ENDEMIC GOITRE IN NEW ZEALAND, AND ITS RELATION TO THE SOIL-IODINE.

STUDIES FROM THE UNIVERSITY OF OTAGO, NEW ZEALAND.

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(With Plate III, 4 Charts and 3 Figures.)

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Chapter I.

Introduction.

The Dominion of New Zealand lies isolated in the south-western Pacific Ocean. Its two chief islands, lying almost antipodeal to Spain, stretch between latitudes 34° and 47° S., and comprise an area of one hundred thousand square miles. Nowhere within them can one be more than one hundred miles from the sea. Yet within this limited area a wonderful range of geographic conditions may be found. Two races with differing habits live side by side: the indigenous Maori, of whom there are now 53,560, and the European, numbering 1,271,741, 98 per cent. of them of British origin, whose migration into this country commenced about ninety years ago. Topographically, the land is most varied. From snowy alpine ranges one may descend on the one hand into dense rain-forest, and on the other to dry foothills and gravel plains. Rich volcanic and alluvial lands contrast with rather infertile areas of schist or pumice. In those portions where settlement is close, however, the climatic conditions are fairly

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uniform. Lying wholly within the temperate zone, the yearly average temperature varies between 60° in the northern portion, and 50° in the southern, with a humidity of about 75 per cent.; and there is a moderate and well-distributed rainfall, save in the dry regions within the rain-shadow of the mountains. Thus the climate approximates very closely indeed to the optimum climate for human civilisation as deduced by modern geographers such as Taylor (1916) and Huntington (1922). These climatic advantages are accompanied by a relatively high standard of general sanitation and of personal hygiene. There is a well organised and active Department of Health, with Divisions of Public Hygiene, Infant Welfare, School Hygiene, Maori Hygiene, Dental Hygiene Hospitals, Nursing, and Food and Drugs. These agencies combine to produce a reasonably satisfactory standard of general health, as is shown by such delicate indices as the infantile mortality rate (41·89), the typhoid morbidity rate (·41) and the crude death-rate (8·77). Moreover, there is in this favoured country a marked absence not only of venomous animals but also of disease-producing parasites. Malaria, typhus and uncinariasis, for example, are unknown, though hydatid disease, introduced by the Europeans, is not uncommon. The high average health in New Zealand makes all the more noteworthy the presence of endemic goitre to a marked extent among both the Maori and European population.

There is a curious blindness in human beings to the obvious and habitual. This is seen in many fields of thought, including that of medicine. Thus in districts where, for example, the incidence of dental caries and endemic goitre is widespread, their significance tends to be disregarded.

It was only after an absence of over five years from his native soil of Canterbury that one of us (C. E. H.) realised the extent of its endemic goitre problem, and endeavoured to determine with some degree of accuracy its incidence. This work was extended throughout the country, and led to the chemical and geological studies which are here presented.

The situation revealed by these studies is not of academic interest merely, but is of such significance to the State as to demand attention. The experience of Switzerland and other countries where goitre had long been prevalent is too definite to be ignored. Endemic goitre is undoubtedly "the stepping-stone to cretinism," and already an occasional case of cretinism has occurred in New Zealand in areas of high endemicity. Other pathological conditions related to the thyroid gland, such as goitres clinically called "toxic" and mild degrees of myxoedema also occur to a small extent in the country, and all these conditions, being so closely related etiologically, would eventually respond to the same preventive measures.

As a result of the studies here presented we have established the fact that goitre is widely prevalent in New Zealand (31 per cent. of the school-children are affected by it), and that its incidence is in general roughly inversely proportional to the average amount of iodine in the soil, which determines the amount of iodine in the plant- and animal-food consumed by the population of the district. Where exceptions to this occur, it has been shown that the required iodine is supplied in drinking water rather than in foods. (It may be worthy of note that the majority of the analyses were made before the sources of the samples were disclosed or the regional incidence of goitre ascertained.) This leads us to infer that so far as this country is concerned the most important factor in the causation of the disease is an iodine-intake below the safety limit. We conclude, therefore, that in districts where the disease is endemic, and where the soils and foods have been shown to be deficient in iodine, the iodine should be supplied by adding minute quantities of the element to some widely used article of diet. Evidence of the value and the harmlessness of this procedure is advanced in a discussion of the prophylactic measures that are being investigated.

This leads to very considerable modification of the widely held view that goitre is essentially a disease characteristic of mountainous countries or those where limestone is abundant, or that it is in consequence of their iodine-laden breezes that coastal districts enjoy a comparative immunity, for we find that even in such areas the amount of iodine in the soil is the determining factor.

Arising also from these studies is a discussion of the distribution of iodine in the soils and waters in relation to the geological formations from which they are derived, and also the consideration of the source of iodine in these formations.

The chemical work has been subsidised by a grant of two hundred pounds from the Department of Health. For this grant and for many courtesies, we are indebted to Sir Maui Pomare, Minister of Health, and to Dr T. H. A. Valentine, C.B.E., Director-General of Health.

To the officers of the School Medical Service we are deeply indebted for the assistance given in determining the goitre-incidence in the various districts. We would like to mention particularly the Director, Dr Ada Paterson; Dr Eleanor Baker, who assisted in the original survey in Canterbury, and has controlled the prophylactic work; and Dr R. J. R. Mecredy, especially for his studies in the Otago and Auckland Provinces. To our colleagues Dr Drennan and Dr Carmalt Jones, Professors of Pathology and Medicine respectively, we are indebted for much helpful information and criticism. We have also received the greatest assistance from the various Medical Officers of Health of the Dominion, and from their inspectorial staffs, in collecting samples of soil, water and food. We would like to mention particularly Dr Hughes of Auckland, Dr Findlay of Wellington, Dr Telford of Canterbury, and Dr McKibbin of Otago. On the geological side, our thanks are due especially to Mr P. G. Morgan, Director of the Geological Survey, and to Mr H. T. Ferrar, who was engaged in mapping the North Auckland District, for supplying important geological information, much of which is still unpublished. We have also received soil-samples and valuable suggestions from Mr B. C. Aston, F.I.C., Chief Chemist to the Department of Agriculture. Dr Inglis, Professor

of Chemistry in this University, has given us valuable advice in the choice of analytical methods. While the majority of the analyses given have been made by one of us (C. L. C.), Mr F. H. McDowall, M.Sc., A.I.C., and Mr K. C. Roberts, M.Sc., research scholars of this University, have been responsible for part of the work.

It will be understood that the responsibility for Chapters I, IX, X and XI rests with Hercus, and for the analytical work in Chapter III chiefly with Carter, while the classification of the samples analysed and the remaining discussion is for the most part the work of Benson.

Chapter II.

The Incidence of Endemic Goitre in New Zealand.

It is always a matter of difficulty to determine the exact incidence of a disease in a community. Endemic goitre is no exception, in spite of the comparative ease of diagnosis. Factors of age and sex, of diet and infection, of race and exact locality, all combine to complicate the task.

The first figures indicating the distribution of endemic goitre in New Zealand were supplied from the returns of recruits examined by military medical boards during a period when conscription was in operation, from November 1916 to November 1918. These can be regarded as a rough index only, confined as they were to an examination of males between the ages of 20 and 45, and to goitres sufficiently marked to render the recruits unfit for active service. 135,282 men were examined, and of these 1,581 were declared unfit for active service on account of thyroid-enlargement. Sixty-three per cent. of these rejects were from the Canterbury military district, Otago coming next with 19 per cent. Out of 31,739 men examined in Canterbury, 1,009, or 3 per cent., were rejected for goitre as against 1·5 per cent. in Otago.

The method usually adopted by a health authority is that of notification, but even in infectious diseases the method is an unreliable one. In a disease such as goitre notification has even greater limitations, for as a rule the doctor is consulted in a minority only of the severe cases, and these give little indication of the actual extent of the disease. The New Zealand Department of Health for some months in 1920 made endemic goitre a notifiable disease, in the hopes of being able to define the goitrous areas. The results were, however, disappointing, and the method was abandoned. Canterbury certainly returned approximately five times the notifications of any other health district.

Another index, which in a general way gives some indication of the prevalence of a disease such as endemic goitre, is supplied by hospital returns. We are indebted to Professor Drennan for permission to use the following figures which he had collected from the public hospitals of Christchurch, Dunedin and Auckland. During the period 1921–1923, 152 goitre cases were admitted to the Christchurch Hospital for treatment. This represented just over 1 per cent. of the total admissions for that period. Dunedin Hospital came next with 0·8 per cent. of the total admissions, and Auckland last with 0·35 per cent.

While these varied evidences, taken individually, are of little value statistically, collectively they at least indicate that the highest incidence of goitre would be found in Canterbury.

In April 1920 one of us (C. E. H.), assisted by Dr Eleanor Baker of the School Medical Service, determined to establish accurately the extent to which thyroid-enlargement prevailed amongst the school-children of Canterbury and Westland. This section of the community was selected as being at once the most accessible for examination purposes, and the most important from the public health point of view. The majority of the children examined were in the age-group of five to fourteen years.

Method of Classification. A uniform method of classification had first to be established. We were uncertain at the outset as to whether our classification should be based in inspection, palpation or measurement. It soon became apparent that any measurements which we could make, whether of the circumference of the neck over the isthmus, or of the distance from the superior to the inferior pole, were factors too variable to be of value for this purpose. We found, as might be expected, that there were wide variations in children of the same age and height. Finally, we decided to retain neck-measurements only for the control of therapeutic results, where they constitute an essential record, and supply data for determining the rate of growth of a child's neck.

A combination of the methods of inspection and palpation was therefore adopted, and after a little practice was found to give consistent results with different observers, the margin of error being below 5 per cent.

We established five arbitrary categories practically identical with those of Marine and Kimball (1917). We called them normal, incipient, small, medium and large, and recorded them by the plus system. The condition of each lobe was registered. We considered as normal those cases in which no thyroid-enlargement could be detected either on inspection, particularly during deglutition, or on palpation. Those cases were classed as incipient in which a thickened isthmus could be clearly seen on deglutition, and distinctly felt as a thickened band lying across the trachea. As small were classed those cases in which the enlargement of the glands caused definite alteration in the normal contour of the neck, readily detected on inspection and palpation. In these cases one or both lobes were generally affected as well as the isthmus. As medium were classed cases showing lateral and anterior bulging, producing deformity obvious on superficial inspection. The large class included all those with excessive deformity. Nodular, lumpy masses, when encountered, were called adenomata. They were occasionally detected in apparently normal glands. We did not include in our classification the occurrence of persistent thyroglossal tracts which are claimed to denote thyroid-enlargement during intra-uterine life (Marine and Kimball, 1917). Its registration by different observers was found to be inconstant.

Results. The results have in part been published (Hercus and Baker, 1921) and may be summarised as follows: Fourteen thousand nine hundred and sixteen children were examined. Thirty-nine per cent. were found to have normal thyroids and 61 per cent. enlarged. Of the latter, 29 per cent. were classed "incipient," 26 per cent. "small," 5 per cent. "medium," and 1 per cent. "large." If objection should be raised to including as goitrous the slight but definite departure from normal which we call "incipient," on the grounds that this may be physiological and transient in character, there would still remain 32 per cent. with glands sufficiently enlarged to be readily detected on inspection.

District Distribution. With the exception of one district, the distribution throughout the Canterbury and Westland Provinces was remarkably uniform. The exception was Bank's Peninsula and a portion of Christchurch adjacent to the estuary of the Avon and Heathcote Rivers. Lyttelton, the port of Christchurch, separated from it by a range of high hills, has 20 per cent. less goitre than has Christchurch itself. As its water supply is derived from the Christchurch artesian system, and the majority of its food supplies from the Canterbury Plains, the explanation would appear to lie in the beneficial action of proximity to the sea. Timaru, however, is also on the sea coast, and its incidence is as high as Christchurch. Closer investigation showed that the particular artesian wells from which the Lyttelton supply is pumped are close to the estuary, and that in dry seasons slight salinity of the water has been noticed. There is also some tidal variation in the height of the water in the wells, suggesting that some admixture of fresh and sea water may occur. Analysis of the water showed a higher figure for chlorides and iodine than obtains in the Christchurch supply (Table IV, Chap. III).

Influence of Age and Sex. The influences of age and sex are brought out in the following graph (Fig. 1) which is based on the examination of 1666 children at Timaru, and may be taken as representative of the district.

The large number of children who arrive at school at the age of five years with enlarged thyroids indicates the extent to which the disease is endemic. The family histories of many of these children were investigated, and in the large majority of cases there was a definite goitre-history, one or other, and in many cases both parents, as well as brothers and sisters, showing well-marked goitre.

The influence of sex does not assert itself until puberty, which occurs in this country about the age of twelve years. In boys, the slight enlargements tend to disappear, and the total incidence falls markedly in consequence. In girls, many thyroid glands which were before apparently normal become rapidly enlarged, and the slight enlargements also increase in size. It is difficult to resist the comment that in districts where the supply of iodine is on the border-line of safety any increased metabolic activity and particularly any additional loss of iodine by the establishment of further channels of loss is of the utmost importance to the thyroid gland. Fellenberg (1923) has shown that menstrual blood contains an appreciable amount of iodine, and unless compensated by reduction of excretion in other directions this must turn the balance against the gland. We are at present carrying out investigation on this subject.

Site of Enlargement. Ninety per cent. of the "incipient" enlargements occurred at the junction of the isthmus and the right lobe. In only three cases was the left lobe alone enlarged, with no detectable enlargement elsewhere in the gland.

In the majority of the larger types of goitre the gland showed a diffuse uniform enlargement.

Influence of Water Supply. Varied sources of water supply are found throughout the area, and an endeavour was made to determine whether they exercised any influence on the incidence.

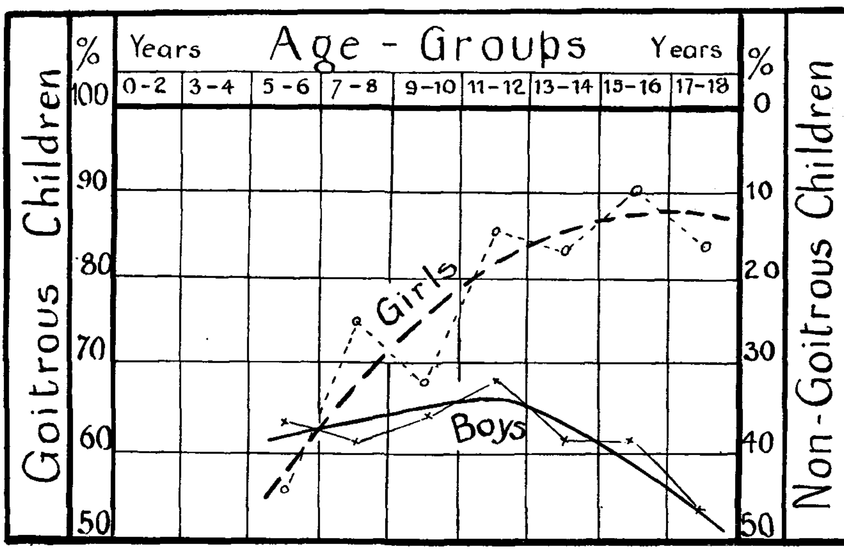

Fig. 1. Curves showing influence of age and sex on incidence of goitre among school-children in Timaru, New Zealand.

The following table shows the source of drinking water and the incidence of goitre:

Source of water supply	No. of children examined	No. normal per cent.	No. goitrous per cent.
1. Rain water entirely	916	453 (49·4)	463 (50·6)
2. Surface drainage water	2336	770 (32·9)	1566 (67·1)
3. Artesian water	5548	1994 (35·9)	3554 (64·1)
4. Artesian water with sea water admixture	1303	770 (59)	533 (41)

Analyses of both the surface and spring waters of the district show them to be waters of medium hardness containing 3 to 15 parts per 100,000 of dissolved solids, of which calcium carbonate constitutes on the average approximately one-third. An average of the analyses of twelve samples from the

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artesian wells of Christchurch, of depth averaging from 80 to 200 feet, shows, in parts per 100,000:

Total solids	7·81 (fixed 6·30, volatile 1·51)
Hardness	3·36
Chlorine	0·16
Iodine	0·00
Silica	1·46
Free and saline ammonia	0·001
Albuminoid ammonia	0·001
N as nitrates and nitrites	0·01

An analysis from a surface water shows, in parts per 100,000:

Total solids	13·9
Hardness	5·85
Chlorine	2·9
Iodine	0·00
Silica	2·0
Free and saline ammonia	0·006
Albuminoid ammonia	0·015
Nitrates	0·3

So the chemical constitution of the surface drainage water from rivers and watercourses is found to differ from that of the artesian water in the increased figure for total solids, hardness, chlorine, ammonia and oxidised nitrogen.

A comparison of the incidence of goitre in the rain water and the artesian water groups shows approximately 14 per cent. more goitre in the latter. If it be assumed that all other factors are constant, this difference might be ascribed to the influence of dissolved salts in the artesian supply. It is realised, however, that the number of children in the rain water group is too small for sound comparative purposes.

The presence in the water of the fourth class of 0·02 part of iodine in 10^7 is apparently responsible for a diminution in incidence at Lyttelton of 10 to 20 per cent.

Bacteriologically, there is a considerable difference between artesian and surface water. Thus the Christchurch city supply (artesian) shows no *B. coli communis* in 100 c.c. of water, whereas an average surface water supply shows *B. coli communis* in 0·1 c.c. It might be noted that the bacterial standards of purity laid down by the English authorities do not apply to the surface waters of Canterbury. The country abounds with rabbits, sheep are plentiful, and a high *B. coli communis* count is given where no possibility of human contamination exists.

It would appear, therefore, that an increase of calcium of about 1 part per 100,000 and of bacteria accompanied by other evidences of contamination do not influence the incidence of goitre appreciably.

Diet. The diets of the children in the district were investigated in a general way, and on the average they appeared adequate, although somewhat ill-balanced. Meat, bread, potatoes, and tea bulked somewhat disproportionately, and the consumption of vegetables, especially leafy vegetables, and of fruit impressed us as being too low.

Heredity. The unexpectedly high incidence of enlarged thyroids in children of five years of age led to a study of the incidence of congenital goitre. Observations at the Government Maternity Hospital in Christchurch show that approximately 60 per cent. of the mothers have enlarged thyroids, and that approximately 8 per cent. of the babies are born with enlarged thyroids. The thyroid-enlargement was found at times to have interfered with the normal flexion of the head in delivery. In a recent study by a medical student, Mr Davidson, of twelve cases of congenital goitre occurring in Christchurch, six had thyroids sufficiently enlarged to cause obstructive symptoms in the child, two of these infants dying within ten days of birth. As a rule, the size of the goitre rapidly diminishes after birth, even when no iodine is exhibited. Sufficient time has not yet elapsed to show how many of these babies from goitrous mothers show thyroid-enlargement on arrival at school at the age of five years. The evidence points to the conclusion that thyroid-enlargement in the mother induces thyroid-enlargement in the child at birth or before the age of five years. Enquiry from old settlers in the province points definitely to an increased incidence with each successive generation.

Myxoedema and Cretinism. No definite cretins were seen in the schools, but medical practitioners reported an occasional case. No obvious cases of myxoedema were encountered, but in areas of high endemicity cases of mental dullness, accompanied by adiposity and some thickening of the skin, were seen. In one such area a teacher of 23 years' experience of children aged about 12 years, who had nine months before come from a non-endemic area, complained as to the dullness of his class. On examination, it was found that the average age of the class was one year above the Dominion normal for this grade, and that 29 out of 34 girls showed goitres ranging from medium to large, and 19 out of 23 boys were goitrous.

Influence of Race. The number of Maoris living in Canterbury is small, and the amount of goitre among them is low. One hundred and sixty-four Maoris of all ages were examined, and 137 were found to have normal thyroids. These Maoris are living in villages, apart from the European population, but their occupation and diet, and habits of life, are practically identical with those of the Europeans. Their sanitation is on the whole more primitive, and the possibilities of infection are greater. If only children are considered, the incidence of goitre rises to 25 per cent. No adequate explanation can yet be offered for this fact.

Incidence in Animals. Goitre was found to be not uncommon in horses, sheep, cattle, dogs, and trout bred in captivity. An interesting fact was noted in the racehorse training-paddocks, where several cases of goitre have developed in horses during the period of training. In dogs, fox terriers appeared to show the highest incidence. The histories of two "epidemics" of congenital goitre amongst lambs were obtained.

Summary of Canterbury Investigations. Sixty per cent. of the school-children in this area show some degree of thyroid-enlargement. Further, the condition runs in families, is sometimes present at birth, and in some cases a mild degree of myxoedema can be detected. Goitre is also found in many species of animals. The only factor reducing the incidence of the disease found at this stage of the investigation was the trace of iodine present in water supplies contaminated by sea water.

Extension of Survey throughout New Zealand. In February 1921 the survey was extended to Otago. Dr Mecredy and Dr Irwin of the School Medical Service, adopting the same standard of classification, proceeded to find the incidence of the disease in this district. Some of the observations have already been published (Mecredy, 1923) and these, with much new information, are incorporated in Table V, given below. It will be seen that though there are several areas where goitre is endemic, notably in the valleys of the Clutha and Taieri rivers, the general incidence is considerably lower than in Canterbury.

Towards the end of 1921 Dr Wilkins, at that time Director of the School Medical Service, instructed all school medical officers to devote particular attention, during their routine examinations, to the detection of thyroid-enlargement, and that they were to adopt the classification given above. The results of these investigations are now published for the first time (see Table V herein).

In January 1925 one of us (C. E. H.) carried out a public health survey of the Maoris in the Urawera country, an inaccessible forest region, where the Maoris are still living apart from the Europeans under more or less primitive conditions, although white flour and sugar are in constant use, and other evidences of European civilisation are frequently seen. The total population of this area is about 500, and 300 were examined for goitre: 53, or approximately 18 per cent., were found to be affected, and the majority of these cases were classified as medium and large. Plate III, fig. 3, illustrates one of the latter. If only children are considered, the incidence rises to 30 per cent. The general sanitation of the area was found to be primitive, and typhoid was epidemic at the time of the survey. The food supply was poor and ill-balanced, protein and fat being low and carbohydrate high.

Enquiry from old Maoris established the fact that goitre has been present in this region for a considerable period, certainly before the European occupation of New Zealand, in spite of numerous published statements to the contrary. This fact was later confirmed by the Hon. Sir Maui Pomare, Minister of Public Health, who pointed out that the Maori language has contained the name "tenga," meaning "goitre," for many generations. The disease occurred amongst such inland tribes as the one under investigation, and was unknown amongst the coastal tribes, where fish and edible seaweed bulked largely in the dietary.

Chapter III.

THE IODINE IN SOILS, WATERS, FERTILISERS AND COMMERCIAL SALT IN NEW ZEALAND.

In connection with the investigation of the cause of endemic areas of goitre throughout New Zealand, it was necessary to find a method for estimating the iodine-content of soils. The researches of Fellenberg and McClendon had not yet appeared when this research was commenced, and no reference to any such work on soils could be found in the available literature, so several methods were tried in turn as follows:

I. Steam distillation of dry soil with an oxidising agent. A sample of dry soil was mixed with potassium permanganate and dilute sulphuric acid and distilled.

The distillate contained no trace of free iodine or of iodate, so it was concluded that the colloidal nature of the soil was responsible for adsorption and retention of the iodide.

II. In the hope of the above method proving successful when the colloidal nature of the soil had been destroyed, the sample of soil was first ignited and then steam distilled.

The distillate in this case was rich in chlorine, but no free iodine was detected. Iodate formed by oxidation was present, and was estimated, giving one part of iodine per million parts of soil approximately.

Other samples of ignited soils were taken, and were treated with known amounts of iodide, but the results obtained did not agree with the amounts of iodide added. The conclusion drawn from method II was that the iodine did not distil over quantitatively, part of it probably being oxidised to iodic acid in the flask.

III. Other oxidising agents were employed in turn, each giving inconclusive results, *e.g.* ferric chloride, cupric sulphate.

IV. It was thought that the difficulty of extraction might be obviated by washing the iodide quantitatively from the incinerated soil. This method was found to give quantitative results and proved quite satisfactory. It has since been found, however, that the extraction of the soluble iodide from the soil by this method is not quite complete, probably owing to imperfect dehydration of the colloids. Mr K. C. Roberts, using a modification of Fellenberg's method, has repeated the analyses of a number of the samples of soil, and has obtained greater amounts of iodine, usually about twice as much unless the samples were very rich in that element, when they were more nearly equal. For the purposes of this investigation it may be assumed that the method here described (which was used in all the analyses tabulated) yields figures approximately *proportional* to the amount of soluble iodine in by far the greater number of the soils analysed.

