EFFECTS OF CLIMATIC EXTREMES

BY

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The time is opportune for a re-discussion of the important problem of climate and human survival. During the recent war it was made plain to us that campaigning might take place in all parts of the globe and in climates which were as varied as they were extreme. It was not merely a question of carrying on a desultory or sedentary existence in inauspicious environments, but of maintaining the highest possible vigilance and efficiency while engaged in heavy manual work. We are reminded of the statement of Burot and Legrand, that "in the tropics the soldier is always in campaign; if not against the enemy, at least against the climate." And again of the Roman axiom, "In the land of the enemy, beware of the country, the water, and the time of the day."

With the return of peace the future of the Empire—whether it is to be developed or neglected—will arise. Search for new sources of raw materials, transpolar air-routes, and development of naval bases in the tropics will necessitate efforts to make remote regions more habitable and more endurable. The question must soon be faced whether the torrid and the frigid zones can ever be made suitable for the maintenance, not only of a sedentary official caste of white settlers, but of commerce, trading, and industry at the hands of non-indigenous personnel. As Ripley put it, "To tolerate a climate is one thing: to become independent of it is quite another." For the past half century, at least, certain geographers, anthropologists, and biologists have discussed the matter of the future of the white race in regions where the climate is unfavourable, more especially in the tropics. Polar territories have not received so much attention. Many of these papers have been thoughtful and provocative contributions, but unfortunately the views expressed have largely cancelled each other out, so that the reader ultimately finds himself alive to the difficulties of a complex problem, but bereft in his own mind of any clear convictions or opinions.

As far as the tropics are concerned, there are

broadly two opposing views: (1) that the coloured races alone are capable of consistent survival; and (2) that in certain circumstances it is by no means impossible for a white civilization to flourish in such regions. The arguments adduced by those who are dubious of the future of the whites in the tropics may be summarized as follows.

1. Since Hippocrates, it is believed that there is an intimate connexion between climate, geographical configuration, and the personality of the indigenes. Hence colonization is handicapped. Uniform climates are non-stimulating, especially hot humid climates.

2. In the tropics, coloured peoples have certain physical advantages over white newcomers, for example: their protective pigment; more efficient sweat apparatus and a different distribution of apocrine to eccrine sweat glands; centuries of acclimatization, with survival of the more robust specimens; and individual habits of work and conduct which are more appropriate to the environment. White folk are disadvantageously placed in these respects, while Mediterranean peoples are in an intermediate position, whether because of their colouring or because of their intermingling with native blood.

3. Ubiquitous tropical disease constitutes a hazard which reduces the expectation of life and considerably influences vital statistics.

4. A psychological, later a physiological, deterioration of white newcomers is the rule after about two or three years.

5. Acclimatization is virtually an impossibility in colonizers, despite pious hopes to the contrary.

6. Even in the rare cases where the white settler does not suffer any mental or physical impairment, his children will not be endowed with the robustness of those born in temperate countries.

7. The fertility of white races actually decreases in the tropics.

8. Hence, after a period of colonization the colonizers are represented either by a small aristocratic caste of newcomers, or else by an inept "poor white" community of old-timers.

9. History has always demonstrated a steady march of civilization to the north and to the west—the "coldward course of progress."

Without necessarily trying to counter directly the arguments of their opponents, those who are optimistic about the future of the white races in the tropics put forward reasons of their own. Chief among them may be mentioned the following.

1. It is too sweeping a statement to assert that the tropics are unpropitious for white races. Desert regions certainly can be made habitable, and the overwhelming success of the colonization of the northern territories of Australia can be quoted. It is perhaps safer to assert that jungle areas rather than desert may not support a healthy white stock.

2. Most of the handicaps of tropical life arise from the numerous diseases which flourish in such environments. Such are theoretically preventible, and indeed even within the last two years the newer insecticides and insect-repellents have put an entirely new complexion on the problem. If tropical disease were stamped out, then tropical areas would be fit for habitation.

3. Civilized man is able to erect barriers between himself and his environment. Or, to quote Eijkman, "If he cannot be made fit for the climate, then make the climate fit for him." The assistance which might be afforded by air-conditioning, and by scientific housing and plumbing, has not yet been explored fully.

4. But little attempt so far has been made to select scientifically those best fitted for tropical residence, and to reject the unsuitable. Hitherto, merely a very strict medical examination has been relied on. Such may perhaps not be the ideal screening procedure.

5. When white and negro labourers are put to the same job, the former excel in productive capacity.

6. Intermarriage of white with indigenous stock may conceivably be the correct biological answer to the problem. It may be argued that the alleged drawbacks of Eurasian or mulatto or mestizo populations are examples of pure prejudice and divorced from scientific support.

It will be noted that most of the arguments, for and against, concern the hotter regions; cold climates have come in for far less discussion in this connexion.

It is also clear to any outside critic that most of the arguments on both sides of the controversy are matters of opinion. Facts are sadly lacking in this problem, and emotion and prejudice appear to intrude too much into the province of what should be a purely objective and scientific debate. Obviously we do not know enough about the subject. Equally clear is the fact that the study is a worthy one, which might repay with high dividends the labour and cost of research.

Linked to the primary question, "Can whites survive in the tropics and polar regions?" there are two very important supplementary questions: (1) to what extent is human efficiency, physical and mental, affected by working or living in atmospheres of undue heat or cold? and (2) how can the

efficiency of such individuals be enhanced, in these adverse circumstances?

Measurements of Environmental Conditions

An essential preliminary to any scientific study of the effect of climatic extremes is the exact measurement of environmental conditions. Simple thermometric readings are not enough, for we also require to know (1) the extent to which the surrounding air is in movement; (2) the amount of water vapour which is present in the atmosphere; and (3) the extent to which radiation of warmth or cold occurs from the environment. There may of course be other physical, chemical, or electrical variants which are significant, but at present we have but little inkling of these.

According to Bedford (1937 a, b; 1946), the main single or combined environmental measurements are the following:

Air Temperature.—The ordinary dry-bulb mercury thermometer is widely used. Its value can be enhanced (a) if the bulb is covered by bright metal foil (to reflect radiation), or (b) if the thermometer is whirled through the air (as in the sling psychrometer).*

Humidity.—This is usually measured by noticing the difference between the dry-bulb and the wet-bulb thermometer reading. For more accurate work a whirling instrument, or an Assmann hygrometer, should be used. There is also a direct reading instrument, operated by the expansion or contraction of a hair. Humidity is expressed either as absolute humidity or relative humidity.

Air Velocity.—Anemometers of the rotating vane or propeller type are used to record the speed of unidirectional air currents. For low air-velocities, and for measuring the combined air-movement of eddies, the kata thermometer is valuable.

Radiant Heat.—Measurements of radiant heat from a localized source are best carried out by an electrical thermopile recorded with a galvanometer.

Kata-thermometry.—Originally introduced by Hill as a measure of body cooling, this instrument has since proved to possess other useful qualities which are less open to criticism. Thus, as Hill and others (1916) showed, it is a valuable method for estimating the velocity of air movement even when the velocities concerned are extremely low. The kata thermometer can be used "dry" or "wet." The former was regarded originally as a means of estimating the sum of the effect of the air temperature and the velocity of its motion in cooling an instrument whose temperature is about that

* According to Bedford, calculation of the total heat of the air, expressed in British thermal units per pound of dry air, is of great practical importance, especially in ventilation engineering. It expresses the heat that would be given up by the air if it were cooled to 32° F. and all the moisture condensed out. The number of grains of water vapour per pound of dry air (g) is determined from the ordinary psychrometric chart. Then, from a table, the formula $H - h_a + gh_w$ will supply the desired figure: H being the total heat of that weight of moist air which contains one pound of dry air; h_a being the heat contained in one grain of water vapour.

of the human body. It is the instrument of choice in environments where the skin remains dry. The wet kata thermometer allows for the effect of evaporation, to temperature difference and wind. It was believed to give a better index of the true state of affairs in the tropics, where the subject is lightly clad and sweating freely. For the measurement of air velocities, the dry kata is the one ordinarily employed. Special high-temperature kata thermometers are devised for the study of air velocities in specially hot atmospheres, such as boiler- and engine-rooms, and deep mines.

The valuable papers of Hill and others (1916), Hill (1920), Angus (1924), Vernon and others (1926), and especially Bedford (1937 a, b; 1946) should be consulted for details and criticisms of kata-thermometry. One of the earliest and best field studies of the use of the kata thermometer, namely at sea in the tropics, was made by Dudley (1928).

