THE CAWTHRON INSTITUTE

OF

SCIENTIFIC RESEARCH.

CAWTHRON LECTURES.

VOL. I.

1916—1919.

NELSON, NEW ZEALAND.
R. W. STILES AND CO., PRINTERS, ETC., WAIMEA STREET.
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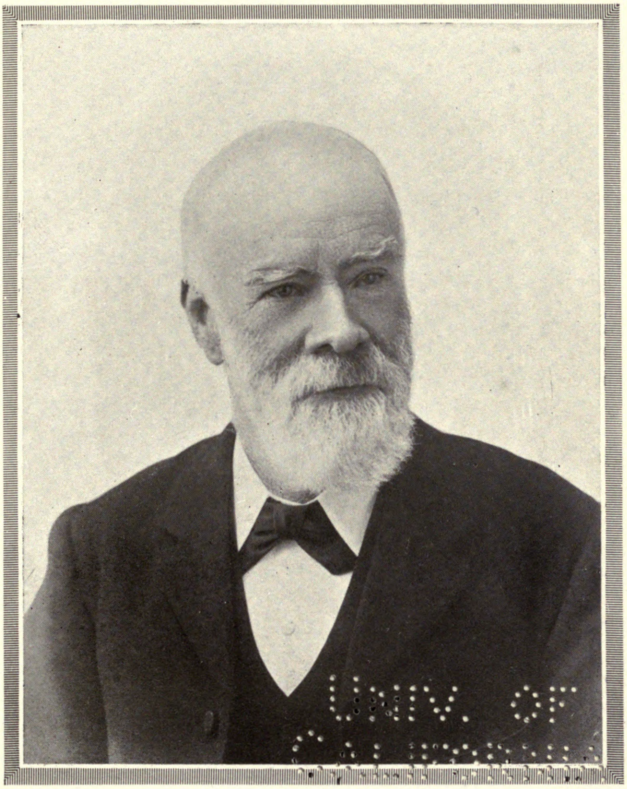

THOMAS CAWTHRON

Born at Camberwell, May 26, 1833
Died at Nelson, N.Z., Oct. 8, 1915

STAFF, 1920:

Director: Thomas H. Easterfield, M.A., Ph.D., F.I.C., President of the New Zealand Institute, Emeritus-Professor, Victoria University College.

Agricultural Chemist: Theodore Rigg, B.A., M.Sc.

Assistant Chemists: E. J. Champtaloup, Maxwell Young, F.C.S.

Chief Biologist and Entomologist: Robin J. Tillyard, M.A., Sc.D., sometime Linnean McCleay Fellow in the University of Sydney.

Assistant Entomologist: Alfred Philpott.

Mycologist: Kathleen M. Curtis, M.A., D.I.C., D.Sc.

Curator: William C. Davies.

Assistant: H. Harrison.

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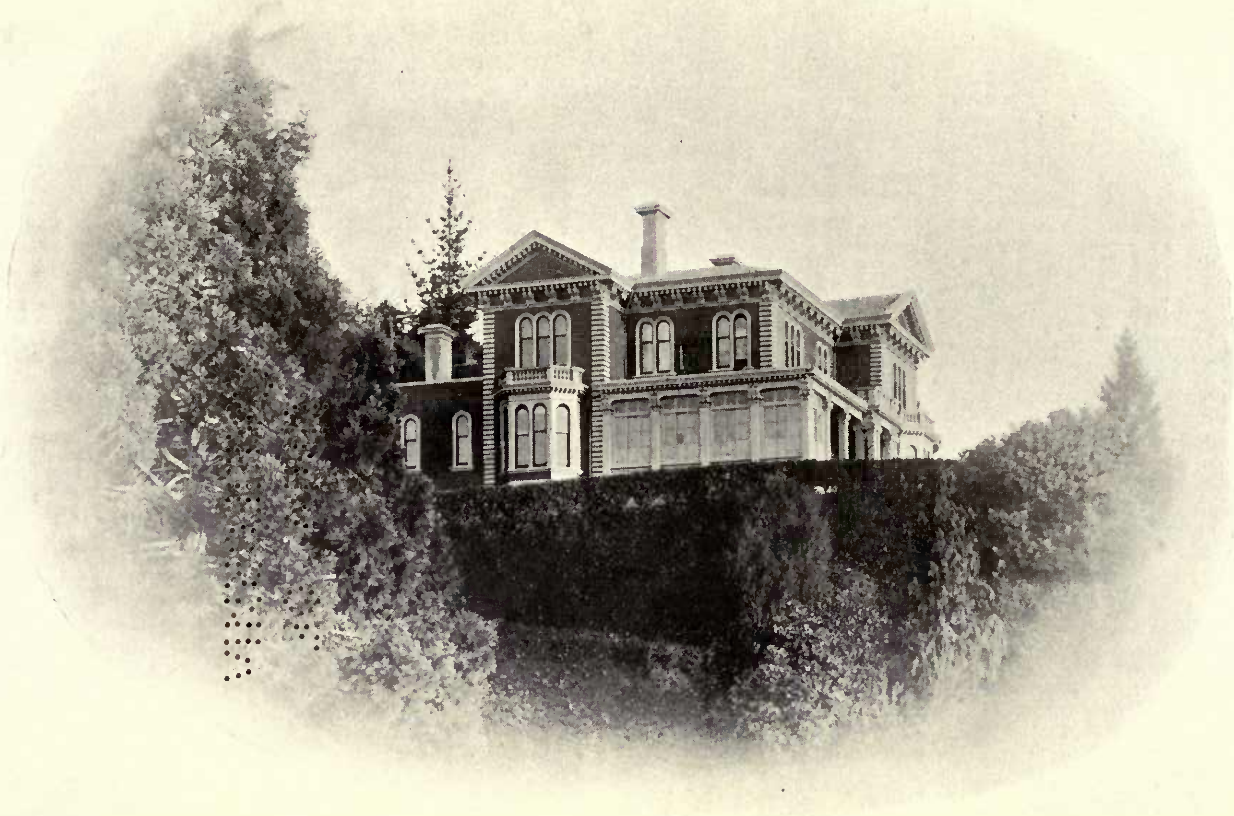

THE CAWTHRON INSTITUTE OF SCIENTIFIC RESEARCH.

PREFACE.

THE CAWTHRON LECTURE.

The Trustees resolved on May 4th, 1917, that there should be an annual Scientific Lecture of a popular character in memory of Thomas Cawthron, the Founder of the Institute.

The first public announcement by the Trustees was made at the inaugural lecture delivered by Professor Easterfield on July 10th, 1917, in the School of Music, Nelson. The Bishop of Nelson, Chairman of the Trustees, presided over a large and representative gathering. In addition to the Trustees, there were on the platform the Mayor of Nelson (Mr W. Wallace Snodgrass), the Hon. A. T. Maginnity, M.L.C., the Principal of Nelson College (Mr H. L. Fowler), the Principal of the Girls' College (Miss Lorimer) and the Editor of the "Colonist" (Mr Hastings Braddell).

In his introductory remarks, the Chairman said he trusted that the lecture of that evening would be the first of many scientific gatherings. He would not then say anything as to the generosity of Mr Cawthron in providing means for scientific research. The words of the will were simple. The Trustees had very wide powers, so wide indeed that they had induced many suggestions, some not at all wise, and some useful. It was, however, a case of what they were able to do, not what they would like to do. As to several of Mr. Cawthron's proposed benefactions, which had he lived he would undoubtedly have carried out, the Trustees had had to take the opinion of the Court, and very much against their personal wishes some had to be dropped. The speaker then detailed the setting up of a Commission of scientific men, who met in Nelson, and whose deliberations led to the evolution of the scheme which the Trustees had now in hand. The central idea was to do one thing well and not spread effort over too large a field and thereby lose effectiveness. The one thing they had adhered to strictly was the investigation of biological and chemical problems bearing on the agricultural industries of New Zealand. It was not intended to enter upon all of these subjects at once, nor to go in for any great building: they were looking for brains rather than for bricks. One thing at a time and that done well was their aim, and the expressed wishes of the Founder of the Institute would ever be kept in view. There were two dangers which the Trustees were specially anxious to avoid in order that the spirit of those wishes should be given effect to, and those dangers were commercialism and officialdom. Every care would be taken to avoid red tape and to see that the work of the Institute was not hindered by commercialism in spirit. He then introduced Professor Easterfield as first lecturer on behalf of the Institute.

At the conclusion of the lecture, the Mayor (Mr W. Wallace Snodgrass) moved that a vote of thanks be accorded to the lecturer, and said the address had been all too short, and that he was sure all those present would have been glad if the Professor had continued longer. He expressed the opinion that the Professor had given a very true estimate of the feelings which had actuated Mr. Cawthron in making the grand bequest he had to Nelson. He (the Mayor) had been an intimate friend of the late Mr. Cawthron, and knew that he had a great heart, which was specially tender towards the people of his own town. The Mayor complimented the Trustees upon selecting Professor Easterfield to give the inaugural address.

The Hon. A. T. Maginnity, who seconded the motion, said that a kindly thought must be in every mind for the gentleman who had conferred so great a benefit upon the community in which he had spent the greater part of his life, and this benefit would descend to their children's children.

The motion was carried by acclamation, and after Professor Easterfield had briefly replied, the meeting closed with the National Anthem.

LECTURE I.

THE AIMS AND IDEALS OF THE CAWTHRON INSTITUTE.

By THOMAS HILL EASTERFIELD, M.A., PH.D., F.I.C., F.C.S.,
Professor of Chemistry, Victoria College, Wellington.

Let me express to you my deep appreciation of the honour which has been conferred upon me by the Cawthron Trustees in inviting me to make the first public statement as to the manner in which it is proposed to carry out the wishes of the late Thomas Cawthron, in whose memory this lectureship is founded.

For years I have held the view that in New Zealand there is great need of an institution the special object of which shall be the carrying out of scientific investigations, but I scarcely expected to live to see the fulfilment of this ideal. I therefore rejoice to announce that by the munificent bequest of a great benefactor such an institution will be erected in your city. It is to be called the Cawthron Institute of Scientific Research. All truly great men are lovers of the country of their birth, but it is peculiarly characteristic of the British to develop an equal love for the countries which they colonise. Thomas Cawthron was an outstanding example of such great men. Coming to New Zealand as a weakly boy, he eventually became a strong man and developed an equally strong character. Frugal in his habits and shrewd in business, he was very liberal in regard to all matters which make for the public welfare. This city is rich in evidence of the catholicity of his civic ideals. The Cawthron Park, with seven thousand acres of mountain and forest, the Nelson Institute and Library Building, the School of Music, the imposing flight of Cathedral Steps, need only be mentioned as objects of his generous care during his lifetime. By his will an estate of the value of £240,000 has been left for the material and intellectual advancement of the city and district which he so dearly loved.

In this time of stress our natural desire is to honour those who are risking their all in fighting on behalf of the ideals for which the British Empire stands; but let us not forget that patriotism may be of many kinds, and that to live for one's own country may be a still harder task than to die for it. To every patriot a meed of praise is due. The work of the Cawthron Institute will, we trust, be a perpetual memorial of the patriotism of its founder. I have already stated that the Trustees have decided that the Institute shall be primarily an Institution for Scientific Research. They recognise that the value of research work has been too little appreciated throughout our Empire, and that this defect has greatly retarded national efficiency. It is indeed surprising how little the general public is aware of the debt which it owes to the scientific workers of the past, and how little it appreciates the extent to which the future of our Empire may depend upon the organisation of our resources and the submitting of them to systematic scientific investigation.

Objection may be raised that in concentrating on scientific research a tribute is being paid to the success of German methods, for it is doubtful if any country has benefited so much and in so many directions from the application of research methods as modern Germany has done. Let me remind you of that old Latin proverb which teaches us the wisdom of learning from the enemy. True wisdom and foresight demand that not only shall we learn from our enemies, but that by proper attention to organisation and detail we shall surpass our opponents in the realisation of the national value of science. In speaking of scientific research to an audience consisting largely of laymen, I know that many among you will scarcely understand what is meant by this expression; let me therefore draw your attention to a few concrete cases so that you may clearly appreciate the utility and value of scientific research.

And here I pray you not to confound utility with money-making or money-producing. By utility I understand anything which makes for good—which makes life sweeter—which develops an appreciation of art, music, or literature, or which tends towards the raising of public ideals. The value of all education must eventually be judged in terms of utility. Nearly all of you are interested in agriculture. I therefore mention first of all the work of Liebig, who devoted his great chemical knowledge to researches on the ashes of plants and to the chemistry of animal and plant nutrition, and thus laid the very foundation of modern agricultural chemistry. It is true that many of his conclusions were wrong, but he demonstrated beyond doubt the value of potash and phosphoric acid as fertilisers; and the continuation of his work has undoubtedly revolutionised agriculture and been of the greatest value in increasing the world's supply of foodstuffs. Following closely on Liebig we have the epoch-making work of Gilbert and Lawes, whose lives were practically devoted to the study of the scientific aspects of wheat-growing. By their bequest the estate at Rothamsted, on which for so many years the experiments were carried out, is secured for the British people as an agricultural experimental station.

Let us turn to the oft-told tale of the coal tar industry. Owing largely to the efforts of Prince Albert Victor, Lyon Playfair, and Sir James Clarke, a Royal College of Chemistry was established in London in the late 'forties. In it were trained Mansfield, the first chemist to prepare benzene and toluene on a commercial scale, and William Henry Perkin, who, at the age of seventeen, discovered mauve, the first of the so-called aniline dyes. Hundreds, if not thousands, of investigations have arisen upon the foundation laid by these discoverers and by their teacher, Professor Hoffmann, and coal tar colours have now almost replaced the vegetable dye stuffs. Many of the substances obtained in these coal tar researches have proved to be of the greatest value in medical practice. I need only allude to such products as carbolic acid, cresol, antipyrin, aspirin, and phenacetin.

Upon the foundations well and truly laid by Davy and Faraday has been raised the magnificent edifice of modern electro-chemistry.

By electro-chemical means we now obtain calcium carbide, carborundum, artificial graphite, caustic potash, nitrogenous fertilisers, and nitrates for the manufacture of explosives. Indeed, electro-chemistry promises to revolutionise the manufacture of nearly all chemical products.

Michael Faraday's researches on the liquefaction of gases, extended notably by Andrews of Belfast, by Pictet, Cailletet, Joule, and Playfair, Dewar, Olzewski, and Kammerlink Onnes, led to the commercial practice of gas liquefaction. To New Zealanders the history of gas liquefaction should be of great interest, for our export trade is based upon efficient cold storage, which in turn depends for its success upon the economic liquefaction of ammonia and carbonic anhydride. Faraday's researches in electro-magnetics paved the way to the invention of the electric telegraph and telephone and to the production and distribution of electric power. Clarke-Maxwell's investigations on oscillatory discharges first made known the probable existence of electric waves. Their existence was shown to be a reality by Hertz, after which wireless telegraphy became a commercial success in the hands of Marconi.

Not less remarkable are Pasteur's researches on micro-organisms. Their results have been far-reaching. The application of aseptic methods in surgery and the use of antitoxins in the treatment of disease, though not due to Pasteur, are certainly based upon his discoveries.

The investigations of Patrick Manson and Ronald Ross proved that a special mosquito *Anopheles* is the carrier of malarial fever; and the successful completion of the Panama Canal became possible only after a decisive victory had been gained by Dr. W. C. Gorgas over another type of mosquito *Stegomyia fasciata* found by Charles Finlay to be the agent of infection in cases of yellow fever.

Researches on the radiating power of the rare earths led to the invention of the Welsbach mantle, which, with a consumption of one-half of the quantity of gas, gives at least four times the quantity of light yielded by the old flat flame gas burner. Parallel with this reduction in the cost of gas lighting must be placed the development of metallic filament lamps, which have rendered a like service to electric lighting.

There is indeed no class of industry and no art or profession which has not benefited by the researches of scientific men; nevertheless, it must be admitted that the British have been slow to recognise the national importance of science and the benefit to be derived from the organised application of science to industry. The value to the Empire at which the trained investigator is officially assessed is, I think, fairly well represented by the action of the War Office, which in the early stages of the war, advertised for skilled chemists at a salary of £2 0s. 6d. a week.

It is undoubtedly true that the phenomenal extension of German industries from 1870 onwards has been largely, though not entirely, due to the alertness with which the German people have recognised the importance of both pure and applied science. A French savant dealing with this question has recently stated that in proportion to population Germany and Switzerland have six times as many trained chemists as have France and Great Britain. Assuming that the mental calibre of the inhabitants is approximately equal, the probability of a large output of scientific discovery is obviously on the side of the countries with the largest proportion of trained scientific workers. An examination of the scientific literature, pure and applied, will convince anyone of the accuracy of this contention.

What I have said will, I trust, convince you of the far-sightedness and wisdom of the Trustees in deciding that the Cawthron Institute shall be a home for scientific research; but I will forestall three questions which may perhaps have suggested themselves to you:—

I. Is New Zealand a country sufficiently advanced to furnish men who can be trained to carry out high-class research work?

To this I unhesitatingly say "Yes." Let me remind you that the secondary school of this city—Nelson College—has produced Sir Ernest Rutherford, Brigadier-General Chaytor, and Professors Evans and Worley; and that other secondary schools in New Zealand can point to a number of former students who, after further training in the University Colleges, now hold high scientific positions in Great Britain, India, Australia, and America. Let me add that your fellow-townsman Lieutenant Athol Hudson, the brilliant athlete whose loss in action we so deeply deplore, had already shown by his manipulative skill, his scientific attitude of mind, and his earnestness of purpose, that as an investigator a great future was before him.