The method may be studied under three sections:

A. Ignition of soil with caustic soda.

B. Extraction of the iodide from the soil.

C. Estimation of the iodide.

A. *Ignition of the soil with caustic soda.*

A weighed portion of dried soil (50 gms.) is powdered in a nickel crucible and treated with enough 8 per cent. caustic soda to saturate it. The moist soil is carefully dried without charring over a small flame, and then loosened and powdered with a pestle. With the lid on the crucible the soil is heated moderately to dull red heat for 10 to 15 minutes with occasional stirring to ensure uniform carbonisation. At the end of this time the soil is more or less charred and the copious evolution of ammonia has ceased.

B. *Extraction of the iodide from the ignited soil.*

The contents of the crucible are transferred dry to a Buchner funnel (4 inches diameter) and washed quantitatively with small quantities of boiling water until the filtrate constitutes about 70 c.c. If the ignition has been complete, the filtration should be rapid and the filtrate clear or straw-coloured. The filtrate is then acidulated with dilute sulphuric acid and refiltered through filter-paper to clarify it further. The filtrate is caught in a 70 c.c. test-tube and the iodide in solution is estimated.

C. *Estimation of the iodide (modification of the Baumann colorimetric method).*

In this method the iodine is liberated in solution by an oxidising agent such as nitrous acid or "nitrosulphuric" acid, which is a solution of fuming nitric acid in concentrated sulphuric acid. The iodine is concentrated by shaking the solution with carbon disulphide to which a pink colour is given.

Reagents. Pure carbon disulphide.

"Nitrosulphuric" acid (fuming nitric and concentrated sulphuric acid —1 : 1).

Concentrated sodium acetate solution.

Sodium thiosulphate $N/1270$ 1 c.c. = 0·1 mg. iodine.

To the cold filtrate of iodide 2 c.c. of carbon disulphide and ten to fifteen drops of "nitrosulphuric" acid are added, the tube is corked and thoroughly shaken for about two minutes. The colour developed in the carbon disulphide varies from faint pink to deep purple. The whole of the iodine is not extracted by the carbon disulphide, for the amount depends on the partition number for carbon disulphide and water, and on the quantity of filtrate and the dimensions of the tube; but using the same tube and the same quantity of filtrate constant results are obtained, and the correction may be added. A table is given on p. 333 showing the corrections applied in these determinations.

The tube is then allowed to stand until the carbon disulphide has settled, and the water is carefully decanted off. The carbon disulphide, after repeated washing with distilled water, is transferred to a small stoppered glass bottle, 1 c.c. sodium acetate added to destroy any free mineral acid, and the whole titrated with $N/1270$ sodium thiosulphate until on thorough shaking the last tinge of pink disappears.

The faintest pink colour discernible in 2 c.c. of carbon disulphide, against a white background corresponds to 0·01 mg. of iodine, so that by using 50 gms. of soil, 2 parts of iodine may be detected in 10^7 parts of soil.

When standard iodide solutions were estimated, using the same tube and the same quantity of filtrate as in all the later results, the following corrections were necessary:

	C.c. of thiosulphate required					
Iodine present	0·1	0·5	1·0	2·0	4·0	8·0
Iodine found	0·1	0·4	0·8	1·7	3·5	7·0
Correction added	0	0·1	0·2	0·3	0·5	1·0

For solutions richer in iodine than those requiring 8 c.c. of thiosulphate, the correction may be minimised by further extraction of the filtrate with 2 c.c. of carbon disulphide.

Method used in Determination of Iodine in Waters.

Ten litres of water were evaporated, with sodium carbonate added in sufficient quantity to give a pink colour to phenolphthalein, until the bulk was reduced to 300 c.c., when the solution was filtered free from deposited carbonate. The latter was washed with small quantities of distilled water and this was added to the filtrate. The whole was then evaporated to dryness, extracted repeatedly with 85 per cent. alcohol, evaporated to dryness again and re-extracted with 85 per cent. alcohol. The alcoholic solution was then evaporated to dryness in a platinum dish, heated for one minute to a dull red heat to destroy organic matter, and the residue was then dissolved in 20 c.c. water in a test-tube and acidulated with 10 % nitric acid. To this was added 1 c.c. carbon bisulphide, one drop of nitrosulphuric acid and the whole was shaken in the stoppered tube for two minutes. The colour of the solution was then compared with that of a similarly treated standard solution and the amount of iodine thus indicated was checked by titration with $N/1270$ thiosulphate. (1 c.c. = 0·1 mg. iodine.)

In the case of sea water, the evaporation was undertaken under the above conditions and the salt that crystallised from time to time was filtered hot, washed and removed until the final extractions with 85 per cent. alcohol left a residue that was free from iodine.

Statement of Results.

In the following tables of soil analyses and in the subsequent discussion the unit amount of iodine is taken as one part per ten million (10^7) or 0·1 mg. per kilogramme. For the sake of brevity symbols have been adopted to indicate the nature of the geological formation from which the soil was derived, and the nature of the soil itself. These symbols may be explained as follows:

The main types of geological formations are indicated by the Roman numerals I to VI with suffixes according to the special variety indicated.

I indicates plutonic rocks (which are not very widespread). I g and I n stand for the acid siliceous granites and basic norites respectively.

II indicates mica schist, a much more widespread formation in the South Island.

III indicates greywackes, argillites, etc., which form most of the highlands in New Zealand. (They are mostly rocks of Mesozoic, but also in part of Palaeozoic age.) The mica schists were derived by metamorphism from rocks similar to these.

IV indicates the younger Mesozoic and chiefly Tertiary sediments which rest on the schist and greywacke. They are very varied, including conglomerates and sandstones (sometimes with coal measures) (s), greensands (gs), claystone or marl (c), limestone (l), and volcanic tuffs (t) and are indicated respectively by IV s, IV gs, IV c, IV l, IV t).

V indicates volcanic rocks which are either acid (rhyolite, rhyolite tuff and pumice or siliceous dacites), intermediate (andesite) or basic (basaltic). These are indicated by the signs V a, V m, and V b respectively. Phonolites are comparatively rare and are indicated by V p.

VI indicates a widespread and varied group of post-Tertiary sediments of fluviatile, marine, or glacial origin. They are classified thus:

VI g (gravel), VI s (silts—mixed mud and sand).
VI sa (sands in beach or river), VI sw (swamp deposits).
VI ds (dune sands), VI ls (loess deposits), VI c (clays).

Where it is of importance to indicate the formations immediately underlying the post-Tertiary cover this is done by writing the symbol for the upper formation above that for the lower, as the numerator and denominator in a fraction.

From the weathering of these formations, various types of soil are derived, the natures of which are indicated by the symbols in the second column of the table. The colour of the soil is indicated by capital letters: B, black; Br, brown; R, red; G, grey; W, white; and Y, yellow; while the texture of the soil is indicated by small letters: clayey (c), gritty (g), loamy (l), micaceous (m), sandy (sa), silty (s), stony (st), and where peaty or full of plant remains (v).

Table I.

Amount of Iodine in New Zealand soils of different Origin and Nature.

Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND.			
(1) *Stewart Island.*			
1. Half Moon Bay	I g	Br l	134
2. Horse Shoe Bay	I g	Br l	120
3. South of Paterson Inlet	II	sa l	6
(2) *Bluff.*			
4. Partly weathered	I n	Br st l	4
5. Well weathered	I n	Br l	42
6. Virgin bush	I n	B l	14
(3) *Invercargill and Southland Plain.*			
7. Invercargill South	VI s	G g	4
8. ,, ,,	VI s	G Br l	20
9. ,, Georgetown	VI s	B Br l	4
10. ,, Gardens	VI s	G g	8
11. ,, Waihopai	VI s	C	22
12. ,, North	VI s	Br l	106
13. Ryal Bush Gardens	VI s	B l	58
14. ,, Lea	VI s	B l	50
15. ,, Virgin	VI s	B l	6
16. ,, Paddock	VI s	B l	16
17. ,, in ditch	VI sw	B s	2
18. ,, in Creek bed	VI sw	B s	4
19. Taramoa School	VI s	C	16
20. ,, Millars	VI s	C l	50
21. ,, Burns	VI s	Br c l	50
22. ,, Virgin	VI s	C	96
23. Tuatapere	VI s	Br l	0
24. ,,	VI s	Br l	0
25. Orawia	IV sa	Br l	2
26. Otautau	VI s	G Br l	2
27. ,,	VI s	Br l	16
28. ,,	VI s	Br l	10
29. Drummond	IV s	Br l	24
30. ,,	IV s	Br l	8
31. Winton Gap Road	VI s	G l	6
32. ,, North	VI s	G l	6
33. Centre Bush Hill	IV s?	G l	10
34. ,, ,,	IV s?	G l	10
35. South Dipton	VI s	G l	6
36. Dipton	VI s	G l	4
37. Caroline River Flat	VI s	G l	4
(4) *Waimea Plains.*			
38. Mossburn	VI s	Br l	12
39. Castle Rock	VI s	G l	10
40. Gore (Avon Street)	VI s	G l	2
41. ,, ,,	VI s	G l	6
42. ,, (Kitchener Street)	VI s	G l	2
43. ,, ,, ,,	VI s	G l	6
(5) *Clutha Valley.*			
44. Kaitangata—Efi Street	IV sa	G l	10
45. ,, Pool Street	IV sa	Br B l	15
46. ,, School	IV sa	G l	4
47. ,, No. 1 Mine	IV sa	G l	4
48. ,, ,,	IV sa	G l	10

Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND (*contd.*)			
49. Kaitangata—Water Street	VI s	G l	3
50. ,, Berry Street	VI s	G l	2
51. ,, River Bank	VI s	G l	4
52. ,, ,,	VI s	G l	2
53. Lovell's Flat	VI s	G l	4
54. Stirling	IV sa	G l	2
55. ,,	IV sa	G l	3
56. ,,	IV sa	G l	4
57. Matau	II	G l	2
58. ,,	II	G m	1
59. Inch Clutha	VI s	G l	4
60. North Clutha	III	G l	10
61. ,, ,,	III	G l	9
62. Balclutha Flat	VI s	G m	5
63. ,, Subsoil Flat	II	G m	10
64. ,, ,, ,,	II	G m	0
65. ,, Renfrew Street	II	G m	0
66. ,, Argyle Street	II	G m	2
67. ,, Clyde Street	II	G m	2
68. ,, School	VI s / II	G m	2
69. ,, Pumping Station	,,	G m	6
70. ,, Sinclair's	,,	G m	7
71. ,, Kelsy's	,,	G m	7
72. ,, O'Hara's	,,	G m	10
73. ,, Nash's	,,	G m	0
74. ,, Rosebank	VI s / III	G l	10
75. ,, ,,	,,	G l	10
76. Beaumont Hill	II	G l	10
77. ,, ,,	II	G m	2
78. ,, ,,	II	G m	4
79. Alexandra (*a*)	VI s / II	G m	0
80. ,, (*b*)	,,	G m	2
81. ,, (*c*)	,,	G m	2
82. ,, (*d*)	,,	G m	2
83. ,, (*e*)	,,	G m	2
84. ,, (*f*)	,,	G m	2
85. ,, (*g*)	,,	G m	4
86. ,, (*h*)	,,	G m	4
87. ,, (*i*)	,,	G m	7
88. ,, (*j*)	,,	B l	24
89. Clyde—Hill	II	G m	4
90. ,, Flat	VI s / II	G s	2
91. ,, ,,	,,	G s	4
92. Cromwell (*a*)	,,	G sa	4
93. ,, (*b*)	,,	G s	2
94. ,, (*c*)	,,	G s	0
95. ,, (*d*)	,,	G s	0
96. ,, (*e*)	,,	G s	0
97. ,, (*f*)	,,	G s	0
98. ,, (*g*)	,,	G s	0
99. ,, (*h*)	,,	G s	2
100. ,, (*i*)	,,	G s	2
101. Chatto Creek	II	G l	0
102. Manuherika Valley	VI s / II	C l	0
103. Queenstown	II	G m st	0
104. Lake Hawea	II	G l	2
105. ,, ,,	II	G l	2
106. ,, ,, "Timaru Creek"	II	G l	2

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Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND (*contd.*)			
(6) *Taieri Valley and Milton.*			
107. Naseby	VI s / II	G st	6
108. Kokonga	V b	Br l	2
109. ,,	V b	Br l	8
110. Silverstream Gorge	II	C l	7
111. Silverstream	VI s / II	C l	7
112. ,, Butter Factory	,,	G l	2
113. Mosgiel	VI s	G l	6
114. ,,	VI s	C l	7
115. ,, (1 mile south)	VI s	Br l	16
116. ,, ,, ,,	VI s	Br l	14
117. Riccarton	VI s	G s	2
118. Allanton	VI sa	Br l	14
119. Taieri—Outram Road	VI s	Br l	5
120. Outram river bank	VI s	G m s	2
121. ,, ,,	VI s	G m s	6
122. ,, ,,	VI s	G m s	4
123. Maungatua	VI s	G m s	6
124. Berwick	VI s	Br l	4
125. Berwick—Henley Road	VI s	Br l	2
126. Henley river bank	VI s	G m s	4
127. ,, Hill	IV sa	sa l	0
128. Milton	VI s	G Br l	10
129. ,,	VI s	G Br l	8
130. ,,	VI s	G Br l	8
131. ,,	VI s	G Br l	8
(7) *Dunedin District.*			
132. Water Race—South Road	V m	Br B l	14
133. Dunedin—N.E. valley	V b	Br l	12
134. ,, ,,	VI s / V b	Br l	14
135. ,, ,,	V b	Br l	12
136. ,, ,,	V b	Br l	16
137. ,, ,,	V b	Br l	16
138. ,, Opoho	V b	Br l	20
139. ,, ,,	V m	Br l	12
140. ,, Gardens	V b	Br l	15
141. ,, Dalmore	V m	Br l	22
142. ,, Woodhaugh	VI s / V m	Br l	18
143. ,, Forth Street	V p	Br l	16
144. ,, St Margaret's	V m	Br l	22
145. ,, Balmacewen	V b	Br l	25
146. ,, Maori Hill	V m	G l	12
147. ,, Town Belt	V m	B l	10
148. ,, Dunottar	V m	B l	12
149. ,, Roslyn	V m	Br l	10
150. ,, ,,	V b	Br l	18
151. ,, Kaikorai	V b	Br l	14
152. ,, Belleknowes	V b	Br l	33
153. ,, ,,	V b	Br l	30
154. ,, Jubilee Park	V b	B l	36
155. ,, Mornington North	V b	Br l	14
156. ,, ,, South	V b	Br l	15
157. ,, Carlton Hill	V b	Br l	30
158. ,, Glen Road	V b	G l	16
159. ,, Lower	VI c / V b	G l	10

Locality		Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND (*contd.*)				
160.	Dunedin—Monticello	V b	Br l	30
161.	,, Rockyside	VI c / V b	G l	8
162.	,, Industrial School	VI c / IV sa	G l	14
163.	,, Main South Road	,,	G l	14
164.	,, Kew House	,,	sa l	26
165.	,, St Clair Hill	V b	Br l	17
166.	,, George and Howe Street	VI c	c	14
167.	,, George and Albany Street	VI c	c	11
168.	,, Castle Street	VI c	c	20
169.	,, Triangle	VI sw	Br B l	40
170.	,, Kensington	VI sw	B l	56
171.	,, South Dunedin	VI sw	Br l	30
172.	,, Convalescent Home	VI sw	B l	26
173.	,, Forbury, Chinese Gardens	VI sw	B l	15
174.	,, ,, ,, ,,	VI sw	B l	36
175.	,, Coughtrey Street	VI sw	B l	32
176.	,, Richardson Street	VI sw	Br B l	180
177.	,, Princes Street, St K.	VI sw	Br B l	150
178.	,, Orphanage, St K.	VI sw	B l	136
179.	,, ,, ,,	VI sw	B l	182
180.	,, Forbury Park	VI sw	sa	24
181.	,, Bay View Road	VI sw	B l	36
182.	,, Tahuna Park	VI sw	sa	38
183.	,, Tainui, Chinese Gardens	VI sw	B l	64
184.	,, ,, ,, ,,	VI sw	B l	74
185.	,, Botha Street	VI sw	B l	64
186.	,, Musselburgh Rise	V p	B l	34
187.	,, Anderson's Bay Tunnel	VI sw	B c	0
188.	,, ,, ,, ,,	VI sw	B c	0
189.	,, Anderson's Bay Cemetery	VI ds	W sa	2
190.	,, ,, ,, Convent	V m	Br l	8
191.	,, ,, ,, Glendining Home	V m	B l	24
192.	,, Highcliff Road	V b	Br l	36

(8) *North Otago District.*

193.	Palmerston South—Flat	VI s	Br l	10
194.	,, ,, ,,	VI s	Br l	4
195.	,, ,, Hill	IV gs	Br l	8
196.	Dunback	VI s	Br l	4
197.	,,	VI s	Br l	7
198.	Kakanui	IV l	G l	14
199.	Maheno	IV l	G l	10
200.	Oamaru—Wharfe Street	VI l	Br l	10
201.	,, Towey Street	VI l	Br l	4
202.	,, Chelmer Street	V b	sa l	34
203.	,, Eden Street Hill	V b	Br l	24
204.	,, ,, Flat	VI g	Br l	7
205.	,, Usk Street	VI g	Br l	10
206.	,, Trent Street	VI g	Br l	10
207.	,, Todd Street	VI g	Br l	14
208.	,, Davidson's	VI g	Br l	2
209.	Duntroon Flat	VI s	Br l	4
210.	,, ,,	VI s	Br l	5
211.	,, Hill	IV s	Br l	10
212.	,, Swakino Creek	IV c	c	0
213.	,, ,, ,,	IV c	c	0
214.	Kurow	IV c	Y c	50
215.	,,	IV c	Y c	45
216.	,,	IV c	G c	24
217.	,,	IV c	G c	25
218.	Omarama	III	Br l	2
219.	,,	VI s	G l	6

Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND (*contd.*)			
(9) *South Canterbury.*			
220. Waimate	VI s	G l	1
221. Te Ngawai	?	Br l	5
222. Mona Vale	?	Br l	2
223. Albury	VI s / IV c l	Br l	6
224. Cave	,,	Br l	4
225. Gleniti	,,	G l	1
226. Timaru (1 mile station)	VI l / V b	B l	4
227. ,, (2 miles W.)	V l / V b	B l	4
228. ,, (3 miles N.W.)	VI s	G l	4
229. Arowhenua	VI s	G l	2
230. Temuka	VI s	Br l	4
231. Winchester	VI s	B Br l	4
232. Rangitata Bridge	VI s	c l	2
233. Ashburton	VI s	G l	4
234. Rakaia	VI g	G l	0
235. Ladbrook	VI s	sa l	3
(10) *Christchurch.*			
236. Christchurch (*a*)	VI s	sa	1
237. ,, (*b*)	VI s	Br G l	12
238. ,, (*c*)	VI s	Br l	15
239. ,, (*d*)	VI s	c l	11
240. ,, (*e*)	VI s	Br l	15
241. ,, (*f*)	VI s	Y sa l	10
242. ,, (*g*)	VI s	Y sa l	6
243. ,, (*h*)	VI s	G l	5
244. ,, (*i*)	VI s	Br l	14
245. ,, (*j*)	VI sa	sa	0
246. ,, (*k*)	VI s	Br l	13
247. ,, (*l*)	VI sa	sa	2
248. ,, (*m*)	VI s	G l	16
249. ,, St Martins	VI s	G l	17
250. ,, Spreydon	VI s	G l	6
251. ,, Papanui	VI s	G l	10
252. ,, Woolston	VI s	G l	12
253. ,, Sumner	VI s	G l	7
254. ,, St Brighton	VI ds	G l	0
(11) *Banks Peninsula.*			
255. Heathcote	VI l (?) / V b	Br l	15
256. Lyttleton	,,	Br l	9
257. Barry's Bay	,,	Br l	4
258. Pigeon Bay (*a*)	,,	Br l	6
259. ,, (*b*)	,,	Br l	10
260. ,, (*c*)	,,	Br l	10
261. Little River	,,	Br l	6
262. Birdling's Flat	,,	Br l	10
(12) *North Canterbury.*			
263. Kaiapoi	VI s	G l	5
264. Rangiora	VI s	G l	6
265. Waikari	VI s / IV l	G l	6

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Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
SOUTH ISLAND (*contd.*)			
(13) *Marlborough.*			
266. Kaikoura	VI sw	B v	2
267. ,,	IV l	W g	0
268. Blenheim	VI s	G l	4
269. Wairau	VI s	G l	6
(14) *Nelson.*			
270. Nelson	VI g	Br st l	10
271. ,,	III	G l	4
272. ,,	IV c	Br l	38
273. ,, (7½ miles N.E.)	V b	Br l	38
274. ,, (14 miles S.)	III	G l	18
275. Richmond	VI gs	Br l	20
276. Stoke	VI gs	B l	6
277. ,,	VI gs	G l	4
278. Wakefield	VI g	Br st l	10
279. Moutere Hills	VI gs	G l	12
280. Motueka	VI sw	G l	42
281. ,,	I g c	G m l	4
(15) *West Coast.*			
282. Collingwood	VI g	G sa	2
283. Ngakawai	VI g	sa l	4
284. Granity	VI g	G l	3
285. Westport	VI g	G l	4
286. Reefton	VI s	B l	38
287. Moana	VI s	G l	7
288. Kumara	VI s / I g	B l	48
289. Hokitika	VI s	G l	4
290. ,,	VI s	G m l	2
NORTH ISLAND.			
(16) *Wellington District.*			
291. Wellington Government Gardens	III	G st	6
292. ,, Mount Victoria	III	B g l	8
293. ,, Island Bay	III	G l	62
294. ,, Miramar	VI sw	Br l	24
295. ,, Karori	VI sw	c l	132
296. Makara (R. 757)	III	G l	6
297. ,, (R. 760)	III	G l	10
298. ,, (R. 763)	III	G l	38
299. ,, (R. 765)	III	G l	82
300. Oharui (R. 814)	III	Br l	80
301. ,, (R. 816)	VI	G l	4
302. ,, (R. 818)	VI sa? / III	G l	42
303. ,, (R. 820)	VI s / III	G l	26
(17) *Hutt Valley.*			
304. Lower Hutt	VI s / III	Br l	12
305. Epuni	,,	Br l	20
(18) *Wairarapa and Dannevirke.*			
306. Martinborough	VI s	Br l	10
307. Greytown	VI s	G Br l	4
308. Masterton	VI s	Br l	6
309. Ekatahuna	IV	Br l	46

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Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
NORTH ISLAND (*contd.*)			
310. Ekatahuna (2 miles from)	IV c	G l	4
311. Pahiatua	VI s / IV s	Br l	8
312. Woodville	,,	Br l	86
313. Dannevirke	IV sa	G sa l	26
314. ,,	IV sa	G sa l	24
(19) *Hawke's Bay.*			
315. Hastings (5 miles E.)	IV sa	G g l	6
316. ,, (4 miles E.)	VI s	Br l	4
317. ,,	VI s	G c l	4
318. Napier—Hospital Hill	IV c	Br l	12
319. ,, Bluff Hill	IV l	Br l	16
(20) *Gisborne District.*			
320. Gisborne	VI s / IV c	Br l	16
321. ,,	,,	Br l	20
322. Waikohu	IV c	G c	2
(21) *Horowhenua Plain.*			
323. Levin—South-East	VI s	Br l	166
324. ,, East	VI s	G l	78
325. ,, Government Farm	VI s	Br l	128
326. ,, ,, ,,	VI s	Br l	130
327. ,, North-East	VI s	Br l	146
328. ,, ,,	VI s	Br l	158
329. ,, ,,	VI s	Br l	182
330. Shannon	VI s	Br l	110
(22) *Palmerston District.*			
331. Foxton	VI s	Br sa l	6
332. Palmerston North	VI s	Br l	10
333. Feilding	VI s / IV s c	G l	10
334. ,,	,,	Br sa l	10
335. ,,	,,	Br sa l	8
336. Marton	,,	G c l l	10
(23) *Wanganui and Patea.*			
337. Wanganui—Keith Street	VI s and VI ds	B sa l	6
338. ,, ,, ,,	VI s and VI ds	B sa l	8
339. ,, Bates Street	VI s and VI ds	B sa l	4
340. ,, Pitt Street	VI s and VI ds	B sa l	10
341. ,, Nelson Street	VI s and VI ds	B sa l	0
342. ,, College Street	VI s and VI ds	B sa l	4
343. ,, St George Street	VI s and VI ds	B sa l	4
344. ,, Gonville Street	VI s and VI ds	B sa l	2
345. ,, Matheson Street	VI s and VI ds	B sa l	8
346. ,, Campbell Street	VI s and VI ds	B sa l	4
347. ,, St John's Hill	VI s and VI ds	B sa l	4
348. ,, ,, ,,	VI s and VI ds	B sa l	4
349. Aramoho Foothills	IV s c	Br c l	16
350. ,, ,, Cumbrae Race	IV s c	Br l	12
351. ,, Kaikoukoupu Road	IV s c	Br l	26
352. ,, River Bank	VI s	s	4
353. Patea	VI s	B l	10
354. ,,	VI s	B l	24
(24) *Taranaki.*			
355. Hawera	VI s	B l	68
356. ,,	VI s	B l	72

