. 6 ..	9 p.m.	..	..	*i*	..	..	..
„ 7 ..	5 a.m.	..	..	*i*	..	..	..
„ 12 ..	11.39 a.m.	..	..	*i**	..	..	..
1879.							
Jan. 5 ..	8.45 a.m.	..	..	*i**	..	..	..
„ 5 ..	8.47 and 9.50 p.m.	..	*f**	..	..	..	..
„ 12 ..	6.20, 6.42 p.m.	..	..	*i**	..	..	..
„ 16 ..	..	..	*g**	..	..	..	..
Mar. 4 ..	11.30 p.m.	..	..	..	*j*	..	..
April 20 ..	12 p.m.	..	..	..	..	..	*r*
„ 24 ..	10.55 p.m.	..	..	*i*	..	..	..
May 3 ..	2–3 a.m.	..	..	*i*	..	..	..
July 9 ..	2.35 p.m.	..	..	..	*j*	..	*r*
„ 21 ..	10.40 p.m.	..	*f*	..	..	..	..
„ 22 ..	10.50 p.m.	..	..	..	..	*n**	..
„ 27 ..	6.15 a.m.	..	..	*i*	..	..	..
Aug. 5 ..	7.45 a.m.	..	..	*i**	..	..	..
„ 8 ..	Noon	..	..	*i*	..	..	..
„ 18 ..	3.30 p.m.	..	..	*i*	..	..	..
Sept. 17 ..	8.15 a.m.	..	*e*	..	..	..	..
„ 23 ..	4.4 a.m.	..	..	..	..	*m**	..
Oct. 30 ..	2.15, 2.30 a.m.	..	*e*, *f**	*g*, *i**	*j*	..	..
Nov. 17 ..	0.15 p.m.	..	..	..	..	*n**	..
17 ..	6, 6.10 a.m.	..	*e*	*i*	..	..	..
„ 19 ..	6.10 a.m.	..	*e*	..	..	..	..
Dec. 25 ..	6.30 a.m.	..	..	..	..	..	*r*
1880.							
Jan. 9 ..	0.15 p.m.	..	..	..	..	..	*r*
Feb. 10 ..	1 p.m.	..	*g*	..	..	..	..
„ 22 ..	9.30 p.m.	..	..	..	*l*	..	..
Mar. 4 ..	11.51 a.m.	..	..	..	..	*p*	..
„ 5 ..	..	..	..	..	..	..	*r**
„ 6 ..	Early	..	..	..	..	..	..
„ 10 ..	5.30 a.m.	..	*f**	..	..	*n**	..
„ 11 ..	11.20 p.m.	..	*f*	..	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1880.								
April 17	..	..	..	*f*	..	..	..	..
„ 20	..	0.39 p.m.	..	..	*i**	..	..	..
„ 29	..	2.30 a.m.	..	..	..	..	..	*r*
May 4	..	4.45 a.m.	..	..	..	..	..	*r*
„ 9	..	8 and 8.10 p.m.	..	*f**	..	..	..	..
„ 27	..	11.30 a.m.	..	..	..	..	..	*r*
June 8	..	6.30 p.m.	..	..	..	..	..	*r*
July 4	..	10 p.m.	..	*f*	..	..	..	..
„ 12	..	11.30 p.m.	..	..	..	*l*	..	..
„ 28	..	5.12–5.15 p.m.	..	*c*,* *f**	*g**, *i**	*k*	..	..
„ 31	..	1.18, 1.25 a.m.	..	..	*g**	..	..	..
Aug. 4	..	2.56 a.m.	..	..	*i*	*j*	..	..
Nov. 27	..	1.15 p.m.	..	*f*	..	*k*	..	..
1881.								
Jan. 3	..	8.30 a.m.	..	..	*i*	..	..	..
April 8	..	6.45 p.m.	..	..	..	..	*n**	..
May 6	..	6.45 p.m.	..	..	..	..	*n**	..
„ 14	..	11 p.m.	..	..	..	..	*n*	..
„ 22	..	..	..	..	..	*k*	..	..
„ 23	..	..	..	..	..	*k*	..	..
„ 24	..	..	..	..	..	*k*	..	..
June 26	..	5.20 a.m.	..	..	*i*	..	..	..
July 6	..	5.15 a.m.	..	..	*i*	..	..	..
„ 12	..	2.51 a.m.	..	..	*i*	..	..	..
Aug. 8	..	10.25 a.m.	..	..	*i*	..	..	..
„ 10	..	4–5 p.m.	..	..	*i**	..	..	..
Sept. 1	..	2.25 a.m.	..	*e**	*i**	*j**	..	..
„ 8	..	10.50 p.m.	..	..	..	..	*q*	*r*
„ 14	..	7.30 am.	..	..	*i*	..	..	..
„ 14	..	2 a.m.	..	..	*i*	..	..	..
„ 15	..	7.37 p.m.	..	..	*i*	..	..	..
„ 20	..	3 a.m.	..	..	..	..	*p*	..
„ 26	..	3 p.m.	..	*f**	..	..	..	..
Oct. 17	..	1.23 a.m.	..	*f**	..	..	..	..
„ 25	..	4.20 a.m.	..	*c*, *f*	..	..	..	..
Dec. 3	..	6.30 a.m.	..	..	*i*	..	..	..
„ 5	..	7.37 a.m.	..	..	..	*j*, *k*, *l**	*n*, *o*, *p*	..
„ 6	..	5.6 a.m.	..	..	..	..	*n*	..
„ 9	..	5.22 a.m.	..	..	..	*l*	*n*	..
„ 23	..	7.13 a.m.	..	..	*i*	..	..	..
„ 23	..	10.54 p.m.	..	..	*i*	..	..	..
„ 31	..	1 p.m.	..	..	*i*	..	..	..
1882.								
Jan. 7	..	8 a.m.	..	..	..	..	*n*	..
„ 9	..	2.20 a.m.	..	..	*i*	..	..	..
„ 10	..	Midnight	..	..	..	..	*n*	..
„ 17	..	10.45 p.m.	..	..	*i*	..	..	..
Feb. 1	..	2.20 p.m.	..	..	*i*	..	*n*	..
„ 1	..	3.3 p.m.	..	*c*, *e*, *f*	*g*, *i*	*k*, *l*	*n*	..
„ 20	..	Midnight	..	..	*i*	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1882.								
Feb. 21	..	6.30 a.m.	..	..	*i*	..	..	..
" 24	..	11.22 a.m.	..	..	*g*	..	..	..
April 4	..	Morning	..	..	..	..	*q*	..
" 6	..	4.9 p.m.	..	*e, f*	*i*	*j, k*	*n*	..
May 5	..	Early	..	..	..	..	*p**	..
" 13	..	Midnight	..	..	*i*	..	..	..
" 15	..	0.20, 4.15 a.m.	..	..	*i*	..	..	..
June 1	..	11.20 p.m.	..	..	..	*j*	..	..
" 6	..	8 p.m.	..	..	*i*	..	..	..
" 12	..	7 a.m.	..	..	*i*	..	..	..
" 24	..	11.30 p.m.	..	*f*	..	..	..	..
July 16	..	10.50 a.m.	..	..	..	..	*o*	..
" 20	..	3.45 a.m.	..	..	..	*l*	*o*	..
" 24	..	Midnight	..	*f**	*i*	..	..	..
" 25	..	Early	..	..	*i*	..	..	..
" 26	..	6.30 a.m.	..	*f**	..	..	..	..
Aug. 20	..	..	..	..	..	..	*n*	..
" 29	..	Early	..	..	..	..	..	*r*
Sept. 25	..	..	..	..	..	..	*n*	..
Oct. 20	..	0.20 a.m.	..	..	*i**	..	..	..
" 20	..	Noon	..	..	..	..	*p*	..
Nov. 2	..	2.30 a.m.	..	..	..	..	*p*	*r*
" 18	..	11.4 p.m.	..	..	*i**	..	..	..
" 25	..	10.5 p.m.	..	..	*i*	..	..	..
Dec. 11	..	2 a.m.	..	..	..	..	*q*	..
1883.								
Feb. 5	..	10 p.m.	..	..	*i*	..	..	..
" 14	..	2–3 a.m.	..	..	*i*	..	..	..
" 22	..	9.10 p.m.	..	..	..	*l*	..	..
" 24 and 25	..	..	..	*d**	..	..	..	..
Mar. 14([a])	..	Noon	..	*d**	..	..	..	..
" 28	..	10.30 p.m.	..	*f**	..	..	..	..
April 26([b])	..	..	..	*d*	..	..	..	..
June 24	..	11.50 p.m.	..	..	..	*j*	*n*	..
July 4	..	After midn't	..	..	*i**	..	..	..
" 5	..	3.30 a.m.	..	..	*i*	..	..	..
" 9	..	2.40 a.m.	..	..	*i*	..	..	..
Aug. 15	..	3 a.m.	..	..	*g*	..	..	..
" 27	..	4.30 a.m.	..	..	*i*	*j*	..	..
" 29([c])	..	9.30 p.m.	..	*f**	..	..	..	..
Dec. 8	..	7.15 p.m.	..	..	*i*	..	..	..
" 18	..	0.50 p.m.	..	..	..	*l*	*o, p, q*	..
" 24	..	5.7 a.m.	..	*f*	..	..	..	..
1884.								
Jan. 6	..	0.2 p.m.	..	*f**	..	..	..	..
" 19	..	5.20 p.m.	..	..	..	..	*n*	..
" 30	..	1 a.m.	..	..	*i*	..	..	..

(a) Several shocks at Taupo during this week. On the 11th heavy rollers suddenly began to break on the south-west coast. High tides at Collingwood. 24th, hurricane, earthquake, and tidal wave at Samoa. (b) Eruption of Tongariro. (c) On 28th and 31st tidal disturbances in New Zealand, due to Krakatoa eruption. Earthquakes in Australia.

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1884.							
Feb. 2	Afternoon	..	..	..	..	*n*	..
" 2	After midn't	..	..	*i*	..	..	..
" 6	5.15 p.m.	..	..	..	..	..	..
" 8	0.30, 2.30 a.m.	..	..	*g**	..	..	..
" 19	4.30 p.m.	..	..	..	..	..	..
Mar. 10(a)	..	..	*d*	..	..	..	..
" 11	11.20 p.m.	..	*f**	..	..	..	..
" 20	..	..	*d**	..	..	..	..
" 21	7 a.m.	..	*d**	..	..	..	..
" 28	10 a.m.	..	*e,* f**	*i*	..	..	..
April 11	6.49 p.m.	..	*e,* f**	*i**	*j,* k,* l**	*n**	..
" 16	6.27 a.m.	..	..	*i**	*j*	..	..
" 25	11.55 a.m.	..	..	*i**	*j*	..	..
May 1	8.40 p.m.	..	..	*i*	..	..	..
" 8	8.30 p.m.	..	..	*i*	..	..	..
June 2	..	..	..	..	*j*	..	..
" 5	3 a.m.	..	..	*i**	..	..	..
" 10	11.30 p.m.	..	..	..	..	*n**	..
" 10	0.10 p.m.	..	..	*i*	..	..	..
July 31	10.35 a.m.	..	..	..	*l**	..	..
Aug. 20	0.50 p.m.	..	..	..	..	*q*	..
Sept. 24	7.15 a.m.	..	..	*g*	..	..	..
Oct. 10	5.52 a.m.	..	..	..	..	*n**	..
" 6	0.13 p.m.	..	*f**	..	..	..	..
" 8	9.10 a.m.	..	..	..	*j*	*n*	..
Dec. 28	9.27 p.m.	..	..	..	*j*	..	..
1885.							
Jan. 15	6.10 p.m.	..	*f*	*i*	*j, k*	*n*	..
Feb. 25	2.30 p.m.	..	..	..	*l**	..	..
" 27	2.8 a.m.	..	..	..	..	*o**	..
Mar. 20	2.15 p.m.	..	*e*	..	..	..	..
May 9	4 a.m.	..	*f**	..	..	..	..
July 26	7.45 p.m.	..	*f**	*i**	*j,* l**	*n*	..
Aug. 5	5.20 p.m.	..	..	*i**	*j*	..	..
Sept. 27	8.55 p.m.	..	..	..	..	*o**	..
Oct. 11	6.20 p.m.	..	..	..	*j*	..	..
Dec. 26	Midnight	..	..	..	..	*o**	..
1886.							
Jan. 26	4.30 p.m.	..	*d*	..	..	..	..
Feb. 7	1.30 a.m.	..	..	*g**	..	..	..
" 7	9.45 a.m.	..	..	*g**	..	..	..
Mar. 2	2–3 a.m.	..	..	*i*	..	..	..
" 30	1 a.m.	..	*d*	..	..	..	..
April 19	9.25 p.m.	..	..	*i*	..	..	..
" 22	3 p.m.	..	*d*	..	..	..	..
" 28	4.30 a.m.	..	*d*	..	..	..	..
" 30	5.30 p.m.	..	*d*	..	..	..	..
May 16	3.30 a.m.	..	*f**	*i**	..	..	..
June 10(b)	6.20 a.m.	..	*d**	..	..	..	..

(a) Fifteen shocks at Taupo. (b) Tarawera and Rotomahana outbreak, followed by local earth-tremors until 24th June.

SCHEDULE OF EARTHQUAKES—*continued.*

Date.	Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1886.							
June 23 ..	..	..	..	..	..	*n, p, q*	..
„ 29 ..	0.30 a.m.	..	*f**	*i*	..	..	..
July 10 ..	7.12 a.m.	..	..	*i*	*j*	..	..
Aug. 27 ..	9.25 p.m.	..	*f*	..	..	..	..
„ 30 ..	0.10 p.m.	..	*f**	..	..	..	..
„ 31 ..	Midnight	..	..	*g*	..	..	..
Sept. 3 ..	Noon	..	*e, f**	*i**	*j,* k,* l**	*m, n*	..
„ 5 ..	..	..	..	..	*j*	..	..
„ 7 ..	7 a.m.	..	..	*i*	*j,* k*	..	..
„ 20 ..	4.30 p.m.	..	..	..	*j,* k*	..	..
„ 26 ..	..	..	..	..	*j*	..	..
„ 27 ..	3 a.m.	..	..	..	*j*	..	..
Nov. 2 ..	0.15 a.m.	..	..	..	..	..	..
„ 14 ..	..	..	..	*i**	..	..	..
„ 26 ..	0.47 a.m.	..	*f**	*i**	*j*	..	..
„ 29(a) ..	Evening	..	*d*	..	..	..	..
Dec. 1 ..	9.57 p.m.	..	..	..	*l*	..	..
„ 2 ..	8 a.m.	..	..	..	..	..	..
1887.							
Jan. 16 ..	4 a.m.	..	..	*i*	..	..	..
„ 31 ..	6.20 p.m.	..	..	*i,* j,* k**	..	*n**	..
Mar. 15 ..	4.30 a.m.	..	*e*	*i*	*j,* k* l**	*n**	..
„ 29 ..	10.40 p.m.	..	*d*	..	..	..	..
April 12 ..	4 a.m.	..	..	*g, i*	..	..	..
„ 15 ..	0.35 p.m.	..	*e**	..	..	..	..
„ 22 ..	2 a.m.	..	..	*i*	..	..	..
„ 28 ..	2 a.m.	..	*d*	..	..	..	..
May 3 ..	..	..	..	..	..	..	..
„ 13 ..	Noon	..	..	*i*	..	..	..
„ 22 ..	2 a.m.	..	..	*i*	..	..	..
June 1 ..	9.30 p.m.	..	..	*i**	..	..	..
„ 21 ..	1.50 p.m.	..	*d*	..	..	..	..
„ 27 ..	1.50 p.m.	..	..	*i*	..	..	..
July 17 ..	..	..	..	..	..	*n**	..
„ 18 ..	..	..	..	..	..	..	..
Aug. 13 ..	6.35 a.m.	..	..	*i*	..	..	..
Oct. 6 ..	7 a.m.	..	..	*i*	..	..	..
„ 6 ..	10.30 p.m.	..	..	*i*	..	..	..
Nov. 11 ..	2 a.m.	..	..	*i**	..	..	..
„ 13 ..	..	..	*d*	..	..	..	..
Dec. 18 ..	11.30 p.m.	..	*d*	*i**	..	..	..
1888.							
Jan. 18 ..	..	..	..	..	*l, l**	..	..
„ 19 ..	..	..	..	..	..	*n*	..
Feb. 14 ..	..	..	..	..	..	*n*	..

(a) On 29th November earth-tremors at Rotorua, Tarawera throwing up steam for twenty minutes.

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1888.								
Feb. 17	..	7 a.m.	..	..	*i*	..	..	..
Mar. 23	..	..	..	*f**	..	..	..	..
„ 23	..	..	..	*f**	..	..	..	..
„ 31	..	7.30 a.m.	..	..	*i*	..	..	..
April 3	..	6.50 a.m.	..	..	*i**	..	..	..
„ 21	..	6.55 a.m.	..	..	*i*	..	..	..
May 3	..	2.15 a.m.	..	..	*i*	..	..	..
„ 4	..	5 a.m.	..	..	*i**	..	..	..
„ 21	..	8.25 p.m.	..	*e,* f**	..	*k**	*n**	..
„ 29	..	11.15 a.m.	..	*d**	..	..	..	..
„ 31	..	2.15 p.m.	..	*d**	..	..	..	..
Aug. 1	..	..	..	..	..	*l*	..	..
„ 2	..	..	..	..	..	*l**	..	..
„ 9	..	..	..	..	..	..	*n**	..
„ 16	..	6.10 p.m.	..	..	*i*	..	..	..
„ 17	..	7.20 a.m.	..	..	*i*	..	..	..
„ 30	..	10.30 a.m.	..	..	..	*l**	*n**	..
Sept. 1	..	4.15 a.m.	..	*e, f*	*i*	*j,* k, l**	*m, n,* o, p, q*	*r*
„ 2	..	..	..	..	*i*	..	*n*	..
„ 5	..	..	..	..	*i*	..	*n*	..
„ 6	..	..	..	..	..	..	*n*	..
„ 9	..	..	..	..	..	*l**	*n**	..
„ 15	..	..	..	..	..	..	*q**	..
„ 20	..	10 p.m.	..	..	*i*	..	..	..
Oct. 12	..	2.25 p.m.	..	*d*	*i*	*l*	*n*	..
„ 17	..	8.15 p.m.	..	*d**	..	..	..	..
„ 23	..	8.15 p.m.	..	*d,* e,* f**	*h,* i**	*j,* k,* l**	*n,* o**	..
„ 26	..	..	..	..	*i**	..	..	..
Nov. 23	..	..	..	..	..	..	*p**	..
Dec. 8	..	7.10 p.m.	..	..	*i*	..	..	..
„ 27	..	9.30 p.m.	..	..	..	..	*n, p*	..
„ 31	..	9 p.m.	..	..	..	..	*n*	..
1889.								
Mar. 6	..	12.26 p.m.	..	*f*	*h, i*	..	..	..
April 8	..	2.58 a.m.	..	*d*	..	..	..	..
„ 19	..	..	..	..	*i*	..	..	..
May 13	..	8 a.m.	..	..	*i*	..	*o*	..
„ 27	..	8 a.m.	..	*f*	*h, i*	..	..	..
June 12	..	8 a.m.	..	..	*h*	..	..	..
„ 12	..	8.35 a.m., 4.20 p.m.	..	*f*	*i*	..	..	..
„ 24	..	1.25 p.m.	..	..	*g*	..	..	..
July 20	..	..	..	*d*	..	..	..	..
„ 21	..	..	..	*d*	..	..	..	..
„ 22	..	..	..	*d*	..	..	..	..
„ 23	..	..	..	*d*	..	..	..	..
„ 25	..	..	..	*d*	..	..	..	..
Aug. 13	..	..	..	*d*	..	..	..	..
Sept. 19	..	10.15 p.m.	..	..	*i*	..	..	..
Nov. 29	..	10 p.m.	..	..	*i*	..	..	..

SCHEDULE OF EARTHQUAKES—*continued.*

Date.		Hour.	Dist. I.	Dist. II.	Dist. III.	Dist. IV.	Dist. V.	Dist. VI.
1889.								
Dec. 10	..	5.34 p.m.	..	*f*	*h, i*	..	..	..
„ 20	..	..	..	*f*	..	..	..	..
1890.								
Jan. 25	..	9.50 p.m.	..	..	..	..	*o*	..
Mar. 7	..	5 p.m.	..	*c, d, f*	*g, i*	..	..	..
„ 31	..	..	..	..	..	..	..	*r*
April 19	..	4.5 a.m.	..	..	*i*	..	..	..
May 1	..	..	..	..	..	..	..	*r*
July 15	..	8.30 a.m.	..	..	*i*	*l*	..	..
„ 16	..	9.30 a.m.	..	..	*i*	..	..	..
Aug. 15	..	6.45 a.m.	..	..	*i*	..	..	..
Oct. 4	..	1.55 a.m., 4.20 p.m.	..	*d*	..	..	..	..
Nov. 12	..	5.15 p.m., 5.25 p.m.	..	*e*	..	..	..	..
Dec. 23	..	12.45 a.m.	..	*f*	*i*	..	..	..

Earthquakes from 1856 to 1863, recorded by Mr. Triphook, of Napier, and published by von Hochstetter.

