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TROPICAL AUSTRALIA AND ITS SETTLEMENT

BY

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I. INTRODUCTION

Tropical Australia and its settlement by a British race has formed the theme of numerous public utterances and of a good deal of writing in both the scientific and lay press. Sometimes these utterances have been dictated by utilitarian reasons alone, sometimes they have only formed part of a general political propaganda; many have been influenced by personal prejudice, and were put forth by writers whose experience of life in Northern Australia did not qualify them to express an opinion on this subject.

On many occasions, when the ultimate fate of Northern Australia has formed the subject of discussion at various scientific meetings, the speakers have applied indiscriminately to Northern Australia the outcome of experiences gained by themselves or by others in various parts of the tropics, without realising that Northern Australia occupies a different position, on account of the absence of a settled native population and its peculiar climatic conditions.

The following pages are the outcome of several years' investigation in and consideration of conditions obtaining in Northern Australia and their influence upon a settled white race. A résumé is included of previous investigations by other workers into the practicability of a white settlement of other parts of the tropics and the influence of tropical life upon a population of European descent. An attempt is made to sift facts and to review the results of previous investigations, published in numerous scattered journals, most of which, with the exception of the experiments carried out in the Philippine Islands, not only have been done in a haphazard way, but sweeping conclusions have been based upon a few unsystematic observations.

The problem of the settlement of tropical Australia by a white race is a very difficult and complicated one, since two factors enter into the question. In the first place, climatic conditions and their effect upon the white man are of paramount importance, since racial degeneration, brought about by climatic conditions alone, would decide the problem. At the same time the economic side of the question plays an important part and cannot be neglected, and a discussion on this aspect has been included.

Opportunity is taken here to thank Mr. H. A. Hunt, the Commonwealth Meteorologist, for putting at our disposal the climatic data, and also Mr. G. H. Knibbs, C.M.G., the Commonwealth Statistician, for help and suggestion in connexion with the statistical data.

II. THE CLIMATE OF NORTHERN AUSTRALIA

The Australian living in the southern parts of his continent generally possesses only a very uncertain knowledge of the climate of the northern parts. He assumes that the whole of the north above the tropic has a uniformly hot climate, that heat and mugginess persist and that a feeling of personal comfort is only a rare sensation. This popular conception arises from the general idea of 'tropics'; most people in their early youth associate with 'tropics' a land of impenetrable jungle, heat, swamp and fever, an impression gained by reading books of adventure and travel.

The scientific study of climates within the tropics shows, however, that there exists a great diversity of climatic conditions, regulated by a number of factors, such as the nearness to the ocean, elevation above sea level, proximity to high mountain ranges which control rainfall, prevailing wind and, above all, the amount and monthly distribution of the rainfall.

To describe climate from the point of view of its effects upon a human race is impossible with our present means. It is only to a certain extent that climate, as we feel it, finds a graphic expression in those meteorological observations usually recorded, which measure heat and humidity only, namely, the readings of the dry and wet bulb thermometers. From these readings is further calculated the relative humidity, that is, the extent to which the atmosphere is laden with moisture. The degree of personal comfort or discomfort experienced is indicated to some extent by these readings; but it is certain that many other factors play a large part in determining individual sensations.

Numerous attempts, summarized as far as 1908 by Hann, have been made to construct a 'discomfort scale,' but no satisfactory solution has yet been attained. Conspicuous amongst these is that of Cleveland Abbé, who suggested a 'curve of comfort,' based upon three factors, namely, air temperature, relative humidity and wind velocity. By plotting temperatures against humidities for a certain velocity of wind and estimating personal comfort or discomfort under these conditions, he obtained charts which correlated his personal sensation with the above factors.

Wet bulb temperatures alone were first used as a guide to comfort by Harrington, who termed them 'sensible temperatures' and mapped out wet bulb isotherms for the United States of America for the month of July. The importance of wet bulb readings has been further emphasised by Haldane (1905), who demonstrated experimentally that the regulation of body temperature above a certain wet bulb reading became disorganised and human energy was paralysed. He therefore suggested wet bulb temperatures as a standard by which to regulate conditions in factories, mines and workshops.

Griffith Taylor (1916) has suggested a tentative scale of discomfort, applying only to warmer regions, where humidity and temperature are the chief factors, a scale depending on wet bulb readings. He divided 'climate' into the following grades:—

- 8·3°-12·7° C. (45°-55° F.) wet bulb—Most comfortable.
- 12·7°-15·5° C. (55°-60° F.) wet bulb—Very rarely uncomfortable.
- 15·5°-18·3° C. (60°-65° F.) wet bulb—Sometimes uncomfortable.
- 18·3°-21·1° C. (65°-70° F.) wet bulb—Often uncomfortable.
- 21·1°-23·7° C. (70°-75° F.) wet bulb—Usually uncomfortable.
- Over 23·7° C. (over 75° F.) wet bulb—Continuously uncomfortable.

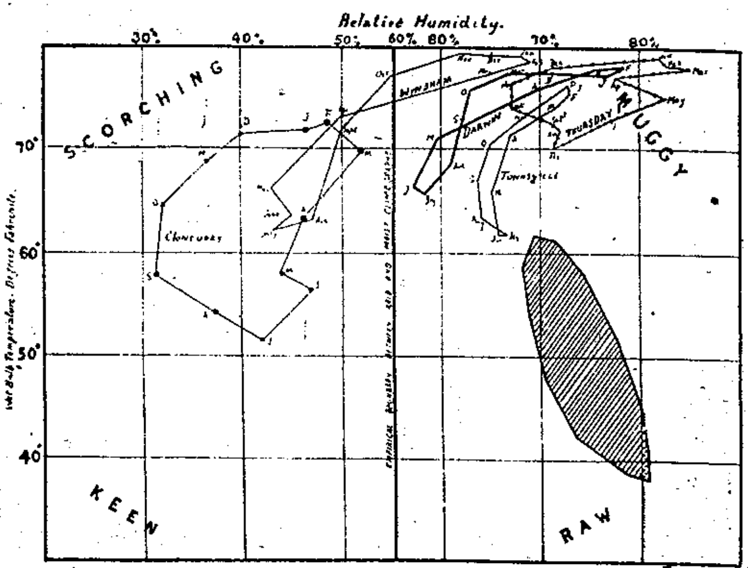
A rough-and-ready indication of the degree of discomfort, used by Osborne (1916), is the amount of clothing required to enable him to lie in an open-meshwork hammock. His experiences have led him to set a wet bulb of about 22·75° C. (73° F.) as an empirical standard above which truly tropical conditions arise.

Many authors, however, contend that wet bulb readings alone are not an unerring indication of the subjective sensation caused by climate. L. Hill (1914, 1916), for example, pointed out: 'It is no use to trust to the ordinary thermometer, either wet or dry, because it does not show heat loss. It only shows its own temperature, the average temperature of the furniture, surroundings and walls; it does not show the heat loss of the body. Whilst the thermometer is a static instrument indicating average temperature, the human body is a dynamic structure, continually producing and losing heat, while its temperature remains sensibly constant.' He deprecated the use of relative humidity as a criterion of comfort, and suggested the katathermometer, a new apparatus, which would register the rate of heat loss and thus indicate more closely the effect of temperature and atmospheric conditions upon the human body. This instrument

consists of two thermometers, each having a large bulb filled with alcohol; one of these is kept dry—the dry bulb katathermometer; the other is kept moist by means of a wet cotton glove—the wet bulb katathermometer. Both are heated to 43·3° C. (110° F.) and the time which each takes to cool from 43·3° to 32·2° C. (110° to 90° F.) is noted. The dry bulb katathermometer thus measures the rate of cooling by convection and radiation, the wet bulb katathermometer that by convection, radiation and evaporation and thus measures not the actual air temperature but the rate of cooling of a moist body, due to the effects of the atmospheric condition at an actual temperature approximating to that of the human body. Practical experience has shown, however, that the wet bulb katathermometer is too sensitive to air currents. Osborne (1916) has pointed out that a series of readings taken in rapid succession yields fairly uniform results only in still air indoors, or outdoors if a steady breeze be blowing. On the other hand, when the wind comes in gusts, consecutive readings show great variations. Observations in Townsville with the katathermometers have confirmed Osborne's experience, and have proved that calm weather, as far as the katathermometer readings are concerned, is a rare exception, and days classed as still to personal sensation may not be so to the katathermometer.

Griffith Taylor (1916) attempted to overcome in a novel manner the difficulty of judging a climate, by introducing a graphic representation, termed a climograph, and plotting the monthly means of relative humidity against monthly means of wet bulb readings. He compiled as a standard a composite climograph, by using average figures for towns situated in regions where human energy is at its best, selecting for this purpose five towns in the southern and seven towns in the northern hemisphere, where the average monthly wet bulb readings ranged between 2·7° and 16·6° C. (37° and 62° F.). This climograph, according to Taylor, represents ideal conditions for the white race, and he terms it the 'white race climograph.' On the same principle he constructed a number of climographs for different parts of the world and differentiated in this way four extreme climatic types—hot and damp, ~~hot and dry, cold and damp~~ and cold and dry—and compared the climographs of Australian towns with these types (see fig. 1). The shape of the climograph also indicates the seasonal distribution of rainfall.

It is an ingenuous and striking method of comparing in a general way the climate of any given locality with a type, but does not convey any further information than the mean readings of dry and wet bulb thermometers, and it is significant that Taylor himself, when discussing the question of discomfort in relation to climate, uses the wet bulb readings as guide.



NOTE.—The shaded figure is the composite white race climograph based on twelve typical cities.

FIG. 1.

Bruce (1916) has proposed the use of dew point as an indicator of the effects of atmospheric conditions upon the human body, and comes to the conclusion that the dew point most desirable for human activity is 16·6° (62° F.), that is to say, that air saturated with moisture at 16·6° (62° F.) is neither muggy nor chilly. If the dew point, however, rises over 21·1° C. (70° F.) the conditions become exceedingly trying.

This principle has been applied to the average temperatures recorded in Townsville, and the results have indicated that the dew point at 9 p.m. is, as a rule, higher than at 9 a.m. or 3 p.m., although the conditions in the evenings are, on the whole, undoubtedly less trying than those prevalent during the day. Furthermore, this principle does not take into account the effects of other conditions, such as wind and sunshine.

It would appear, therefore, that neither humidity nor dew point give any more information in regard to personal comfort than the readings of dry and wet bulb thermometers.

Hunt, at Osborne's suggestion, constructed wet bulb isotherms for Australia—the only part of the world for which such complete isotherms have been published—attempting thus to represent graphically climatic conditions as far as personal comfort is concerned. As pointed out previously, wet bulb temperatures alone in this respect are only of limited value, since experience has shown that, although high wet bulb temperature, approaching the limit of safety, may be a guide to discomfort, yet lower ones, without the accompanying dry bulb readings, are indefinite. From our personal experience, wet bulb readings above a certain limit invariably denote discomfort, yet the dry bulb temperature even then modifies the degree of discomfort felt. For example, a wet bulb reading of 26·6° C. (80° F.) is never pleasant, but the degree of discomfort becomes exaggerated in direct proportion to the dry bulb reading. For these reasons it has been thought advantageous to make use simultaneously of the mean dry and wet bulb readings for the comparison of the various parts of Northern Australia. In the accompanying graphs (fig. 2) are plated the average monthly dry and wet bulb temperatures, taken at 9 a.m. over a period of five years, and the points are connected by lines for distinctness only, the 10° C. (50° F.) line being indicated in order to make a comparison easy. Since the temperatures are so dependent on the rainfall, average rainfalls obtained from Hunt's publications have been plotted in these charts. The relative positions of the graphs of the various towns are arranged diagrammatically as near as possible in accordance with their geographical position (compare map, fig. 3). Thus the coastal towns are represented on the outside of the diagrams and the inland towns in the interior. The graphs

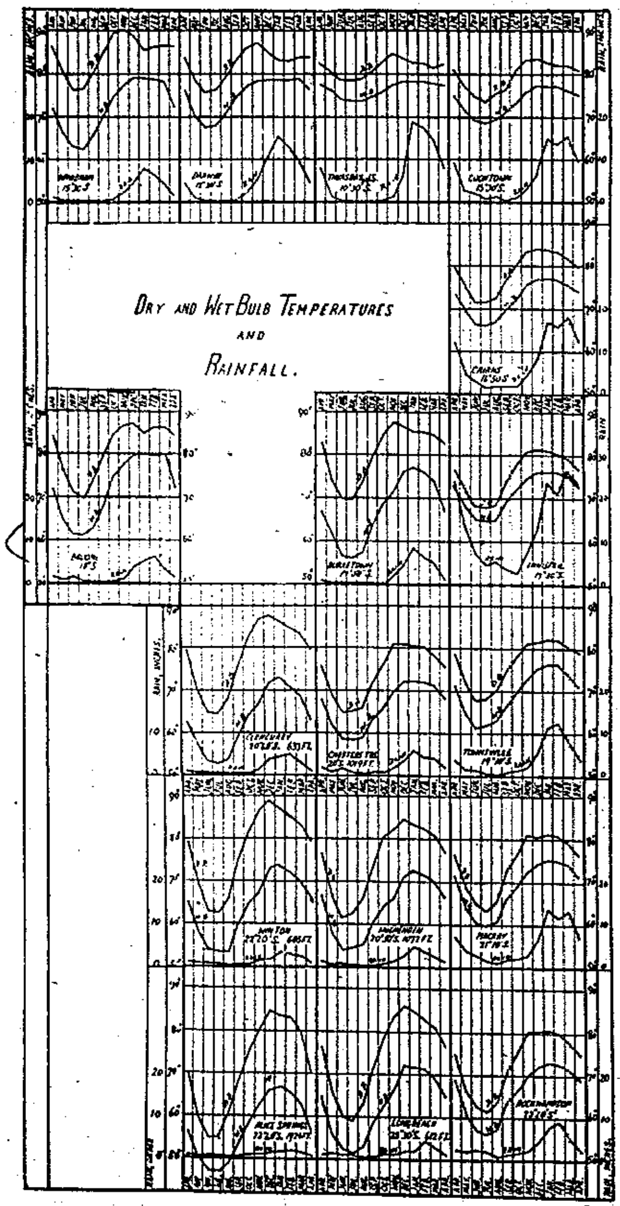


FIG. 2.

commence with the month of April, as in this month a distinct change of season sets in; beginning from then, the average temperature falls (rapidly at first and more gradually afterwards) and begins to rise again on or about July. In this way both fall and rise are more conveniently displayed for comparison than if the graphs were commenced with January in the usual way. In order to make the comparison more complete, the monthly averages for the maximum and minimum temperatures are displayed in a similar manner on a second series of charts (fig. 4).