Globe Thermometer.—Vernon devised this instrument as a means of studying the effect of temperature upon human comfort where there exists a source of radiant heat. It consists merely of a dry mercury bulb thermometer inserted within a 6-inch hollow sphere coated with black matt paint. Equilibrium with the environment is reached in about twenty minutes, and the result is an integrated measure of the radiation impinging upon the surface of the sphere (cooling due to air movement must be allowed for). This device has been used a good deal of late in H.M. ships, where unilateral or multilateral sources of radiant heat are commonly encountered and so interfere with the accuracy of ordinary psychrometric readings (see Bedford, 1946).

Effective Temperature.—This indicates the temperature of still air saturated with water vapour, in which an equivalent sensation of warmth was experienced in a series of tests made by Houghten and Yaglou (1923). It is a combined measurement which embraces temperature, humidity, and air movement. This measure is one which has of late been used widely in ventilation practice, more particularly in America. Undoubtedly it possesses many advantages, but it nevertheless is not free from certain serious drawbacks. It fails to account for human acclimatization: it is probably inaccurate at the higher velocities of air movement and at the upper ranges of temperature; it is not applicable when radiant heat is a factor; it does not cater for subjects engaged in manual work.

Corrected Effective Temperature.—To overcome the error introduced by radiation, Bedford has suggested the use of Vernon's globe thermometer in the nomograms, to replace the ordinary dry-bulb temperature. The calculations are then made as usual, and the final figure is spoken of as CET or the "corrected effective temperature" (see Bedford, 1946). When these nomograms are not available, the mean temperature can be calculated from the following formula, where t_s , t_g , and t_a are the temperatures of the surroundings, the globe thermometer reading, and the air temperature in degrees Fahrenheit, and where v is the air velocity in feet per minute:

$$(t_s + 4bo)^4 \times 10^{-9} = (t_g + 4bo)^4 \times 10^{-9} + 0.1028 \sqrt{v(t_g - t_a)}$$

Resultant Temperature.—This is another combined measurement which aims at allowing for radiation. Devised by Missenard (1933), with the aid of a function termed the "fictitious air-velocity," allowance is made for radiation, exercise, and clothing. It would appear that this omnibus measure—very promising in its practical application—is not yet out of the experimental stage.

Equivalent Warmth.—This is another combined measure devised by Bedford and based upon the subjective sensations of a large series of factory workers. Based upon about 2,600 so-called "comfort votes," it was found that the equivalent warmth scale was the best index. It depends upon the rate of heat-loss from an instrument named the "eupathoscope," a heated cylinder 22 in. $\times$ 7½ in.

Thermal Comfort

Freedom from excessive temperature levels, from abrupt changes from one level to another, from unduly high humidity, and from inordinate wind velocities, predispose to a state of personal thermal comfort. The subject concerned must himself be adequately clad, yet not too heavily so. He must not be generating heat to excess, as, for example, from pyrexia or from bodily exercise; nor must he be losing heat to an undue degree by evaporation of sweat, by convection, or by radiation. This "comfort" state is largely a negative one, comprising a freedom from the impingement upon the sensorium of thermal stimuli. Many attempts have been made to draw up the personal and environmental conditions necessary to produce such a comfort state. In their original work upon the effective temperature scale, Houghten and Yaglou (1923) plotted an area upon their nomogram, between the limits of which lay a so-called "comfort zone." This extended between the minimum and maximum of 57° and 63° F. But, of course, racial factors, habit, and acclimatization play an important role, and it does not follow that the original subjects tested, who were Americans, have the same standards of atmospheric comfort that we would recognize in this country.

Bedford's study of the requirements for satisfactory ventilation and heating laid down the following desiderata: (1) a suitable degree of warmth; (2) the air at head level should not be appreciably warmer than that near the floor; and the heads of the occupants should not be exposed to excessive radiant heat; (3) the air should be moving rather than still, and variable in its rate of movement rather than uniform and monotonous, but there should be no local draughts; (4) the walls should be warmer than the air; and (5) the fresh air supply should be sufficient to keep the room free from odours.

Turning to actual figures for the foregoing stipulations, Bedford defines a suitable comfort zone as one in which

70 per cent. at least of their subjects were quite comfortable. This zone is represented by an equivalent temperature of 58° to 66° F.; a globe thermometer reading of 62° to 68° F.; or an effective temperature of 57° to 63° F. Standards of "fresh air" supply, considered as a component of a comfort zone, are more difficult to fix. Removal of odours is a traditional touchstone. The early figure of 20 cubic feet/minute/person was raised to 50 cubic feet/minute/person by Chaumont (1875). Recent work has shown that it is necessary when discussing standards of fresh air supply, to take account of the size of the compartment under consideration and the number of occupants. As the space per person decreases, the ventilation requirement increases. A small room requires more air circulation than a large one, for the same number of persons. In ordinary circumstances and conditions 17 to 20 cubic feet/minute/person is enough, that is, a change of 1,000 to 1,200 cubic feet an hour.

In H.M. ships special conditions of occupancy occur, and the unavoidable crowding, the accumulation of body odours, and the risk of airborne infections, necessitate special standards. The 1910 conference on tubercle in the Royal Navy led to an Admiralty Committee on Ventilation which enacted (in 1914) a minimum supply of 3,000 cubic feet/person/hour. As an index of adequacy of air change it was laid down that samples of air from any living-space must always contain less than 0.12 per cent. of carbon dioxide. A second Ventilation Commission (1937) covered the standards to 1,500 cubic feet (2,000 cubic feet if possible)/person/hour, that is, a change of air every five minutes.

In the U.S. Navy, during the war, ventilation was stepped up, as much as 300 per cent. in some cases. The new requirements of the Bureau of Ships were a minimum supply of 30 cubic feet/man/minute for sleeping and working spaces, and 20 cubic feet/man/minute for messing spaces. (In U.S. ships the ratings do not eat and sleep in the same compartment.) In general, however, levels as high as 40 to 60 cubic feet/man/minute were often achieved.

It is interesting to note, on reading the history of marine and civil ventilation, that the standards varied as the emphasis passed from one atmospheric constituent to another. The earlier engineers and surgeons were preoccupied with odours arising from stagnant water in the bilges, and vitiation of the air from animal exhalations and various fumes and gases.* Later they began to speak in terms of carbon dioxide. Only to a lesser degree was humidity considered, while the environmental temperature was rarely, if ever, discussed. Perhaps

* An interesting contemporary account of the conditions in the sick bay of *H.M.S. Thunder* can be read in Smollett's description. "About fifty miserable distempered wretches, suspended in rows, so huddled one upon another, that not more than fifteen inches space was allotted for each with his bed and bedding; and deprived of the light of the day, as well as of fresh air; breathing nothing but a noisome atmosphere of the morbid steams exhaling from their own excrements and disordered bodies, devoured with vermine hatched in the filth that surrounded them, and destitute of every convenience necessary for people in that helpless condition." (Roderick Random, Chapter 25.)

the wheel has turned nearly full cycle, with the present interest in the risk of droplet infections, especially from atmospheres artificially ventilated with re-circulating air.

In computing sensorial effects of differing environmental states we have in the past been handicapped by the lack of adequate standards. Crowden and Lee (1940) have largely met this objection by their "thermal sensations scales," which attempt to mark the humidity and temperature levels in terms of the subjective sensations of observers at rest or at least engaged only in light work. The scales are shown in Table 1.

TABLE 1
THERMAL SENSATION SCALES

Heat sensation scale (Hot and cold sensations)		Humidity sensation scale (Moist and dry sensations)	
Sensation	Index	Sensation	Index
Unbearably hot ..	+7	Unbearably moist	+7
Much too hot ..	+6	Much too moist ..	+6*
Too hot ..	+5	Too moist ..	+5†
Hot ..	+4	Moist ..	+4‡
Too warm ..	+3	Too humid ..	+3
Warm ..	+2	Humid ..	+2
Comfortably warm	+1	Comfortably humid ..	+1
Neutral ..	0	Neutral ..	0
Comfortably cool	-1	Comfortably dry	-1
Cool ..	-2	Dry ..	-2
Too cool ..	-3	Too dry ..	-3
Cold ..	-4	Parched ..	-4
Too cold ..	-5	Too parched ..	-5
Much too cold ..	-6	Much too parched	-6
Unbearably cold ..	-7	Unbearably parched ..	-7

* Sweat dripping off.

† Conscious sweating.

‡ Skin moist.

The question of optimum environmental conditions for rest and work leads naturally to the consideration of the most desirable type of climate. Later the problem is discussed more fully, but it is worth while at this point to mention Brunt's (1943) conception of an ideal climate. In his opinion it is desirable for a lightly clothed man to walk at four miles an hour in the sunshine without sweating, and to sit in the sunshine, or stand or sit in the shade indoors and engaged in light work, without shivering. With humidity at 60 per cent., the temperature which complies with these conditions would be between 66 and 68° F. Markham (1942) also earlier laid it down that an ideal climate entails a mean temperature of no more than 75° F. in the hottest month of the year, and in the coldest month a mean temperature not below freezing point. The virtues of a variable over a uniform climate are considered later.