II. Are there actual scientific problems awaiting solution in this country?

(a) In agriculture alone there are many problems waiting to be investigated, though the researches of the scientific staff of the Department of Agriculture have done much work of very great value. One of the most recent departmental investigations has dealt with the cause of bush sickness, which rendered approximately one million acres of the North Island unfit for the rearing of stock. Mr. Aston has demonstrated very clearly that this is a deficiency disease, associated with shortage of iron in the grass growing in a soil poor in the same element. Further experiments by Dr. Reakes show that when this iron is suitably provided the diseased animals recover. Assuming that this discovery can be generally applied and that a "research tax" (? !) of 3d. per acre were levied upon the bush sickness area, for improved value resulting directly from these researches, it would yield an income as large as that which will be available for the Cawthron Institute.

(b) The fruit industry, which has risen so rapidly in the Nelson district, and which if suitably fostered may become one of our greatest national assets, may, on the other hand, be stamped out if means are not discovered for combating the natural enemies of the fruit tree. Forty years ago blights are said to have been practically unknown in this district; even the peach tree was in those days free from attack. At the present day we hear constant complaints of blights and insect pests, of bitter pit, black spot, aphis, and codlin moth. I do not doubt that all these plagues are capable of scientific control, and the workers at the Institute will no doubt show us step by step how each of these troubles is to be dealt with. Some of these investigations will require to be very lengthy, involving, as they certainly will, a study of the life history of the various pests and of the conditions which are most and least favourable to their development. "Good bread needs baking," and it is only by a very careful examination of each problem, in consultation with the practical men engaged in the industry, that improvements, such as we all desire, can be effected. It is perhaps worth while to point out that a comparatively small improvement in the general producing value of the land in the Nelson district would represent an annual sum exceeding the whole capital value of the Cawthron Bequest; and if only one investigation out of twenty carried out in the Institute proved to be of direct economic value the expenditure on the researches would be more than justified.

(c) The flax industry, the third largest of the New Zealand export trades, will benefit greatly by the applications of scientific method. Very little work of value has been published about *Phormium tenax* since Hector's valuable report in 1889 based chiefly on the reports of the Commissioners in 1871. Three tons of refuse are produced for every ton of fibre, and no use is made of this refuse, though it is known to have a considerable manurial value. My experiments have convinced me that the substance may become a profitable source of alcohol, of mill fuel, and of potassic fertiliser. Experiments are badly needed upon flax cultivation under rigorously controlled conditions with the object of producing disease-resistant strains, more rapid development, larger leaves, increased quantity and better quality of fibre. Such experiments will certainly be attended with great difficulties, but in view of the success which has followed similar investigations in the case of wheat, of beetroot, and of sugar cane, there is no doubt that the researches should be at once initiated.

(d) Much experimental work is needed in connection with our forests; indeed, according to that noted forester, Mr. D. E. Hutchins, "scientific forestry in New Zealand has yet to begin."* Timber shortage is almost world-wide; it is pressing in New Zealand, and will in a few years become acute. With a sane forest policy this country would have abundance of timber for its own needs and for a large export trade. This trade would support a large forest population and would lead to the conversion of many inferior beech forests into areas of high-class timber and to the reafforestation of districts in which the forest has been thoughtlessly and disastrously destroyed. There are apparently few systematic records of the rates at which our native trees grow

*A Discussion of Australian Forestry. Perth, 1916, p. 389.

under forest conditions in different localities and on different soils. There is too wide a conviction, based upon insufficient evidence, that it can never pay to grow native trees for timber, and that the only imported trees worth planting are *Pinus insignis (radiata)* and *Eucalyptus globulus.* Australasia is without a well-appointed scientific arboretum, and if the Cawthron Trustees will establish such a park for the study of forest problems they will be initiating a great and much-needed educational work and will earn the thanks of all tree lovers.

III. Should only researches of obvious economic importance be carried out at the Institute?

I think not. Every large economic research involves the collection of so many purely scientific data that to confine attention to researches which we can see to be useful would, in the end, lead to disaster. The instances already mentioned illustrate clearly how very generally investigations in pure science form the basis upon which industrial development becomes possible.

Let me now outline to you the plan which the Commissioners have recommended and which the Trustees propose to follow. First of all a site has been secured. This is the Annesbrook Estate of twenty acres, bounded by the Rocks road, the Waimea main road, and the railway; it is nicely wooded, well-drained and partly in orchard. The site overlooks Tasman Bay and the Waimea Plains, and is, I consider, an ideal situation, whether from the aesthetic or practical standpoint.

The Institute will contain well equipped chemical and biological laboratories, suitable offices, and a fine library, rich in scientific journals and memoirs containing the original researches of investigators in all parts of the world. By exchanging the bulletins from the Cawthron Institute with those of other institutions, the library will be further enriched; these bulletins will form a valuable record of investigations carried out in the Institute.

Included in the Institute will be a Technical Museum, this being wisely specified in Mr. Cawthron's will. The museum will illustrate in an interesting and striking manner the value of science to agriculture in its widest sense, to mining, forestry, and the secondary industries. A further important function will be to demonstrate the results of the investigations carried out by the members of the staff.

The researches will in the first instance bear chiefly upon agricultural and in particular upon fruit-growing problems.

A Director will be appointed who should be a man of high scientific attainment and administrative ability. He will be responsible for the organisation of the researches to be carried out by a staff of trained investigators. The plan of work will be decided by the Director in consultation with a Board of the most eminent scientific men in New Zealand. The Trustees have requested the Cawthron Commissioners to act for the present as an advisory board. The workers in the Institute will not consist of boys and girls who have just left a secondary school; for without a higher training such students would be of little use in a research institution, and would seriously interfere with the work of the staff. On the other hand, students who have already received efficient training in the scientific departments of our University Colleges would benefit greatly by working in the Institute, and would render material assistance to the investigators with whom they would collaborate. They would obtain a deeper knowledge which would be of great help in later life, whether they became scientific experts, agriculturalists, teachers, or professional men. It is therefore proposed to allow any student who can produce evidence of efficient scientific training to work in the Institute, the special work of each student being allotted to him by the Director, after consultation with the members of the scientific staff.

In order to attract to the Institute the most brilliant students from all over New Zealand, it is proposed to establish a series of scholarships and fellowships, commencing with a Cawthron Minor Scholarship* of the value of £100 per annum, to be awarded annually to the most able candidate in science in the University Entrance Scholarship Examination, on conditions which I need not here detail. Preference will be given *ceteris paribus* to candidates from Nelson and Marlborough districts. The Scholarship will be tenable for three or four years at any one of the University Colleges.

The Cawthron Foundation Scholarships will be of higher value, and will attract the best science graduates of the University, men or women who have already shown high promise of carrying out research work.

Cawthron Fellowships will also be established. The holding of these Fellowships will, I doubt not, be regarded as one of the highest scientific honours in New Zealand. No doubt the Fellows will in general be selected from those foundation scholars who have carried out work of such value that it is deemed advisable to retain their services for a further period of one or two years.

We may reasonably expect that as the value of the work of the Institute becomes known and appreciated, private benefactors will contribute additional endowments to the general fund of the Institute, or for special researches, or in the form of scholarships or fellowships. Should any association, society, or private firm desire to have technical researches of a special type carried out in the Institute the Trustees will be prepared to allow this to be done, the parties interested bearing the cost of the investigations, including the salary of a Fellow, who will be appointed by the Trustees in consultation with the Advisory Board. A similar scheme has given satisfaction in some American institutions.

*Owing to a decision of the Supreme Court, it has been found necessary to abolish the Minor Scholarship scheme.

It is seldom wise to assume the role of a seer, but so certain am I of the wisdom of the course upon which the Trustees are embarking that I foretell a brilliant future for this Institute. The problems solved in it will lead to results of the greatest value to this city, to the Dominion, and to the human race. Workers who have carried out these researches are destined to become scientific leaders with a world-wide reputation, and the Institute itself to be a centre of light, learning, and culture, honoured throughout the civilised world, and a lasting tribute to the memory of Thomas Cawthron.

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LECTURE II.

BIOLOGY IN RELATION TO AGRICULTURE.

By W. B. BENHAM, M.A., D.Sc , F.R.S., F.Z.S. (Professor of Biology at the University of Otago).

Delivered in the School of Music, Nelson, on May 30th, 1918.

I have to thank the Cawthron Trustees for doing me the honour of inviting me to deliver the annual Cawthron Lecture this evening. I esteem it a high compliment, the more so as we hope that the Cawthron Lecture will continue to be an annual event in Nelson, and that the lecturer will always be chosen as being of some note in his special profession.

In the Old Country there are many such foundations providing an annual lecture in order to perpetuate the memory of a man who has by his generosity or his researches aided or advanced science or literature, and men of note in all walks of life—literary men, scientific men, statesmen, churchmen. and others—are invited to do honour to his memory. I recall the Hunterian Lecture at the Royal College of Surgeons in memory of that most distinguished anatomist, John Hunter, who in the Eighteenth Century commenced the formation of that great museum of comparative anatomy; the Hibbert Lectures; the Gifford Lectures, at which many notable men have spoken; the Romanes† and the Boyle at Oxford; the Huxley Lectures, and a dozen others.

Those of us who are interested in the future of the Cawthron Institute for Scientific Reasearch hope that, within the limits set by our geographical situation, eminent men—not scientists only—will be invited to commemorate the benefactions of the late Mr Thomas Cawthron.

The citizens of Nelson should be, and I have no doubt are, proud of having had dwelling among them so generous and yet so modest a man as Mr Cawthron. Although, as I understand, he lived a retired and quiet life, taking no share in public matters, yet he did many a kindly action in the quietest way, helping financially and otherwise those of whose difficulties or distress he heard; and this he did in so unobtrusive a fashion that one may almost say that his left hand knew not what his right hand gave.

But, as we all know, he also gave large sums of money towards the improvement and beautification of this city. To him you owe the fine organ in this hall; to him the handsome steps which form so grand an approach to your Cathedral—itself to be replaced some day, by an edifice more in keeping with the progress of the city. You

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†Thus the Right Hon. H. Asquith, M.P., is to give the Romanes Lecture in 1918, on "Some Aspects of the Victorian Age"—a leading statesman is to commemorate the work of Romanes, who was a distinguished evolutionist.

owe to him, too, a large monetary gift for a new Hospital, and the Cawthron Park. And, as you are aware, Mr Cawthron had contemplated several other improvements, which unfortunately had to be left unfulfilled owing to his death in 1915.

Nelson is indeed fortunate in having had as a citizen a man who used his wealth to such good purpose and with such large ideals, for many men who have accumulated a fortune by business in the Dominion retire to Great Britain and spend it there, instead of returning the money in the form of benefactions to the people from whom and amongst whom they have derived it. All praise is due, and all honour, to the late Mr Thomas Cawthron, both for what he did and for what he proposed to do for this city.

These varied benefactions and improvements are sufficient to render Mr Cawthron's name memorable in Nelson city and provincial district; but in the Cawthron Research Institute there will be a monument to him that will bring his name constantly before scientific agriculturists all the world over. We hope that in time when the Institute is established it will become the home of important discoveries in aid of agriculture, and especially of orchardry. If the ideals of the Commission, which the Trustees selected to advise them in the matter, are carried out, we may look forward to the time when the Cawthron Institute will take rank with the older establishments like the Rothamsted Experimental Farm in England, and with many American institutes for research; that it will become the centre of research in New Zealand, and will ultimately attract to it men of science from all parts of the Dominion and from Australia, and even in the years to come from further afield. That will, however, not be for many years; the Institute has yet to be organised, to be provided with a staff, who will have to feel their way amongst many and difficult problems.

What I particularly want to impress upon you is that research is not a matter of a month or two, nor of a year; in order that it may yield results of permanent value the whole scheme for research must be most carefully planned and patiently carried on by efficient and scientifically trained men. In the first Cawthron Lecture, "On the Aims and Ideals of the Cawthron Institute," Professor Easterfield set out fully the benefits that research would confer not only upon this district, but on the Dominion.

So far as I can gather from the press report of that lecture, Professor Easterfield dealt in general terms with the valuable results that have accrued from the application of science, especially of chemistry, to industry, and I propose to-night to deal with a restricted field and attempt to interest you in an account of some little fragments of help that research in biology has conferred on certain agricultural problems.

I find that I must confine myself to a very limited field, and shall discuss mainly the organisms which by their activity serve to enrich the soil and make it suitable for the growth of plants, and later will refer to the subject of diseases which attack fruit trees

THE BIOLOGY OF THE SOIL.

A plant derives its food partly from the air by means of its leaves and partly from the soil by means of its roots; and the whole process depends on sunlight, which affords the energy necessary for the manufacture of sugar by the green leaves, to which mineral salts from the soil are carried up the stem from the roots. Here in the leaves new chemical changes occur, raising the sugar a step higher in chemical complexity by the addition to it of nitrogen, and the substance thus formed travels away from the leaves to all parts of the plant in order to undergo further chemical elaboration step by step, till new living matter, protoplasm, has been built up. The plant is, indeed, a creative agent—it can build up living substance from wholly inorganic or mineral matter; in other words, from the dust and from the air it can raise inorganic matter to organic matter.

It is the business of the horticulturist and the agriculturist to provide his plants with abundant and suitable food material. He is not content with that quantity of mineral food that is already in the soil, for that sooner or later would be exhausted under intensive cultivation.

It is at present impossible to alter the amount of food material obtained from the air, but it has been found possible to improve and increase the food material contained in the soil, effectively and economically, and the knowledge that we have of this principle of manuring has largely been brought about by experiments carried out during many years by Lawes and Gilbert and their successors at the experimental farm at Rothamsted, in Hertfordshire. Last year Professor Easterfield dealt with the chemical aspect of this question. To-night I propose to discuss the biological aspect, for biology has played a considerable part in recent years in advancing our knowledge of the chemical processes going on in the soil, whereby the nitrogenous material of manure is rendered available to the plant.

I say "available" for it is not every mineral salt that is useful. The plant can select from the mixture we call the soil just what it needs; but it can only take it if it be in a special state of chemical combination.

The soil consists of irregular particles, varying in size and shape and material in different kinds of soil—fine in clays, coarser in sandy soils—and these particles consist of minerals of different sorts, including the nutritive or food material of plants. This nutritive material consists of the phosphates, sulphates, nitrates of such bases as potash, lime, and magnesia. With these mineral materials there is always more or less organic matter derived from the decay of plants and animals that live in the soil. And in order that a soil may be "rich" it must contain a proportion of this organic matter or "humus," the material that is dark in colour, and supplies the "open" character of soils. The soil particles are separated from one another by smaller and larger spaces containing air, which is as necessary for the health of the roots as for that part of the plant above ground. These spaces also contain water, which forms from 15-30 per cent. of the weight of the soil. This water is mainly distributed in very thin films over the solids, though of course after rain the spaces may be filled with water; and unless the ground be properly drained the soil becomes waterlogged, and it is common knowledge to all of you that this is quite unfavourable for agricultural or horticultural purposes. The aeration or ventilation of the soil is to a great extent provided by the burrowings of earthworms, insect grubs, and other animals.

THE WORK OF EARTHWORMS.

I daresay some of you are acquainted with a work entitled "The Formation of Vegetable Mould by Earthworms," written by Charles Darwin and published as long ago as 1881. In that work he showed the great importance of these lowly animals to the agriculturist both in ventilating the soil and in improving its properties. Earthworms swallow small quantities of soil in order to obtain decayed vegetable matter occurring therein. This they do while making their burrows, although they also feed on young fresh leaves. The small particles are ground still smaller in the gizzard, which is like that of a fowl.

[Reference was then made to the mode of action of earthworms; the formation and extent of their burrows; to the astonishing numbers per acre, and the surprising amount of "vegetable mould" brought up by them to the surface annually, as estimated by Darwin in England, by Urquhart†, and by Smith‡ in New Zealand.]

This vegetable mould or "humus" differs from the subsoil in its fine grain and dark colour, in its freedom from stones of a size greater than can pass through the worm's digestive tract. It has undergone certain changes while passing through the worm's body and owes its dark colour to the presence of much organic matter, that is, of decaying or decayed vegetable matter, and it contains therefore an abundance of nitrogenous compounds. This "humus" is alkaline, and affords energy to numerous micro-organisms which convert it into simpler substances appropriate for plant nutrition. It also improves the physical character of the soil.

THE IMPORTANCE OF NITROGEN.

I want now to direct your attention to the importance of nitrogen, a gas which forms a considerable part of the air we breathe, but which plants can take from the soil only in the form of nitrates. The life both of animals and plants depends on the stock of nitrogen retained in the soil in the form of nitrates. The total nitrogen in arable soils is about 0.15 per cent; higher in some soils than in others. But the amount present as ammonia is only .0001 per cent., that is, about one part in a million in arable soils, and about ten times as much in heavily dunged soils. No soil constituents fluctuate more than the nitrogenous. Plants remove them, rain drains them away.

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†Urquhart, A. T., "On the Habits of Earthworms in N.Z." Trans. N.Z. Inst., vol. xvi., p. 266. 1884; and "On the Work of Earthworms," ibid, vol. xix., p. 119. 1887.

‡Smith, W. W., "Notes on N.Z. Earthworms." Trans. N.Z. Inst., vol. xix., p. 123. 1887. (The names given by him to our earthworms are quite wrong, and are corrected in next article). Smith, W. W., "Further Notes on N.Z. Earthworms," ibid, vol. xxv., p. 111, 1893; and vol. xxvi., p. 155, 1894.

In pastures flocks are feeding all the summer and furnish us with nitrogen in the form of milk, cheese and meat; yet the soil of these natural pastures still contains quantities of nitrogen greater than are to be found in ploughed and copiously manured land. Crops of all kinds remove from the soil more nitrogen than the manure supplies.

It is evident that there must be some recuperating agency, or the stock of nitrogen would long ago have disappeared from the old countries. Experiments show that soil gains nitrogen if it is allowed to remain undisturbed or in natural conditions.

Whence comes this nitrogen? It can only come in the last place from the inexhaustible reservoir of the atmosphere.