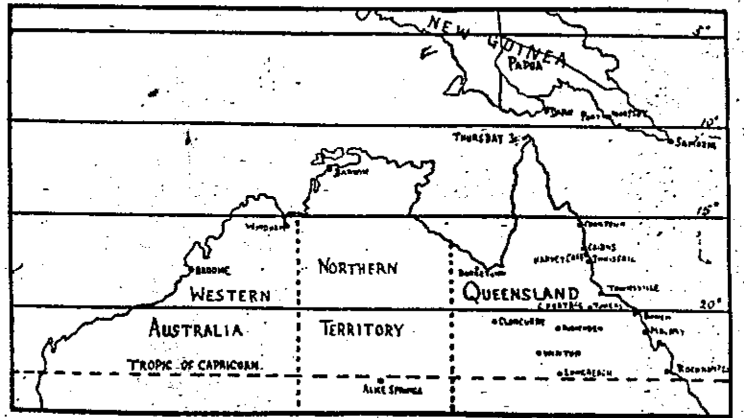


FIG. 3.

The graphs make it clear that the climate of the coastal towns differs essentially from that of the inland towns. The former towns have, on the whole, higher wet and lower dry bulb readings than the latter. With the coastal towns the average readings increase gradually with decreasing latitude and the contrast between the cool and hot season becomes less and less pronounced. The charts of Rockhampton and Thursday Island, the two extreme towns of Queensland, situated within the tropics, illustrate this contention. In Rockhampton (latitude 23° 24') the coolest month (July) has average dry and wet bulb readings of 16·3° C. (61·4° F.) and 13·3° C. (56° F.) respectively, and the hottest month (January) has readings of 27° C. (80·6° F.) and 22·7° C. (73° F.) respectively. The average dry bulb temperature is therefore 10·7° C. (19·2° F.) higher,

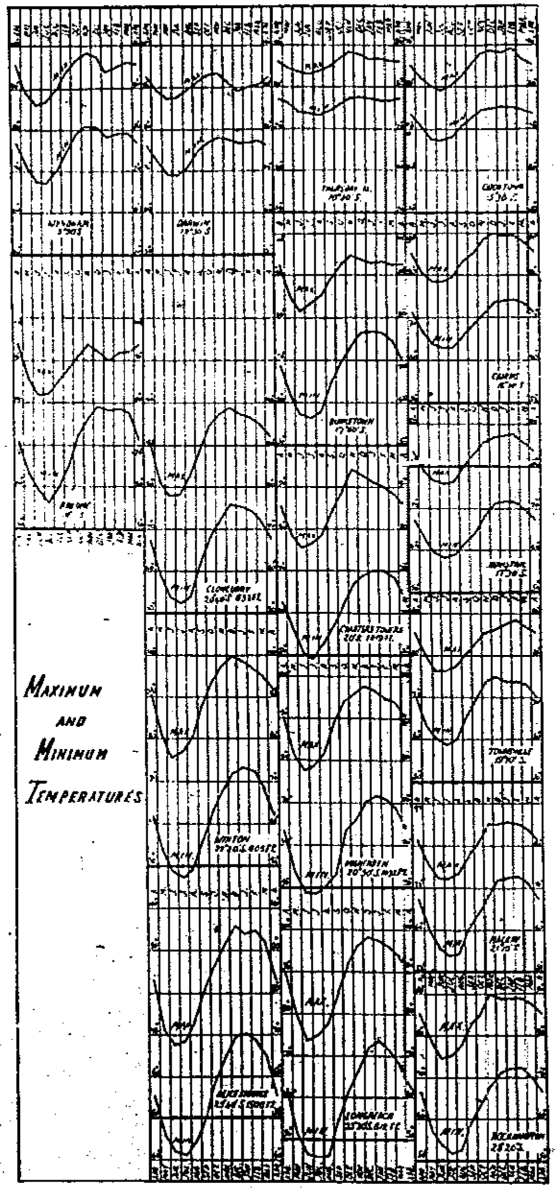


FIG. 4.

and the average wet bulb reading is 9·4° C. (17° F.) higher in January than in July. In Thursday Island, however (latitude 10° 34′), the corresponding averages are 25·8° C. (78·3° F.) and 23·2° C. (73·8° F.) for July respectively and 28·1° C. (82·7° F.) and 25·9° C. (78·7° F.) for January, showing much smaller differences, namely, 2·3° and 2·7° C. (4·4° and 4·9° F.) respectively. In other coastal towns, such as Darwin, Wyndham and Broome, situated on the northern coast of Australia, the seasonal variations are more pronounced when compared with Thursday Island. During the hot season the average readings there are higher than in towns on the eastern coast in the same latitude. Broome and Innisfail, for example, both situated between 17° and 18° South, show this difference in a marked degree (see charts), but the geographical position alone explains this difference, since Innisfail lies within the region of the trade winds, and, in addition, possesses a larger average rainfall.

For comparison only, graphs representing the climates of Daru, Port Moresby and Samarai, all in Papua, have been added (fig. 5). These graphs do not differ essentially from those of Thursday Island.

In most of the inland towns of Northern Australia weather conditions are greatly influenced by altitude, and changes with latitude are consequently less pronounced.

The graphs representing the average maximum and minimum temperatures exhibit the same seasonal variations, which in the coastal towns become less marked with decreasing latitude and show smaller ranges of temperature. In the inland towns the average maximum readings in general are much higher and the average minimum readings much lower than in towns on the sea coast.

A comprehensive account of the distribution of rainfall throughout Northern Australia has been published by Hunt in a series of monographs issued by the Meteorological Bureau. The rainfall in North Queensland shows a seasonal distribution corresponding to the monsoonal type of climate, the heaviest falls taking place during the hot months (December to March), and only occasional showers occur during the cooler months.

There is a 'wet belt' on the north-eastern coast, the centre of which lies about Harvey Creek and which extends northward to a point beyond Port Douglas and southward as far as Halifax, where a very high general rainfall is registered (see Table I).

TABLE I.—RAINFALL

Cooktown	181·9 cm.	(71·6 inches)
Port Douglas	210·6 cm.	(82·9 inches)
Cairns	229·9 cm.	(90·5 inches)
Harvey Creek	426·0 cm.	(167·7 inches)
Innisfail	384·0 cm.	(151·2 inches)
Cardwell	218·6 cm.	(86·1 inches)
Halifax	226·6 cm.	(89·2 inches)
Ingham	204·5 cm.	(80·5 inches)
Townsville	125·2 cm.	(49·3 inches)

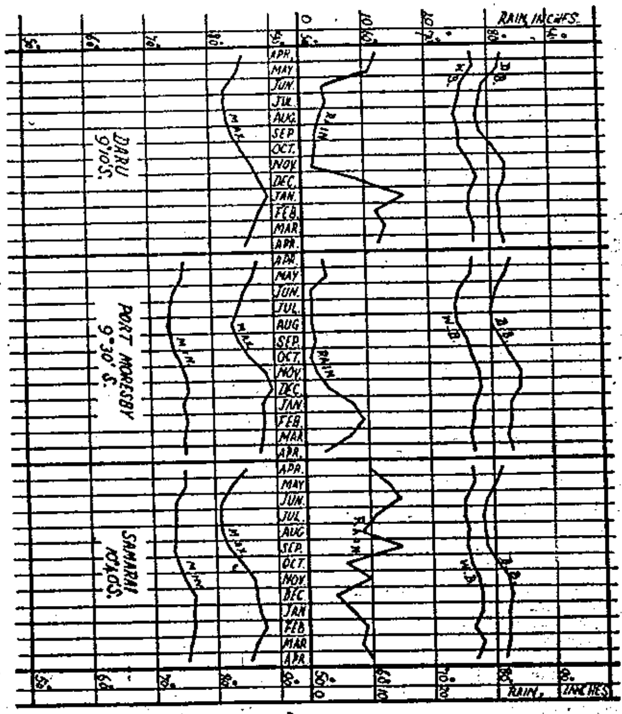


FIG. 5.

The inland towns, on the whole, are much drier than the coastal towns and show a similar seasonal distribution of rainfall.

In the coastal towns of other parts of Northern Australia conditions similar to those of North Queensland prevail, with the one difference that Broome and Wyndham show a comparatively small average rainfall, namely, 58·2 cm. and 71·4 cm. (22·9 inches and 28·1 inches) respectively. In New Guinea, Port Moresby and Daru, both situated within the monsoonal belt, possess in the same way a dry and wet season, whereas Samarai has its rainfall of 296·4 cm. (116·7 inches) more evenly distributed over the whole of the year.

III. SUNLIGHT IN THE TROPICS

The main difference between a temperate and a tropical climate lies in the greater intensity of the sun's rays in the tropics. This greater intensity is solely due to the less oblique path of the rays striking the earth, whereby they have thus passed through a smaller layer of atmosphere. As a result, a less degree of absorption and scattering has taken place, and the chemical and physical activities of these rays are therefore greater the nearer to the equator. This greater activity of the sun's rays manifests itself in everyday life. The newcomer to the tropics soon becomes aware that coloured materials, such as curtains, carpets and clothing fade quickly, and written matter in ink, when exposed to the sun, gradually gets fainter, and, after a time, almost disappears. Similarly, a number of chemical preparations decompose, rubber rapidly perishes and certain qualities of glass are altered. The frosting of glass flasks, microscopic slides and high-power lenses are examples only too well known to laboratory workers in the tropics.

The bactericidal action of sunlight has been known for a long time and has been investigated again recently by Clemesha (1912) in India, who exposed cultures of faecal bacteria to the sun. In other experiments he added large quantities of faeces to water contained in a tank with a large surface area (0·6 hectares, or 1 acre) exposed to the sunlight and examined the liquid from day to day for bacterial content. Furthermore, he studied the bacteriological flora of waters of natural lakes during the monsoonal and dry seasons. All these inquiries led him to conclude that the sun has a very powerful action in destroying faecal organisms in water.

Such changes as the above, together with numerous others of a similar nature, led to the question of the nature of the rays producing these results. Are they brought about by those rays of shorter wave length in the violet and ultra-violet portions of the solar spectrum (chemical rays), or are they to be attributed to rays of longer wave length, situated at the other end of the spectrum, the red and infra-red rays (heat rays)? The ultra-violet rays are known to increase chemical activity, and many chemical reactions and decompositions may be brought about by exposure to these rays. An example is the decomposition of oxalic acid into carbon monoxide, carbon dioxide and water when exposed to the sun in the presence of a uranium salt. This decomposition is almost entirely due to those rays of the solar spectrum in the ultra-violet extending from 550μ to 291μ (Freer (1912)). Observers in the Philippines attempted to make use of this decomposition of oxalic acid under standardised conditions, in order to compare the intensity of the ultra-violet rays of the sun in different parts of the world. The results, however, showed that the amount of decomposition in the Philippines and other parts of the tropics was inconstant and did not bear any definite relationship to latitude. The figures obtained by the same method in a temperate zone were sometimes as high, and even higher, than those found in the tropics.

The extensive observations of the Philippine workers have led them to the conclusion expressed by Aron (1911): 'That the spectrum of the sun's rays does not extend much, if any, further into the ultra-violet in Manila than in northern climates.' These observers do not agree with Woodruff (1905) and others, who attribute the effects of tropical sunlight on the human organism to the influence of ultra-violet rays only. Aron (1911) believes that 'the rays of the tropical sun, having greater wave length than those in the red and ultra-red end of the spectrum, play the most important rôle in producing the untoward effects generally attributed to tropical sunlight'; in other words, he attributes such effects to the heat rays alone.

Gibbs (1912), working in conjunction with Freer and Aron, expresses a somewhat similar opinion, and, if altitude and local meteoroligical conditions are taken into consideration, he does not believe that 'when the normal intensities are compared, the light of

the tropics is different from the sunlight of any other regions.' Effects upon life in the tropics, usually attributed to sunlight, are, in his opinion, due to 'other meteorological modifications, which go to make up climate, namely, duration of sunshine, clouds, rainfall, winds and humidity, all of which affect the air temperature; the last is probably the most important fact and depends to a large extent upon the duration of sunshine.'

In Manila and Baguio, both in the Philippines, Aron (1911) and Gibbs (1912) carried out experiments on animals in order to study the effects of exposure to the sun's rays under varying conditions. Different experimental animals, such as rabbits and monkeys, were exposed to the midday sun for varying periods. These animals, when shielded from draughts, died after an exposure of from thirty-four minutes to about one and a half hours, and showed the post-mortem appearances characteristic of heat stroke. Black rabbits, as a rule, succumbed more quickly than light-coloured animals, and it was noticed that the sub-cutaneous temperatures, taken by means of a thermocouple, in the case of black rabbits, rose quicker and higher than in that of the lighter-coloured ones.