Year and Date.	Time.	No. of Shocks.	Place.	Remarks.
1856.				
Dec. 11	6.45 a.m.	2	Wellington ..	Wind south-west.
„ 13	8.45 p.m.	1	Hutt Valley.	
1857.				
Feb. 21	3.20 p.m.	1	Wellington ..	Undulatory motion.
Mar. 18	5.15 p.m.	1	Porirua Harbour.	
April 9	10.0 a.m.	2	Wellington ..	Undulatory motion.
July 30	12.55 a.m.	2	„ ..	Violent vertical shock.
Aug. 23	9.50 a.m.	1	„ ..	Fine calm day.
Sept. 6	1.20 a.m.	1	„ ..	Fine calm day.
„ 27	12.25 a.m.	1	„ ..	Wet day.
Oct. 8	8.10 a.m.	2	„ ..	Wind south-west, rainy and cold.
Dec. 27	1.20 a.m.	1	Port Napier ..	Changeable weather.
1858.				
Jan. 6	4.15 a.m.	1	„	
April 16	2.0 a.m.	1	„ ..	Showers of rain.
„ 18	1.0 a.m.	1	„ ..	Showers of rain.
July 20	1.0 a.m.	1	„ ..	Fine weather.
Aug. 2	2.0 p.m.	1	„ ..	Fine weather, swelling sea.

Earthquakes from 1856 to 1863, recorded by Mr. Triphook
—continued.

Year and Date.	Time.	No. of Shocks.	Place.	Remarks.
1858. Oct. 23	6.10 p.m.	1	Port Napier ..	Wind south-east, swelling sea. Vibrative motion.
1859. July 1	7.0 a.m.	1	" ..	Showers.
1863. Feb. 23	..	1	Hawke's Bay ..	Destroyed several houses, and left various crevices in the soil.

The following information respecting the earthquakes of 1848 and 1855 is reprinted from documents that are now very rare, copies having been lent to me by the Hon. W. B. D. Mantell, F.G.S.:—

Earthquake of 1848.

The 1848 earthquake has been very fully recorded by Sir William Fitzherbert and the late Mr. Justice Chapman. It commenced at 1.40 a.m. on the 16th October, as a violent rocking motion. For three-quarters of a minute it was difficult to stand, but the vibration gradually lessened, the whole lasting about ten minutes, and during the night a tremulous motion was more or less continued. The direction of the shock was from north-east to south-west. On Tuesday, the 17th, at 3 p.m., another shock of still greater force occurred, accompanied by a loud roaring sound through the earth from the north-east. The tremulous motion was now almost continuous; and on Thursday, the 19th, at 5 a.m., there was a still stronger shock than either of the two preceding. The extreme force was experienced for less than half a minute, but the vibration lasted eight minutes. Slight shocks continued in quick succession, sometimes as many as fifteen in an hour, each lasting only two or three seconds, until the following Sunday, 22nd October; and up to the 18th November five or six daily shocks were felt. Their direction gradually changed more as if they were coming from the eastward.

In the previous years Judge Chapman recorded fourteen earthquakes in 1846, fourteen in 1847, and thirteen in 1848 prior to the date of the great earthquake, which is a larger number than has been recorded in any subsequent year, notwithstanding greater facilities for observations and recording.

Earthquake of 1855.

On the 23rd January, at 8.50 p.m. As in 1848, it appears to have had a direction of from north-east to south-west, commencing with an extremely continued shock, accompanied by a fearful noise. The motion was violent, and sharply changed at right angles, or from north-east to north-west. Still increasing, it partook of both motions, with a sensible upward impulse. The duration was about a minute and a half. The vibration continued at intervals throughout the night from north-east to south-west, and slight shocks were frequent until the 11th April, on forty-seven days. The first shock was felt a hundred and fifty miles from the coast, and affected New Zealand from the extreme south to the East Cape, about 360,000 square miles, or three times as large an area as the British Isles. An area of 4,600 miles was estimated to have been raised from 1ft. to 9ft., the greatest elevation being on the west side of the Wairarapa Valley, the vicinity of Porirua Harbour not being affected, and the west side of Cloudy Bay, north of Blenheim, having actually been depressed to the extent of 5ft.

An Account of the Earthquakes in New Zealand.

[Extracted from "The New South Wales Sporting and Literary Magazine and Racing Calendar," from information supplied by Mr. W. (since Sir W.) Fitzherbert. (Abstract.)]

During the whole of the last winter (1848) the district of Wellington experienced much less wind than usual, and during the same period the wind came principally from the east, which was a very unusual circumstance. The rain during the same season had been abundant. For eight days previously to the 16th October heavy rains were constant, the wind being in the south-east, and blowing a gale ; and the highest floods known for three years occurred in the town.

The earthquake consisted of three grand shocks occurring at intervals of about thirty-six hours, and followed by a succession of minor shocks that extended, according to the latest dates, over a period of one month.

The first shock was felt at about 1.40 a.m. on the 16th October—estimated in Wellington to have lasted two minutes, oscillatory, not rapid, unaccompanied by noise. It was attended by a most remarkable phenomenon—viz., the instantaneous suppression of the gale* which was blowing at the time, and which sprang up again with redoubled fury on the termination of the earthquake, as if it had been "bayed back."

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* Same in 1855.

The second grand shock occurred about 3 p.m. on Tuesday, the 17th October. The day was beautifully fine, the wind variable but light. A slight report and shock first occurred, followed instantly by a loud roar and *tremblement de terre*. The noise came from the northward. The earth in some parts was moved in waves averaging about 12in. in height. Some persons were thrown down (partly, perhaps, from fear), but all found more or less difficulty in walking. The movement may be defined as a horizontal rapid concussion. Several brick buildings and walls were thrown down, and there were three lives lost. The duration of this shock was ninety seconds.

The third grand shock occurred about 5 a.m. on Thursday, the 19th October. It was accompanied by a loud roaring noise, and was the most violent of the three. It happened in the midst of a terrific storm from the south-east, with the same temporary lull observable at the first. It completed the destruction of the brick buildings.

Subsequently to the three grand shocks numerous slight tremors occurred: forty were counted in the course of one afternoon, but their character differed altogether from that of the first. In the two last of the three grand shocks the roaring was certainly considerable, but it was inconsiderable as compared with the concussion, whilst in the minor shocks the vibration was trifling as compared with the report. Loud reports, precisely resembling the discharge of distant artillery, or the escape of gas, were heard from the northward, succeeded by slight concussions. Sometimes these concussions were vertical, sometimes horizontal; a motion travelling beneath the feet was palpably perceptible. On all occasions persons walking or riding felt the shocks much less (in some cases, not at all) than those sitting, and these again much less than those lying down. Horses, cows, and poultry evinced great alarm.

One extraordinarily high tide occurred during the period of the earthquakes; it was not, however, contemporaneous with any particular shock, and may be rationally accounted for otherwise. The south-east wind, which blows directly into the harbour, had prevailed for a long time, and, an unusually large quantity of rain having fallen, the harbour overflowed. The rise of tide was about 18in. above its ordinary level. It was observed that the shocks occurred at all times of tide, at all indications of the barometer, in rainy and in fine weather.

Several rents were observed in the ground, chiefly where the soil was gravelly or of a loose character, along the edges of cliffs and terraces; but none were of any considerable depth or breadth.

The thickest walls fell the most readily, unless there were bonding-timbers in the walls, in which case the elasticity of the timber mostly preserved the buildings. *Cæteris paribus*, a 9in. wall withstood better than a 14in. one.

The mortar seemed to be a matter of little consequence: it was bad in most of the buildings, but even where Roman cement had been used the walls fell just the same; only that, instead of the bricks falling separately, they came down in masses of eight or ten together.

Hipped roofs stood decidedly better than gable-ends; the roof seemed to act as a tie to the walls. The chimneys of many houses were twisted.

Abstract of Account in Westminster Review *by the late Mr. Justice Chapman.*

At 1.40 a.m. on the 16th October, 1848, I was awakened by the shock. The house rocked violently, bells rang, and clocks stopped. For about three-quarters of a minute the shock was so strong that it was with difficulty I kept my legs. It continued with some force for two or three minutes, and the whole vibration lasted ten minutes. For one hour the shocks scarcely ceased for a minute. During the whole morning until between 6 and 7 o'clock the intervals were not long, and the tremulous motion of the earth was continuous and nearly incessant. Wind south-east to north-west during the night, blowing a fierce gale with very heavy rain. At 9 on the previous night the mercury stood at 29in. (500ft. above sea); it had risen to 29·04 immediately after the first shock; in the morning it had subsided to 29·02, a very insignificant variation. Many chimneys thrown down in town. Brick buildings slightly injured. Most of the shocks came from about north by east or north-north-east; one or two seemed more easterly—say, north-east; and one seemed to have a double source, meeting about this neighbourhood. The twisted appearance of some of the chimneys confirms this.

Tuesday, 17th.—The shocks continued all day at varying intervals. At twenty minutes before 4 a shock took place of greater violence than the first. I was at Government House. The house shook, jerked, and then vibrated, so as to shake all loose articles to the ground. I found it necessary to steady myself on my legs. There was first a short shock of four or five seconds' duration, and of moderate force; then came a loud sound from the northward and eastward; and then the strong shock. The French windows burst their fastenings, and flew outwards. The chimney-piece was cleared of its ornaments, the bottles flew from the table. Its extreme force continued about a minute, perhaps rather less. Chimneys lay prostrate in all directions.

Wednesday, 18th.—Shocks continued all night and all day, but none of strength sufficient to do injury to undamaged buildings. The earth is in a continued state of tremulousness, and the dull sound of the earthquake is continually heard. This sound has been much exaggerated. It is something like the sound of a railway-train rumbling through a tunnel, as heard by a person outside and near the mouth. I have also heard nearly a similar noise made by a very large steamship chimney, except that the earthquake sound is less sonorous. It has been compared with distant thunder and with distant guns; but it is more rumbling in its nature: in short, it admits of no exact comparison. I have noted that when the shocks occur during a heavy gale, as on Monday, this dull rumbling sound is not perceptible—it is overcome by the nearer noise of the wind. When the shocks occur in calm, they are generally preceded, and sometimes followed, by a strong puff of wind.

Te Aro seemed to have been the seat of the greatest force of the earthquake. All the large merchants' stores, the ordnance stores (late Waitt and Tyser's), the Methodists' Chapel, and a great number of brick dwellings, are rent in pieces. The walls just hold up the roofs, but large masses of brickwork have fallen out: all must be taken down. The gables of Mr. Fitzherbert's store and of the ordnance store fell across Farish Street, and unfortunately buried Barrack-master Lovell and his two children, all three receiving fatal injuries.

All Tuesday a large volume of smoke was seen hanging over the Hutt. It collected afterwards into a dense smoke-cloud. It looked like a bush-fire; but after so much rain no bush would burn. I should hardly have noted this had it not been that on Tuesday night the sky to the northward was said to be illuminated, apparently by some distant fire; and it is suggested that Tongariro, about a hundred and forty miles north of Wellington, may have burst out.

Thursday, 19th.—Precisely at 5 this morning we had a sharp shock, stronger than either of the two already noted. The extreme force of the shock lasted rather less than a minute, there was considerable motion for three minutes and a half, and the vibration lasted eight minutes from the commencement of the shock. It has done us more damage than all the others together. It has split the solid bed of brickwork which forms the lower part of our oven, completed the destruction of the other chimneys, torn the plaster of our lower rooms to pieces (the upper are lined with wood), and broken a great many loose articles. Our windows (French casements) flew open. After this, shock followed shock in quick succession all day and all night.

In the evening, until about half-past 9, the sky to the south and south-west presented a remarkably lurid appearance; but I do not think it needs an eruption of a volcano to account for it. In very angry skies during gales of wind at sea I have seen something of the kind. If the state of the atmosphere be such as to increase refraction the sun's light may have some effect long after sunset (say two and a half or three hours in this case), and, falling on very dense clouds, would produce a very angry appearance.

Friday, 20th.—The shocks have continued in quick succession all night. They have, I think, rather diminished, both in force and frequency, during the day. . . . All wooden buildings have hitherto been safe, and much of the damage to the brick buildings is owing to the miserable manner in which they are built. Both lime and bond-timber have been far too scantily used.

I learn that on Wednesday there was an unusually high tide. Although the tides are at the neap, the tide rose over the beach road and flooded the lower parts of some houses. The continuance of south-east gales would, in the absence of earthquakes, be enough to account for this, yet it seems to have produced a good deal of alarm.

Saturday, 21st.—Weather fine, barometer rising, shocks frequent. It is noted that they come more frequently at or about low water. They are not of a dangerous character, and are, I think, weakening.

Sunday, 22nd.—Weather most beautiful; still, the shocks continue about every hour. They only last two or three seconds, and are sometimes only heard, not felt. At 4 o'clock, rather a sharp shock (it is about low water). There are some earth-cracks on the beach near high-water mark, and some pipi-shells (or cockles) have been thrown up.

Monday, 23rd.—Day also fine, with fresh north-west breeze. Shocks rather frequent—say, about every half-hour—but not strong.

State of the Weather previous to and during the Shocks.

During the latter part of September, and up to the 6th of October, the weather had been remarkably fine and dry. The barometer ranged during the first week of the month from 29·42 to 29·80, with a north-west wind (with which wind it is generally lower), and at about 500ft. above the harbour. In the night of the 6th the barometer began to fall lower (it had been slowly falling from the 1st) and rain came on.

The following is a table of the weather from the 7th to the 15th:—

—	Thermometer.		Barometer.		Winds.	Weather.	Observations.
	9 a.m.	2 p.m.	9 a.m.	9 p.m.			
	°	°	In.	In.			
Saturday, 7th ..	50	54	29·15	29·06	N.W., gale	Rainy.	
Sunday, 8th ..	50	52	29·11	29·12	S.E., fresh gale at night ..	Showery.	
Monday, 9th ..	42	42	29·17	29·24	S.E., gale	Rainy ..	Ten inches of rain said to have fallen in the week.
Tuesday, 10th ..	46	52	29·24	29·24	S.E., gale	Rainy ..	
Wednesday, 11th ..	48	52	29·25	29·25	S.E., moderate	Showery	
Thursday, 12th ..	48	56	29·20	29·17	N.W., moderate	Fine ..	
Friday, 13th ..	52	62	29·11	28·97	N.W., fresh	Fine ..	
Saturday, 14th ..	48	48	28·97	29·00	S.E., fresh; p.m., gale ..	Rainy ..	
Sunday, 15th ..	42	48	29·02	29·00	S.E., gale	Rainy ..	
Since the first shock:—							
Monday, 16th ..	45	48	29·02	28·95	S.E. to N.W., moderate ..	Showery	Strong shock about twenty minutes before 2 a.m.
Tuesday, 17th ..	52	56	28·87	28·88	S.E., gale..	Fine ..	Stronger shock twenty minutes to 4 p.m.
Wednesday, 18th ..	48	50	28·48	28·37	S.E., gale..	Showery.	Stronger shock than the last, 5 a.m.
Thursday, 19th ..	48	48	28·80	29·10	S.E., gale, very strong ..	Cloudy ..	
Friday, 20th ..	48	50	29·24	29·32	S.E., strong breeze ..	Fine ..	Shocks continuing at short intervals.
Saturday, 21st ..	50	54	29·50	29·50	S.E., moderate	Fine ..	
Sunday, 22nd ..	54	62	29·56	29·56	N.W., light; freshened, p.m.	Very fine	
Monday, 23rd ..	59	64	29·58	29·58	N.W., fresh	Very fine	Strong shock of short duration at 2 p.m.
Tuesday, 24th ..	60	64	29·56	29·44	N.W., moderate	Very fine	Shocks continue.
Wednesday, 25th ..	60	66	29·38	29·30	N.W., moderate	Very fine.	
Thursday, 26th ..	60	56	29·27	29·35	N.W., moderate; S.E., p.m.	Very fine.	
Friday, 27th ..	51	52	29·42	29·42	S.E., fresh	Showery	Shocks decreasing—only five to seven in twenty-four hours.
Saturday, 28th ..	54	62	29·40	29·35	S.E., light; E., p.m. ..	Fine.	
Sunday, 29th ..	62	64	29·30	29·30	S.E., fresh	Very fine	Thermometer 71° at noon, but fell with wind.
Monday, 30th ..	56	66	29·27	29·20	N.W., strong	Very fine.	
Tuesday, 31st ..	50	54	29·10	28·95	N.W., gale	Rainy ..	Shocks weaker.

Earthquakes of 1846.

30th January.—Sharp shock, 9.30 p.m.; gust of wind after, calm before. North-west, gentle wind. Very fine.

10th February.—Slight shock, 11 p.m. South-east, fresh. Showery.

9th April.—Slight shocks, 2 a.m., 11 a.m. North-west, gale. Very fine.

30th June.—Shock at 10 p.m. South-east. Fine.

1st July.—Shock at 9 a.m. North-west. Fresh, cloudy.

2nd July.—Shock at 3 p.m. North-west. Fresh, showery.

4th July.—Shock in night. North-west, moderate. Very fine.

31st August.—Shock in night. Calm. Showery.

11th September.—Smart shock in night. South-east, light. Very fine.

19th November.—Shock of long duration, 6 a.m. North-west, moderate. Fine.

20th November.—Slight shock in night. North-west, moderate. Fine.

4th December.—Seven shocks; one very smart. North-west, gale. Cloudy.

5th December.—Shocks at 2 a.m. and 7 p.m. North-west, gale. Fine.

26th December.—Shock at 10.30 p.m. North-west, fresh. Fine.

Earthquakes of 1847.

3rd February.—Slight shock; heard rather than felt. South-east, fresh. Very fine.

4th February.—Sharp shock, 6 a.m. South-east, moderate. Fine.

28th March.—Slight shock, 8.30 a.m. Calm. Fine.

16th April.—Slight shock, 9 p.m. North-west, moderate. Fine.

8th May.—Sharp shock, 1.30 p.m. North-west, moderate. Fine.

1st June.—Shock at 7 a.m. Calm. Very fine.

24th July.—Shock at 11.30 p.m.; vibration long-continued. North-west, fresh. Rainy.

11th August.—Two slight shocks. North-west, gale. Fine.

12th October.—Two shocks. North-west, gale. Very fine.

27th October.—Sharp shock, 11.30 p.m. North-west strong. Very fine.

9th November.—Slight shock, 9 p.m. North-west, gale. Fine.

10th December.—Sharp shock, 8 a.m. North-west, fresh. Very fine.

Earthquakes of 1848.

15th January.—Shock at 8 a.m. South-east, moderate. Fine.

17th January.—Slight shock. North-west, fresh. Showery.

19th January.—Slight shock, 2 p.m. South-east, calm Fine.

26th February.—Smart shock, 9.30 p.m. North-west, moderate. Showery.

9th April.—Slight shock, 7 p.m. North-west, strong. Showery.

10th April.—Slight shock, 7 p.m. North-west, strong. Showery.

13th April.—Shock at 8 a.m. and 8.20 a.m. North-west, fresh. Showery.

17th April.—Smart shock, 8.30 a.m. Calm. Cloudy.

2nd May.—Shock at 2 p.m. North-west, fresh. Showery.

6th June.—Shock at 5 a.m. North-west, strong. Cloudy.

25th July.—Shock at 5 a.m. South-east, moderate. Fine.

15th August.—Slight shock in night. North-west, light. Cloudy.

16th August.—Slight shock in night. North-west, strong. Rainy.

15th to 18th October.—Shocks daily, as described.

N.B.—Others may have occurred in the night without being noticed.

Was there evidence of strong vertical shock, or torsion of loose objects?

1848. 17th October.—The house shook, *jerked*, and then vibrated so as to shake all loose articles to the ground. . . . The French windows burst their fastenings, and flew outwards. The chimney-piece was cleared of its ornaments, the bottles flew from the table.

Tuesday, 24th.—A very sharp shock while I am writing, at a quarter to 6 p.m. The motion decidedly undulating, and seeming to force up from below. During one of the shocks after 2 p.m. I was standing on the lawn, and I felt myself jerked up. Another similar shock, now, at ten minutes to 6, stronger than the one five minutes ago.

Wednesday.—In a store-room at Alzdorf's Wellington Tavern, a large number of short, stout bottles of anchovies were ranged closely together on the floor, and occupying about a square yard. At about 4ft. distance, and south from them, was a cask of beer (twelve or eighteen gallons, I forget which) half full. This cask was jerked up and deposited on the top of the anchovy-bottles without knocking down or breaking one.

The motion evidently was along a line, and at the same time undulating so as to produce this upward motion. . . . Some of the shocks had a cross-motion with a curious grinding sound underground. During one of these the milk in the pans acquired a circular motion, so as to accumulate the cream in the centre.

1855. 23rd January.—This (the backward-and-forward and side-to-side motion) was followed by a continuation of both, a sort of vorticose motion, exactly like the motion felt in an ill-adjusted railway-carriage on a badly-laid railway at a very high speed, where one is swayed rapidly from side to side. This was accompanied by a sensible elevatory impulse. It gradually subsided, and the above, constituting the first and greatest shock, lasted altogether, I should say, one minute twenty seconds or one and a half minutes, at Wellington.

Was the area of activity circular or elliptical, and, if latter, what was the direction of the major axis?

1848.—Not stated. Judge Chapman says, "The shocks commenced at north-north-east and perhaps even north by east; then some were observed to come from north-east and north-east by east, as my house stands; then from east, and latterly from east to east-south-east. The few that I have noted from south-west I attribute to reverberation or some other deception on the ear and senses."

1855.—Direction north-east to south-west.

How many shocks? Were first or last strongest?

1848. (1.) Judge Chapman says, "Taking the whole of the shocks during the five weeks, only four have occurred of sufficient force and duration to do damage, though at times as many as fifteen have been counted in an hour, and perhaps more than a hundred and fifty in the twenty-four hours. During the present month the number of shocks has ranged from two or three to seven or eight a day." (2.) The shocks gradually decreased in strength.