Psychological Efficiency in the Heat

This important question may be approached in several ways. It may be discussed from the point of view of short exposures, that is, a matter of hours or at the most days, as contrasted with prolonged exposure as in the tropics. In either event the problem can be approached first of all from studies in the field, and secondly from the exact methods of an experimental laboratory. Field study is possible wherever men or women congregate for employment in atmospheres of unpleasant heat. Coal mines; gold mines; boiler-houses; engine-rooms; cotton mills; factories in the tropics; these are some of the pastures for the field worker. Of great significance is the performance of troops in tropical jungle or desert terrain, especially when the more skilled tasks are considered, such as marksmanship, signals, gun-laying, or tank manœuvring. Considerable experience has been gained by noting the performance of sailors in H.M. ships in the tropics, where most of the tasks are sedentary but highly skilled psychomotor activities (for example, range-takers, transmitting station operators, wireless telegraphists, high-frequency direction finders, or asdic and radar watchkeepers).

One must beware of certain intrinsic sources of error in these field-tests, especially when reliance has to be made upon subjective evaluations rather than objective scores. First, there is often an unawareness of the fact, not to mention the extent, of the falling-off in efficiency. Officers may hotly deny that they or their staff are any the less efficient during tropical campaigning, until actually presented with the proofs of their deterioration. This is due to the blinker-effect of high morale, traditional of the sort of man who never knows when he is beaten. On the other hand, the opposite phenomenon may occur, namely an hysterical exaggeration of any defects there may be, motivated by a desire to escape the discomforts, boredom, or dangers of a tropical milieu. This is a psychological mechanism apt to arise in the presence of an indifferent or inadequate morale. A third point is the question of how far it is possible to extricate oneself from the shackles of apathy, and to improve one's performance under the stimulus of volition or of strong emotion. It has often been argued that if action were joined all tropical langour would instantaneously disappear, and alertness, vigilance, and efficiency would return to a peak level. How far that belief is well founded is uncertain, and in any case there is an obvious danger in war of relaxing one's standards of performance and exhausting one's reserves for emergency use. Lastly, it is believed that there is a tendency for heat effects to resemble those described

by Bartlett as occurring with fatigue, where there comes a tendency to be satisfied with one's own efforts but to blame others, or the machine, for any resulting defects. The subject becomes worried, irritable, and obsessed with his physical discomfort. "He is at once more optimistic about his performance and pessimistic about his state." (Bartlett, 1941.)

Bearing in mind these mental mechanisms, we may study the data. Among the earliest work was the industrial research of Wyatt (1926) on cotton operatives. In an environment of a high humidity, output reached its peak at 74° F. and fell off with higher temperatures. This was all the more striking because the higher wet-bulb readings increased the mechanical efficiency as shown by a reduced number of warp thread breakages. Similarly, Weston (1922) showed that the capacity of linen weavers dropped when the wet bulb exceeded 73° F. By increasing the air movement Wyatt was able to demonstrate a rise in human efficiency, while the fragility of the thread was not increased as this depended upon temperature and humidity. Steel and tinplate production, both carried out at very high temperatures, was shown by Vernon and others (1926) to fall off in the summer months. The same observers found that the rate of production of coal fell from a standard 100 per cent. at 73.5° F. dry bulb, 66.0° F. wet bulb, to only 59 per cent. at 86.2° F. dry bulb, 79.3° F. wet bulb. Sickness and accident rates were likewise much greater at the higher temperatures.

These foregoing studies date from the period 1922 to 1928. From then until the war a gap seems to have occurred.

In 1939 the Research Laboratory of the American Society of Heating and Ventilating Engineers made a study of the accuracy and variability of work carried out in hot spaces. They found that an effective temperature of 80° F. was consistent with maintained overall efficiency; but at an effective temperature of 87° F. there was a measurable decrease in the amount, accuracy, and variability of the work done. Unfortunately, levels between 80° F. and 87° F. were not studied. This interesting piece of research is also complicated by the fact that the researchers were at the same time studying the simultaneous factor of loud noise, though they were unable to note any deterioration in performance when the noise level was increased from 72 to 90 decibels.

Next, in order, come the American Naval Studies of 1943 (Pace and others, unpublished). Two groups of men were observed: both worked in hot environments, but whereas one set rested in the heat, the others rested in quarters cooled to just below the sweat-provoking level. A battery of thirty-two mental and physical tests was employed. In every case a better performance was noted in the men who rested in the cool. As might be expected, it was found that those in the cool slept better, and suffered far less from prickly heat, than did the others. The overall inefficiency may perhaps be ascribed to lack of sleep, fatigue, or the distraction of skin-irritation, rather than to the immediate thermal environment.

In Australia, Lee devoted much attention during the war to the difficulties of tank crews in desert warfare. He devised an ingenious gun-laying test which measured psychomotor efficiency. He was able to record the deterioration in performance, and also its improvement when air-cooled garments were worn—a device termed “personal air-conditioning.”

During the war, the Royal Naval Personnel Research Committee also was gathering information from the field as to tropical efficiency. Observers in 1943 noted that in tropic-going ships, wireless telegraphists might become slow and inaccurate in transmitting signals, with a tendency to lengthen the dashes and to accentuate the dots. Wireless receivers would perhaps betray their inefficiency by their posture, their untidy penmanship, and a tendency to miss the first few words of a signal. Engine-room ratings were observed to be sleepy and lackadaisical in very hot weather, and when off watch they would turn in rather than read, write, or play cards. In submarines, before the introduction of coolers, personnel sometimes made silly mistakes. Two medical officers taking records in a hot and stuffy shell-handling room found difficulty in making correct arithmetical calculations. The ship's doctor found it an effort to embark upon the writing-up of his quarterly journal. On the gunnery side there may be a premature flattening-out or severe decline in the learning or working-up curve. All these data were of a psychomotor order and were independent of a falling-off in the performance of hard and heavy manual tasks. Men in key positions, requiring vigilance and rapid hand-eye co-ordination, became “drowsy and mentally sluggish.” A high-ranking executive officer had previously made specific complaints on the score of slowness in the complicated human chain of operations between range-taking and gun-laying.

It is not easy to carry out a laboratory test upon the personnel in H.M. ships at sea prepared for action. Nevertheless, Ommaney-Davis (1944) devised an ingenious test for the speed of the visuomotor reaction-time and the accuracy of a manual performance. His results were suggestive but not altogether conclusive; the endeavour is a notable one in being the first recorded instance of the employment of such a test in the field. It is to be hoped that other such investigations will follow.

One may now turn from field observations upon efficiency in hot environments to work of a laboratory order. Most of the available data comes from the Department of Psychology at the University of Cambridge, at the hands of Professor F. C. Bartlett, and his team of assistants, including the late Dr. Craik, Dr. Mackworth, Dr. Cameron, and others. Many of the investigations were carried out upon naval ratings, and not all the results have yet been published.

From these laboratories the first hot-room researches concerned the effect of a hot, humid environment upon a performance which combined heavy physical effort with accurate muscular control. An instrument called a persuitmeter was constructed for this purpose, and the task entailed the alignment of two moving pointers, one

of which was heavily weighted. This work, equivalent to 210 kg./calories/hour, or 4 “met”, reproduces fairly well the naval tasks of gun-laying or the repair of heavy machinery. A series of trained and artificially acclimatized subjects was found to show impaired efficiency when an effective temperature of 85° F. was exceeded. It was noticeable that body-temperature began to rise before there was any detectable sign of deterioration in working efficiency.

The effects of heat and high humidity were next tested by Mackworth (1946) upon wireless telegraphists engaged in receiving morse signals. Mackworth found that a serious reduction in the accuracy of reception first appeared at an effective temperature of 87.5° F. An interesting correlation was noted between the telegraphist's technical competency, and his deterioration in the heat. The performance of competent wireless operators of ordinary ability was more severely affected than that of exceptionally skilled men. The “very good” operators occupied an intermediate position. Once again it was found that a rise in rectal temperature did not in itself lead to impaired efficiency in wireless telegraphy reception. The average number of errors per man per hour rose considerably and progressively throughout a three-hour watch period. As a rule, twice as many errors were made in the second hour, and three or four times as many in the third. Exceptionally skilled operators stood up to this ordeal better than those of average ability. There was no evidence that the deterioration was cumulative over a period of days.