Aron, furthermore, carried out exposure experiments on dogs which had been tracheotomised and thus had part of their effective heat-regulating mechanism put out of action.* It is well known that dogs do not possess sweat glands on the body, but keep their body temperature from rising by means of an increased rate of respiration and an increased evaporation from their respiratory tract. These animals died after about an hour with typical symptoms of heat stroke and corresponding post-mortem appearances. In a similar manner the body temperature of tracheotomised rabbits rose on exposure to the sun more rapidly than that of normal rabbits.

When monkeys were exposed to an artificial draught during the experiment, or were protected by shade from the direct sun rays, no injurious effects were noticed. These experiments, according to Aron (1911), show that 'when placed under the fan animals lost the excessive heat which reached them by radiation from the sun. Rays including the ultra-violet were nevertheless present, and were

* Considering the relatively small surface of mouth, nose and throat above the tracheotomy wound, compared with the breathing surface of the lungs, it is evident that the operation had put out of action only an extremely small portion of the respiratory surface, and cannot altogether account for the quicker death of these animals.

absorbed by the body in the same manner and degree as by that of the control monkeys.'

These experiments have recently been repeated by Shaklee (1917) and further amplified, to ascertain whether it is possible for monkeys to become accustomed to the sun (acclimatised) by a gradually increasing daily exposure. His results differed from those of Aron, as several of his monkeys, even in the beginning of the experiment, lived for hours in the direct sunlight without being protected in any way. Summarising his results, he states that experimental monkeys, exposed to the sun in Manila, may die from heat stroke after varying periods, depending to a less extent upon the sun's rays than on other local conditions, such as proximity of a large, hot surface (ground or roof), high relative humidity of the atmosphere and low wind velocity. Monkeys, however, may become temporarily acclimatised by gradually increasing the time of exposure to the sun. This, in his opinion, increases the sensitiveness of the nervous mechanism which regulates body temperature by an increased rate of perspiration. The fact that administration of atropine, which impairs the function of the sweat glands, causes the death even of an acclimatised monkey on exposure, is evidence in support of this conception.

Animal experiments were also carried out by Schmidt, who, working in a temperate climate, exposed rabbits to the sun and found a rise in the anal temperature which was more pronounced in a black than in a white rabbit. In the same way Schilling (1909) observed a rise in the skin temperature of rabbits exposed to the sun, and several other authors have made similar observations. It must be kept in mind, however, that the temperature of rabbits varies considerably even under normal conditions, and the struggling alone, when the animal is handled, may cause a considerable rise.

It is not a new observation that animals, even in a temperate zone, may succumb to exposure to the sun, as the following example illustrates. In a laboratory in the north of England, in which monkeys were kept in a glass house, on more than one occasion during the summer months several animals died under the symptoms of heat stroke, showing an ante-mortem rectal temperature of 43·3° C. (110° F.), which still rose after death. The painting of the glass roof with a white wash reduced the inside temperature of the animal house and prevented death.

A consideration of the foregoing observations makes it evident that exposure to the direct sun's rays caused such an increase in body temperature that the animals finally succumbed to hyperpyrexia. In every case animals of dark colour died more quickly than those with light fur, on account of the greater absorption of heat.

The dark skin of most of the aboriginal races in the tropics, from the above point of view, would appear to be a disadvantage, and the explanation that dark skin affords protection against the effects of the sun merely by insulating the body against the deep penetration of harmful rays must be modified.

Attempts to elucidate the rôle played by the pigment in a protective sense are not lacking in the literature. Eijkman (1895), in Batavia, covered the bulbs of two thermometers with pieces of white and coloured human skin and placed the thermometers in the sun. He noticed that the brown skin caused a higher rise of the mercury (50·1° C.) than the white skin (47·5° C.).

Aron (1911) and Gibbs (1912), in the Philippines, experimenting with live skin, exposed white and coloured persons to the sun and recorded the skin temperatures of various parts of the body by means of a thermocouple. Their results were somewhat inconstant; the skin temperature invariably rose after a time to from three to four degrees above normal. Whilst Gibbs found temperatures distinctly higher for the dark skin, Aron noted that the white skin was always hotter than the brown, and that after prolonged exposure the temperature of the brown skin showed a more distinct fall. 'It may be said,' as Freer (1912) remarks in summarising the results of both investigators, 'that as regards rise in temperature on exposure to the sun, the white and brown skin (Filippino) are about equal, with a slight factor in favour of the white, but that in regard to the very dark skinned negro the temperature on exposure reaches a decidedly higher point than it does with either of the others.' In its physiological action, on the other hand, the dark skin is superior to the white skin. It absorbs a greater quantity of heat rays, warms up more quickly and reaches the point where perspiration commences earlier and the evaporation of the sweat causes heat loss and consequently affects the cooling of the body.

A consideration of the foregoing experiments and observations upon the effects of exposure to the sun suggests that any ill-effects are due not to light but to heat. These experiments, however, only take into consideration those effects known as sun stroke or heat stroke, and it is, moreover, an almost impossible task in such experiments to study the physiological action of the other rays with the entire exclusion of heat rays.

The effect of sunlight on living organisms has formed the subject of many publications, and many opinions have been put forward which are not founded upon facts but are only wild speculations. Woodruff (1905), for example, wrote an extensive monograph on the effects of tropical light on the white man, and his conclusions have been widely quoted in the literature. He contended that the ultra-violet rays of the tropical sun are inimical to white settlement, but, unfortunately, he based many of his arguments on false premises, and many of his statements were merely expressions of personal opinion. As a glaring example, the following sentence may be quoted: 'The southern hemisphere, except the tip of Patagonia, is north of 45° and therefore unfit for blondes (he assumes that a blonde race cannot live nearer to the equator than 50°), and even in New Zealand and Australia the native white families are already dying out or kept alive by constant new importation from home.' He assumes, further, that in New Zealand there is ample evidence of the physical decay of the white population. In view of such statements, entirely without foundation, it is difficult to consider any of his conclusions seriously.

IV. EFFECTS OF HEAT AND HUMIDITY ON THE ANIMAL ORGANISM

In all warm-blooded animals the temperature of the body under normal physiological conditions only varies slightly. This temperature is maintained by two processes—heat production and heat loss. The former is brought about by chemical processes, the combustion of food material inside the body, the latter by physical means, namely, radiation and convection and evaporation of sweat. In the clothed human being the heat production plays a much less important part in regulation of temperature than the heat loss by physical means, and it is evident that the extent to which these physical means operate must depend on the surroundings. Whereas in a cold climate heat loss takes place mainly by radiation and convection from the body, in a hot climate, where the air temperature often approaches or even exceeds that of the body, the heat loss through radiation can only be very small or nil, and heat is mainly lost by evaporation of sweat from the skin.

It was of great interest to inquire into the physiological reaction of the animal body to increased outer temperature, and a great deal of experimental work has been done in this direction. Attention has been paid to the body temperature and the metabolism in conjunction with the calorific value of the food, but a great deal of this work has been carried out in temperate climates under artificial conditions, and comparatively few observations have been made in the tropics.

(1) *Regulation of Body Temperature under Artificial Conditions*

Blagden and Fordyce (1775) noticed that their mouth temperatures did not rise above normal when remaining for fifteen minutes in a dry room heated to a temperature of 115° C. to 126·7° C., although the heat was sufficient to cook a beef steak. Exposure for the same length of time, however, in a moist room heated to 54·4° C. caused the body temperature to rise to 37·8° C. In recent times Haldane (1905) carried out his classical experiments on the effect of humid heat. His observations were made on human beings, both at rest and at work, in an artificially heated chamber, as well as underground in deep mines, in still air or exposed to artificial draughts. He concluded that the temperature of the human organism exposed to humid heat begins to rise after a period varying according to the individual and the conditions and then continues to do so. The rise in body temperature corresponds with the reading of the wet bulb temperature and is practically independent of the dry bulb temperature. During rest in still air, wet bulb temperature of about 31·1° C. (88° F.) could be borne without any abnormal rise in rectal temperature, but when the thermometer rose above that temperature the rectal temperature immediately commenced to rise, which rise was accompanied by an increase in the pulse rate, profuse sweating and dyspnoea, until finally exhaustion set in. During muscular exercise in still air this increase in body temperature commenced at a much lower wet bulb (27° C., or 80·6°F.,) and in moving air much higher wet bulb temperatures were required to produce the same effect.

These experiments were continued and amplified in Haldane's laboratory by Harvey Sutton (1908), who studied the changes in the gaseous metabolism of the body when exposed to humid heat. He observed a large increase in the metabolism, running parallel to the rise in body temperature; in fact, analogous conditions to those existent in fever. He concluded that 'all experiments point to the fact that once the balance of the mechanism of heat regulation in the human body has been definitely upset by high external temperatures, combined with almost total abolition of heat loss in evaporation, a vicious circle is established. The internal temperature rises and as a result the oxidation processes——and therefore the production of heat also increases—so that the body temperature rises still further, and so on. Once the ball has been set rolling, nothing seems to check its progress, and it slowly but surely gathers speed. The rectal temperature not only continues to rise, while the external temperature still remains constant, but the rise gradually increases in rapidity as if momentum were being gathered.'

Conditions similar to those under which the experiments of Haldane and Harvey Sutton were conducted, may, according to Pembrey (1913), give rise to heat stroke. He analysed the history of a large number of cases of heat stroke which had occurred amongst British troops in India, and came to the conclusion that heat stroke is brought about by a failure of the mechanism which regulates the body temperature, after prolonged exposure to excessive moist heat. In an excessively hot and moist atmosphere the cooling effect of the evaporating sweat is insufficient to prevent the body temperatures from rising, and a prolonged exposure to these unfavourable circumstances leads to a gradual rise in body temperature and ultimately to heat stroke.

Observations on the influence of wind and draughts on the body bring additional evidence to show that, with high external temperature, the loss of heat due to evaporation of sweat is the most important factor in regulating the body temperature. As far back

as 1883 Herman suggested that the ill-effects due to bad ventilation and crowded rooms were caused by heat stagnation. This view was confirmed experimentally by Heyman, Paul and Ercklentz (1905), and later still by Hill, Flack, Rowlands and Walker (1913). Hill and his colleagues confined individuals in a small experimental chamber until the carbonic acid content rose from 1 per cent. to 1·5 per cent. in one instance and from 3 per cent. to 4 per cent. in another. The subjects experienced discomfort at a wet bulb temperature of 27·7° to 28·4° C. (82° to 85° F.) and this discomfort was considerably allayed when the air in the chamber was moved by a fan. No relief, however, was experienced when fresh air was breathed through mouthpiece and tube passing through the wall of the chamber. Subjects outside the chamber who breathed the chamber air suffered no discomfort, thus proving that the discomfort was caused not by the increased carbon dioxide of the air in the chamber, but by the heat stagnation, following the failure of evaporation of sweat.

The part played by the evaporating perspiration is illustrated in Zuntz and Tendlau's observations upon the body temperature of a man whose skin was devoid of sweat glands. The exposure to the summer sun of a temperate climate caused his temperature to rise to 39° C. (102·2° F.) and a slight amount of manual work produced the same effect. He was, however, able to find a substitute for the missing function by frequently soaking his shirt in water.

Such a condition as described above can be artificially produced by immersion in a hot-water bath, when the evaporation from the skin is prevented and the effects of perspiring are eliminated. Hill and Flack (1909) studied the pulse rate, blood pressure, body temperature, breathing volume and alveolar tensions of man in a hot bath. They found that immersion up to the neck in hot water (40·5° to 43·3° C., or 105° to 110° F.) for fifteen to thirty minutes caused an increase in the body temperature of 39·1° to 40·3° C. (102·5° to 104·6° F.). The pulse rate and respiration rate and volume rose and the blood pressure was lowered. In the alveolar air a notable fall in carbonic acid tension and a corresponding rise in oxygen tension were observed, caused by the washing-out effect of the increased breathing.

The foregoing observations make it clear that the main difference between temperature regulation in the tropics and in a temperate climate lies in the greater activity of the sweat glands, and the evaporation of the increased amount of sweat plays a more important part in the cooling of the body. It is a common experience in the tropics that the quantity of water secreted in the urine is greatly diminished during hot weather, in spite of the larger intake of fluid; the balance of the water leaving the body by way of the skin and the lungs is considerably larger.

The establishment of an equilibrium between the water secreted by the kidneys and that secreted by the sweat glands is probably of importance in the process of acclimatisation. Inhabitants of the tropics know only too well the discomfort caused by the frequent necessity of micturition during a sudden cold spell, even at times when the temperature is well above that regarded as comfortable and even warm in a temperate climate. Moreover, the feeling of subjective discomfort on such occasions is very marked, and this sensitiveness to cold has given rise to the popular belief that the blood of dwellers in the tropics is thinner than that of a person living in a temperate climate.

(2) *Changes in the Physiology of the White Man Living under Tropical Conditions*

The tradition that the white man cannot flourish in tropical climes has given rise to a great deal of controversy, and the possibility of an acclimatisation has constantly occupied the attention of authorities interested in the development of the tropics. It has been propounded by several observers with experience of life in tropical countries that, apart from diseases peculiar to the tropics, climate *per se* comprising heat, humidity and light make it impossible for a white race to settle and thrive. Attempts have therefore been made to study the physiology of the white man living in the tropics, in order to ascertain whether changes have actually taken place, and for comparison the investigations have been extended to native races. The results so far are by no means complete, and a decided answer is still to seek.