1855.—The motion increased in violence, and then gradually subsided. "The earth continued to vibrate all night like the panting of a tired horse, with occasional shocks of some violence, decreasing in frequency and violence towards morning, and nearly all in the north-east and south-west direction; some of them a single jerk back and forwards like that of one railway-carriage touching another, but generally they were followed by a vibration gradually decreasing."

Did each shock begin with a gentle, slow motion, followed by rapid or intense motion?

In 1848 the shocks appeared to begin suddenly, and gradually to die away.

Earthquakes in New Zealand. (Letter from Mr. S. Vennell, Tauherenikau, Wairarapa.)

Seeing the accounts of severe earthquakes in other countries has set me thinking of them in this country. I am an old settler. I came here in the early part of 1841, so have had some experience of their terrible power. I do not wish to alarm people, but facts must be faced, and, as there are some thousands of colonists who have arrived here since 1855, the year we felt the heaviest earthquake, I should like to caution them against the insane building with bricks. . . . . I will try and tell you what I know to be facts regarding the terrible power of our earthquakes. In the most forcible one—that of 1855—the mountain near Masterton was literally rent in twain, and remains to be seen this day. The Maroa Plain, near Greytown, was rent for several miles, one part subsiding about two feet; and the whole of the country was upheaved many feet. If an earthquake can rend a solid mountain asunder, how will bricks and mortar fare? I myself saw the earth open twice three or four feet wide, right across a paddock and the road, and shut again with a fearful snap. The road, being made ground, sank nearly three feet where the earth opened, leaving one part so much higher than the other. There was hardly a sound chimney to be seen; they were either down or shaken to their foundations. Many people may imagine, because we have had no heavy shakes since 1855, that they have ceased, or that we shall only have very slight ones. I certainly should be very thankful if they had, but I cannot believe in anything so pleasant. Nature's laws will have their course. The Natives tell us they have always had earthquakes—some very heavy, and many slight ones, but seldom dangerous with proper precautions. My advice is, Build good strong, well-braced wood and iron houses, not too high, and there is, perhaps, very little to fear. When you feel a shake, keep away from the chimneys, and also the marble mantelpieces and any heavy piece of furniture. Do not run outside the house (unless it is built of bricks), but keep in the middle of the room, or in the passage. The only person killed in 1855 perished from the mantelpiece falling across him and nearly cutting him in two; he died from loss of blood in about five minutes. I heard from persons whose word I could rely upon, and who were present, of the terrible earthquakes which occurred near Auckland about 1834 or 1835, that lasted nearly three months off and on, the earth feeling as if you were standing on a large jelly. The Natives threw themselves down and held on by the grass or fern when a heavy shake came,—and they were many. The next earthquake was in 1840, when the very first colonist arrived in New Zealand; I don't know how heavy that was, but I am told it was pretty sharp. The next was in 1848: three sharp shocks occurred, one on Sunday morning early, one on Tuesday, and one on Thursday, throwing down houses and chimneys, and a brick wall, killing three persons—a father and two children. I myself picked up the youngest, of course quite dead. The last—the most fearful of all—was in January, 1855, lasting nearly a minute. I do not think Lisbon experienced a heavier shock, but history tells us that city had several. So, you see, they seem to come about once in seven years—that is, severe ones. No doubt the heavy shake in 1855 exhausted Nature's powers for a long time, but I am afraid we may expect another heavy shake either this year or the next. Three periods of seven years have passed away, and we are going on to the end of the fourth seven. It is possible we may be exempt from heavy shocks some time longer, but, from what we know of earthquakes in New Zealand, through the Natives and others who were here more than sixty years ago, I do not think we shall be. At any rate, I think it would be courting danger to go on building brick buildings. I would not even build wooden houses so tall as many are in Wellington. Again, how will the large plate-glass windows stand a heavy shake either in wood or brick houses? To conclude, if my caution should be the means of saving one life, I shall feel I have not written in vain.

The foregoing information includes all the records that the Secretary has been able to collect up to the present time upon which any reliance can be placed. Until seismographs and registering tide-gauges have been distributed throughout the Islands it is obvious that no records will be obtained sufficiently exact to form the basis of scientific investigation into the causes of the New Zealand earthquakes.

Report of the Committee, consisting of Professor BRAGG, Professor LYLE, *and* Mr. R. W. CHAPMAN (*Secretary*), *appointed to investigate and report upon the Tides of South Australia.*

THE Committee have been engaged during the year in the harmonic analysis of the tidal curves obtained at Port Adelaide, but, owing to the immense amount of numerical computation involved, the work is not yet complete; the Committee consequently beg to be reappointed.

The working strength of the Committee has been increased by the inclusion of Captain Inglis, of Port Adelaide.

The title of the Committee has been slightly altered, as, owing to a misunderstanding, we were appointed as a Committee on the Tides of Australia, whereas our particular work applies only to South Australia.

Report of the Committee, consisting of Mr. H. Y. L. Brown, Sir J. Hector, Mr. R. L. Jack, Mr. R. A. F. Murray, Mr. C. S. Wilkinson, Mr. Woodward, *and* Professor Hutton (*Secretary*), *appointed to report upon the Unification of Colours and Signs of Geological Maps.*

In consequence of the impossibility of the members of the Committee meeting together, the only way in which a report could be made was for the Secretary to write to the other members, and ask for their opinions. This was done; and replies were received as follow:—

Victoria.

Mr. R. A. F. Murray says that he finds that, as regards the colours of small-scale maps of large areas, there is very little discrepancy between those used respectively in Victoria, New South Wales, South Australia, and Queensland. So that for the main rock-groups—*i.e.*, granite, Silurians, Devonians, &c.—a general accordance is already noticeable, and no difficulty ought to be experienced in eliminating the few discrepancies which exist. With respect to large-scale maps unification of the colours used would be more difficult, especially in the case of minor subdivisions. But for well-marked formations, common to all or most of the Australian Colonies, it would be easy to agree on distinguishing colours to be used for them throughout, and to avoid the use of any of those colours to represent formations occurring in only one or two colonies. Thus, assuming twenty different formations—requiring as many colours—to exist in the colonies A, B, C, and D, ten might be common to all, five might be confined to A, B, and C, three to A and B, and two to A. The first ten colours could be agreed on by the four colonies; the five by the three colonies, &c. As to signs, there appears to be no difficulty in achieving a uniform code for the whole of the Australasian Colonies. But, on the other hand, if a uniform system of colouring were adopted, the value of all previous maps would be lessened, and the issuing of new ones coloured according to the code adopted would entail enormous expense.

New South Wales.

Mr. C. S. Wilkinson being in England, Mr. R. Etheridge, jun., replied that he did not believe in the possibility of unification of colours, especially in countries where so little has been done towards working out the equivalent formations as in the Australasian Colonies. This Survey has just adopted a new scheme of colours, which is not yet published (27th November, 1890).

South Australia.

Mr. H. Y. Lyell Brown thinks it very advisable that a uniform system should be adopted, and that the colours and signs used on the Victorian maps might, as a whole, be adopted by all the colonies; but that the colours denoting the formations of Secondary and Tertiary age would want modification by a Committee.

Tasmania.

There is no Geological Survey in the colony, but the Government has published a coloured geological map with Mr. R. M. Johnston's "Geology of Tasmania." The colours agree generally with those of Victoria and South Australia.

Western Australia.

No information.

New Zealand.

The colours and signs used in this colony were adopted in the years 1885–86; but there are several differences between the map and the table then issued. With the exception of the crystalline rocks—massive and foliated—the colours differ widely from those used in Australia, and the divisions also differ much from those of the other Surveys.

The following table shows the different divisions and colours in use in the different colonies:—

Divisions.	Victoria.	South Australia.	Tasmania.	New Zealand. Map, 1885.	New Zealand. General Table, 1886.
Recent	Blue-green ..	Sap-green ..			Chrome-green.
Post-pliocene	Sap-green ..			Gamboge ..	
Newer Pliocene..	Vermilion ..	Gamboge ..			
Older Pliocene	Gamboge ..		Gamboge ..		Orange.
Miocene	Yellow ochre ..			Orange ..	
Upper Eocene or Oligocene ..	Emerald green ..	..			
Lower Eocene	..	..		Green ..	Green.
Cretaceous		Brown.. ..	..		
Jurassic	Burnt-sienna ..	..	..		Blue.
Triassic		..		Blue ..	Indian red.
Permian	Indian red ..	..	Grey ..		Sepia.
Carboniferous	..	..			Grey.
Devonian	Brown	..	..	Sepia ..	Stone-ochre.
Upper Silurian	Pale grey ..	..	..		Pink.
Lower Silurian	Pale purple ..	Grey	..		
Cambrian	..	..	..	..	
Archæan	..	Carmine ..	..	Carmine-dotted.	
Metamorphic	..	Pale purple ..	Pale purple..	Dark purple.	
Limestone	Cobalt (all ages)	..	..	..	
Granite	Carmine ..	Carmine ..	Vermilion ..	Carmine-dotted.	
Plutonic, basic	Carmine-lined ..		Carmine ..	Carmine.	
Volcanic, basic	Pale carmine ..	Carmine-lined ..	Pale brown ..		
Volcanic, acidic	..	..	..	Carmine-lined.	

RELIEF-MODEL OF NEW ZEALAND, 1886.

Upper Tertiary, *yellow*. Upper Secondary, *green*. Palæozoic, *dark brown*. Crystalline schists, *light red*.
Lower Tertiary, *pale pink*. Lower Secondary, *blue*. Foliated schists, *dark pink*. Igneous, *scarlet*.

Queensland.

Mr. R. L. Jack writes as follows :—

"I object strongly to the proposed unification, for the following reasons :—

"In the first place, it is impossible. Human ingenuity could not foresee and provide for all the future requirements of geological mapping. No hard-and-fast scale of colours could be contrived by which all possible subdivisions of geological formations could be denoted.

"The colours and symbols used in any particular case will always depend on the object of the map. In a general map of Europe, for example, perhaps forty different colours might be employed; and the ingenuity of the geologist and colourist would have to be exercised in contriving colours which would (1) contrast sufficiently, and (2) at the same time group the members of each formation or system under modifications of one colour. But if, on the other hand, a geologist undertook to map out in detail the various recognisable horizons of any one system or formation—say, for example, the Carboniferous system—he would require to make so many modifications of the same colour that they would cease to present a sufficient contrast. In such a case he would probably do best to avail himself of colours which would contrast strongly and at the same time present a pleasing and harmonious general effect.

"It is easy to imagine a case where a map of a limited area —say, a twenty-acre lease—showing the outcrops of all the visible strata, might be valuable for mining purposes. Such a map might be useful to a geologist, although it might be prepared by a surveyor or miner possessing no particular knowledge of geology; and its object would be best served by using a series of colours plainly distinguishable from one another without reference to the colour on the scale set apart for the subdivision of the formation to which the strata belong—a matter which might not be within the knowledge of the constructor of the map, nor even ascertainable by a geologist.

"A general unification of colours and signs implies an agreement between the different formations and subdivisions all over the world—in fact, the old 'coats of an onion' idea, which, as every geologist knows, is not tenable, and the attempt at unification would be a formidable difficulty in the way of depicting homotaxial relations, or varying physical conditions, such as contemporaneous elevation in one region and depression in another.

"In the second place, the proposed unification is undesirable and unnecessary. It implies an absolute consensus of opinion as to the position on the geological scale of every formation and subdivision, to which geologists have not yet attained, and to which they are not likely ever to attain. For instance, one geologist may regard the Desert sandstone of northern and western Queensland as Tertiary, another as Upper Cretaceous, and a third as Permian. The mapping of all three may have its value, but it would be absurd to insist before recognising it that all three should agree on the colour and symbol by which the deposit is to be represented.

"In selecting the colours to be employed on any given geological map, I would say the general conditions are: first, a sufficient contrast; second, something in common to all the subdivisions of each formation or system; and, third, a pleasing and harmonious general effect. It is of the highest importance, in view of the fading of all colours with age, that each map should be accompanied by an index, in which the various colours used are repeated and explained; and that a symbol should be written or printed on every coloured area in the body of the map, as well as on the corresponding tablet in the index.

"In selecting colours, due consideration should be given to the style of topography of the map. Thus the fine distinctions between the shades of black which might be employed under a 'unification' system for subdivisions of the Carboniferous rocks would be lost on a map already black with hill-shading. But most of all the method of reproduction of the colours would have to be taken into account. It may sometimes be convenient to use water-colours; at other times, simple black and white may suffice, when cross-hatching, stippling, and other devices may be resorted to with advantage. Different combinations and modifications of colour will be possible and advisable according as lithography, photo-lithography, zincography, photo-zincography, or chromo-lithography is employed as the means of reproduction. The main thing is that the index should correspond, both in colour and symbol, with the body of the map, and that it should be self-explanatory.

"In anticipation of an answer to the above objections, I may add a few words of a personal bearing. I do not point to my own maps as examples of my *beau ideal* of geological mapping. It so happens that the office of the Geological Survey of Queensland is in the northern part of the colony, while the reports of the department, and maps accompanying the reports, have to be sent to the capital to be printed. Owing to the haste with which the reproduction of reports and maps has generally to be carried out, the distance between Brisbane and Townsville, and the fact that when proofs are ready I am frequently absent from head-quarters, the proofs are rarely revised by me. Hence it is no uncommon thing for colours to be employed the use of which I never contemplated. Even when this happens, however, I rely on the index and symbols to make my meaning sufficiently clear."

Conclusions.

In New South Wales the following main divisions, or formations, have been adopted, but the colours assigned to them have not yet been published: Tertiary, Cretaceous, Triassic, Permo-carboniferous, Carboniferous, Devonian, Silurian, Cambrian. Each of these formations is divided into series, to most of which local geographical names have been given.

In New Zealand, also, the formations—which, however, do not correspond with those of New South Wales—are broken up into series, to which usually local geographical names are attached; but sometimes the names are lithological.

In Victoria the formations are divided into series or beds, which usually have lithological names, but in a few cases they are geographical.

It seems, therefore, that if thought advisable the colours of geological maps in Australasia might be made uniform for small-scale maps, provided there was a uniformity in the divisions into which the rocks are grouped, the only great difficulty in the way being that of expense. But, before any unification in colours can be attempted, it is necessary that there should be a general agreement as to the nomenclature of the divisions to be adopted; and at present very little has been done towards working out the equivalent formations of the different Australasian Colonies. This is especially the case with New Zealand, the Mesozoic and Palæozoic fossils of which have not yet been described, or compared with those of Australia.

If the colours were made uniform, there would be no difficulty at all in attaining uniformity in the signs, by which is meant the lettering or symbols of the divisions on the map.

All geologists will agree as to the desirability of having uniformity if it be possible; and the first step towards attaining so desirable an end appears to be the establishment of a palæontological department for the whole of Australasia, where the fossils from all the colonies could be compared and identified.

Report of the Committee, consisting of Mr. C. W. de Vis, Professor Hutton, Professor McCoy, Mr. A. Morton, Dr. Ramsay, Dr. Stirling, Professor Thomas, *and* Professor Parker (*Secretary*), *appointed to consider and report upon the Improvement of Museums as a Means of Popular Instruction.*

The Committee have the honour to recommend that they be reappointed, with the addition of the following names:

Professor W. A. Haswell, D.Sc., Professor W. Baldwin Spencer, M.A.

For the present they confine themselves to affirming the following as important principles in the management of popular museums :—

1. The collections should be arranged with a view to the requirements of the general public, in whom no special knowledge of the subjects illustrated should be assumed.

2. Index-collections are of great importance, and should be widely used : special as well as general index-collections should be arranged wherever practicable.

3. Collections illustrating the general phenomena of nature are of great value—*e.g.*, models, diagrams, and specimens illustrating denudation, ice-action, the formation of gravels, variation, mimicry, protective colouring, &c.

4. In the zoological collections special cases illustrating zoo-geography are highly recommended.

5. Descriptive labels in non-technical language should be freely employed.

6. As far as possible specimens should be shown only with a definite object, and the overcrowding of cases should on no account be permitted.

Report of the Committee, consisting of Mr. F. M. BAILEY, Mr. C. FRENCH (*Secretary*), Baron VON MUELLER, Mr. A. S. OLIFF, *and* Professor THOMAS, *appointed to investigate the Fertilisation of the Fig in the Australasian Colonies.*

THE Committee report that the subject remitted to them had proved to be much wider and more difficult than was originally anticipated. The Committee therefore request to be reappointed. They report the following communication received from H.M. Vice-Consul at Smyrna, A. C. Wratislaw, Esq., dated 4th July, 1890 :—

The process of caprification, generally followed out in the fig-growing districts of Asia Minor, is one of the simplest. About the 21st June, when the first two figs on each branch are ready for fertilisation, about five wild figs, strung together, are placed on one out of every two fig-trees. This process is repeated once or twice more, according to the further development of fruit on the trees. The owners of groves are very careful in observing the fruit itself and the size of the crop of the trees, as it has been remarked that the distribution of too many Caprifici in the groves has at times the effect of causing the crop to sicken, and to fall before it is quite mature. In fact, the application of the wild fig requires discrimination and care. The fig, after being dried, should have one Cynips, in its wingless state, fully developed within it. When more than one are found the fig is said to be unfit for long keeping.

At the present date it would be difficult to obtain specimens of the Cynips, as the wild figs have already dropped and dried up; next season it will be easy enough.

Where the Caprificus grows along the fruit-bearing figs in sufficient quantity, the caprification is generally left to nature. At times the Caprificus is mature before the fig is ready for fertilisation, and fig-growers are obliged to bring wild figs at a heavy expense from more northerly or cold regions. As much as 5s. to 7s. per pound has been paid for fruit of the wild fig to serve caprification purposes.

Report of the Committee, consisting of Mr. J. M. Coane, Mr. A. W. Craven, Mr. A. M. Henderson, Professor W. C. Kernot, Professor W. H. Warren, *and* Mr. John Sulman (*Secretary*), *appointed to consider and report upon the Location and Laying-out of Towns.*

We have the pleasure to report that we have given the above question a considerable amount of attention, and have obtained additional information thereon. This all tends to confirm the necessity for action, and we therefore beg to recommend that, in view of the importance of the subject, it is desirable that strong representations be made to the Government of each colony of Australasia with a view to securing the adoption of the following suggestions:—

1. That no town be laid out on soil of unhealthy character, such as—(*a*) a morass; (*b*) land subject to floods.

2. That no allotment to be used as a site for a dwelling-house shall be less than one-twentieth of an acre in area; and that no further subdivision of such allotment for dwelling-sites by sale, lease, or otherwise be permitted.

3. That the areas of streets and reserves taken together be, where possible, equal to one-third the area leased or sold for occupation.

4. That no town or suburb contain an area of more than two square miles.

5. That a belt of land at least one-eighth of a mile in width be reserved, where practicable, between adjoining towns or suburbs.

6. That a town or suburb is any subdivision containing allotments of less than one acre in extent.

7. That, to give effect to the above, plans of every town or

suburban subdivision be submitted to a specially-appointed official or board for approval, and that without such approval no sale or lease be valid. That the official or board veto the plan if any of the foregoing stipulations be not complied with, and further require that a satisfactory scheme of surface-drainage, sewerage, and water-supply be submitted for future realisation, such scheme to show contour-levels and all natural features.

We therefore suggest that the above, if approved and indorsed, be forwarded to the Premier of each Australasian Colony by the Honorary Secretary, urging on behalf of the Association that the question be carefully considered.

We append a copy of the paper on "The Laying-out of Towns" by Mr. John Sulman, which was the proximate cause of the appointment of the Committee, and also the contributions by Professor Kernot and Mr. J. M. Coane on the subject. These contain many suggestions which we venture to deem worthy of attention, but yet scarcely such as would command a united expression of opinion or recommendation on the part of the Committee.

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1. A Paper on the Laying-out of Towns read before Section J of the Australasian Association for the Advancement of Science at Melbourne University, in January, 1890. By John Sulman, F.R.I.B.A., Architect. (See p. 730 of Report of Second Meeting.)

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2. Letter from Mr. J. M. Coane, President Vict. Inst. of Surveyors.

I MAY say that in considering the matter of the laying-out of towns I have chiefly paid attention to the sanitary aspect of the question, believing that in fairly easy ground the rectangular system offers the greatest advantages; while in hilly places, if the natural contours be studied with a view to satisfactory drainage and easy road-gradients, it will generally be found that the result, from an æsthetic point of view, will be fairly good. The whole question seems to resolve itself practically into two divisions: (1) the selection of sites and laying-out of Government townships in a new country by the Government; (2) the subdivision of alienated land by private owners for residential and business purposes.

Work under the first head naturally falls to the chief of the Survey Department, who, in choosing the sites, has to be guided by a variety of considerations, most of which are well understood and acted on. The very important question of the suitability of the site as regards natural configuration, however, seems to have been very frequently overlooked, and towns have been located in situations utterly bad, and impossible to drain at a reasonable cost, while near at hand were sites desirable in almost all respects. The accidental circumstance that some one had erected stores or hotels at fords near river-flats has, in some instances, led to the establishment of towns in places where they are actually submerged by floods every few years. In these cases it is plain that no account was taken of the levels.

In work under the second head, where private property is cut up, there is, as a general rule, no restriction, beyond provision that each street shall be at least so many feet wide, and that each allotment shall have a certain minimum superficial area.