The great German chemist Liebig, who contributed so much to our knowledge of the chemistry of plants, supposed that they obtain their supply of nitrogen directly and in its elemental form from the air. But about the same time a French chemist, Boussingault, showed by experiments conducted during some twenty years that plants are quite unable to do this, but must obtain it from some mineral in the soil. The discovery of this fact was a step of great importance in plant physiology.

How, then, is this nitrogen fixed? In what form does it occur in the soil? And how is it made available for the plant? In the farmer's manure heap are found countless minute organisms, fungi or moulds and bacteria, which are feeding on the vegetable substance which makes up the manure. By the action of these a fermentation is set up; in other words, the manure becomes rotted. It owes its warmth to this chemical action, and as we know the gas ammonia is given off in abundance. This ammonia is one of the results of the decomposition of the vegetable matter, and is wholly the work of these minute bacteria, and all nitrogenous manure except nitrate of soda, all such substances as guano, dung, wool-waste, bone-meal, sulphate of ammonia, have to undergo the action of bacteria before the products are of any use to the plants. The result of the action, then, is the formation of ammonia. But in this form the nitrogen is still useless. The gas enters the soil, and is here converted by chemical combination into ammonium carbonate. But still further changes have to take place before it is of use to the plant. Now scientific agriculturists are generally agreed that the most important food materials of the plant are nitrates; that is, nitric acid in combination with mineral bases, and for the moment we may speak of nitric acid as the important thing. "If the soil were utterly devoid of this substance it would be incapable of yielding the barest pretence of a crop of any sort, even if the soil be in other respects of the most superfine texture, however favourably it might be situated, however well drained, tilled and supplied with the purely mineral ingredients of plant food."† Yet nitric acid occurs in only very minute quantities in the soil.

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†Frankland, P. F., "Our Secret Friends and Foes." (Romance of Science Series, S.P.C.K.).

SOIL BACTERIA.‡

The question then is—How is the ammonia converted into nitric acid? It was not till 1877 that two French chemists showed by a very simple experiment that the power of soils to convert nitrogen, that is, the ammonia of the manure, into nitric acid was the work of some kind of living thing or organism.

Muntz and Schloessing* allowed dilute sewage to trickle down through a vessel packed with chalk, i.e., carbonate of lime. They found that no change took place for the first fortnight or three weeks, but then suddenly the fluid that accumulated at the bottom of the vessel was found to contain nitrate of lime, i.e., nitric acid had been formed. If this process of nitrification was due to some chemical or physical procedure it should set in at once. Why then was this delay? They argued that it could only be because the process was biological; that is, was due to some living organism, and the period of delay was needed for the multiplication of this organism.

The theory was tested by adding chloroform to the soil. This, of course, would put a stop to the action of any organisms. The process at once ceased. But on the replacement of the chloroform by air or oxygen the process set in again. That is, the organisms had been temporarily numbed, but had recovered in the air. Although Muntz did not follow this particular aspect of the matter any further, others did, and there arose a new branch of science, that of "Soil Bacteriology."

Amongst those who continued to work at this problem was notably Warington, who worked many years at Rothamsted. After a series of experiments he obtained a culture which was able to turn the ammonia into nitrous acid. This was in 1879. But he recognised that he must go further, for nitrous acid only combines to form nitrites, which are quite useless to plants. After two more years of work he obtained a further culture which was able to convert the nitrous acid into nitric acid. This was an important step, and perhaps you might think that it sufficed. So perhaps it would for the practical man, but the scientific man wants to know how these two changes are brought about. What is there in the liquids that bring about these chemical changes? Muntz had proved that some organism was concerned in the process, and people now set about to try and find what that organism might be. The credit of discovering a specific organism in these cultures is due to Dr. Percy Frankland, of the Royal College of Science in London.† He in 1890 succeeded in isolating a special bacterium, and his discovery

‡Dr. Russell's useful work, "Soil Conditions and Plant Growth" (Longmans, Green, and Co., 1917), contains an admirable historical account of all that relates to the soil.

*Schloessing and Muntz, "Sur la nitrification par les ferments organisés." Comptes Rendues. 1877.

†Frankland, loc cit, p. 87.

was shortly afterwards confirmed by others, especially by Winogradsky,‡ who was then working in Pasteur's laboratory in Paris. The bacterium thus isolated and bred by Frankland had so long eluded detection because it does not and cannot feed and grow upon the materials usually employed in bacteriological cultures, broth, jelly, etc., that is on organic stuff. Winogradsky discovered that it will grow and flourish only on mineral matter. A most astounding discovery at that time, but having found out this, he had no difficulty in keeping the bacterium alive and multiplying for years. He was able to prove that his little organism played only a part in the history. It converts ammonia into nitrous acid. It was the organism that occurred in Warington's first culture. Having started the work, others profited by this discovery, and Warington with this hint found in 1891 in his second culture the second organism or link in the chain, namely the organism that converts the nitrous acid into nitric acid.* And thus at last the whole process of nitrification of the soil, that is the continued supply of nitrates, became intelligible. It is due to two distinct forms of bacteria which occur in enormous numbers in the soil, anything from ten millions to forty millions per gramme of soil. So that in spite of the constant removal of the nitrates from the soil by plants bacteria are as constantly producing them.

Yet these facts which to-day are known to every elementary student of botany took many years of continuous, arduous, patient, and ingenious research, carried on by several people, working at first independently:—Muntz 1877, Frankland 1890, Warington 1891; a total of fifteen years of work, Warington himself devoting, on and off amidst other work, thirteen years to the elucidation of this problem.

It must be borne in mind that this long piece of research work, which is of as great importance to biology as to agriculture, was carried out by men who were working from a purely scientific interest in the problem. They found sufficient reward in the gradual overcoming of the successive difficulties and in pushing forward the discoveries step by step to a solution.

Although we owe the commencement of our knowledge of these bacteria to the experiments and observations of Englishmen, it is only fair to mention that others put the matter on a firm footing by confirming the experiments under varied conditions and extending the work. For instance, Winogradsky, who did an immense amount of work later, and was attacking the problem at about the same time as Warington, gets most of the credit. Yet it is the discoverer, the conceivor of new ideas, the initiator of new methods, who is really deserving of most praise.

Since Frankland's discovery of the nitrous ferment in England it has been found that the process is not carried out by the same organism in all parts of the world. Different kinds of bacteria, some of them motile, act as "nitrous ferment" in different parts of

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‡Winogradsky, Annales Inst. Pasteur, 1890, 1891.
*Warington, Journ. Chemical Soc., 1878, 1879, 1884, 1891.

the world. But in all parts of the world it is the same bacterium which is responsible for the production of nitrates.

In America the living bacteria of suitable soil are actually cultivated and distributed for trial in poor soils, by the U.S. Department of Agriculture.

In the laboratory, where pure cultures can be obtained, these two organisms can be demonstrated separately, but in nature they work simultaneously. They are most active a few inches below the surface, for, like most bacteria, they work in the dark and object to the light of day. This nitrification of the soil by means of bacteria can take place only under certain conditions, namely, the presence of small amounts of easily oxidisable organic matter. In other words, imperfectly rotted manure is detrimental to their activity. Hence the importance of applying well-rotted manure to crops. They will not tolerate acid condition, hence the need of a sufficiency of carbonate of lime. In this manure the ammonia arising from the action of putrefactive bacteria is changed into carbonate, which is rapidly converted by "*Nitrosomonas*" to nitrites, and then by "*Nitrobacter*" to nitrates, the changes proceeding so rapidly that only traces of ammonia or nitrite are ever found in normal arable soil. Absence of air puts an end to the activity of the bacteria—hence the importance of harrowing.

From these facts it seems that if and when the vast deposits of nitrate in Chili and Peru become exhausted, it would be possible to make nitre artificially by the aid of bacteria.† But that is for the future.

In addition to these nitrifying bacteria there are in the soil numerous organisms that are able to fix atmospheric nitrogen, and of these a bacterium, "*Azotobacter*," is most important. For the action to be rapid the bacteria must be sufficiently provided with carbonate of lime, potash, phosphates, organic matter, and moisture. A suitable temperature must be maintained.

It has long been known that leguminous plants will flourish on soils that are very poor in nitrogen, on sandy soils for instance, and it was for many long years a mystery as to how they managed to do this. It was known as long ago as 1866 that the root nodules that occur on lucerne, beans, clover, vetches, and other leguminous plants contain bacteria, and it is now known that these have the power of fixing free nitrogen; these plants are independent of nitrogenous manures. These facts are perfectly familiar to everyone, and form an important factor in the rotation of crops. These plants can be used in increasing the supply of nitrogen in cultivated soils and reclaiming barren sands and clays. Wherever leguminous plants grow they enrich the soil in organic nitrogen through the co-operation of nodular bacteria. When the host plant dies or is ploughed into the land the nitrogen compounds are speedily changed into plant food. Few improvements in agriculture have produced more marked effects than the extension of leguminous cropping. Yet how were these facts discovered? By countless experiments lasting over many

†Burnet, Etienne, "Microbes and Toxins," 1912, p. 15.

years during which time a number of scientific men discovered the facts which constitute our present knowledge.

It was the French chemist Berthelot† who in 1885 suggested that there might be in the soil certain organisms that were able to fix atmospheric nitrogen. It was a German botanist, Hellriegel, who in 1886 suggested that in the case of the leguminous plants this property was possessed by the bacteria in the nodules. It was at Rothamsted that Lawes and Gilbert made the field trials and laboratory experiments that established the truth of these suggestions and made them available to agriculturists.

Glancing over what I have said, it becomes clear that we owe a big debt of gratitude to these extremely minute but extremely abundant bacteria. We are so accustomed to think of them as harmful, as the cause of disease, on which medical men are never tired of insisting, that the general public may be pardoned if they do not recognise, or even know, of the vast utility of these microbes. Indeed, the disease-producers are comparatively few, and we are justified in saying that "All bacteria are useful and beneficial to humanity, though some have become injurious by the accident of their location within our bodies under certain circumstances." Life as a whole could not continue without their aid. They do not create life, perhaps, but they supply it with the necessary maintenance. It is by their means that the remains of dead animals and plants are cleared away and the organic substances stored up in them are returned to the air and soil in the form of inorganic matter, and rendered once more available for the food of plants.

As the prophet says,‡"All flesh is grass"—the sheep feed upon the grass, we feed upon the sheep; hence our food supply is in the last resort dependent upon bacteria of the soil.

PROTOZOA OF THE SOIL.

It is known that at times and under certain circumstances a soil loses its nutritious character and becomes "sick" in spite of the fact that it has received the usual amount of proper manure.

This subject attracted the attention of Dr. Russell and Mr Hutchinson a few years ago (1909),† and they found that if such a soil be partially sterilised by being heated to a temperature of about 60deg. Centigrade, or if it be treated with some volatile antiseptic such as toluene, the number of bacteria normally present undergoes remarkable changes. At first this number is greatly reduced, which means the soil has lost in nutritive character. Then there is a very marked increase. This rise in number sets in soon after the removal of the antiseptic or after sterilisation has ceased, and the soil conditions are now more favourable to the development of bacteria, and

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†Berthelot, "Fixation directe de l'azote atmospherique libre par certain terrains argileux." Comptes Rendues. 1885.

‡Isaiah, chap. xl., verse 6. The prophet used the expression, of course, with an entirely different connotation.

†Russell and Hutchinson, "Journ. Agric. Science," vol. iii., 1909. Proc. Roy. Soc., vol. 84, B., 1911, p. 165.

their number continues to rise till it exceeds that present in the original soil. Simultaneously there is a marked increase in the ammonia. It is evident that the soil has been improved by the treatment, and this improvement is found to be permanent. They argued, therefore, that there must be in the soil some factor that limits the activity of the bacteria, and since this limiting factor is abolished by the treatment it cannot be the lack of anything, but must be the presence of something which is affected by the treatment. They came to the conclusion that some living things existing in the soil were detrimental to the bacteria. They proceeded to search for these living things in cultures of untreated soil, and they discovered the presence of minute animals known as Protozoa. The investigation is a very difficult one, and these difficulties are only now being partially overcome.

Stimulated by these preliminary observations, several biologists proceeded to examine the fauna of soils, and a series of researches published in 1911, and still going on, has already resulted in the discovery of quite a large variety of much larger organisms, though, of course, they are still of microscopic size.† These are unicellular animals or Protozoa, known to us as Amoebas, Flagellates, and Ciliates, such as exist in great numbers in pond water and in sewage. They are now known to occur in considerable numbers in the soil, being especially numerous in "sick soil," where there may be as many as thousands to a gramme, which is, indeed, but a low number compared with the bacteria, which occur in millions per gramme of soil. It is these Protozoa that feed upon the bacteria, and hence the cessation of the important nitrifying process. When the soil is treated by partial sterilisation or by antiseptics, the Protozoa are killed, while the more hardy bacteria may escape, but after the removal of the toluene, or after sterilisation has ceased, the bacteria renew their activity and multiply rapidly.

This then is an important additional piece of knowledge allowing soils to be effectively treated when they become sick. Until this discovery was made any attempt to effect a remedy could only be a matter of working in the dark.

It is found, indeed, that burnt lime, quick lime, spread on the soil has the same effect as partial sterilisation. It kills the Protozoa, whereas ordinary carbonate of lime does not.

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†Goodey, "A Contribution to our Knowledge of the Protozoa of the Soil," Proc. Roy, Soc., vol. 84, B., 1911, p. 165.

Martin, "A Note on the Protozoa of Sick Soils, with some account of the Life-Cycle of a Flagellate Monad," ibid., vol. 85, B., 1912, p. 393.

Thornton and Smith, "On the nutritive conditions determining the growth of certain Freshwater and Soil Protista," ibid., vol. 88, B., 1914, p. 151.

Russell, "Soil Protozoa and Soil Bacteria," ibid., vol. 89, B., 1915, p. 76.

Goodey, "Further Observations on Protozoa in Relation to Soil Bacteria," ibid., vol. 89, B., 1916, p. 297.

Martin and Lewis, "Some Notes on Soil Protozoa," Phil. Trans. R. Soc., vol. 205, B., 1914, p. 77.

‡Hutchinson, "Journ. Agric. Science."

PLANT DISEASES.

In approaching the second part of my address I cannot improve on the following succinct statement on the matter of disease, by Prof. Keeble:—†

"About fifty years ago the belief that disease is the work of maleficent evil spirits still lingered in the minds of simple folk, and though the better educated had given up that idea they were very little wiser.

"At about the time (1877) that Pasteur was studying the nature of diseases in animals, a botanist, de Bary by name, demonstrated that many diseases in plants are due to the entrance of a parasite into the body of the plant. In some cases it is a fungus, and specific diseases are due to specific fungi: in other cases bacteria. Gradually contemporary and succeeding workers arrived at a precise appreciation of these infectious diseases. As a result of their prolonged labours it is now recognised that three conditions are necessary to make that quarrel that we call disease:—

"(1) The existence of an infecting organism, whether it be a bacterium or a fungus.

"(2) The condition of the plant which exposes it to attack or screens it from attack.

"(3) Conditions in air or soil which favour either the parasite or the plant and so facilitate or discourage the attack.

"The professional botanist, i.e., the plant pathologist, is apt to fix his attention too exclusively on the first of these conditions. He is naturally more interested in the structure and life history of the fungus. The professional agriculturist seeks to preserve his plants from disease by improving his methods of cultivation. There is much room in the world for a race of botanists who not only discover how to cure plants but know how to cultivate them, and from wide experiments to endeavour to find varieties which are immune to specific disease."

In a work on "Diseases of Economic Plants," published in America in 1916, I find that no fewer than two dozen infectious diseases are there known to attack the apple trees alone—the fruit, the leaves, the bark, the root. Some are due to bacteria; others to fungi; others appear to be functional. Some of these are limited to the United States, some to only parts of the States; others are more widespread. Many of them can be distinguished from others only by a botanist who is familiar with the disease-producing fungi or bacteria. Further, several of these diseases are outwardly similar to one another, and yet may be caused by quite different parasites. The use of such names as "black spot," "scab," and so on, does not necessarily mean that what is so named in America is identical with that so named in Australasia, and consequently a particular treatment which may be found useful in one part of the world is not necessarily beneficial in some other locality.

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†Keeble, "The Science of Botany and the Art of Intensive Cultivation" in "Science and the Nation," edited by Seward. 1917.

Until the attacking organism, be it fungus, bacterium, or insect, is tracked down, and its life history studied by a competent biologist, it is little more than a waste of time in many cases to guess at the cause of the disease.

Further still, some of the diseases, such as the apple rust, are due to a fungus which presents two distinct phases in its life history, in one of which it attacks the apple, in the other usually some other plant which need not be the same in all parts of the world, and which has to be sought for in each locality.

Again, there are various insects like the codlin moth and others which, as you are aware, do much damage to our apple trees when once they gain an entrance into the orchards. In Collinge's "Injurious Insects" I find he enumerates 29 insects which attack apples in England.

I was appalled at the list as enumerated in these two works, and I came to the conclusion that I would not touch so big a subject in any particularity.

"You must remember that," as Prof. Gregory† puts it, "every fly that troubles the agriculturist, every fungus that infests his plants, has to be studied laboriously by biologists specially trained in these particular matters before any accurate knowledge of its life history and its habits can be elucidated, and only then can means of suppression or amelioration be suggested. Whatever is known of the exact relation between cause and effect in all branches of agriculture, and whenever fact can be placed against opinion as regards the diseases of plants, the credit is found to belong to the scientific investigator, and not to the actual cultivator of the soil."

But I will refer to two diseases: "Bitter pit" and "Crown gall."