Little reflection is needed to appreciate the difficulties which stand in the way of a practical solution of the question. Tropical

diseases have up to recent times been very prevalent in most parts and have been a large factor in preventing settlement by a white race. The pioneer work of Manson and Ross on the rôle of insect carriers in such diseases as filariasis and malaria has laid down new lines for the investigation of other tropical complaints. The practical application of the results has led to increased public health activities, and has thus created a new era in the permanent settlement of the tropics by inhabitants of European descent. Moreover, the tropics, with only few exceptions, such as the South American Republics, have only recently been settled; a second and third generation is rare, and it is impossible to obtain and select subjects in sufficient numbers for carrying out observations which would yield results which could not be attacked on the plea of insufficient time of observation. The conditions of life in general there, for example, housing, ventilation and food, are so different that the difficulty of obtaining figures suitable for a comparison of physiological functions is greatly increased and comparative standards in many respects are lacking.

A critical review of the literature on acclimatisation brings to light the fact that nearly all observations have been made on Europeans who have resided in the tropics for a comparatively short time. The majority were men chosen for service in the tropics on account of their physical fitness, and few of them could boast of an uninterrupted residence in the tropics for more than a few years at most.

As an example, in the work of the American observers in the Philippines, the figures relating to Europeans were obtained with male subjects only, and, furthermore, cannot be accepted, excepting on the supposition that changes due to climatic influences become established within a comparatively short time. The same criticism may be applied to experiments on metabolism carried out by Eijkman in Java, whose subjects had resided in the tropics for from four and a half to fifteen years, and out of nineteen Europeans only one could show a continuous residence for fifteen years. Results such as those of Rattray, Wick, Schilling and many others are the outcome of observations on one or a few subjects only, collected during a flying visit to the tropics.

Investigations on aboriginal races, although interesting from a comparative point of view, do not help to solve the problem, on account of the different mode of living, customs and personal habits.

(*a*) *Body Temperature in the Tropics.* The fact that the external temperature in the tropics is considerably higher than in a temperate climate suggested a raised body temperature. On account of the ease with which the body temperature can be taken, it is not surprising that the literature contains records of numerous observations, many collected during a sea voyage between Europe and the tropics, others on Europeans and native races living in the tropics.

John Davy, in 1839, published a number of observations made upon the mouth temperature of seven healthy men during a voyage from England to Ceylon, and he concluded that the temperature of a European increased whilst passing from a temperate to a warm climate, and that, in addition, the body temperature of residents in the tropics is slightly raised above normal. He amplified his work during a residence of three years in Barbados, and stated that his own temperature was higher by 0·5° C. (0·9° F.) when compared with his body temperature in England. Many others, including Reynaud and Blossville, Rattray, Brown-Séquard, Jousset, Maurel and others (referred to by Pembrey, 1898) confirmed this slight rise (less than 0·55° C., or 1° F.), which was more pronounced during the first few weeks of residence in the torrid zone, that is, during the time of acclimatisation. Crombie (see Pembrey, 1898) recorded the results of 1,288 observations upon his own mouth temperature in Bengal, and found it slightly higher (namely, 0·23° C., or 0·7° F.) than in England. Neuhauss (1893), who, during a voyage round the world, observed his own rectal temperatures, found the following differences (see Table II).

TABLE II.

Temperature of Air	6 a.m.	12 noon	10 p.m.	6 p.m.	Remarks	
Temperate Zone Minimum Maximum 11·5° C. 19·1° C. (51·7° F.) (56·5° F.)	36·6° C. (97·9° F.) 55	36·9° C. (98·5° F.) 55	36·7° C. (98·2° F.) 56	37·1° C. (98·8° F.) 62	Temperate in rectum Pulse	Mean of 20 days
Tropical Zone Minimum Maximum 28·8° C. 26·6° C. (75·8° F.) (79·9° F.)	36·9° C. (98·5° F.) 60	37·3° C. (99·2° F.) 68	37·1° C. (98·8° F.) 64	37·3° C. (99·2° F.) 72	Temperate in rectum Pulse	Mean of 20 days

On the other hand, many observers have denied that there is any marked difference in the body temperature; amongst others were Thornly (1878) and Furnell (1878), and more recently Wick (1910), who could not observe any alteration in his body temperature during the passage from a temperate zone to the tropics.

Chamberlain (1911), as the result of 3,000 mouth temperatures, taken at quarterly intervals upon 600 healthy American soldiers living in the Philippines, arrived at a similar conclusion. According to him, the temperature of American soldiers doing duty in the Philippines showed no appreciable variation for season or for complexion type; it averaged 37° C. (98·7° F.), and this average differed little, if at all, from the mean normal temperature for white men living in the United States. In Plehn's (1898) opinion there is a slight rise in temperature during acclimatisation, but after continued residence this rise disappears.

The body temperature of dark-skinned native races in the tropics does not differ appreciably from that of Europeans. A. Jousset (1884) found that the average temperature of Hindoos, Chinese and negroes was 37·8° C. (100° F.), whereas that of Europeans under similar conditions was 37·87° C. (100·1° F.). Eijkman (1895) in Batavia compared the axillary temperature of Malays and Europeans, and found that the Malays had a slightly lower temperature (36·85° C., or 98·3° F.) when compared with Europeans (37° C., or 99° F.).

Young (1915) in a recent paper on this subject recorded a number of observations taken during the hot season in North Queensland. He pointed out that it is fallacious to speak of a normal mean body temperature, as that of a healthy person, even at rest in a cool climate, varies considerably during the twenty-four hours,* and considered it more rational to employ as standard the range of body temperature which has been observed in healthy individuals. He concluded that :—

* Benedict and Carpenter (Carnegie Institution monographs, No. 126, 1910), writing on this subject, state that: 'the idea of constancy in body temperature has become so generally accepted that it is commonly believed that the body remains at the temperature of 98·6° F. or 37° C. without material change, other than that produced by disease. This impression is so firmly fixed that one finds to-day on all clinical thermometers a special mark opposite this temperature, to indicate what is supposed to be the normal temperature. It is somewhat difficult to place the exact history of this mark being selected, and it may be looked upon as more or less of a thermometric fetish, which has been worshipped by long-continued usage.'

1. The temperature of the mouth of Europeans living in the tropics is often considerably lower than that of the rectum and that this difference is generally much more marked after exercise, just as in temperate climates. The temperature of the mouth is thus not reliable as a measure of the body temperature.

2. During complete rest the rectal temperature did not show any marked variations from the limits of temperature observed in Europe.

3. A considerable rise in the rectal temperature was produced by slight muscular work and this was usually maintained for some time after the work had ceased.

These observations make it clear that the discrepancies in the records quoted above are in all probability partly due to the mode in which the temperatures were taken and partly to individual and daily variations.

At rest the body temperature in the tropics does not vary from that in a temperate climate, but with exercise the temperature rises more quickly and subsequently decreases more slowly than in a temperate zone. A good example of this is quoted by Young in respect to one of his subjects, who was in the habit of taking exercise in the early morning; during a period of eighteen days his average rectal temperature at 8 a.m. was 37·9° C. (100·3° F.). On three occasions on which the exercise was omitted the rectal temperature at the same time was only 37·5° (99·6° F.).

(*b*) *Rate of Respiration.* A comparison of the respiration rate of tropical inhabitants with that found in Europe has yielded conflicting evidence. According to Rattray (1870) the total volume of air expired was about 7 per cent. less than in a temperate climate, and he attributed this to a decreased rate of respiration, since spirometer measurements showed that the lung capacity was increased. These observations, made on a small number of subjects, were not confirmed by Jousset and by Plehn, who, on the contrary, found an increase in the respiration rate. Chamberlain (1911) made observations on 608 American soldiers in the Philippines. He found the average to be 19·3, which is much higher than the figure usually accepted as normal for Europeans in Europe, namely, 17 to 18. It may be mentioned here that Osborne (1910) carried out observations during the summer months in Victoria (Australia), and found that with a high outer temperature (37·7° C., or 100° F.) the pulmonary ventilation was increased.

In consideration of the fact that the human body loses a certain amount of water in the expired air and consequently heat due to

the evaporation of the water, it might be expected that the body would make use of this means for cooling purposes and an increased respiration would be the outcome.

(*c*) *Blood Pressure.* Estimations of the blood pressure in the tropics have been made by a number of observers, with contradictory results. Musgrave and Sisson (1910) in Manila examined 97 Americans, 10 sisters of charity and 40 Filipinos. They graded the former two groups according to their length of tropical residence and found a decided decrease in the blood pressure, corresponding to the length of residence in a hot climate, and suggested that the lower blood pressure might be due to a lowered peripheral resistance, brought about either by a decrease in the vasometer tone or by splanchnic influences. Chamberlain (1911) took the blood pressure of 992 American soldiers in the Philippines and made 5,368 observations, and concluded that 'the average blood pressure of 115 to 118 millimetres found in these large bodies of men differed little, if any, from the accepted standard among males of the same age in a temperate zone when the 5-inch armlet is used.'

Breinl and Priestley (1914) estimated the blood pressure of North Queensland school children, and concluded from 573 observations that the climate as such has no marked influence on the blood pressure in children.

Theoretically a permanent change in the blood pressure in the tropics should not be anticipated, as a sound heart and sound arteries are adaptable to any change. Only temporary variations are observed, such as a rise in blood pressure on exertion or a lowering due to venous hyperaemia of the skin, similar to that produced by a hot bath, but both would only be evanescent and not peculiar to tropical life.

(*d*) *Blood Conditions of Europeans in the Tropics.* The existence of tropical anaemia has for a long time been regarded as an established fact, and most of the early text-books on tropical medicine speak of an anaemia due to climatic influences only. There is no doubt that the greater proportion of the cases in the time before microscopical examination became general were in all probability caused by malaria and hookworm (anchylostomiasis). The skin of the healthy European inhabiting a tropical climate appears to the newcomer pale and sallow, the degree of the sallowness depending on many factors, especially complexion and skin texture. The unprotected skin of individuals with red or fair hair is invariably more sallow and appears more anaemic for the same reason that it has, on account of the lack of pigment, a lesser defensive power against the action of the sun's rays. The paleness of the skin has naturally given rise to the conception that there exists a tropical anaemia and that 'thinness and poorness' of blood is a natural sequence of prolonged residence in the tropics. It is not unexpected that the advent of accurate microscopical methods has led to an investigation of blood conditions of Europeans in the tropics, and the results of these investigations have been rather surprising.

Marestang (1889), van der Scheer (1890) and Eijkman (1891) examined the blood of Europeans living in the Dutch East Indies without finding any marked differences when compared with figures obtained for Europe. Glogner (1892) in Sumatra, and Plehn (1892) in the Cameroons, carried out similar investigations with identical results. These observations, however, are not entirely conclusive, since they were based on a comparatively small number of estimations.

Work of a similar nature was carried out by the Americans in the Philippines. Wickline (1908) examined the blood of about 70 American soldiers, after a varying period of residence in the Philippines. The first examination was made three months after their arrival; it was repeated after the lapse of three months and twice again after an interval of approximately eight months. He discovered a gradual decrease in the amount of haemoglobin from 97 to 83 and a regular rise in the number of erythrocytes from 4·9 to 5·3 millions. Chamberlain (1911), following up Wickline's work, performed 1,718 red cell counts and 1,433 haemoglobin estimations of 702 soldiers, and concluded that 'the red cell counts, averaging 5·2 millions, rarely falling below 4·5, do not differ from the normal at present recognised for healthy young men in a temperate zone.' The haemoglobin figures are perhaps a little low, but not sufficient to indicate a definite anaemia.

Cuthbert (1911) collected similar observations from 21 healthy soldiers of European descent on the West Coast of Africa with a similar result. Wickline's and Chamberlain's figures were obtained

from healthy subjects especially chosen for tropical service, and after a comparatively short residence in the tropics (two years), and are open to the objections already mentioned.

Breinl and Priestley (1914) made observations on apparently healthy school children in North Queensland of ages ranging between seven and fifteen years, most of whom were born and had lived all their life in North Queensland. Five hundred and eight blood counts were performed on 305 boys and 269 girls, and the haemoglobin content of the blood was estimated by the Fleischl-Miescher method.

They concluded from their investigations that there is no striking difference in the number of erythrocytes and the colour index in North Queensland children when compared with averages obtained in children of a temperature climate. The number of white blood corpuscles (leucocytes), according to Chamberlain (1911), also to Breinl and Priestley (1914), is slightly higher when compared with that generally accepted as the standard for a temperate climate.

Differential counts, which estimate the percentage of the various types of leucocytes, showed, according to these observers, a distinct alteration. The proportion of the polymorphonuclear neutrophile leucocytes appeared to be decreased to 56·1 per cent. (Chamberlain and Vedder (1911)) and 56·8 per cent. (Breinl and Priestley); 65 per cent. to 70 per cent. is generally accepted as average. The percentage of the eosinophile leucocytes was distinctly increased.

Chamberlain and Vedder (1911) studied the blood conditions of American soldiers and natives in the Philippines, and came to the conclusion that the Arneth blood picture of the soldiers showed a slight 'shift to the left,' that of the Filipinos a much more marked shift, which means that the nuclear condition of the polymorphonuclear neutrophile leucocytes in respect to the numbers of nuclear fragments was altered when compared with those of healthy Europeans living in a temperate climate; the number of cells with a smaller number of fragments (one to two) was considerably increased. Breinl and Priestley (1914) carried out analogous observations on North Queensland school children, and found that similar conditions prevailed and that the blood picture resembled closely that of the Filipinos. The authors concluded that the 'shift to the left' was due to the effect of a tropical climate upon the white race living in the tropics.

For comparison a number of Arneth counts on apparently healthy native children in the Northern Territory were performed, and their 'Arneth index' corresponded closely to that of North Queensland school children.

The significance of the altered Arneth index is uncertain and, according to Breinl and Priestley (1914), the presence of a large number of neutrophile leucocytes belonging to class one (possessing a single nucleus) 'indicates a greater activity of the bone marrow, but does not necessarily imply that the resistance of the organism is lowered' (to disease) 'in any way.'