I venture on the following general suggestions:—

(*a.*) That all land intended for subdivision into town lots be carefully contoured before any scheme be decided on. (This in general need not entail great expense.)

(*b.*) That every design for subdivision show clearly the contour-lines, and be submitted to a competent civil engineer for his approval before being acted on, so that surface-drainage, sewerage, and road-communication may be adequately provided for.

(*c.*) That, if there is a Health Department, every design be submitted to that department for its approval from a sanitary point of view.

(*d.*) That suitable minimum areas be decided on in accordance with the circumstances of the particular cases, no allotment for residential purposes being anywhere less than 2,500 square feet.

(*e.*) That widths of streets and lanes be fixed by law at certain minima in accordance with the varying conditions.

The question of public reserves should, of course, be carefully considered, and these made ample in the case of Crown townships. In private subdivisions the local authorities would generally have to attend to this matter. Possibilities of water-supply would naturally also require careful attention.

The whole subject has recently received the careful attention of the Victorian Institute of Surveyors, of which I have the honour this year to be the President, and I forward under separate cover copies of papers read by Captain Keily, C.E., and myself on the question. You will note that Captain Keily has treated the subject exhaustively, and carefully considered its æsthetic side.

I think that the Government Architect should in all cases be consulted as to the effect likely to be produced by the arrangement of the reserves for public buildings, &c., but would again repeat that the health of the people appears to me to be the paramount consideration.

3. Letter from Professor W. C. Kernot, M.A., C.E., &c.

As to the question in hand, my views are briefly as follow:—

1. I consider that the laying-out of both town and country lands in the colonies with which I am most familiar has in time past been conducted in a most unsatisfactory fashion, and has given rise to most serious, and in many cases incurable, evils, which might have been avoided had a little intelligent consideration been given to the conditions of the problem. Who is to blame, it is perhaps now hardly worth while to discuss. As far as I can gather, however, in many cases a rigid rule or system has been laid down by high officials who were unacquainted with the nature of the ground, while field officers who did see the difficulties were snubbed when they recommended modifications. After being once so treated, the field surveyor would naturally carry out his instructions to the bitter end, no matter what the absurdity of the result. Hence we have roads charging straight up precipices, running for many chains or even furlongs along the beds of creeks, and passing exactly over the summits of isolated conical hills which might have been avoided with little or no extra distances.

2. With reference to towns, I have come to the following conclusions, from my experience in municipal and sanitary matters in Victoria:—

(*a*.) The site should be carefully chosen. It should be well above flood-level, sufficiently sloping for efficient drainage, sufficiently elevated to afford a good outfall for underground sewers, and yet not so steep as to impede traffic. A general slope—after small irregularities have been removed in the process of grading the streets—of at least 1 in 100, and not more than 1 in 30, is to be desired. Ground too steep and rugged for buildings and streets may be utilised with splendid effect as public parks and gardens. Also, low-lying alluvial flats liable to occasional floods may be similarly employed, and are usually exceptionally fertile.

(*b*.) For the central business portion of the town, I think the chessboard system might be continued, but under restrictions. Rectangular blocks are very convenient, allowing a simple and regular type of building, and giving straight streets, suitable for tramway purposes. The spider's-web system has no doubt been used with grand effect in Paris; but, to my mind, it is rather too irregular. A central square, round which the principal public buildings may be clustered, and a street of extra width dividing the town into two halves, as at Adelaide, are good features. Add to the Adelaide plan two diagonal streets, so as to produce a Union Jack;* and I think it would

* The plan of the City of Christchurch, New Zealand, is a near approach to this arrangement.

be perfect. The diagonal streets would reduce the length of many a journey, and add interest.

3. With reference to the orientation of the plan, I consider a most grave mistake has been made in the vast majority of colonial cities and towns. The streets have been run north-and-south or east-and-west. Consequently, the front rooms of the houses on the north side of the east-and-west streets, and the back rooms of those on the south side of the same streets, are deprived of the purifying action of sunshine. No building should, if it can be avoided, face the south or the west: in the former case the rooms are almost entirely deprived of sunshine, in the latter they get too much. Nearly all our towns would be improved greatly could they be turned 45° in azimuth. In the case of detached houses with windows on all sides, the evil does not specially press. It is in the case of long rows of houses, having light at the front and back only, that it is serious. My attention was first directed to this point by a prominent Melbourne architect, and reflection has convinced me of its importance. Strange to say, the city of Melbourne is correctly laid out from this point of view, while nearly all the suburban towns and up-country places are wrong.

4. From most towns from five to ten main lines of road radiate. In Melbourne, eight well-marked ones are traceable. At from three to six miles out these generally bifurcate. Along these roads the suburbs cluster like beads on a string, while between them the population is but scanty. These lines of road should be laid out as carefully as a railway. In locating them, it should be remembered that easy grades are most desirable, while a little extra length on a good road is not of much importance. There is a main road leading out of Melbourne that is an excellent example of what to avoid in this respect. Being a cyclist of long experience, as well as an expert in road matters, I speak with some authority when I say that a little care in locating four miles in length of this road would have saved 40 per cent. of the labour of driving a bicycle over it, would have reduced the time needed to travel it by 20 per cent., and would have increased its length only 5 per cent. And what is true of the bicycle is true of the waggon. Only cyclists really know what an enormous addition is made to the labours of the poor beasts that drag their heavy loads up and down the utterly unnecessary hills that disfigure some of our main roads. I would not, however, have these main roads perfectly level; gentle undulations of about 1 in 70, each grade not being more than a quarter of a mile long, are a positive advantage; and grades of even 1 in 30, if not more than 10 chains long, are not a serious impediment; but steeper grades than that involve excessive labour in ascending, and

also labour and risk in descending. For all grades steeper than 1 in 50, it is true, from cycling experience, that every foot of rise is a greater impediment than 30ft. extra horizontal distance.

5. In good residential suburbs, where houses stand detached, the chess-board should be absolutely abandoned, and picturesque irregularity encouraged. If the country is hilly the roads should approximate to the contour-lines, and streets running straight up the steepest slope of the hill be absolutely forbidden. In this way convenience and appearance would both be secured.

6. Both in town and suburbs care should be taken to see that every street and lane can be properly drained without the water passing over private property. Blind lanes should have the blind end highest, and through lanes should slope from one end to the other or from a central summit down to each end. Any arrangement that does not admit of this must be altered until it does. Examples of the neglect of this reasonable precaution abound in Melbourne, and great have been the trouble and expense of drainage in consequence.

7. As to width of streets, extremes should be avoided. The 3-chain streets and the $\frac{1}{2}$-chain streets in Melbourne are both objectionable. A central 2-chain street, as at Adelaide, is good, and all the others should be, according to probable importance, 1 or $1\frac{1}{2}$ chains. Lanes for simply giving access to back yards, and having no through traffic whatever, should be not less than 22ft. At convenient but inconspicuous points in the lanes of city blocks sufficient areas should be reserved for public closets and urinals, the want of which is much felt in Melbourne.

8. Public parks, cricket-grounds, bowling and tennis lawns, should be liberally provided. Land too low for building purposes can often be so utilised. Rugged and steep hills often make very picturesque parks, and afford good sites for public monuments. The area of land so set apart for recreation purposes should be at least one-third of the whole area, and should be so arranged that no point is more than half a mile from some such public reserve.

9. The main radiating roads from the centre to the outskirts should be most carefully laid out by a properly trained and experienced road-engineer, who would attend to the question of grades, and choose proper bridge-sites at the crossing of all the larger streams. The general arrangement of the central city and the separate suburbs should be devised by an experienced architect, in consultation with an equally experienced municipal surveyor; and the services of a good landscape gardener would be very desirable in connection with parks and gardens, for, though many years would probably elapse before these could be brought to perfection, it would be a good

thing to settle upon the general design at the outset, so that every little expenditure could be utilised as a step towards the final result. The mere land-surveyor unacquainted with the principles of architecture, sanitation, and road-engineering, should on no account be permitted to perform any part of the work other than the simple marking-out of lines the position of which had been already determined by the experts previously mentioned.

These, then, are my views. They partly agree with and partly differ from those given in your excellent paper at the Australasian Association. From the conflict and comparison of different opinions nothing but good can result if the discussion be fairly and reasonably conducted. In any case we agree that there is vast room for improvement upon the bulk of the work hitherto done.

Report of the Committee, consisting of Mr. J. Barnard, Mr. R. L. J. Ellery (*Secretary*), the Hon. J. Forrest, Mr. G. S. Griffiths, Baron von Mueller, Professor Spencer, *and* Professor Stephens, *appointed to consider the question of Antarctic Exploration.*

Your Committee beg to report that during the past year this topic has been kept well before the public, and that there are gratifying evidences that the labours of the past few years are bearing fruit in the shape of a growing widespread interest in the projected scheme of exploration.

Early in the year the Swedish Consul in Melbourne (Mr. Gunderson) communicated an offer to equip an expedition, subject to an Australian contribution of £5,000. The generous offer to find the balance of the sum required comes from Baron Oscar Dickson, of Stockholm, a nobleman of English descent. Baron Nordenskiöld will superintend the equipment of the vessel, and may command the expedition; we hope that he will. The ship will sail under the Swedish flag, but, in return for the monetary assistance which we hope to be able to give, Australia will have some voice in the direction, and also the right to appoint some of the scientific staff.

As geographers we are cosmopolitan in our ideas, and, while we here should prefer to see the British flag leading again the way to the South Pole, we readily welcome the aid of all nations, and especially we hail the co-operation of our kinsmen of the Scandinavian race.

We have had promises of various sums of money, and are in hopes that the subscription-lists now issuing may quickly enable us to announce that much towards the £5,000 required has been collected.

During the next few weeks the Federal Council will meet, and the Hon. J. Munro and the Hon. J. G. Duffy have promised, as Victorian delegates, to bring the desirability of subsidising South Polar research officially before that Conference, so that the various colonies may co-operate in this grand task.

It is reported that a British owner of whale-ships has asked the Tasmanian Government to grant him a lease of Macquarie Island for a whaling-station, from which he seemingly proposes to test the Antarctic seas for further whaling and sealing. We trust that his enterprise will receive proper encouragement from the authorities; but no privileges should be given him which would prevent other expeditions from utilising that island.

Our colleague, Baron von Mueller, has suggested that the Swedish-Australian expedition should, as an experiment, embark carrier-pigeons, by the homing of which from Macquarie Island, and perhaps other high latitudes, news of the progress of the ship could be conveyed to Australia or New Zealand. Such an experiment might or might not be successful. The intense cold might kill the birds, which might also fall victims to the rapacity of the skua gull, the which bird, or a closely-allied species, is abundant.

Our colleague is anxious also that a balloon should be carried on this occasion, for observational purposes where great barriers of ice or precipitous rock would intercept views further southward. Recently French war-ships have used captive balloons, when under way, for the purpose of securing the view of an extended horizon, with some degree of success; and the experience thus gained might be utilised. He has suggested, further, that, if Nordenskiöld does come out with his ships, Commander Foyn, the great Swedish shipowner, should be invited to send out one of his whalers to keep company or to co-operate with the scientific expedition, though, perhaps, not otherwise connected with it.

Report of the Committee, consisting of Mr. J. H. Maiden, Mr. D. McAlpine, Mr. C. A. Topp, Mr. F. Wright, *and* Mr. A. N. Pearson (*Secretary*), *with power to add to their number, appointed to investigate the question of Rust in Wheat.*

Before leaving Melbourne, Mr. Frederick Wright, of Adelaide, —who, at the general meeting of the Association, moved the resolution appointing the Committee,—called on Mr. Pearson, the Secretary to the Committee, and submitted a sketch of his ideas as to the general policy to be pursued. He was of opinion that, on as early a date as possible after the Committee had formulated a scheme of investigation, the various members or branches should communicate with their respective Governments, explaining the nature of the work to be done, and requesting Government aid in defraying the expenses of experimenting and of collecting evidence and information. He was of opinion also that the Committee should be enlarged by the addition to it of Principals of Agricultural Colleges, Secretaries of Agricultural Departments and Bureaux, microscopists, experts in the diseases of plants, practical farmers of intelligence and experience.

The Secretary endeavoured to call a general meeting of the Committee before the South Australian and New South Wales members returned to their respective colonies; but this was found impossible. Subsequently, Mr. C. A. Topp, M.A. (one of the Victorian members), intimated his inability to remain on the Committee, owing to the absorbing nature of his duties as President of the Board of Public Health, to which office he had been appointed since the formation of the Committee. In consequence of the return of the members to their respective colonies, it remained with the Victorian members to take the initiative; and these consisted now of only Mr. McAlpine and Mr. Pearson. It was agreed to ask Mr. J. L. Thompson, the Principal of the Agricultural College, Dookie, and Professor W. Brown, the Principal of the Longerenong Agricultural College, to join the Committee. Professor Brown readily accepted the invitation.

Mr. J. H. Maiden, of Sydney (the New South Wales member of your Committee), communicated with our Secretary, giving in a general way his ideas of the work to be done, and stating that he was engaged in gathering information and samples of rust-affected wheat from different districts in New South Wales. Mr. Frederick Wright frequently wrote indicating that he was similarly engaged in South Australia, and that he was already in communication with his Government.

In the meantime it was announced that the Victorian Minister of Agriculture was about to invite the Governments of the different colonies to send representatives to an Intercolonial Conference in Melbourne to discuss the subject of rust in wheat; and it was felt by the members of your Committee that it would be useless for them to wait upon the different Governments for financial aid in experimenting, &c., if the Governments themselves were about to undertake an investigation into the matter. It was not possible, therefore, to take any definite action until after the Intercolonial Conference had met.

On the 27th February, however, shortly before the date appointed for the meeting of the Conference, the Victorian branch of the Committee—consisting of Professor W. Brown, Mr. D. McAlpine, and Mr. A. N. Pearson—met in Melbourne for the purpose of considering the relations of your Committee to the Conference, and also of drawing up a preliminary programme of work to be done. At this meeting it was suggested that, since the Conference was likely to be only a deliberative body of short duration, and as some longer-lived organization would be needed for carrying out the suggestions of this body, your Committee, when suitably enlarged so as to meet the requirements of the different colonies, might perhaps serve as an executive body for carrying out the investigations to be suggested by the Conference. At the close of their meeting the members waited upon Mr. D. Martin, the Secretary for Agriculture (in the absence of the Minister), and made this suggestion. Mr. Martin stated that it was a matter for the Conference itself to decide, and advised that Mr. Pearson (who had been appointed as one of the Victorian members of the Conference) should bring forward the proposal at the sitting of the Conference. At this same meeting of the Victorian members of your Committee the following preliminary programme of work to be done was agreed to: The work should be divided into two kinds—namely: (*a*) the taking of evidence, and (*b*) experimenting and improvement of seed.

(a.) *Taking Evidence*—

1. As to the nature and life-history of rust.
2. Species or varieties of rust in Australia.
3. Years of occurrence.
4. Kind of weather in years of occurrence.
5. Time of year at which rust first shows itself.
6. Time of sowing affected and unaffected wheat.
7. Areas affected.
8. Climate of affected districts.
9. Soil of affected districts.
10. Manuring of affected districts.
11. Cultivation (deep, shallow, drainage, &c.) of affected ground.
12. Kinds of wheat affected and unaffected.
13. Other plants attacked.
14. Records of colonial experiments, observations, or researches on the subject.
15. Amount of damage done.

(b.) *Experimenting and improving Seed*—

The experiments to be in different colonies, and in different districts of each colony; and to be continued for at least three years.

Test experimentally the effect — (1) of treatment with manures; (2) of treatment of soil with lime; (3) treatment with ferrous sulphate, &c.; (4) of different kinds of cultivation (deep, shallow, drainage, and so on); (5) of using infected straw as manure; (6) of burning off infected stubble; of disinfecting the soil by burning or otherwise.

Demonstrate experimentally the relative value of plump, healthy wheat-seed and of rust-shrivelled seed.

Select as many as possible of the most rust-proof wheats, both Australian and foreign, and cultivate in experimental plots. Improve from these, both by systematic selection and by cross-fertilisation. Continue this improvement indefinitely, establishing a permanent system of intercolonial co-operative exchange and distribution of the best and most rust-resisting wheats. The latter portion of the work to be made self-supporting.

This programme, with a few modifications and additions, was subsequently adopted by the Intercolonial Conference as a basis for action.

At the sitting of the Conference Mr. Pearson duly proposed that your Committee might be associated with the work as an executive body, but the general feeling was against such an arrangement, it being considered that the machinery already existing in connection with the various Agricultural Departments would be sufficient for the work. This decision being arrived at, there remained nothing further for your Committee to do, as the work intrusted to it would necessarily be of a costly kind, and it was not to be expected that the Government would contribute to two independent organizations for the performance of the same work.

The appointment of your Committee has, however, had a good practical result to the extent of reviving an interest in the subject, and of giving a general direction to the work undertaken in these colonies. The recent appointment of Government Vegetarian Pathologists in New South Wales and Victoria, and the inquiries and experiments now being carried out in Queensland, New South Wales, Victoria, and South Australia in connection with rust-investigations, may justly be regarded as, to a certain extent, the outcome of the appointment of your Committee.

LECTURES.

Oysters and Oyster-culture in Australasia.

A Lecture by W. SAVILLE-KENT, F.L.S., F.Z.S., V.P.A.A.Sc. 1891, Commissioner of Fisheries, Queensland; delivered, in the absence of the Author, by Professor T. Jeffery Parker, F.R.S., at the Third Evening Meeting, on 19th January, 1891.

THE oyster question, which for many years past has so greatly exercised the minds of both the producer and the consumer in the Old World, bids fair in the no very distant future to occupy as prominent a position among British polemics in the Southern Hemisphere. The halcyon days of oysters at 6d. per dozen represents but a dream of the past in the English market, the world-renowed Colchester "native" being now retailed at the almost prohibitory price of 3s. 6d. for that small number. Matters have not arrived at so serious a pass as yet in Australia, but, with the present rapidly-increasing rate of population and coincident increase in the consumption of the bivalve, the time cannot be so very far distant when it will here also be a luxury at the disposal of the wealthy only—that is, unless some drastic means are inaugurated to counterbalance, by artificially-assisted propagation, the present unlimited consumption. More than one of the colonies that in former years produced enough oysters and to spare in its own waters has so far devoured and laid waste its natural inheritance that it is now dependent mainly, or even exclusively, upon neighbouring countries for its supplies. By-and-by, probably, these supplies will not suffice for more than the producing country's home consumption, and on arriving at that stage it may be taken for granted that the price of oysters to the Australian public will be very materially advanced.

VARIETIES OF AUSTRALIAN OYSTERS.

Before entering further into the discussion of this undeniably unsatisfactory condition of affairs, and its possible remedy, a brief enumeration of the commercial oysters indigenous to Australasia may prove acceptable. An oyster indistinguishable to the ordinary public apprehension from the British native and recognised by most scientists as a variety only of that highly-esteemed species, *Ostrea edulis*, represents the commercial type indigenous to the shores of Tasmania, Victoria, and the southern districts of South Australia. New Zealand also produces in her southern waters a species of oyster identical with or very closely allied to the British type, and enjoying the superior advantage of possessing, under natural conditions, the smooth, suborbicular, polished shell and full luscious body which can only be artificially produced in the British native by a prolonged course of culture and manipulation. I refer here to the celebrated Bluff or Stewart Island oyster, in which New Zealand undoubtedly possesses a valuable property, that should be most jealously protected from reckless dissipation. New Zealand is further fortunate in producing in great abundance in her northern waters the sub-tropical commercial oyster, *Ostrea glomerata*, commonly denominated the rock-oyster, in contradistinction to *O. edulis*, which is usually and somewhat detrimentally named a mud variety. New Zealand has hitherto produced such an abundance of these two oysters that she has exported largely of both kinds to the Australian Colonies of Victoria, Tasmania, and New South Wales. How long she will be in a position to maintain this supply is a matter that will undoubtedly demand grave consideration in the near future. The commercial oyster indigenous to New South Wales and Queensland is the rock-oyster, *Ostrea glomerata*, indistinguishable from the form produced in the northern waters of New Zealand. Its southernmost range on the Australian coast-line is the Genoa River estuary, just within the border-line of Victoria, while its maximum of development is undoubtedly attained in Moreton and Wide Bays, on the Queensland coast, whence vast quantities are annually exported to Sydney and Melbourne. The same species of oyster attains to a sufficient size, and occurs in sufficient quantity, to be of commercial value as far up the Queensland coast as Rockhampton. Beyond this point it dwindles in dimensions and numbers, but nevertheless may be found in a stunted form as far away as Port Darwin and Cambridge Gulf, in the remote Northern Territory, at both of which places I gathered it some two years since. From growths of this species I have recently seen on the mangrove-roots in the Endeavour River, near Cooktown, I am of opinion that under favourable conditions this oyster might be greatly improved and profitably cultivated in tropical waters in, at all events, sufficient quantities for local consumption.