A later report by Mackworth (1946) dealt with his “clock-test”—a visual performance test which mimics the work of a radar operator—which he had previously investigated under “normal” environmental conditions. The test involves close attention to the boring task of gazing for a long time at a visual display and noting the rare and quite irregular appearance of an unusual and inconspicuous visual stimulus. Long blank spells upon this synthetic radar apparatus led to the missing of about 25 per cent. of all visual stimuli, while during active spells only 2 to 5 per cent. of stimuli were missed. The task was now repeated in a hot, humid environment. It was found that as the temperature rose, so the human responses became sluggish; a more marked change was a decline in accuracy. This falling-off in efficiency became statistically significant when an effective temperature of 87.5° F. was reached, the same figure as was noted in the case of wireless operators. An hour-to-hour decline in efficiency occurred, more marked in regard to accuracy than to speed of reaction. There was some evidence that previous look-out experience had an advantage in maintaining accuracy of work over a two-hour watch in a hot environment.

One may finally quote the study of a motor co-ordination test in a hot, humid environment made by Weiner and Hutchinson (1945). The subjects were instructed to pick up as quickly as possible with a pair of forceps a number of steel ball-bearings and to drop them through a series of holes along the periphery of a rotating disk. (This test is an elaboration of the one carried out at sea by Ommaney-Davis.) There were three groups of experimental subjects: (1) resting nude subjects

exposed for a short time to an effective temperature of 91° F.; (2) clothed subjects who had worked in an environment with an effective temperature of 88° F.; and (3) one nude subject who had lived for thirteen days in an atmosphere varying from 82° to 96° F. effective temperature. In all cases there was a deterioration in performance, as shown by slowness and clumsiness. This particular experiment did not demonstrate which level of temperature was the critical one.

Psychological Efficiency in the Cold

Here again one must distinguish between changes of a psychological character which may slowly develop as the result of prolonged residence in arctic or subarctic regions, and the alterations, if any, which may occur in efficiency through exposure to relatively short periods of uncomfortable cold. One must also distinguish between field observations and laboratory data.

As an instance of the problem of maintaining efficiency in the cold, Critchley's (1945) description of naval life in Arctic convoys may be quoted:

"On the bridge or weather-deck, or in the control top of a ship in the Arctic, a watchkeeper may remain immobilized up to four hours, unable to keep warm by exercise. During this time he is required to keep alert at some responsible, if not vital task, the temperature being well below zero. Impeded by many layers of clothing, he faces a wind of high velocity with driving sleet or snow. Gradually, the bulky clothing proves tiring and burdensome. The high wind makes hearing difficult and handicaps intercommunication. Lacrimation and smarting of the eyes impair visual acuity. The northern twilight and the mist may combine with fatigue to produce visual illusions, so that the look-out may mistake a breaking top for a bow wave or the wake of a periscope. The pain of the intense cold produces a general sensation of distress, which, as it continues, more and more dominates consciousness. In this way attention becomes distracted; the victim becomes slow and inaccurate in perception and performance. A mood of depression may supervene, though irritability is the commonest effect. Finger movements become clumsy, either through numbness from cold or because of the cumbersome Arctic handwear. Lastly, somnolence is common, and may become overwhelming when the rating comes off watch and goes below to his warm mess-deck.

"The contrasting picture is that of a rating in the tropics, trying to maintain vigilance while crouched in some minute compartment with a dry bulb standing at 95° F. (I have known it to be 110° F.) and a wet bulb at 85° F. There may possibly be some near-by electrical apparatus which itself is generating heat to the figure of some 1 to 1.5 kilowatts, which is almost equivalent to the amount of heat that would be given off by 15 men at rest. He may be naked except for shorts; his body is streaming with sweat, and in addition he is probably covered with the irritating rash of prickly heat, perhaps secondarily infected. Hot nights—precluding regular sound sleep—diarrhoea, toe-rot, otitis externa, and other maladies and discomforts have perhaps already left their mark, and he has to cope with an exacting, boring, but highly important task."

How usual are the features common to these two pictures? How much is non-specific? and how much is due to the precise thermal component, that is, heat versus cold? To what extent do these two pictures resemble the reactions which take place as the result of a continuous and distracting pain stimulus? or as the result of an environment of intense noise? To what extent can both of them be related to a common factor of anoxaemia? These questions are crucial, but up to now they cannot be dogmatically answered.

Precise measurements of efficiency in the heat and in the cold can be sought first of all in the field, that is to say, in industry, in high-flying aircraft, in tanks, or in ships. Secondly, the study may be pursued under test conditions in a psychological laboratory, the temperature of which can be adjusted as desired.

The effects of relatively short exposures to cold have but rarely been the object of close psychometric study. We know that loss of manual dexterity will take place and interfere with the correct carrying out of psychomotor tests. Bedford (1937b) found that operatives engaged in assembling the links of bicycle chains took about 12 per cent. longer time to perform a standard task when the room temperature was reduced from 75° F. to 68° F. Hence we find clumsiness of finger manipulations, whether of machine-tools, predictor controls, gun-sights and aiming devices, or triggers. Hence, too, an enhanced accident rate in unheated factories. Such falling off in efficiency occurs, however, at a purely executive or effector level, and it does not follow that the central mechanisms are necessarily implicated. Nevertheless, there is some evidence that, in airmen at any rate, flying at great altitudes, there occur such phenomena as restlessness, distracted attention, mental distress, indifference if not distaste towards the object of the mission, and, later still, anxiety. Distorted judgment and intellectual falling-off, leading to incoherence, confusion, and torpor are also described (Armstrong, 1936; Grow, 1940). Some of these features, for example the restlessness and the wavering attention, may well be ascribable to simple non-specific stimuli of growing discomfort. The others probably lie outside that picture. More difficult to answer is the question how much these features owe to a mere oxygen lack, and hence whether they could be reproduced by a state of anoxaemia at a thermal-comfort level.

Such important matters, and many other related problems, can be answered satisfactorily only in an experimental cold room equipped with all the appurtenances of an experimental psychological laboratory. Undoubtedly there is a pressing need

for scientific data of this sort, and there seem to be few if any such facilities at any centre. In the United States there are, of course, experimental low-temperature chambers but they have been used mainly for testing the efficacy of protective cold-weather clothing.

Physiological Responses to Heat

This subject is one which has attracted considerable notice in the past seventy years. After Claude Bernard's monograph, *La Chaleur Animale*, written in 1876, there has been a series of able presentations and résumés. The work as it stood in 1926 and 1927 was brought up to date by two useful reviews, by Sundström (1924, 1927) on the effects of tropical climate, and by Bazett also in 1927. The tropical side of the problem was later re-examined by Lee (1940). During the late war there was much physiological research carried out, stimulated by the operational needs for tropical campaigning. In Australia Lee and his colleagues were responsible for much study of the physiological problems entailed first by temporary sojourn within ill-ventilated air-raid shelters, and later (and in more detail) by the arduous duties of tank crews operating in a desert terrain. In America there was study of military (and to a lesser degree naval) problems in tropical warfare. Questions of acclimatization, physiological effects, optimum tropical clothing, and psychological efficiency were considered in great detail by Robinson and his staff (1943). The researches carried out by medical staff of the American Society of Heating and Ventilating Engineers deserve particular notice. In Great Britain naval requirements were responsible for the greatest advances, and hot-room studies were pursued by McArdle, Scott (1937-8), Weiner and Hutchinson (1945), and others. Unfortunately, most of this work has not yet been released for publication. It follows, therefore, that any such review as the present one will of necessity be already out of date, being largely unable to incorporate war-time studies. Of recent work which has not come under the ban of security may be mentioned the review by Blum (1945) on the physiology of sunlight.

Other countries contributed but little to war-time problems. There is, of course, the pre-war work of the Anglo-Iranian Oil Company's medical staff, as well as the valuable pre-war studies from the medical directorate of the Johannesburg gold-mining industry. Germany contributed little if anything.

The main facts dealing with the physiological adjustments can be readily studied in most textbooks. The chief facts may be outlined here, as

expressed particularly in the monographs of Bazett (1938) and of Lee (1940). The latter speaks of three stages in the process of human adjustments to heat, namely (1) immediate passive adaptation; (2) primary active adaptation; and (3) secondary active adaptation.

Immediate Passive Adaptation.—Elevation of the temperature of the skin-surfaces themselves, as well as of the lining membrane of the pulmonary alveoli, constitute a minor part in the physiology of heat-effects.

Primary Adaptive Reactions.—These include first of all cutaneous vasodilatation. This may be due either to direct action on the blood vessels of raised skin temperature; or local or central nervous reflex activities; or some humoral effect. Lee suggests that all three mechanisms may operate. The effects of this vasodilatation will comprise a rise of temperature of the part; transudation of fluid through the vessel walls into the tissues; increase in the insensible perspiration and in the amount of sweating; visceral vaso-constriction; and blood dilution. Vasodilatation probably also occurs in the respiratory tract, but it is suggested by Lee that this is of minor significance in man compared with animals, who lose heat by panting. The dilution of the blood previously mentioned is an early phenomenon, which is succeeded by the opposite process when there is fluid loss from sweating. (Lee dislikes and gives reasons for jettisoning the term "blood concentration.")