A few observations on the specific gravity of blood were made by Eijkman (1896) in Java, and by Breinl and Priestley (unpublished) in Townsville. The results did not show any marked deviation from the average specific gravity of the blood considered normal for a temperate climate, and, when considered in conjunction with the previously mentioned blood work, proves that there is in general no evidence of an anaemia in the tropics due to climatic influences only. The popular belief of the 'thinness of the blood' after prolonged residence in the tropics is, apart from anaemia due to disease, from a scientific point of view only a myth.

(*e*) *Metabolism in the Tropics.* In a cold climate, as has been stated previously, the temperature equilibrium of man is maintained mainly by regulation of the heat loss through radiation, convection and evaporation (termed by Rubner physical heat regulation), whilst changes in the heat production (Rubner's chemical heat regulation) take place only to a small extent. In fact, Rubner has said that a man feels comfortably warm only when the chemical regulation of his heat balance is completely eliminated. In a cool climate chemical heat regulation can only be spoken of in the sense that the stimulating effect of cold on the skin causes reflex innervation of the muscles, resulting in their movement or increased tone, which brings about an increase in the production of heat, i.e., the increased metabolism is really due to the muscular action and not to cold *per se.*

The question naturally arose whether the chemical heat regulation plays any part in maintaining this equilibrium in the tropics where the external temperature is high; in other words, whether the body responds to these different conditions by a reduced combustion of food material. This problem has been attacked in two ways: first,

by a comparison of the calorific value of the food actually katabolised by Europeans living in the tropics, with the average value found in temperate climates, and, secondly, by a comparison of the total metabolism in both parts of the world, as determined by the respiratory gas exchange, that is, the oxygen absorbed and the carbon dioxide eliminated, the experiments being carried out otherwise under exactly the same conditions.

The most important work in the first direction is that of Eijkman (1893), who investigated the food of seven Europeans living in the Dutch Indies. His experiments, lasting for several days, were carried out as follows:—At each meal each person under observation took a second portion of each dish, similar in quantity, as judged by the eye, to that which he consumed, and these duplicate meals were collected for each day and the protein, fat, carbohydrate, etc., in them estimated. At the same time the faeces were collected and analysed to determine the quantity of food actually absorbed.

Allowing for the loss in the faeces, he obtained the following figures for the average constituents of the food actually utilised:—

Protein	88·2 grms.
Fat	79·1 grms.
Carbohydrate	256·4 grms.
Ash	17·5 grms.
Alcohol	28·5 grms.

From the results he calculated that for a man weighing from 65 to 70 kilograms the heat production from the food amounted to 2,400 to 2,500 calories, a figure which does not differ from that given by Rubner for men doing a similar class of work in Euorpe, namely, 2,445 calories. The excretion of nitrogen in the urine and faeces showed that, on the whole, his subjects maintained nitrogen equilibrium during the experiment.

Eijkman concluded from these experiments that there was no evidence that chemical heat regulation played any significant part in the thermo-equilibrium of inhabitants of the tropics.

A different conclusion was arrived at by Ranke (1900), who published the results of observations upon himself extending over a few days, comparing the calorific value of his food in Europe and during a short residence in Brazil. In Europe the heat value of his daily food in two experiments was 3,527 and 3,514 calories, respectively. In Brazil, however, the calorific value of his food was much less, being only 2,812, 1,920 and 1,948 calories, respectively, in three series of observations.

Ranke's experiments have been criticized adversely by Glogner (1909), who conducted similar determinations upon himself at different times during his residence in Sumatra and Padang, and again after his return to Europe. He stated that loss of appetite is a common experience during the first period of residence in the tropics, and attributes the lower values obtained by Ranke to the fact that the latter had only been a few months in the tropics when the experiments were carried out.

Glogner's experiments, conducted after a six years' residence, and lasting for fourteen days, showed the average energy value of his daily food to be 2,118 calories, or 28·8 calories per kilogram of body weight per day. A similar experiment was performed in Europe fifteen years later—five years after his departure from the tropics—and then the daily average was found to be 2,038 calories, or 25·5 calories per kilogram of body weight. It is doubtful, however, whether any value can be placed on these observations, since the first series was made when the subject was 32 years old and weighed 71·1 kilograms, and the series for comparison when the subject was 47 years old and weighed 80·3 kilograms.

Experiments were carried out also upon themselves by Schilling and Jaffé (1909) during a visit to West Africa, and the results were compared with observations made in Berlin, both before and after their journey. There were no appreciable differences between the heat value of their food in both parts of the world, the average being 2,863 and 2,953 calories per day for Jaffé, and 2,953 and 3,021 calories per day for Schilling, in Europe and Africa respectively. In both places nitrogen equilibrium was approximately maintained on about 17 grammes of nitrogen per day.

In a similar way the nutritive value of the food of native races in the tropics has been estimated for comparison with that of white people. Eijkman (1893) examined the food of five Malays in a similar manner to that employed in his experiments quoted above, and found the following average for the food actually katabolised, after allowing for the material lost in the faeces:

Protein	59·9 grms.
Fat	25·0 grms.
Carbohydrate	462·0 grms.
Ash	13·2 grms.

The heat value of the food was about 2,349 calories for an average body weight of 50 kilograms, i.e., a figure slightly higher per kilogram of body weight than that given by Rubner for men in Europe. The amount of unabsorbed matter in the faeces was much greater in the Malays than in the Europeans, probably on account of the large preponderance of vegetable food in their diet.

An extensive inquiry has been made by McCay (1912) in India into the food of various native races. For Bengalis he found that the calorific value of the food was higher (3,196 calories) and the nitrogen lower than that of Europeans. A study of the diet and nutrition of the Filipinos was made by Aron (1909), and the average composition of the daily allowance in the Manila native prisons was given as:

Protein	55·9 grms.
Fat	27·0 grms.
Carbohydrate	510·0 grms.
Calories	2,646

An estimate of the calorific value of the food eaten by a Filipino living under normal conditions corresponded to from 2,500 to 2,600 calories, and when allowances were made for the smaller body weight of Filipinos (50 to 55 kilos), this value corresponded to the requirements of a working-man in Europe performing moderately hard labour.

Recently, Campbell (1917) examined the food of several native students (Chinese, Tamil, Malay and Brahmin), and obtained values ranging from 1,502 to 2,492 calories per day.

The results of these investigations into the food value in the tropics make it clear that in general the requirements in calories, either of white men or coloured natives, does not differ appreciably from European standards. The experiments quoted above indicate that the amount of heat produced by the combustion of food is not any less in the tropics than in a temperate climate, and that nature does not have recourse to a reduced metabolism to regulate body temperature.

The energy involved in the total process of oxidation (heat production) taking place in the animal body may be measured either by the actual heat value of the food digested (calorific value of the food), or again by the quantity of oxygen used up and carbon dioxide and water produced (the respiratory exchange), which measures the end products of this oxidation.

If metabolism would play any appreciable part in controlling the body temperature in the tropics, it would find its expression in a reduced oxygen absorption and carbon dioxide production.

Experiments upon the influence of high external temperature and humidity upon the respiratory exchange have been carried out from this point of view under artificial conditions upon man and animals, and on man in the tropics.

The general results of these experiments show that with cold-blooded animals the oxygen absorbed and carbon dioxide eliminated are directly proportional to the external temperature; in other words, there is no heat regulation, and the body temperature is that of the surroundings. With warm-blooded animals, on the other hand, the organism regulates its heat to a more or less extent. With the monotreme, *Ornithorhynchus*, the mechanism is almost entirely chemical; thus, with increasing external temperature the metabolism decreases until a temperature of 32° C. (89·6° F.) is reached, the body temperature remaining throughout almost constant. Above this the animal's temperature rises, thus indicating that the regulatory mechanism is failing, until finally, with increasing outer temperatures, the animal behaves like a cold-blooded animal.

In the rabbit the same is observed, but to a less degree, because the mechanism is complicated by loss of heat by physical means.

In man the elimination of carbon dioxide is not affected by rising external temperature in a constant manner. In some experiments, carried out under artificial conditions, it has been noticed that with rising temperature the carbon dioxide sinks in quantity at a temperature of about 15° C. (59° F.), reaches its minimum between 20° C. (68° F.) and 25° C. (77° F.), and then rises slightly. In other experiments, however, no such change has been observed. Generally speaking, all that can be said is that there appears to be an ill-defined zone of temperature in which the metabolism is at a minimum. When the external temperature and humidity are so

high that the physical regulation fails, and a rise in body temperature results, this rise is accompanied by an increased metabolism, still further increasing with continued rise of body temperature, until dangerous conditions are reached, as already stated.

A study of the gaseous metabolism under actual tropical conditions was made by Eijkman in Java. By means of the Zuntz-Geppert method he determined the quantity of oxygen consumed and of carbon dioxide eliminated during rest by eleven Europeans and twelve Malays. He obtained the following averages as the result of forty-eight experiments on Malays and thirty-seven experiments on Europeans (see Table III). The numbers are calculated to a body weight of 64 kilos.

TABLE III.

	Oxygen absorbed per minute	Respiratory quotient
Europeans in Java	245·7	0·791
Malays in Java	251·5	0·880
Europeans in Europe	250·3	0·775

Eijkman interpreted these results as confirmatory of his other experiments already quoted, namely, that the heat production by the body in the tropics is not less than in a temperate climate, and that therefore change in heat production plays an insignificant part in the regulation of temperature. He attributes the higher respiratory quotient of the Malays to the larger proportion of carbohydrates in their diet.

In reviewing these researches on the metabolism in the tropics it is necessary, before drawing any conclusions, to consider the limitations of metabolic experiments in general. Contradictory results may be accounted for in some measure by different food, habits and customs in various countries in which the experiments have been carried out, and by individual variations. Moreover, up to the present no definite standard has been acknowledged.

A large number of observations upon metabolism during complete rest, which is termed basal metabolism, have been carried out during several years in the Nutrition Laboratory of the Carnegie

Institute in the United States by Benedict and his co-workers. Subjects included men and women of various ages, athletes, vegetarians, etc. The general conclusions drawn from these experiments have been embodied in a paper by Benedict (1915) upon the factors affecting basal metabolism, in which he pointed out that a much larger number of factors enter into this question than has been hitherto recognised. Although body weight plays an important part, there is no direct relationship between the body weight and the total heat production. Similarly with body surface, the general belief that heat production is determined by body surface is not strictly accurate; a careful analysis of metabolism measurements shows that the heat output is not proportional to the body surface. Other factors are the proportion of inert fat and active protoplasmic tissue in the body composition, and also the height and age. Finally, there are large variations from day to day in the same individual. Summing up his conclusion, Benedict says:

> It is clear that the basal metabolism of an individual is a function first of the total mass of active protoplasmic tissue and second of the stimulus to cellular activity at the time the measurement of the metabolism is made. Apparently at present no law can be laid down that will cover both of these important variables in the basal metabolism of an individual.

In the light of this work it is at once seen that units for comparing the metabolism are still only in the making, and a comparison is only possible of the averages of experiments on large numbers of individuals, extended over a long period of time, so as to eliminate changes which might be due to the temporary ascendency of any one factor. It is obvious, therefore, that researches which have been made hitherto on total metabolism have not been on a sufficiently large scale to justify any definite conclusion, and probably the discrepancies in the results of different experimenters may be accounted for in this way.

The researches into the total metabolism and heat production in man have so far not revealed any changes which might be attributed to the influence of climatic conditions. It has, however, repeatedly been pointed out that the dietary of the majority of the aboriginal races in the tropics contains a relatively small proportion of protein. This fact has naturally led to the presumption that dwellers in the tropics require a less amount of protein in their food.

Protein differs from the other food constituents in the respect that it is utilised by the organism in both directions, namely, for producing energy and building up tissue. It is, therefore, not unexpected that the protein requirements of tropical inhabitants has been studied in detail.

Eijkman (1893) in Java found that Malays consumed 73·3 grammes of protein per day, of which about 56 grammes were actually metabolised, an amount far below the standard usually accepted in Europe (100 grammes). An extensive series of observations on the protein content of the dietary of native races in India has been carried out by McCay (1912), who investigated its bearing upon the physique and general efficiency of his subjects. In his opinion the small quantity of protein generally consumed by the natives was not the result of want of desire, but of inability to procure a larger quantity, and he convinced himself that most natives would eat more if they could obtain it. He concluded that those races with a higher level of protein interchange were generally more robust, energetic, and more manly. In the same way the daily food of Filipino prisoners, according to Aron (1909), contained only 75 grammes of protein.

A much higher quantity of protein was utilised, according to Eijkman, by Europeans living in Java. He found that the food of his experimental subjects contained 99·6 grammes of protein, of which 88·2 grammes were actually absorbed, which amount corresponds to the normal protein requirements in Europe. Other observers who examined their food during a visit to the tropical zone, confirmed this. Thus Ranke, during his voyage to Brazil, found very little change in the protein of his food, and Jaffé and Schilling found that nitrogen equilibrium was maintained on the same amount of protein in Europe and in West Africa.

Unfortunately the whole question of the protein requirement of man is still unsolved. Atwater's standard of 125 grammes of protein a day, and Chittenden's standard of about 60 grammes, are both accepted by various workers, and recent experiments of Hindhede have shown that nitrogen equilibrium can easily be maintained upon a much lower amount of protein, provided that the diet contains sufficient calorific value. He himself maintained nitrogen equilibrium on 32 grammes of protein for 150 days. The question is further complicated by the necessity of accessory food products and their relation to the different constituents of the food, about which we are as yet in almost complete ignorance.

