Goitre in Ceylon and Nigeria

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Endemic goitre is recognized as a compensatory enlargement of the thyroid gland that occurs whenever adverse environmental or metabolic factors hinder the formation of the thyroid hormone. When the iodine in water is low, the iodine content of crops and vegetables grown locally is likely to be low also. It is recognized that, with an inadequate iodine intake, other influences, such as diets with a high fat, high carbohydrate or low protein content, or extensive consumption of foods containing substances chemically related to thiocyanate or to thiourea, may have a goitrogenic action. The daily requirement of iodine by man is estimated to be about 150 μg.

At an early stage of iodine deficiency the enlarged thyroid is soft and smooth; later the gland becomes firm and nodular. There is a genetic factor, and the effects of lack of iodine are intensified in each generation; degeneration in colloid and nodular goitre, with marked tendency to cystic enlargement, occurs more often in endemic areas. The recent Conference on Endemic Goitre, sponsored by the World Health Organization (Stanbury, 1953), has pointed out that the world distribution of endemic goitre needs to be more carefully mapped. The clinical recognition of endemic goitre is of importance not only for the treatment of individual cases, but as an indication of the need for prophylactic measures to meet low-iodine hazards.

The inverse relationship between the incidence of simple goitre and the iodine content of drinking water has been shown by many investigators (McClendon & Williams, 1922; von Fellenberg, 1933; Murray, Ryle, Simpson & Wilson, 1948). This paper contains the first published analyses of iodine in drinking waters in Ceylon and in Nigeria, and reports the first attempt to correlate these results with surveys of the incidence of endemic goitre and with diet and geological formations.

Ceylon

The island of Ceylon lies to the south of the Indian subcontinent, its size being approximately that of Holland and Belgium combined. The central area towards the south is mountainous and the remaining land is low-lying and flat. High temperatures and heavy rainfall have led to intense chemical weathering of the ancient crystalline rocks of which the island is mainly composed, resulting, according to degree of leaching, in laterite or lateritic soils. In consequence the island's drinking waters are soft. The most extreme conditions of leaching are found in the wet zone. About 85 % of the population (estimated to be slightly above 7 million persons) live in rural districts, the wet zone being the most densely populated.

The quantity of dairy produce available on the island is small; coconuts, which

contain no vitamin A, supply about 70% of the total fat intake. The high incidence of xerosis and of follicular hyperkeratosis has been ascribed to these dietary deficiencies (Nicholls & Nimalasuriya, 1941). Salt, a government monopoly, is cheap and freely used, but is made by long-continued evaporation of sea water and the iodine content is negligible. In the years immediately preceding World War II, Ceylon produced barely one-third of her food requirements, since it was more profitable to grow and export raw materials. In 1942 the Japanese invasion of Burma cut off an important source of imported rice on which more than half the population depended for their staple cereal. During this study (1950), rice was rationed to about 5 oz./head/day, often broken and of poor quality. The people could no longer have their customary two rice meals each day, usually containing 12–15 oz. of rice. Prosperous families obtained additional supplies of good local rice. Others were able to buy some bread or imported wheat flour, both of which were cheaper than imported rice. Especially in the dry zone, it was possible to use a supplement of maize, millet and pulses grown in the neighbourhood. The cultivation of local food crops has been greatly extended in recent years to include roots, chiefly in the wet zone. Such are edible tubers of the leafy Arraceae family, manioc or colocasia, and of various Diascoraceae creepers. To both these groups, the term 'yam' is commonly applied in Ceylon.

The amount of protein in the edible portion of rice varies according to variety from 6·7 to 7·5% and in yams from 1·2 to 2·4%. Rice proteins on hydrolysis yield appreciable amounts of both tyrosine, the precursor of thyroxine, and of phenylalanine, an essential amino-acid which can be converted in the body to tyrosine.

The nutriture (nutritional status) of the various communities in Ceylon has been the subject of considerable inquiry (Nicholls & Nimalasuriya, 1941; Cullumbine, Bibile & Wikramanayake, 1949). For many years past, occasional cases of goitre had been observed in Ceylon, but the starting-point of the present inquiry was a report on adult goitre made in connexion with nutrition surveys carried out by workers of the Medical Research Institute, Colombo, during the years 1947–9 (unpublished). Early in 1950 the World Health Organization was asked by the Government of Ceylon to find out whether the extent of goitre reported in these surveys constituted a public health problem, and the investigation now described was therefore undertaken.