The commercial rock-oyster, *Ostrea glomerata*, last referred to, may be described as an essentially estuarine or brackish-water species, its most luxuriant growth being attained in river-estuaries, or in situations where the salinity of the water is subject to periodical if not permanent reduction by the accession of fresh water. No instance has, in fact, so far fallen within my notice in which this species occurs in permanently pure salt water. There are, however, two species of edible oysters indigenous to the tropical and sub-tropical Australian regions, which are, on the contrary, exclusively salt-water inhabitants. One of these—*Ostrea mordax*—having a pinkish triangular crenulated shell, occurs in the greatest luxuriance on the outlying reefs and islets of Torres Straits and the Great Barrier system, and extends so far south as the Tweed Heads, on the borders of Queensland and New South Wales. The same species is reported to occur throughout Polynesia, and is, I believe, abundant on the sub-tropical coast-line of the North Island of New Zealand. Although excellent eating, this oyster is, unfortunately, of but little commercial value. This drawback to its utility is occasioned by the fact that the species, adapting itself to its environment, amidst the full force of the breakers, adheres with such tenacity to its rocky support that it cannot be detached without breaking the shell to an extent that precludes its transport in a sound condition to any distance. From a biogenetic standpoint it is, I think, highly probable that this oyster, *Ostrea mordax*, represents the type from which the commercial brackish-water form, *Ostrea glomerata*, was primarily derived.

The second species of essentially marine edible oyster grows side by side with *Ostrea mordax*, but is confined more exclusively to the tropics. It is usually of an ovate shape, from 6in. to 8in. in length, and has a dense white porcellanous shell with a black interior border. It may be easily detached from the rocks with a hammer and cold chisel, and, while somewhat coarse and tough eaten *au naturel*, is an excellent oyster for culinary purposes. Not having been able to establish the specific identity of this tropical oyster, examples have been recently remitted by me to the British Museum for identification.*

There are numerous species of oysters indigenous to Australia that are of too rare occurrence to have any commercial value, and are therefore only of scientific import. Although a detailed description of these non-commercial varieties would be outside the scope of this address, a brief reference may be made to two forms among them, since they represent respectively the largest and the smallest species of true oysters inhabiting Australian waters, if not, indeed, the universe. The first, or largest, type is allied to the well-known cock's-comb oyster, *Ostrea crista-galli*, and may be distinguished by the regular zigzag

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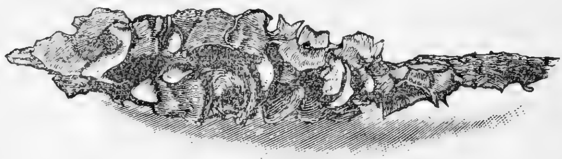
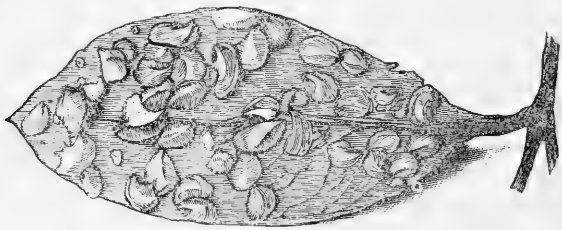
* Mr. Brazier, of the Australian Museum, Sydney, has recently identified this species for me with the *Ostrea nigro-marginata* of Sowerby.—S.-K.

indentations of its free margin. It occurs in some abundance along the Great Barrier Reef system of Northern Queensland, and through Torres Straits to New Guinea. Shells of this species have been obtained by me weighing no less than 6lb. the pair, and having a diameter of from 8in. to 10in. At the opposite end of the scale I may make mention of an exceedingly minute species of oyster discovered by myself in the estuary of the Ord River, Cambridge Gulf, Western Australia, in connection with the surveying cruise of H.M.S. "Myrmidon" in the year 1888. This oyster, which but rarely exceeds $\frac{1}{4}$in. in length, is usually considerably smaller. It grows in great abundance not only on the stems, roots, and respiratory shoots,



Pigmy oysters on "cobbler's peg."

or so-called "cobblers' pegs," of the white mangrove (*Avicennia officinalis*), in the district named, but also on the leaves of the same plant. The only other species of oyster that grows in the same neighbourhood is the stunted tropical variety of the commercial rock-oyster, *Ostrea glomerata*, previously referred



Pigmy oysters on leaf of mangrove.

to. The distinctness of the miniature species from the young or spat of the last-named type was clearly manifested, not only with relation to their comparative shape and size, but in their respective areas of growth, the minuter form being restricted to a band of foreshore so close to high-water mark that it is submerged for two or three hours only during each tide; *Ostrea glomerata*, in its immediate neighbourhood, on the other hand, was confined to rocks that were not exposed to view until the tide was well down. In further corroboration of its specific distinctness it was found, on examination with the microscope, that these diminutive oysters were laden with mature ova. Some idea of the minuteness of this oyster will be gained by a reference to the photographs of this and other species of Australian oysters prepared by me for the illustration of this paper. In the one representative of this pigmy type it may be observed that as many as fifty or more mature oysters were in several instances located, without crowding, upon a single leaf of the *Avicennia*, which is less than 3in. long. Young individuals scarcely exceeding a pin's point in dimensions were also scattered among the mature examples, or, as commonly occurs with ordinary commercial oysters, growing upon the living or defunct shells of their parents. More than a year ago I presented examples of this minute and apparently new species of oyster to an eminent Australian conchologist for the purpose of careful comparison with, and relegation to an appropriate place among, the numerous members of its genus. No results having, however, so far arisen from the steps taken to secure it a recognised position among its congeners, I take this opportunity of naming it *Ostrea ordensis*, with reference to its habitat, and append to this paper a brief technical diagnosis that will facilitate its future identification if obtained from other localities.

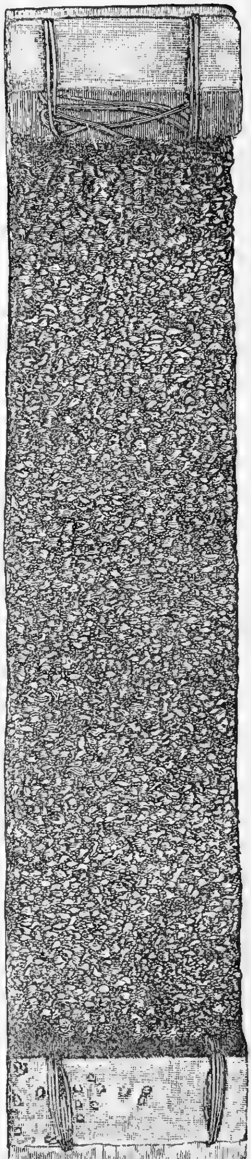
Oyster-cultivation.

In dealing with the important subject of oyster-cultivation, I propose to take the several oyster-producing colonies of Australia in rotation, and to indicate briefly the nature and results of the operations that have been conducted therein. The island of Tasmania being the colony with which I was first officially associated, and where for a period of nearly five years the oyster-fisheries engaged my special attention, I may appropriately select it as the subject of my first remarks. The oyster of Tasmania, as previously indicated, corresponds so closely with the type *Ostrea edulis*, produced and cultivated in British waters, that it is held by most biologists to be identical with it. This oyster was so abundant in former years in Tasmanian waters that, as vouched for in the report of a Royal Commission of Fisheries held in the year 1882, about twenty years previously a quantity representing at current prices a retail value of no less than £90,000 was exported in a single year to Victoria and New South Wales. Oysters, in fact, were so plentiful at that time that it was a common practice to burn them wholesale for the purpose of making lime. This woful waste of Nature's bounties soon reaped its merited reward. The oyster-grounds became so depleted by the unrestricted drain upon their resources that in a few years they were practically exhausted, and thenceforward up to within a recent date Tasmania has had to be beholden to other colonies, and especially to New Zealand, for her supplies. This, in fact, was the position of affairs on my arrival in the colony in 1884. The oyster-fisheries of Tasmania were at that time, and had for some years been, an obsolete industry. Through overdredging, and the reckless destruction of the young brood or spat, the natural beds had, for commercial purposes, become completely exhausted. Now and again spasmodic efforts had been made in various localities to revive the fisheries by artificial cultivation. Such efforts, however, owing to the absence of practical knowledge on the part of the cultivators, were attended with negative results. No brood or spat was collected, and the more or less complete sacrifice of the oyster-stock laid down was in most instances involved. My services were at this time engaged by the Tasmanian Government to prescribe measures for the possible resuscitation of this depleted fishery.

With a vivid recollection of the important evidence concerning oyster-growth in European waters that had been brought forward at the International Fisheries Exhibition and associated conferences held in London during the preceding year, 1883, and more especially the practical testimony of Professor Hubrecht concerning the oyster-fisheries of the Scheldt, in the Netherlands, my first step on becoming acquainted with the position of affairs was to recommend the establishment, in suitable localities, of efficiently-protected Government reserves, upon which breeding-stocks of oysters of the best quality should be carefully cultivated and permanently retained. These reserves, it was intended, should fulfil the double purpose of breeding-centres from whence the surrounding waters could be restocked, and also of model oyster-farms around which private beds might be established on similar lines, and thus contribute collectively towards the rehabilitation of the oyster-fisheries. The scheme recommended being approved, sites formerly associated with the most prolific oyster-production were selected, and operations commenced. These operations were necessarily conducted on a very modest scale. Oyster-stock suitable for laying on the reserves could be accumulated only by slow and laborious processes, and some twenty thousand to fifty thousand oysters represented the approximate numbers that were thus gradually collected and placed under cultivation. Some four or five years, it was anticipated, would have to elapse under these conditions before any substantial results could be looked forward to. In order to secure the catchment of the greatest possible amount of spat produced by the oyster-stocks laid down, various methods were resorted to, the principle involved being identical with that inaugurated with so much success by M. Coste on the west coast of France. In addition to dead oyster-shells, or "cultch," which has from the earliest days of oyster-culture been recognised as representing a most natural and prolific catchment-material for the adhesion of the spat, artificial collectors of various descriptions were introduced. In France tiles cemented on their lower surfaces have been found to constitute the most productive and economic collectors. In Tasmania, as in all the other Australasian Colonies, tiles being much too expensive for such a purpose, a cheap and efficient substitute for them was effectually improvised out of the thin roughly-cleft boards known as "split palings," which can be procured in all timber-producing districts at a cost of from 8s. to 10s. per thousand. These paling collectors are coated on their under-surface with cement, a brick or stone is securely fastened underneath at each end to give them stability, and a wire loop secured through the centre of their upper surface forms a convenient handle by which they can be manipulated on shore, or be raised with a boat-hook for examination from beneath the water. The general plan of construction of these paling collectors, and the efficient assistance they render in collecting the floating spat, are abundantly shown in the illustrations here given. The figure on the left (p. 558) shows a paling collector as it appears before being placed in the water, and that on the right a similar one coated with oyster-brood, recently laid down in Queensland waters.

Proceeding to an examination of the results obtained by the operations described, I may appropriately make a brief quotation from a report submitted by me to the Government of Tasmania in January, 1889. Spring Bay and Little Swanport Lagoon are herein referred to as representing the stations at which the most marked results have been obtained. "These two districts alone," it proceeds to say, "formerly produced about two-thirds of the entire yield of the Tasmanian oyster-fisheries, so many as eight million and five million oysters respectively having been dredged from them in a single season. At Spring Bay, in which the earliest-established reserves are located, the oysters, previously practically exterminated, have so multiplied and spread from the stocks laid down as to afford profitable employment to the local fishermen there to dredge them for further stocking the reserves and for private fisheries. In a recent communication from the district overseer of the reserves I am further informed that, 'While throughout a period of more than ten years preceding the establishment of the Government reserves the local oysters had almost disappeared, they are now present in millions, filling up the beds and bay, and adhering to everything, including stakes, stumps, rocks, old bottles, crockery, and other refuse in the water, and even to the bottoms of the vessels stationed in and

Paling collector before being placed in the water.



Paling collector coated with oyster-brood.

that frequent the port.' The most practical testimony to the substantial progress that is being made towards the revival of the oyster-fisheries in this district, as well as to the confidence established by the operations initiated, is perhaps adduced by the fact that as many as fifteen areas, varying in size from one to sixteen acres, are already occupied or have been bespoken by individuals or associated companies for the purpose of forming private oyster-fisheries."

Since the compilation of the report just quoted, and, indeed, within the past few weeks, intelligence of a still more gratifying nature has reached me concerning the newly-resuscitated oyster-fisheries of Tasmania. By a resident at Spring Bay I am informed that oysters have now become so plentiful there that the Hobart market is glutted, and that the dealers have been obliged to reduce their sale-price 50 per cent. From another source, the daily press, I have learnt that at a recent meeting of the Tasmanian Fisheries Board attention was drawn to the necessity that had arisen for amending the existing regulation concerning the sale of oysters during the close months. As originally framed, the regulation applied only to oysters dredged or taken from the natural oyster-grounds, and did not anticipate or make provision for the holding of beds by private lessees, by whom supplies of oysters can be consequently without legal interference, and, as a matter of fact, are now being, placed upon the market at all times and seasons. No further evidence is, I think, required to accentuate the fact that the erstwhile exhausted oyster-fisheries of Tasmania have been re-established upon a solid basis, and that by perseverance in the maintenance of the breeding reserves it is only a question of time to restore them to their original remarkable fecundity. One point in this connection demands brief notice. In accordance with my recommendations all holders of private oyster-beds in Tasmania are bound by the terms of their leases to retain a certain amount of breeding-stock—namely, not less than ten thousand mature oysters to the acre—permanently on their oyster-beds. This regulation contributes materially towards the distribution of spat throughout the surrounding water, and to the re-establishment of the oyster-fisheries upon a durable basis.

VICTORIA.

The oyster-fisheries of Victoria next invite attention. The specific form of oyster indigenous to the Victorian coast-line is, as previously mentioned, the miscalled mud-oyster, identical with that produced in Tasmanian waters, and to all outward appearance indistinguishable from the British native, *Ostrea edulis*. In former years vast quantities of this oyster were obtained from Western Port Bay, Port Albert, and Corner Inlet.

Insatiable greed and overdredging, however, reduced these prolific natural beds to the very verge of extinction, and thus it happens that Victoria for many years past has been, and still is, dependent upon New South Wales, Queensland, South Australia, and New Zealand for her oyster-supplies. Some two years since I was invited by the Government of Victoria to make a tour of and report upon the fisheries of that colony, giving special attention to the practicability of reviving the oyster-fisheries. As a result of that tour of inspection, I strongly recommended that Government oyster reserves should be established, and stocked with oysters, at Western Port and Port Albert more particularly, on the same basis as those which have proved so effective in Tasmania. One such reserve, with a very small stock of oysters, was formed at Port Albert. As, however, contrary to my anticipations, no provision was made for its periodical skilled supervision, it has not surprised me to hear that this reserve has failed in its mission, and has dwindled to decay. Unless such reserves can be maintained in efficient working-order, and the operations periodically required thereon be supervised by a practical ostreiculturist, the money expended on their establishment is simply wasted.

Victoria will not, however, I hope, abandon the latent potentialities she possesses of again becoming a prolific oyster-producing colony, in consequence of the check experienced in association with this first insufficiently-supported effort. One formidable obstacle that has hitherto stood in the way of resuscitating the inshore oyster-fisheries has been the difficulty of obtaining sufficient quantities of the species indigenous to the colony for the establishment of sufficient reserves. This difficulty has apparently now found its solution. In my reports to the Victorian Government I drew attention to the fact that along the Ninety-mile Beach and other portions of the coast-line visited by me I had observed considerable numbers of oyster-shells, evidently derived from deep water, that had been recently cast upon the shore by storms. In consequence of these observations I predicted the existence of more or less extensive beds off the coast, and recommended the Government to undertake experimental operations with the dredge in order to ascertain the whereabouts of these beds. This recommendation has, I am informed by the newspapers, been recently acted upon with success, the Inspector of Fisheries, in association with the steamer "Lady Loch," being therein reported to have discovered some offshore beds. The extent of these beds, and whether it is intended to throw them open to indiscriminate dredging until they are commercially exhausted, is not recorded. It may be pointed out, however, that a most favourable opportunity is afforded by their discovery for restocking the inshore fisheries, and for establishing in association therewith that system of leasehold culture that yields so substantial a revenue to the Colonies of Queensland and New South Wales. Acting upon these lines, many years should not elapse before Victoria will be in a position to produce from her own waters a substantial portion, if not the whole, of the vast quantities of oysters annually consumed within her territory.

Through official sources I have been quite recently informed that about seventy bags of oysters have been so far obtained by the experimental dredging off the Victorian coast. These oysters are described as of poor quality, and as having realised a price of from 5s. to 15s. per bag only in the market. Like the ocean-dredged oysters in British waters, they evidently require cultivation before they can be brought up to a high commercial or gastronomic standard. But, as indicated in the foregoing paragraph, they are eminently fitted for collection and laying down as a nucleus towards the resuscitation of the depleted inshore fisheries.

New South Wales.

On proceeding to discuss the oyster fisheries of New South Wales, a separate species of oyster, associated with separate conditions of growth and propagation, has to be taken into consideration. The commercial species of this colony is the familiar rock-oyster, *Ostrea glomerata*. At the same time a mud-oyster, identical with or most closely allied to the Victorian and Tasmanian type, *Ostrea edulis*, occurs in some numbers upon the coast, but in consequence of the hitherto profuse abundance of the rock variety it has not been considered worthy of commercial attention. In form and general aspect the New South Wales rock-oyster somewhat resembles the Portuguese oyster, *Ostrea angulata*, and also the American, *Ostrea virgincana*. With these two species it further corresponds in its breeding habits, which are essentially distinct from those of the English, Victorian, and Tasmanian mud-oyster, *Ostrea edulis*. In the last-named type, as is familiar to those who can claim an intimate acquaintance with the British native, there is a time when that sapid mollusc is most decidedly out of season. On opening it, it is found to be filled with grey, gritty matter, that feels like sand in the mouth. Placed under the microscope, this gritty substance is found to consist of millions of minute oysters, each enclosed by a pair of perfect transparent shells, and which, in the course of a few days or weeks, would be ripe for liberation into the surrounding water. This species of oyster, in fact, nurses its brood, or spat, previously fertilised in the mantle-cavities of its parent, up to an advanced stage of development. The same phenomena, as I have personally ascertained, are distinctive likewise of the Tasmanian and Victorian representatives of *Ostrea edulis*. One point that may be mentioned regarding the Australian race of this species, and which is to the advantage of the Australian oyster-cultivator, is the circumstance that, owing apparently to the more genial temperature of the water, it reproduces its kind nearly all the year round, though most abundantly during the summer months. In British waters the spatting season is restricted to the summer months, the close time on that account being popularly defined as consisting of those months —May to August—into the vocabulary of which the letter "r" does not enter.

The propagation of the Australian rock-oyster, *Ostrea glomerata*, is accomplished on an entirely different plan. There is in this case no nursing of the young brood, which is turned out to shift for itself, not only in a shell-less, but even in an unfertilised condition. Like the spawn of many fishes, these ova are fertilised in the water. The rock-oyster—at all events in Queensland waters—propagates all the year round, February, however, being regarded as the most prolific month. It is, moreover, so precocious that, as ascertained by me in a recent investigation of this subject, mature ova, from which new oyster-broods can be reared, are produced by baby-oysters, measuring no more than $\frac{3}{4}$in. in diameter, and probably only three months old. The artificial fertilisation of the ova of this species can be accomplished with the same facility as obtains in the American and Portuguese types, *Ostrea virgineana* and *O. angulata*, and was successfully achieved by me in association with the investigations just referred to. Continuing these investigations, I ascertained that, under favourable circumstances, four days only elapsed from the time the ovum was fertilised before the shells, which made their appearance on the second day, had become so dense that the embryo oysters could no longer support themselves in the water, and, subsiding to the bottom, entered upon their permanently-fixed condition.

Such is the fecundity of the Australian rock-oyster (*Ostrea glomerata*) that the rocks and every available holding-place in the bays, estuaries, and inlets of the districts it affects become literally plastered with the embryo brood, insomuch that up to within a recent date artificial culture in the more restricted scientific, or European, sense has in New South Wales been usually regarded as an unprofitable and unnecessary superfluity. Oyster-culture, in the simplest interpretation of the term—consisting merely of the collection of the brood or mature oysters from positions where they cannot grow to a marketable size, and their redistribution upon favourable sites —is practised very extensively throughout the oyster-growing district of that colony, the lands leased for that purpose, together with the royalty (recently discontinued) charged upon the oysters taken off them, yielding a very considerable revenue to the Government.

Taking the year 1886 by way of example, and as a fair average, 14,774 bags, representing roughly (reckoning from 1,200 to 1,500 to the bag) about 22,000,000 oysters, were derived from the tidal waters of New South Wales during that twelvemonth. The royalty collected on these oysters amounted to £2,216, and the rents and deposits for leased areas and on applications for leases to £3,641, or a total of £5,857. This oyster-harvest derived from her own tidal waters does not, however, suffice for the requirements of New South Wales, statistics for the same year quoted showing that 4,906 bags, or close upon 7,000,000 oysters, were in addition imported from New Zealand and Queensland. Within the last few years the number of imported oysters has increased. A considerable check, moreover, has been given to the indigenous fisheries of New South Wales through the appearance of a disease in many of the most prolific grounds, which either destroys the oyster or renders it unfit for food.

The latest official returns (Reports, 1889–90) received during the preparation of this lecture do not, I regret to say, indicate any improvement in the condition of the New South Wales oyster-fisheries. On the contrary, the output from her tidal waters for the years 1888 and 1889 has fallen as low as 9,184 and 6,914 bags respectively. The number last quoted only equals the importations from New Zealand and Queensland for the same period. As shown by these figures, urgent necessity undoubtedly exists for strenuous efforts being undertaken in sufficient time; and I would advise the Government to preserve the New South Wales oyster-fisheries from absolute destruction.

Disease in Oysters.