The protein metabolism has been further studied by the examination of the various constituents of the urine, since the final products of its degradation are excreted in the urine. Eijkman found that the urine of Europeans living in the East Indies did not differ appreciably from standards in Europe. He found the average volume for twenty-four hours as 1,442 c.cm., the specific gravity 1·017, whilst the average nitrogen content was 13·04 grammes. In the physiological text-books the average for Europe is generally given as 1,200 to 1,500 c.cm., with a specific gravity of 1·015 to 1·025, and a total nitrogen content of 14 to 18 grammes. He allowed for 1·6 grammes of nitrogen lost in the sweat, and concluded therefore that an acclimatized European passed as much nitrogen in his urine as he did in Europe.

Other observers, such as Wick, Ranke and Neuhauss, however, found that the urine is much more concentrated. Observations in this respect, extending over some time, have been made in Townsville by Young (1919). A number of urine samples collected during the hot months have been examined in this Institute, and the average figures were obtained for the daily urine of twenty-five persons, some of whom were engaged in manual labour, and others followed a sedentary occupation. The averages calculated are given in the Table IV, together with European standards:—

TABLE IV.

	In Townsville	European standard
Quantity	782 c.cm.	1,500 c.cm.
Specific Gravity	1.025	1.015 to 1.020
Total Nitrogen	10.4 grm.	16 grm.
Sodium Chloride	7.00 grm.	15 grm.
Phosphates	1.73 grm.	2 to 3.5 grm.
Freezing Point	—0.935° to —2.259° C.	—0.87° to —2.71° C.

These observations reveal decided differences. The volume was much lower and the specific gravity higher. The total nitrogen, too, was smaller. The most striking difference lies in the quantity of sodium chloride, which may be accounted for by the increased quantity of sweat lost, which carries with it sodium chloride. Estimations of the amount of water lost from the skin during exercise in Townsville have yielded interesting figures. After a brisk walk of about seventy minutes with an external temperature of 24·4° C. (76° F.) wet bulb, as much as 1,100 grammes in weight have been lost.[1] As the subjects of these experiments were weighed in their clothing, this figure only represents the water which had actually evaporated. Samples of sweat carefully collected contained from 0·1 to 0·3 gramme of sodium chloride per 100 c.cm., and the cutaneous excretion would account for several grammes of sodium chloride in the above experiment. The nitrogen lost in the sweat can only be small, and is almost negligible, since samples of sweat only contained 0·03 to 0·04 grammes per 100 c.cm.

The urine measured during the cold weather averaged a higher volume, 1,357 c.cm., a lower specific gravity, 1·019, and an increased salt content, 9·44 grammes, per day.

The total nitrogen in the urine in Northern Australia was decidedly below the European standard, even considering that a small amount (1 to 2 grammes per twenty-four hours) may leave the organism by way of the skin. There is thus an indication of a decrease in the amount of protein metabolised. Whether this is due to a smaller intake of food brought about by a want of appetite during the hot weather, so commonly observed, or whether other factors come into play, must be left an open question.

(*f*) *Effect of a Tropical Climate on the Nervous System.* In many of the writings on health and disease in the tropics attention has been drawn to the frequent occurrence of a mental condition resembling neurasthenia, of the same type as that found in temperate climates. It occurs mostly amongst Europeans, women and men, after a prolonged residence in the tropics, and is referred to in the literature as tropical neurasthenia. In its mildest form it manifests itself in a lability of the mental equilibrium, fits of depression alternate with states of exuberance; unwarranted irritability over trifling matters is hardly ever absent, leading to uncontrollable outbreaks of temper. It is associated with a loss of mental activity and power of concentration, lack of confidence and failing memory, all of which cause a decreased working capacity. The realisation of this state, and the futile attempts to overcome it by increased spurts of energy, tend to exaggerate the trouble. This condition may be stationary for a long time, influencing the career of the sufferer, or may get steadily worse and lead to a condition termed by Plehn 'tropical fury' (*Tropen Koller*), which often explains the committal of deeds of violence in an outburst of uncontrollable passion.

Amongst others, Fales (1907) has drawn attention to the occurrence of neurasthenia amongst men and women after a residence of a year or more in the Philippines, which in women is often associated with disturbance of menstruation and of the vasomotor system. In his opinion it is in most instances not directly attributable to parasitic invasions, but to climate only, and forms one of the chief drawbacks to acclimatization. Woodruff made the same observation in the same locality, and attributed the condition entirely to the effects of tropical light.

In 1913 the Society of Tropical Medicine devoted a meeting to the discussion of this subject, at which the President, Sir Havelock Charles, delivered an introductory address on 'Neurasthenia and its Bearing on the Decay of Northern Peoples in India.' He discussed the occurrence of 'Punjab head' in Bengal, which is characterised by shortness of temper, forgetfulness, sleeplessness and disinclination to work, etc., which corresponds to tropical neurasthenia. Similar 'heads' occur throughout India and other parts of the tropics, and affect Europeans after having lived in the tropics for a considerable period without furlough. In a number of cases, according to Havelock Charles, tropical disease may be held primarily responsible for the condition, but in many instances he considers climate alone as the root of the evil. Since 'the constitution of the northern races is developed in temperate latitudes,' he believes 'that its powers are injuriously affected by the climatic conditions of the hot zone, and this must be attributed to damage done mainly to the nervous system by a hot and humid climate.' Unfortunately his address, and a great deal of the discussion which followed, were marred by statements which were merely expressions

of personal opinions, collected during a shorter or longer residence in the tropics, and often coloured by prejudice; actual data in support of these opinions were sadly lacking.

Basil Price (1913), who for many years examined the causes of invaliding home of members of the Church Missionary Society, found that neurasthenic conditions were the cause of 25 per cent. of invalidity in most countries.

A perusal of the general literature on the tropics confirms the fact that a complaint similar to neurasthenia is very prevalent amongst Europeans who have emigrated to the tropics, but it is difficult to gauge how far climatic influences alone may be held responsible, or what part is played by the altered conditions and habits of tropical life. The novelty of the strange environment often leads to an increased output of energy, and it is only after a time that the newcomer realises his energy capacity under the new conditions and begins to husband his strength, but often too late to avoid paying the penalty.

It is, however, beyond doubt that the monotony and discomfort of life and climate, the lack of pleasure and excitement, the big distances from the centres of civilisation and, in women especially, the confinement to the house during the hot hours of the day, all help towards producing a mental condition resembling neurasthenia.

(*g*) *Clothing in the Tropics.* The degree of bodily comfort in the tropics, in the same way as in a cold climate, is governed by a number of factors, many of which may be modified artificially. In a cold climate bodily comfort is attained by conservation of heat, in a hot climate by the allowance of a maximum amount of cooling, and the clothing is a very important factor in this respect.

The literature contains numerous accounts of experiments and suggestions on the most suitable kind of clothing for a tropical climate. The aboriginal inhabitants possess a dark pigmented skin, and, theoretically, therefore, a dark-coloured garment, allowing of ample ventilation, would appear to be the ideal, since it would imitate nature. Practice, however, does not bear out this assumption. It has been shown that a dark skin absorbs heat rays to a greater extent than does the white skin; its temperature, therefore, rises more quickly and the sweating mechanism is brought into action earlier and the cooling due to evaporation is more effective. A dark dress material absorbs heat in the same way as a dark skin, promotes perspiration, but at the same time acts as an obstacle to the free evaporation of sweat from the skin. There is between the skin and the clothing a space filled with stagnant air, which in fact contains more moisture than the surrounding air, on account of insufficient ventilation. In consequence, the dress material becomes more and more impregnated with moisture, and the meshes of the fabric clogged with water, and the degree of saturation of the air space between skin and clothing exaggerated. *Young has recorded observations in North Queensland upon the temperature between skin and shirt—'skin-shirt temperature'—which confirm and amplify Hill's (1914) previous experiments in the same direction, which were carried out in England. Wet and dry bulb thermometers were used, the bulbs of which were encased in wire cages to prevent contact. The temperatures thus observed were invariably several degrees higher than the outer temperatures. Hill's observations, made during an English winter, showed figures as high as those recorded in North Queensland, but his subjects wore heavy clothing suitable to winter conditions in Europe, whereas Young's subjects only wore a thin shirt. This is a clear proof that the quantity of clothing and the nature of the material is of paramount importance in determining the condition of the air surrounding the skin. The former does not require any further explanation; the latter, however, the nature of the material, may be further discussed here. It should possess two properties, firstly, that of absorbing moisture and allowing of a maximum surface for speedy evaporation—the difference between woollen, cotton and silk material is well known—and, secondly, it should prevent, as far as possible, penetration of heat waves.

Attempts to obtain this objective have been made by several workers, who experimented on the suitability of material of various colours for tropical use. This question has been discussed by Sambon (1907), who based suggestions upon experiments carried out by Baly upon the penetration of rays from an electric arc through a piece of dark pigmented skin derived from an Indian. Baly photographed the spectrum after passage of the rays through

* See these *Annals*, p. 313.

the skin, and noticed that rays of shorter wave length than 3,600μ (ultra-violet) were entirely absorbed, proving thus that the skin pigment excludes the ultra-violet rays. From these observations Sambon suggested that, for tropical use, material coloured black, red or orange should be used, colours which eliminate the rays of short wave length. As all these colours absorb heat rays, he suggested at first a combination of white outer garments and coloured underwear, the former to reflect heat rays, the latter to exclude actinic rays. Later he suggested the manufacture of a special material, combining both advantages, and this has been put on the market as 'Solaro.' This fabric is composed of white and suitably coloured threads, woven in such a way as to present a warp (upper surface) of white, and a weft (under surface) of orange, red or black, and it has been proved by spectroscopical examination to be as impervious to actinic rays as the black skin.

Schmidt (1909) suggested the wearing of loose garments made of either thick light-coloured or thin dark-coloured material, and recommended the use of material similar to that suggested by Sambon.

The practical test of coloured underwear, however, has not proved it to be advantageous. Phalen (1910) conducted experiments on a large scale on soldiers in the Philippines. He supplied five hundred soldiers with orange-red underwear, and compared their well-being in the course of a year with another group wearing white underwear. He compared body weight, the number of red cells and haemoglobin, blood pressure, pulse and respiration rate, body temperature, and incidence of sickness in both groups. He found that the men wearing orange-red underwear showed changes due to heat, such as loss in body weight and haemoglobin and decreased blood pressure, more marked than the control group. Phalen concluded from his experiments that the coloured garments were more receptive to heat rays than were the white, since wearers complained persistently of greater heat, greater weight, and increased perspiration, and expressed the opinion that khaki clothing alone affords the same protection from chemical rays as the special underwear.

The question of clothing in the tropics has been dealt with from a more commonsense point of view by Gibbs (1917). 'Clothing which in the sun will cast a shade upon the body without hindering the air circulation and heat radiation will be the most desirable, and if a colour is used which will give a minimum of heat absorption the efficiency is increased. This ideal condition is fulfilled by the umbrella, and it is evident that a large white umbrella lined with a material of a colour agreeable to the eyes, for example, a shade of green, will be most efficient.' He states that, since custom prescribes that man shall cover his body, this mode of 'clothing' is in fact impracticable, and substitutes for the umbrella a large-brimmed helmet, casting a shadow over the back, shoulders and chest, and a loosely fitting white suit of material as thin as possible.

Judging by our own experience, the wearing of light-coloured suits of porous material assures the maximum amount of comfort possible, but it is obviously impossible for a labourer to wear white clothing at his work. In North Queensland he wears, as a rule, khaki-coloured trousers and a thick, dark-coloured flannel shirt, which prevents the sun's rays from penetrating to the skin, and absorbs perspiration, and thus allows a maximum degree of evaporation of the sweat.

On the whole, an extended inquiry amongst the residents in tropical Queensland has revealed such a diversity of opinions as to what type of clothing is the most comfortable that it appears presumptuous to lay down definite rules. Many prefer cotton for underwear, others pin their faith on wool, but all agree on the one point that outer as well as under garments should be as porous and as light in weight as possible.

(3) *Summary of Physiological Changes of the White Man in the Tropics*

A review of the known facts concerning the physiological changes of the white man transplanted to the tropics is, from a scientific point of view, disappointing. Throughout the literature published since the beginning of the last century may scrappy attempts have been made to obtain evidence in this respect; figures have been collected and experiments on metabolism and other physiological functions have been performed. In spite of the energy expended, the results are not conclusive; firstly, on account of the smallness of the number of observations recorded by the different individual observers, too small to eliminate individual variation and error,

secondly, on account of the uncertainty of the generally accepted standards which may be considered normal for a temperate climate. The question of body temperature is a case in point. Several observers formed their conclusions by accepting 37° C. (98·6° F.) as a normal body temperature, and considering even a small rise above this as an indication of an increase in body temperature in the tropics. If a series of observations had been taken on a few subjects at intervals during the day and night, and the average calculated, discordant results would have been the outcome, even in Europe.

The same criticism applies to experiments regarding other physiological functions, as, for example, the total metabolism as measured by the gaseous exchange. As already pointed out, a great deal of work has been attempted in Europe, and recently on a much larger scale than hitherto in the large nutrition laboratories in the United States. In spite of these concentrated and intensive efforts, as Benedict has pointed out, no definite unit for the comparison of the metabolism of normal individuals has been discovered, and there does not exist at present a definite knowledge of the factors influencing individual variations.

Such changes as have been noted have been of a qualitative, but not of a quantitative, nature. Thus, with regard to maintenance of body temperature under tropical conditions, no evidence could be found in support of the view that heat, generated by internal combustion, is reduced in order to regulate the body temperature; even under the altered conditions the body still relies on physical means for this purpose. As convection and radiation of the body are greatly decreased with the high temperature, cooling must be brought about to a much larger extent by sweating and evaporation than in a temperate climate.

Again, the increased loss of fluid from the body by the skin is accompanied by a decrease in the quantity of the urine voided. As the sweat contains sodium chloride, ~~an increased amount~~ of this salt must be lost through the skin, which in its turn again leads to a decreased amount of salt excreted in the urine.