Nigeria

The territory of Nigeria is about four times the size of Britain, and the surface rocks consist of two large areas of pre-Cambrian granites, separated by marine sediments in the Niger and Benue valleys.

Goitre is prevalent in many parts of Africa (Iodine Educational Bureau, 1946; Woodman, 1952) and gross enlargement of the thyroid gland has been observed on the Bauchi Plateau (Anonymous, 1947). Surveys in different parts of Nigeria have drawn attention to the influence of seasonal variation in diet on the clinical symptoms of nutritional deficiency (Chartres, 1951; Nicol, 1949, 1952). The growing appreciation of the influence of antithyroid factors in nutrition, and renewed interest in methods for the provision of iodized salt amongst primitive peoples, led to the present study of the distribution and incidence of goitre in Nigeria.

The study was carried out at the same time as a survey of customary dietaries and nutriture of schoolgirls in Nigeria. This survey is described in another paper (Wilson, 1954) which gives further details about Nigeria.

Experimental

Methods. In both countries the distribution of endemic goitre was studied at all ages in relation to environment. Information concerning diets was obtained. Samples of drinking water and of salt were sent to England for analysis.

Iodine in the water samples was estimated in the Laboratory of Human Nutrition at Oxford by Miss H. M. Grundy, B.Sc. She used a modification of the chloric-acid method for estimating protein-bound iodine in the serum (Zak, Willard, Myers & Boyle, 1952). This modification will be published elsewhere. Professor Margaret Murray kindly examined samples of Nigerian waters for their fluorine content by the method of Bond & Murray (1953) and analysed samples of Nigerian local salt.

The criteria for thyroid enlargement were those suggested by the Medical Research Council (Murray *et al.* 1948). As surveys of established goitre at all ages are generally impracticable, since to be reliable they involve intensive home visiting, our statistical analyses were limited to the observations on schoolchildren. Investigations in the United Kingdom have shown that in goitrous areas, or in nutritionally or hygienically unfavoured groups, where there is a 'high' incidence (over 15%) of enlarged glands visible at rest among adolescents, enlargement persists in a number of these cases after puberty, and is followed in later life by established goitre. Pathological goitre was almost limited to areas in which the general incidence of thyroid enlargement during adolescence was high; the greater the amount of goitre, the higher the relative incidence in males (Murray *et al.* 1948).

Ceylon. The state of the thyroid gland was examined and recorded in 722 Ceylonese schoolchildren (317 boys and 405 girls) attending rural schools in ten different parts of the island. Only those who had always lived in the same district were included in the survey. It was possible to divide the village families from which the children came into two broad social classes: (i) Families having an estimated monthly income of more than 50 rupees. These were considered by their neighbours as relatively well-to-do. (2) Families below the foregoing economic level. About two-thirds of the children included in the survey belonged to this social class.

Observations on goitre in adults were made during visits to village homes, in the wards of rural maternity hospitals and among groups of patients attending village dispensaries.

Nigeria. The Central Plateau was chosen as a convenient area for inquiry (October 1951–March 1952) since it offers both easy access to clinical material and good facilities for air transport of laboratory samples. Later (December 1952–March 1953) the inquiry was extended to Niger, Zaria, Kano and Bornu Provinces.

As few pagan children attend school, clinical observations on the state of the thyroid gland and on nutriture were made in hospitals, in dispensaries, in the few schools available and at various communal gatherings. Home visits on the Central Plateau were made with the assistance of people familiar with the tribal languages amongst

pagans (so called because they were neither Moslem nor Christian). These are the Berom, Iregwe, Hill Jarawa, Jere, Rebinawa and Rukaba peoples. It was also possible to study groups of Moslem Fulani, formerly nomads, who had settled on the land as farmers. During the second, and wider, survey access to families amongst the Nupe, Hausa, Kanuri and Shuwa Arabs was made possible by the help of the Education Department of Northern Nigeria; children of southern immigrants, Ibo and Yoruba, who had settled in the north, were also examined.

Note was taken of obvious goitre reported elsewhere in Nigeria and of areas where no goitre had previously been observed.

RESULTS

Ceylon

Incidence of goitre

In general, in endemic areas thyroid enlargement was more obvious in females than in males. Table 1 gives the incidence in girls to illustrate the relationship of thyroid enlargement to environmental conditions in Ceylon. In the wet areas there was a high percentage of thyroid enlargement in girls, whereas in boys the incidence was only moderate, ranging from 6.0 to 18.0 %. Many women of child-bearing age had enlarged, soft, smooth glands, and invariably patients in rural maternity hospitals showed obvious goitre.