In the case of "bitter pit" I would remind you that the Australian Commonwealth Government appointed a well-skilled botanist to investigate the cause of the disease and to suggest a cure and prevention. Professor McAlpine, with other botanists, has been at work on this problem for some three or four years, and only now is he prepared to state how the disease arises and to propose remedies. From the reports that have been published from time to time‡ by Professor McAlpine, it is clear that this disease presents many complications. In the first place he has shown that it is not due to bacterium, nor to fungus, nor to the attacks of any insect or other animal, but that it is what is called a functional disease, and is due to some defect in the physiology of the plant. Many theories have been propounded to account for it, some of them founded on observation; others merely speculative. But from the later reports it appears to be due to the death of some of the pulp cells immediately below the skin, which is not ruptured, at any rate in early stages of the disease. In order to ascertain the probable cause McAlpine had first to make a more careful study of the anatomy of the apple fruit than had been hitherto done. He found that it is penetrated

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†Gregory, R. A., "Discovery: or, The Spirit and Service of Science" (Macmillan.

‡D. McAlpine. The Cause and Control of Bitter Pit. Government Printer, Melbourne.

by an immense number of extremely fine vessels which distribute the sap throughout the growing fruit, and that owing to the imperfection of some of these vessels near the skin there is not that proper co-ordination between the amount of water received by the apple from the tree and that removed by transpiration, so that extra pressure is exerted by the contents of the cells which then burst. He admits that he is not quite clear as to whether this is the effect or the cause of the disease.

The attacks of "bitter pit," he says, are most virulent where the sap flow and the transpiration are subject to violent alterations. Hence the disease is traceable in some degree to climate and in some degree to the variety of the apple.

I need not enter here into the various practical applications of his discoveries, but he notes that varieties vary considerably in their susceptibility to "bitter pit"; while some varieties are liable in one district, they are fairly free in others. The commercial varieties best suited to the district should be considered in planting out the orchard and a suitable site chosen.

Stated generally, excess must be avoided and moderation practised in the various orchard treatments, such as pruning, manuring, and irrigation. The object is to maintain as far as possible steady and uniform conditions of growth.

I will take the other disease, the "crown gall" or "hairy root."

Some time last year a consignment of young apple trees was received from Australia, but they were condemned in New Zealand by the Inspector of the Agricultural Department as being attacked by an infectious disease. The consignors and the Australian Agricultural Department were naturally annoyed at this. They contended that the disease "crown gall" is not infectious. And so representatives were sent over to try and convince our people that there would be no risk in allowing them to come into the Dominion. The Agricultural Department had recourse to the Professor of Bacteriology at the University of Otago, and cultures were made in his department and under his supervision. Subsequently, Mr Waters, who had studied biology under Professor Kirk at Victoria University College, and bacteriology under the guidance of Professor Champtaloup, took up the subject. He had been in communication with American plant pathologists and received cultures of the organism that is responsible for the "crown gall" for comparison with those in the imported plants. He established the fact that here too, as in America, the disease is infectious, that it will attack not only apple trees but other plants—that if the bacteria get into a wound the disease makes its appearance in a few weeks.

Incidentally, I may mention that while at Dunedin Mr. Waters has turned his attention to another important matter. He has been able to make cultures of the bacterium which constitutes the essential feature in the "starter" used in cheese-making. Hitherto, as you may be aware, these starters have been imported from Europe in the form of powders, and they have not always been quite satisfactory or reliable owing to the length of time they have been in stock and from other causes. But Mr. Waters has been providing the local dairy farmers with freshly prepared starters with very satisfactory results. In time, no doubt, the Government will be able to manufacture these starters and supply them throughout the Dominion, and thus provide our dairymen with more reliable cultures than those that they make for themselves from the imported powders.

THE NEED FOR RESEARCH.

I mention these facts in order to impress upon orchardists that there is no short cut to the making of important discoveries. The day of empiricism is or ought to be past, and no advance can be made in the diagnosis of disease or the finding of a remedy without more or less prolonged research.

The work of pure science is intimately related to industries of all kinds, and not least to agriculture. It is true that the man doing scientific work in the laboratory may not have sufficient acquaintance with the industry to see exactly the best way in which to employ his new-found knowledge, but the industrialist ought to be so educated as to be able to apply it for himself.

In a recent number of "Nature" I read an article on the "Organisation of Research in Agriculture,"* where a contrast is drawn between the encouragement given by Germany to research and that given by Britain, and I may add, by British colonies in general. It is not that German science is any better than that of British scientific men, or that more important discoveries have originated there, for, as we have seen, many valuable lines of investigation have been initiated in England, but the Germans have appreciated the value of scientific research to industries in a way that British people never have, till the present war has forced the Government to recognise the importance of employing scientific men to solve many of the difficulties met with by industrialists in their present needs. "The German people as a whole believe in the economic value of knowledge, respect the scientific method, are eager to give practical effect to the results attained by that method, and as a result are ready to submit their industries to scientific direction. It will avail us little to endow scientific research unless scientific knowledge is treated with greater deference than it has been in the past. The fond belief that scientific results can be ordered and paid for like goods and that the knowledge which gives these results birth has no continuing value must be abandoned if we set out to compete with the German in his own field."

As evidence of the hold which scientific work has gained on the German agriculturist, we have the remarkable fact that some years ago the German farmers and landowners raised a sum of one and a-half million pounds sterling which they presented to the Kaiser for the purpose of founding industrial and agricultural laboratories. The gross revenue of the agricultural research stations in Germany approaches £400,000; in England only £40,000; whereas in America it reaches one million pounds.

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*"The Organisation of Research in Agriculture"—in "Nature," Feb. 28, 1918, p. 507.

"Discoveries are not made by a stroke of a magician's wand. What the State or any Research Institute should provide for the scientific worker is the means of research. It should not impose methods or predetermined ideas, otherwise all initiative will be stifled."

Now I think that we in New Zealand may learn something from this article which I have here summarised. Mr. Cawthron has provided the means for research; and it is not sufficient to know what has been done as the result of previous researches. It is necessary. if orchardry is to improve to have really competent scientific men who are capable of initiating research, of adding to the already existing stock of knowledge, and these men must be left untrammelled by laymen, and allowed to pursue their investigations on their own lines, even if no immediate beneficial results are obtained. Merely to treat the fruit trees as they have been treated hitherto by some one else in some other part of the world is not going to lead to any real improvement in cultivation.

I am glad to hear that recently a body of New Zealand industrialists have come to recognise that it would pay them to employ science in certain difficulties that had met them in their work. The Flax-millers' Association and the owners of the Makerua flax swamp a few months ago requested Dr Leonard Cockayne, F.R.S., to investigate a certain diseased condition that had appeared in the flax plants. The value of this industry is somewhere about a million pounds annually, and it employs a large number of people. It seemed likely that this important industry would in a few years be wiped out unless something could be done to stop the disease. I do not know that he has finished the work, but I understand that he has satisfied himself as to the cause of the disease, and no doubt his observations and experiments will have beneficial results. It is, I believe, the first time that any extensive industry in New Zealand has called in the aid of the scientific man to solve its difficulties. Yet surely an industry of this monetary value was wise to expend a few pounds in getting scientific advice. This is the kind of thing that the orchardists might do, even if it is at present impossible to build and equip the Cawthron Institute. Let them band themselves together and employ men trained in scientific method in order to overcome the troubles that some of them suffer from.

To use Bordeaux mixture or some other fungicide for every sort of fungoid pest is good enough for small farmers who can carry out the excellent instructions given by the experts of the Agricultural Department, but the aim of the Research Institute should be something more than this—to find out the life history of each particular pest which in this particular district attacks this or that particular variety of apple or other fruit tree, whether it be the leaves, the bark or the fruit—to track it down and find out in this way what means can be devised to put a stop to its development before it attacks any more trees. "Prevention is better than cure" is an old adage with much truth in it.

There is here any amount of work and abundant opportunity for a well-trained, and by that I mean a scientifically-trained, plant pathologist to work out the whole life history of each fungus. Much is being done in America and France; very little has been done in New Zealand. The conditions here are different from those in America or Britain, the diseases are different; the remedy obtained elsewhere can only be a guide to us here; but it is part of the work of the scientifically trained man to know what has been done elsewhere before he begins to work, and then to improve the method.

As I have attempted to show you, the knowledge that we have to-day on which depends a proper system of manuring, and the same could be said of cultivation in general, is the result of the experiments of many farmers, agriculturists and scientific men. It has occupied the close attention of men trained in the scientific method, not for a month or two, but for years. That is why the commission on which I had the honour to sit offered the advice to the Trustees of the Cawthron Institute to proceed slowly, and see to it that the Director should be a first-class man, trained to deal with the various chemical aspects of agriculture, with experience gained at one or other of the large Institutes in Britain or America; then to appoint an equally well-trained plant pathologist to investigate the diseases, to find out their cause and to initiate experiments as to their prevention.

WORK FOR THE INSTITUTE.

It will be seen that much of our present day knowledge on manuring is the result of long-continued experiments in soil biology, carried out in the first place by Englishmen. Much remains to be done, and there is a fruitful line of work for the Cawthron Institute. There is plenty of room for research conducted on scientific lines on the matters referred to in Mr. Allport's report to the trustees, which is included in the report of the commission.

There is need for systematic experiments on the efficiency of different kinds of sprays on different kinds of trees, both as to strength to be used and the proper time to use them, as well as the effect of the sprays on the health of the trees. No systematic record appears to have been published on such matters as these. Then we ought to have experiments to decide what are the most suitable stocks upon which to propagate the apple trees, and to endeavour to find such a stock and variety as would be immune from different types of disease. The most productive methods of pruning, too, and the most suitable and economic methods of manuring, should be investigated.

Amongst other matters that ought to receive attention are:—

(1.) A thorough soil survey, the investigation of the chemistry, physics and biology of the soil, and especially of the humus and its effect on plant growth, of which little is as yet known.

(2.) An extended programme of investigation of the diseases that attack our plants and especially those that are injurious to the fruit tree.

These are a few of the lines of research, which in the near future should occupy the attention of the Cawthron Institute.

R. W. STILES & CO., PRINTERS, WAIMEA STREET, NELSON.

CAWTHRON LECTURE

1919.

The Distribution of the Vegetation and Flora of New Zealand.

BY

L. COCKAYNE, Ph.D., F.L.S., F.R.S.

CONTENTS.

LECTURE III.

THE DISTRIBUTION OF THE VEGETATION AND FLORA OF NEW ZEALAND.

By L. COCKAYNE, PH.D., F.L.S., F.N.Z.INST., F.R.S.

1.—GENERAL REMARKS.

The vegetation of New Zealand composed, as it is, of numerous plant-associations varying in their characteristics from subtropical to subantarctic and from hygrophytic to intensely xerophytic, together with the species of diverse origin (Palaeozelandic[1], Malayan—including Polynesian—Australian and Fuegian[2]), offers excellent material for studies in plant-distribution which should be of general phytogeographical interest. Such studies, too, are simplified by the comparatively small flora (about 1830 species of vascular plants) to be dealt with, the somewhat less extreme complexity of the ecological factors than that which botanical regions with an equally diverse vegetation afford, and the clear-cut effect on distribution over a wide area of a sudden change in the rainfall.

It need hardly be pointed out, that in the brief time allowed by a lecture, only a quite incomplete sketch of the subject under consideration can be presented, though it should be possible to portray some of the more striking features of New Zealand plant-distribution.

The New Zealand Botanical Region includes not only New Zealand proper (North Island, South Island, Stewart Island, and the islets adjacent to these) but also the Kermadec Islands, the Chatham Islands and the New Zealand Subantarctic Islands, thus extending from lat. 29deg. 15min. S. to lat. 54deg. 30min. S. (Macquarie Island). In this lecture, however, excepting when illustrating certain points, distribution in New Zealand proper is alone dealt with.

Regarding the available material from which this lecture is prepared, it might be objected that such is inadequate. New Zealand, it may be argued, is far from being fully explored botanically, so that the actual distribution of many species cannot be known; while, as so much of the primitive vegetation is modified, or destroyed, it must be impossible to picture accurately its primeval physiognomy and composition, or to trace its distribution. Such objections are valid only to a minor degree. It is true that much remains to be accomplished before a full list of specific forms and complete details of their distribution

1. For explanation of this term see L. Cockayne, "New Zealand Plants and their Story," 2nd Edition, 1919, p. 205.

2. This is the Subantarctic South American element, but here called "Fuegian" in order to avoid confusion with the New Zealand Subantarctic flora.

are available; but, during the past fifteen years, that is, since the publication of Cheeseman's "Manual of the New Zealand Flora," there has been unparalleled botanical activity in the Dominion. Many new species have been discovered and much has been added to the knowledge already existing regarding the distribution of the older species; nevertheless, this recent knowledge has been rather in the direction of confirming the older ideas than of disproving them. It may, indeed, be asserted that, for all practical purposes, the present knowledge of the distribution of New Zealand vascular plants is sufficiently accurate to permit the establishing of reliable conclusions on certain fundamental points.

With regard to its vegetation, New Zealand has been singularly fortunate in having had from the earliest days of settlement, when virtually all the plant-covering was primitive, a number of ardent naturalists, who, if not supplying a picture of the vegetation from the modern ecological standpoint, have given such indications of its nature as to permit anyone versed in the subject to read between the lines. Still, this would have been inadequate were it not that numerous areas, large and small, of virgin vegetation stand unmolested in all the plant-geographical districts; or, where modified, many are not yet so seriously damaged as to have effaced the primeval stamp. In the South Island, more especially, there are extremely extensive tracts still truly virgin, but at present unsuitable for settlement; while, in all parts of the Botanical Region, numerous reserves, some of great extent, have been set aside as sanctuaries for the indigenous plants and animals. Second in importance to none of such sanctuaries is the late Mr. Cawthron's splendid gift to Nelson and to the people of New Zealand—the "Cawthron Park" (see Fig. 1.) Other reserves may, in course of time, be alienated, or interfered with, but the Cawthron Park can never be turned from the object for which it was set aside by its far-sighted founder. Never should plant or animal foreign to its precincts be permitted to desecrate its sanctity. Through the long years it should remain, as its founder intended, a living monument builded by Nature and by Her alone to be maintained it all its pristine beauty!

The study of plant-distribution is two-sided. First of all comes the comparatively easy task of noting and recording the facts of distribution; while, in the second place, is the vastly more difficult matter of referring such facts to their causes. Here comes in the estimation of the effect of those two complexes of ecological factors, climate and soil. Then, too, there are the biotic factors, i.e., the relation of the living organisms—plant and animal—to one another, and their effect upon the habitat of the plant-association as a whole, or upon the various growing-places of its members. Then there are the historical factors to consider, dealing with the histories of the species and the geological history of the area they occupy. No particular section of this lecture is devoted to these questions of ecological and historical factors, highly important though they be, still

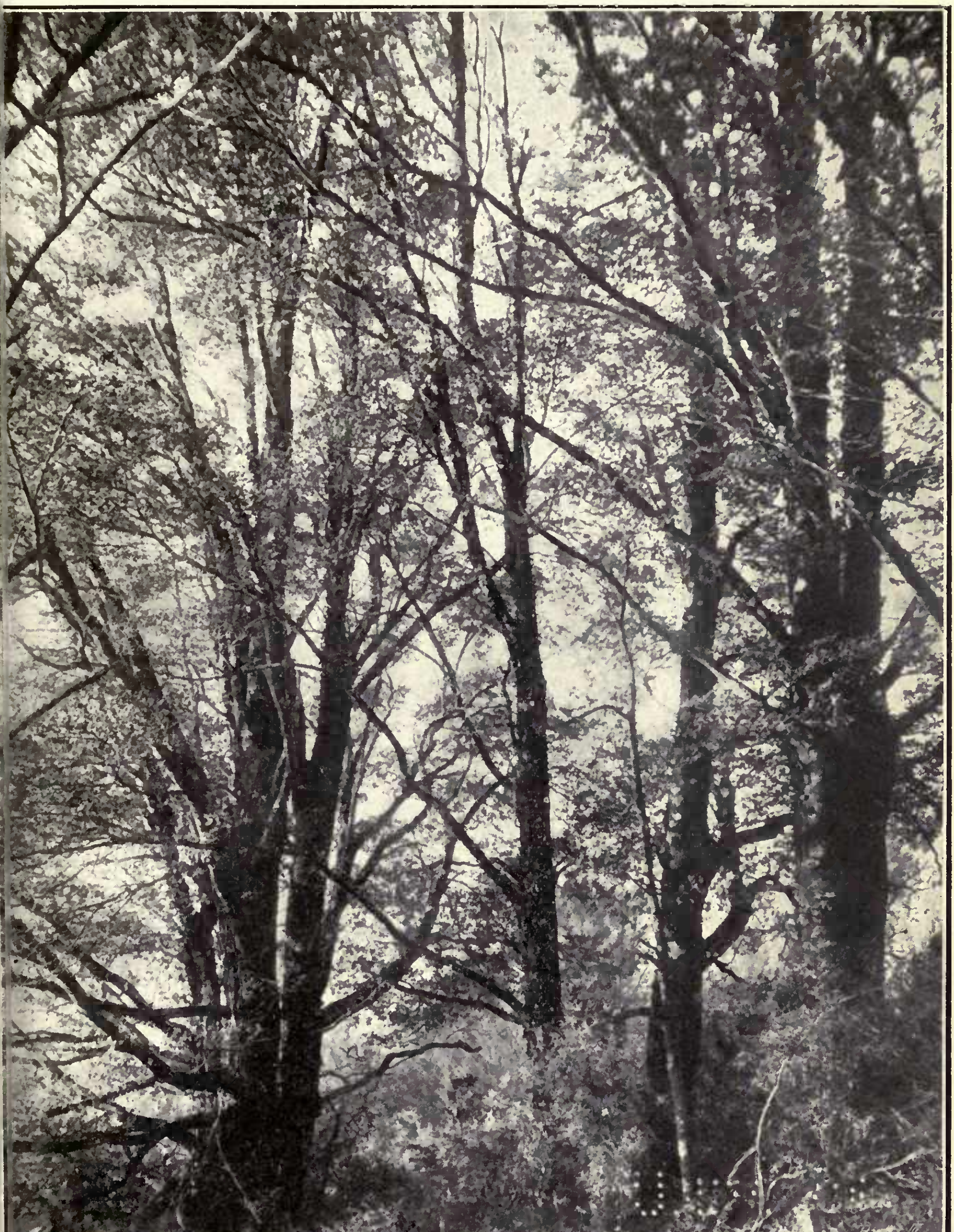

Photo., W. C. Davies.