Blood examinations performed on a large scale have not proved the occurrence of a tropical anaemia as such, since the figures for haemoglobin and for the formed elements do not show a definite decrease. There is a certain alteration in the percentage of the various types of white blood corpuscles, and in the number of cell fragments in the polymorphonuclear neutrophile leucocytes, showing that the percentage of 'young leucocytes' in the circulation, that is, leuçocytes containing a smaller number of nuclei or nuclear fragments, is larger than in a temperate climate. This is expressed in haematological language as a 'shift of the Arneth index to the left.' The significance of this change is, however, not clear, but at any rate does not seem to indicate a decreased power for resisting disease, as supposed by the Philippine observers.

The concensus of opinion gleaned from experiences in various parts of the tropics seems to indicate that living in the tropics affects the nervous system, and that neurasthenia seems to be more prevalent than in a temperate climate. It is, however, impossible to obtain definite figures and data, and most statements are only based on personal experience. In the light of this it would be interesting to ascertain whether a detailed examination of the functions of the nervous system would reveal any definite alterations, which, on account of their frequent incidence, would have to be considered an outcome of life in a tropical climate.

It appears, therefore, possible that a closer study of the functions of central and peripheral nervous system might reveal definite alterations. It would be advisable to obtain figures for the promptitude and quality of the response given by the nervous system to various stimuli. Reaction times and responses to different stimuli are quantities readily capable of exact measurements by means of generally used apparatus.

An extensive investigation into the mental activities in general would perhaps yield figures of definite value. The testing of a great number of individuals in the tropics on similar lines to those applied in choosing aviators would be very interesting. The applying of the Binet-Simon test for mentality to a great number of school children, again, would furnish figures of definite value for deciding the presence or absence of racial degeneration. In the mentality tests the methods are rough, and only a very large number of tests, sufficiently large to eliminate personal error on the part of the observer and to minimise the influence of a few feeble-minded children, would yield figures of value. In short, all the

efforts to detect physiological changes due to living in a tropical climate have not yielded definite results. It would, however, be premature to conclude that such changes do not exist, and it is possible that the advent of refined methods and more sensitive apparatus may in the future demonstrate definite alterations.

WHITE SETTLEMENT IN TROPICAL AUSTRALIA

(1) *General Conditions and Statistics*

When comparing tropical Australia with other countries situated in the torrid zone, it becomes apparent that Northern Australia occupies a somewhat unique position from more than one point of view. On the whole, the general conditions of a tropical country are modified to a much greater extent by climate *per se*, meaning seasonal incidence and degree of rainfall, than a country within the temperate zone. With the exception of a wet belt on the Queensland coast, mentioned previously, the rainfall is limited to a few months in the year, and during the remainder of the year at the most an occasional light shower disturbs the monotony of sunshine, and during about seven months of the year the weather conditions correspond to the 'dry tropics.' Vegetation, which is luxuriant during the wet season, dies down, and the green of the countryside gives place to a uniform brown. The shrivelled up undergrowth is often consumed by bush fires, which are said to be sometimes started by an accidental focussing of the sun's rays, and which sweep for miles over the country, leaving only the trees standing, bare of their bark.

Many phases of insect life, which are dependent on vegetation and moisture, die down during the dry months, only to become all-pervading again as soon as the rains start. These changes are more marked inland than on the coast, since many of the inland districts have a very small rainfall and the hot winds arising from the barren desert of Central Australia cause the inland plains of Northern Australia to approximate to a typical 'desert type' of climate, with cold nights and scorching hot days.

Another respect in which Northern Australia differs from other tropical regions is the sparcity of the aboriginal population. The natural conditions of Northern Australia seem to militate against a large aboriginal population, and the natives have never evolved beyond the nomad state and have for an unknown reason never made any attempt towards settlement. The uncertain food conditions, aggravated by droughts, have helped to keep down their numbers. After the arrival of Europeans, the inability of the aboriginals to change their nomadic habits has led to a decrease in their number and has prevented them from living alongside the white man. In consequence, in any part where a large white population exists, the black man has become extinct.

The white population is still very scanty, and is mostly concentrated in a few towns which are long distances apart.

The climatic conditions, especially the small and erratic seasonal rainfall, in conjunction with the scarcity of population, have created the unique position which Northern Australia holds to-day. The long dry season influences the insect life, and those tropical diseases which are transmitted by certain insects, such as the mosquito, are apt to show a corresponding seasonal incidence, and are to a certain extent kept in check. Other diseases, such as infectious and contagious ailments, are in a similar way kept down by the sterilizing action of the sunlight, which may kill the virus before it can spread over large and scantily populated areas.

The contention that the prevalence of certain diseases is favoured by larger and more evenly distributed rainfall is borne out by the fact that in districts situated within the wet belt a greater incidence of certain diseases is observed. Various fevers, such as endemic glandular fever, other scrub fevers of unknown aetiology, which are most probably insect-borne, occur throughout the wet belt, but are absent from other drier districts. In the same way hook-worm disease is far more prevalent in those places where the rainfall is higher, and is, as far as our present experience goes, practically absent from other districts showing similar local conditions but a smaller and strictly seasonal rainfall.

The effects of climate and surroundings upon any race finds a clear expression in the vital statistics, such as birth and death rates, infantile mortality rates, and expectation of life.

The statistical data for North Queensland and Northern Australia have not been published separately for comparison with

similar statistics for the rest of Australia; moreover, it is impossible to obtain definite data as to the number of inhabitants in Australia, since the last census took place in 1911, and the population of Northern Australia is of a migratory character; any figures obtained are therefore only of approximate value. The Commonwealth Statistician, Mr. G. H. Knibbs, C.M.G., was able to supply information which throws light upon this question, and has kindly given permission to include his statements in the present publication.

The area and population of the tropical portion of the Commonwealth are shown in the following table:

TABLE V.

Area and population of the tropical portion of Australia.

Tropical Portion of—	Area in square miles	Population (exclusive of full-blooded aboriginals) at Census of—			
		1881	1891	1901	1911
Northern Territory	426,320	3,451	4,898	4,096	3,310
Queensland	359,000	56,041	108,986	145,982	157,112
Western Australia	364,000	661	3,711	4,664	4,998
Total	1,149,320	60,153	117,595	154,742	165,420

These figures relate to all that portion of the Commonwealth which lies to the north of the Tropic of Capricorn. For the tropical portions of Queensland and Western Australia population figures are available at the date of a census only. For the Northern Territory they are compiled quarterly, and the returns for December 31, 1917, give a total of 4,908—an increase of 1,598 since the census of 1911.

At the census of 1911 the total population of Queensland (exclusive of full-blooded aboriginals) was 605,813, so that at that date the tropical population of Queensland represented rather more than 25 per cent. of the total. It also represented about 95 per cent. of the total tropical population of Australia. It might consequently be presumed that any unhealthiness of tropical Australia would have left its impress on the vital statistics of Queensland. That this is not the case is clearly shown from the following comparison of the

Queensland death rates per thousand of population with those for the Commonwealth as a whole:

TABLE VI.

Comparison of Queensland and Commonwealth Death Rates, 1906 to 1917

	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Queensland	9.50	10.31	10.26	9.70	9.71	10.65	10.96	10.39	9.97	11.00	11.09	9.64
Commonwealth	10.92	10.99	11.07	10.33	10.43	10.66	11.23	10.78	10.50	10.66	11.04	9.80

It will be seen that in ten out of the twelve years under review Queensland recorded a lighter death rate than the Commonwealth as a whole, and that in one of the other two years (viz., 1916) the difference was inappreciable. The remaining year (1915) was that in which Queensland suffered from the most severe drought ever known there, while the greater part of the remaining States experienced normal conditions, having suffered from drought in the preceding year.

Another test of salubrity often applied is that derived from a comparison of the deaths of infants under one year of age with the total births. The rate so deduced (i.e., the number of deaths of infants under one year of age per one thousand births) is what is generally known as the 'infantile mortality.' A comparison of the Queensland results with those of the Commonwealth as a whole for the past twelve years is furnished in the following table:

TABLE VII.

Comparison of Queensland and Commonwealth Infantile Mortality, 1906 to 1917

	1906	1907	1908	1909	1910	1911	1912	1913	1914	1915	1916	1917
Queensland	74.68	77.65	70.67	71.50	62.90	65.36	71.73	63.35	63.93	64.33	70.27	53.87
Commonwealth	83.26	81.06	77.78	71.56	74.81	68.49	71.74	72.21	71.47	67.52	70.33	55.91

In every one of the twelve years under review the infantile mortality of Queensland was more favourable than that of the Commonwealth as a whole. Further, in both the foregoing tables the comparison has been between Queensland on the one hand and the Commonwealth, inclusive of Queensland, on the other. A comparison between Queensland and the Commonwealth exclusive of Queensland would have given results even more favourable to Queensland than those deduced above.

In the absence of complete data in respect to the population and mortality of the tropical parts of Australia, it is impracticable to carry the test further, but the figures given above indicate that the vital statistics of the Commonwealth furnish no evidence of lack of salubrity in those parts. On the contrary, the State having 25 per cent. of its population within the tropics, and containing some 95 per cent. of the tropical population of the Commonwealth, has a record for general and infant mortality much more favourable than that for the Commonwealth as a whole. It may be noted that practically the whole of the State of Queensland lies in the north of the twenty-ninth parallel of south latitude.

Striking as the foregoing Queensland figures are in comparison with those for the whole of Australia, an even more telling result is obtained by comparing them with those of some of the leading European and other countries.

TABLE VIII.

Country	Year	Death Rate	Rate of Infantile Mortality
Queensland	1913	10.4	63
Commonwealth	1913	10.8	72
Netherlands	1913	12.3	91
Denmark	1913	12.5	94
Ontario (Canada)	1913	12.7	117
Norway	1913	13.2	65
Sweden	1913	13.6	70
England and Wales	1913	13.8	108
U.S.A. (registration area)	1913	14.1	*
Switzerland	1913	14.3	96
Belgium	1913	14.8	120
Germany	1913	15.0	151
Scotland	1913	15.5	110
Ireland	1913	17.1	97
France	1913	17.7	98

* Not available.

TABLE VIII—*continued*

Country	Year	Rate	Rate of Infantile Mortality
Italy	1913	18·7	137
Japan	1913	19.5	150
Austria	1913	20.5	180
Jamaica	1913	21.7	171
Spain	1913	22.1	*
Hungary	1913	23.3	186
Rumania	1913	25.9	202
Ceylon	1913	28.4	189
Chile	1913	30.1	255

* Not available.

In addition to the foregoing, it may be pointed out that the mortality experience of Queensland has been continuously improving, both absolutely and also in relation to the experience of the Commonwealth as a whole. This is clearly brought out in the next table, showing the expectation of life at age o in each of the last three decades:

TABLE IX.

EXPECTATION OF LIFE AT AGE 0.

Decade	Males		Females	
	Queensland	C'wealth	Queensland	C'wealth
	Years	Years	Years	Years
1881-1890	41·330	47·199	49·754	50·844
1891-1900	49·512	51·076	55·800	54·756
1901-1910	54·203	55·200	59·294	58·837

In Mr. Knibbs's opinion, local statistics relating to individual towns would not give results sufficiently reliable to warrant definite conclusions, owing to the migratory character of much of the population, and, in connection with birth, owing to the tendency to move into the towns for purposes of confinement.

(2) *Housing*

The question of the construction of suitable dwellings in the tropics has been the object of a great deal of study and controversy. A suitable tropical residence should be so constructed that the interior is protected as much as possible from the direct rays of the sun, in order to prevent excessive heating of the walls of the room, and at the same time sufficient ventilation should be provided in order to secure the quickest possible cooling of the structure. Unfortunately, in the construction of the average dwelling house in North Queensland these principles have not been sufficiently considered. The greater proportion of the dwellings of the settlers on the land are entirely unsuitable, and a great number in the larger towns are far from ideal. A statement of a leading firm of architects with twenty years' experience in the north is of interest, namely, that they have never designed one cottage as they know a cottage should be designed, on account of the prejudice against the introduction of novel ideas.

The majority of the scattered habitations of the smaller settlers in north-western Queensland are built of galvanized iron on a wooden framework, without verandahs or any insulation, and the temperature of the interior during the hot hours of the day surpasses by far the outer air temperature.

The small dwellings in the towns are raised on piles, and contain as a rule four rooms; they possess a narrow verandah in front, and sometimes also on the side. The rooms are as a rule low, and the roof is composed of galvanized iron sheets and often does not possess an inner lining. The kitchen is nearly always detached and generally consists of a small cubicle built of galvanized iron only. Most of the larger wooden houses have a verandah all round, and higher rooms with ample ventilation.

A good type of tropical house may be seen in Darwin, where many of the houses are constructed after a design similar to houses in the Far East. The verandahs are wide and are closed in by bamboo shutters, which are kept shut during the heat of the day and thus prevent the heating up of the rooms and at the same time allow of sufficient ventilation; the shutters are opened as soon as the sun gets low.

It is quite evident that a galvanized iron 'humpy,' without verandah, is the most unsuitable structure to reside in in a hot climate. During the day the heat is nearly unbearable, and the only advantage is the speedy cooling of the walls after sundown. The larger houses, built of timber, with open verandahs, are, on the whole, suitable for the climatic conditions if attention has been paid to several points.