Relatively few goitres were seen in men. Eye signs of Graves's disease and tremor were absent and no cases of cretinism or deaf-mutism were seen. In the dry areas, the incidence of thyroid enlargement amongst both girls and boys in the school populations was low, only occasional cases of goitre in women were seen. These findings were checked by inquiry at urban hospitals where the records showed that cases of simple goitre had usually come from village homes, whereas exophthalmic goitre was peculiar to townspeople, living in economically more favourable circumstances. Histological examination of thyroid glands, removed from village-dwelling patients who had come from the wet area for operative treatment, showed clearly the colloid nature of the goitre. No cases of goitre in animals were seen.

Iodine content of drinking water

Six samples of Ceylon rural drinking waters were obtained for examination and in three the iodine content was low, 1·4–2·7 μg/l. One water, draining from igneous rocks, had a very high iodine content of 61·0 μg/l. Villagers rarely appreciated the importance of a pure water supply and in both wet and dry zones samples taken for bacteriological examination gave evidence of faecal pollution.

A sample of manioc, the tuber most widely cultivated on the island, was kindly tested for any goitrogenic action by Dr E. E. Pochin (London). From a study of the effects of short-term feeding of manioc on the uptake of ^{131}I by the thyroid gland in six human subjects, it was concluded that none of the changes observed were greater than would commonly occur in repeated determinations on normal subjects of either sex receiving an ordinary mixed diet.

Nigeria

Incidence of goitre

Observations showing how the incidence of thyroid enlargement was related to environmental conditions in Northern Nigeria are summarized in Table 2. A photograph of three sisters from Northern Nigeria illustrates the condition (Pl. 1).

Table 1. *Goitre survey of girls in Ceylon villages. Incidence of thyroid enlargement in relation to soil and to iodine content of drinking water*

Place	Soil	No. of girls examined	Percentage incidence of thyroid enlargement (visible at rest) in girls of school populations	Iodine content of drinking water (μg/l.); mean of at least five readings with its standard error
Wet area				
1. Village W, inland	Lateritic loams derived from igneous and gneiss rocks	50	38·0	2·2 ± 0·1
2. Village P, on sea coast	Lateritic loams derived from igneous and gneiss rocks	50	40·0	5·3 ± 0·2
3. Village B	Lateritic loams derived from igneous and gneiss rocks	50	22·0	Not available
4. Village I, in foothills	Lateritic loams derived from igneous and gneiss rocks	26	23·1	Not available
5. Village H, on hillside	Lateritic loams derived from igneous and gneiss rocks	50	56·0	2·7 ± 0·1
6. Village B–K, altitude over 5000 ft. (local cabbage freely eaten)	Lateritic loams derived from igneous and gneiss rocks	30	40·0	1·4 ± 0·1
Dry area				
7. Village C, on sea coast	Sandy soil derived from Pleistocene deposits	50	6·0	Not available
8. Village P, on coastal lagoon	Soil from Pliocene gravels	30	6·7	Not available
9. Village M, on Jaffna peninsular	Soil associated with Miocene limestone	50	12·0	6·6 ± 0·5*
10. Village K, on inland plateau (extensive tank rice cultivation)	Soil from igneous and gneiss rocks of dry zone	19	5·3	61 ± 2

* A large amount of solid matter made sampling difficult.

Amongst the Rukabi, families living on the pre-Cambrian granites used low-iodine waters (0·6–0·7 μg/l.); they were goitrous and included cretins and deaf mutes. Those living or farming on the basalt (iodine content of water 5·0 μg/l.) were free from signs of goitre. They obtained much larger yields of crops. The Vom section of the Berom tribe lived on granite, but farmed on basalt, and most were free from goitre. Another section of Beroms at Forum lived and farmed on granite, and many of their women were goitrous. Thyroid enlargement was absent in villages situated on marine sedi-

Table 2. *Goitre survey in Northern Nigeria. Incidence of thyroid enlargement in relation to source and to iodine and fluorine content of drinking water*