FIG. 1: View of piece of southern-beech (*Nothofagus*) forest in Cawthron Park.

they are not entirely neglected, but receive some consideration when certain cases of distribution are discussed.

Generally in researches dealing with phytogeographical distribution, the vegetation receives no consideration, the distribution of the species being alone the theme. Such treatment of the subject is not on natural lines. The species are the ultimate units of the vegetation, and its distribution includes that of the species. Once a species has become a member of one or more plant-associations, its movements are apparently governed by those of the associations to which it belongs. The dynamics of plant-distribution, except before an association is stabilized, is not a moving of individual species, but of plant-associations. Once an association has become stable, it can receive only with the most extreme difficulty additional species from elsewhere. The gradual evolution of the association has led to rigorous selection and the final product is perhaps the most epharmonic that the species available would permit. For one hundred years, or thereabouts, a gradually increasing band of plant-immigrants has attempted to gain a footing in the virgin associations of New Zealand, and yet, despite the many millions of seeds cast forth yearly, not one introduced plant has been able to gain a place in any purely virgin plant-association, if certain water and rock associations be excepted. Foreign plants there are in profusion growing wild throughout the length and breadth of the islands along with the indigenous species, but this is only in those plant-associations which have been directly or indirectly modified or brought into existence by the action of man himself, his grazing animals, or his fires[3].

As this lecture treats of plant-distribution in New Zealand it might well be expected that I should say something regarding Willis's "Age and Area Theory," since that distinguished author bases it to no small extent on the distribution of the vascular plants of New Zealand[4]. However, at the present time, I have not the leisure to deal with that important generalization, since, apart from special crticisms, I should like to examine it by means of a quite different set of figures from those used by Willis which would take into consideration not merely latitudinal distribution in one plane, but would deal also with vertical distribution and distribution according to the plant-formations, or even the clearly marked plant-associations. Nor do I think that the distribution of the high-mountain plants—a flora, as may be seen further on, amply distinct from those of the lowlands and sea-coast—can be treated along with the two last-mentioned floras. The flora of the high-mountains is essentially a South Island and Stewart Island matter, for the paucity of the North

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3. For a detailed account of the behaviour of the introduced plants in New Zealand see Cockayne, L., "New Zealand Plants and their Story," Ed. 2, 1919, pp. 144–158.

4. Willis, J. C., "The Distribution of Species in New Zealand," Ann. Bot., vol. xxx, 1916, pp. 437–57, together with other papers on New Zealand distribution which have appeared in the same journal at later dates.

Island high-mountain flora is probably due—as pointed out later—rather to there being so little space above the forest line for its development than to any other cause. Also it cannot extend further north than the Thames Mountains, these being the final heights suitable for occupation by other than forest plants, while on them it is the wind factor alone which has rendered the small high-mountain element possible. Other statements and facts appear in the body of this lecture which have an obvious bearing on Willis's work, but I am purposely not calling attention to their import. To Dr. J. C. Willis, F.R.S., as he has pointed out[5], I wrote some time ago at considerable length regarding his theory, and he has done me the honour in referring to this letter to state that my suggestions and criticisms will receive consideration in his further papers on New Zealand

Before concluding these general remarks, I must express my thanks to Mr. W. C. Davies, Curator, Cawthron Institute, for valuable assistance in preparing the photographs for publication and to Mr. F. G. Gibbs, M.A., whose untiring labours have thrown a flood of light upon the distribution of the Nelson flora.

2.—THE NATURAL FLORISTIC AND ECOLOGICAL DIVISIONS.

(a) The Coastal, Lowland and High-Mountain Floras.

From the standpoint of distribution it is not satisfactory to deal with either the flora or vegetation of New Zealand as a whole, since both may naturally be divided into three groups, virtually independent of one another—the coastal, the lowland and the high-mountain—each of which possesses a large percentage of species, associations, and to some extent growth-forms, wanting in the other two groups. There are also a considerable number of generic and some family distinctions.

(1) The Coastal Flora.

The coastal flora consists of about 144 species which are confined to the coast-line, or its immediate neighbourhood; also some 46 species which occur inland to a limited extent are virtually coastal. Eight families and 35 genera are confined, or almost so, to the coast-line. Possibly about 100 species occur both inland and on the coast, some of which ascend far into the high mountains, e.g., *Aciphylla squarrosa*[6], *Celmisia Lindsayi* (see Figs. 2 and 3), *Claytonia australasica, Dracophyllum longifolium, Gunnera albocarpa, Netera Balfouriana, Metrosideros lucida, Olearia Colensoi, O. Fosteri*[7], *O. insignis, Phormium Colensoi, Raoulia australis var., R. apice-nigra, Scirpus aucklandicus, Senecio lagopus var.*, and *S. Monroi.*

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5. "The Flora of Stewart Island (New Zealand): A Study in Taxonomic Distribution," Ann. Bot., vol. xxxiii, 1919, p. 42.

6. None of the lists in this article aim at completeness.

7. This species ascends to about 4000ft. altitude in the Inland Kaikoura Mountains.

Photo., L. Cockayne.

Fig. 2: *Celmisia Lindsayi* growing on rock-face, Nugget Point (South Otago Bot. District); in left-hand corner is *Poa Astoni.*

Photo., L. Cockayne.

FIG. 3: Close View of Mat of *Celmisia Lindsayi* at Nugget Point (South Otago Bot. District).

The principal ecological factor determining the presence of true coastal species is an excess of salt in the soil above that which ordinary inland plants can tolerate. Thus the plants of salt-swamp, salt-meadow, seashore, and rocks exposed to sea spray are mostly actual coastal species, e.g., *Arthropodium cirratum, Atriplex Billardieri, Atropis stricta, Avicennia officinalis, Carex litorosa, Crassula moschata, Mesembryanthemum australe, Mimulus repens, Rumex neglectus, Salicornia australis, Sonchus littoralis, Suaeda maritima.* But the following characteristic coastal, salt-tolerating species occur in one or more localities far inland: *Eryngium vesiculosum, Juncus maritimus var. australiensis, Leptocarpus simplex, Scirpus americanus, Selliera radicans, Triglochin striatum var. filifolium, Apium filiforme* and *Samolus repens var. procumbens.*

The comparatively mild climate of the coast as compared with that further inland is responsible in part, at any rate, for the presence of species which cannot tolerate much frost. To this category the following probably belong: *Avicennia officinalis, Coprosma Kirkii, C. retusa (C. Baueri* of the Manual), *Corynocarpus laevigata, Dodonaea viscosa* (in the southern part of its range), *Dysoxylum spectabile* (in the southern part of its range), *Entelea arborescens, Hymenanthera novae-zelandiae, Macropiper excelsum* (in the southern part of its range), *Myoporum laetum* (in the southern part of its range), *Olea apetala, Paratrophis opaca, Pisonia Brunoniana, and Sideroxylon novo-zelandicum.*

Moving dunes present uncommon conditions demanding special growth-forms for their plant inhabitants and such swell the list of purely coastal plants. There are the major sand-binders:—*Scirpus frondosus, Spinifex hirsutus* and *Euphorbia glauca;* the minor sand-binders, *Calystegia Soldanella* and *Carex pumila;* and the sand-collectors, *Cassinia retorta, Coprosma acerosa, Pimelea arenaria* and *P. Lyallii*[8], this also a sand-binder to some extent.

There are many different coastal plant-associations besides those already mentioned, some of which (forest and shrub associations) are dealt with when treating of distribution in regard to latitude.

(2) The Lowland Flora.

The lowland flora (including in this term the flora of the lower parts of the mountains up to 2000ft. altitude as an average) contains about 1009 species, of which some 517 are purely lowland, 350 (many extremely common) also belong to the high mountains, 100 are virtually high-mountain plants but they occur in the lowlands under special circumstances, and 42 are

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8. Here the view is taken that the name *Pimelea Lyallii* be restricted to the sand-hill plant of the South Otago and Stewart Districts and that the high-mountain plants formerly referred to this species fall into one or more unnamed species, excluding the bushy shrub of Central Otago which I am naming elsewhere *Pimelea aridula.*

usually coastal. No less than 15 families and 93 genera are confined to this lowland-lower mountain belt.

The following are the families confined to the area under consideration:—*Amaryllidaceae, Elatinaceae, Gesneriaceae, Icacinaceae, Oleaceae, Lauraceae, Lemnaceae, Meliaceae, Monimiaceae, Palmae, Pandanaceae, Passifloraceae, Rutaceae, Salviniaceae*, and *Sparganiaceae*. Nine of these families have only one species each, and none have more than four species. Much more important than any of the above in the lowland flora are the following:—*Filices* (85 species), *Cyperaceae* (46 species), *Orchidaceae* (45 species), *Compositae* (41 species), *Rubiaceae* (19 species), *Gramineae* and *Scrophulariaceae* (16 species), and *Myrtaceae* (13 species).

Coming next to the plant-formations, the most important are forest and grassland. Their distribution receives some attention under another head. Shrubland, swamp and bog are also important ecological groups. At the present time there is abundant *Pteridium* (bracken-fern) heath, but how much of it is primitive no one can say, for it is readily induced by burning forest and certain classes of scrub.

(3) The High-Mountain Flora.

The high-mountain flora differs to an astonishing degree from that of the lowlands. It contains in all some 950 species. If about 100 species which occur in the lowlands only under special conditions be added to the purely high-mountain plants, this element of the New Zealand flora will number about 600 species.. The following 15 genera (7 endemic) are essentially high-mountain:—*Corallospartium* (end.) *Exocarpus, Forstera, Haastia* (end.), *Hectorella* (end.) *Logania*[9] *Leucogenes* (end.), *Marsippospermum, Mitrasacme, Notothlaspi* (end.) *Pachycladon* (end.) *Pernettya, Phyllachne, Swainsona* and *Traversia* (end.). In addition to the above, 32 genera, most characteristic of the high mountains, possess far more high-mountain than lowland species. The most important of such genera from the physiognomic standpoint are the following:—*Acaena, Aciphylla, Anisotome, Celmisia, Danthonia, Dracophyllum, Epilobium, Gentiana, Helichrysum, Olearia, Ourisia, Raoulia, Ranunculus* and *Veronica*.

The headquarters of the high-mountain flora is in the South Island, to which more than 70 per cent. of the species are confined. This is probably due in part to the fact that the mountain-area of the South Island is far more extensive than that of the North Island, owing partly to the far fewer and lower mountains of the latter and partly to the forest ascending higher. Thus Mount Egmont with its small area for plants above the forest-line has at most 100 species as compared with the 150 species of the more extensive high-mountain area of the

9. Through a slip in my book, "New Zealand Plants and their Story," the family *Loganiaceae* is stated to be purely high-mountain, but it includes the strictly lowland genus *Geniostoma*.

Photo., F. G. Gibbs.

FIG. 4: Wide breadth of *Celmisia Traversii* growing in the lower sub-alpine belt of Mount Arthur.

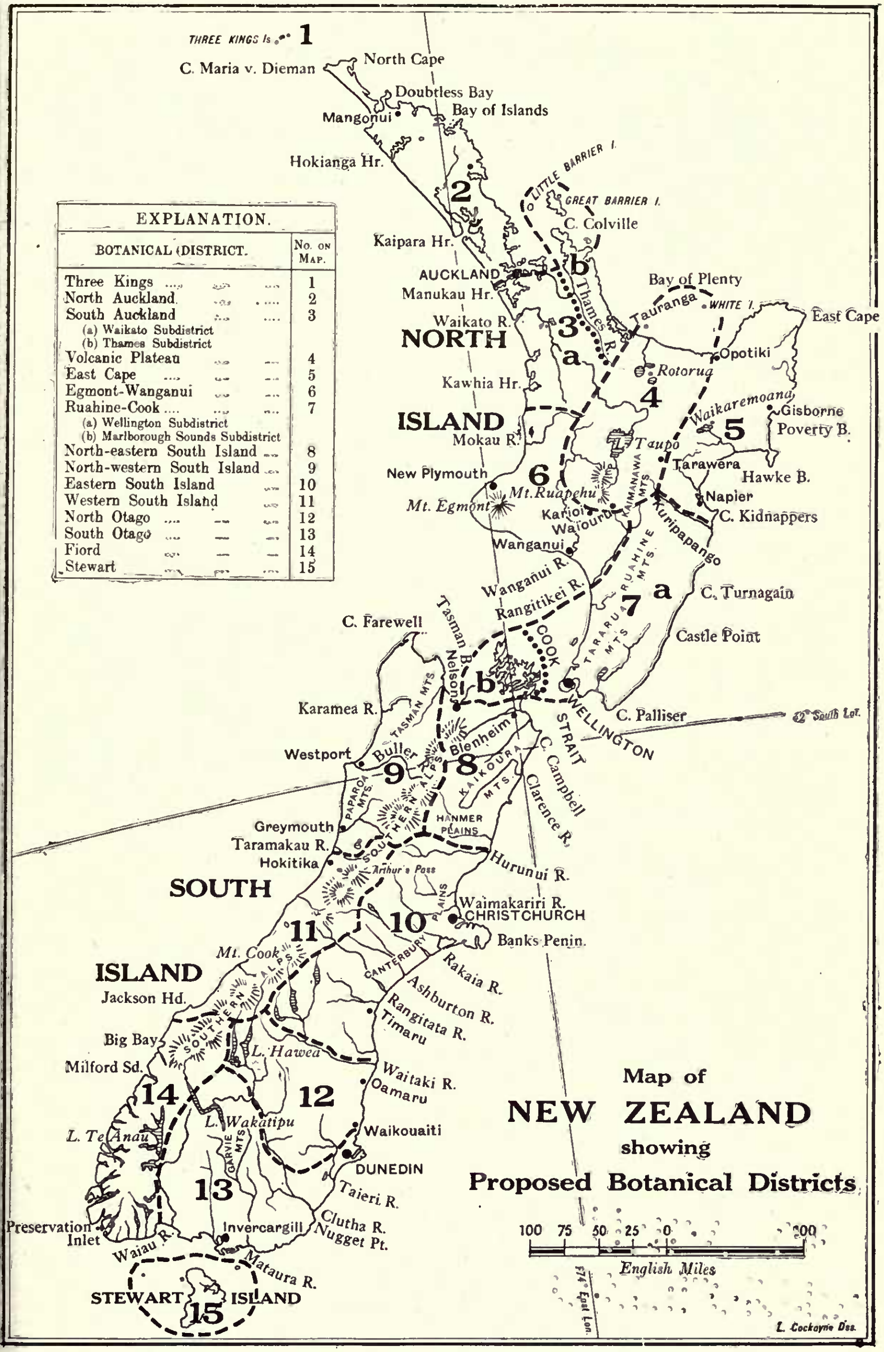

Fig. 5 : Map of the Botanical Districts of the main islands of New Zealand.
From Trans. N.Z. Inst.

Volcanic Plateau, or the 140 species of the Tararua Mountains. But these last figures are not so strikingly different when the isolation of Mt. Egmont and the difficulties in its original plant-colonization be considered. There may be an additional reason for the poverty of the North Island high-mountain flora. This may be that a large percentage of the South Island high-mountain species is quite young—a conclusion warranted by their affinities and also by their extreme polymorphy.

The vegetation of the high mountains differs greatly according to their rainfall—a point stressed later. The forests are largely made up of species of *Nothofagus,* but there are also associations where *Libocedrus Bidwillii* and *Podocarpus Hallii* dominate. In herb-field and fell-field the genus *Celmisia* is represented by many species and growth-forms (see Fig. 4). There are considerable areas of tussock-grassland, which on the schist mountains may ascend to the highest summits, whereas the readily-weathered greywacke mountains present great diversity in their rock, debris and fell-field associations. Under certain circumstances subalpine-scrub made up of shrubby *Compositae, Epacridaceae, Rubiaceae,* and species of *Veronica* is a remarkable feature, and it may become actual forest. At high altitudes the cushion-form is often greatly in evidence; it is also encouraged by dry stations.. The property of dead leaves and other vegetative parts remaining attached to the living plant in a wet, semi-peaty condition is a fairly frequent characteristic of the high-mountain plants. So, too, strong xerophily is common.

(b) The Botanical Subdivisions of the New Zealand Region.

The Botanical Districts as proposed by me in 1917 are shown on the map (Fig. 5). These districts, it must be clearly understood, are provisional only. and, to quote from my article where they first appeared, "will be subject to considerable modification for years to come."[10]

There is no need here to define the boundaries of these districts, nor to cite their names since both are shown on the map. Nor am I giving the characters of each district, including the lists of locally-endemic species. These matters are briefly dealt with in the second edition of "New Zealand Plants and Their Story," p. 180—p. 194, and to this the reader is referred. Here only certain critical remarks are made regarding the boundaries of certain of the districts. First of all, however, the principles upon which the delimiting of the districts was based, may be quoted from the original article (loc. cit.). "In the delimiting of a 'district' an attempt has been made to mark off natural areas which are distinguished principally by the following circumstances—some floristic (these the most important, since the districts are essentially floristic), some ecological: (1) The presence of a more or less extensive locally

10. Cockayne, L., "Notes on New Zealand Floristic Botany, including Descriptions of New Species, etc." (No. 2). Trans. N.Z. Inst., vol. xlix, 1917, p. 62.

endemic element; (2) the absence of species more or less characteristic of adjacent botanical districts; (3) the presence of species of restricted distribution elsewhere; (4) the presence in abundance of widespread species much rarer elsewhere; (5) the relative abundance of the various species comprising the florula; (6) the general physiognomy of the vegetation; (7) the presence of special characteristic plant-associations; (8) the differences in widespread plant-formations; (9) the agriculture, horticulture, and introduced plants of the proposed area."