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Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
NORTH ISLAND (*contd.*)			
357. Stratford	V m	Br l	36
358. Inglewood	V m	B l	90
359. Opunake	V m	B l	48
360. Omeho	V m	Br l	280
361. New Plymouth	V m	Br l	360
362. Waitara	V m	B l	268
363. Clifton	V m	B l	270
(25) *Main Trunk Line—Rangitikei Valley.*			
No soil analyses.			
(26) *Taumaranui District.*			
364. Taumaranui	VI s / IV c	B l	20
365. ,,	,,	B sa l	10
366. ,,	,,	G c l	8
367. ,,	,,	Br sa l	4
368. Hikimutu	,,	B l	20
369. ,,	,,	B l	20
370. ,,	,,	B l	16
(27) *West Coast District.*			
371. Kopaki	V a	B l	20
372. Te Kuiti	VI s / IV s	Br B l	8
373. Waitomo	IV l	Br l	28
374. ,,	IV l	Br B l	46
(28) *Waikato and Piako Valleys.*			
375. Te Awamutu	VI s	B l	86
376. ,,	VI s	Br l	106
377. Frankton	VI s	B sa l	4
378. Hamilton (1 mile N.)	VI s	sa	0
379. ,, (1 mile S.)	VI s	B l	74
380. ,, (1 mile E.)	VI s	B l	10
381. ,, (1 mile W.)	VI s	B l	35
382. Cambridge	VI s	Br l	52
383. Putaruru	VI s	Y c	68
384. ,,	VI s	Y sa c	3
385. ,,	VI s	sa	1
386. Morrinsville—North	VI s	Br l	98
387. ,, South	VI s	Br sa l	8
388. ,, East	VI s	Br c l	160
389. ,, West	VI s	Br l	68
390. Ngata	VI s	Br l	6
391. Paeroa	VI s	Y c	10
392. Hikutaia	VI s	Br l	2
393. Orongo	VI s	W G s	36
(29) *Rotorua and Taupo District.*			
394. Rotorua Gardens	V a	G l	16
395. ,, Government grounds	V a	G l	14
396. ,, Hospital	V a	G l	8
397. Taupo	V a	G g l	8
398. Tokaanu	V a	G g l	6
(30) *Bay of Plenty.*			
399. Maungapohatu	V a	Br sa l	4
400. Ruatahuna	VI sa	Br sa l	2
401. ,,	V a	G sa	4
402. Poroporo	VI sw	Br l	92
403. Thornton—River swamp	VI sw	B sa l	10

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Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
North Island (*contd.*)			
404. Thornton—Peaty	VI sw	Br l	10
405. ,, ,,	VI sw	Br l	8
406. ,, Gritty	VI sw	Br sa l	6
407. ,, Clay	VI sw	G c l	4
408. Pongakawa	VI s	B l	10
409. Te Puke	VI s	B l	10
410. Tauranga	VI s	B l	52
(31) *Cape Colville Peninsula.*			
411. Waihi	V a	Y sa c	6
412. Thames	VI s / V m	G l	6
413. ,,	,,	Y l	42
414. Mercury Bay	V a	B sa	0
415. Coromandel	V m	Br l	12
(32) *Auckland District.*			
416. Mercer	V b	Br l	224
417. Pukehoe	V b	Br l	240
418. Onehunga (*a*)	V b	Br l	68
419. ,, (*b*)	V b	Br l	80
420. ,, (*c*)	V b	Br l	160
421. ,, (*d*)	V b	Br l	560
422. Auckland Domain	V b	B l	34
423. ,, Mount Eden	V b	B l	62
424. ,, One Tree Hill	V b	Br l	256
425. Belmont School	IV st	B l	23
426. Takapuna	V b	Br l	34
(33) *North Auckland Peninsula.*			
427. Helensville (*a*)	VI ds	Br sa l	6
428. ,, (*b*)	VI ds	Br l	46
429. ,, (*c*)	VI ds	Br l	62
430. ,, (*d*)	VI ds	Br l	62
431. Wellsford	IV c l	G l	2
432. Port Albert	IV c l	G l	6
433. Paparoa	IV c l	G l	4
434. Dargaville	VI ds	G sa l	2
435. ,,	VI ds	G l	4
436. Titoki	?	G l	74
437. Poroti	V b	B l	304
438. Waipu	IV c	G c	12
439. Whangarei (½ mile S.E.)	VI s	G l	10
440. ,, (½ mile S.W.)	VI s	G l	6
441. ,, (½ mile N.E.)	VI s?	G l	6
442. ,, (1½ miles N.W.)	V b	B l	700
443. Glenbervie	V b	B l	330
444. Kiripaka	III	G l	4
445. Kauri	V b	Br l	96
446. Ruatangata—East	V b	Br l	82
447. ,, West	V b	Br l	88
448. Purua	IV c	G l	2
449. Hikurangi	IV c	G l	8
450. Ngararatunua	V b	Br l	124
451. Whakapara	IV c	G l	4
452. Riponui	IV c	G l	6
453. Hukerenui	IV c	G l	4
454. Opua	III	G l	4
455. Ohoeawai	V b	Br l	84
456. Oue	IV c	G c	2
457. Rawene	IV c	G c	0
458. Kohukohu	IV c	Y c	2
459. Motukaraka	IV c	G l	4

Locality	Geological formation	Nature of soil	Iodine in parts per 10,000,000
NORTH ISLAND (*contd.*)			
460. Takahue	IV c?	Br l	2
461. Herekino	IV c?	G Br l	4
462. Kaiataia	VI c	G c	2
463. Rangitihi	VI s	Y c	2
464. Victoria Valley	VI s	Br l	4
465. Waipapakauri	VI s	G B sa	0
466. Awanui	VI s	G c	10
467. Kaeo	III	G st l	4
468. Peria	V b?	Br l	190
469. Fairbarns	IV c?	G Br l	2
470. Totara North	III	G l	14
471. Mongonui	VI s?	Br l	12
OUTLYING ISLANDS.			
472. Chatham Islands	VI sw	B l v	104
473. Raratonga	V b	Br l	80

Iodine in Fertilisers used in New Zealand.

In considering the relation of the amount of iodine in the soils to the geological formations from which they were derived it was clearly necessary to obtain the samples free from contamination by fertilisers, as are nearly all those tabulated above. Nevertheless, the data from such soils alone would not give adequate information in regard to the iodine available for plants in the soils from which the food products were derived for the human population, many of which have been treated with fertilisers. Accordingly, tests were made of the principal fertilisers used, with the following results:

Table II.

Amount of Iodine in Fertilisers used in New Zealand.

Stable manure	10 parts of iodine in 10^7
"Kainite" (trademark)	6 ,, ,, ,,
Bone dust	2 ,, ,, ,,
"Turnip manure"	54 ,, ,, ,,
Nauru Island phosphate	42 ,, ,, ,,
Walpole Island Guano	240 ,, ,, ,,
Superphosphate	0 ,, ,, ,,
Rock salt (cattle-lick)	14 ,, ,, ,,
*Chilean nitrate	490 ,, ,, ,,
* ,, ,,	1920 ,, ,, ,,

* These two figures are taken from Fellenberg's (1924, III) paper.

Assuming that the soil has been treated with the regular amount of these fertilisers evenly spread, it may be calculated that in the top six-inch layer of soil the amount of iodine would be increased by 0·03 part in 10^7 as the result of a dressing of Walpole Island guano, and 0·40 part by a dressing of Chilean nitrate rich in iodine. The latter fertiliser, however, is rarely used in New Zealand. These quantities are too small to be recognised by our method of soil analysis, and so will not affect the value of soil-iodine in so far as the geological discussion is concerned.

The conditions are different when we discuss the relationship between the amount of iodine in the soil and the vegetable products therefrom. It would appear that any soluble iodide added to soil is taken up very quickly by the plants, which therefore become rich in iodine, while the soil, thus impoverished, may show little more iodine on analysis than is normal for the unfertilised soil of the district. In this connection we may therefore note that a dressing of guano may add 3·2 gms. of iodine to an acre of soil, and a heavy dressing of Chilean nitrate as much as 59·8 gms., which may have very considerable effect on the iodine-content of the plants grown thereon. This point is discussed further in Chapter IX.

Iodine in Spring Waters in New Zealand.

Iodine is present in certain waters in New Zealand and has been derived apparently from several sources. In the waters of hot springs derived from the siliceous volcanic rocks it may have either been leached from such rocks by waters that rise to the surface after a long circulation underground (the resurgent water of geologists) or have been given off with other volatile substances from the molten rocks which crystallise at great depths and which now appear at the surface for the first time. The former of these derivations is certainly that of the iodine in the cold springs escaping from the basic rocks of Dunedin. Iodine in spring waters derived from marine sedimentary rocks comes in part from the sea salts dissolved in the water that had been enclosed in the pores between the grains of the rocks (connate water); but, as the ratio between iodine and chlorine in such spring waters is usually much in excess of that between the iodine and chlorine normally found in sea water, it is evident that, either there must have been in some previous circumstances an extensive leaching of the chlorides but not the iodides from the sediments, or, much more probably, there was some other source of the iodine. Probably it was present in the various organisms, plant and animal, the decomposing remains of which were entombed in the sediments. Fellenberg (1924, VII) indeed has noted that the fossiliferous rocks he examined contained more iodine than the unfossiliferous.

We may class the iodine-bearing waters under two heads—the mineral springs too saline for normal drinking purposes—and potable waters of town supplies.

Table III gives the figures obtained by recasting of the analyses published by the Dominion Laboratory, with the exception of Nos. 10, 11, 16, 17, 18 and 19 which were the work of Skey (1877). The figures for carbonic oxide have been omitted in each case and for phosphoric acid in several. Skey believed that the free iodine obtained in No. 11 was almost if not unique at the time it was noticed, but a further example is afforded by No. 9 which Wohlmann (1914) describes as follows: "At the actual source free iodine would appear to be almost if not quite absent, but a short distance away, especially where the water has been allowed to fall in a douche form into the baths, some decomposition of the iodide appears to take place, and iodine makes its presence known in sufficient quantities to be appreciated by its pungent smell and to colour the water pale brown."

Table III.

Composition of Iodine-bearing Mineral Spring Waters in New Zealand stated in parts per 10,000,000 (10^7).

	Locality	Na	K	Ca	Mg	Fe	Cl	Combd I	Free I	SO_4	SiO_2 Al_2O_3
SPRINGS ISSUING FROM THE YOUNGER MARINE ROCKS.											
	Gisborne District—										
1.	Waimata Valley	38,700	—	1,100	920	—	65,710	157	—	—	450
2.	,, ,,	22,290	—	370	120	—	33,980	36	—	—	710
3.	,, ,,	30,860	—	270	810	—	46,300	8	—	—	390
4.	Near Waimata Valley	21,060	—	3,360	140	320	27,160	49	—	130	130
5.	,, ,, ,,	27,440	—	3,640	840	—	47,870	280	—	3,220	3,630
6.	,, ,, ,,	37,070	—	3,640	360	300	74,900	141	—	1,120	1,120
7.	Kaiti	37,510	160	2,950	830	20	60,500	483	—	—	310
8.	Waipiro (Te Puia)	55,550	210	8,160	70	—	83,470	29	—	—	940
9.	Morere	69,870	1,000	24,070	850	—	153,250	325	?	—	250
	Wairarapa District—										
10.	Wallingford	31,330	410	320	1,020	170	34,340	tr.	—	100	920
11.	Masterton (Pahua)	73,200	30	6,790	1,260	—	127,810	76	270	310	280
12.	Masterton (Ihuraua)	39,000	—	1,400	560	50	60,010	195	—	—	650
	Taranaki and West Coast Districts—										
13.	New Plymouth (Bore)	122,520	10,200	20,200	10,580	180	261,210	180	—	360	400
14.	Totoro	41,830	150	35,480	1,460	—	131,800	tr.	—	—	1,430
15.	Ohura	27,710	310	2,930	210	450	47,360	74	—	210	730
SPRINGS ISSUING FROM SILICEOUS VOLCANIC ROCKS.											
16.	Hikutaia	28,430	370	1,580	1,140	—	1,900	tr.	—	410	400
17.	Waiwera	9,150	10	370	40	50	10,970	tr.	—	40	350
18.	Tarawera	6,640	530	290	70	150	5,780	102	—	310	400
19.	Taupo, Parkes Spring	11,530	810	280	90	—	8,010	142	—	310	2,390

On averaging the analyses of waters coming from the younger marine rocks it will be seen that the ratio of iodine to chlorine therein is as 1 to 530, whereas the proportion between the iodine and chlorine in sea water as accepted by McClendon and Hathaway (1924) is only 1 to 500,000. Our analysis of the sea water near Dunedin, and Fellenberg's (1924, IV) of that from Capri and from the Isle of Wight, would give rather less than half that proportion. The iodine is therefore present in these mineral spring waters in a ratio with regard to chlorine that is about a thousand times as great as that existing in sea water. In comparison with these we may note the presence of 10, and 63 parts of iodine in 10^7 in the Fortunatus Spring of Passug, and the iodine water of Wildegg, the two Swiss mineral waters which are richest in iodine among those analysed by Fellenberg (1924, III).

Skey's examination of the water of the hot springs in the immediate neighbourhood of Rotorua failed to reveal the presence of any iodine, but it was present often in notable amounts in a dozen samples of hot springs nearer Taupo, though estimated quantitatively only in the two instances cited (Nos. 18 and 19). Don's (1893) examination of the waters of fifty-three unspecified gold mines, probably including those of the Cape Colville Peninsula, showed the presence of a trace of iodine in one sample only.

The potable waters of lakes and rivers, and town supplies derived from them, or from springs or wells, contain far less iodine than do such mineral waters. The results of our examination of New Zealand waters are tabulated below, together with the records of analyses of drinking waters in Switzerland and America, and of the sea in various regions.

Table IV.

Total Iodine in Potable Water and the Sea.

Stated in parts per 10,000,000 (10^7)

New Zealand Rivers.	
Clutha	0
Taieri	0·01
Leith	0·02
Springs derived from between Basaltic lavas near Dunedin.	
Maitland Street	0·08
Royal Terrace	0·04
Queen Street	0·02
Caversham	0·02
Artesian Waters.	
Christchurch	0
New Brighton	0
Heathcote	0·02
Hastings	0·20
Napier	0·16
Town supply drained off younger marine rocks.	
Gisborne	0·18
Swiss drinking waters (according to Fellenberg).	
Effingen, non-goitrous	0·0308
,,	0·020
Hunzenschwil, goitrous	0·0025
,,	0·0004
Average of 12 river and drinking waters	0·0056
United States (according to McClendon and Hathaway) Non-goitrous regions.	
Average of 4 rich samples (springs and wells)	1·0460
Average of 27 other samples	0·0193
Goitrous regions.	
Average of 38 samples	0·0008
Sea waters.	
Adriatic, Winkler (1895)	0·38
Atlantic Ocean, Gautier (1899)	0·23
,, ,, Thorpe (1912)	0·04
Mediterranean, Capri, Fellenberg (1924, IV)	0·174
English Channel, Isle of Wight, Fellenberg (1924, IV)	0·137
Average of 5 samples, Fellenberg (1925)	0·23
Pacific Ocean by Dunedin	0·18

The quantity of iodine relative to that of chlorine in the waters of Hastings, Napier and Gisborne is found to be about 600 times as great as in the case of the Adriatic water analysed by Winkler. To summarise:

These tables show that iodine is present in nearly all the soils analysed. In only 6 per cent. of the samples could no iodine be detected; in 45 per cent. it occurred in amounts less than 10 parts per 10^7; in 36 per cent. between 10 and 50 parts per 10^7; in 7 per cent. between 50 and 100 parts in 10^7, and in 6 per cent. of the samples only was iodine present in amounts greater than 100 parts per 10^7. The richest sample contained 700 parts, and the average for the whole series 27. It is further proved that the application of the com-

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monly used artificial fertilisers, if well-distributed, could have little effect on the amount of iodine in the soil when analysed according to the methods here followed, though it does appear to affect the iodine-content of the vegetables grown thereon. Spring waters issuing chiefly from the younger marine sediments are found to contain iodine in considerable amount, the average of the samples analysed (134 parts per 10^7) being richer in iodine than the richest of the iodine-bearing mineral spring waters of Switzerland for which we can obtain analyses. The iodine in the potable waters (town supplies) of New Zealand varies somewhat, but their range of composition compares, both as regards amount of iodine and position, with the waters of goitrous and non-goitrous regions of Switzerland and the United States of America. It is worthy of note that both in the spring and potable waters derived from the younger marine sediments in New Zealand the proportion of iodine to chlorine is over 500 times greater than that in sea water. The detailed discussion of these tables is given in later chapters, in which are deduced the relationship of the iodine in the soils and waters to the geological nature of their sources on the one hand, and on the other to the incidence of goitre in the districts from which they are derived. Further, an endeavour is there made to ascertain the sources of the iodine in the soil, and the causes determining its quantitative variation.

Chapter IV.

Previous Investigations of the Distribution of Iodine in Rocks, Minerals, Soils and Water.

The distribution of iodine in plants and animals, in the air, in fresh and salt water, and in various geological formations, and its relation to the incidence of goitre was first emphasised by Chatin between the years 1850 and 1860. He noticed that not only living but also fossil plants contain iodine, for it is present in noteworthy amounts in coal, less so in anthracite and only sporadically in lignite. It occurs in the soakage from turf, and is very marked in graphite. Moreover, as the result of the examination of the water of over three hundred streams, Chatin found iodine present in amounts varying according to the geological formation over which the streams passed. Water from igneous rocks is usually richer than that from sedimentary rocks, while ferruginous waters usually contain more than those deficient in iron. The formations which yield iodine most abundantly to the traversing waters are igneous rocks, greensands, ferruginous oolites and coal measures, while iodine is present in traces only, or quite lacking, in the water of streams from calcareous or dolomitic rocks, saline marls, and especially those rivers fed by glaciers. Chatin also investigated the amount of iodine in the atmosphere, and the conditions influencing its variation, volatilisation from the soil or water surfaces, humidity, temperature, season, situation, etc. He further compared the incidence of goitre in any region with the average daily intake of iodine by its inhabitants in air, food and drink, and concluded that the

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incidence of the disease was directly related to a deficiency of iodine. These researches are the more remarkable as the presence of iodine in the thyroid gland was not detected until 1896.

Skey (1877), in the examination of a number of New Zealand spring waters, showed the presence in them of noteworthy amounts of combined iodine and in one instance free iodine.

Winkler (1895) found that the water of the Adriatic contained 0·38 parts of inorganically combined iodine per 10^7, and could not recognise the presence of any organically combined iodine. His results have been accepted as generally true for sea water by McClendon and Hathaway (1924). On the other hand, Gautier (1899) arrived at very different results from his examination of Atlantic water at different depths, holding that on the surface the iodine was present entirely in the organisms, while at depths of 1000 metres a subordinate amount of soluble iodide and iodate were present. The average value of 0·23 part of iodine per 10^7 was obtained, but a later investigation (1920) of samples ranging down to greater depths gave much lower figures, though their value was not stated. Fellenberg (1925) finds the same figure (0·23 part in 10^7) as the average of five samples of sea water, and agrees also that the iodine is mostly organically combined. Gautier also attempted to determine the iodine in the air (though he used amounts which later investigations have shown to be too small to yield conclusive results) and decided that the iodine here also was in micro-organisms and not in water soluble salts. He further determined the presence of iodine in a few rocks and notably in granites, giving results which have been recast into the following table:

Granite from Cauterets	12 parts per 10^7
Impure mica from the same	7·5 ,, ,,
Yellow mica-granite from Clermont	2·3 ,, ,,
Granulite locally rich in apatite	1·7 ,, ,,
Mica schist from the Tyrol	Doubtful trace
Chlor and fluor apatite from Norway	2·3 parts per 10^7
Apatite from Canada	Nil
Diabase from Villafranche	Nil

He adds: "It seems from these observations that the iodine which exists in all the granites we have examined does not appear to make a constituent part of them nor of the apatite which is often found abundantly present in the rock. This element is, as one sees, very rare as though it were held by all substances in the form of a simple impurity."

Thorpe (1912) notes that iodine has also been found in a dolomite from Saxony, a limestone and a lime phosphate mineral from France and in a shale from Sweden. A few rare iodine and iodate minerals are known to occur among saline deposits; but have not been recognised as present in any rock masses.

Fellenberg (1923) has summarised the work of previous investigations into the distribution of inorganically combined iodine here considered, and also that on the iodine-content of plant and animal materials. Fellenberg (1923, 1924, 1925) has carried out a very extensive series of researches into the distribution of iodine in nature, and has confirmed in general Chatin's conclusions.

The chief results of this work may be summarised as follows: Iodine is present in a variety of crystalline rocks in fairly uniform amount, varying from 2 to 4 parts in 10^7, the granite gneisses being generally the richest and in one example contain 8 parts. Quartzite is a curious exception, and the samples tested contain respectively 11, 37 and 88 parts. The Pleistocene gravels average 11 parts, and the Tertiary fresh water beds only 2·2 parts. The Tertiary marine sediments contain, however, an average of 15 parts, and the fossiliferous beds are richer than the unfossiliferous. The Tertiary and Cretaceous limestones, lower Jurassic and the Triassic dolomites, limestones and sandstones, and shales have an average of 5 parts, but the Upper Jurassic limestones, marl and mudstones have an average of 21 parts and a fossil from them contained 92 parts. Of 37 minerals examined, a dozen samples of rock-forming minerals including apatite, topaz, tourmaline, quartz, flint and calcite (but not the more usual constituents of rocks) contain an average of 4 parts; resuvianite and scapolite 14 parts, and a series of ores an average of 5 parts; but in addition to these are some exceptional cases, pyromorphite varying from 4 to 100, wulfenite 85, native copper 7 to 40, and cuprite 380. The various forms of silica are shown to differ considerably in their content of iodine. He concludes that it is probable that the halogen-bearing mineral apatite is probably an important source of iodine in rocks in which it is widespread, though the few samples investigated do not afford proof of this. We may also suggest as sources of iodine such rock-forming minerals as micas or amphiboles, which contain hydroxyl which may be replaced by a halogen. Though in the weathering of rocks the iodides must be partly removed in solution, some will be retained adsorbed in the colloids of the soil and this is usually much richer in iodine than the rock from which it was derived, owing also to the storing up of the iodine by the anaerobic micro-organisms in the soil, and in the higher plants, as seen by the notable content of iodine in peat or coal. Lichens and especially algae are shown to contain iodine to the extent of 0·31 and 3·02 mg. per kilogram, the average of several samples analysed, and it is held that this is derived only from the air, either directly by the leaves, or dissolved in rain water absorbed by the roots. The iodine is only partly soluble in acid, and very little can be leached out by water. Iodine dissolved in percolating water may, on the other hand, be absorbed by rock material, and by siliceous rocks more than by basic. In the case of calcareous rocks made up of the remains of marine organisms it is noteworthy that these contain iodine, *e.g.* 3·5 mg. per kg. in two recent corals, and 2·7 mg. in two species of bivalve molluscs. In both cases the iodine is in organic as well as inorganic combination in the conchin and the calcareous material. It has long been known to be present in sponges and the alcyonarian *Gorgonia* (Dreschel, 1896; Wheeler and Jackson, 1905). Fellenberg found it also in fossil mollusca.

Apart from the processes by which iodine may be accumulated in soil, Fellenberg recognised that there are also processes bringing about its volatilisation and escape into the air, in which the catalytic action of ferric oxide and not the intervention of micro-organisms appears to be the essential factor. The effect is but weak when the iron salts are in the ferrous condition, and is less in manured than in unmanured soils, since the former contain organic substances that will absorb the iodine when it is freed from its former combination as iodide. This process of separation is of importance in that ferruginous rocks should accumulate less iodine during their transformation into soil than would those in which the escape of iodine from combination was less favoured (Fellenberg, 1924, VIII). Because of the factors influencing so very greatly the amount of iodine in the soil, he concluded that it has little direct dependence on the geological formations from which the soil is derived (*ibid.* 1924, VII). Nevertheless, there is a marked connection between the amount of iodine in spring waters and that in the rocks from which they are derived, which is illustrated in the following table drawn from Fellenberg's data:

Amounts of iodine	In rocks	In soil	In spring water	In air
Locality	In 1 kg.	In 1 kg.	In 1 litre	In 1 cubic metre
	mg.	mg.		
Effingen	5·400	11·900	(av.) 0·00254	0·00051
Kaisten	0·430	1·970	0·00054	0·00003
,,	0·420	0·820	0·00084	
Hunzenschwil	0·320	—	0·00025	—
	0·700–1·600	—	0·00004	—

Extensive investigations of the iodine in the air were also carried out by Fellenberg (1924, V) who found it to vary considerably in the same area, though depending to some extent on geological conditions, as appears from the above figures. It is more abundant near to the ground than at great elevations. It is dissolved especially in the dew, and in mornings after the dew has evaporated the air near the soil is particularly rich in iodine which is dissipated by evening. As iodine is relatively abundant in coal, it is also more abundant in the air and rain water in the vicinity of manufacturing towns and other places where much coal is consumed. (The frost on railway bridges contains a notable amount of iodine.) The atmospheric iodine is dissolved in rain water, snow, dew and frost, and brought thus down to the ground surface, and though it naturally varies greatly in amount it was estimated that approximately 23,000 kg. was so added annually to the soil of Switzerland. This figure would be the equivalent of an average annual addition of 2·3 mg. per acre.