The form of disease that is apparently chiefly responsible for the great deterioration of the oyster-fisheries of New South Wales is characterized by the presence within the oyster-shells of patches of mud, which are more or less completely covered in by a shelly or membranous redeposit, one or more small worms being almost invariably found enclosed within these mud-cavities, which maintain a communication with the outer water. These worms are usually credited with being the prime origin of all the mischief, which is accordingly denominated the "worm disease." This so-called "worm disease" is not prevalent in the oyster-beds of Queensland; but, judging from a passing acquaintance I made with it in New South Wales, and all the facts concerning it that have been published, I am strongly inclined to believe that this worm is only an accompaniment, and not the cause, of the disease. An excellent description, with illustrations, of the worm, *Leucodore ciliata,* together with an account of the phenomena attending its existence in the oyster-shells, has been prepared by Mr. W. T. Whitelegge, of the Sydney Museum, for the New South Wales Fisheries Commission; the view favoured in that pamphlet being that it is the direct cause and propagator of the disease.

Leucodore is not a newly-discovered species. It was first described as a British species so long ago as the year 1838, and has been found to be practically cosmopolitan in its distribution. The habitat ascribed to it by Dr. Johnston, in his "Catalogue of Non-parasitical Worms," 1865, is as follows: "Found living between seams of slaty rock near low-water mark, and burrowing in the fine soft mud which lines the fissures." I have been recently informed, by an experienced and highly observant oyster-grower, that the same species of worm was noticed by him many years ago burrowing in the mud-filled crevices of timber-work in Sydney Harbour. The species, like other members of its class, is an essential mud-lover; and its natural instincts guide it in its earliest embryonic days to seek out and settle down in a congenial mud-lined cradle.

Turning to the conditions accompanying the appearance of the disease in New South Wales, as described by Mr. Whitelegge, much evidence is found that supports the interpretation I am disposed to advocate. He remarks that "the principal home of the worm appears to be on the mud-flats about low-water mark. The oysters from this region were invariably infected with the worm, particularly those which lay loose on the surface, or were partially buried in the mud. Those oysters which were fixed to some solid substance, and elevated ever so little above the surface of the mud, were comparatively free from the pest." This testimony goes far to show that this so-called worm disease is essentially a "dirt disease." It is only in a muddy environment unsuitable for the healthy growth of the oyster that it spreads; and that it is the mud that attracts the worm, and not the oyster *per se,* is demonstrated by the fact attested to, that the oysters elevated but a few inches above the muddy stratum are relatively free from the affection. The primary cause of the disease has yet to be fully determined, and it is a subject of high importance to all oyster-growing communities. The rock-oyster, *Ostrea glomerata,* affected by the disease, is, as previously remarked, a species that attains to its maximum development in brackish water, and, indeed, survives exposure to fresh-water immersions in times of floods that would prove fatal to the so-called mud-oyster, *Ostrea edulis.* As a corollary to these brackish-water proclivities of

Ostrea glomerata, its most luxuriant development in New South Wales has been high up the river estuaries that so abundantly intersect the coast-line. The Hunter, the Hawkesbury, and the Clarence Rivers may be mentioned not only as the most important of the oyster-growing areas, but also as those in which the worm disease, or, as it may be more correctly termed, the "mud disease," has been most prevalent. In my opinion it is the altered conditions of these rivers, brought about mainly through human agency, that has induced the diseased condition of the oysters, their waters, in fact, being rendered more or less incapable of supporting the mollusc in a healthy state.

Through the clearance of the land and the establishment of townships and settlements throughout the watersheds of these rivers, the rainfall, which in former days fell upon and was more completely absorbed by the primeval forests, is now carried quickly away, and emptied by drains and culverts into the watercourses communicating with the rivers. Simultaneously with this augmented discharge of water into the rivers a vastly larger quantity of sediment is brought down, accompanied by a considerable percentage of organic and chemical pollution that had no place in the composition of the water under those conditions in which the oysters originally grew and flourished. This greatly-augmented accession of flood-water, with its accompaniment of sediment and chemical pollution, cannot exert other than a very deleterious influence upon the river oyster-fisheries.

A case in point, in which the oysters, formerly growing abundantly many miles up a river's course, have been gradually pushed further and further down towards the sea through the agencies just described, fell under my personal observation in Tasmania. In the River Tamar, debouching on the northern coast-line of that colony, the mud-oyster (*Ostrea edulis*) was originally abundant from the Heads half-way to the town of Launceston, some forty miles distant. By degrees—as testified to by residents of the district — the oysters have disappeared from the formerly prolific higher portions of that river, known as Whirlpool Reach and the Middle and Eastern Arms. On my first visit to the Tamar estuary a few oysters were still left in the lowest bay, known as the West Arm; but these, both young and old, were in a dead or dying state, owing chiefly to prolonged immersion in water containing an insufficient amount of saline ingredients, organic pollution from the town of Launceston probably also playing an important part in their destruction. Within a few years after this first visit oysters were practically extinct in the Western Arm, and no success attended the efforts made to resuscitate the fishery in that district by artificial culture. The last lingering remnant gathered there were in a decidedly unhealthy state, the shells being discoloured and wanting in solidity, and the contained oysters being in the poorest possible condition.

Should the interpretation here suggested be correct with relation to the diseased condition of the New South Wales oyster-fisheries, it is evident that the prospects are but small of recovering the ground lost to oyster-culture in the several districts affected. It will consequently be incumbent on the oyster-growers of that colony to make the most of the water-area left to them where the water is pure and not liable to be invaded by the disease; and, if they are ambitious to regain that position formerly held, in which the colony was independent of supplies from external sources, they will require to turn their attention to the culture of the mollusc on a far more scientific basis than has been hitherto attempted in New South Wales waters. It is somewhat surprising in this connection to find how imperfect a comprehension of this most important branch of aquaculture is possessed in quarters where the fullest technical knowledge might be naturally looked for. Letters have recently appeared in the *Sydney Morning Herald* from the pen of a leading oyster-merchant in that city, dealing with this question of oyster-culture. No need would have arisen for taking notice of these letters had it not been for the fact that they have been reproduced in all good faith in a Government report of a neighbouring colony as representing the latest and most accurate information on the subject treated. Through the public prominence given to these letters they are therefore, if not as publicly refuted, calculated to mislead the Australian mind concerning the achievements and capabilities of scientific oyster-culture, and to retard progress in what may be anticipated in the near future to develope into a necessary and highly-important industry.

The French System.

The French system of oyster-culture, which owes its inception to M. Coste, who has won by it a world-wide reputation, is characterized in the documents referred to as having been "a dead failure in Europe, hundreds of thousands of pounds having been lost on it in England and France." Among other matters, and as a final perversion of the truth, the absurd statement is made that "but few people in France have had as much experience in oyster-culture as many of us (in New South Wales) have had, so that, instead of Frenchmen being able to teach us, we can teach them." The explanation of this tirade against M. Coste and his system of culture is apparently furnished by the fact that steps had been taken to introduce a parliamentary Bill providing for the bringing-out of French oyster-culturists to practise their system in the waters of New South Wales. Such action would doubtless be regarded with disfavour by many of the oyster-growers of that colony, and would possibly affect certain existing monopolies. Herein probably lies the solution of the entire matter.

The slender fragment of truth upon which the Sydney merchant's wholesale denunciation of M. Coste and all his works is based is apparently furnished through the possession by that writer of a copy of a report of a Royal Commission on the oyster-fisheries (Ireland) dating so far back as the year 1870, at about which time, as testified to by witnesses engaged to collect evidence, the French oyster-fisheries were undoubtedly in a very declining state. No reference, however, is made to the admitted explanation of their depreciation—namely, "the killing of the goose that laid the golden eggs" through the selling from off the private beds of so many of the parent oysters that too few were left to propagate the species in profitable numbers. This error was corrected as soon as recognised, with the result that within a very few years the French oyster-fisheries had not only regained their former position, but eclipsed previous years in productiveness. Here are a few figures, taken from the French statistical returns, that abundantly substantiate this statement. In the year 1873 the official value of the oyster-produce of France was estimated at 2,447,565fr., or, roughly, £99,000. For the three succeeding years the numbers and value of the French oyster-fisheries are given as follow:—

	Oysters taken off Beds.	Value in Francs.	English Equivalent.
1874 ...	104,731,350	7,727,000	£309,080
1875 ...	227,640,212	11,247,416	449,896
1876 ...	335,774,070	13,226,296	529,051

In the year 1887, representing the latest statistics immediately available, the total number of oysters taken from the French fisheries is quoted at 375,000,000, showing that even the magnificent output of the year 1876 has been eclipsed.

The figures just quoted throw into complete insignificance not only the oyster-produce of New South Wales, but that of the collective Australasian Colonies. It is placed on record that some twenty years since the Hon. Thomas Holt, recognising the value and capabilities of the French system of oyster-culture, undertook, at an expense of some £10,000, the construction of extensive *claires* at George's River, New South Wales, for the culture of oysters on a similar principle. This undertaking, it appears, did not meet with the success it merited, and the occasion has been turned to account in the documents previously quoted to throw discredit upon the system. The system, however, cannot be held responsible for the failure that resulted from this experiment. The circumstance that did lead to the failure reported was evidently the error in judgment in applying the principle on so extensive a scale to the culture of a species of oyster differing materially in form, habits, and methods of propagation from the European type. In dealing with a matter of this sort it is, before all things, desirable to proceed cautiously, and, as it were, to feel one's way. In this particular case the knowledge obtained at the sacrifice of so large an amount of capital as £10,000 could doubtless have been gained by an expenditure of from £50 to £100.

The *claire* system of culture adopted by Mr. Holt is prosecuted in France for fattening and the development only of particular qualities in the mud-oyster (*Ostrea edulis*), and not for the propagation of the species. Properly constructed, these *claires* are in the form of shallow ponds, of from 12in. to 18in. in depth, and so connected with the sea by means of sluices that fresh streams of salt water obtain access to them at spring-tides only. Throughout the intervening periods the water is completely stagnant, and it is, I think, very questionable if the Australian rock-oyster (*Ostrea glomerata*) could be induced to thrive under such conditions. The French oysters are distributed in these *claires* at distances of about 5in. or 6in. from one another, so as to allow sufficient space for each individual to obtain an ample supply of food. This food consists chiefly of the microscopic plants known as diatoms, which are so abundantly developed in the shallow tranquil water of the *claires* as to form a greenish scum over the surface of the mud on which the oysters are placed. In course of time this particular food imparts to the flesh of the oyster a distinct greenish colour, which has been found by analysis to be due to the presence of chlorophyl, or the essential green colouring-matter of plants. A period of at least two years' culture in the *claires* is occupied in imparting to the oysters the full green hue and prime condition for which they are so justly famous. Marennes, on the River Seudre, is above all places celebrated for oysters thus cultivated, and the brand known as the "vraies huîtres vertes de Marennes" obtains a specially high price in the Paris market.

Although it is doubtful if the Australian rock-oyster would lend itself to culture in the manner just described, or whether under such conditions it would acquire that superior quality which would command for it a price that would repay the cost of production, New South Wales possesses in her waters a variety of the mud-oyster (*Ostrea edulis* var. *angasi*) that should be perfectly amenable to this method of treatment.

Dr. James C. Cox, the President of the New South Wales Fisheries Commission, has recently directed notice to this oyster as well worthy the attention of oyster-growers, in face of the diminished supply, through disease, of the common rock variety. The time, it may be anticipated, is not far distant when this valuable suggestion will be practically acted upon. Doubtless, too, New South Wales possesses a sufficient population of epicurean tastes able and willing to pay the higher price that superior cultivated oysters of this description should command in the market.

Queensland.

So far as commercial value goes, Queensland is at present, like New South Wales, exclusively dependent on the rock variety, *Ostrea glomerata*, which may be said to attain to its maximum development in both quantity and quality in the Moreton and Wide Bay districts of the colony. The species is so profusely abundant in the areas indicated that large consignments, above those required for home consumption, are exported to New South Wales and Victoria. The disease which has so seriously depleted the fisheries of New South Wales has not as yet affected the Queensland beds. This immunity from affection is probably attributable to the circumstance that the Queensland oyster-fisheries are chiefly located in bays and channels in close proximity to the open sea, from whence, even after heavy floods from the tributary rivers, they are speedily revived by an inflow of sea-water. Jealous care will have, nevertheless, to be taken by the Queensland authorities to preserve these tributary streams as far as possible from pollution by chemical or other noxious works, which, if allowed to increase to any considerable extent, cannot fail to exert a very deleterious effect upon both the oyster and all other fisheries of the bays into which the rivers flow. Artificial oyster-culture, with the exception of one or two small experiments, has been so far carried out in Queensland waters on the simple lines only of transporting the young brood or ware, locally known as "cultivation," from one locality, and laying it down on ground where it will develope more speedily to maturity. The amount of brood available for this purpose is so abundantly produced throughout the areas of Wide Bay and Moreton Bay, in southern Queensland, as to satisfy all present demands without the necessity of resorting to the more elaborate European methods of culture. This, at any rate, holds good with the big oyster companies and other proprietors of extensive oyster-grounds to operate upon. There can be no question, however, that the numerous smaller proprietors, having but a limited water-frontage at disposal, could, at a trifling outlay, greatly increase their oyster-crops by the employment of suitable collectors, as used in France, for the catchment of the spat. In many instances, moreover, land that has yielded no return hitherto may be made to produce an abundant harvest by these methods.

Artificial Spat-collectors.

As a practical illustration of what can be accomplished in Queensland waters with the aid of artificial spat-collectors, I have forwarded for exhibition at this meeting a sample specimen constructed on the same principle as those that proved so efficacious in Tasmania. It is of more elaborate make than those employed in the last-named colony, for the simple reason that "split palings," of which they are customarily constructed, were not immediately available at the time they were required, and the apparatus has been manufactured out of sawn board and in a Government workshop, instead of roughly and readily at the water-side. Split palings, however, can be obtained to order in Queensland and throughout the Australian Colonies of the dimensions found most convenient—namely, 4ft. long, 8in. wide, and 1in. thick—at the rate of 10s. per thousand, a price which places them within easy reach of the most modest oyster-cultivator. It is necessary only to attach a rough stone about the size of a brick, as a substitute for those employed in the sample, to each end, and to cement the surface of the board or paling between the two stones. This cemented surface is underneath when placed in the water. How well this form of collector fulfils its purpose is fully demonstrated by the example submitted, upon which, after having been immersed between three and four months only, the young oysters are crowded together so thickly that they cover the entire surface of the cement, and are jostling one another aside for growing-space. Roughly estimated, it would appear that there are at least two thousand oysters on this one collector; and all the collectors simultaneously experimented with were similarly covered. At this period of their growth, or a little later, this oyster brood can be readily detached, with the cement, from the surface of the collector for distribution on ground suitable for their freer growth, and the collectors, being recemented, are ready for replacement in the water.

There are many other cheap and effective descriptions of spat-collectors that can be profitably utilised in association with, or in place of, the form just described. Old oyster-shell, or "cultch," as it is called in England, represents one of the best and most natural materials for the spat to adhere to, and has been utilised for this purpose from the earliest date of the British oyster-fisheries. There are many oyster-growing areas, however, on which this material is liable to sink into the mud or to get covered up by sedimentary deposits, and here the split-paling collectors, on which the attachment-surface for the spat is raised some inches above the surface of the bottom, has a distinct advantage. Branches of certain trees, utilised after the manner of the French fascines, are also exceedingly effective spat-collectors in some localities. Discrimination must, however, be used in the choice of the timber; the majority of varieties, and in Australia the many species of gum-trees or Eucalyptus more particularly, being altogether unsuitable for the purpose, and apparently distasteful to the young oyster on account of the resinous secretions they contain. Different varieties of pine-trees, and the Casuarinas, or "bull-oak" and "sheoak," as they are locally termed, have been found by personal experience to yield the most favourable results. The wood, or, more correctly, the aerial roots and shoots of several varieties of mangroves, notably *Rhizophora* and *Ægiceras*, form, as is well known, natural attachments to the young of the rock-oyster, giving rise to the truism, at first regarded as a mere traveller's tale, that Australian oysters grew upon trees. One little species, as described in the earlier portion of this discourse, outstripping *Ostrea glomerata* in ambition, has actually established itself upon the leaves of the favoured mangrove.

The Chinese, with the patience characteristic of their race, have propagated their oyster, which closely resembles *Ostrea edulis*, for centuries in great abundance by means of oyster-shells inserted into the cleft ends of pieces of bamboo, which are then stuck upright in the mud, the shells being raised a few inches above the surface. The spat soon collects on these shells, and when of sufficient size is removed and distributed over the fattening-beds. A similar plan would, it may be anticipated, prove equally successful if applied to the Australian rock-oyster. Cemented tiles, utilised so extensively in association with the French fisheries, are scarcely likely to find favour with Australian oyster-growers on account of their costliness. In France even their standard price is £2 per thousand, and out here they could scarcely be produced at less than double that sum. Split palings, which give twice the surface-area for the attachment of the spat, and, at the most, at only one-quarter of the cost, cannot fail to recommend themselves as a matter of pure economy. One special advantage possessed by this form of collector, but not previously referred to, is the shelter from the sun's heat they afford to the young brood when left high and dry by the receding tide. Thousands, or, more correctly, millions, of the brood of the Australian rock-oyster are destroyed annually through exposure to the overpowering heat of the subtropical sun in the early days of their attachment to exposed rocks near high-water mark. The overhanging ledges of larger rocks, and the shady sides of stone jetties or embankments, are invariably found to attract and support the greatest amount of oyster-brood, and this shelter, which is naturally sought, plainly indicates the lines that may be most profitably followed in operations connected with the artificial cultivation of the species.

South and Western Australia.

My personal experiences will not permit me at the present date to enter at any length upon a discussion of the nature and prospects of the oyster-fisheries of the colonies of South and Western Australia. Excellent oysters, of fine quality and magnificent proportions, allied to *Ostrea edulis*, are, however, to my knowledge exported from Spencer's Gulf, in South Australia, to the Victorian markets, and more especially to Ballarat. Some of these South Australian oysters are of such Brobdingnagian dimensions that it is customary to cut them in four pieces for sale at the oyster-saloons, the quarters thus divided being severally allotted to separate shells of ordinary size and sold as single oysters. The stunted tropical variety of the rock-oyster (*Ostrea glomerata*) has been collected by me at Port Darwin and Cambridge Gulf, in the Northern Territories of the respective colonies named, and doubtless attains, or would attain, to its normal growth in the more temperate regions of their coast-lines.

It would be a matter of presumption on my part to preach to the people of New Zealand on the subject of their oyster-fisheries, I not having as yet set foot on New Zealand territory. This privilege, however, while denied to me on the present occasion, I look forward to enjoying at no very distant date, in which event the oyster-fisheries of the colony will not be among the least attractive objects to engage my attention. Of the gastronomic excellence of New Zealand oysters in general, and of the Stewart Island species in particular, the crowd of witnesses now assembled at Christchurch can doubtless furnish abundant testimony. It remains for me chiefly to congratulate the colony upon the abundant stores of oysters of diverse varieties she possesses, and to express the good wish that she may long occupy her leading position as a producer and exporter of the favourite mollusc to other countries. The days for the systematic artificial cultivation of the oyster in New Zealand have apparently not yet arrived, and with a careful husbanding of her natural resources they may be long delayed. The lessons taught, however, by the dearly-bought experiences of older-established communities must not be lost sight of, and in the heyday of plentifulness and prosperity it is well to lay to heart the words of wisdom that have fallen from the lips of no less an authority than Professor Huxley upon this very subject. His closing paragraph to a lecture delivered at the Royal Institution, London, on the 11th May, 1883, upon "Oysters and the Oyster Question," reads thus: "I, for my part, believe that the only hope for the oyster-consumer is, first, in oyster-culture, and, secondly, in discovering a means of breeding oysters under such conditions that the spat shall be safely deposited. And I have no doubt that, when those who undertake the business are provided with a proper knowledge of the conditions under which they have to work, both these objects will be attained."

When present in London at the delivery of Professor Huxley's lecture I scarcely anticipated being called upon, a few years later, to take up its refrain at the Antipodes; and with the foregoing quotation from my first and much-esteemed teacher in biology I feel that I can scarcely bring this essay to a more appropriate conclusion.

Ostrea ordensis, S.-Kent.

Shells very irregular in shape, the most typical examples somewhat elongate, arcuato-triangular, from one and a half times to twice as long as broad, the convex border represented by the anterior and the concave one by the posterior edge; the umbones acuminate. Usually attached by the left valve, which may be adherent entirely or in part only to the supporting fulcrum; from one to three or four raised keels frequently originating at the umbone of the right or unattached valve, extending to the distal margin, and there produced in the form of projecting crests or lappets; a series of smaller crestlike projections, frequently developed from the antero-lateral edges of the left valve, when completely adherent, contributing towards its firm attachment. The largest shells not exceeding $\frac{1}{4}$in. in length, the average being about $\frac{3}{16}$in.

Habitat.—Brackish water, attached to the leaves, stems, and respiratory shoots of the white mangrove (*Avicennia officinalis*). Collected by the discoverer at Adolphus Island, Ord River, Cambridge Gulf, Northern Territory of Western Australia, in association with the surveying cruise of H.M.S. "Myrmidon," Captain the Hon. F. C. P. Vereker, October, 1888. All individuals examined found to contain an abundance of mature ova and milt.

A Short History of Vocal Music from its Earliest Times to the Time of Palestrina (Sixteenth Century), together with a Brief Description of Some of its Principal Forms of Development from the Sixteenth to the Nineteenth Centuries.

A Lecture by G. F. TENDALL, Mus. Bac. Oxon. and N.Z., Organist and Choirmaster of Christchurch Cathedral, and Honorary Member of the College of Organists, Lond.; given at the Fourth Evening Meeting, 20th January, 1891.