As pointed out in the original article, the "actual boundaries of many of the districts are extremely hard to fix and in no few cases must always be artificial." This leads up to an inquiry as to how far, based on four years' trial of these districts, supplemented by a good deal of field-work in the South Island, the boundaries, etc., of these districts should be modified.

Taking the North Island first of all, it is a moot point whether or not latitude 36deg. S., a most critical point, as explained later, should not be made a boundary-line and the area to the north be constituted either a district or a subdistrict. As for the boundary of the South Auckland District the Mokau River would probably be more natural than that shown on the map. The Volcanic Plateau and East Cape Districts seem natural enough, but their limits require extended study in the field. Probably the southern boundary of the East Cape District should be moved further to the south. The southern part of the North Island offers exceptional difficulties. It cannot be right to treat it as one district, and yet, according to the present arrangement, the Egmont-Wanganui district is based chiefly on negative characters and on the vegetation rather than the flora. A far more exhaustive botanical survey of the whole area, especially west of the Tararua—Ruahine Mountains, is required and many local lists of species must be compiled, and descriptions of the plant-associations writtten, before enough material is available for comparative purposes.

Coming now to the South Island, the southern boundary of the Marlborough Sounds subdistrict is unsatisfactory. The Wairau river forms the natural boundary between the forested area of the north and the tussock-grassland of the south. But here comes in a great difficulty. That is, what is to be done with the high-mountain vegetation of the Dun Mountain and the mountains drained by the R. Pelorus and the R. Wairau from Mt. Patriarch eastwards. Their flora cannot possibly be united with that of the Tararua Mountains, and it is not really a part of that of the North-eastern Botanical District proper, neither can it be united to the high-mountain flora of the North-western Botanical District. On the other hand, the lowland flora, as bounded by the Wairau River, might quite well come into the Marlborough Sounds Subdistrict. This critical matter is one for Nelson botanists to investigate, and its solution could well be undertaken by the Cawthron Institute. The North-western and North-eastern Botanical Districts are well-marked, as may be seen from the lists given under another head, but their southern and their common boundaries require exhaustive study. The same criticism is even more true for the Eastern and Western Districts. Probably the Mackenzie Plains and some of the area adjacent thereto should be added to the North Otago Botanical District. The position of Banks Peninsula is somewhat doubtful. Laing[11] would include it with the North-eastern District on account of its forest-flora resembling that of the Seaward Kaikoura Mountains rather than that of the foot-hills of the Canterbury Plain. But it must not be forgotten that *Nothofagus* is an important genus in the upper part of the Kaikoura forest and that the general construction of the latter forest is not similar to that of Banks Peninsula, while the Kaikoura forest contains some species absent on Banks Peninsula, notably: *Astelia Solandri, Melicope ternata,* × *M. Ralphii* and *Metrosideros scandens.* Also the *Podocarpus dacrydioides* forest of the Canterbury Plain is similar to that of Banks Peninsula. Be the above as it may, Banks Peninsula should be distinguished from the Eastern Botanical District in general, and made into a subdistrict distinguished by its forest; its local endemism of *Anisotome* sp. near *A. Enysii, Celmisia Mackaui, Senecio saxifragoides, Veronica Lavaudiana* and *V. leiophylla* var. *strictissima*[12]; its being the southern limit on the east of a number of northern New Zealand plants; its luxuriant fields of *Dactylis glomerata* harvested for seed and its mild climate allowing the cultivation of many garden-plants not hardy in the Eastern Botanical District generally.

3.—SOME OUTSTANDING FEATURES OF PLANT-DISTRIBUTION IN NEW ZEALAND.

(a) Cook Strait not a Barrier to Plant-distribution.

At first thought it would seem that Cook Strait would have been a barrier to the movements of species, and that the flora and vegetation on its opposite sides would be strikingly dissimilar. So little is this the case, as far as the coastal and lowland vegetation are concerned, that the associations of these areas present no differences of moment. The lowland *Nothofagus* forest in the vicinity of the Marlborough Sounds, and near the City of Nelson, strongly resembles that of the eastern side of the Hutt Valley (Wellington). The forest-floras in general are almost identical. To come to a few details: the shore veronica of both areas is *Veronica salicifolia* var. *Atkinsonii; Hymenanthera obovata* of coastal rocks occurs on both sides of the Strait and also on Kapiti Island; *Phormium Colensoi* is common on rocks near Island Bay (Wellington) and in a similar situation at Queen Charlotte Sound; *Cassinia leptophylla*

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11. "The Vegetation of Banks Peninsula, with a List of Species (Flowering-plants and Ferns)." Trans. N.Z. Inst., vol. li, 1919, p. 370.

12. *V. leiophylla* Cheesem. var. *strictissima* (Kirk), Cockayne comb. nov.= *V. parviflora* Vahl var. *strictissima*, Kirk in Trans. N.Z. Inst., 28 (1896), 527.

becomes a bad weed in both areas after forest is destroyed (see Fig. 6); *Dysoxylum* coastal-forest is a well-marked feature; *Muehlenbeckia Astoni*—a plant of extremely limited distribution —occurs at the mouth of the R. Ongaonga (Wellington) and near the mouths of the Awatere and Flaxbourne Rivers (Marlborough); finally, the introduced *Glaucium flavum* occurs on shingly beaches on the northern shores of Cook Strait and at the mouth of the Awatere. To be sure there are some differences of minor importance One of some moment, however, may be cited. This is the abundance of *Arthropodium cirratum* on coastal rocks in the Marlborough Sounds; in the North Island, I do not know of its occurrence except in the Auckland Botanical Districts. Other localities for this species are Stephen's Island (Cook Strait), Takaka and West Wanganui Inlet (Nelson).

Against all that has just been said, it may be urged that Cook Strait has proved a formidable barrier for the high-mountain plants to overcome as proved by the much smaller high-mountain flora of the North Island. But I may again point out that the poverty of this flora is due in part, at any rate, to the limited space available for alpine and subalpine plants in the North Island. Certain common North Island subalpine plants are present, however, only on the Nelson mountains, but do not extend further south. Such are *Celmisia hieracifolia, Leucogenes Leontopodium, Ranunculus insignis* (see Fig. 8), *R. geraniifolius* and *Senecio Adamsii.* To these may perhaps be added *Senecio elaeagnifolius* var. *Buchanani* which occurs on Mount Stokes (Marlborough Sounds) and *Ourisia macrophylla* which extends south as far as the Seaward Kaikoura and Hanmer Plains mountains. The North Island high-mountain flora consists of about 175 species and of these about 142 are also South Island species. Probably for a long period North and South Island mountains have been separated by forest, so that the settlement upon a North Island mountain of a species coming from the south would be a matter of difficulty.

(b) The relation of latitude to distribution.

(1) General.

New Zealand proper extending, as it does from about latitude 34deg. S. to about latitude 47deg. S., offers an excellent example of the effect of change of temperature upon the distribution of the lowland-coastal flora and vegetation. It will be seen from what follows that near certain parallels of latitude there are critical belts on, or near which, species more or less common further north come to a halt. This does not say that such species could not exist further to the south. On the contrary, cultivation has proved that many of them are hardy in gardens, etc., far to the south of their natural area of distribution. The kauri *(Agathis australis)*, the puriri *(Vitex lucens)*, the nao *(Colensoa physaloides)* and the puka *(Meryta Sinclairii)* are cases in point. Nevertheless, it is well-known that many—

Photo., L. Cockayne.

Fig. 6: *Cassinia leptophylla* Scrub, a weed-association in the neighbourhood of Cook Strait.

perhaps most—species of New Zealand vascular plants, even those of the high mountains, will only tolerate a comparatively small amount of frost, while not a few, even where they grow wild, are very near their frost-tolerating limit. It may be asserted then, with some degree of confidence, that the climate of these latitudinal boundary-lines, dealt with below, represents the minimum heat-requirement of the species which have their southern limit of distribution in their vicinity. In certain cases this is most likely not the sole deciding factor, but each species would require to be dealt with on its merits. Nor must it be forgotten that the species forming an association are subject to competition and that this also helps to decide what is the minimum heat-requirement. The critical parallels of latitude are, 36deg.S., 38deg.S., and 42deg.S. This latitudinal distribution concerns only the lowland-coastal flora, the distribution of the high-mountain flora is a more complex matter, for a greater variety of ecological factors is concerned, while the heat-factor is equalized at different latitudes by the gradual lowering in altitude of the various vertical belts of distribution in proceeding from north to south. In other words, latitude plays a far smaller part with regard to the high-mountain flora than it does with that of the coast or the lowlands. There is probably no high-mountain plant that, given its other ecological requirements, especially its water requirement, could not flourish on any New Zealand mountain irrespective of latitude, but, in the lowlands some can grow only under special conditions. This is well-known to the cultivator of New Zealand alpine plants who can grow some with the greatest ease and others with extreme difficulty, while some apparently are impossible to cultivate at all.

(2) LATITUDE 36°S. AS A PHYTOGEOGRAPHICAL BARRIER.

A considerable number of species occur only to the north of lat. 36deg.S.; and, as some of these are restricted to the far north of the island and others do not nearly reach the above parallel, this is not so much a "barrier" as a dividing line between two phytogeographical divisions. This was originally pointed out by Colenso in his classical essay[13] written so early as 1865, and he distinguished north of that latitude two botanical areas, namely, "The Northern Area" (34deg.S. to 35deg.S.) and "The Bay of Islands area" (35deg.S. to 36 deg.S.). The following is a list of the species:—(Lycopodiaceae) *Lycopodium Drummondii;* (Filices) *Asplenium japonicum, Todaea barbara;* (Gramineae) *Microlaena Carsei;* (Cyperaceae) *Cladium complanatum, Lepidosperma filiforme;* (Centrolepidaceae) *Hydatella inconspicua;* (Orchidaceae)[14] *Thelymitra intermedia,*

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13. On the Geographic and Economic Botany of the North Island of New Zealand. Trans. N.Z. Inst., vol. i, 2nd Ed., pp. 233-283, 1876 (written for the New Zealand Exhibition, 1865, and published in the 1st Ed. of the Trans. N.Z. Inst in 1870).

14. When the distribution of the terrestrial orchids of New Zealand is better known, doubtless some of the orchids listed here will be found to have a wider range.

T. Matthewsii, Caladenia exigua, Chiloglottis formicifera, Corysanthes Matthewsii, C. Carsei; (Piperaceae) *Macropiper excelsum* var. *major* on the Poor Knights Islands; (Loranthaceae) *Phrygilanthus Raoulii;* (Lauraceae) *Cassytha paniculata;* (Crassulaceae) *Crassula pusilla;* (Pittosporaceae) *Pittosporum pimeleoides* vars. *major and reflexum;* (Cunoniaceae) *Ackama rosaefolia;* (Malvaceae) *Hibiscus diversifolius,* (Halorrhagaceae) *Halorrhagis cartilaginea, H. incana;* (Araliaceae) *Pseudopanax Gilliesiana;* (Cornaceae) *Corokia Cheesemanii;* (Epacridaceae) *Leucopogon Richei*—also on the Chatham Islands; (Loganiaceae) *Geniostoma ligustrifolium* var. *crassum;* (Scrophulariaceae) *Veronica speciosa* var. *brevifolia, V. Bollonsii*—on the Poor Knights Islands; *V. ligustrifolia, V. acutiflora;* (Rubiaceae) *Coprosma neglecta;* (Campanulaceae) *Colensoa physaloides*—also on the Three Kings Islands; (Compositae) ; *Lagenophora pinnatifida* var. *tenuifolia, Olearia angulata; Celmisia Adamsii* var. *rugulosa*—hardly a case in point; *Cassina amoena.*

(3) Latitude 38° S. as a phytogeographical barrier.

Some 56 species of which 45 are common, or fairly common plants, either do not quite reach latitude 38deg.S., or go beyond it only for a comparatively short distance. The following is a list of the species:—(Filices) *Pteris comans, Lygodium articulatum,* (Lycopodiaceae) *Phylloglossum Drummondii, Lycopodium densum, Psilotum triquetrum;* (Taxaceae) *Phyllocladus glaucus;* (Pinaceae) *Libocedrus Doniana, Agathis australis;* (Gramineae) *Paspalum scrobiculatum, P. distichum, Stipa teretifolia;* (Cyperaceae) *Schoenus Carsei, Cladium Huttoni, Lepidosperma laterale;* (Restionaceae) *Sporodanthus Traversii;* (Orchidaceae) *Thelymitra pulchella, Prasophyllum pumilum, Caleana minor, Pterostylis barbata;* (Proteaceae) *Persoonia toru;* (Lauraceae) *Beilschmiedia taraire, Litsaea calicaris;* (Saxifragaceae) *Ixerba brexioides, Quintinia serrata;* Pittosporaceae) *Pitttosporum Huttonianum, P. virgatum, P. crassifolium;* (Cunoniaceae) *Weinmannia sylvicola;* (Rutaceae *Phebalium nudum;* (Rhamnaceae) *Pomaderris elliptica, P. Edgerleyi;* (Malvaceae) *Hoheria populnea (H. populnea* var. *vulgaris* of the "Manual") ; (Violaceae) *Melicytus macrophyllus.*[15] ; (Myrtaceae) *Metrosideros albiflora, M. diffusa, M. tomentosa;* (Araliaceae) *Pseudopanax discolor, P. Lessonii, P. crassifolium* var. *trifoliolatum;* (Cornaceae) *Corokia buddleoides;* (Epacridaceae) *Dracophyllum Sinclairii, Archeria racemosa;* (Sapotaceae) *Sideroxylon novo-zelandicum;* (Verbenaceae) *Vitex lucens, Avicennia officinalis;* (Scrophulariaceae) *Veronica macrocarpa, V. diosmaefolia, V. pubescens;* (Lentibulariaceae) *Utricularia delicatula;* (Rubiaceae) *Coprosma arborea, C. spathulata;* (Compositae) *Olearia albida, Celmisia Adamsii*—the type, *Cassinia retorta, Siegesbeckia orientalis, Bidens pilosa* and *Senecio Banksii.*

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15. Cheeseman, " Manual of the New Zealand Flora," 1906, p. 47, refers a plant collected near Dunedin to this species.

Photo., L. Cockayne.

FIG. 7: View of Piece of Kauri Forest (North Auckland Bot. District). The trees on left and to right are Kauri (*Agathis australis*), and in centre is the smaller tree, *Beilschmiedia taraire*.

The vegetation, too, north of lat. 38deg. S., right to the North of the North Island is distinguished by certain distinct plant-associations, of which the most striking are Kauri *(Agathis)* forest (see Fig. 7) mangrove *(Avicennia)* salt-swamp the shrub and bog associations of the barren clay gumlands, and the pohutakawa *(Metrosideros tomentosa)* association of sea-cliffs. Coastal forest, coastal scrub and stable dune associations are also of a special character. Natural grassland is absent, its place being occupied by shrubland.

(4) LATITUDE 42°S. AS A PHYTOGEOGRAPHICAL BARRIER.

In the following list North Island species which extend to Banks Peninsula on the east and beyond the Taramakau River on the west are excluded. On the other hand, species which have, so far, been recorded only from the extreme northern parts of the South Island are included. The phytogeographical dividing-belt is therefore of considerable width. The list given below emphasises what has been already stated concerning the close relationship between the adjacent lowland and coastal floras of the North and South Islands. The following is the list of species: (Filices) *Adiantum aethiopicum, A. hispidulum, Pellaea falcata, Pteris tremula, P. macilenta, Blechnum filiforme, B. Fraseri, Doodia media, Asplenium umbrosum, Arthropteris tenella, Polypodium dictyopteris;* (Lycopodiaceae) *Lycopodium cernuum;* (Taxaceae) *Phyllocladus trichomanoides;* (Gramineae) *Spinifex hirsutus, Dichelachne sciurea, Poa anceps* var. *elata, Bromus arenarius, Agropyron multiflorum;* (Cyperaceae) *Elaeocharis neo-zelandica, Schoenus brevifolius, S. tendo, Cladium capillaceum, Gahnia setifolia, G. pauciflora, G. xanthocarpa;* (Liliaceae) *Astelia Banksii, A. Solandri, A. trinervia, Arthropodium cirratum;* (Orchidaceae)[16] *Prasophyllum rufum, Pterostylis trullifolia, P. puberula, Acianthus Sinclairii, Calochilus paludosus, Corysanthes Cheesemanii;* (Piperaceae) *Peperomia Urvilleana;* (Proteaceae) *Knightia excelsa;* (Polygonaceae) *Muehlenbeckia Astoni;* (Magnoliaceae) *Drimys axillaris;* (Monimiaceae) *Laurelia novae-zelandiae;* (Lauraceae) *Beilschmiedia tawa;* (Cruciferae) *Lepidium incisum;* (Pittosporaceae) *Pittosporum cornifolium;* (Leguminosae) *Carmichaelia australis, C. odorata;* (Rutaceae) *Melicope ternata, × M. Mantellii;* (Meliaceae) *Dysoxylum spectabile;* (Tiliaceae) *Entelea arborescens;* (Malvaceae) *Hibiscus trionum;* (Violaceae) *Hymenanthera obovata*[17]; (Thymelaeaceae) *Pimelea longiflora;* (Myrtaceae) *Metrosideros Parkinsonii*[18], *M. Colensoi,*

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16. Some of these orchids may extend much further south on the west of the South Island since the orchid florula of the Western Botanical District is comparatively unknown. Mr. W. Townson collected orchids most assiduously in the neighbourhood of Westport, hence the number of species recorded. So, too, for the neighbourhood of Kaitaia (Northern Auckland), thanks to the labours of the late Mr. R. H. Matthews and Mr. H. Carse.