Iodine in river and lake water Fellenberg found to be present in very varying quantity, and in both organic and inorganic combination. Snow water, having been precipitated in the higher levels of the atmosphere, contains less iodine than the rain water falling at lower levels, through air that is richer in iodine (Fellenberg, 1923, I). Iodine tends to escape from water stored in lakes, possibly being displaced as a result of the absorption of carbonic acid. In the sea water, iodine (Fellenberg, 1924, V, 1925) occurs in both organic and inorganic forms, the former, and more abundant, being 0·013 mg. per litre in two cases measured. It escapes in elementary form from the sea water, though more slowly than in the case of fresh water, a difference probably offset by the large expanse and constant movement of the sea surface. Thus wind and rain driving on to the shore may bring on to the land a good deal of free iodine that has been given off from the sea.

Fellenberg (1923, I) also proved that the food materials, vegetables, milk, etc., contained an amount of iodine varying with that in the soil in which it grew and the water supplied to it, and showed the close relation of such regional variations to the incidence of goitre. In later investigations (1924, VI) he was not able completely to confirm this conclusion, as will be noted in the sequel.

McClendon and Hathaway (1924) also showed that a relation existed between the distribution of iodine in plants and drinking waters and the incidence of goitre in the United States of America.

Chapter V.

The Distribution of Iodine in Soils and Spring Waters, in Relation to the Geological Formation from which they are Derived.

It is proposed here to state the results of the present investigation independently of other work, and then to discuss their bearing upon Fellenberg's investigation of the source and amount of iodine in soils.

The table of analyses given shows that nearly all the soils containing less than 10–15 parts of iodine in 10^7 lie on the mica schists, greywackes, the younger marine sediments, acid (siliceous) volcanic rocks, beach or river alluvium, loess and dune sands. Sometimes very well-leached clays, derived from less siliceous and more ferruginous igneous rocks, mostly andesites and basalts, contain less than 15 parts of iodine. The soils which contain from 15 to 50 parts of iodine are mostly those occurring on andesites and basalts, notably those of the Dunedin district. They sometimes lie on greywacke, younger marine rocks or river alluvium. The soils with 50–200 parts of iodine comprise certain of those lying on river alluvium, swamp deposits, especially brackish swamps, granitic soils, and those derived from basalt. The soils with more than 200 parts of iodine are derived from either the andesites of Taranaki (maximum 360 parts) or the basalts of the Auckland province (maximum 700 parts). Speaking generally, the soils with least iodine are of a sandy nature with little clay or iron in the ferric state. They are usually pale in colour, unless darkened by the presence of ferrous minerals, "ironsand," or carbonaceous matter. Soils of the last type, however, are not invariably poor in iodine, as the plant remains in them may retain a good deal of this element. The soils which contain most iodine are in general the fertile brown or red loamy soils.

Again, we may consider the range of iodine-content in the soils derived from each type of rock.

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I. Plutonic rocks are rarely exposed in New Zealand. Two samples of granite soils from Stewart Island average 120 parts of iodine, and the abundance of iodine in soils from some alluvial deposits may be due in part to their origin from granites, though it may be organic. Such are samples 1, 2, 286, 288. Basic plutonic rocks are even less abundant. The single region studied showed 4 parts in the partially weathered condition, and 14–42 in the fully decomposed soils.

II. The soils derived from mica schists are pale-coloured, gritty, and with little or no colloidal or clayey material, and do not contain more than 10 parts of iodine in 10^7, save in one instance, where the black colour indicates the presence of plant remains, accounting for the higher amount (24 parts of iodine). Water draining from the schists never has more than a trace of iodine, so that neither the insoluble product (soil), or the soluble product of the weathering of schists, contains much iodine.

III. The greywackes exhibit the slightly altered form of the same type of material as that which when highly altered appears as mica schist. Probably some of the iodine it contains is removed in solution during the process of alteration, as the soils derived from the greywacke are richer in iodine on the average (18 or 30) than are those on the schist, though hardly enough samples have been analysed to permit generalisation.

IV. The soils derived from the younger marine sediments generally contain less than 15 parts of iodine. The deficiency is most marked in the sandstones and grey marly clays. In one region, Kurow, the clays contain gypsum, suggestive of some concentration of sea water by evaporation in temporarily isolated basins, and here iodine is notably more abundant (averaging 36 parts) in the samples of soil analysed (Nos. 214–217). It has been observed that sheep and cattle eat these clays, which contain a greater proportion of iodine than ordinary rock salt. The spring waters derived from the younger marine formations are notably rich in iodine. Fifteen mineral springs in the North Island contain on an average 15·4 mg. of iodine per litre, while the water supplies of Hastings, Napier and Gisborne, which are derived from artesian wells or streams draining from these rocks, average 0·018 mg. of iodine per litre. In both cases the amount of iodine in relation to the chlorine in the waters is more than five hundred times as much as it would be were the chlorides and iodides solely derived from sea water included in the pores in the sediments. The iodine in soils from limestone varies considerably in amount (0–46) and is greatest in the rich red loams of Waitomo (Nos. 373, 374).

V. The amount of iodine in the soils derived from volcanic rocks increases with the increase in lime and iron and decrease of the silica of the parent rocks, apparently the reverse of the relation in regard to plutonic rocks. Siliceous rocks, rhyolite and pumice yield soils that average 9 parts in the few samples analysed. Intermediate rocks are represented by the trachydolerites, "andesites" of the Dunedin district, averaging 14 parts, and the andesites of Taranaki which contain a far greater amount, averaging 192 parts. There is also a great variation among the basaltic soils; those of the Dunedin district average 25 parts of iodine, while those of the Auckland province average 205 parts, with a range of 34 to 700. Where the soil is in a very thoroughly leached condition, as in the drifted and residual clays, the amount of iodine is smaller, averaging only 13 parts per 10^7 in such clays in Dunedin where the less completely leached soils contain an average of 21 parts. The iodine is removed in solution by the processes of weathering of these rocks, this being shown by the presence of 0·002 to 0·008 mg. of iodine per litre in the spring waters derived from them. On the other hand, though most of the hot springs coming through the siliceous rhyolite and pumice of Rotorua district do not contain noteworthy amounts of iodine, two samples of similar origin nearer Taupo contained 1·23 mg. of iodine per litre. An explanation for this will be suggested later.

VI. Soils produced from post-Tertiary deposits are of extremely variable character, and the generalisations offered are subject to exceptions. Dune sands, if mostly of quartz with or without "ironsand" (magnetite) and free from humus, are very deficient in iodine, *e.g.* Nos. 189, 254, 337–348, in which there is an average of 4 parts of iodine. If the sands containing some material derived from basic igneous rocks have been overgrown with vegetation, making some humus, iodine may be more abundant, *e.g.* perhaps Nos. 428–430 (average 56 parts). Loess, the wind-borne rock dust derived from greywackes beneath glaciers, is easily leached, and retains only a small amount of iodine. Even though soils of this nature in Timaru and the Banks Peninsula (Nos. 201, 226–229, 255–262) have probably been mixed with detritus from the underlying basalts, they contain only an average of 7 parts of iodine. Sands that have accumulated in brackish or salt lagoons and contain carbonaceous matter derived from decayed seaweeds are often notably rich in iodine, though it is very unevenly distributed, *e.g.* Nos. 169–186, 280, 294, and 402 (average 60 parts, range 17–180). The silts and gravels in the river alluvium make up an important part of the agricultural land of the Dominion, and vary in a marked degree, with a significant effect on the incidence of goitre. River alluvium derived from mica schists is very deficient in iodine. So also is the alluvium derived from the greywackes in the widespread plains of Southland and Canterbury. This is notably the case where the soils are frequently flooded, and therefore well leached. On the other hand, in parts of Southland, soils of similar origin but on terraces not covered by floods, may develop to some depth, and retain an average of 50 parts or more of iodine (contrast Nos. 13 and 14 from a terrace with 16 and 17 from adjacent flooded areas). This richness of iodine on the terrace does not appear as yet in the soils from the Canterbury Plains, which contain an average of 8 parts of iodine. In the Horowhenua Plain, however, the river gravels have much the same origin as those of Canterbury, but have very consistently a much higher content of iodine (average 137). This iodine appears to be fully available for plant food, and thence for human consumption, as the incidence of goitre here lies on the normal *xy* curve. The slope of this plain, like that of Canterbury, is too great to permit the accumulation of much swampy material, and the alluvium is chiefly a coarse gravel. In the valleys of the Waikato and Piako (a former outlet of the Waikato) the slope is much less, and the detritus chiefly derived from rhyolites and pumice of a finer grain, and swampy conditions have been widespread during its deposition. In these, iodine, derived probably from fresh water plants, is distributed irregularly, though on the whole abundantly (average 45 parts). It is present, however, in a form that apparently is not directly available for plant and human food, since the incidence of goitre in this district, if the figures available are truly representative, is far higher than the normal curve indicates, and corresponds with that for a district in which soil-iodine averages about 10 parts only. Further investigations as to the state of combination of iodine in the soils of the Horowhenua and Waikato plains are now in progress. Other instances occur locally (*e.g.* Nos. 88, 286 and 295) of river silts enriched in iodine by the remains of swamp vegetation.

In regard to the spring waters we may note that nearly all those waters in which iodine is abundant issue from the younger marine rocks, and in these the amount of iodine is far greater in proportion to the chlorine than would be the case were the dissolved salts obtained solely from the sea water contained in the pores of the sediments as they were deposited. It is therefore probable that the greater part of the iodine in such waters was set free by the decay of the marine organisms and especially lowly plants (seaweeds or micro-organisms) incorporated in such sediments. Only a few waters from siliceous volcanic rocks contain appreciable amounts of iodine, and may have obtained that element from the molten rocks deep within the earth, which gradually give off their volatile constituents as they consolidate.

The variation of iodine in the drinking waters from various sources is clearly in accord with the variation of iodine in the soils from which they have drained away, and is due to the partial leaching of such soils.

Summarising, we may state that we find that iodine is relatively abundant in the soils from igneous rocks. It is most noteworthy on the basic volcanic rocks (basalts and andesites) and in the siliceous plutonic rocks (granite); it is not very marked in basic plutonic rocks, and very small in amount on siliceous volcanic rocks. It occurs in moderate amount in those sedimentary rocks (greywackes) in which the material was derived from igneous rocks with but little chemical alteration, but is greatly diminished during the metamorphic processes by which the greywackes are recrystallised to form mica schists. In marine limestones iodine is usually rather small in amount, though the figures vary considerably. In the soils derived from marine sandstones and greensands there is similarly but a small amount of iodine as a rule, and a very minute amount on the grey clays, though some exceptions occur. The iodine is derived chiefly from the organisms incorporated in these sediments, and may be high in amount if carbonaceous matter is present, indicating the former abundance of such organisms. In the gravels of rivers, etc., iodine is generally deficient, but may also be accumulated in plant remains. Generally,

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deep weathering of the rock allows a thorough leaching of its debris, producing residual clay, which may contain but little iodine. On the other hand, it may be accumulated, adsorbed in the clay colloids if such are present, and in the humus, the remains of organisms, and thus become fairly abundant in the soil. Thus it is not possible to make definite correlations between the amount of iodine in the soil and its geological origin.

Chapter VI.

The Source of Iodine in Soils.

From a consideration of Fellenberg's researches and from the soil analyses here recorded, it may be concluded that the iodine in the soil is derived from two sources, namely, from the minerals present in the rocks from which the soil was produced, and from the atmosphere. Atmospheric iodine is in turn derived in part by volatilisation from the soil, from which the iodine is set free by the decomposition of rocks and minerals by weathering processes, and by the decomposition of iodine-bearing organic matter, and especially by the burning of wood and coal. Iodine is also volatilised from the sea, from lakes and from rivers. Probably also it is exhaled from volcanic vents. This iodine is brought down to the soil in rain, dew and frost, and is taken up by plants, especially algae and lichens, and as they decay their iodine, now in organic combination, forms part of the humus. Under certain conditions which promote oxidation it may be "mineralised" or converted into soluble iodides; in other circumstances it remains insoluble in organic combination and can be set free only when the soil is charred. The method of analysis adopted in the present research gives results approximately proportional to the total amount of iodine in the soil, either in the state of insoluble organic combination or as a soluble iodide. It does not, however, indicate the amount of iodine that may be included either in chemical combination or mechanical mixture in the insoluble mineral grains in fresh or partially decomposed rocks, which would be set free during the continuance of the process of rock-weathering and formation of soil, but is not immediately available for plant-food. An example of this process may be afforded by the analyses of partially and completely weathered norite (Nos. 4 and 5) in the first of which only 4 parts of iodine in 10^7 were detected, while in the second there were 42 parts in 10^7. This may, however, be merely an illustration of what Fellenberg shows to be a general process, namely the increase of the iodine in decomposing rock material (soil) by the formation of a humus containing organically combined iodine abstracted by plants from the atmosphere. Even more important than the land plants in this respect are the marine organisms, especially algae. Thus may be explained the abundance of iodine in the soil of reclaimed salt marshes. In lesser degree the marine animals are effective in abstracting iodine from the sea water, and hence it becomes stored in fossiliferous marine sediments.

There are, on the other hand, processes which tend to remove iodine from the soil. Soluble iodides may be abstracted by percolating soil waters, though the process is not a very effective one, so far as Fellenberg's experiments may show. It seems to be efficient, however, in some circumstances. A recently deposited mass of river gravel or silt, especially if frequently flooded, can contain but little soluble iodide, for the crust of weathered material about the pebbles in which the soil iodine may be retained is very thin, and constantly being leached. On the other hand, gravels, etc., that have remained for a long period on high terraces, above the flood level, may become more deeply weathered, and have produced more soil in which iodine may be retained adsorbed. Examples (Nos. 13, 14, 16, 17) illustrating this have been discussed above. This appears to be in part the explanation for the apparent deficiency of iodine, and consequently marked incidence of goitre, on river flood plains.

In addition to this removal of iodine by leaching from the soil, there is also a volatilisation of iodine set free by processes in which ferric oxides have a catalytic action. Fellenberg, on recognising this action, concluded that soils rich in ferric oxide would be unlikely to accumulate much iodine, though it might be found in the grey soils in which the iron was in a ferrous state. Our experience, however, is that in general the brown or red loams rich in ferric oxide are those in which iodine is most abundant. Chatin's view that iodine tends to be associated with iron may be recalled in this connection. The fact that iodine tends to occur in loamy or clayey soils rather than sandy soils seems to indicate that the colloidal hydrous silicates which form clay adsorb the iodine, and thus prevent its being removed by percolating waters. Since, however, it is in brown loams rather than the grey clays that iodine is retained, it must be the ferruginous rather than the purely aluminous colloids that are of importance in this connection.

We are again in agreement with Chatin's conclusion that iodine tends to be more abundant in soils on igneous rocks than those on sedimentary, which apparently results from the leaching of iodine from the rock material during its weathering and subsequent vicissitudes before it is accumulated into sedimentary deposits. Except for the iodine which may be exhaled from volcanoes or volatilised from volcanic springs, all the iodine in the atmosphere, the ocean, surface waters and soils must have been derived in the first place from igneous rocks. There is unfortunately very little information concerning the form in which iodine may exist in the igneous rocks. As Goldschmidt (1924) has remarked, "We know nothing concerning the distribution of iodine among the rock-forming minerals." Gautier, who found traces of it in mica and apatite, thought it existed there merely as "an impurity." If so, it would be either in liquid filled cavities (the probable mode of occurrence of the iodine found by Fellenberg in crystals of quartz), or in solid solution, or in chemical combination replacing part of the hydroxyl in silicate minerals such as amphibole or mica. In minerals such as apatite, in which a haloid is an essential part of the molecule, the normal fluorine or chlorine may be replaced in part by iodine, and this mineral which in minor amounts is present in nearly all igneous rocks may be found to be the chief source of the iodine therein. Such, indeed, is Fellenberg's suggestion, though he has not yet examined a sufficient number of samples of apatite to give it much support. The amounts of iodine in more abundant rock-forming minerals than quartz have not yet been determined.

If these surmises are true, modern conceptions of the conditions of consolidation of igneous rocks would suggest that iodine should be most abundant in the basic volcanic and plutonic rocks, andesite, basalt, norite or gabbro, in which apatite is often very abundant, and also in the more acid siliceous plutonic rocks such as granite or syenite, into which the volatile elements of the molten rocks tend to be concentrated. On the other hand, it should be deficient in the siliceous volcanic rocks, rhyolite and obsidian, and especially pumice, which contain very little apatite, and from which the volatile materials have escaped during their eruption. On the other hand, iodine might occur in the hot springs that issue in the neighbourhood of such siliceous lavas, for the minerals and volatile matter dissolved in these waters are in great measure those that are escaping from the molten rock slowly consolidating below, into which they had been concentrated. These deductions are in very good accord with the results of the analyses here recorded.

There remains to discuss the possibility that iodine derived from dried sea-spray, whether as iodides or in micro-organisms, may be brought down by the rain in sufficient amounts notably to enrich the soil in coastal districts. The problem has been considered by McClendon and Hathaway (1924), who point out that since Winkler's (1895) analyses of Adriatic water show that the proportion of iodine to chlorine in sea water is as 1 : 500,000, an estimate of the amount of iodine precipitated may be obtained from the more easily determined amounts of chlorine in the rain water. Fellenberg's (1924) more recent analyses of sea water from the Mediterranean and the English Channel would indicate that the ratio should be more nearly 1 : 1,000,000, or even 1 : 1,500,000. In the subsequent discussion we shall adopt the ratio 1 : 1,000,000, which acçords with the analyses of the sea water near Dunedin. Using Jackson's (1905) study of the amount of chlorine in the rain water of the north-eastern part of the United States, McClendon and Hathaway deduce that the rain water in the Atlantic coast contains about 0·2 to 1 part of iodine per hundred billions, and 0·04 part on the Great Lakes. On our reckoning, these figures would be halved. Taking into consideration the annual rainfall, it may be seen that this is equivalent to an annual precipitation of from 5 to 22 mg. of iodine per acre on the seaboard, and 0·7 mg. on the Great Lakes. From Fellenberg's roughly estimated figures it may be deduced that the annual precipitation of iodine in Switzerland is of the order of 2·3 mg. per acre, to which he attributes the source of much of the iodine which enriches the soil. If this be so, the importance of the sea-spray iodine in coastal districts in so far as it may be retained by the soil would be considerable.

Lincoln, in New Zealand, lies near the base of Banks Peninsula, and receives its rainfall from the north-easterly and south-westerly winds which, blowing along the coast, come off the sea only twenty miles in either direction from Lincoln. They bear so much dried spray that the annual precipitation of chlorine as chloride is notably high. Calculating from Gray's (1888, 1910) earlier and later estimates, it may be deduced that there is an annual precipitation here of from 27 to 15 mg. of iodine per acre, an amount which would be quite inappreciable in soil-samples analysed by the method adopted herein.

The Horowhenua district, a narrow coastal plain, faces directly towards the north-west whence come the dominant rain-bearing winds of the Tasman Sea, bringing on to the land immense quantities of sea-spray. After a gale the leaves of the trees are often killed for miles inland. Dried salt is often seen on the windows of houses, *e.g.* in Levin. If we consider also that the rainfall here is nearly twice as high as at Lincoln, it seems not unreasonable tentatively to assume (in the absence of any analyses of rain water in the district) that the precipitation of iodine annually is four times as much on the Horowhenua Plains as it is at Lincoln. In addition to the iodine in the salts and micro-organisms in the sea-spray, iodine directly volatilised from the sea would be brought in by the wind and precipitated by the rain. Assuming, therefore, for the purpose of calculation an annual precipitation of 100 mg. of iodine per acre, we find that this would add annually only about 0·0008 part in 10^7 of the top six inches of soil, provided that all the iodine was retained therein, which seems hardly possible. This amount of iodine is much too small to be detected by our method of soil-analysis, and is so minute in comparison with the amount actually present in the soil (137 parts per 10^7) that it is scarcely credible that any noteworthy proportion of the soil iodine may be considered to be derived from the sea.

In order further to test the possibility, a series of samples were obtained for us by Mr Aston, Chief Chemist to the Agricultural Department. They were collected at Ohau Bay, near Wellington, at successive distances from the sea, and were analysed by Mr K. C. Roberts, M.Sc., with the following results:

Distance from the sea in yards	20	90	210	360	410
Iodine in 10^7 of surface soil	70	72	66	72	60
Iodine in 10^7 of subsoil	72	63	—	14	—

The full explanation of these figures is not yet apparent, but they appear to indicate that while the iodine in the surface soil remains fairly constant, that in the subsoil diminishes with increasing distance from the sea.

In the above discussion the assumption has been made that the soils considered have not been artificially treated with fertilisers containing any appreciable amount of iodine, and for the majority of samples this has been ascertained to be true, even though certain soils, *e.g.* those of Morrinsville (Nos. 386, 387, 388, 389), have been treated with the usual phosphatic fertilisers, and a few elsewhere with stable manure. Chilean nitrate is rarely employed as yet. In these fertilisers the amount of iodine has been proved to be almost negligible (Table II, Chapter III), considering the proportionally small amount of fertiliser that is added to the soil. Hence the geological discussion of the source of soil-iodine given above cannot be seriously challenged on the ground that no due consideration has been given to the possibility of artificial addition of iodine to the soil. Owing, however, to the ready absorption of soluble iodide in soil by the plants growing therein, the addition of such fertilisers to the soil may have an appreciable effect on the amount of iodine in the vegetable crops.

Chapter VII.

The Relation between the Incidence of Goitre and the Geographical Conditions, and especially the Amount of Iodine in Soils and Waters in New Zealand.

In order to ascertain if possible the geographical factors (including the geological) influencing the incidence of goitre in New Zealand, we have divided the country into thirty-three districts of varying size, each more or less uniform in regard to its geographical conditions, and have determined the average amount of iodine in a representative series of soils from each. A corrected value has sometimes been obtained by omitting from the calculation of the average, abnormally large figures that cannot be taken as fairly representative of considerable areas of agricultural or pastoral land. In each district also has been determined the average incidence of goitre as determined by the examination of school-children by the State Medical Officers. The figures given are those of the numbers of inspections rather than of children examined, for as the examinations extended over several years it is probable that many children may have been examined more than once, and by different officers. This may enhance the general accuracy of the averaged figures of incidence given in Table V. The figures for goitre-incidence and soil-iodine have been plotted as ordinates and abscissae respectively in Fig. 2, and a smoothed curve has been drawn through the points obtained. So closely do most of these points lie to the curve that it is apparent that an intimate connection must exist between the amount of iodine in the soil and the incidence of iodine. Our curve, indeed, may be expressed approximately by the formula

$$y = \frac{360}{x} + 6,$$

in which "x" represents the amount of iodine in parts per 10^7 of the soil as determined by Carter's method and "y" the percentage incidence of goitre in school-children, according to the general standard of diagnosis adopted in New Zealand. It can be seen that, so long as "x" is less than 50, the formula expresses the curve almost exactly, but where the iodine is more abundant the final constant must be decreased and is only 2 at the far end of the curve. Such a relation cannot, however, be generally true unless the following con-

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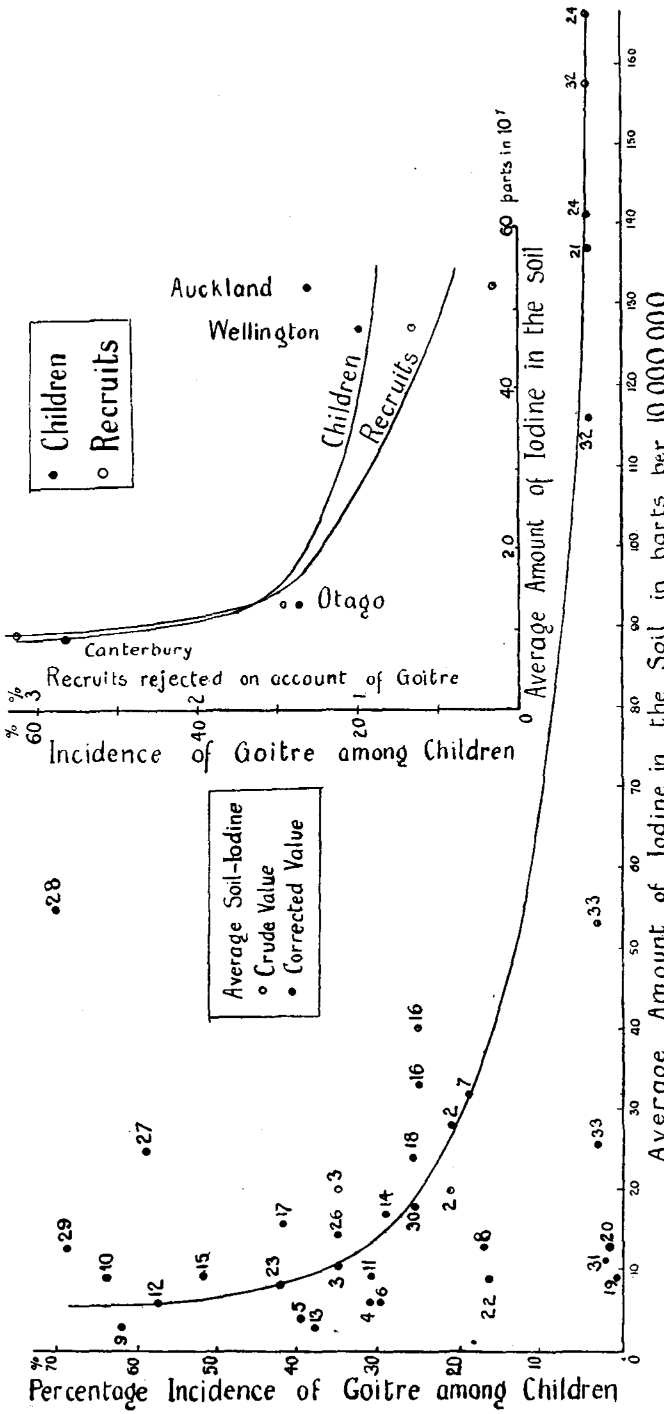

Fig. 2. Curves showing the relationship between the average amount of the iodine in the soils and the regional incidence of goitre among school-children and military recruits in New Zealand. The figures by dots denote the districts indicated in Table V.