I HAVE the honour of addressing you this evening on a subject in which, I presume from your presence here, you are all more or less interested—viz., the history of vocal music. Such a subject covers a very wide field of inquiry—so wide that only to a very limited extent, and as succinctly as possible, can I hope to traverse it this evening. I shall, however, endeavour to the best of my ability to trace as clearly as my limited time will allow the history of vocal music from its root, through its stem, and through some of those principal branches which will, I think, prove most interesting to you.

To show that it is necessary to so far limit my field of discourse, let us think for one moment of a few of the forms of development suggested by the term "vocal music"—namely, Egyptian, Hebrew, and Greek music; Ambrosian and Gregorian ecclesiastical music; monotone, or melody; songs, duets, trios, quartetts, canons, fugues, motetts, masses, anthems, oratorios, operas, madrigals, glees, part-songs, &c. Each of these forms may be said to possess a distinct history, and to treat of them individually would require our full attention for many lectures, instead of the one allotted to us this evening.

One of the first of these items—Gregorian music—possesses a history of the greatest interest, though perhaps to the student and enthusiast chiefly, and so likewise do such forms as the madrigal, the oratorio, and the opera.

Many of us are proud—perhaps too proud—of our own personal accomplishments in the vocal art, however great or small. Most of us think very highly—probably, again, too highly—of the vocal powers of the community in which we live, as exhibited in the performances of our choral societies, our choirs, and the like. Such a state of things may be the result of vanity or some other weakness of human nature, but is, as a rule, an innocent failing, a pardonable result of the delight and pleasure we take in the vocal performances of ourselves and of our friends. A thousand years ago our forefathers had probably the same weaknesses and failings, just the same vanity, notwithstanding that their music as an art was very crude, and would be to us intolerably harsh.

I feel sure that, did an ancient minstrel appear amongst us this evening, and did he attempt to sing with the same amount of pride and pleasure as in his own days one of those old English melodies which delighted the pride of King Alfred the Great, the most accomplished musician of his time, we should consider him a dreadfully conceited and execrable musician. But our tone of criticism would change somewhat if it were possible to hear one of the musicians who lived in England, say, four hundred years ago. We should be pleased not only with the perfection of his singing, but also with the beauty of the music in use in his day, which is still the delight of musicians of the nineteenth century.

In the sixteenth century all civilised Europe was musical, and it is very gratifying that England was then in the very front rank of musical nations, her musicians and their compositions second to none. The sixteenth century saw the culmination of her musical powers. Then followed a decline: music and the sister arts were neglected, a natural result of revolutions, civil wars, and political strife.

In this nineteenth century England is perhaps making for the head of the list again. At any rate, if money and machinery—by which I mean the enormous system of musical training, and the numbers of music schools and colleges, in existence at the present moment—have anything to do with position and progress, England should soon be at the head of all musical nations. Of course, opinions differ as to the probability of such a result, but perhaps something might be said on both sides.

New Zealand, I am afraid, is behind the Old Country in its cultivation of music, and unless a change is made it is likely to be more so. To a musician who has lived the greater part of his life in England it does seem extraordinary that one should find in New Zealand such a splendid system of training in existence for every other secular subject but that of music, for neither in our State schools nor in our universities, if we except Auckland, does it receive more than a passing notice.*

Yet, though a thorough and proper cultivation of music is not spreading amongst us as it should, the love of vocal music is gaining ground through other forces. We especially, in this cathedral city, must endeavour to emulate the cathedral cities of old, for it is an undoubted fact that the cathedral cities of mediæval Europe were the cradles of art, and especially of the vocal art.

Music is both an art and a science, and hence her claim to

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* Since this lecture was delivered a Lectureship in Music has been established in the University College of Christchurch, Canterbury, and Mr. G. F. Tendall has been appointed Lecturer.

recognition in this week's proceedings. I sincerely wish her cause were in more able hands than my own.

Before concluding this introduction to my lecture, I ought perhaps to say that where I have found historians differ—and differ they did, even as musicians are said to differ in the present day—I have avoided controversy, and given you what appears to me to be the nearest approach to the truth.

Fortunately for me, when, presently, you will probably be falling asleep, I have at my disposal resources represented by my friends the members of the Cathedral choir, who, I feel sure, will amply atone for any failure on my part to keep your interest from flagging, and, example being better than precept, they will be able to illustrate from the works of the greatest masters of the art of vocal composition perhaps more clearly than I can do by words what has really been the progress and growth of the particular branch of the art under discussion.

The history of music previous to the fourth century is more or less conjectural.

From the various relics that are preserved to us, we know that the ancient Egyptians cultivated music: if instrumental, as is certain, then we may feel sure they must have studied vocal music also, for it is most probable that the latter is of an earlier origin than the former. Hitherto we have had no knowledge of their music whatever, but it is thought, owing to Mr. Petrie the Egyptian explorer's late discoveries of two almost perfect ancient Egyptian flutes, we shall be able to form some idea of the kind of scale used by them.

That the Hebrews were vocalists we know from our Bibles. I need only refer to the Song of Moses.

The Greeks, the successors of the Egyptians as far as civilisation is concerned, cultivated music to a high degree, their plays being sung on a monotone, and probably also to some kind of melody, as we know they used certain fixed scales, though these scales were of a more limited number of notes than, and of totally different construction from, our modern scales. The performances of these plays were exceedingly popular, being attended by as many as fifty thousand people at one time; and it was only possible for the performers to be heard by the adoption on their part of monotone or melody.

From the Greeks the art passed to the Romans, a people who eventually became licentious and slothful, and consequently music was of a too pure and refining nature for them to cultivate it with any amount of enthusiasm, and at last, from pure indifference, it was allowed to die out amongst them.

To all these nations—Egyptians, Hebrews, Greeks, and Romans—vocal music in harmony was unknown, song being purely melodical; and their scales were so unlike our modern scales, and consequently their ideas of tuning so different from ours, that their melodies would sound intolerable to us.

Although neglected by the Romans, it was in Rome that the spark of vocal music was rekindled.

In the first century of the Christian era many Hebrew Christians fled to Rome, but were immediately driven for further refuge to the catacombs, or underground burying-places of the city. Here, we are told, they joined together in prayer and praise, and in the singing of hymns. When we read of these wonderful catacombs, and of the enormous multitudes once taking refuge in them, the scene for hundreds of years of the birth, life, and death of tens of thousands of human beings, we can but feel that at no time in the history of music has the art of singing been a greater blessing to mankind. Probably the one bright ray of light that entered those solemn dens of solitude, though by no means of despair, was during their daily service, in which, according to an historian of the day, they were able to sing to "none but the Supreme Being and His only Son;" the melodies used by them being no doubt the very same which their ancestors had sung in the Temple of Jerusalem.

Freedom came at last, and that in the time of Constantine, 320 years after the birth of Christ, when all Christians were allowed to worship as they would, and consequently their voices were continually heard in their religious services in various parts of the city.

Attention was thus directed to the musical strains used by them; and by St. Sylvester—of whom I shall speak further on —an endeavour was made to collect and write down these tunes for the benefit of his successors; for music had hitherto been committed to memory, and orally transmitted from generation to generation. Hence arises much of the difficulty with which inquirers are met when tracing its ancient history.

From the fourth century the history of music may be regarded as more or less authentic; and I shall now be able to discuss the actual works and writings of individuals, although, as to the true progress of the art, something must yet be left to conjecture until the tenth century.

The people, the greater mass of the inhabitants of Europe, were unable to read or write, they lacked refinement altogether, and music was very little, if at all, cultivated by them, though we read that they were attentive and enthusiastic listeners to the folk-songs and ballads of the time, the rendering of which was in the hands of wandering minstrels, who, as a rule, committed them to memory, though their performance was sometimes extempore.

But, fortunately, there were some highly-educated men in the world. These were the clergy of the Church of Rome, through whose efforts sacred music began to assume a definite tone and character very soon after the fourth century had elapsed. Pope Sylvester, indeed, established a school of music in Rome as early as the year 330. Thus we know something of the state of sacred music several hundred years before we have any idea of the progress of secular music.

When we consider the attitude of the clergy of those days to the people, the gulf which the education of the former and the ignorance of the latter constituted, the fact that the services of the Church were rendered in Latin, a language the people did not understand, we shall not be surprised to find that the Church music also was far removed from their sympathy and comprehension.

About the year 400, St. Ambrose, Bishop of Milan, being struck with the want of clearness and definiteness in the rendering of the melodies of the Church, endeavoured with considerable success to collect those melodies in writing, and also to fix in what scales or keys they should be sung—a most difficult task, for, with all his ingenuity and enthusiasm, he could only find or invent four scales, and they were imperfect and incomplete; and, as neither stave nor notes were thought of, he had to content himself with writing down his music in mere scratches, or *neumæ*, as they were called—signs which contained the smallest possible idea of the pitch of notes, and certainly none as to their duration.

Crude as these examples appear to us, we know that St. Ambrose did much to raise music to the dignity of an art. A form of chant invented by him, and in itself a great stride in advance of those days, has been sung in the Cathedral of Milan from the time of its invention to the present day, and for hundreds of years the singing of the choir as established by St. Ambrose was the most famous in Europe.

Two hundred years later there arose a greater man than the Bishop of Milan, in the person of Gregory the Great, Pope of Rome. It was this same Gregory who sent St. Augustine to England, who became the first Archbishop of Canterbury; and probably it was by the advice of Gregory that Augustine introduced the choral service into Canterbury Cathedral thirteen hundred years ago, the first choral service ever held in England.

Gregory, like his predecessor Saint Ambrose, was anxious that the music of his Church should not be at the mercy of oral tradition, and he therefore collected in writing the various melodies in use, and also composed others. The result of his labours was that the scales were increased to eight, and a complete mode or system of sacred music was introduced, to eventually become known as Gregorian music, the history and further progress of which would be very interesting to us did time permit. It has a history and tonality entirely its own, neither being affected to any great extent by, nor perhaps having much influence—certainly not a lasting one—on, the music of the people outside its own churches. We know the River Jordan flows through the Sea of Galilee without mixing with its waters, and that those of the lake have no influence on the river.

Of course, I do not mean to say that the Gregorian system had no effect on the tastes of the people. For several hundred years it was the system taught in the schools, and during that time it was supported and patronised by the most despotic and powerful organization the world ever saw. It was thus bound to command careful attention and respectful study ; but, being confined to the sphere of sacred music only, its effect could but be narrow and limited, and when the sixteenth century saw the power of the people equal to, if not greater than, that of the Church itself, it was only natural that a new tonality should spring up—a new school, in fact—more in accordance with the tastes and ideas of the people, who were henceforth to have a voice in the matter of Church ritual.

In the ninth century Charles the Great was a supporter of the Gregorian system, and he founded music-schools in France and Germany. Our own Alfred the Great is also supposed to have established a music-school at Oxford about the same time.

Arriving at the tenth century in our history, we find that music as a study had spread in earnest all over civilised Europe, and yet it is an almost incredible fact that harmony—that is, the combination of two or more notes in a chord—was almost unknown.

Music at different periods of its history has undergone various reforms, and these reforms I may call the landmarks of its history, and such reforms may, I think, be emphasized and more clearly brought before you this evening by studying the works of the men by whom they were created.

Singers became tired of nothing but melody, and no doubt at times they tried to improve matters by adding a second part by ear; but it required a genius to be bold enough to step forward and lay down some fixed rules by which vocalists might sing in harmony.

Such a reformer appeared in the year 900 in the person of Hucbald, a monk of Flanders, who not only invented a system for writing down music more clearly (a system not used after his death, although it possessed much merit, as our illustration will show), but also wrote a work on harmony, in which most original progressions and combinations were suggested. I give an illustration of one of his examples, but it is impossible to produce the effect its performance must have had in Hucbald's time, the system of tuning being so different from our own. Those progressions of fourths are to us intolerable—we should like to see thirds or sixths in their places; but our ideas would have been equally intolerable to Hucbald. The second illustration strikes us as better; it was, indeed, a step towards modern counterpoint, although the idea of counterpoint had not occurred to Hucbald, or any other musician of his time. Hucbald died about 950. Musical culture no doubt made some progress after his death, but it was not until about the year 1000 that the second great reformer, Guido, an Italian monk, appeared.

I find historians differ as to Guido's true position as an inventor. I use the word "inventor," because the word "composer" had hardly been thought of at this time. Music was still looked upon as a species of mathematics.

Guido's writings are very numerous, and they give us a very good idea of the state of music in his time, but he himself was so modest that he sometimes does not claim credit for new ideas that subsequent research has proved conclusively to have been his own. Time will not permit me to enter very deeply into his personal history, although it would be very interesting. His fame and popularity during his lifetime were immense, chiefly owing to his then wonderful method of singing; and at the present day his works, which consist of many volumes on the art of music, are amongst the most valuable records of musical history.

I cannot refrain from relating one important event in his life which must have had great influence for good on the cause of music. I quote from an article by an eminent writer, Mr. Rockstro. "About the year 1022, Pope Benedict VIII., hearing that a learned monk of the Benedictine monastery of Arezzo had invented a new method of singing, invited him to Rome, and, during the time that he remained there, treated him with marked honour and deference. Guido, however, was of so retiring a disposition that he took the earliest opportunity of retiring to the solitude of his beloved monastery; and it was not until he had received reiterated invitations from the succeeding Pope, John XIX., that he consented to visit the Eternal City a second time. This second visit was, indeed, a memorable one. It marks a momentous epoch not only in the personal history of Guido himself, but in the annals of the art he practised. He took with him a copy of his then newly-completed and now most celebrated 'Antiphonarium,' constructed upon the principle of the system he had invented; and the merits of the work made so deep an impression on the Pontiff's mind that, at his first interview with its author, he refused to let him leave his presence until he had himself so far mastered the difficulties of the method as to be able to sing an antiphon in accordance with its rules. So pleased was he with the result thus attained that he at once proposed to retain the learned monk in his own service. But Guido's retiring habits were altogether unfitted for continual residence amongst the splendours of the Papal Court. He was allowed to quit Rome on condition that he returned during the following winter, a provision which he never complied with. He spent the leisure of the rest of his life in teaching the monks his new system, and in instructing the children of the choir to sing by aid of its rules."

Let us now take a glance at some of the results of Guido's labours. We have seen what St. Gregory and St. Ambrose did towards the development of the scale: Guido went still further, and arranged the scale in hexachords—*i.e.*, scales containing six sounds, in place of the more primitive scale containing three notes. The chief feature of the hexachord was that a semitone always occurred between the third and fourth note. Guido used seven hexachords, and from them in later years was obtained the complete scale. His system was taught as late as the eighteenth century, Dr. Burney, the historian, having learnt it from the organist of Chester Cathedral.

Guido was also the inventor of our modern form of solmisation—in other words, of sol-fa-ing. The idea was not actually his own, but was probably due to the Greeks of old; but, of course, Guido's extended scale formed a new basis altogether, and required a new nomenclature—Do, Re, Mi, Fa, Sol, La. Bear in mind he had only six notes to name; the seventh, Si, was not added till many years after his death. Perhaps you may not all know what suggested the now familiar terms to Guido. I have an illustration which is a copy of a hymn sung in Guido's time: it was really composed two hundred years earlier—

UT queant laxis REsonare fibris
MIra gestorum FAmuli tuorum,
SOLve pollutis LAbiis reatum,
Sancte Johannes.

You will notice that each of the six musical phrases begins with a note of the hexachord, taking each in succession. Guido also observed this, and took the syllables sung to those notes—Ut, Re, Mi, Fa, Sol, La—as the foundation of his "sol-fa" system—a system which, with slight modification, has been in use from that day to this. The changes that have occurred are, that for Ut is substituted Do; and about five hundred years after the death of Guido a seventh syllable, Si, was added, to be, of course, followed by a repetition of Do, thus completing our scale—Do, Re, Mi, Fa, Sol, La, Si, Do.

Guido is also credited with the invention of the stave and the clef—not exactly the stave of five lines and four spaces used by us, but he certainly used lines and spaces, thus giving to the world the first idea of our stave—a stave which was at first allowed to consist of any number of lines. It was not till about the sixteenth century that it was decided that a stave of five lines would suffice for vocal music, four lines being sufficient for ecclesiastical music only. At the present day four lines are considered sufficient for the representation of Gregorian music.

Vocal composition made little advance in Guido's time, part-singing being very similar to that in the time of his predecessor, Hucbald.

Numerous other reforms and inventions are sometimes placed to Guido's credit, but I have given the most important of those bearing on our subject this evening. The perfection of the scale, the stave, the clef, and solmisation, were rendered possible, and did, indeed, follow as a natural consequence of these inventions, but yet one great feature remains to be added to render the system complete.

Guido and his predecessors had been content to leave to the singers the entire control of the time in which to sing. They were guided probably by the demands of the words as to accent and rhythm. But as the art of part-singing grew more complicated it became imperative that the composer should have the power of giving to the singer the proper idea of rhythm and time; and we come to another landmark in our history—viz., the invention of notation, or what is more familiarly known to us as the time-table.

Franco, a monk of Cologne, about fifty years after Guido invented a system of notation so perfectly clear and to the purpose that it has successfully stood the test of more than eight hundred years. I give an illustration of his ideas of notes and rests. He did not think of using bars, but he used breath-marks, which divided the music into phrases, and which may have suggested bars later on. Franco also wrote valuable treatises on harmony, and through his exertions part-singing made immense strides.

From the examples which I have shown you, you see that Franco and his contemporaries had ideas which contained the germs of the music perfected and used by their successors until the sixteenth century, and even then Franco's ideas of notation were not discarded, and, as I have said before, are but slightly modified in the present day.

I have now spoken of the works of St. Sylvester, Bishop Ambrose, Pope Gregory, and the monks Hucbald, Guido, and Franco, and have thus shown you that the clergy were the originators, inventors, and composers of all ecclesiastical music prior to the twelfth century. I may also add that it is to them we owe the only authentic history we possess of the music of those times.

The world of art—of music, painting, architecture, sculpture, &c.—is under great obligations to the Church of those early days, which contained men of such high culture and artistic tastes as Gregory and Guido; but, on the other hand, we cannot but regret that they did not give us a broader view of musical matters, and furnish us with some knowledge of the music of the people, instead of contenting themselves with merely mentioning that songs of the people existed. What do we really know about the secular music of that time?

In the eleventh century—*i.e.*, in Franco's time—troubadours or wandering minstrels (later on called minnesingers) first appeared at Toulouse, in France, where was established a famous academy for the study of secular music and poetry. These men carried the love of their art into every country in western Europe. Their songs—ballads, as they were subsequently called—were of so exalted and noble a tone that they were destined to have an enormous influence on humanity in that age of chivalry and knight-errantry; and probably no more enthusiastic and popular race of musicians and poets ever trod this earth. Kings, princes, and nobles became troubadours, many of them famous in history, and their names were legion. I need only remind you of Richard I. and Blondel.

The result of this enthusiasm was that men became nobler and purer, and woman was no longer regarded as the slave of man, but was respected and esteemed. From a musical point of view, the love of melody and song made great progress amongst the people, though their progress in the vocal art itself was hindered from the fact that these songs were sung from memory, or, perhaps, composed for the occasion at their festive gatherings.

The troubadours themselves must have felt this, for in later years they had a plan of writing down their songs by means of notes or points, which, to use the words of the dictionary, were counter to or over against each other, from which system is probably derived our word "counterpoint." They then came under the influence of the works of such men as Franco, and finally, from causes which I cannot now discuss, the troubadours ceased to exist by the fifteenth century, their chief musical legacy to posterity being probably the "national song," the "folk-song," as the Germans have it, or the "chanson" of the French. This, in its turn, was the precursor of the ballad, a form of song exceedingly popular from the days of Queen Elizabeth.

When once secular music became influenced by the rules of harmony, as written by such men as Franco, minstrelism, which chiefly depended for its success on unharmonized melody, was bound to cease, and in its place arose a system of part-singing so perfect, and a series of vocal compositions so beautiful, that not only were they the delight and pride of the fifteenth and sixteenth centuries, but at the present time they still hold their own amongst the most beautiful compositions of the kind.

The oldest piece of music in existence which exhibits good polyphonic writing, in excellent taste and style, was written by an Englishman, probably a monk in the Abbey of Reading, in Berkshire, about the year 1226. I will now ask the choir to sing you this "rota," as it was called. The words are descriptive of a summer's day as it should be in Old England. The notation in the old original manuscript, found in Reading Abbey, and now in the British Museum, is similar to that of Franco. The music is in the form of a canon, a very common device amongst composers in those days.

The rota you have just heard is said to be a proof that musical culture was no longer the monopoly of the Church, and a hundred years later we find still further proof that there were decidedly two distinct currents of musical development, the sacred and the secular, each progressing separately, until the sixteenth century, when their union was brought about by circumstances which I shall presently relate.

Musical study became general both among the people and the clergy by the end of the fourteenth century, each country boasting—and rightly so—of its schools of music, its musical productions, and of its musicians. It is therefore impossible for me to give you other than a very short and brief review of the progress of the art in the fifteenth and sixteenth centuries.

For the beauty and perfection of their compositions at this period, the musicians of Flanders were the earliest to distinguish themselves. They wrote masses, motetts, and madrigals, greatly admired in their day, but which would to modern hearers sound more ingenious and clever than melodious and inspired. When, in the fifteenth century, the prosperity of the country began to decline, the musicians of Flanders emigrated to Italy. Here the atmosphere was more genial, and the result was the foundation of a school of vocal music of such beauty that Italy became known as the "Land of Song," and the most musical country in Europe. It was in Italy that the oratorio and the opera had their origin.