17. Excluding from the conception of the species the Castle Hill (Canterbury) plant.

18. Recently discovered by W. R. B. Oliver on Great Barrier Island—its only station north of Cook Strait, so far as is known.

M. robusta, Myrtus bullata, × *M. Ralphii, Eugenia maire;* (Halorrhagaceae) *Myriophyllum robustum;* (Epacridaceae) *Epacris pauciflora, Dracophyllum latifolium;* (Oleaceae) *Olea Cunninghamii, O. lanceolata, O. montana;* (Myrsinaceae) *Rapanea salicina;* (Loganiaceae) *Geniostoma ligustrifolium* (Scrophulariaceae) *Veronica speciosa, V. salicifolia* var. *Atkinsonii, V. parviflora, V. gracillima, Euphrasia cuneata;* (Rubiaceae) *Coprosma retusa, C. tenuicaulis, Nertera Cunninghamii;* (Caprifoliaceae) *Alseuosmia quercifolia;* (Cucurbitaceae) *Sicyos australis;* (Compositae) *Olearia Cunninghamii, Gnaphalium subrigidum, Cassinia leptophylla, Brachyglottis repanda.*

This list together with that given for latitude 38deg., almost exhaust the North Island element of the New Zealand forest flora[19], but Banks Peninsula is the southernmost halting-place for a few more species (e.g., *Alectryon excelsum, Adiantum fulvum, Corynocarpus lævigata, Dodonæa viscosa, Griselinia lucida, Leucopogon fasciculatus, Macropiper excelsum, Mariscus ustulatus, Rhopalostylis sapida, Tetrapathœa australis* and *Zoysia pungens.* On the west, those most common species of North Island forests—*Astelia Cunninghamii, Metrosideros florida* and *M. scandens* are a characteristic feature of the forest of the Western Botanical District as far south as Okarito, at any rate; so too is *Freycinetia Banksii,* which extends further south into the Fiord Botanical District. The North Island tree-ferns, *Cyathea Cunninghamii* and *Dicksonia lanata,* are also found in some localities of the Western District. *Hedycarya arborea,* on the east, has its southern limit on Banks Peninsula, but on the west it extends as far south as Preservation Inlet.

(c) The effect of the Southern Alps and the Coastal Mountains of North-western Nelson on plant-distribution.

The mountains situated at so short a distance from the Tasman Sea near the west coast of the South Island cause the moisture-laden westerly winds to deposit nearly all their moisture, so that an extremely wet climate extends from the coast-line to a definite point on the eastern side of the actual Divide. This area in the lowland, montane, and lower-subalpine belts is clothed with a dense forest-mass, but, at its eastern boundary at a point marking the average limit of the western downpour, it gives place, all on a sudden to tussock-grassland. Frequently the rain extends to the very margin of the forest, while less than a mile to the eastward the sun is shining, or, at most, a few drops of rain are carried by the furious gale which nearly always accompanies the downpour. So sharp is this distinction between western forest and eastern grassland from the north of the South Island to the forest of Southland that hardly a single tree invades the grassland, but the forest stands a dense, dark barrier with clean-cut margin, whence

19. Of course certain species in these lists do not belong to the forest flora.

Photo., F. G. Gibbs.

FIG. 8: *Ranunculus insignis*, a large-leaved sub-alpine herb (also occurring in the North Island), growing on Mount Arthur plateau.

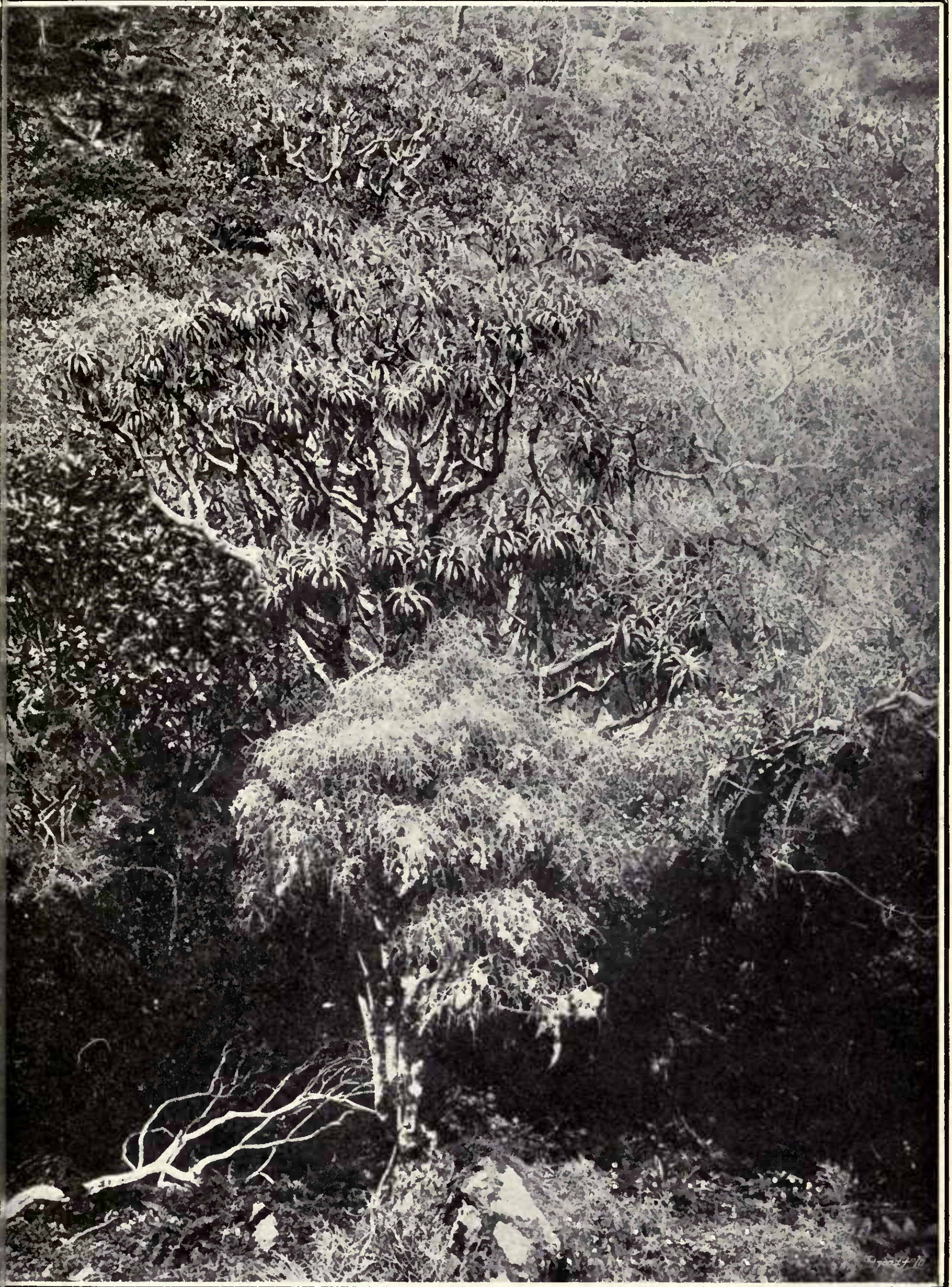

Photo., L. Cockayne.

FIG. 9: View of piece of upper sub-alpine forest of Westland. In centre *Dracophyllum Traversii*, and below it *Suttonia divaricata*.

extends eastwards the tussock-grassland. The change in the physiognomy of the vegetation is instantaneous—there is no transitional phase.

This sudden change in rainfall, and the number of rainy days, is not reflected merely by the forest, or the tussock-grassland, but it greatly affects the high-mountain vegetation also. On the west dense subalpine-scrub is common,—on the east it is absent, or in isolated patches; fell-field and unstable debris-slopes with their special plants are a feature of the east, whereas herb-field is the physiognomic subalpine plant-association of the west; extreme xerophytes (both herbs and shrubs) are characteristic of the eastern mountains and mountain-valleys (e.g.—*Aciphylla Dobsoni, Carmichaelia Petriei, Clematis afoliata, Colobanthus brevisepalus, Coprosma brunnea, Helichrysum coralloides, H. depressum, Hymenanthera dentata* var. *alpina, Lepidium sisymbrioides, Muehlenbeckia ephedroides, Myosotis uniflora, Olearia coriacea, Pimelea sericeo-villosa, Poa acicularifolia, Raoulia Parkii, Sophora prostrata* and *Veronica epacridea)* but, on the west, though xerophytes are far from lacking, there are more mesophytes and a few specially large-leaved herbs (e.g.—*Anisotome capillifolia, A. Haastii, Ourisia macrocarpa* vars. *calycina* and *cordata, Ranunculus insignis* (see Fig. 8), and *R. Lyallii);* the east is the home of the majority of the high-mountain species of *Veronica;* the upper subalpine forest of the west may consist of shrubby *Compositae, Libocedrus Bidwillii, Podocarpus Hallii, Dacrydium biforme* and *Dracophyllum Traversii* (see Fig. 9): whereas, on the east, forest is confined to gullies and shady slopes and usually consists of *Nothofagus cliffortioides* with but little undergrowth.

East and west, though possessing many species in common, have each a rich locally-endemic element. As an example of this the locally-endemic species of the North-eastern and North-western South Island Botanical Districts may be cited.

The endemics of the North-eastern District are the following: (Ranunculaceae) *Ranunculus lobulatus;* (Rosaceae) *Geum divergens;* (Leguminosae) *Carmichaelia Monroi* (the type), *C. juncea* var., *Notospartium Carmichaeliae, Chordospartium Stevensoni;* (Onagraceae) *Epilobium chloraefolium* var. *kaikourense, E. rostratum* var. *pubens;* (Convolvulaceae) *Convolvulus fracto-saxosa;* (Boraginaceae) *Myosotis Cockaynei, M. Laingii, M. saxatilis;* (Gentianaceae) *Gentiana Astoni* (Scrophulariaceae) *Veronica rupicola, V. decumbens, V. Hulkeana;* (Campanulaceae) *Wahlenbergia flexilis, W. Matthewsii, W. cartilaginea;* (Compositae) *Olearia insignis, O. coriacea, Celmisia Cockayniana, C. Monroi, Haastia pulvinaris, H. recurva* var. *Wallii, Gnaphalium nitidulum, Raoulia cinerea, Helichrysum Sinclairii, H. coralloides, H. Fowerakeri, Cassinia albida* vars. *typica* and *canescens, Abrotonella Christensenii, Senecio Monroi, S. Christensenii.*

The following are the local endemics of the North-western District:—(Cyperaceae) *Carex trachycarpa, C. Gibbsii;* (Orchidaceae) *Townsonia deflexa;* (Ranunculaceae) *Ranunculus verticillatus;* (Magnoliaceae) *Drimys Traversii;* Pittosporaceae) *Pittosporum Dallii;* (Leguminosae) *Carmichaelia Fieldii;* (Umbelliferae) *Aciphylla Hookeri, A. indurata, A. trifoliata, Anisotome diversifolia;* (Epacridaceae) *Dracophyllum Townsoni, D. pubescens;* (Boraginaceae) *Myosotis angustata, M. concinna;* (Loganiaceae) *Mitrasacme montana* var. *Helmsii;* (Gentianaceae) *Gentiana filipes, G. gracilifolia, G. vernicosa;* (Scrophulariaceae) *Veronica Townsoni, V. divergens, V.* albicans [20], *V. coarctata; Euphrasia Cheesemanii;* (Compositae) *Celmisia rupestris, C. Gibbsii, C. Morgani, C. parva, C. dubia, C. semicordata, C. cordatifolia, C. Dallii, C. lateralis, Senecio glaucophyllus, S. laxifolius, S. Hectori.*

If the species of the two previous lists be compared as to their habitats it will be seen that 22 of the North-eastern endemics are rock or rock-debris plants, whereas the North-western endemics are mostly forest, herb-field, or scrub species. Many of the rock plants of the North-eastern district, together with certain more wide-spread species, form one of the most clearly-defined plant-associations of the New Zealand Region, the composition of which at its full development is as follows:—*Angelica montana, Anisotome aromatica* var., *A. filifolia, Celmisia Monroi, Clematis afoliata, Coriaria sarmentosa* var., *Linum monogynum, Olearia insignis, Phormium Colensoi, Senecio Monroi, Veronica Hulkeana* and *Wahlenbergia Matthewsii.* This association is confined to the drier parts of the district, with the addition of the seaward Kaikoura mountains—a wet area—but does not extend into the Eastern Botanical District, but halts all on a sudden, although the habitat it affects is everywhere in abundance. The characteristic member of the association *(Olearia insignis)*—a most aberrant member of the genus, probably of generic distinctness, with no near relatives in the New Zealand region, or elsewhere—should theoretically be of great age and so of wide-spread distribution, yet the contrary is the case.

(d) The effect of the frequent south-west wind on plant-distribution in the South Island and Stewart Island.

On Stewart Island, and for a certain distance northwards in the south of the South Island, the downpour which so often accompanies the frequent south-westerly gales favoured the establishment of forest on such parts of the lowland and montane belts as the edaphic and other climatic conditions were favourable. Much of the great South Otago forest has been destroyed as settlement progressed, but that of Stewart Island is virtually intact. On the mainland here were both taxad and

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20. *V. albicans* may be only a synonym for *V. carnosula.* It is related to *V. amplexicaulis*, a species hitherto only recorded from the Rangitata river-basin. There are other glaucuous-leaved veronicas more or less closely related to *V. albicans*, apparently peculiar to this district, but they have hitherto been referred to *V. pinguifolia*, a very large aggregate species consisting of many most distinct microspecies.

Nothofagus forests, but this genus, strange to say, is absent in Stewart Island, nor does it occur in the New Zealand sub-antarctic islands.

The low temperature of the atmosphere during a south-west gale, the cold rain and the frequent cloudy skies of the South Otago and Stewart Districts are strongly reflected in the vegetation. Thus sphagnum bogs are a striking feature in many places; there is a cold, "sour" soil which favours the establishment of tall tussock-grassland of *Danthonia Raoulii* var. *rubra* which is accompanied by certain species generally confined to the high mountains elsewhere (e.g., *Astelia montana* var. *Blechnum penna marina, Cyathodes empetrifolia, Gaultheria depressa, G. perplexa, Herpolirion novae-zelandiae, Oreostylidium subulatum, Pentachondra pumila, Raoulia glabra.* Other high-mountain plants also descend to sea-leval, and this is especially the case in Stewart Island, where the following have been noted: *Astelia linearis, Caltha novae-zelandiae, Carpha alpina, Celmisia argentea, Coprosma repens, Donatia novae-zelandiae, Dracophyllum Pearsoni, D. politum, Gaimardia ciliata, Geum leiospermum, Olearia Colensoi, Oreobolus pectinatus, Senecio elaeagnifolius, S. Lyallii.*

In the high mountains the abundant south-west rain is reflected by the presence of extensive herb-fields—a spectacle altogether different from the tussock-grassland of the dry North Otago Botanical District, where *Poa intermedia* dominates. At that point, where the Old Man Range is at the limit of the south-westerly rain, its rich vegetation and florula stand out in striking contrast to the adjacent hills and mountains of the North Otago Botanical District now without tussocks for hundreds of feet, their main vegetation mats of *Raoulia lutescens.* Originally these hills were tussock-clad, but they never bore the abundant collections of alpine herbaceous and semi-woody plants which distinguish the flat summit of the Old Man Range, while their present depletion bears striking testimony to the effect of the south-west rain upon plant-distribution.

The climate of the South Otago Botanical District has favoured a certain amount of local endemism, but as this climate is somewhat similar to that of the Fiord Botanical District they possess many species of restricted distribution in common (e.g., *Aciphylla pinnatifida, Anisotome intermedia, Celmisia argenta, C. Hectori, C. lanceolata, C. ramulosa, C. verbascifolia, Dracophyllum Menziesii, Gentiana saxosa, Olearia moschata, Ourisia prorepens, Ranunculus Buchanani, Senecio revolutus, Veronica dasyphylla, V. Hectori, V. Petriei.*

Stewart Island has a fairly strong local endemism (19 species) made up as follows:—(Gramineae) *Danthonia pungens;* (Cyperaceae) *Uncinia pedicellata, U. compacta* var. *caespitiformis, Carex longiculmis;* (Liliaceae) *Chrysobactron Gibbsii;* (Ranunculaceae) *Ranunculus Kirkii, R. Crosbyi;* (Umbelliferae) *Schizeilema Cockaynei, Aciphylla Traillii,* *Anisotome intermedia* var. *oblongifolia, A. flabellata* (Epacridaceae) *Dracophyllum Pearsoni;* (Gentianaceae) *Gentiana Gibbsii;* (Scrophulariaceae) *Veronica Laingii, Ourisia modesta;* (Compositae) *Olearia divaricata, Celmisia glabrescens, Raoulia Goyeni, Abrotonella muscosa.*

An interesting point is that, notwithstanding the Stewart flora being separated from the South Island by 15 miles of sea at the nearest point, it has only 6 per cent. of its florula locally endemic, much less than might be expected when the florulas of the North-western and North-eastern Botanical Districts are considered, the former with 4 per cent., and the latter with 4.4 per cent. of locally endemic species. Again, the Chatham Islands, situated 500 miles from the New Zealand mainland, have only 13 per cent. of locally-endemic species.

(e) Effect of altitude upon plant distribution.