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ditions hold: (1) the iodine-intake must be the sole factor determining the incidence of goitre in children; (2) and this must be obtained solely from the products of the local soil; (3) the averages in each case must be based on the examination and analysis respectively of a sufficiently large number of repre-

Table V.

Incidence of Goitre in School-Children in New Zealand in relation to the amount of Iodine in the Soil.

No.	District	Number of medical examinations of children	Recognition of goitrous condition	Percentage incidence of goitre	Number of soils analysed	Crude average of iodine in parts per 10^7	Corrected average of iodine
1.	Stewart Island	—	—	—	3	87	—
2.	Bluff	280	59	21	3	20	28
3.	Invercargill and Southland	2,960	1,049	35	31	20	10
4.	Waimea Plains	1,025	324	31	6	6	—
5.	Clutha Valley	2,947	1,197	40	63	4	—
6.	Taieri Valley and Milton	1,366	406	30	25	6	—
7.	Dunedin	8,413	1,573	19	61	32	—
8.	North Otago	895	155	17	27	13	—
	Southland and Otago	17,886	4,763	26·6	219	13	—
9.	South Canterbury	5,206	3,228	62	16	3	—
10.	Christchurch	5,548	3,548	64	19	9	—
11.	Banks Peninsula	1,293	397	31	8	9	—
12.	North Canterbury	2,782	1,608	58	3	6	—
13.	Marlborough	700	263	38	4	3	—
14.	Nelson	929	273	29	12	17	—
15.	West Coast	1,675	889	52	9	12	—
	Canterbury, Marlborough and Nelson	18,133	10,206	56·3	71	9	—
16.	Wellington	2,633	657	25	13	40	33
17.	Hutt Valley	2,343	968	41	2	16	—
18.	Wairarapa and Dannevirke	5,164	1,310	26	9	24	—
19.	Hawke's Bay	2,101	10	1·5	5	9	—
20.	Gisborne	2,770	40	1·4	3	13	—
21.	Horowhenua	560	21	4	8	137	—
22.	Palmerston and Marton	6,823	1,061	15·5	6	9	—
23.	Wanganui and Patea	3,591	1,581	44	18	8	—
24.	Taranaki	4,503	177	4	9	166	141
25.	Main Trunk Line	2,129	460	22	—	—	—
26.	Taumaranui	100*	35	35	7	14	—
	Wellington, Taranaki and East Coast	32,593	6,320	19·3	80	47	—
27.	West Coast and Te Kuiti	796*	468*	59	4	25	—
28.	Waikoto and Piako Valley	3,505	2,454	70	19	55	—
29.	Taupo and Rotorua	534	366	69	5	10	—
30.	Bay of Plenty	1,443	381	26	12	18	—
31.	Cape Colville Peninsula	220	5	2	5	11	—
32.	Auckland	3,240	147	4	11	158	118
33.	North Auckland	2,400	75	3	45	53	25
	Auckland Province	12,138	3,896	32·1	101	54	—
	New Zealand	80,750	25,185	31·2	471	27	22

* Approximations only.

sentative children and soils; and (4) the medical and chemical methods of investigation should be rigidly uniform throughout. Further, the form of the curve makes it necessary that each district must be strictly homogeneous. The arithmetic mean of dissimilar districts cannot lie on the curve, but must be above it. None of these conditions can be realised in practice, and departures from the normal curve are therefore inevitable. However, the curve does show clearly that variation in the average amount of iodine in soils containing more than 100 parts per 10^7 has little effect on the small incidence of goitre (less than 5 per cent.) which there exists; but as the amount of soil-iodine decreases, so the incidence of goitre rises. The effect of varying conditions in bringing about departures from this normal relation will be discussed later. Apart from the factors noted above, the most important causes of variation are the state of combination of the iodine in the soil, and the presence of abundant iodine in the drinking water, in regions in which the soil is relatively poor in that element.

Stiner (1924) held that the incidence of "school-goitre" had no regular relationship to the amount of adult goitre in Switzerland, as indicated, for example, by the results of the medical examination of military recruits. If we compare, however, the proportion of New Zealand recruits, ages 20 to 45, rendered by goitre unfit for military service, shown by the medical examinations in 1916–1918, with the incidence of goitre observed in the school-children in 1922–1924 in the four military districts, we find a like variation, and dependence on the soil-iodine. Roughly, the school-incidence is about twenty times the proportion of military rejections. Table VI and Fig. 3 give the closest approximation to the actual facts obtainable from all the available figures. The chief exception to this rule is the Auckland province, in which it appears that the incidence of school-goitre is much more than twenty times the percentage of military rejections.

Table VI.

Goitre among Military Recruits in New Zealand.

Military district	Recruits examined	Unfitted by goitre	School-children	Goitre-incidence	Soil analyses	Average iodine per 10^7
		%		%		
Auckland	35,235	0·15	14,908	26·3	104	53
Wellington	46,315	0·66	30,323	20·8	77	48
Canterbury	31,757	3·11	18,133	56·3	71	9
Otago	21,975	1·44	17,886	26·6	219	13
Total	135,282	1·24	80,750	3·12	471	27

This seems explicable in part by two factors: The incompleteness and biassed nature of the data in regard to the children in this province, for the figures for the most goitrous area, the Waikato and Piako Valleys, are nearly complete and as will appear are possibly excessive, while only a small proportion of the much larger number of children in the non-goitrous urban district of Auckland have been examined. It is also probable that in non-goitrous regions a slight incidence during childhood will be less likely to affect permanently the adult than in regions where the incidence of goitre is heavy.

In the following paragraphs a brief description is given of each district as regards geological and geographical features, climate, and animal and vegetable food products. As the bulk of the iodine derived from foodstuffs is yielded by the milk, fresh vegetables and fruit, the relation between the amount of iodine in the soil and the incidence of goitre should be closer in rural districts than in urban districts, which do not draw their supplies entirely from their immediate surroundings. The incidence of goitre and the average amount of iodine in the soil in each of these districts are given in Table V.

1. *Stewart Island,* a sparsely populated and hilly island, 660 square miles in area, chiefly forest land, is composed of quartzose, schists and granites, the latter yielding soils averaging 127 parts of iodine per 10^7. Rainfall, 50 to 70 inches per year. No figures are available of the incidence of goitre.

2. *The Bluff.* A ridge of about 10 square miles in extent; the only inhabited area of basic plutonic rock (norite) in New Zealand. The annual rainfall is 40 to 50 inches. The incidence of goitre is 21 per cent., and the corrected average shows 28 parts of iodine in 10^7 of soil.

3. *Invercargill and Southland.* Chiefly a plain of greywacke gravel, with small areas of younger marine sediments and coal measures, and greywacke hills. The annual rainfall is about 40 inches. The chief food-industries are dairying, and the production of oats and mutton. The incidence of goitre is 35 per cent., and the corrected average amount of iodine in the soil is 10 parts per 10^7.

4. *The Waimea Plains* are also composed of gravel derived from the greywacke and mica schist hills on either side. Its rainfall is 30 to 40 inches annually, and its products are chiefly those of the last region. The incidence of goitre is 31 per cent. and the average amount of iodine in the soil is 6 parts in 10^7.

5. *The Clutha Valley* lies mostly in mica schists and the gravel and sands derived therefrom. The chief sources of the river water are snow-fed lakes. The greater part of the catchment-area of the river, a broken plateau about 1500 feet above sea level, has a low annual rainfall, 15 to 30 inches. The chief food product in this region is mutton, with fruit in irrigated areas, while dairying is carried on in the very goitrous regions about Balclutha, near the mouth, where no trace of iodine could be observed in the river water. The incidence of goitre is 40 per cent. and the average amount of iodine in the soil is 4 parts in 10^7.

6. *The Taieri Valley and Milton.* The Taieri River drains the same broken plateau as the Clutha, but includes a high widespread alluvial plain, and another near sea level, from which the bulk of the soil samples were obtained. The river water contains only 1 part of iodine in 10^7. Mutton is produced on the greater part of the area, and grain on the plains, with some dairy produce (cheese) on the lower plain. The incidence of goitre is 30 per cent. and the average amount of iodine in the soil is 6 parts per 10^7.

7. *The Dunedin district* consists of hills of intermediate and basic volcanic rocks on which the soil contains an average of 21 parts of iodine per 10^7. On these are pastured the cattle from which is derived the bulk of the dairy supplies. There is a stretch of raised marine marsh, on which the soil contains an average of 70 parts of iodine. From this comes the bulk of the market-garden

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produce for the city. The rainfall is about 37 inches per annum. The town water supply drains chiefly from mica schists, and contains no recognisable iodine, though a portion of it derived from the volcanic hills contains 0·02 parts in 10^7. The springs issuing from these hills also have some iodine—0·02 to 0·08 part in 10^7. The incidence of goitre is 19 per cent. and the average amount of iodine in the soil is 32 parts in 10^7.

8. *North Otago* consists of a broken plateau of mica schist and greywacke, which is but little inhabited, and a margin of younger marine rocks, and occasionally basic volcanic rocks partly covered by greywacke gravel and loess. The largest town, Oamaru, draws its water supply from the snow-fed Waitaki River. The rainfall is approximately 20 inches per annum. The food products are mutton on the high country, butter and cheese, eggs, and grain on the seaward margin. The incidence of goitre is 17 per cent. and the average amount of iodine in the soil is 13 parts in 10^7.

9. *South Canterbury* has a background of high greywacke hills (rainfall 40 to 100 inches), which are sparsely settled and produce mutton, a wide coastal strip of gravel plain producing mutton and grain and a minor amount of dairy produce, and a very limited area of foothills composed of younger marine rocks. The rainfall on this lower portion is low (20 to 25 inches), and it is largely irrigated from the partially snow-fed streams which cross it. Its soil-iodine is very low, and the goitre index high. The incidence of goitre is 62 per cent. and the average amount of iodine in the soil is 3 parts in 10^7.

10. *Christchurch* is situated on this plain. It draws its grain, fruit and vegetable supplies from local sources, and its dairy products from the Canterbury plain and Banks Peninsula. Its water supply comes from artesian wells, the water of which is derived originally from partially snow-fed rivers, and has percolated through fluviatile greywacke gravels in which there is only rarely any carbonaceous matter or marine deposit. No iodine was recognised in the water supply. The incidence of goitre is 64 per cent. and the average amount of iodine in the soil is 9 parts in 10^7.

11. *Banks Peninsula* consists of basalt, but is covered by a layer of loess, the wind-blown dust derived from the greywacke rocks of the Southern Alps. This forms much of the soil. The rainfall is about 40 inches per annum. The food products of the region are chiefly those of the dairy. The chief settlement, Lyttelton, derives its water supply from artesian wells at Heathcote, on the margin of the Canterbury Plain, and the occasional salinity of the water indicates that, as a result of pumping, some sea water has been drawn into the supply. The tidal fluctuation of the level of the wells supports this hypothesis. The ratio of chlorine to iodine in the water is, however, only a twentieth of that in sea water, so that some iodine in excess of this ratio has been added from other sources, probably the organic remains in the sediments through which the water percolated. A sample from Heathcote gave chlorine 42,000 parts per 10^7, iodine 0·02 part. The incidence of goitre is 31 per cent. and the average amount of iodine in the soil is 9 parts in 10^7.

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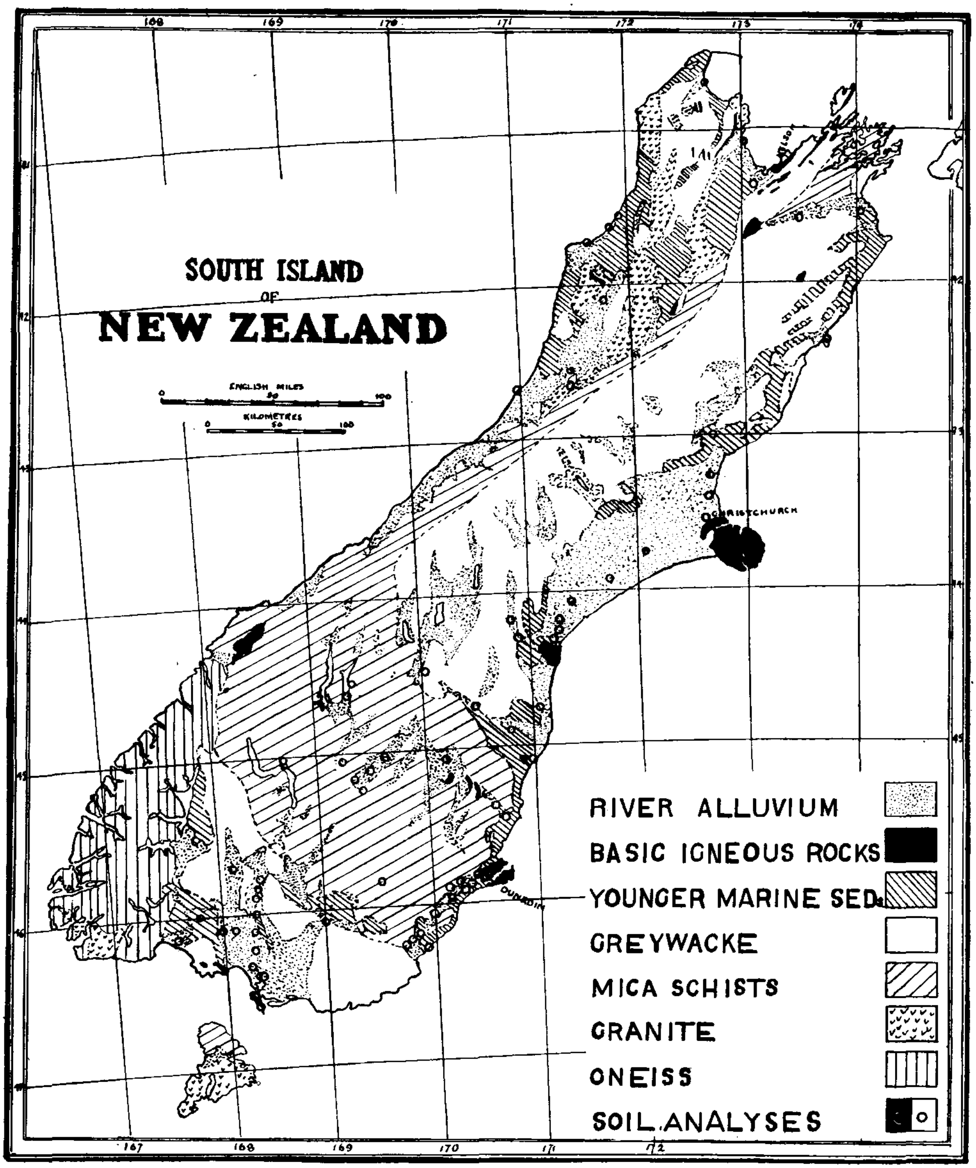

Chart A. Geological sketch-map of New Zealand. South Island.

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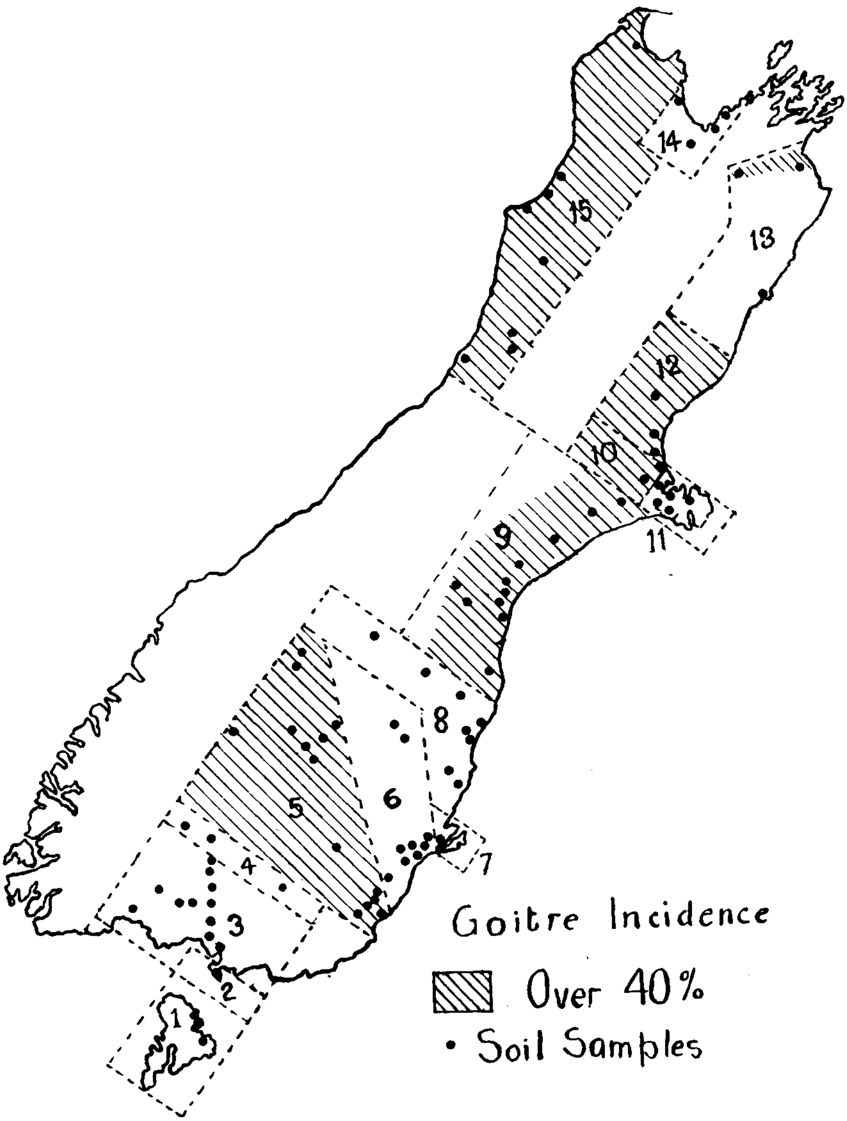

Chart B. Districts of goitre-incidence and localities of analysed soils in New Zealand. South Island.

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12. In *North Canterbury* the geographic conditions and products are similar to those in South Canterbury, save that the regions of younger marine rocks are more extensive, and the rainfall a little greater. The incidence of goitre is 58 per cent. and the average amount of iodine in the soil is 6 parts in 10^7.

13. The *Marlborough* district consists chiefly of high greywacke mountains, partly covered by younger marine sediments, and especially a thick limestone on which the rainfall is about 40 inches. The area of greatest settlement is the broad, gravel-filled Wairau Valley, extending into the greywacke hills, with a lower rainfall—26 inches. Here grain is produced. This is an area of marked endemicity of goitre. This district as a whole is not fully represented by the few soil-samples and schools studied. The incidence of goitre is 38 per cent. and the average amount of iodine in the soil is 3 parts in 10^7.

14. In the *Nelson* district the geological features are complex. It consists of an eastern range, chiefly of claystones and greywackes, and a western range of slates, granite and marble, between which is a wide area of low gravel-hills and river-alluvium, on which are the orchards, the fruit of which is the chief product of the district. The rainfall is approximately 50 inches. The incidence of goitre is 29 per cent. and the average amount of iodine in the soil is 17 parts in 10^7.

15. Theinhabited parts of the *West Coast* are chiefly on foothills, the coastal plain itself, and in front of the main range of the island. The rocks are slates, greywackes, granites and diorites in the ranges, sandstones and coal measures with a minor amount of younger marine rocks in the foothills, and widespread gravelly river-terraces and raised beaches. The rainfall is about 100 inches. Coal- and gold-mining are the chief industries. The incidence of goitre is 52 per cent. and the average amount of iodine in the soil is 12 parts in 10^7.

16. The *Wellington* district consists chiefly of greywacke hills from which are derived the city water supply and part of its vegetables and dairy-produce. There are also small areas of upland marsh, and low level brackish swamp land near the city, which do not yield an appreciable proportion of the vegetable supply. The average soil-iodine is obtained from a rather widely varying range of samples. The bulk of the fruit and vegetables comes from the adjacent gravel plain of the Hutt River (District 17), where the soil is deficient in iodine, and a large part of the milk supply from the Horowhenua coastal plain, where it is abundantly present in the soil (District 21). That the ratio of school-goitre to soil-iodine is approximately normal in this district results from a balance of very diverse factors. The rainfall is about 60 inches annually. The incidence of goitre is 25 per cent. and the corrected average amount of iodine in the soil is 33 parts in 10^7.

17. The *Hutt Valley* is a broad alluvial river plain between greywacke and claystone mountains, with a rainfall approximating to 60 inches per year. Its products are those of market-gardening and dairying. The incidence of goitre is 41 per cent. and the average amount of iodine in the soil is 16 parts in 10^7.

18. The *Wairarapa* and *Dannevirke* region is one of rather diverse features. The region lies east of the high greywacke ranges, and west of lower hills largely made up of younger marine sediments and some limestone. From these issue spring waters which in two cases have been found to be rich in iodine (Nos. 11 and 12 in Table III). Widespread alluvial plains of greywacke gravel cover much of the more thickly inhabited parts, though the other two formations are exposed over considerable areas. The average rainfall is 40 inches per year. Grain and dairy-produce are the chief food supplies from this region. The incidence of goitre is 26 per cent. and the average amount of iodine in the soil is 24 parts per 10^7.

19. The *Hawke's Bay* region, which is the northward continuation of the preceding one, differs from it in that the younger marine sediments now form the most of the hills enclosing a broad alluvial plain. This plain is made up of greywacke gravel derived from the distant highlands, and of clay and sand from the younger marine sediments, and is interstratified with layers of very young sea-beach deposits. This great deltaic series yields abundant artesian water, the chief source of drinking water for the district. Samples of this have been found to contain 0·16 to 0·20 part of iodine per 10^7. The soil, however, is unusually poor in iodine. The incidence of goitre is far below the normal soil-iodine-goitre curve. This result seems to show the effect of the iodine in the water supply in making good the deficiency in the soil. The region has a rainfall of about 40 inches per year, and produces much meat from the hilly parts, wheat, vegetables, dairy-produce and fruit from the alluvial plain. The incidence of goitre is 1·5 per cent. and the average amount of iodine in the soil is 9 parts in 10^7.

20. The *Gisborne* district consists almost entirely of the younger marine rocks, chiefly claystones, with only a minor amount of river-alluvium. The rainfall averages about 50 inches per year. Apart from the chief export-food (mutton), the vegetables and dairy-produce are only those required for local use. The number of soil-analyses is scarcely sufficient to characterise the district, but yields the average figure of only 13 parts per 10^7. The goitre-incidence, 2 per cent., is far below that normal for such an amount of soil-iodine. Again, the effect of iodine in spring and river waters appears to explain the discrepancy. Table III shows this to be the region where the greatest number of analysed iodine-bearing spring waters has been obtained. The water supply of the chief town, Gisborne, derived from rivers, contains 0·18 part of iodine in 10^7. It is perhaps noteworthy that in a small country school in this district, Waikohu, where rain, rather than river water is the chief supply of drinking water, goitre is very marked, but the number of children—24—is too small to permit of generalisation. The incidence of goitre for the whole district is 1·4 per cent. and the average amount of iodine in the soil is 13 parts in 10^7.