The house should be raised off the ground and built on piles in order that the air should have free access to every part of the house. It should be so placed, if practicable, that it lies in the direction of the prevailing breeze, and windows and doors should as far as possible be opposite, in order to allow of the maximum of ventilation. The verandah should be sufficiently broad to protect the walls from the direct rays of the sun at any time, but the minimum width depends upon the latitude in the geographical sense. According to Schilling (1909), the houses in regions near to the equator require a verandah on the four sides, as the path of the sun is more vertical. In regions below the Tropic of Capricorn a verandah on the south side is not absolutely necessary, as the path of the sun is inclined from the north and the south side of the house is not struck by the direct rays at any time. The rooms should be spacious and with as many windows and doors as practical for the sake of ventilation and lighting. It is only too well known that mosquitoes and other insects choose dark corners and avoid light. A roof of galvanized iron is suitable provided that the necessary ventilation is allowed for. The roof should be slightly raised from the wall. The top gable should be provided with a ventilator and, if possible, there should be louvres on either side below the gable to provide additional ventilation. If the roof be closed in, there is a layer of hot, stagnant air between the roof and the ceilings of the rooms, which is heated by the sun to a higher temperature than the outside air, and this keeps the temperature of the rooms high after sunset.

We are indebted to Messrs. Lynch and Hunt, architects, of Townsville, whose activities extend throughout North Queensland, for the framing of the following recommendations for building small dwellings suitable for North Queensland, and costing approximately from £200 to £600:

Apart from any further items that may be found advisable, as many of the

following recommendations as the site will permit should be embodied in every cottage:—

1. Buildings should face due east and have verandahs to front and back of not less than nine feet in width.
2. In addition to other necessary openings, there should also be doors and windows so arranged in every room to allow the wind to enter on the weather side and escape on the lee side. Doors should also be arranged so as to avoid the necessity of retracing one's steps to get to any section of the house.
3. Buildings should not be more than one room in depth.
4. The size of a room built under the most favourable circumstances should be regulated by the number of prospective occupants. Eight hundred cubic feet per head would be a fair minimum.
5. Side verandahs and excess widths to other verandahs should not be constructed at the expense of the size of the rooms. Large rooms and limited verandah space are infinitely better than small rooms and wide verandahs.
6. Blocks should be approximately 2 feet 6 inches above the ground. They should be either brick or concrete.
7. All buildings should be constructed to resist cyclones.
8. Fully exposed walls should be double-sheeted and ventilated.
9. Roofs should be fitted with ventilators.
10. Ceilings should stand two feet below the top of top plates. In this connexion studding should not be less than twelve feet in length for the smallest cottage and proportionately longer for larger cottages.
11. Fan-lights should be hung immediately under ceilings.
12. Ledges and corners should be avoided as far as possible.
13. Roofs should be hipped and continuous, having eaves approximately two feet in width, to walls and verandahs.

Mr. C. D. Lynch has kindly put at our disposal a novel suggestion for building suitable houses, which would entail an expenditure of at least a thousand pounds, and which scheme is the outcome of twenty years' practical experience of house designing in North Queensland. The building, the idea of which is shown in the accompanying sketch (fig. VI), is constructed of reinforced concrete or brick, and possesses double outer walls, with an intervening and suitably ventilated air space of about three inches, thus ensuring coolness and dispensing with the necessity of verandahs. The floor space is sub-divided by wide corridors (3·5 to 4·5 metres, or about 12 to 15 feet) arranged in the form of a cross, on to which the rooms, placed at the corners of the house, open. The corridor may serve as a general living room, since it enjoys the maximum amount of ventilation, whatever the direction of the wind may be. A flat roof, surrounded by a balustrade, would, according to Mr. Lynch, add further to the roominess and comfort of the building.

Suggestions are found in the literature for cooling houses by artificial means. Attempts have been made to circulate artificially cooled air through buildings, but in practice this method has not proved satisfactory on account of the high initial expense of the necessary machinery and the technical skill required for its maintenance. Less costly, but at the same time less effective means, are fans run by electrical or water power; but as the majority of the northern towns of Queensland are without electrical power, and as the water rate is excessive and the supply often uncertain, fans in private houses have not come into general use.

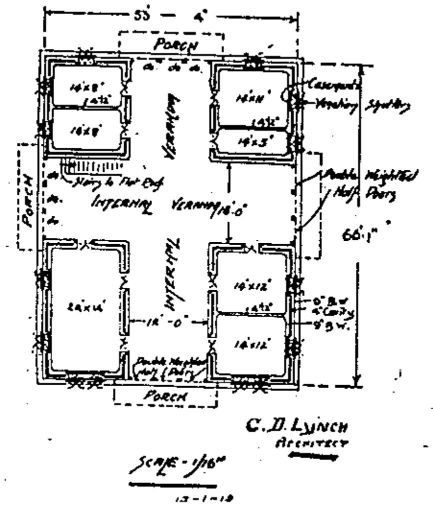


FIG. 6.
(Reduced one half from original drawing.)

The systematic laying out of towns in tropical Australia has unfortunately been sorely neglected, and most settlements have been allowed to grow up in a haphazard way. In the main streets of the larger towns ground has become too valuable to permit of an adequate space between buildings to allow free circulation of air. The main streets have often been laid out regardless of the prevailing winds. Flinders Street, the main street in Townsville, runs in the direction from north to south, the prevailing breezes blowing from south-east, and, as a result, the street has the well-

deserved reputation of being the hottest corner in North Queensland. If, in the original laying out of the town, this point had been considered and a number of cross streets in the direction of the prevailing winds allowed for, a great deal of discomfort might have been spared.

GENERAL RÉSUMÉ

A consideration of the position in Northern Australia at present shows evidence that the progress in North Queensland, and to a still greater extent in the Northern Territory, has not been commensurate with the advance of time and with the undeveloped resources of the country. Certain townships, without doubt, have gone ahead, have increased in population and prosperity, but at the same time other towns have ceased to prosper, have decreased in population, and their inhabitants have migrated to the prospering townships. It is, however, difficult to get definite figures which would illustrate this point, as the census is only taken every ten years, but the relatively small increase of the population of the north when compared with the south of Queensland during the decade between two census (1901-1911) is significant. The total increase in population for Queensland during this time amounted to 108,657 souls; of these, only 7,577 represent the increase in the north. Considering that in 1911 25 per cent. of the total population of Queensland was living in the northern division, the increase in district was relatively much smaller than in the centre or in the south. Even if figures for the last seven years could be obtained, their value for gauging the progress of the country would be doubtful, on account of conditions brought about by the war which led to a nearly complete cessation of immigration.

The population of the Northern Territory has slightly increased lately. Even so, at the end of 1917 the total population is 4,908, and represents approximately one inhabitant to about 80 square miles.

It is therefore obvious that Northern Australia is not as favoured for settlement as the southern parts of the Commonwealth, and in this connection it was pointed out by Sir Thomas Anderson Stuart on the occasion of a meeting of the Royal Colonial Institute, in 1912, that the southern and more salubrious parts of Australia were not by any means over-populated yet, and that immigrants naturally preferred to settle there than to go further afield; thus, in the course of time they would find it an easier matter to obtain a settlement in the northern parts than in the south. It was simply a case of filling up, and the rapidity would depend on the rate of immigration. A similar conclusion was arrived at by Atlee Hunt (1915) regarding the Northern Territory. 'Should any new and rich mining field be discovered, the question of populating the Territory will settle itself; but in the absence of any such happening, it is submitted that the only course open is to wait until, in the natural course of things, the trend of population moves gradually northward.'

It is well known that economic conditions play an important part in the settlement of any country, and especially of the tropics. There is no doubt that life in the tropics is burdened with a great deal of discomfort, due to heat and other general conditions brought about by climate. For this reason the settlement of the tropics carries with it more difficulties than settlement in a temperate climate. This is borne out in practice by the experience that, throughout the world, the white population in tropical parts is largely of a migratory character. Tropical Australia does not form any exception to this rule. Even during a comparatively short residence one notices that the population is continuously changing, and that there exists a general desire amongst the inhabitants that their stay in the north shall be as short as possible, and the whole aspect of the majority of northern towns bear testimony to this. A lack of public interest is noticed everywhere, and has led to putting up with makeshifts. Houses are only rarely built for comfort, as their owners hope to occupy them only for a few years. Town improvements are often only of an ephemeral character, and short-sighted policies are the rule in most instances. This again is due to the unsettled mental condition of a migratory population which is unable to concentrate on anything but the most pressing immediate needs.

Many conditions co-operate in bringing about this state of affairs. North Queensland is the most recently settled part of Australia; it is an enormous stretch of country, with comparatively

few lines of communication with the centres, and consequently it has received a great lack of consideration from the centres of government. A feeling of isolation is a natural outcome, and exaggerates migratory tendencies and the desire to 'get back to civilisation.'

The hot summer naturally militates against permanent settlement, especially since the housing, lack of water, etc., do not mitigate the severe discomforts. If a person residing in northern Europe were obliged to live during a severe winter in a draughty wooden house, without artificial means of heating, a strong desire to move to a more congenial climate would be created. In the same way one could not expect a white population to thrive in the tropics unless all possible means be adopted to alleviate climatic conditions.

Many newcomers arrive in the north with a prejudice against northern Australian heat, which has been instilled into them by their southern friends, and adds greatly to this discomfort. Dressed in their southern clothing they walk about perspiring, but never think that a cold day in the south, spent in a light cotton suit, would be equally, if not more, uncomfortable for the opposite reason.

In addition to climatic influences, the mode of employment in general tends to attract a migratory population. North Queensland is dependent almost entirely on raw products for supporting its inhabitants, and permanent institutions, such as factories, giving employment throughout the year, are lacking.

The settler in the north has thus to face conditions which, when compared with those of a temperate climate, render life in one way more uncomfortable, although in another way less strenuous on account of the lack of competition. During the hot season work is carried out under trying conditions; the least exertion causes profuse perspiration, the degree of discomfort depending mostly on the nature of the work and on the surroundings, but is well pronounced, even in people who follow a sedentary occupation. In addition, during the very hot months of the year the continuous pouring out of perspiration during the day is not relieved by a respite during the hot night, when, although at rest with doors and windows wide open, one perspires freely and wakens up in the morning unrefreshed and more tired than one felt on going to bed.

It requires but little thought to realise that this discomfort plays a still more important part in the life of the women. Their work—domestic duties—is carried out during the hottest part of the day, indoors in the hottest part of the house, and in most instances in that part which has been most neglected in construction. It is very difficult to obtain domestic help, on account of the small number of domestic servants available, whose wages are in consequence very high, demanding an expenditure which is in most instances prohibitive for a medium income. The wife of the settler on the land is in a still worse plight, as she has not only to do her own housework, but in many instances has to cook for the employees. There is, in fact, no eight-hour working day for these women.

As man is largely affected by his surroundings, and the quality and quantity of his work influenced by outer conditions, it can be readily understood that a tropical climate with a hot atmosphere laden with moisture, where the discomfort following any bodily exertion is great, is not conducive to a maximum output of energy, especially if the lack of competition makes the condition of life easy. There is no doubt that climate *per se* tends to affect greatly the quality and quantity of physical and mental work. A cold climate conduces to physical activity, a warm climate to lassitude, and the economic conditions are then the determining factor for the output of energy.

In North Queensland, with its remarkable natural resources, its remarkable recuperating power after a series of bad seasons, and its small population, the conditions of life are such that poverty is unknown and an easy living earned at a minimum cost of exertion, and the rate of wages is very high.

Another factor which plays a very important part in the determination of the quality of work is the abuse of alcohol, which is rampant amongst all classes of the community. A number of factors contribute to this abuse, such as the thirst caused by the heat, the temptation to quench this thirst owing to the great number of licensed public houses, the temporary stimulating effect of the slow poison, and last, but not least, the well-known open-hearted hospitality of the north, which finds its expression in 'shouting.'

The foregoing observations prove that in North Queensland both climate and economic conditions, namely, the lack of competition

and high wages, have created a tendency in the same direction, towards a deterioration of labour, and it is impossible at present to apportion correctly the influence of either factor. It is quite probable that, in the future, when the population of Northern Australia has increased and competition has become keener, the quality of labour may improve, unless in the meanwhile a definite decay of the race, due to climate, has set in. Up to the present, however, no such decay is apparent, but it must be kept in mind that in a newly-settled country, with a floating population, which to a great extent is maintained by immigration, racial degeneration would not make itself felt until after a somewhat prolonged period.

The 'Great Experiment of White Australia' in most previous discussions has been considered entirely from one point of view, namely, the health point. It has been assumed that the possibility of a population of European descent to live, propagate and thrive in a tropical climate, alone would decide the question. In Northern Australia, however, the economic conditions are of equal importance and present a problem as far-reaching in its influence as health for the permanent settlement of tropical Australia.

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THE EXPERIMENTAL INFECTION IN ENGLAND OF *ANOPHELES PLUMBEUS*, STEPHENS, AND *ANOPHELES BIFURCATUS*, L., WITH *PLASMODIUM VIVAX*

BY

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AND

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HISTORICAL

The potentiality of *A. plumbeus* as a malaria carrier has been variously assessed. Theobald (1901),* in his Monograph of Culicidae, remarks that both *A. plumbeus* (= *A. nigripes*) and *A. bifurcatus* are malarial carriers, but are not nearly so abundant as *A. maculipennis* in England. Nuttall and Shipley (1901) give '*A. nigripes?*' as a carrier of malaria. Bacot (1918) says that there is no evidence that this species is able to carry malaria. Grove (1919), in a report to the Local Government Board, states '*A. plumbeus* from the rarity of its occurrence is certainly of very little danger. It has not yet been proved whether it is capable of transmitting the malarial parasites.'

These apparently irreconcilable statements confronted us in the commencement of our investigation, and it became necessary to ascertain which view should be considered the correct one. On making a search through the literature we found no mention of experimental work associated with *A. plumbeus* (vel *nigripes*) beyond that in the early Italian records, more especially the works of Bastianelli, Bignami and Grassi. These workers (1898) dissected amongst other mosquitoes one specimen which they identified as *A. nigripes*; the mosquitoes were caught in the room of four patients

* For literature consulted, see pp. 441-444.

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