It has already been noted that New Zealand has a high-mountain flora very distinct from that of the lowlands in that out of its 950 species no less than 500 are entirely mountain-dwellers, while 100 others descend to the lowlands only under exceptional circumstances. These high-mountain species are not arranged haphazard, but each has its special altitudinal range; while, as in mountains everywhere, the flora as a whole is arranged in altitudinal belts. Thus, beginning at sea-level, there is the lowland belt which extends to an altitude of about 1000 feet throughout most of the South Island, but in the North Island it will be from 500 to 1000 feet higher. Above the lowland belt comes the montane belt, and it extends upwards for 2000 feet. Then the next thousand feet is the lower subalpine belt, above which for one thousand feet is the upper subalpine belt, and above this, up to the limit of vegetation, is the alpine belt. These figures are altogether approximate, for latitude, aspect and climate all affect altitudinal distribution, so that there is no uniformity even on any one mountain. This is evidenced by the sheep-farmer with his "summer" and "winter" country, and in this he recognises the fundamental fact regarding vertical distribution, namely the average length of time that the snow lies on the ground during the cold months of the year. Thus the alpine belt is that area where the winter snow lies for some six months; on the subalpine belt it may lie for two months or so in its upper part and a week or two in its lower part; on the montane belt the snow will lie usually only a few days; while on the lowland belt there may be snow only occasionally, or perhaps not at all. These facts regarding the effect of snow stand out clearly from an examination of the vegetation of gullies and hollows where the snow lies for a long time—far into the summer it may be. A few examples may be of interest.

On Mount Egmont, in the subalpine belt, there are two well-marked plant-formations in close proximity; the one tall tussock-grassland of *Danthonia Raoulii*, var. *rubra,* the tussocks densely crowded, but with here and there open spaces occupied by a turf of prostrate herbs, semi-woody plants and shrubs; the other, and here the snow lies long, is herb-field with the vegetation reduced to a turf, so that plants of the mat-form are mats no longer, e.g., *Helichrysum prostratum* has its densely-leafy silvery shoots dotted about, but not spreading and forming a thick mat. Here and there are very small shrubs of *Veronica buxifolia.*

On Mount Ollivier (Sealey Range) at an altitude of 4200 feet and upwards are here and there hollows where the snow lies until the beginning of February, and later. Such hollows, as the snow melts, are bathed with ice-cold water for several days at a time. Their vegetation differs from that of the adjoining slopes where the snow melts much earlier. At about 4300ft. there are, in such hollows, mats of *Danthonia oreophila* var. *elata,* perhaps 10in. thick, and so dense that hardly any other plants can gain a footing. At a higher altitude there are masses of *Astelia nivicola* flattened to the ground, and cushions of the silvery *Celmisia Hectori,* which apparently, on this mountain is confined to this station. On the adjacent slopes is tall tussock-grassland of *Danthonia flavescens,* and its accompanying plants. At a higher altitude this tussock is replaced by *D. crassiuscula.*

On the flat summit of the Old Man Range (South Otago Botanical District), at an altitude of 5000 feet and upwards, the winter-snow lies long, and late snow-storms are frequent. The ground, owing to the large quantity of snow-water, and the powerful winds, is cut into hummocks some 9in. high, which are covered with cushions of various species (e.g., *Dracophyllum muscoides, Phyllachne rubra, Raoulia Hectori, Hectorella caespitosa, Veronica dasyphylla),* and there is abundance of the shrubby *Celmisia ramulosa.* After the snow melts the plants are subjected to the full fury of the south-west gales—hence, apart from the snow-covering, the prevalence of the cushion-form.

A good many species are usually not met with until the line marking the average limit of the winter snow is encountered. Certain species of *Celmisia,* especially *C. Haastii,* and *C. viscosa* are excellent indications of the snow-line, as, also in certain parts of the North-eastern and North-western Botanical Districts, the remarkable mat-forming grass, *Danthonia australis.* Apart from the excess of ice-cold water which the plants are obliged to tolerate, they are subjected to great pressure, and are so flattened to the ground that one seeing them for the first time could hardly believe they would recover. Plants forming dense mats such as the two grasses mentioned above, are admirably suited for their yearly burial, and their form may be considered epharmonic.

(f) Effect of the edaphic factor on plant-distribution.

The edaphic factor, or to use Warming's term, "the nutrient substratum[21]," is here used in the widest acceptation, and in-

21. Oecology of Plants, 1919, p. 40.

cludes not only the soil proper (from rock to ordinary soil), but also water. With the soil are included the gases and water which it contains. It is this edaphic factor, in conjunction with the local climate, which chiefly governs the habitats of the associations and the growing places of the species. A consideration of plant-distribution on edaphic lines would open up the whole of the ecology of New Zealand plants—a vast field as yet but superficially explored. All that can be attempted here is the statement of certain generalities together with an account of a few cases where the effect of the soil is clearly apparent.

Generally, in New Zealand, the nature of the underlying rocks has apparently but little influence on plant-distribution. Rain-forest consists of the same species, at similar latitudes and altitudes, whether the underlying rock be greywacke, volcanic, limestone, or schist. That familiar sight, cliffs or steep banks covered with the great leaves of *Blechnum capense* is in evidence both on the calcareous mudstone declivities of the Wanganui River and on ancient moraines of Southern Westland. The *Olearia insignis* association, already referred to, thrives equally well on either limestone or greywacke. There are fine forests of *Podocarpus totara* both on the volcanic hills of Banks Peninsula and on the pumice of the Volcanic Plateau.

Taking the case of limestone, it is true that a few species *(Asplenium lucidium* var. *anomodon, Anisotome palula, Senecio glaucophyllus)* have been recorded from limestone rocks only, but so far as I know, limestone and greywacke, side by side, bear exactly the same species. Still, more detailed research might reveal certain constant distinctions between the vegetation of limestone and that of non-calcareous rocks.

With one or two exceptions, to be noted presently, it is not the chemical constitution of soils in New Zealand which determines the species, or plant-associations, but their physical condition and, above all, their water-content. Thus stony river-bed in the wet climate of Westland may carry forest, while in the drier eastern climate there is merely an open vegetation of species of *Raoulia* and *Epilobium,* to be finally replaced by low tussock-grassland or xerophytic shrubland.

Stony debris slopes in the high mountains, so long as they are not subject to an excessive rainfall, have a remarkable number of plants in common—many of which, in their growth-forms, stand in special categories to themselves. As with forest in its area of distribution, so with tussock-grassland, that of the South Island extends for hundreds of miles, covering many classes of soils and exposed to many local climates, but the dominant tussocks remain the same, e.g., *Poa caespitosa* and *Festuca novae-zealandiae,* or where the soil is sour, usually at higher altitudes, *Danthonia flavescens* or *D. Raoulii* in their various varieties. In both these cases (forest and grassland) the formation, as a whole, is governed by climate, but its changes in structure depend upon the edaphic factor. The poa and fescue tussocks, when both occur, indicate respectively the wetter and the drier ground.

Photo., F. G. Gibbs.

Fig. 10: The sharp line of demarcation with *Nothofagus* forest on right and the open, scanty vegetation of the Magnesian Mineral Belt, Nelson, on the left.

With regard to special edaphic examples three cases stand out clearly—the associations of soil with excess of salt, the vegetation of ground near fumaroles and the magnesian soil of the Mineral Belt.

The leading salt-soil associations are salt-swamp, salt-meadow, peaty salt-meadow (coastal moor), rocks exposed to sea-spray and salty patches in dry inland areas. The coastal salt-associations consist of a small florula which extends with but few changes throughout the three islands. A few of the species are confined to salt ground, but most grow equally well in non-saline stations, and some of these, which are characteristic halophytes, extend inland, far from the sea, (e.g., *Eryngium vesiculosum, Leptocarpus simplex, Selliera radicans)*.

The association near hot-springs on the Volcanic Plateau is shrubland with, as so frequently, *Leptospermum ericoides* dominant. According to the amount of sulphur fumes and the excess of certain salts, etc., in the soil, so do the species gradually decrease until only *Lycopodium cernuum, Leptospermum ericoides* (now prostrate) and *Leucopogon fasciculatus* (still erect) remain.

The Mineral Belt is a narrow girdle of serpentine and peridotite rocks, which in places crop out and in others lie as debris, large and small, upon the surface-soil. It extends from D'Urville Island to the Dun Mountain and beyond. It can be recognised at a glance, and from a long distance, by its scanty, stunted vegetation standing distinct from the adjacent forests. So soon as the magnesian soil is encountered at its full strength the neighbouring forest gives place all at once to shrubland or tall tussock-grassland (see Fig. 10). Most of the species are common New Zealand plants; but, if trees of the adjacent forest, on the Mineral Belt are dwarfed at once to shrubs (e.g., the species of *Nothofagus, Griselinia littoralis)*. The species *Myosotis Monroi* and *Pimelea Suteri* are local endemics. The rare species *Notothlaspi australis* and *Colobanthus quitensis* are common. Many of the shrubs are pronounced xerophytes.

4.—CONTINUOUS AND DISCONTINUOUS DISTRIBUTION.

The fact that species are arranged in associations most diverse in character postulates the impossibility of the really continuous distribution of any species. Continuity can only mean that the associations in which the species in question occurs extend for a longer or shorter distance, either latitudinally or vertically, with breaks between. Species belonging to wide-spread formations (e.g., dune, salt-swamp, salt-meadow, forest, tussock-grassland, *Leptospermum* shrubland, *Pteridium* heath, stony river-bed) may extend for long distances. Thus *Scirpus frondosus* (dune), *Leptocarpus simplex* (salt-swamp), *Selliera radicans* (salt-meadow), *Dacrydium cupressinum* (forest), *Poa caespitosa* (tussock-grassland), *Leptospermum scoparium* (shrubland), and *Pteridium esculentum* (heath) afford common examples of continuous distribution. But these species *(Poa* *caespitosa* excepted) though extending from the north of the North Island to Stewart Island are not by any means on an equality in the power of extending their area, in the variety of stations which they occupy, or in the actual distance they have travelled. The extremely plastic *L. scoparium* easily comes first both for vertical range and the number of associations to which it belongs, while the *Dacrydium* is limited to lowland and montane forest or occasionally lower subalpine scrub (Stewart Island) and the *Scirpus* to unstable dunes. The length of time it must have taken the latter to pass from dune to dune must have been comparatively short to that required by a species of equal latitudinal range, but which, in addition, is a member of the lowland and high-mountain floras and belongs to several plant-associations demanding special adaptations. Between continuity and extreme discontinuity of distribution there is every degree of transition. Each species has its northern, southern, eastern, western and altitudinal limits. Taking the 517 purely lowland species, according to statistics I prepared nearly seven years ago, but have not verified since, 249 occur in all the mainland Botanical Provinces, but only 102 of these extend to Stewart Island. A number of wide-spread species have their northern limit in the South Auckland Botanical District, a rather remarkable fact when the capabilities for dispersal of some of them are considered. Amongst such are various ferns and lycopods (e.g., *Hymenophyllum pulcherrimum, H. unilaterale, Blechnum penna marina, Polystichum vestitum, Lycopodium varium, L. fastigiatum* and *L. scariosum)* but notwithstanding their capacity for spreading by means of spores, it must be pointed out that these are generally mountain species or they appear to "prefer" more or less subantarctic conditions. So, too, with most of the spermaphytes of the same category, e.g., *Phyllocladus alpinus, Enargea parviflora, Cordyline indivisa, Nothofagus Menziesii, Nothopanax simplex* and *Coprosma foetidissima.*

Coming now to some cases of isolation, or extremely restricted distribution, the following may be noted:—*Lycopodium Drummondii* occurs only in one station, a bog near Kaitaia (North Auckland). This is also indigenous in Australia and when the number of suitable stations for its occupation are considered, and its power of far-dispersal by means of spores, its isolation is remarkable. For some reason or other it is most likely dying out. *Logania depressa* grows to the south-west of the Kaimanawa Mountains. Evidently it is extremely rare as it has not been collected since its original discovery by Colenso more than sixty years ago. It apparently has no close New Zealand relatives, so it may be looked upon as dying out. *Veronica Astoni* is confined to the Tararua Mountains where it is abundant. As this species is closely related to the more widely spread *V. tetragona* of the Volcanic Plateau, Kaimanawa and Ruahine Mountains, it must be considered of recent origin.—*Coprosma Buchanani* occurs only in a few places on the shores of Cook Strait. Apparently it has no near relatives, and so may be considered of considerable age.—*Pittosporum Dallii* is restricted to one locality in the North-western district; it differs considerably from any other known species of the genus; here again if strong individuality be a test of age, the species should be a relict.—*Cassinia amoena* and *Halorrhagis cartilaginea* are confined to the North Cape Peninsula; in this case extreme youth is suggested especially for the latter, originally considered by Cheeseman a variety of *H. erecta*. *Helichrysum dimorphum* is recorded from only one portion of the Waimakariri river-basin; this differs from all the other species in that it is a thick-stemmed liane. *Myosotis albo-sericea* is only known from one locality in the North Otago District; it is a xerophytic rock-plant allied to the much more widely spread, but not common, *M. Goyeni;* this may be a young species. *Lepidium Kirkii* a species not closely allied to any other is confined to salt patches on the Maniototo Plain. *Poa pygmaea,* another most distinct plant is confined to the elevated plateau of the Mount Pisa Range. *Notospartium Carmichaeliae,* a common plant within its range extends only from the R. Waihopi to the R. Awatere, where it is rare; further south it is represented by *N. torulosum* or perhaps by this and another species; the genus itself extends at wide intervals from the Waihopi to Peel Forest. *Veronica amplexicaulis* is confined to the Rangitata river-basin, where there is more than one variety; it is related to the *V. pinguifolia* series and like many species of the genus in New Zealand is probably young. If the special ecology of most of the above species be considered it can be seen they are not specially adapted for the locality, or even the exact habitat they occupy.

There remain now to be noted only a few examples of extreme discontinuous distribution. The following list does not aim at completeness. After the name of the species is given its distribution, its habitat is in brackets.

Angelica trifoliolata (sphagnum bog) Mount Torlesse and neighbourhood of Lake Tennyson—*Celmisia Traversii* (herb-field and fell-field), common in parts of the North-eastern and North-western Districts and not again met with till in the south of the South Otago District. *Drosera pygmaea* (wet ground), North Auckland District in far north, Waimarino Plain and the Bluff Hill, at each in only a few stations. *Leucopogon Richei* (heath), common on dry ridges in the Chatham Islands and in the North Auckland District, but rare. *Metrosideros Parkinsonii* (forest), common in west of the North-western District and rare on the Great Barrier Island. *Pittosporum patulum* (forest) North-western District, but not common, and rare near Lake Hawea. *Pittosporum obcordatum* (forest) Banks Peninsula but now probably extinct, extremely rare near Kaitaia (North Auckland District). *Myosotis Townsoni* (herb-field), west of North-western district and on Browning's Pass. *Ranunculus crithmifolius* (Shingle-slip) mountains, Wairau Gorge and Mount Arrowsmith Range. *Sporodanthus Traversii*

(Sphagnum bog), common in the Chatham Islands and near Kaitaia and in the Waikato sub-district.—*Suttonia chathamica* (forest and scrub), common in the Chatham Islands and in one or two places in Stewart Island, but in small quantity.—*Urtica australis* (seashore) Lord Auckland Islands, Antipodes Island, Chatham Islands, and some of the small islands in Foveaux Strait.—In all the above cases it seems safe to assume that the species were at one time far more wide-spread and that the actual dying-out of these species is being witnessed.

Such dying-out may actually be seen in progress in certain cases in what are apparently climax associations. The following two examples are of special interest. The common forest of Stewart Island has now as its principal trees *Weinmannia racemosa* and *Dacrydium cupressinum*. But at one time there was evidently abundance of *Podocarpus spicatus*, for the remains of this tree may be constantly seen enclosed by the base of the *Weinmannia* trunk, which is composed of roots which originally grew upon the fallen *Podocarpus* trees.

At the present time the *Dacrydium cupressinum* trees in the Egmont National Park are being strangled by the originally epiphytic *Metrosideros robusta*, so that in a comparatively short time that tree will have replaced the *Dacrydium*.

This matter of species apparently dying-out also receives confirmation through the extreme rarity of certain species in isolated localities, where, when the extreme difficulty of a new member joining a well-established plant association is remembered, they must be considered as almost defunct. The following are examples; all are common, often exceedingly common, in the North or South Islands (usually in both), and of continuous distribution: In Chatham Island—*Coprosma robusta, Discaria toumatou, Dodonaea viscosa, Leptospermum scoparium* (most ubiquitous of species!) *Myoporum laetum, Plagianthus divaricatus;* in Lord Auckland Islands—*Blechnum fluviatile, Halorrhagis micrantha* (especially suited for the wet peaty soil), *Fuchsia excorticata, Hemitelia Smithii, Samolus repens* var. *procumbens, Uncinia uncinata;* in Stewart Island—*Cordyline australis, Cyathea medullaris, Olearia ilicifolia, Plagianthus betulinus, Podocarpus dacrydioides, Senecio elaeagnifolius* and *Suttonia chathamica*.

ADDENDA.

1. p. 12. *Leucogenes Leontopodium,* or a closely-related plant, has been recently discovered on Mount Peel (Eastern Botanical District) by Messrs. H. H. Allan and R. M. Laing.

2. p. 14. The following 5 species have also their southern limit in the neighbourhood of latitude 38deg. S.: *Cladium articulatum, Clianthus puniceus, Dryopteris gongylodes, D. parasitica* and *Fimbristylis dichotoma* var. *velata,* but the last three are confined to the neighbourhood of hot springs.

3. p. 15. The list of species is restricted to those of the lowland and coastal belts.

4. p. 19. Tall tussock-grassland with *Danthonia flavescens* dominant is a common feature of the subalpine belt of the South Otago Botanical District.

5. p. 23. On the Dunstan Mountains (Central Otago) the usually coastal *Selliera radicans* is confined, not to salt soil, but it forms a green turf on wet limestone rocks; while, near Lake Wanaka, it grows in soil always saturated with ice-cold water issuing from an old moraine.

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