21. The *Horowhenua* coastal plain is a strip of lowland between the greywacke ranges and the sea. It is open to the dominant north-westerly winds

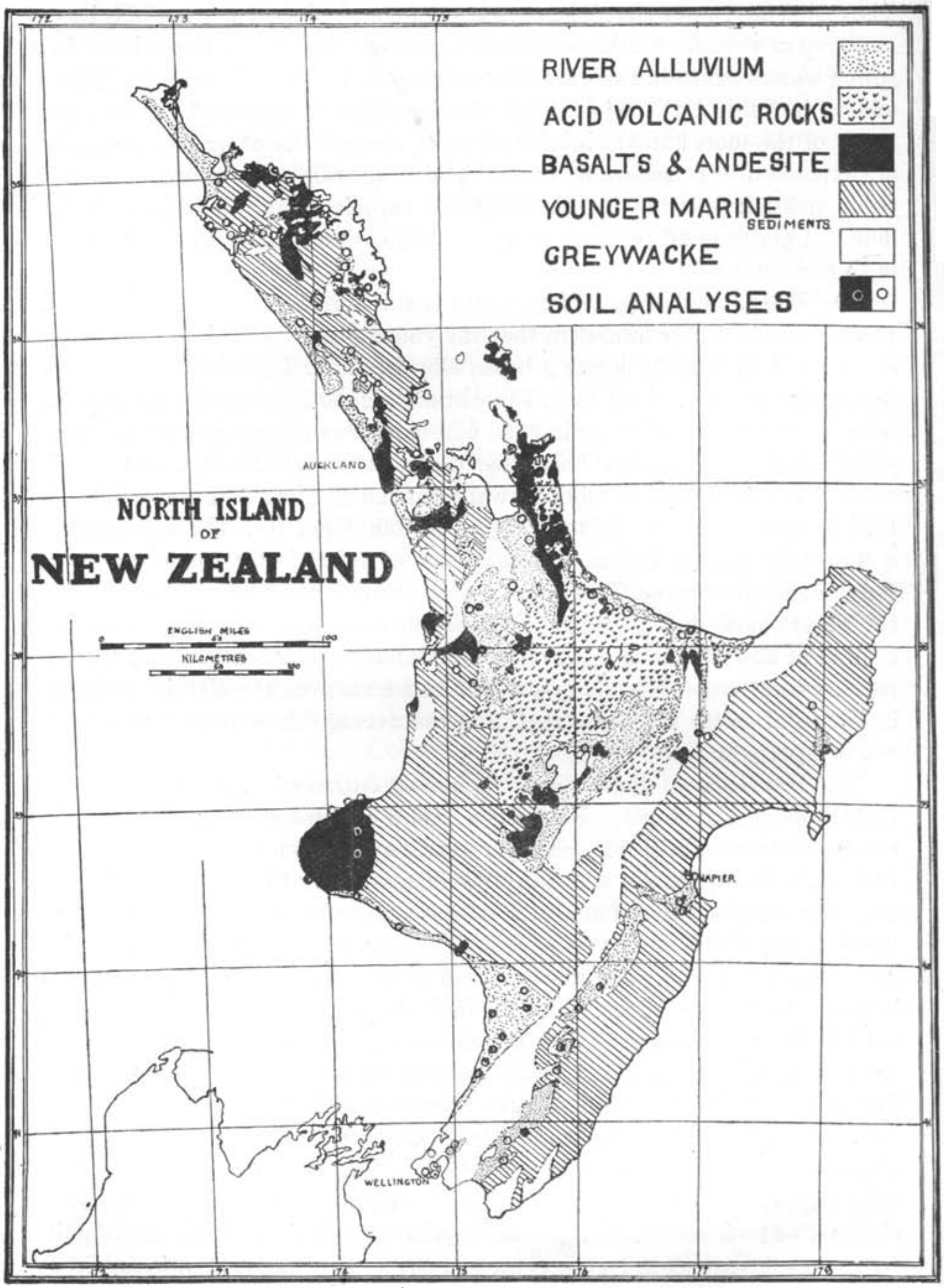

Chart C. Geological sketch-map of New Zealand. North Island.

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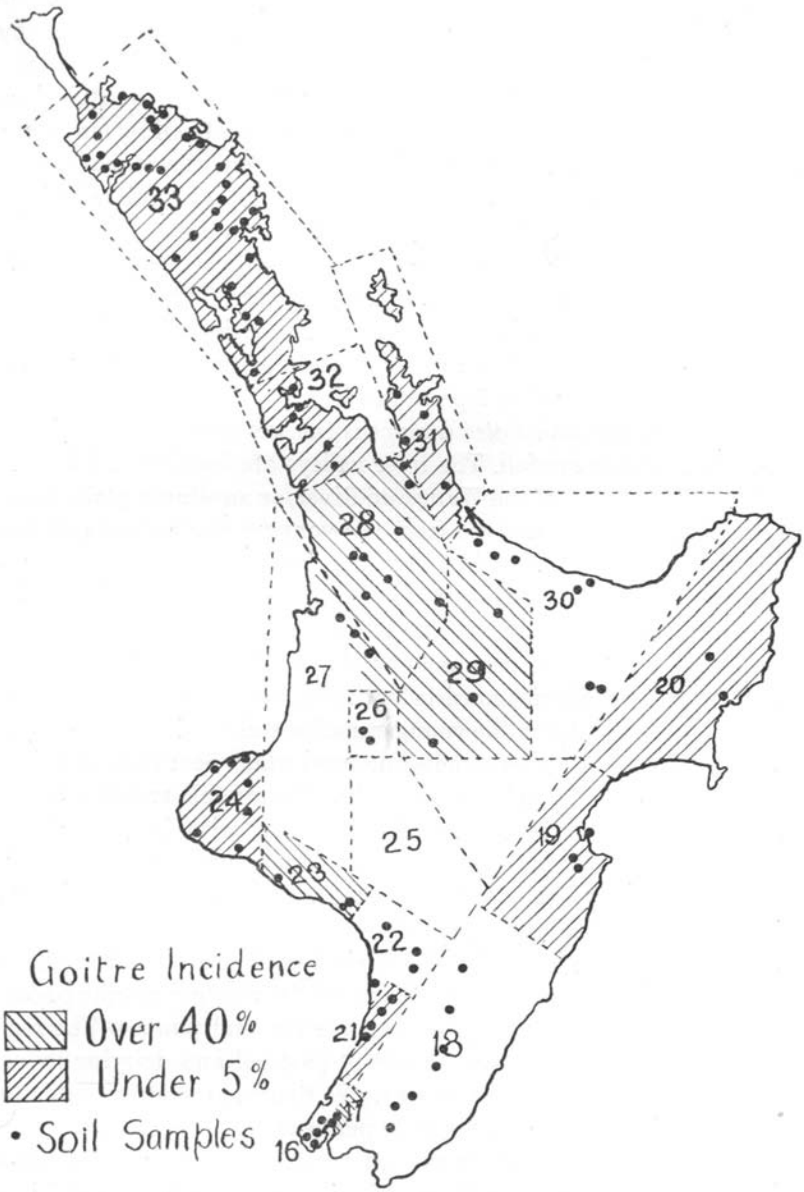

Chart D. Districts of goitre-incidence and localities of analysed soils in New Zealand. North Island.

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coming off the sea. The rainfall is about 40 inches per annum. The geological formation is a complex of river gravels (greywackes), swamp deposits and beach sands, but the soil is consistently rich in iodine. The chief food products are those of dairying. The incidence of goitre is 4 per cent. and the average amount of iodine in the soil is 137 parts in 10^7.

22. The *Palmerston* district has an annual rainfall of about 40 inches. Its underlying formation is the younger marine clays and sands, but there is a covering near Palmerston of greywacke gravels from the Manawatu River. The food products are those of dairying and wheat. The goitre-incidence is lower than would be normally expected from the amount of soil-iodine, but the latter figure was based on the examination of only six soil-samples. No investigations have been made of the water supply, but the spring waters might be expected to contain a certain amount of iodine derived from the marine sediments. The incidence of goitre is 15·5 per cent. and the average amount of iodine in the soil is 9 parts in 10^7.

23. The *Wanganui* and *Patea* district is the westward continuation of the last, and has a similar rainfall. The river valleys are broader and deeper, and the chief town lies in that of the Wanganui River, on an alluvial plain, composed of thoroughly leached silt derived from the younger marine rocks, covered in part by dune-sand. Its soil is thus very deficient in iodine. The town water supply, derived from lakes among dunes, must also be very deficient in iodine, though it has not been analysed. The incidence of goitre is accordingly high —44 per cent.—and the average amount of iodine in the soil is 8 parts in 10^7.

24. The *Taranaki* district consists for the most part of intermediate volcanic rocks (breccias, etc.) lying on the younger marine series, with a central andesite mountain, Egmont, the streams radiating from which bear the volcanic debris beyond the limits of the solid igneous rocks. The rainfall averages from 60 to 70 inches. Dairying is the pre-eminent industry, with bacon-curing as an accessory. The soil-iodine shows the highest crude average in New Zealand, and the incidence of goitre is only 4 per cent. The corrected average amount of iodine in the soil is 141 parts in 10^7.

25. The region through which the *Main Trunk Line* runs from Marton to Taumaranui consists of rather precipitous hills of younger marine rocks, with some covering of river-borne andesitic material, and pumice. The region is passing from a saw-milling stage to one of pastoral and dairying industries. The rainfall is about 70 inches per year. No figures are yet available for the soil-iodine. The incidence of goitre is 22 per cent.

26. *Taumaranui* is a northern extension of this region, in which, however, there is some settlement on the flood-plains of the upper Wanganui River and its branches, which are composed of well-leached sediment from the marine rocks, with some covering of pumice. No data are available as to the total number of scholars in the various schools examined. The incidence of goitre is 35 per cent. and the average amount of iodine in the soil is 14 parts in 10^7.

27. The *West Coast* district includes the region between the Main Trunk

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line and the Tasman Sea. It consists of younger marine sediments, a small area of pumice, and the widest stretches of limestone in the Dominion. The soil is unusually rich in iodine (average, 37 parts per 10^7). The rainfall is about 60 inches per year. The chief food industries are those of dairying and sheep-raising. Unfortunately, there are insufficient soil-analyses, and records of goitre-incidence, to permit detailed discussion. Such as are available show that the coastal portion, where the younger marine rocks predominate and the soil is likely to contain most iodine, has a low goitre-incidence, probably not over 12 per cent., while the eastern part, namely, the town of Te Kuiti and other settlements along the railway line, and for the most part on river-flood plains where the iodine is low, show a high incidence. As the data for the latter are more complete than for the former, it is but natural that the average incidence for the whole district is well above the normal curve value. The region is especially worthy of detailed study, as it contains the most extensive area of limestone in the Dominion, and an unusually large proportion of Maoris in the population, being largely an old native reserve, the "King Country." In this connection it may be well to cite Notter and Frith's (1908) comment, also noted in other standard works, that in New Zealand the greater part of the native population live on magnesian limestone, and goitre and cretinism are entirely unknown among them. It is open to criticism, in that this is the only district where the majority of Maoris live on limestone. Elsewhere, they usually live on other formations. The limestone in question is not magnesian, and though goitre may have been rare among the Maoris when the land was first colonised by Europeans, it has since appeared among them in considerable amount. The incidence of goitre is 59 per cent. and the average amount of iodine in the samples of soil examined is 25 parts in 10^7.

28. The *Waikato* and *Piako Plains* consist of river-alluvium formerly more or less swampy, but now being drained. The material for this alluvium was derived chiefly from the siliceous volcanic rocks, ashes and pumice in the centre of the island, and to some extent from the adjacent greywacke hills. The annual rainfall is approximately 60 inches, and the chief food industry is dairying, with a minor amount of fruit-growing. The soil-iodine varies considerably, but reaches a high average figure, which makes the very high incidence of goitre difficult of explanation. It is possible that here the personal factor may be involved, as the figures quoted for this district are those obtained by one medical officer only. Previous (but less complete) investigations by other observers indicated that a lower figure might be expected. It is to be noticed also that a large proportion of the cases included in the figures here given were classed as merely "incipient." The incidence of goitre is 70 per cent. and the average amount of iodine in the soil is 55 parts in 10^7.

29. The *Rotorua-Taupo* district is made up entirely of the infertile siliceous rocks, rhyolite and pumice. The thermal spring waters are not utilised to any extent in the normal domestic supply, and the presence of iodine in some of them will not appreciably influence the average daily intake of iodine by the

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population of Maoris. The local food products are largely sufficient to supply the district. The average rainfall is about 60 inches. The incidence of goitre is 69 per cent. and the average amount of iodine in the soil is 10 parts in 10^7.

30. The *Bay of Plenty* has a diversified character, and when more data are available may be divisible into several distinct goitre-iodine districts, with characteristic geological features. Its originally deeply indented coast has been filled in by the great river plains of the Rangitaiki, composed mostly of pumiceous alluvium with a low content of iodine. There is a moderate incidence of goitre, the inhabitants including a large number of Maoris, among whom the incidence is only half as great as among the Europeans. Along the coast, marine swamp-deposits occur, with higher iodine-content, and in the north-western angle of the district the ranges coming down to the sea are largely of andesite volcanic rocks, on which the incidence of goitre is very slight. Again, in the eastern portion of the district, the region drained by streams coming from greywackes, Tertiary marine sediments and pumice, is somewhat lower than on the river-alluvium. This is the "Urewera country," in which the population is almost exclusively of Maoris, living under rather primitive conditions. According to the recent investigations of one of us (C. E. H.), the incidence of goitre among children and adults is here about 18 per cent. The average of eight soil-samples obtained shows approximately 12 parts of iodine in 10^7. These are not included in the above table. It is interesting to note that even in this small community of 550 persons the incidence of goitre is notably higher where the soil is most deficient in iodine. For the whole Bay of Plenty region the goitre-incidence among children is 26 per cent., and the average soil-iodine 18 parts per 10^7. The rainfall for the district is about 60 inches per year.

31. The *Cape Colville Peninsula* is a high ridge consisting chiefly of acid and intermediate volcanic rocks, rhyolite, dacite and andesite, in which gold-bearing reefs occur together with some sulphides of the common metals. The rainfall is high (about 75 inches annually) and the soil-iodine in the analysed samples is low (11 parts in 10^7). The incidence of goitre, however, is remarkably low, 2 per cent. in the single town examined (Waihi). The fresh foods are probably locally produced. The information concerning both goitre and soil-iodine is unfortunately far from complete, and it is not possible at present to discuss the cause of the abnormally low incidence of goitre that is at present apparent.

32. The *Auckland* district consists of three main geological formations. There is a very widespread series of flows of basalts and ashes, which yield soils rich in iodine. These overlie younger marine sediments in which some volcanic ash occurs, but they yield soils not nearly so rich in iodine. In the west of the city the hills which yield the town water supply consist chiefly of these sediments and basic volcanic agglomerate, probably richer in iodine. It is not possible to state the proportion which each formation would contribute to the town food supply. The annual rainfall is about 42 inches. The incidence

of goitre is 4 per cent., and the corrected average amount of iodine in the soil is 118 parts per 10^7.

33. The *North Auckland* district has an annual rainfall of about 60 inches. It is very complex geologically, being made up of the older greywackes, etc., younger marine sediments, clays, and limestones (comparatively poor in iodine), a little rhyolite and much more basalt, the latter yielding soils often very rich in iodine, and post-Tertiary brackish swamp-deposits and sand, which may be either rich in iodine (organically combined) or else contain but little. The local incidence of goitre is not less varied, but though numerous samples of soils have been examined and the amount of goitre determined in a number of schools, it does not yet seem possible satisfactorily to analyse the figures to determine whether the area may be subdivided into separately uniform districts, or to explain the low average incidence of goitre in relation to the medium amount of iodine in the soil. In attempting to do this we have been much helped by the Director of the Geological Survey, Mr P. G. Morgan, and the geologist in charge of the survey now in progress in the area, Mr H. T. Ferrar, who have made many helpful suggestions and supplied much pertinent information. Among the influences affecting these average values, is the fact that the soil-samples analysed come from school gardens often situated on the poorer ground, not typical of the richer agricultural land of the locality, and that much of the area has been recently opened up so that the newly arrived settlers may not have become physiologically adjusted to their environment. There is need here for a very intensive survey of the distribution of the disease, the various types of soil and the other environmental factors. The incidence of goitre is 3 per cent., and the corrected average amount of iodine in the soil is 25 parts in 10^7.

Summarising, it appears that, in spite of great variety of conditions in regard to topography and climate, 27 out of the 33 districts into which New Zealand has been divided in this discussion have an average amount of iodine in the soil very close to that indicated by the curve and empirical formula given. Of the four in which the goitre is abnormally low, the presence of abundant iodine in the drinking water rather than in the soil is the obvious explanation in two cases (Gisborne and Hawke's Bay), while the data are too incomplete to afford the explanation in the other two (Cape Colville and North Auckland Peninsulas). Of the two cases in which the goitre is reported to be far more abundant than would correspond with the average amount of soil-iodine, we have in the one case (27, West Coast) very incomplete results with an obvious bias towards high goitre-incidence, and in the case of 28 (the Waikato and Piako Valleys) the rather special condition of an extensive area of reclaimed swamp and river-alluvium, largely derived from pumice, in which the mineral salts containing iodine are almost certainly in small amount, and in which the organically combined iodine may not have been readily yielded to the higher plants, the grasses, etc. The same explanation may hold in the case of 29 (the Taupo and Rotorua districts), in which also goitre is reported

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to be abnormally high. In all three of these districts, however, which were examined by the same medical officer, it seems possible that the personal factor may be involved in the high incidence reported. It is proposed to investigate further both the incidence of goitre in these districts and the state of combination of the iodine in their soils.

Chapter VIII.

The Incidence of Goitre in relation to Geological Formation.

The following is an account of the chief published studies of geological formation in relation to the incidence of goitre, and their reconsideration in the light of New Zealand experience. The hypothesis of deficiency in soil-iodine as the cause of goitre is considered.

The incidence of goitre recorded by the medical examination for fitness of all Frenchmen attaining age for military training was analysed by a commission appointed by the Sardinian Government in 1848, and the facts were reviewed by St Lager in 1867. His conclusions, restated by Lebour, showed that goitre was endemic on claystones and marls, on some limestones and especially those rich in pyritous inclusions, and on schists containing metalliferous veins. It was not endemic on alluvial and glacial deposits, on conglomerates and sandstones, on the majority of coal measures, on certain other limestones, and gypsiferous marls, and on all igneous rocks. His view was that goitre is most directly associated with the distribution of metalliferous deposits, especially of iron pyrites. Baillarger's (1873) review of the relation between the incidence of goitre and geological formation has not been accessible to the present writers, but is cited by Clarke and Pierce as indicating that goitre does not prevail exclusively on any particular formation; though extremely common on dolomites or magnesian limestones and rare on others, and it is contended that such soils are particularly liable to contain these metallic sulphides.

Lebour (1881) concluded from much less complete British data that goitre was absent from areas of alluvial and glacial deposits; the sandstones, claystones and limestones of Jurassic age; and also from the majority of the New and Old Red Sandstone, the grits and coal measures, the slatey older Palaeozoic rocks and all igneous rocks. On the other hand it is present, though but rarely, on the Cretaceous claystones and chalk, but is endemic on the Carboniferous limestone. He held that in both England and France the rocks which support most goitre are such as are both calcareous and metalliferous, but metalliferous impurities alone cannot be credited with the origin of the disease, nor can absence of limestone check its development.

McCarrison's observations in North-Western India again showed the frequency with which goitre is associated with limestone areas, though he believed that the water draining from these areas was the vehicle of the disease-infection. He stated "that in general goitre is most prevalent in the regions

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underlain by Silurian, Carboniferous and Permian rocks, while sediments of Jurassic, Cretaceous and post-Tertiary seas, as well as all fresh water deposits, are comparatively free from the disease. In some cases, goitre does appear in localities over the second group, but in these places the underlying strata are thin and ground water penetrates to the lower groups. It is observed that the influence of the first group is weakened or lost by superposition of the fresh water strata."

This is summarised by Clark and Pierce (1914), from whose work the above citation is taken. They remark, moreover, that Baillarger's conclusion as to the general but not exclusive association of goitre with dolomitic limestone is largely in accord with its distribution in the Virginias. An exception to the general rule is noted in the northern peninsula of Michigan, where Clark "observed a considerable amount of thyroid-enlargement among, but not exclusively confined to, the Indian population. Here the rocks belong to the upper levels of the Algonquin formation of the Huronian period. On the other hand, over two-thirds of the area of West Virginia is underlain by the Carboniferous system of rocks in the south-eastern portion and the Silurian limestone in the south-west, where goitre is extremely prevalent." Reference is made also to certain counties in the Virginias underlain by Carboniferous coal-bearing formation, in which there is a very low incidence of goitre.

From a geological view-point there seems little reason why the mere age of a formation could have any influence on the prevalence of goitre on its surface (except in so far as leaching might deprive it of soluble iodine in the course of ages), though the physical and chemical characters of the formation might have some such relation. The contrast between the general features of the Silurian, Carboniferous and Permian rocks, and those of the Jurassic and lower Cretaceous of the most thickly populated parts of Europe and America, suggests that the former and more goitrous formations are those containing more abundant limestone and sandstone, and are therefore poorer in colloidal matters than the largely clayey Jurassic and lower Cretaceous formations. If the incidence of goitre depends on the amount of iodine in the soil, the power of the ferruginous clay-colloid to retain adsorbed iodine may be a partial explanation of the relationship between the geological formation and the incidence of goitre. In accordance with this suggestion it may be noted that the northern peninsula of Michigan, a goitrous region, is largely made up of the Keewanawan sandstone deficient in clay matter. The non-goitrous areas of Virginia, where the coal measures are exposed, may derive their iodine from the plant-remains and coal therein, or from the associated claystones, and so contrast with the goitrous limestone regions about them.

A group of Swiss writers have considered the possible relation of the incidence of goitre to geological formations. As their writings are not here accessible, a brief review by Messerli (1922) will be quoted. "The geological theory, admitting that the constitution of the soil, with the presence or absence of certain salts, was the cause of endemic goitre, defended in our country

(Switzerland) by Bircher (1883) and Kocher (1889) is equally abandoned by the majority of observers who have interested themselves in this question. Schittenhelm and Weichardt (1912), Dieterle, Hirsfeld and Klinger (1913–16) and myself (1913–21) have concluded that endemic goitre has no relation with geological constitution. On the other hand, nearly all modern researches show the geographic distribution of endemic goitre to be adjacent to rivers. A very great number of authors attach much importance to drinking water as a factor in this question. Even for the partisans of the geological theory of goitre, water was the intermediary between the soil and the goitrous inhabitants. Bircher (1908) has pointed out more than forty observations of various authors proving the importance of the part played by drinking water in the incidence of goitre. My observations speak equally of the importance of water, at least as the means of transmission of the agent of goitre. Bircher (1911), in restating his father's theory, sought to demonstrate that in traversing certain geological formations in Switzerland, the marine-molasse, the drinking water became charged with a specific colloidal substance. I have already set out that the properties of the colloidal toxin described by Bircher are precisely those of a bacterial toxin—it disappears on boiling, but not on filtration. Repin (1911), after having supported the hypercalcification of waters, has accused their radioactivity, a theory which has been broken down by several authors, among others Hesse (1913)."

The rarity of goitre in areas of river-alluvium, which is emphasised by St Lager, Lebour and McCarrison, and apparently disputed by Messerli, needs revision in the light of New Zealand experience. With three notable exceptions, the river-valleys and flood-plains are the areas on which goitre is most prevalent. In these the detritus is a gravel and silt derived with but little *decomposition* from schist, greywacke or pumice, or after thorough leaching from the younger marine rocks[1]. The soil and the drinking water derived here from wells or rivers contains very little iodine. On the long series of confluent river deltas which make up the Horowhenua coastal plain, goitre is, however, rare; but here the soils have been enriched by iodine, the source of which is not yet quite apparent. In the Hawke's Bay and Gisborne district the river-valleys cutting through the younger marine rocks have flood-plains made of well-leached detritus derived therefrom and contain but little iodine; but the drinking water utilised has drained across or through the marine formations and contains a noteworthy amount of iodine derived from them, and the incidence of goitre is low. Thus it appears these last two areas exemplify to some extent the conditions in English and French river-valleys studied by St Lager and Lebour, which are cut into marine sediments, while the rivers of the South Island of New Zealand draining from the Southern Alps and other

[1] In porous soils on slopes the opportunity for a thorough leaching of the iodine from the soil is at a maximum, and it is noteworthy that McCarrison (1913, p. 226) mentions these as ideal conditions for the development of goitre. At the same time also he describes a high content of organic matter as being also an ideal condition, but to this our experience is directly opposed. Organic matter is decidedly low on the areas of greatest incidence of goitre in the South Island.