		Clinical assessment of incidence of goitre											
		Total		Adults				Children (under 16 years of age)					
				Goitre		Goitre		Enlarged thyroid (visible at rest)		Enlarged thyroid (visible at rest)			
Place	Source of water	No. of subjects examined	Incidence of goitre (%)	M.	(%)	F.	(%)	M.	(%)	F.	(%)	Mean iodine content of water with its standard error (μg/l.)	Fluorine content of water (μg/ml.)
1*a*. Zagun village	Older granite of the Pre-Cambrian basement complex	162	46	34	32	68	72	44	23	16	25	$0{\cdot}7 \pm 0{\cdot}05$	0·4
1*b*. Zagun village, Het quarter												$0{\cdot}6 \pm 0{\cdot}06$	0·4
2. Miango	Basaltic lava flows of Tertiary and Recent Age	150	Nil	60	Nil	40	Nil	25	Nil	25	Nil	$5{\cdot}0 \pm 0{\cdot}1$	0·1
3. Vom	Vom granite of the pre-Cambrian series (farming mainly on basalt)	250	3	50	Nil	100	8	50	Nil	50	Nil	$0{\cdot}6 \pm 0{\cdot}04$	0·2
		Niger river basin, Nigeria											
4. Marine sediments near Abakaliki, Ogoja Province	Deep water shaft on Ameri lead-zinc lode	301	Nil	50	Nil	50	Nil	150	Nil	51	Nil	92 ± 8*	3·3

M. = Male, F. = Female.

* A large amount of solid matter made sampling difficult.

ments in the Niger river basin, and a sample of water from the shaft of a lead-zinc mine in this area had a very high iodine content (92·0 μg/l.); people living on the granite outcrops of the Niger valley had obvious goitre.

The areas of endemic goitre that were found to lie on granites of the pre-Cambrian basement complex, or were associated with waters which drain off these rocks, were as follows (see Wilson (1954), Fig. 1):

north-west and south of Sokoto Province
east of Katsina Province
west of Kano Province
south of Bornu Province
south and east of Zaria Province
south-east and west of Bauchi Province
north and east of Niger Province
north-east of Ilorin Province
north of Oyo Province
north and west of Ondo Province
east and west of Kabba Province
north and east of Benue Province
north of Ogoja Province and in the Cameroons
western part of the Mamfe Division
Bamenda District and the hill country south of Yola

We do not know the true incidence of goitre in these districts. Hyperthyroidism is rare. In Nigeria livestock is moved about over wide areas, and the only record of goitre in animals comes from pigs belonging to a bacon factory situated in a district where human goitre is present; the condition cleared up with the addition of a supplement of iodine.

On the central Plateau an obvious difference in incidence and degree of thyroid enlargement was found amongst aboriginal peoples living in adjacent districts where basaltic lava flows of Tertiary and Recent Age cover parts of the granite.

Possible goitrogenic agents

Fluorine. It has been suggested (Smith, 1951) that an appreciable amount of some other halide such as fluorine in drinking water may affect excretion of iodide by the kidney. The fluorine content of ten representative samples of Plateau drinking waters from goitrous areas was determined; in nine waters the fluorine content was low (0·2–0·4 μg/ml.) and one sample had none. These waters, although derived from granite rocks known to have a high fluorine content, have little fluorine since the rocks do not break down into compounds soluble in water. The teeth of people born in this area showed a very mild degree of dental fluorosis; mottled enamel was also present in the teeth of schoolchildren who used shallow wells in a region where the deep water from the shaft of a lead-zinc mine, already mentioned above, had a fluorine content of 3·3 μg/ml. In Bauchi province, water from wells in Maiduguri town had fluorine contents varying from 0·1 to 1·2 μg/ml., but we have no evidence in Nigeria that fluorine in drinking water acts as goitrogen.

Salt. Four samples of mineral salt bought at local markets in Northern Nigeria were sent for analysis. Only one sample, that from Lafia, in Benue province, contained an appreciable amount (84%) of sodium chloride. Two samples of salt, red and white, from Bornu province, and one sample from Sokoto province, contained less than 5% sodium chloride. These samples consisted mainly of sodium sulphate and of sodium carbonate. The iodine content of these salts was low, as in similar salts examined by Godden (1928–9): Sokoto, 0·0002% (2 p.p.m.); red Bornu, white Bornu and Lafia, < 0·0001% (< 1 p.p.m.). In West Africa, where cereal salt is used, goitre is endemic. Pales (1950) has suggested that the alkalinity of potassium carbonate in the pot ashes

may have a goitrogenic influence. But in Nigeria the distribution of endemic goitre is not confined to the regions where vegetable ashes are used as salt. Some Nigerian pagans use cereal salt, and a sample made by Beroms from the burnt stalks of a locally grown millet *Penisetum spicatum* had the following composition: total ash 71%, Na 1·5%, K 33·8%, Cl 5·3%, SO_4 2·2%, CO_3 23·6%. These figures indicate that the original cereal salt contained 2·7% sodium chloride and 38·5% potassium carbonate. The solution of the cereal salt was very alkaline.