Sweating is, of course, the chief adaptative mechanism, in man at any rate. The rate of sweat-loss is very variable. Hot dry environments evoke a greater sweating than hot humid conditions, the effective temperature being the same. Mild degrees of dehydration depress the rate of sweating only a little. There is a considerable amount of individual variability in the number and distribution of the sweat glands; in the composition of the sweat; and in the facility or otherwise of the process of sweating. The interesting and valuable monograph of Kuno (1934) should be studied.

Secondary Adaptive Reactions.—These may appear after a delay if the circumstances are more severe. Lee mentions five of these reactions: rise of body temperature, increased pulmonary ventilation, decreased appetite, alteration of endocrine balance, and decreased activity.

Fever appears when heat gain outweighs heat loss. For obvious reasons it is technically difficult to assess the precise internal temperature of the body, and rectal readings are usually taken as sufficient. For more accurate work one may employ Murlin's formula, $T_b = \frac{1}{3}T_r + \frac{2}{3}T_s$. Where T_b = mean temperature of the whole body, T_r is rectal temperature and T_s the skin temperature. The physiological benefits of a rise in body temperature are not without their associated drawbacks, especially in respect to an increase in the metabolism, which may attain dangerous proportions. When equable and cool conditions follow, the body temperature usually settles to its normal level within a half to two hours; but occasionally a state of thermal instability may develop. The roles played by hydration and dehydration do not seem to be constant, though on

the whole the latter state appears to exercise a deleterious effect in threatening thermal stability. The taking of food and physical work assist in raising body temperature.

Endocrine balance is altered by a possible reduction in thyroid activity, dubious alterations in the function of the suprarenals, a putative reduced activity of the islets of Langerhans, and an enhancement of the action of the posterior pituitary.

Increased pulmonary ventilation is especially seen in tachypnoeic animals but only to a very minor extent in man. Lee says that "in man the reaction is archaic or adventitious, may easily become detrimental and is produced only under severe conditions."

Decreased alimentary function is shown by a relative anorexia, especially in unacclimatized persons first visiting the tropics, though there may be an initial day or two of hearty appetite.

Mental and muscular activity are both reduced in hot environments, whether climatic, industrial, or experimental. The change is best seen in the stage of non-acclimatization. Lee rightly distinguishes between various types of effort according to whether they are spontaneous or not. He recognizes three grades of effect: (1) light exercise undertaken spontaneously; here there is both reduced will to work and reduced activity; (2) most severe forms of work: fatigue rapidly follows; and (3) intermediate grades of work undertaken in response to demand: in such, neither the capacity of work nor the total energy production is necessarily altered.

Lee goes on to describe what he calls "adventitious involvements," stressing that it is difficult to demarcate between the physiological adaptative reactions, and phenomena which may be detrimental to the organism.

Cardiovascular disturbances must be included not only within the adaptative reactions but also among the adventitious involvements. If the blood volume/capacity ratio falls, there will result a reduced venous return, a reduced cardiac minute volume, a reduced blood pressure, and partial anoxæmia. Circulatory inefficiency produces disorders referable to many systems. Even the so-called "neurasthenia" and dyspepsia may be, according to Lee, the expression of protracted minor circulatory insufficiency.

Changes in the acid-base balance may be considerable and have been demonstrated by many workers, though much of the work is contradictory. According to Bazett, the tendency of altered circulatory rate is to render the blood more acid; but the direct temperature effect is in the opposite direction and actually outweighs the other, so as eventually to bring about an increased alkalinity. Nothing seems to be known, according to Bazett (1938), of any changes in the acid-base balance in the tissues.

Disturbances of the water and electrolyte balance may be expressed as dehydration (with its manifold attendant effects) and chloride depletion.

Disturbances of the nervous system constitute the fourth of Lee's "adventitious involvements." The clinical effects of such will be discussed later, but mention may be made at this point of the possibility that oxygen

deficiency may be the *causa causans* of the nervous manifestations.

Physiological Responses to Cold

This subject was largely brought up to date in 1946 by Critchley in his William Withering Lectures. The subject may be divided chronologically into two periods, that is, up to 1939; and the recent war-time research.

Knowledge before 1939.—Omitting consideration of the local effects of cold, one may tabulate the situation as it existed at the outbreak of the war as follows.

1. We were aware that, within narrow limits, individuals differ in their tolerance towards cold: that healthy male adults of large build and moderate adiposity withstand cold best, though there are exceptions. Yet it is unlikely that anyone has summed up his ideas on the matter better than Moricheau Beaupré in 1826, who wrote, "Newly born, or sickly children,—lean and weakly persons,—individuals old or very impressible and irritable,—valetudinarians or exhausted debauchees,—convalescents,—those who have been tenderly reared and early accustomed to warm themselves,—those who habitually practice warm bathing, who perspire much, and do not regulate their clothing by the season,—the poor, who are ill clothed and nourished,—persons of morbidly changed sensibility, such as hypochondriac or hysterical persons, or those affected with organic lesion, as the phthisical, scrofulous, etc.; all those dread cold, and show themselves very sensible to it; children fear it less than adults, men than women; those of sanguine or bilious temperament are less chilly than those of the nervous or lymphatic. The fatty covering which clothes the extremities of the nerves, and retains the heat, shields from cold those who enjoy a succulent fulness of person."

2. That some measure of acclimatization is possible seemed obvious though its mechanisms were imperfectly understood.

3. We knew that there is a limit to the endurance of cold: that the operative factors include the environmental temperature; the velocity of the air movement; the conductivity of the surrounding medium; the duration of exposure; and the metabolic activity of the living organism concerned. It was known that, with ambient temperatures somewhat above freezing point, the heat-regulating mechanism of the body slowly drops behind; and that when the internal temperature falls to 20° or 22° C. serious if not fatal ill-effects result. At that time, however, we knew more about the temperatures and durations of exposure which prove lethal to insects, frogs, and rabbits.

4. The clinical effects of cold were a matter of common knowledge though little advance had been made over the preceding century. They may be said to comprise: a specific unpleasant feeling of coldness; shivering; reluctance to move; a tendency to adopt flexion attitudes; inattentiveness; irritability and depression;

rigidity and impaired motility; altered cutaneous sensibility; dysarthria; increasing discomfort, leading to pain, to be replaced later by an absence of bodily feeling; somnolence, torpor, coma, and death.*

5. Minor degrees of cold exposures had been studied superficially. An environment of mild cold was shown to be a circulatory stimulant, that is, until very low temperatures are attained. Basal metabolic rate is increased. Cardiac output is augmented, respiration is quickened. Blood volume decreases and leads to a certain amount of hæmoconcentration.

6. The cause of death from cold was uncertain. Though heart failure was most commonly blamed, some implicated a respiratory arrest; others anoxia; while others again visualized a direct cellular katabolism.

7. The morbid anatomy was regarded as comprising an early rigor mortis, with cutaneous patches of red discoloration. The cadaveric blood was said to be bright, the brain and viscera congested. Such changes were realized to be in no way specific for cold.

8. Certain mammals were known to be able to withstand long periods of severe cold by adjusting their metabolism. Hibernation, as this phenomenon was called, was not regarded as ordinarily possible in human beings.

Such, briefly, was the position of our ideas about the physiology of cold in 1939.

After 1939.—Early in the war a considerable amount of work started all over the world on the effects of cold upon man. The necessity of waging sea and land warfare in the Arctic, the Aleutians, and on the Russian front brought pressing practical considerations, and the fruits of these Canadian, American, and British researches have been rich. The main findings are tabulated below. The conclusions are given, rather than the arguments, and at times it will be necessary to quote the findings of anonymous workers whose researches have yet to be published.

* At this point may be quoted verbatim the description of the terminal events from exposure to cold made during the retreat of Napoleon's army from Moscow in 1812. The author, Moricheau-Beaupré, wrote as follows: "Shiverings, puckering, paleness, and coldness of the skin, livid spots, muscular flutterings and symptoms of the shock given to the vital forces; the person feels syncope approaching, his stiff muscles contract irregularly; his body bends and shrinks; his limbs are half-bent; sometimes lassitude and languor invite him to stop to repose; sometimes a feeling of weight and general numbness retard his steps; his knees bend; he squats down and falls; he then feels an invincible propensity to sleep; everything grows strange to him; his senses are confused; a thick veil darkens his view; his mind grows dull, his ideas incoherent; he stammers and raves; if he be free from suffering, he is not often so from agitation. Should you try to prevent him from stopping and sleeping, should you strongly represent to him the danger to which he exposes himself, he looks at you coldly and stupidly; if he has not lost all consciousness, he pronounces with difficulty a few words, entreating to be allowed to go to sleep; his relations with all surrounding objects quickly cease; he slumbers; the parts farthest from the centre of the circulation become cool; respiration, at first interrupted, becomes slow; the contractions of the heart become feeble, quick, hard, irregular, and sometimes painful; the pulse becomes smaller progressively; the central beat is extinguished; the brain is stupified; the pupil dilated; finally, a deep and mortal coma may be regarded as a certain sign of approaching inevitable death, unless the asphyxiated receive timely assistance."