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ranges approximate more closely to the conditions pertaining in the Swiss river-valleys, where the incidence of goitre is high. The incidence in New Zealand, however, accords with the conclusion of St Lager and Lebour in that it is very slight on igneous rocks, exception being made of the siliceous lavas and pumice, extensive areas of which were not available for the study of these authors; and if reliance can be placed on the medical data concerning Waihi, where but 220 children were examined, it may be noted as a region where a low incidence of goitre was found in a region of pyritic deposits (certainly not in limestone).

Stiner's (1924) chart of the incidence of goitre among the young men of Switzerland, as shown by the proportion found to be unfitted for military service by goitre during the examinations of recruits in 1921–2, is of particular interest in this connection and is shown in modified form herewith. In Fig. 3

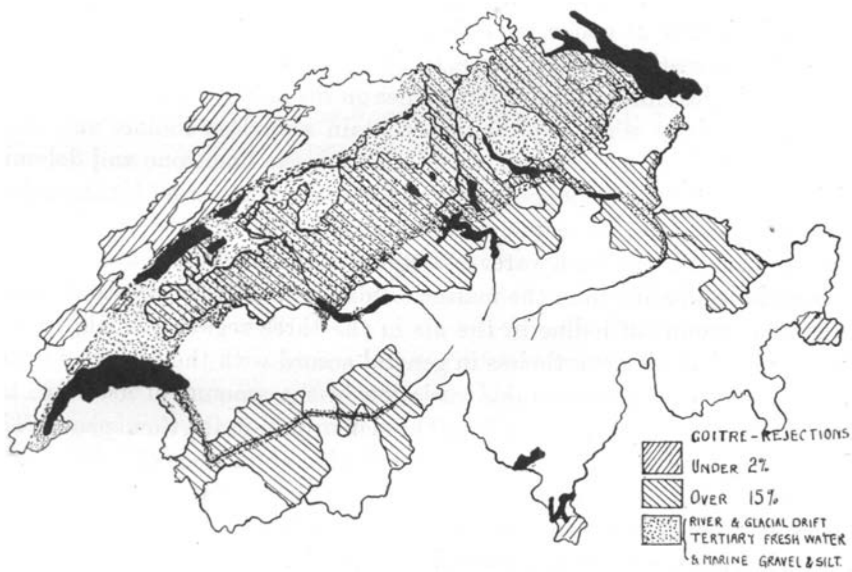

Fig. 3. Map showing the distribution of the younger geological formations and the incidence of goitre in Switzerland as determined by the percentage of military recruits rejected on this account during medical inspection. (The black areas are lakes.)

are indicated the areas for which the rejections of recruits are respectively less than 2 per cent. and more than 15 per cent. Comparing these with the recently published official geological map of Switzerland it will be seen that the areas of lowest incidence of goitre are those occupied by the marine Mesozoic rocks of the Jura Mountains and about Lake Lugano (chiefly limestone, marl and claystone), together with some areas of granite-gneisses in the Val Maggia and Upper Engadine. The high Alps, with their gneisses, schists and limestones, are the area in which the rejections have an intermediate value between 2 per cent. and 15 per cent., while the regions of highest incidence are the deep alluviated river-valleys of the Aar and Lauterbrunnen, emerging from the

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Alps, the foothill ranges and the great central lowland. Here the chief formations are Tertiary deposits of silt and gravel, mostly of fluviatile or fresh water origin, but also in part marine (the "Molasse" and "Nagelfluh"), together with an unevenly distributed covering of post-Tertiary glacial and fluviatile drift. The boundaries of the areas of goitre-incidence are of course influenced by the politically determined statistical districts, and are not the natural ones, but nevertheless their close approximation to the geological boundaries is striking, and, we believe, significant of a real control of the incidence by the nature of the environing geological formations, though this is doubted by Stiner himself[1]. He points out for example that in the regions of lowest incidence of goitre in recruits, among the marine rocks of the Jura Mountains, the disease may nevertheless be extremely prevalent among school-children. This objection is discussed in another part of the present work.

The Aargau district lies on the boundary between the areas of highest and of lowest incidence of goitre, and Fellenberg (1923, 1924) has made special comparative investigations in three typical villages therein, built on very different geological formations. Effingen lies on the marly Jurassic formations; its rocks, especially when fossiliferous, contain abundant iodine, and so do the soils and springs derived therefrom. The Triassic limestone and dolomite of Kaisten, and the Tertiary marine or fresh water sandstones of Hunzenschwil are alike much poorer in iodine, as are also the soils and the spring waters derived from them. The fresh water sandstones of the last-named area and their soils contain less iodine than the marine sandstones. There is a distinct difference in the amount of iodine in the air in the three regions, which, though obscured by winds, is nevertheless in general accord with the variation in the soil. There was also a comparable variation in the amount of iodine in the animal products—meat, eggs, milk and human urine—in the three places. The incidence of goitre was in accord with the relative abundance of iodine in the three places. On the other hand, there was no such regular variation in the amount of iodine in the vegetable products of the three regions. These figures will appear from the averaged figures in Table VII.

The last conclusion contrasts with the earlier work of Fellenberg himself (1923) and that of McClendon and Hathaway (1924), which showed a generally higher content of iodine in regions where the spring waters contain noteworthy amounts of iodine and the incidence of goitre was low, than in those where the reverse relation existed. It is perhaps due to a seasonal variation in the amount of the iodine in plants and the chance conditions of collection of the samples analysed. In none of the districts had Chilean nitrate been employed as a fertiliser. This cause of uncertainty, however, which still needs investigation,

[1] An earlier map of the distribution of goitre based on less consistently determined figures yielded by the medical examination of recruits in 1884 to 1891 and 1908 to 1912 was drawn by Hunziker (1915) and showed an approximately similar incidence. It was copied by McClendon and Hathaway, but unfortunately the north and south were inverted, so that the erroneous conclusion was reached that the highest and not the lowest regions were those in which the disease was most prevalent.

cannot obscure the patent fact of the intimate connection between the incidence of goitre, the environing geological formations, and the amount of iodine therein, which the other figures make clear.

Table VII.

Relation of Incidence to general distribution of Iodine in Switzerland (after Fellenberg).

	Effingen	Kaisten	Hunzenschwil
Incidence of goitre	1 %	56 %	62 %
Iodine in 1 kg. of rock	5·4 mg.	0·43 mg.	0·32–0·70 mg.
,, 1 kg. of soil	11·9 ,,	0·82–1·97 mg.	0·62–1·60 ,,
,, 1 litre of water	0·00254 mg.	0·00069 ,,	0·00014 ,,
,, 1 cb.m. of air	0·00051 ,,	0·00003 ,,	—
,, 1 kg. of eggs	0·215 ,,	0·147 ,,	0·080 ,,
,, 1 kg. of milk	0·276 ,,	0·073 ,,	0·085 ,,
,, 1 kg. of human urine	0·064 ,,	0·019 ,,	0·018 ,,
,, 1 kg. of four vegetable foods—grass, lettuce, potatoes and apples	0·0386 ,,	0·0434 ,,	0·0394 ,,

Chapter IX.

THE IODINE-CONTENT OF FOODS IN GOITROUS AND NON-GOITROUS AREAS IN NEW ZEALAND.

Cameron (1915) has shown that regional variation can occur in the iodine-content of vegetables of the same species when growing under almost the same conditions. The same worker draws attention to the fact that the marked difference in the iodine-content of fresh water plants and vegetables on the one hand and marine algae on the other, is due to the differences in the iodine-content of their environments. It is reasonable, therefore, to expect that food products grown in soils poor in iodine will contain less iodine than similar products grown in iodine-rich soils.

Work on this subject was commenced in New Zealand in April 1923 by Mrs Hercus and Mr F. H. McDowall, who used a modification of Hunter's method for the estimation of iodine in thyroid glands (Hunter, 1910). The attempts, however, did not meet with success, since the method was not sufficiently sensitive to detect the minute quantities of iodine concerned.

With the assistance of a grant from the Department of Public Health, the work is now being continued by Mr K. C. Roberts, who is using Th. v. Fellenberg's method for the quantitative estimation of traces of iodine (Fellenberg, 1923). By this method 0·0000003 gm. (= 0·3 microgram = 0·3 γ) of iodine may be detected with ease, so that the weight of the samples to be analysed is reduced to a minimum; also the method is of quite general application, being readily adapted to the analysis of soils, waters, manures, flesh, fats and fatty foods, root- and leaf-vegetables, etc. Fellenberg's method has been adopted in preference to McClendon's (1923, 1924), since, though less accurate, it is more expeditious. The following brief outline of the work done to date is submitted as a progress report.

Fellenberg, in his latest paper (1924, III), records having failed to differentiate the iodine-content of vegetables in endemic and non-endemic areas, although the differentiation was definitely established in the case of animal foods, and also of urines. The case of vegetables seems now also to be coming into line in New Zealand, as is indicated by the following series of results:

Table VIII.

Relation of Amount of Iodine in soils to that in Vegetables grown thereon (New Zealand).

Locality	Average soil-iodine*	Iodine-content of dried vegetable† Carrot	Swede	Parsnip	Turnip	Beetroot
Non-endemic—						
Horowhenua	137	775	670	—	—	—
Nelson (iodine-rich area)	22	—	—	—	—	414
Dunedin (iodine-rich area)	32	—	—	—	870	—
Intermediate—						
Palmerston	9	260	—	—	—	—
Nelson (iodine-medium area)	10	150	—	180	—	—
Endemic—						
Clutha (iodine-poor area)	4	—	480	100	—	—
Well-manured soil, Clutha	—	2400	850	—	—	—
South Canterbury	3	—	460	—	475	—
North Canterbury	5	143	—	—	370	200

* In parts per 10^7. † In γ per kilogram.

Many fertilisers have a relatively high iodine-content (cf. Fellenberg (1924, III) and also the present paper), and it has been shown that the iodine supplied to the soil in this form is reflected in the vegetables grown therein. Thus, carrots and swede-turnips grown in a well-manured garden in the Clutha district, the soil of which contains 10 parts in 10^7 (goitre strongly endemic, cf. table above) contained 2400 γ and 850 γ respectively of iodine per kilogram of dried substance. These figures suggest that the soluble iodine has been absorbed directly by the vegetable, leaving very little in the soil.

The influence of an additional supply of iodine is further shown by the following results for turnips:

	Iodine in soil	Iodine in γ per kg. of dried turnip
A. Experimental plot. Soil untreated	12 parts in 10^7	870
B. Experimental plot. Same soil analysed 18 months after addition of potassium iodide	180 parts in 10^7	Over 20,000

The failure hitherto to establish the correlation between iodine-content of soils and vegetables may thus be due to the fact that the influence of manures has not been considered sufficiently.

It is hoped in the near future to apply the method over a wide range of products from typical endemic and non-endemic areas.

Chapter X.

ETIOLOGICAL CONSIDERATIONS.

The investigation of the etiology of endemic goitre has been very extensive, and though substantial progress has been made in elucidating important secondary factors there is a distinct reluctance to regard the disease as due fundamentally to an iodine-deficiency. The chief hypotheses of causation have laid stress on various aspects of water and food supplies, infective, chemical and physical, on gastro-intestinal infections and on iodine-deficiency. In the study of the disease in New Zealand we have reviewed these various hypotheses with special reference to the last factor which we believe to be the dominating one.

Because of its isolated oceanic position, its racial homogeneity, its varying geological formation and the relatively high standard of sanitation of its inhabitants, referred to above, the country seemed peculiarly well adapted for a study of this character.

Water supply. From the times of the early Greeks there has been a popular belief that the cause of goitre was to be found in drinking water, and the agents which have been thought to be responsible are numerous and diverse.

Calcium excess. The apparent association between endemic goitre and regions of calcareous rocks has led to an etiological rôle being ascribed to an excess of calcium ions. McCarrison (1924) claims that calcium excess causes distension of the thyroid vesicles with colloid and that the lining epithelium of the vesicles becomes flattened. He suggests that the action of the calcium is to increase the viscosity of the colloid, and thus favour its accumulation in the vesicles. This is well known to be the usual action of calcium ions on colloids (Holker, 1923); in addition, Lillie (1907) and Bayliss (1907) have shown that the action of electrolytes is to reduce markedly the osmotic pressure of colloids.

Without entering into a discussion on the rôle of calcium on the flocculation of colloids, the New Zealand data give no support to this factor being in any way responsible for an increased incidence of goitre. Thus, in the Kaikoura Peninsula, which is a pure limestone district, the incidence of goitre amongst school-children is lower than in other parts of Canterbury. Table I in Chapter II also shows that the influence of dissolved salts is small.

Radio-activity. Repin, finding a high degree of radio-activity in the "goitre-waters" of the Swiss Alps, propounds the theory that radium emanations, which are 150,000 times more powerful than radium itself, may be the causal agent. It has been shown (Farr, 1909) that the artesian water supply of Christchurch contains as much radium emanation as the Swiss waters. Other districts in New Zealand, whose sources of water supply are free from radium emanation, as shown by Rodgers' work now in progress, have a high incidence of goitre.

The evidence suggests that the influence of water supply on the incidence of endemic goitre in New Zealand is very small. Nothing in this theory

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modifies the view stated in this paper that the influence of geological formation in the etiology of goitre is confined to the iodine-content of the soils.

Infection. The question of bacterial infection in the water supply being the cause of goitre has naturally been raised and the operation of a specific organism has been suggested. McCarrison (1913) in India and Messerli (1922) in Europe, have produced evidence in favour of such a hypothesis. The experimental work of Marine and Lenhart (1910) showed a direct connection between water and goitre, and could be interpreted as proving that the water directly carried the causative organism, though capable of other interpretation.

Opposed to this hypothesis we may note the fact that the boiling of water in an endemic area such as Canterbury in New Zealand does not prevent thyroid-enlargement, nor, on the other hand, does there appear to be any increase of goitre where the water supply becomes appreciably contaminated. Again, outbreaks of congenital goitre have occurred among lambs, both in Canterbury and the Clutha Valley (another highly goitrous area), where it has been ascertained that throughout the winter the ewes have had no access to surface waters, but derived their necessary fluid solely from turnips,which contain about 90 per cent. of water, and form the staple food, being supplemented by small quantities of more concentrated nourishment in the shape of crushed oats, bran and oil-cake.

Diet. The importance of diet in the production of goitre in animals has been clearly demonstrated by various workers. Thus Marine and Lenhart (1911) showed that a rich protein diet was an important factor in the production of goitre in trout. Chalmers Watson (1912) confirmed this observation. Recent work by McCarrison (1920) and Mellanby (1921) shows that fats are important in the production of thyroid hyperplasia. Carbohydrates in excess do not have the same action. These facts suggest that diets rich in proteins and fats increase the rate of discharge of iodine from the thyroid gland. Marine (1922) suggests that thyroid activity is more necessary for the oxidation of fats and of proteins than of carbohydrates. Mellanby suggests that the unsaturated fats such as the oleates may reduce the available iodine in the diet by uniting it to the unsaturated linkages. The incomplete absorption of an excess of these fats in the diet would then lead to a loss of iodine through its discharge in the faeces. The power of various natural fats and oils to absorb iodine is well known and is used as a means of identification.

New Zealand experience does not bear out the view that diet *alone* influences the incidence of goitre in man, though in districts where the iodine available in the food supply is on the border-line of safety a diet relatively rich in protein and fat may be the factor which determines thyroid-enlargement.

The average dietary throughout the country is very uniform, there being little difference in the type of food consumed in goitrous Christchurch and non-goitrous Auckland. The primary products of New Zealand are largely wool and dairy-produce, and our enquiries suggest that more meat and fat are consumed than in Europe and that fruit and vegetables are used more sparingly.

The Maoris in the Urewera country referred to in Chapter II were found to be living on a diet distinctly deficient in protein and fats, and yet the incidence of goitre was high. Members of the same tribe living in a river-valley close to the sea, with shell-fish occupying a prominent position in the diet, showed very little goitre.

Gastro-Intestinal Infection. There is, however, much experimental evidence available to show that infection introduced into the alimentary tract by food and water can produce goitre. McCarrison (1912) has been the chief British exponent of this aspect of the subject. He describes good results from the removal of contamination from food and water in man and in animals, and he concludes that goitre is due to the absorption of toxic bacterial products from the intestine. Later publications by McCarrison (1924) on this subject indicate that he has considerably modified his etiological view-point in the light of recent work, and now appears to recognise the importance of iodine in this connection. No experimental work on this subject can be considered complete which does not include data as to the iodine-content of all food and water used for feeding purposes during the whole course of the experiment. It is unsound to make any assumptions as to the constancy of iodine-intake. For example, in McCarrison's oft-quoted villages of the Gilgit fan we are told that the lowest village in the series obtained its water supply from a spring issuing from igneous rocks, and it was goitre-free. We are asked to assume that being far from the sea and at an elevation of 4000 feet its iodine-content must be low, and that the factor of removal of infection is the determining one. Our New Zealand experience would suggest that springs derived from igneous rocks might contain an appreciable amount of iodine, sufficient at least to affect the incidence of the disease. Moreover, it is probable that the soil around this village differed from that around the others. Unfortunately, in none of McCarrison's publications available to us is there any account of the exact situation and geographical condition of these villages. From other sources, however (*e.g. Encyl. Britannica* (1911), McMahon's (1899) and Hayden's (1915) accounts), it may be ascertained that besides limestone large amounts of mica schists and slates, granites and diorites occur, and that from the high valley sides there descend immense quantities of detritus that build up wide alluvial fans. Our experience in New Zealand would lead us to expect that the scanty soil on these fans derived from chiefly limestone and mica schists would be notably poor in iodine, whereas the soil near a village "low down on a fan deriving its water supply from igneous rock," probably granite or diorite, but possibly altered basic lava, would also be likely to contain a noteworthy amount of detritus from such igneous rocks, and this would almost certainly contain more iodine.

That infections are of importance in the production of goitre is obvious. Farrant (1913, 1914) has shown that the reaction of the thyroid to most infections is that of hyperplasia. This work has been confirmed by others (Marine, 1922) and clearly indicates that the thyroid is an important indirect factor in resistance to infections. The effect may be in part determined by a primary injury to the suprarenal cortex, for, according to Marine (1922) the suprarenal cortex exercises an inhibitory control over thyroid activity. This contention is supported by the marked hyperplasia seen in the thyroid glands of guinea-pigs which have died of diphtheria toxaemia in virulence tests where the suprarenals suffer so severely. Fever, if present, increases the metabolism of the body and tends to produce thyroid-enlargement. Thus Hume (1918) records an epidemic of goitre occurring during the course of malarial infections in German East Africa. Bacterial toxins apparently damage the tissue of the thyroid gland, leading to compensatory hypertrophy. The increased susceptibility to infection seen in myxoedema also indicates the importance of the gland in the defensive mechanism of the body. We have met with several cases in Canterbury where removal of septic foci from the body has led to the disappearance of goitre.

The recognition of the importance of infection in the genesis of some cases of thyroid-enlargement does not, however, necessarily imply that this influence is operative in the large majority of cases in an endemic area. To assume that the majority of the children of Canterbury are suffering from intestinal toxaemia whereas the children of Auckland are free from this complaint, or to postulate that the sheep and cows of the Clutha Valley are similarly affected whereas those of Dunedin are not, in the absence of any other evidence, would appear quite unjustifiable. The hygienic conditions in Christchurch, where goitre is most prevalent, are extremely good. The chances of any faecal contamination in the water or food supply are practically nil. The Maoris living in Canterbury are exposed to more risks of such faecal contamination, although their standard of sanitation is generally satisfactory, and if contamination was the determining factor they might be expected to show a higher incidence of goitre, but, as has been shown, the incidence is lower than amongst the Europeans. In our opinion, gastro-intestinal infection is a factor of minor importance in the causation of the disease in New Zealand. Dental caries is certainly widespread, and introduces an undoubted source of infection, but this disease is as rife in non-endemic areas as in endemic. The enlargement of tonsils and adenoids was not found to be associated with any variation of the incidence of the disease.

There is much experimental evidence to show that the development of goitre may be favoured by an interference in the absorption of iodine from the gastro-intestinal tract. Fellenberg (1924) has shown that *Bacillus coli* in acid solutions is able to absorb free iodine in appreciable quantities. Plummer (1925) draws attention to the fact that in some cases of goitre the basal metabolic rate may be unaffected by the oral administration of thyroxin or dried thyroid, whereas intravenous injection of thyroxin at once raises it. Such evidence suggests that bacterial action in the gastro-intestinal tract may interfere with the absorption of iodine. Some of the anomalous results in our prophylactic work which we record in the next chapter may be due to this

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factor, although, looking broadly over our New Zealand experience, we do not consider that this factor can reasonably be considered as a dominant one.

Deficiency of Iodine. Finally, we come to the hypothesis that the disease is primarily due to deficient iodine-intake.

There is no more fascinating chapter in the history of medicine than that which follows the gradual steps by which was established the knowledge of the intimate relationship which exists between iodine and the thyroid. The discovery of the element iodine in kelp by Courtois in 1812 was followed by the intensive biochemical work of the end of the last century which culminated in the announcement by Baumann (1896) that iodine was a normal constituent of the mammalian thyroid. Oswald (1901) then determined that the iodine was contained in the colloid which he showed was mainly globulin. Marine and Lenhart (1909) showed that the iodine-store in the thyroid varies inversely with the degree of active hyperplasia and in the extreme degrees of hyperplasia seen in cretinism the iodine-store may be entirely exhausted. In the following table they show the relation of iodine to histological structure.

Table IX.

Relation between the amount of iodine in thyroid glands and their histological structure.

	Normal	Early hyperplastic stage	Moderate hyperplastic stage	Marked hyperplastic stage	Colloid or resting stage
Man	2·17*	0·88	0·71	0·32	2·00
Dog	3·32	0·62	0·37	0·11	1·99
Sheep	2·47	—	0·40	0·01	3·00
Ox	3·46	1·65	—	0·19	—
Pig	2·51	1·10	—	—	2·35

* Iodine in milligrams per gram dried gland.

There is a striking seasonal variation in the iodine-content of the thyroid (Seidell, 1913); it is highest in the early autumn and lowest in the early spring. It was later shown (Fenger, 1915) that iodine was present in the foetal thyroid in man early in intrauterine life. The iodine-content gradually rises with the increasing age of the foetus.

The extraordinary affinity of the thyroid for iodine first noted by Claude (1910) and later demonstrated by Marine (1916) in perfusion experiments on the thyroid gland *in vivo* established what is at present one of the few illustrations of the specific affinity of tissue for inorganic substances.

Kendall (1916) reported the isolation of the specific iodine hormone in crystalline form which he called thyroxin. In later publications (1919) he gives the empirical formula as $C_{11}H_{10}O_3NI_3$ and shows that this substance produces the same pharmacological effects as whole thyroid. The most important pharmacological action of thyroxin has been shown to be an increase in total metabolism (Cameron, 1921). Plummer (1921) estimates that the normal individual requires approximately 1 milligram of thyroxin daily to maintain normal metabolic activity. The thyroid contains a considerable amount of tryptophane as has been shown by Furth and Lieben (1920) and this may be closely related to thyroxin.

By such steps as these has been built up a knowledge of the physiology, chemistry and pathology of the thyroid gland, which is probably more complete than that of any other gland in the body. When the thyroid is presented with a sufficient amount of what is apparently the most important element in the production of its hormone, viz. iodine, the hormone is manufactured and stored in the colloid. Here it remains until it is delivered to the blood-stream by the normal stimulation of the gland. When the iodine supply is deficient, the manufacture of the hormone lags behind the demands of the tissues, the gland responds by an increase in all its elements, and an excess of colloid is deposited in the acini constituting the diffuse colloid goitre of adolescence. Once a goitre has started the pathological picture is usually more complicated, as has been shown by our colleague Dr A. M. Drennan (1924). Haemorrhages are common, and the organisation of these leads to scar-formation with distortion and partial elimination of many of the acini.

There are, however, many objections raised to the hypothesis that goitre is purely a deficiency-disease. Cases are cited as being opposed to this, in which striking variations in the incidence of goitre occur in villages and families adjacent to one another, where the food supply is apparently identical. In the majority of the examples, however, as we have already pointed out, no data are supplied as to iodine-intake.

We have shown that the greatest incidence in New Zealand is in regions where the soil is very deficient in iodine, particularly on the recent alluvium of river-valleys, from which such iodine as may be set free from the gravel and sand by weathering processes is quickly leached out of the soil, which, containing but little clayey matter, has small power of absorbing and retaining the iodine. The incidence of goitre we have also shown to be very low indeed in the regions underlain by igneous rocks yielding clayey soils rich in iodine.