Groundnuts. It is uncertain whether groundnuts have an antithyroid effect in man (Greer, 1950); in view of their economic importance in Northern Nigeria, this subject is being investigated.

Drugs. Leprosy is widespread in Nigeria and is treated on a large scale by sulphones, which structurally resemble antithyroid drugs. Lepers under treatment from many districts were examined but the only cases with goitre had lived in endemic areas. Twenty-four goitrous lepers (three males and twenty-one females) on sulphone therapy were given 26 mg potassium iodide weekly for 8 months, and in ten cases the goitre decreased in size.

DISCUSSION

Ceylon

It would appear that the chief factor influencing the incidence of goitre was the high-carbohydrate low-protein dietary of the poorer villagers living in the wet areas where the iodine content of the drinking waters was low. These people had been obliged since 1942 by war, and later by postwar scarcity of imported rice, to limit the consumption of their staple cereal to as little as 5 oz. daily. Many did not know how to utilize the imported wheat flour which they sometimes obtained. The large amounts of locally produced yams and roots, used instead as sources of energy, were indifferent substitutes from the point of view of quantity and quality of protein. At altitudes above 5000 ft., tubers cease to grow freely; in certain districts their place is taken by a long-established local variety of cabbage, and its possible goitrogenic influence cannot be overlooked (Greer & Astwood, 1948). The cost of sea fish, a useful source of dietary iodine, is prohibitive; local salt, made by long-continued evaporation of sea water, does not contain an appreciable amount of iodine. The villagers were therefore dependent on the iodine from their local water supply.

Rural water supplies are soft, so that the calcium, or hard-water factor, known to have a goitrogenic action, cannot be incriminated, but some drinking waters gave evidence of faecal contamination, which could decrease the amount of available iodine (McCarrison, 1908). This contamination was particularly evident (as judged by an extremely high bacterial count) in village P on the sea coast, no. 2, in Table 1.

The high incidence of enlarged thyroids among schoolgirls in the wet areas suggests that there will be a corresponding increase of goitre in later life, whereas, in the dry areas, where the iodine levels in water appear adequate in relation to the other constituents of the diet, there is no indication of an increased incidence of thyroid disorders.

The high incidence of endemic enlargement of the thyroid in the wet areas of south-

west Ceylon may thus be explained by the scarcity of iodine in the drinking water, the recent deterioration in the diet, the known faecal contamination of the water supplies perhaps limiting the availability of the iodine, and the possibility of goitrogenic agents in the diet.