1. Attempts were made to standardize some of the steps in thermo-regulation. The heat produced by an adult male while supine after a night of sleep and fasting averages 40 kg.-calories per square metre of body surface per hour. With the subject seated and at rest this output rises to 50 calories, and this figure has been suggested as a yard-stick or standard, to be referred to as the "met" (Gagge and others, 1941).

2. When the investing atmosphere is cooler than the body, thermal regulation automatically begins. With each fall of 1° C. in skin temperature, approximately 15 calories of stored heat are removed. Migration of blood takes place, and circulation is adjusted in such a way that the appendages are, as it were, sacrificed.

3. When cooling exceeds 1,200 calories the body tissues begin to freeze, and when the cooling rate is 2,000 calories the exposed face will freeze within one minute. When the ambient air drops to -50° F. or -60° F., mild exercise will cause frosting of the bronchi. In these ways we discern limits to human endurance. Operational and experimental data also afforded some clue as to survival rate. Nine sailors out of ten perished within thirty minutes of immersion in the Barents Sea, the temperature of which was 29° F. Of fourteen castaways on a raft near the Arctic Circle (air temperature below zero; sea temperature 32° F. (0° C.)) only six endured forty-eight hours' exposure, the first death occurring within half an hour (Critchley, 1943). Experimental work suggested that several hours' immersion in water at 68° F. (20° C.) would be very dangerous. With water at 50° to 59° F. (10 to 15° C.) the rectal temperature at the end of an hour was 92.3° F. (33.5° C.) and was still falling. Most unprotected men, it was thought, cannot survive immersion in water below 20° C. (68° F.) for "long" though no definition of this period was attempted. Vigorous swimming movements were not regarded as helpful, for heat production was probably already at a maximal level. Clothing makes very little difference to the survival rate.

4. Increased food intake is one of the means whereby body heat is maintained in the cold, and it has been computed that a man doing 4 mets of work will require 4,560 calories of useable food in a twenty-four-hour period, high carbohydrate and fat diets being better than a high protein intake. No virtue exists in a high vitamin ingestion.

5. Ever since the days of Vincent (1890) it has been traditional to associate the subjective feeling of coldness with the actual temperature of the skin. This assumption has been coupled with the belief that a skin temperature of an unclothed body between 88° F. and 92° F. (31.1° C. and 33.3° C.) is associated with a state of comfort. In the skin, end-organs for cold are believed to be more numerous than those for heat, and their threshold five times higher. But recently there has been an increasing tendency to relate the sensations of heat and cold to the rate of heat exchange rather than to the actual temperature of the tissues. Hence one can understand better the occurrence of cold feelings when the skin is warm, and warm feelings when the skin is cool; as well as some of the phenomena of acclimatization to cold.

6. A lot of work has been done on the scientific protection of the body against cold using the exact methods of clothing physiology. First came an attempt to measure the thermal insulating power of clothing. Gagge and others (1941) estimated the amount of clothing necessary to maintain in comfort a sitting-resting subject in a normally ventilated room (air movement 20 ft./min. or 10 cm./sec.) at a temperature of 70° F. (21° C.) and a humidity of less than 50 per cent. This unit of insulation they called the clo. One clo is roughly equivalent to one's indoor clothing—or a top-coat alone. The clo unit has not escaped criticism, especially by textile research workers in this country. Pierce and Rees (1944) of the Shirley Cotton Research Institute have suggested as an alternative a unit of thermal resistance which they term the "tog". By definition, a tog is the resistance which will maintain a temperature difference of 0.1° C. with a flux of 1 watt per square metre. This is the resistance of a light summer suit, and 10 togs represent about the thickest clothing that can be carried. The same authors have also proposed a standard measurement of the physical efficiency of clothing based on the ratio of the equivalent air thickness of clothing to the weight per unit area. This quantity is given as the "thermally effective specific volume" (T.E.S.V.) and its ratio to the actual specific volume, which may be called the specific thermal resistivity, is a useful measure of the efficiency of the structure of the material.

7. Much thought has been given to the scientific clothing of troops for Arctic warfare. The intermediate steps need not be narrated, but the end-result can be witnessed in such items as the Brynje system of dress; the naval Anaraks; the scientific juxtaposition of pile suitings with wind-impermeable outer layers; improved foot- and hand-wear; the scientific design of garments so as to trap insulating layers of air, to seal leakages at the neck and wrists, and to strike a correct balance between undue warming of the extremities as opposed to the trunk. Electrically-heated suits have been devised, improved, and adopted, especially for air crews. Lastly, attempts have been made to construct "exposure suits" to protect shipwrecked seamen in waterlogged dinghies or rafts, or pilots ditched in northern waters.

8. Some work has been done on long-continued exposure to cold. Wartime researches found that there occurs a fall in rectal temperature as well as in basal metabolic rate (—10 to —15 per cent.). These observations suggest that in certain circumstances, and with a restricted physical activity, something like modified hibernation can occur in man.

9. Acclimatization, or habituation, to cold is known to be possible, and some of its mechanisms are recognized. Although from a physiological angle it is in many ways the opposite process to tropical acclimatization, nevertheless practical experience shows that at times unusual hardness to extremes of both heat and cold can exist at the same time in the same person.

10. Neurological and psychological reactions to cold have as yet been studied only superficially. As regards the peripheral nervous system, we know that fibres

of different thickness have a differing vulnerability towards freezing. The electrical activity of the cortex, posterior hypothalamus, and medulla are also depressed in the cold. On the other hand the sympathetic and the parasympathetic systems are apparently stimulated in cold states. Psychomotor efficiency in the cold has been touched upon by work carried out in the Armoured Vehicles Medical Research Laboratory, Fort Knox. An environment of —20° F. markedly inhibited the performance of the Johnson Code Test—a paper and pencil test. But since the percentage of errors did not rise, the falling-off was ascribed to loss of digital dexterity rather than to cortical depression. Measurement of response to visual stimuli showed no deterioration in reaction-time or in precision. On the contrary, another set of investigations showed that cold baths produced a striking if temporary improvement in visual acuity, binocular vision, critical fusion frequency, tapping rate, and eye-leg muscle-reaction time. Hand strength, as measured by grip pressure, decreased about 28 per cent. after three hours' exposure to cold (—10° F. to 15° F.).

11. Changes in gastric secretion and peristalsis in cold environments have been described by Roth and Gabrielson (1940). These findings may prove to have clinical repercussions in the incidence of peptic ulceration after exposure.

During the war years German physiologists were also interesting themselves in the practical problems they encountered, not only in their winter offensive on the eastern front, but also among pilots ditched in the cold seas off the British Isles.

Often it had been found that after rescue, and while in an atmosphere of warmth and comfort, the patient might collapse and die. It was to obtain a better knowledge of this so-called *Rettungskollaps* (resuscitation collapse) or *Weidererwärmstod* (re-warming death) that Weltz and his associates (1942) tried to reproduce this phenomenon in animals by chilling them to the point of death and then dipping them into water at 45–60° C. (113°–140° F.). To their surprise their animals revived and survived. It seemed as though they had stumbled upon some obscure aspect of cold-physiology which promised to have important theoretical and practical bearings. Research projects were drawn up, and one of the first tasks set was to determine the mechanism and exact nature of death from cold. The problem was far from simple, and agreement was never reached. While a few ascribed death to molecular changes ("*Gewebschädigung*") more and more suspected an oxygen lack to be the responsible process (Werz and others, 1943). Of course, anoxia does not necessarily preclude the simultaneous intervention of a cardiac failure due to a direct though reversible action on the heart muscle. They found that the *Spättod*, or delayed death after resuscitation, could at times be prevented by artificial respiration or by the use of oxygen under pressure.

These interesting physiological studies had a bearing upon the practical handling of ditched airmen and shipwrecked sailors. They began to try rapid rewarming methods by putting the rescued in a bath of water at 45° C. (113° F.). New directives were promulgated. Castaways were advised to dress as warmly as possible and to remain quiet and immobile in the water or in their raft rather than to engage in physical exertion. It was asserted that after abandoning ship, stokers endured the cold better than seamen, even though they were less well protected by clothing: this paradox was ascribed to a process of "pre-heating" which had taken place while in the engine or boiler room. Other medical studies of survivors are exemplified in the electro-encephalographic researches of Noell. He found no anoxic patterns in the brain-waves, and he regarded the records as reminiscent of eserine poisoning. At still lower temperatures the tracings resembled the effects of strychnine. Noell drew many tentative theoretical conclusions of a physiological nature, the upshot of which tended to discredit the anoxia hypothesis of cold.