Any deficiency of iodine in the soil is reflected in the vegetables grown thereon, and as the latter constitute our principal source of iodine, it is evident that in regions so deficient the iodine-intake falls to the border-line of safety or below it. In the former case the thyroid may remain of normal size until some increased demand is made upon it. This demand may be a physiological one, such as menstruation or pregnancy, or it may be due to infection or to an unbalanced dietary; but the end result is always the same, namely, thyroid-enlargement. In the districts where the iodine-intake is definitely below the minimum requirements of the gland no increased demands upon the thyroid are necessary to determine a high incidence of goitre. The fundamental cause, underlying all other secondary factors, is therefore a deficient iodine-intake.

Chapter XI.

THE PROPHYLAXIS OF GOITRE.

Assuming that the fundamental factor in the causation of goitre is a deficient intake of iodine, the prevention of the disease should be a comparatively simple problem. In 1849 Prevost of Geneva advocated the use of iodine for goitre-prophylaxis, but it was not until some years later that the measure was put to a practical test in certain districts in France. In 1855 Austria and in 1859 Italy tried the experiment to a limited extent, but the method fell into discredit, apparently on account of excessive dosage (Quervain, 1922).

Iodine-prophylaxis does not appear to have received further attention until 1909, when Marine and Lenhart demonstrated that the so-called carcinomata of trout were in reality enlarged thyroids, and could be prevented by the addition of minute quantities of iodine to the water (Marine, 1914).

In 1917 Marine and Kimball renewed the attempt abandoned in Europe to apply iodine-prophylaxis to man. In the endemic district of Ohio they worked on 1000 school-girls of the age-period when thyroid-enlargement is most frequently developed, using adequate controls. They gave 4 gms. of sodium iodide in 0·2 gm. doses daily for ten consecutive school-days during the spring and autumn terms. Their results were extremely good; thus at the end of thirty months 288 normal girls who had taken the iodine showed no cases of goitre, whereas out of 205 normal control-girls who had taken no treatment 68 showed definite signs of goitre.

In Switzerland, also, the prophylaxis of goitre amongst school-children has been extensively practised by such workers as Klinger, Roux, Hunziker and Eggenberger, with extremely good results (Klinger, 1919). They used smaller dosage than the Americans, and for a longer period.

Prophylaxis amongst School-Children in New Zealand.

In April 1921 prophylaxis was commenced in two schools in Christchurch. The method adopted was based on that of Marine, and consisted in giving sodium iodide in graduated dosage once a week for ten weeks in each of the three terms of the year. The dosage adopted was 40 grains per annum for children of 5 to 8 years, 60 grains for those from 8 to 11 years, and 120 grains for 11 years and upwards. The salt was administered in solution, which involved administrative difficulty, as the illustration will show (Plate III, figs. 1 and 2). In the subsequent extension of the scheme to other centres pills of potassium iodide were used, which greatly simplified the procedure.

The parents were asked to permit the preventive treatment, and the children of those who refused constituted the controls. Each child received a complete medical examination, which included measurements of the neck over the thyroid. The data were recorded on a special card, on which provision was made for six monthly progress reports.

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The results of one year's treatment were encouraging, but were in no way comparable to those of Marine (Hercus and Baker, 1923). Thus, of 258 children of both sexes with normal thyroids, 162 received no treatment, and 89, or 55 per cent. of them, developed thyroid-enlargement during that period, while of the 96 who received treatment 38, or 39 per cent., showed thyroid-enlargement, a difference of 16 per cent. in favour of the prophylactic treatment. The therapeutic result was slightly better, for of 789 children with enlarged thyroids 388 took no treatment and 43 per cent. of them showed an increased enlargement during the period, whereas of the 401 treated children only 21 per cent. showed increase; 15 per cent. of the untreated children with goitre showed a decrease in size, as against 35 per cent. in the treated. The results, both for prevention and cure, were approximately the same for both sexes.

In February 1924 we re-examined the children who had continued the treatment since 1921. The results are summarised in the following table:

Table X.

Results of Three Years' Experience of Iodine-prophylaxis in Christchurch Schools, New Zealand.

	Normal				Goitrous					
	Stationary		Increase		Stationary		Increase		Decrease	
Treated	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls	Boys	Girls
No.	65	49	6	9	68	81	11	12	126	118
Per cent.	91·5	84·5	8·5	15·5	33·2	38·4	5·4	5·7	61·4	55·9
Untreated										
No.	44	19	18	14	51	40	13	23	49	30
Per cent.	91·0	57·6	29·0	42·4	45·1	43·0	11·5	24·7	43·4	32·3

The total number of children of both sexes originally normal was now 224. 33 per cent. of those who had received no treatment showed thyroid-enlargement, as against 11 per cent. of those who had received the treatment. On the therapeutic side, of the 622 children remaining, 206 had not taken treatment and 17 per cent. showed increased enlargement, while 38 per cent. showed a decrease in measurement, whereas of the treated children, 416 in number, only 23, or 3 per cent., showed increased enlargement, and 244, or 39 per cent., showed decrease.

It will thus be seen that the result at the end of three years is distinctly better than after one year, from the point of view of both prevention and cure.

The scheme was then extended to a school in Timaru, with the modification that potassium iodide pills were substituted for the solution of sodium iodide. This alteration greatly reduced the administrative difficulties involved. Four hundred and sixty-seven children were considered. Two grams of potassium iodide were given per annum to all children irrespective of age. After six months' treatment the following results were obtained:

Table XI.

Results of Iodine-prophylaxis in Timaru Schools.

	Treated		Untreated	
Normal (134)—	Number	%	Number	%
Unchanged	49	94·2	78	95·1
Increased	3	5·7	4	4·8
Total	52		82	
Goitrous (333)—				
Unchanged	48	33·3	115	60·8
Increased	9	6·2	12	6·3
Decreased	87	60·4	62	32·8
Total	144		189	

Thus, of the 134 normal children practically no difference could be seen between the treated and the untreated children. In regard to those who were goitrous at the outset, a further enlargement of the thyroid occurred in 6 per cent., both of those who took treatment and those who did not, but of the former, 60 per cent. showed a decrease in the size of the thyroid, which happened in only 32 per cent. of the latter.

This latter scheme of prophylaxis was in 1923 officially adopted by the New Zealand School Medical Service, and potassium iodide in one grain weekly doses can be obtained free of cost by all children in endemic areas.

The controlled experiment in Christchurch and Timaru is being continued, as we consider that a more extensive trial of the procedure is necessary before any definite conclusions can be drawn.

The results so far obtained are, however, distinctly less marked than those obtained by Marine and Kimball in America and Klinger in Switzerland, and in our local experience of the prevention of goitre in trout, lambs and calves. In trout-hatcheries it was necessary to throw only a few handfuls of garden earth into the tanks at regular intervals to prevent the disease. In a farm in the Clutha Valley, where as many as 39 calves had had to be destroyed in one year on account of congenital goitre, it was sufficient to allow the cattle access to rock-salt containing 14 parts in 10^7 of iodine to eradicate the disease. In both of these completely successful attempts at prophylaxis it is evident that the iodine is being obtained in a more physiological manner.

Amount of Iodine required for Prophylaxis. In our anxiety to commence prophylactic treatment as soon as possible, we adopted the method recommended by Marine without waiting to determine what was the exact quantity of iodine required by the thyroid per day, and what amount of iodine was actually present in the diet.

Chatin (1851) estimated that the daily intake of iodine from all sources —air, food and drink—in a non-goitrous region such as Paris was from 0·01 to 0·005 mg., and in a very goitrous region in a Swiss valley 0·0005 mg., a difference of 0·0095 mg., or 9·5 γ. From these figures it is evident that a daily intake of 0·01 mg., or 10 γ, of iodine is sufficient to prevent thyroid-enlargement.

Fellenberg (1923, I) determined that in a non-goitrous region in Switzerland the daily intake of iodine was 0·031 mg., whereas in a goitrous region it was 0·013 mg., a difference of 0·018 mg., or 18 γ. Subsequent work by the same worker on the iodine-content of vegetables would seem to make the difference smaller. Fellenberg's figures for the daily intake of iodine in a non-goitrous area, it will be seen, are somewhat higher than Chatin's—31 γ as compared with 10 γ—but there is a remarkable agreement in the minute amount of iodine which will satisfy the daily needs of the normal gland.

We are at present endeavouring to determine the amount of iodine which is ingested daily in typical endemic and non-endemic areas in New Zealand, and also to compare the daily amount of iodine excreted in the urine in such areas. When this information is obtained it will be possible to determine with some accuracy the amount of supplementary iodine which should be added to the diet daily in order to prevent thyroid-enlargement.

If we accept Fellenberg's figures provisionally it is apparent that the normal adult thyroid gland does not require more than 0·031 mg. of iodine daily, or 0·2 mg. per week, or 10·4 mg. per annum. Marine and Lenhart (1909) have shown that the normal adult thyroid gland weighs 20 to 30 gms. and that the average iodine-content per gram of dried gland is about 2 mg. They estimate that the maximum total store of iodine in a strictly normal human thyroid does not exceed 25 mg.

These facts are of the utmost importance in the consideration of this problem of goitre-prophylaxis, and indicate that the procedure hitherto adopted is excessive in dosage and artificial in method.

In the first place, we have been giving a weekly dose of iodine which is equivalent to twice the total content of the gland. Further, whereas the normal adult gland requires 0·2 mg., or 200 γ, of iodine per week, we have been increasing the iodine-content of the diet by approximately 64,800 γ.

Fortunately, the margin of safety in children is a high one, for in no case have we met with symptoms attributable to the iodine, and Dr Gunn, of the School Medical Service, has been giving 2 grains of sodium iodide five days a week (or 650,000 γ) for 30 weeks in the year, to 140 girls with goitre in the Wanganui district, with good therapeutic results and with no signs of iodism.

Further Considerations. Apart from the question of dosage, there are other serious objections to any scheme of prophylaxis which embraces only school-children. From a brief consideration of the number of congenital goitres, and of the fact that over 30 per cent. of the children in some endemic districts come to school at the age of five years with enlarged thyroids, it is evident that the iodine-deficiency must be supplied to the pregnant woman, to the child *in utero* (for it is known that iodine given to pregnant mothers is readily stored in the foetal thyroid), and, in fact, to all the inhabitants over the whole period of their lives in an endemic area.

There is abundant evidence to show that mineral defects can produce disease in adults, and more particularly during the growth-period. Thus

Sherman (1923) shows that the minimum quantity of calcium, phosphorus and iron in the diet of a child should be 0·23 gm., 0·48 gm. and 0·005 gm. respectively for every 1000 calories. The daily requirement of calcium for an adult he estimates to be 1 gm. per day, and of iron 10 mg. per day; Forbes (1914) estimates the daily phosphorus requirement to be about 1·5 gms. These are recognised as the daily requirements throughout life. What applies to these minerals applies also to iodine. The body requires an adequate daily supply of iodine throughout life for normal thyroid activity. To recognise the deficiency and to supply it during the school period only, subject to the caprice of the parent, is unsound. No country confronted with an endemic goitre problem can afford to adopt a drift policy in the supply of a deficiency so important as this. Switzerland has not only provided the world with an object-lesson of the consequences which attend the neglect of endemic goitre, but latterly she has demonstrated the success which will attend the supply of the deficient iodine.

Iodised Salt. In February 1922, the Canton Appenzell a. Rh. introduced a standard iodised salt which consisted of a mixture of 200,000 pounds of ordinary kitchen-salt with one pound of potassium iodide. When thoroughly mixed, a kilogram of this salt was calculated to contain 2 to 5 mg. of iodine. The mixing is done by a special method, and so evenly that every particle of salt is coated by a minute quantity of iodide.

The results after two years' use are remarkable. The percentage of babies with congenital goitres has dropped from 50 per cent. to nil, and the number of goitre operations diminished by 75 per cent. In February 1924, over 700,000 inhabitants of Switzerland were using standard salt daily (Eggenberger, 1924). The salt is used in the kitchen as well as by bakers, butchers, butter and cheese manufacturers, etc.

In America, Marine has recommended the use of table-salt containing 0·2 per cent. of iodine in districts where endemic goitre prevails to a mild extent. This is four hundred times the concentration recommended by the Swiss Goitre Commission. Many districts in Canada and America have adopted Marine's recommendation, and experience will show whether the excessive supply is detrimental to those adults who have long-standing goitres.

Iodised Salt in New Zealand. In October 1923 one of us (C. E. H.) obtained permission to introduce the use of iodised salt into the orphanage of St Vincent de Paul, in Dunedin, where 54 out of 76 children showed thyroid-enlargement —27 per cent. "incipient," 24 per cent. "small," 9 per cent. "medium," and 9 per cent. "large." The average age of the children was 9 years, and all but ten were girls.

Two medical students, Mr M. Axford and Mr A. A. Macdonald, undertook the supervision of the work as their practical work in Preventive Medicine. Each child received a complete medical examination and a detailed study was made of the dietary of the orphanage. The iodine-content of the soil and water was determined, and specimens of vegetables were collected for the same purpose.

The salt was prepared in the following manner: A pound of ordinary salt was spread thinly in an evaporating dish and 50 c.c. of a 10 per cent. solution of potassium iodide in 60 per cent. alcohol was sprayed over it. The whole was stirred well and allowed to dry in the sun, and thoroughly shaken and labelled "iodised salt." Five teaspoonfuls of this salt were sprinkled evenly over 5 lbs. of ordinary salt and thoroughly mixed. This salt, containing 100 γ of iodine per gramme, was used for both cooking and table purposes.

The average daily consumption of salt was found to be 2 gms., so that each child received an additional iodine-intake of 200 γ or six times the average daily intake in non-goitrous areas as determined by Fellenberg. Before the salt was iodised, the children were observed untreated for 21 weeks, and the majority of the children with enlarged thyroids showed a definite increase in the enlargement. The salt was then iodised and five weeks later 30 out of 31 children showed a definite decrease in measurement. The average decrease was 0·27 inch. This is a further illustration of the fact that the thyroid is one of the most labile tissues in the body, and is capable of extremely rapid involution.

Eighteen months later, during which period the iodised salt was used regularly, the children were re-examined. None of the children who were goitre-free at the previous examination had developed goitre, and 25, or 69 per cent., of the remaining 36 children who had had goitre showed an average decrease of 0·3 inch. The remaining 11 children showed a slight increase in measurement. Some of the therapeutic results were most encouraging, goitres which had previously been classified as "large" being now "small" or "incipient." One girl showed a decrease in measurement of 0·63 inch. It was not found possible to have a control-series.

At the annual congress of the New Zealand branch of the British Medical Association held at Auckland in February 1924, a resolution was passed urging the Government to introduce the use of iodised salt into endemic areas. The Department of Health inserted in their Food and Drug regulations a definition for iodised salt which reads: "Iodised salt shall be salt prepared for table or for culinary use by the addition of one part of potassium iodide or of sodium iodide to every two hundred and fifty thousand parts of salt." If the average daily consumption of salt is 10 gms., this would supply 40γ of potassium iodide or 30γ of iodine per day. This salt is to be labelled "Iodised" in large letters.

They also introduced the term "Medicated Salt," which is defined as "salt prepared for table or for culinary use by the addition of potassium iodide or sodium iodide in proportions other than those of iodised salt, provided that in no case shall the proportion be greater than one part of iodide to one hundred thousand parts of salt." Such salt is to be labelled "Medicated Salt," followed by the statement that "this salt contains one part of potassium iodide to 100,000 parts of salt. It should not be used except under medical direction."

These regulations came into force in June 1924, but so far no iodised or medicated salt conforming to them has appeared on the market.

The above-mentioned congress supported the opinion that the situation demands a compulsory clause. We suggest that salt for use in endemic areas should conform to such a definition as this: "Salt, common salt, or table-salt shall be fine crystalline salt containing, when calculated on a water-free basis, not more than one and four-tenths (1·4) per centum of calcium sulphate ($CaSO_4$), nor more than five-tenths (0·5) per centum of calcium and magnesium chloride ($CaCl_2$ and $MgCl_2$), nor more than one-tenth (0·1) per centum of matters insoluble in water, and shall contain one part of potassium iodide to 200,000 parts of salt." This would augment the daily iodine supply by 50 γ potassium iodide or 38 γ of iodine, assuming that 10 gms. is an average daily intake of salt, which would seem to be an ample provision.

We understand the Department of Public Health are considering the advisability of such a regulation, but are awaiting the results of this and other investigations now in progress.

Objections.

Several objections have been raised to this procedure. That it is an unreasonable interference with the liberty of the subject could be raised with equal force to the compulsory measures directed against the prevention of such diseases as scurvy and beri-beri. Where the soil of a given area is deficient in an essential salt, the supplying of the deficiency can in no way be considered an infringement of the rights of the individual.

In this connection it is interesting to recall the well-known generalisation (MacCallum, 1904) that the blood plasma of terrestrial vertebrates resembles in its content of dissolved salts the composition of the sea water at the time when their evolving ancestors first left the ocean and colonised the land. Now each land vertebrate requires in its food a definite amount of salt to supply its tissue needs. This need is demonstrated to us when we observe the domestic or wild animals making use of natural salt-licks[1] to adjust the mineral balance, and we recognise it so far as it applies to sodium chloride only, by putting out rock-salt for our domestic animals where there are no natural salt-licks, and by adding salt to the human dietary. But marine organisms make use of more than the sodium chloride in the sea water, and in particular the iodine is absorbed into the lower plants, and thus forms an essential part of the food of the marine animals, mollusca or fishes. Land animals, for the most part, have not this dependable source of supply of iodine, and as has been shown both by our own investigations and those of Marine and Lenhart (1909), Gayloid and Marsh (1914) and others, this lack of iodine in the dietary of a wide variety of terrestrial animals and fresh water fishes, and in particular man himself, is associated with a definite incidence of goitre. The lacking iodine cannot be supplied merely by the addition of sea-salt to the dietary, since, as has been noted by Fellenberg (1924), Hayhurst (1922) and others,

[1] As, for example, the peculiar iodine-bearing saline clays of Kurow, New Zealand, cited above.

and confirmed during the present investigation, commercial salt itself contains but little iodine, whether it be derived by direct evaporation of sea water, or, as is most usual, indirectly from the saline deposits that have resulted from the evaporation of sea water in past geological ages. Sloan (1921) notes that in the evaporation of salt brines the mother-liquor which is removed takes with it the natural content of iodine. In order, therefore, to provide the lacking iodine in regions where the geological formations and soil do not yield a sufficiency of it, a direct addition of iodide as such to the dietary appears the most feasible, efficient and economical method, and it is most readily supplied when mixed with sodium chloride. There is less often the need of adding artificially to the human dietary other elements present among the dissolved salts in sea water, such as lime, magnesia and potash, as the amount of these available in foods, natural springs or soil waters, is as a rule sufficient for human needs, though occasions where they must be supplied are well known. The question of the need of bromine opens up another problem, into which we cannot now enter.

A more serious objection is a very real fear expressed by some members of the medical profession that cases of hyperthyroidism may be produced, particularly in the adult population. This objection disappears when it is realised what a minute quantity of iodine is necessary to prevent thyroid-enlargement. In some non-endemic areas more iodine is contained in the natural food supply than would be supplied in the amount of iodised salt consumed. Several workers have determined that there is absolutely no fear of thyroid intoxication as long as the daily iodine-intake is below 700 γ (Hotz, 1922). The dosage in iodised salt is far below this figure, and with a normal consumption of salt does not amount to more than half a grain (30,000 γ) per person per annum. There is an important corollary, however, to the general introduction of iodised salt, which is stressed by the Swiss Goitre Commission, and that is the necessity of prohibition of the sale of all antigoitrous remedies, which are invariably rich in iodine. It is our opinion that this is the best, most economical, and practical method of prophylaxis at our disposal[1].

Other Methods.

There are other methods which have been suggested and utilised from time to time, but, in our opinion, they all have serious limitations or difficulties. Thus, very minute amounts of iodine have been supplied in the water supply in Rochester, New York, U.S.A.; 1/75 gm. of iodine per gallon has been added to the drinking water with good results (Olesen, 1923). This method, however, is limited in application and expensive, and in an artesian area such as Christchurch it would require to be carried out by the individual householder.

[1] For data as to the relative cost of the various methods of administering iodine in Switzerland, see Eggenberger (1924). Assuming that the total salt-consumption per annum in Switzerland is 200 kilograms, allowing for the inevitable wastage which always accompanies the use of salt, the cost of iodising the amount is estimated at 12,000 francs.

The use of foods naturally rich in iodine would be of distinct preventive value, but would be difficult to control. The Japanese are said to use seaweed as a food and to be free from goitre in consequence. The use of oysters, lobsters and shrimps, which are all rich in iodine, could be encouraged, and marine fish generally could replace butcher's meat several times a week. The fresh stem of ordinary kelp is edible and attractive, either raw or roasted, and is generally regarded as a delicacy by Japanese and Maori children, while the young fresh leaves or "dulse" make good eating. In a sea-girt country like New Zealand there should be no difficulty in maintaining constant supplies.

If the primary deficiency is in the soil, and if, as our work suggests, the soil promptly reflects in plants grown upon it any addition of iodine, the use of manures rich in iodine should give good results. Guano, Chilean nitrates, or perhaps seaweed might be used in deficient soils. These manures are, however, expensive, and, as a means of supplying the iodine to foods, infinitely less economical and efficient than the use of iodised salt; and an extensive educational campaign would be necessary to establish their use.

Chapter XII.

Summary and Conclusions.

The incidence of goitre among school-children in New Zealand has been determined by the examinations made by one of us (Hercus) and by the officers of the School Medical Service, of over 80,000 children. The proportion of men of military age who were unfitted for active service on account of goitre was ascertained during the examination of over 135,000 recruits by the Military Medical Boards in the years 1916–1918. Additional information has also been derived from hospital records, by the number of operations for goitre.

The amount of iodine has been determined in nearly five hundred samples of soil, obtained from all parts of New Zealand, together with samples of a number of waters from mineral springs and town supplies.

In order to ascertain whether any relation exists between the amount of iodine in the soil of any district (considered as a soil of plant food, and therefore indirectly of human food), we have divided the Dominion into thirty-three districts, each homogeneous as far as possible in its geological and geographical circumstances, and have ascertained the average amount of iodine in soil and average incidence of goitre among school-children within each district, utilising certain defined methods of soil-analysis and diagnosis of goitre. It is proved that the following relation is approximately true throughout: viz. percentage incidence of goitre among school-children is equal to 6 plus the quotient of 360 divided by the amount of iodine in ten million parts of soil, so long as this does not exceed 50, assuming defined methods of medical examination and chemical analysis. When the soil is abnormally rich in iodine the constant 6 must be diminished. Further (though the records are here less complete), the relation between the average amount of iodine in the soil and the percentage of military recruits medically rejected on account of goitre is of the same general nature, the latter figure being about one-twentieth of the incidence among school-children, though this proportion must also be diminished in regions in which iodine is particularly abundant.

Approximately, therefore, the incidence of the disease is inversely proportional to the amount of iodine in the soil. Further, where, though the incidence of goitre is low, the amount of iodine in the soil is abnormally low, we have proved that it is present in the water supply in greater amounts than usual, and the daily intake of iodine among the inhabitants of such a district is thereby maintained. Further, regions in which the average amount of soil-iodine is low are also those in which goitre is most frequently seen amongst the domestic animals.

Though there are certain points as yet unexplained, the whole body of facts is too large, and the relationship too consistent, to be fortuitous. We believe, therefore, that the hypothesis that goitre is caused by a deficiency of iodine in the diet has been fully sustained by the present investigation. Reasons have been deduced also for believing that a relation holds between the incidence of goitre and the distribution of geological formations (as determining the nature of the soil) in New Zealand, Switzerland, and perhaps in other countries.

Further, a study has been made of the prophylactic treatment of school-children in New Zealand, by administering small amounts of iodine weekly. This has hitherto had fairly good results. We believe that the best method of prophylaxis, considered on physiological grounds, as well as those of efficiency and economy, would be daily ingestion of minute amounts of iodine, obtained by the utilisation for all culinary and table purposes of an iodised salt, in which 1 part of potassium iodide had been added to 200,000 of sodium chloride—the method which has been attended by such satisfactory results in Switzerland. This would afford the minimum amount of 0·005 mg. per day, which seems necessary for the functional requirements of the thyroid gland, while it would be far too small to have any ill-effects in the production of hyperthyroidism.

A consideration also has been given to the source of the iodine in soils and natural waters in the light of our own analyses and those of previous investigators, especially Dr Th. v. Fellenberg, whose work has been of the greatest assistance to us.

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DESCRIPTION OF PLATE III.

Fig. 1. Preparing the individual dose of sodium iodide for school-children.

Fig. 2. Administering the doses to school-children.

Fig. 3. Large goitre in a Maori woman.

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Fig. 1

Fig. 2

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Fig. 3

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