Nigeria

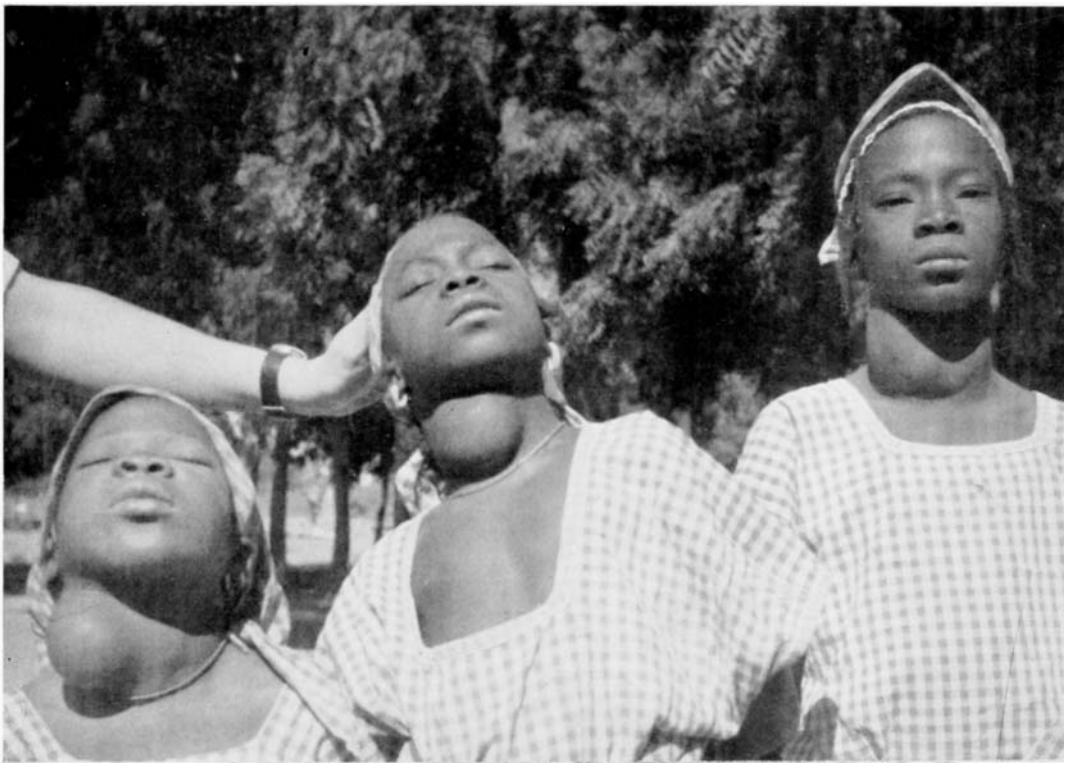
Prosperous households had balanced dietaries; poorer families might not get sufficient food to provide an adequate intake of calories, minerals and vitamins, but poverty itself was not a cause of goitre. Unlike the position in Ceylon, the ratio of carbohydrate to protein in the diets of the peoples of Northern Nigeria, at least in the areas surveyed, was balanced. There was no evidence of other goitrogenic agents. But although the communities examined lived often in close proximity, the incidence of goitre varied markedly according to their water supply and the quantity of food available. Thus, people living and farming on basalt had the advantage of an increased food supply and higher iodine level in drinking water and there was no goitre or evidence of increased enlargement of the thyroid gland in adolescence. On the other hand, those living and farming for a long period on pre-Cambrian granites suffered the joint disadvantage of poor crops (lowering the total calorie intake) and low iodine in their drinking water; amongst them the incidence of goitre and of enlargement of the thyroid gland in adolescence was high. These observations are further confirmed as those living on the granites, but farming on the basalt (where they worked from early morning to late evening), had a very low incidence of goitre; they appeared to benefit both from the high iodine content of drinking water off the basalt and from the more plentiful yield of crops.

It is noteworthy that, on the marine sediments of the Niger river basin, where goitre was absent, the deep water had a very high iodine content (even higher than that in water derived from igneous rocks in the dry area of Ceylon).

It is of interest that in the United States where, in the State of Michigan, the waters from pre-Cambrian rocks have a low iodine content, the incidence of endemic goitre has been very greatly reduced by the widespread use of iodized salt (Brush & Altland, 1952). Measures for the prevention of endemic goitre vary according to local conditions in different parts of the world. In Ceylon, world economic conditions will determine the importation of sufficient amounts of the staple cereal, rice, to limit the use of roots and tubers in the affected areas. Potassium iodate possesses desirable chemical and physical properties for the iodization of crude, moist sea salt (Scrimshaw, Cabezas, Castillo & Méndez, 1953) and its possible use in these areas of Ceylon deserves consideration. In Nigeria, the local sources of salt are insufficient for the country's needs, and imported salt is sold in Nigerian markets; a new grade of vacuum salt has recently been introduced on the West African market, and this can be supplied, already fortified with iodine, at a lower cost than the un-iodized coarse salt at present in use.

SUMMARY

1. This paper describes the incidence of endemic goitre in the island of Ceylon and in the territory of Nigeria and relates the incidence to diet, to quality of drinking water, and to geological formation.



2. In the wet areas of Ceylon, where the incidence of enlarged thyroids in schoolgirls is high, the iodine content of drinking waters is low (1·4–2·7 μg/l.) and the usual diet poor. In Nigeria, the distribution of goitre is associated with water supplies of very low iodine content (0·6–0·7 μg/l.) from pre-Cambrian granites.

3. In both areas a lack of iodine in food and water appeared to be of primary aetiological importance.

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EXPLANATION OF PLATE

Photograph of three girls (sisters) from Northern Nigeria, showing goitre. (By courtesy of Professor R. W. B. Ellis.)