Acclimatization

It is, of course, a commonplace that toleration of a hot environment increases with habituation, but it is only of recent years that attempts have been made to study the nature of this so-called "acclimatization." It is a process witnessed not only among newcomers to the tropics, but also in those who enter industries where work is carried out at high temperatures. Acclimatization is possible not only to atmospheres of high temperature but also of high humidity; but it is open to argument how much these forms of acclimatization are specific. That is to say, habituation to a desert climate may or may not lead to increased work-capacity and comfort in a jungle climate. The phenomenon of acclimatization is complex and entails other factors besides the purely physiological ones, which alone have been the subject of exact study. Certain psychological factors enter the process, and certain attitudes of mind and certain degrees of mental and bodily activity lead to a more rapid adjustment to high temperature environments than others. Modifications in working-hours, in diet, in resting spells, and in social custom may be necessary before acclimatization can be said to be perfect. Perhaps for such reasons certain nationalities or races, for example, Spaniards and Jews, are sometimes regarded as the most suitable type of tropical inhabitant, though not necessarily the best colonizers.

We know that acclimatization is a process which takes time to perfect itself, and that it can be induced

spontaneously or artificially. In the latter case it can be effected slowly or more rapidly according to differing techniques. Furthermore, we know that acclimatization is not a permanent state, but is one that can be weakened, modified, or lost altogether. We believe that some exceptional individuals never succeed in attaining complete acclimatization. These aspects of what might be called the pathology of acclimatization are only dimly envisaged and are far from comprehended.

Up to a decade or so ago acclimatization often developed spontaneously, as it were, by a gradual mounting of the temperature experienced during the sea passage from the United Kingdom to the East. Today, however, a person may be in the cold and damp of London one day and in the arid heat of the Persian Gulf or the humid atmosphere of Bombay thirty-six or forty-eight hours later; and the subject who embarks upon this air trip may be elderly, debilitated, or feeble. This last point raises the issue of whether there are any anthropometric features which influence the rate and efficiency of acclimatization. It is a common experience that a high degree of physical fitness, or an athletic habitus, do not necessarily mean that an individual can adjust himself well to tropic heat, and that the undernourished may actually endure that heat better than the average. Such paradoxical instances are probably the exception, but they are, nevertheless, striking. It is for future study to determine with precision which qualities of body build, stature, colouring, and hirsutism are important in this connexion.

The physiology of acclimatization, as far as we imagine it, entails first a greater degree of circulatory and muscular efficiency, so that physical work is carried out with less rise in skin and rectal temperature and a more stable blood pressure. There is, secondly, a change in the secretion of sweat, though the nature of the change is not at all constant. The rate of sweating may become greater or less, and the composition of the sweat (and in particular its salt content) may alter. Perhaps it is not inaccurate to sum up by saying that the resultant of these changes is to bring about greater evaporative cooling, and a conservation of body-chlorides.

The instability of this acclimatization to heat is well shown in industry. In the Rand gold mines it was found that after a few days' absence from work the heat tolerance of a miner was very upset, so that he needed to return first to a probation gang before resuming his proper job. An intercurrent illness, and even a week-end carousal, similarly upset this acclimatization more or less profoundly.

These facts may perhaps have a bearing upon the propriety or otherwise of introducing "artificial" climates or environments in the tropics. The risk, albeit a faint one, of disturbing natural acclimatization, by working, or alternatively by sleeping, in air-conditioned environments must be studied. The optimum difference in temperature and humidity between the ambient air and the air-conditioned compartment needs to be established.

The question of artificial and rapid acclimatization of workmen or troops for tropical service, has arisen for a great many years. Early in the last war it was rumoured that the Germans were training their tank crews for the Afrika Korps in hot chambers in Europe. As a matter of fact this was not the case, but they were relying on the old custom of training these soldiers in intermediate climates. The naval surgeon, Armstrong, in 1843 noticed that sailors joining the West Indian fleet benefited by a short stay en route in Bermuda or at Gibraltar. So the Germans used Sicily and the south of Italy for working up the Afrika Korps.

Before the war native recruits to the Rand gold mines were put through a preliminary acclimatizing course. Within a hutment artificially heated to an effective temperature of 93° F., they were made to shovel stones for an hour or so. Oral temperatures were taken every fifteen minutes. Those who developed a fever of 103° F. or over, and those who collapsed, were rejected out of hand. Doubtful ones were put on a probationary period of light work for four or fourteen days before being sent to work in the hotter or deeper parts of the mine. This procedure—originally devised as a means of acclimatization—became more and more used as a selection technique.

Work carried out in the United States during the war by Robinson and others (1943) showed that a satisfactory degree of acclimatization could be produced artificially and in a short time. In a laboratory hot chamber simulating desert conditions (T. 104° F.; humidity 23 per cent.) men walked on a treadmill for one to one and a half hours a day. At first this effort produced heat exhaustion, but tolerance increased rapidly during seven days and thence more slowly up to twenty-three days. Heart rates declined from an average of 178 at the beginning to 155 on the seventh day. The average skin temperature fell from 98.4° to 96.5°, and the rectal temperatures from 103.4° to 101.7° F. The degree of acclimatization attained on the seventh day was 80 per cent. of the improvement reached on the twenty-third day.

It is probable that the rate and adequacy of acclimatization to the tropics is bound up with certain physical and constitutional characteristics. Just as certain types endure tropical conditions better, so they may respond better to artificial acclimatization. Individuals who are in good physical condition acclimatize better than those who are "soft," "flabby," or debilitated. The relation of surface area to body mass, the colour of the skin,

the previous habit of muscular exercise, and the state of the blood vessels and heart are probably significant.

Habituation to cold environments is a process which has been studied less thoroughly. The term "acclimatization" is not as a rule applied to this phenomenon. "Hardening" or "conditioning" or "seasoning" have been in use at various times, and, many years ago, the expression "indigenization." This process is slower than acclimatization to tropical conditions. Physiologically speaking, there is a habit of cutaneous vasoconstriction, directed towards a reduction of the heat-loss from the skin. Central blood vessels dilate; blood volume is reduced; and there may be a relative hæmoconcentration. The blood pressure fluctuates until reaching eventual stability, starting with an early though transitory rise. Muscular activity is enhanced, and with it appetite is stimulated and calorific intake augmented.

It is traditional, when discussing habituation to the cold, to refer to the Indians of Terra del Fuego, who wear few if any garments although the temperature of the ambient air is below freezing point. In such conditions it is debatable whether their actual skin temperatures are maintained at a relatively high comfort level by a highly efficient vasomotor mechanism, or, on the other hand, whether their threshold for cold-discomfort is altered by habit.

Toleration towards the cold, like acclimatization to the heat, is a mechanism, which may be lost or weakened as the result of various circumstances. Debility following intercurrent illness certainly reduces powers of enduring cold, especially if it is accompanied by loss in weight. It has been suggested that simple prolonged exposure to cold may lead in time to a lessened habituation, as, for example, in polar explorers. There is a possible fallacy here, in that vitamin deficiency and, in particular, a state of scurvy may be the more direct cause of weakened resistance.

The question has been touched upon elsewhere whether acclimatization to the heat and hardening to the cold are complementary or antagonistic processes: whether endurance to the climate of the tropics is reduced by prolonged residence in a cold country, or *vice versa*. In so far as the physiological adjustments in blood volume are concerned, the two forms of acclimatization may be looked upon as different. Certainly, in persons in mediocre health or with poor stamina previous residence in one sort of climate is a disadvantage if they change abruptly to the opposite type of climate. It is probably otherwise with individuals who are in "hard" condition, or in a state of high muscular

and cardiovascular efficiency. Certainly it is a fairly common experience that a homecomer from the tropics may endure the cold and wet winter of this country surprisingly well, for one season at any rate. Again, it is known by explorers and by campaigners that an individual might prove relatively immune both to the rigours of cold weather and to the heat of the tropics. Cherry-Garrard informs us that, of the members of Scott's Antarctic expedition, the man who was least affected by the cold was an officer of the Royal Indian Navy who had come directly out from the Persian Gulf and who was notoriously indifferent to extremes of both heat and cold.

Nowadays we are increasingly faced with possible ill-effects of abrupt changes from one climate to another, as in air travel. This is especially important when elderly or debilitated statesmen or officials are flown from the wintry United Kingdom to the desert climate of Asia Minor or the jungle environment of Ceylon or Singapore in the course of a couple of days. It is well known that a change from one sort of climate to another is stimulating and beneficial. Herein lies the benefit of change of air. Herein too is the drawback of an equable climate without seasonal change. But when the rise, or fall, in temperature is excessive, or occurs too abruptly, there may be untoward consequences, especially if the individual concerned is elderly, hyperpætic, or arteriosclerotic, or if he is engaged in arduous mental or physical work.