The first great Italian musician who came under the influence of the Netherlands was Festa, the master of the Pope's choir in the Sistine Chapel. You shall now hear his well-known madrigal "Down in a flow'ry vale," which is naturally composed somewhat after the style of the Flemish school.

To Festa and his successors, and to the Popes of Rome, who during the sixteenth century gave their support and patronage to music, principally through their famous choir in the Sistine Chapel, we owe the existence of some of the most beautiful sacred music in existence.

But ecclesiastical music was destined to receive a considerable check in its progress, chiefly owing to the great abuse of the liberty allowed of adapting secular music to the services of the Church.

The clergy and the Church musicians, in their anxiety to absorb into their service a style of music more suitable to the tastes of the people than the plain-song or Gregorian chant, had made use of many secular melodies, adapting them to sacred words of the most solemn character, the music itself being most inappropriate and, indeed, irreverent. At last, the rendering of the musical portion of the service became such a scandal that measures were taken to bring an account of the state of affairs to the notice of one of the great Councils held at different stated periods in some one of the chief cities of Italy, by the cardinals and dignitaries of the Romish Church.

Luther himself was a very good musician, and he was much interested in Church music. He was one of the originators of the chorale or hymn-tune, several of which he composed, and which are used in our churches to this day. Luther may be said to have made a clean sweep of all ecclesiastical music in the churches over which his influence extended, except this one form of hymnody—a proceeding which must have been fatal to the cause of vocal art had it been adopted throughout all Christendom.

To carry out the much-desired reform of Church music required a far greater musical genius than Luther. This reform did not take place until twenty years after his death, when, at the Council of Trent held in 1563, it was decided to appoint a Commission to inquire into the evils complained of, and to propose a remedy. The eight cardinals composing this Commission were men of the highest ability, both literary and artistic, some of them remarkable for their piety, others not only accomplished musicians but magnificent patrons of art; and their appointment to carry out this work shows the importance attached to it.

It was at first suggested that the use of all Church music in harmony should be forbidden, and that only unaccompanied plain-chant or Gregorian melodies should be retained; a proposition which, had it been carried, would probably have delayed the progress and development of music as an art for many years—perhaps for centuries. Before, however, deciding this question, the Commissioners resolved to avail themselves of the aid of the greatest musician then living in Rome, Palestrina, the Master of the Choristers at the Vatican.

Palestrina was born at Palestrina in 1524, became a choirboy in one of the principal churches of Rome, and in early manhood was appointed Chapelmaster at the Vatican. It was in the year 1564, Palestrina being forty years of age, famous as a musician, and noted for his piety, that the Papal Commissioners requested him to compose a mass embodying all the devotion and religious feeling of which he was capable, in order to prove that the Church would be wise to retain for its use music of a polyphonic character, which also should be a real aid to worship, and thus to prevent the proposed plan of what has been called "the barbarous idea of a return to unisonous unaccompanied melody only." The result of this experiment I will give in Mr. Rockstro's own words: "Thus requested, Palestrina composed, not one single mass, as has been generally said, but three masses, each for six voices, but each in a different style, though all designed for the purpose of illustrating, instead of obscuring, the meaning of the sacred text, and all pervaded by a solemn beauty till then unknown in music—a rich harmonious charm which appealed at once to the inmost heart of the worshippers, and could scarcely fail to arouse devotional feelings in the soul of the coldest listener. The great composer spared no pains to attain the desired result; but it was an anxious time for all concerned, for upon the approval or rejection of his efforts the future existence or summary extinction of ecclesiastical music was openly declared to depend. On Saturday, the 28th April, 1565, the three masses were privately sung at the palace of Cardinal Vitellozzo Vitellozzi by the entire body of pontifical singers, whose verdict upon them was unanimous. The first mass, in Modes III. and IV.—the Phrygian and Hypo-Phrygian—and the second, in Mode VII.—the Mixo-Lydian—were enthusiastically admired as works of art; but the third, in Mode XIV.—the Hypo-Ionian—exceeded in devotional expression, all that had ever been conceived possible, in the purest style of vocal music in existence. This wondrous inspiration now known as the 'Missa Papæ Marcelli,' was therefore unanimously accepted by the Cardinals as the prototype upon the lines of which all future music composed for the service of the Church should be modelled. Giovanni Parvi, copyist to the Pontifical Choir, was commanded to transcribe it in notes of extraordinary size and beauty; and on the 19th June, 1565—the Tuesday preceding the Feast of Corpus Christi—it was solemnly sung in the Sistine Chapel, in the presence of Pope Pius IV. and the Ambassadors of the Swiss Catholic Cantons, Saint Charles himself acting as celebrant of the mass. The performance of the music was irreproachable;

and so deeply was the Holy Father impressed by its beauty that on leaving the chapel he said, 'This must surely have been the harmony of the "new song" which the Apostle Saint John heard sung in the heavenly Jerusalem, and of which this other John has given us a foretaste in the Jerusalem on earth.' It is difficult to form a just idea of the beauty of this most perfect music without hearing it actually sung as Palestrina himself intended it to be sung, by a tolerably numerous choir of unaccompanied voices. The amount of learning displayed in its construction is almost incredible, yet the effect produced upon the hearer is that of extreme simplicity. And the reason of this is obvious. Ingenuity and learning are everywhere made subservient to beauty of expression, and beauty of expression to devotional feeling. And herein it is that the music of Palestrina differs not merely in technical construction, but in its inmost essence, from that produced by the very greatest of his predecessors."

The immediate result of the production of this mass, inaugurating what is known as the Golden Age of ecclesiastical music, and which was formally recognised by the Church of Rome as the type of what ecclesiastical music should be, was that the whole system and style of music, secular as well as sacred, underwent a change. The dry, though ingenious and clever, mathematical forms which had been the pride of the schools previous to Palestrina were now supplanted by a style in which, although ingenuity of invention was retained to an extraordinary extent, the chief aim of the composer was to make music appeal directly to the hearts of the people, to convert it from dry bones into a living power of such beauty and strength that it was to become a model for all time, and to be the foundation-stone of all modern music. From henceforth the major and minor scales were also to be used as the material with which composers would work, instead of those plain-song scales or modes which had created so little sympathetic interest in the world generally before the time of Palestrina.

Although this great change in musical art was not consummated until some two or three decades after Luther, yet it is an aid to memory if we think of the reformation as effected by Palestrina in connection with the greater Reformation as effected by Luther.

Palestrina was rewarded by being appointed composer to the Sistine Chapel, a post he retained, together with that of Choirmaster at the Vatican, till his death. He expired in the arms of his friend St. Philip Neri in the year 1594, beloved and revered by all who knew him.

I should have liked you to have heard a selection from this great mass of Palestrina's; for, although you could not, perhaps, form a true idea of the effect of its first performance three hundred years ago in that most magnificent Sistine Chapel, surrounded by the gorgeous ritual which the Church of Rome knew so well how to use, yet you would agree that the music is exceedingly beautiful. We will, however, sing two short motetts of Palestrina's. They are less intricate by far than the music of the mass, less noble in conception altogether, yet they give a fair idea of the simplicity and purity of Palestrina's style, for which he was no less conspicuous.

After the death of Palestrina music continued to progress with rapid strides towards perfection. Composers had not only a most perfect and complete system of notation and scale wherewith to work, but they had as models of harmony and technical construction the most inspired compositions of Palestrina, and it only remained for them to invent forms of an equal elegance and beauty, yet of a distinctive character, through which to express their thoughts and ideas.

I have chosen for illustration by the choir specimens of seven of these forms—viz., the madrigal, the oratorio, the motett, the anthem, the national song, and the cantata.

The madrigal, a species of part-song, was the earliest form of secular vocal composition to attain a high degree of perfection. The name "madrigal" is Italian, but the first madrigals were written by Flemish musicians. The Italians also excelled as composers of madrigals later on. Palestrina wrote very beautiful examples, as did also Festa, the composer of the madrigal "Down in a flow'ry vale," just sung by the choir. But English composers of the sixteenth and seventeenth centuries are said to have excelled all others in the art of writing madrigals, and I have chosen for illustration two very beautiful specimens, "In going to my lonely bed," by Edwardes, and "Flora gave me fairest flowers," by Wilbye.

By the end of the seventeenth century the madrigal was succeeded by the glee, to which class of song belong "Hail, smiling morn," and "The red-cross knight." The glee, in its turn, was succeeded by the modern part-song.

Many of you, no doubt, read with interest a description of a performance of the so-called "miracle" or "passion play" given at Oberammergau last year. I need not now describe these plays further than to say that they represented with remarkable dramatic power and force the story of some of the principal episodes in the life of our Lord. Such representations are not of modern invention—they were in common use before and during the time of Palestrina.

I mentioned just now that Palestrina expired in the arms of his friend St. Philip Neri: six years afterwards—*i.e.*, in the year 1600—the first oratorio ever composed was performed in St. Philip's oratory; hence the name "oratorio."

With the great masters of oratorio you are all so familiar that I need only draw your attention to one, perhaps the greatest of all—Handel.

The choir will sing a beautiful chorus by Handel from his oratorio, "Solomon." It is called the "Nightingale Chorus," from the fact that the accompaniment, together with the words, is said to suggest the song of that bird. You shall also hear two of Handel's beautiful solos—namely, "Arm, arm, ye brave," from "Judas Maccabæus," and "Angels ever bright and fair," from "Theodora."

While the oratorio was being developed in Rome, some enthusiastic musical amateurs of Florence were attempting a revival of a form of drama as nearly similar as they could conceive to a Greek play; but, quite unexpectedly to themselves, though due to their exertions, the first opera ever composed sprang into existence, and was performed in Florence about the year 1600.

By the end of the seventeenth century operatic performances were given in almost every city in Europe. Paris boasted of one of the greatest schools of opera, especially during the time of Glück, who resided in Paris for many years. Christopher Glück was one of the greatest operatic composers that ever lived, and probably was as great a benefactor to that branch of our art as Palestrina was to the sacred art of composition.

I have chosen for illustration a song of Glück's from "Orfeo"—"Che faro." It is a wonderful illustration of the possibilities of melody as an expression of pathos combined with sorrow and entreaty. Orfeo is supposed to be singing this song in Hades when he is begging for the return of his wife. You know the story—how that, in consequence of his beautiful singing (or playing on the lute, as the old classic legend has it), Euridice was allowed to accompany Orfeo from Hades on condition that he would not look back on his wife until they had arrived in the outer world; but poor Orfeo was so anxious to see his wife following him that he forgot all about the compact, and lost her for the second time.

After the Reformation the mass of the Romish Church was replaced by a form of composition suitable to the Reformed Church, known as the anthem, a species of composition for which the English have been famous from the time of its invention as a form until the present day.

Henry Purcell, organist of Westminster Abbey in 1680—one of the greatest musicians that ever lived—wrote many beautiful anthems. Probably the most popular is the famous Bell Anthem, "Rejoice in the Lord," which the choir will now sing, so called from the attempt to imitate a peal of bells in the symphony.

Purcell also wrote much beautiful secular music, some of it in operatic form. You shall hear his setting of Shakespeare's "Come unto these yellow sands," and also that of the words, "Come if you dare," which I think may be classed with our great national songs.

Perhaps the nearest approach to our anthem in the Romish Church is the motett, of which most of the great composers wrote specimens. No finer example exists than Mozart's "O God! when Thou appearest," which you shall hear.

Although music has ever been advancing since the time of Palestrina, very few new forms have been invented during the present century, and none of them have taken the place of those I have mentioned. Some writers think that the oratorio has had its day, and that modern listeners have only patience to hear cantatas, which are shortened oratorios. The best answer to this is perhaps the fact that the days on which the "Messiah" and the "Elijah" are given at any of the principal festivals remain, as they have ever been, the most popular.

I think the most beautiful of cantatas is Sterndale Bennett's "Woman of Samaria," which many of you have heard performed in our cathedral.

Of the many living Englishmen who have attained to a very high standard in the art of composing cantatas, none, probably, have exhibited greater talent than Arthur Sullivan; and, being an Englishman, of whom all English musicians are proud, I think I cannot do better than conclude my lecture by two excerpts from his greatest cantata, "The Golden Legend." The choir therefore will sing "The night is calm and cloudless," and the evening hymn, "O gladsome light!"

The following illustrations were sung by the members of the Cathedral choir (twenty-four boys and fourteen gentlemen):—

1. Rota, "Sumer is a comin in."—*From old MS. about 1226.*
2. Madrigal, "Down in a flow'ry vale."—*Festa, 1490 to 1545.*
3. Motett, "O, be joyful."—*Palestrina, 1524 to 1594.*
4. Motett, "I will give thanks."—*Palestrina, 1524 to 1594.*
5. Madrigal, "In going to my lonely bed."—*Edwardes, 1523 to 1566.*
6. Madrigal, "Flora gave me fairest flowers."—*Wilbye, 1564 to 1612.*
7. Oratorio (solo), "Arm, arm, ye brave" ("Judas Maccabæus").—*Handel, 1685 to 1759.*
8. Oratorio (Nightingale Chorus), "May no rash intruder" ("Solomon").—*Handel, 1685 to 1759.*
9. Oratorio (solo), "Angels ever bright and fair" ("Theodora").—*Handel, 1685 to 1759.*
10. Opera (solo), "Che faro" ("Orfeo").—*Glück, 1714 to 1787.*
11. Anthem, "Rejoice in the Lord."—*Purcell, 1658 to 1695.*
12. Motett, "O God! when Thou appearest."—*Mozart, 1756 to 1791.*

13. English opera (solo and chorus), "Come unto these yellow sands." —*Purcell, 1658 to 1695.*

14. National song, "Come if you dare."—*Purcell, 1658 to 1695.*

15. Cantata, "The night is calm and cloudless" ("Golden Legend").—*Sir A. Sullivan.*

16. Cantata (Evening Hymn), "O gladsome light" ("Golden Legend"). —*Sir A. Sullivan.*

The Glaciers of the Tasman Valley.

A Lecture by G. E. Mannering; given at the Second Evening Meeting, 16th January, 1891.

The lecturer began by saying that he had enjoyed exceptional opportunities during the last six years for observing the scenery and phenomena of glaciers in the Southern Alps, which might be said to extend from Arthur's Pass south-westward for a hundred miles to Haast's Pass. The peaks were between 7,500ft. and 12,350ft. in height, and the snow-line was as low as 5,000ft.; while the glaciers were in some cases larger than those of Europe. On the west side of the Alps the glaciers were sometimes within 600ft. or 700ft. of sea-level, while on the eastern side the lowest was the Tasman, which was 2,349ft. above the sea. An interesting and peculiar feature of our eastern ice-rivers was the extensive moraines. The lecturer drew an ideal picture of the scenery during the Great Ice Age of New Zealand; speculated on the causes of the changes which had taken place, whether from climatic or cosmic influences; and pointed out the gradual movements which had carved that portion of the country with which he was dealing until it assumed its present aspect. He then carried his audience to the head of the great Tasman Glacier—eighteen miles long by nearly two miles wide, and 8,600ft. above the sea—and in vivid language described the numerous peaks and tributary glaciers, especially the Hochstetter, which he considered the most picturesque, being fed by Mounts Cook and Tasman—the noblest peaks in Australasia—from a plateau on whose flanks, at an altitude of 8,000ft., the ice descended in an indescribably grand frozen cascade over a fall of some 4,000ft. in vertical height by a width of a mile. The lecturer then devoted himself to a detailed description of the features of the scenery, and discussed the subject of glacial motion; and concluded by saying that the New Zealand glaciers presented an unlimited virgin field for the investigation of the various glacier phenomena. There was the study of the cause and effect of avalanches, the various forms and types of glaciers, the sources of supply, the geological examination of the mountain-chains, meteorological observations, and the effect of the varied atmospheric conditions on the surroundings; the effect of light, and the cause of the blue or green colour—as the case might be—in snow and ice; the formation of moraines and boulder-fans; and many similar subjects. An endless variety of sub-alpine flora was met with, and he would say that few New-Zealanders were aware of the wealth of blossoms which decked their own mountains. The entomology of the glacier regions was also varied and interesting, while birds unseen elsewhere there abounded. For the artist the face of Nature was always smiling, and yet defied all his attempts to do her justice, while the photographer would find scenes of much grandeur for the camera. It was needless to add that those regions were the mountaineer's paradise, though hard work and bodily discomfort sometimes discounted those pleasures which he would otherwise enjoy to the full.

ADDENDUM.

Transactions of Section A—*continued.*

Note.—The following abstract arrived too late for insertion in its proper place in the report. It is intended to replace the short abstract printed at page 78.

On the Characteristics of the Nor'-westers of Canterbury, New Zealand.

By J. T. Meeson, B.A.

The general features of a typical nor'-wester, as experienced in Christchurch, have, unfortunately, this season been only too familiar to us all. It is, therefore, not necessary to repeat here the full description of the phenomena with which the author commenced his paper. The thermometrical, barometrical, nephological, and other effects of the nor'-wester having been given, the high temperature of the wind was next explained. It had been customary to account for it as the result of compression on the eastern side of the Southern Alps, for it was well known that dry air in descending gained heat at the rate of 1° Fahr. for every 180ft. of vertical measurement. The pneumatic tinder-box clearly enough showed that compression resulted in heat. But compression on one side of the mountains only restored the temperature lost by expansion on the other side—provided the air on both sides were subject to the same conditions of barometric pressure, temperature, velocity, and humidity. Here, however, came in a point of the greatest importance. The north-west wind, on reaching the western slopes of the Southern Alps, was heavily charged with moisture, and this rendered latent the heat brought by the wind from the lower latitudes. Now, wet air in an ascending current lost heat much more slowly than dry—namely, 1° Fahr. for every 300ft. of altitude; because the expansion during ascent resulted in the precipitation of rain, and thus latent heat was rendered sensible. This difference in the rate of losing and gaining heat on the part of wet and dry air was the chief immediate cause of the uncomfortable warmth of our nor'-westers; for, assuming that the wind in Westland was at 60° Fahr., on reaching 9,000ft. in elevation it would fall to 30°—*i.e.*, $\frac{9000}{300}$° would be lost—and on reaching Christchurch there would be an increment of $\frac{9000}{180}$° Fahr.—*i.e.*, 50° Fahr.—which would make, with the 30° Fahr. retained at the summit of the Alps, a temperature of 80°. This reasoning was first given by Espy and Maury (in 1861) without special application, and Dr. Hann, Herschell, and others subsequently used it to explain the föhn wind of Switzerland, a quite analogous wind, which even Dove had failed to account for satisfactorily. This reasoning applied to our nor'-wester, which was a true föhn. But even that explanation did not get to the root of the matter, for it only showed how heavy rain in Westland rendered sensible in Canterbury the heat previously latent. Therefore the question still remained, Whence came that heat? It was brought from the tropics. The hot equatorial wind or return trade, also, in crossing warm oceanic currents, gathered up further moisture and heat as it travelled to higher latitudes. Furthermore, the north-west weather was mostly cyclonic, and all meteorologists agree that, whatever the cause might be—and as yet it was unexplained—a peculiar kind of stifling oppressive heat, giving neuralgia, headache, rheumatism, &c., invariably was developed on the front of a cyclone. In the Southern Hemisphere this heat-spot would be found on the *left* front of the path of the storm, and, granting that the cyclones producing our nor'-westers sheered off to the south of New Zealand, being divertd by the Southern Alps, we should be justified in locating the heat-patch over the Canterbury Plains. Cold nor'-westers occurred occasionally, and were sometimes probably only local. If they occurred in winter, when the initial heat of the winds was great, and little precipitation on the mountains accompanied them, they were not difficult to understand; but they occurred at other seasons, and were then not easy to explain. The clouds of dust which made a nor'-wester so unpleasant were thought by Sir J. von Haast—probably erroneously—to explain the loess formation of the Lyttelton hills and elsewhere. The remarkable fall of the barometer on the approach and during the continuance of a nor'-wester accorded with Dove's law of the Southern Hemisphere generally—the steepness of the baric gradient indicating the intensity of the disturbance. The glass usually went down to 29·2in., and once quite recently had even descended to 28·68in., though in twenty-four hours, when south-west intervened, it had risen to 30in. again. Why the glass fell in a nor'-wester was a difficult question. Maury's explanation about aqueous vapour driving out and being lighter than air did not meet the case so well as what Loomis said about light hot air filling the whole space usually occupied by colder and denser air. The north-west arch of clouds, a very beautiful and distinctive mark of the approach of the equatorial wind, was developed probably by contact and difference of temperature between the north-west wind and the ordinary air lying over the plain. It lay really parallel to the range, but assumed to us the arch form from the operation of a principle of perspective. It altered its position, unless dissipated altogether, as the wind veered round to the exhilarating south-west, whence came the cold squalls which showed the passage of the storm. North-west rains along the foot of the hills, and particularly in certain spots, were then adverted to, and other instances were given of föhn winds, corresponding to our nor'-westers—particularly the chinook of North America. Though very unpleasant, and occasionally disastrous, our nor'-westers deserved more than a passing good word. Dry heat was needful for ripening wheat and fruit. It also killed or blew away the germs of disease, melted the snows on the hills, &c. Most of the health resorts of the world were situated under the protection of mountain-chains across which warm winds blew; and among the many circumstances to which Canterbury owed that salubrity which accounted for its excellent grain, its toothsome mutton, and the average fine physique of its sons and daughters, not the least important, perhaps, was the much-abused nor'-wester.

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