General Effects of Prolonged Exposure to Heat

In those who have come to live within the tropics, there may develop after a few weeks or months certain changes which belong to the borderland between physiology and pathology. There may arise changes in various vegetative functions which, without in any way constituting a disability or a malaise, have to be taken into account when estimating the clinical norm for tropical residents. Alterations in the rate and volume of sweating and in the composition of the sweat have already been mentioned, and these belong to the process of acclimatization. But a general steady reduction in weight perhaps lies outside that process of acclimatization, and doubts may be engendered as to whether this thinning is a natural or a morbid manifestation, and how far it should be investigated and, if possible, checked. There is the same problem in assessing the "normal" temperature of tropical residents. This point is important (and often overlooked) in much of the physiological work on heat-load and acclimatization. It is important, too, in preventive medicine in the tropics and in the

vigilant watch for the early stages of disease. Renbourn and Bonsall (1946) have brought this question up to date. Sundström (1927), Radsma (1938), and Mason (1940) noted that the mean temperature of tropical white residents was above the usual normal. Castellani (1938) denied that the tropics altered the temperature level. From the work of Renbourn and Bonsall it was found that during the summer months in North India the oral and rectal temperatures of military personnel, Indian and British, showed levels above those accepted as normal for temperate climates. Oral temperatures up to 100.6° F., and rectal temperatures up to 101° F., may occur in apparently normal subjects. The distribution curve of 894 cases was not significantly skewed. Other interesting points emerged from their research. It was found that an individual tended to have his own characteristic daily temperature curve, and that on a particular day a group of individuals would behave in the same way as regards oral and rectal temperatures. It was not always possible to find a significant correlation coefficient between resting oral and rectal temperatures. Some subjects—albeit few—had mouth temperatures which lay at a higher level than the rectal readings. Analysis of groups of men and of several individuals, British and Indian, suggested a seasonal trend in the mean oral temperature which depended upon the ambient temperatures. Exercise in the rain might cause a fall in the mouth temperatures. Oral records are probably not a satisfactory indication of the internal temperature of the body.

Other minor deviations in physiological norms and functional activities may be traced in alterations in amount and nature of food ingested; changed water metabolism; broken nocturnal sleep; disturbed habit of alimentary evacuation. We know relatively little of such matters; at all events the precise physiology is obscure. (Hair growth, menstrual history, fertility, and sexual potency have also to be studied.)

The minor psychological changes which accompany tropical residence are a commonplace and of special interest. They will be discussed later.

Sickness Rates in the Tropics

It is sometimes believed, if not assumed, that intercurrent maladies last longer in the tropics and require a longer period of convalescence. The same belief applies to the effect of wounds and injuries. This important matter can be studied only by dealing with much clinical material. One might compare the man-days lost from various types of intercurrent sickness in, say, two regiments, one stationed in the tropics and one in the United Kingdom. Better still, for a ship's company is much more of a closed community, one might compare two ships of similar class and size, one

in home waters and one in, say, the East Indies Fleet. Or one might compare the office staff in a business house in India, Iraq, or Iran with the headquarters staff in London. The various errors which may creep in to invalidate such data must not be forgotten. A ship might put in at an Eastern port, and an outbreak of gonorrhoea result and throw out the total sickness rate. In home waters the higher incidence of upper respiratory infections might complicate the comparison. Some of these fallacies might be avoided by setting out the sickness returns under various nosological headings or system-diseases. Although this enormously increases the burden of the recording medical officers, it pays dividends in producing statistics which can be interpreted. Fraser-Roberts, the Admiralty consultant in medical statistics, in the latter days of the war prepared an analysis along these lines. Divested of the various associated points of interest and of difficulty, the figures revealed that the average number of man-hours lost through sickness is about double in the tropical ship compared with one in a temperate climate. It is, moreover, of great interest to find that the man-hours lost through accidental injury were also twice as great in the tropical station—an observation which affords much food for thought.

Tropical Disease Proper

There is no need to dilate upon the occurrence of the parasitic and other diseases which are characteristic of, or peculiar to, tropical regions, or to discuss at length the part played by such disorders in industrial hygiene or absenteeism. The point need only be made that many, perhaps most, of these affections are preventable, in theory at any rate; and it is not too much to hope or foretell that the future might see such affections stamped out. The 1939–45 war brought to many tropical scenes American lavishness in screening of huts and dwellings; repeated routine examination of the stools of native employees, with elimination of all dysentery carriers; liberal use of new repellents and insecticides—if necessary applied from the air; uprooting and destruction of suspected native quarters if located too near European settlements; free use of refrigerators. Such reckless but logical even if drastic steps in preventive medicine taught us a lesson in hygiene.

Morbid Effects of Heat

From the discussion upon the physiological effects of hot environments, it is obvious that adaptive reactions tail off gradually into adventitious involvements, to use Lee's terminology, and that the mechanism of thermoregulation is a delicate one easily deranged by excessively severe external conditions, or by a series of internal unfavourable circumstances. Thus, extremes of age, malnutrition, hunger, dehydration, corpulency, fatigue, alcoholic habit, intercurrent illness, or trauma, may combine to throw out of gear the workings of the body's adjustment to undue heat. Even before such a stage, however, and while the body can be said to

show satisfactory adaptation to the heat, psychological or psychomotor inefficiency may be demonstrable: in this way a morbid effect can already be traced.

If tropical residence is added to the industrial and experimental environments of heat, then the possible morbid effects can be given under four headings: (1) specific heat effects; (2) enhancement of man-hour wastage from intercurrent illness; (3) tropical disease proper; and (4) the psychological effects of protracted existence in the tropics. The specific heat-effects form an interesting if complex chapter in medicine, and for details one can refer to the numerous excellent studies that are available. Three main disorders are recognized, namely (1) heat exhaustion (heat syncope, heat prostration); (2) heat stroke (hyperpyrexia); and (3) heat cramps. In addition, we must consider the possible specific ill-effects of sunlight.

Ladell and others (1944) have modified somewhat the traditional conception of heat exhaustion by two clinical types. Their type 1 was characterized by conspicuous degree of dehydration and was regarded by them as a salt-and-water deficiency in individuals who have sweated excessively and who are by nature prone to excrete large amounts of chloride in their sweat. Cases which they relegate to their type 2 began to occur towards the end of the Iraqi summer, and a breakdown in the sweating mechanism was envisaged. Three possible causes were proffered for this: (1) glandular fatigue following prolonged overactivity; (2) central or peripheral failure of the controlling mechanisms; and (3) pathological changes in the glands themselves. The authors could not determine with confidence which mechanisms were responsible, but they were impressed by the presence of cutaneous changes due to protracted prickly heat.

The heat exhaustion type 2 of Ladell and others resembles in some ways the "thermal dysidrosis" described in American soldiers in the Arizona desert by Wolkin and others (1944). The authors' table of comparison between type 1 and 2 of heat exhaustion is reproduced in Table 2.

Heat stroke or hyperpyrexia is in the tropics a well-known phenomenon which has been abundantly documented and studied. Modern preventive methods put in force after the first year or two of the war probably went a long way towards reducing the incidence. The difference between the case-numbers in Mesopotamia in the first and second world wars is striking. Ladell and others (*loc. cit.*) had experience of only twelve cases, but their biochemical findings supported the idea that hyperpyrexia is accompanied by a superhydration. Heat stroke occurs when thermoregulatory mechanisms fail to compete with the environmental temperature, and an abrupt cessation of sweating is the threatening

TABLE 2

COMPARISON OF CLINICAL FINDINGS IN
HEAT EXHAUSTION, TYPES 1 AND 2

	Type 1	Type 2
Number in group	45	55
<i>History</i>		
Vomiting	73%	4%
Cramps	70%	4%
Defective sweating	13%	87%
Increased frequency of micturition *	0	82%
<i>On admission</i>		
Dryness of skin	5%	40%
Desquamating prickly heat	7%	80%
Signs of dehydration	50%	2%
Pulse volume poor	33%	0
Lying pulse-pressure less than 30 mm. Hg	46%	2%
Blood-pressure not maintained on standing	72%	2%
Colour of skin	Pale	Red
Av. lying pulse-rate (beats/min.)	90	76
Av. incr. of pulse-rate on standing (beats/min.)	40	20
Av. lying blood-pressure (mm. Hg)	111/79	121/69
Av. rectal temperature (°F.)	100.6	100.9
Av. mouth temperature (°F.)	98.2	99.5
Av. frequency of micturition (per 24 hr.)	2-3	9
Av. weight gain in hospital (oz.)	121	41

* By "increased frequency of micturition" is meant passage of urine five times or more in twenty-four hours.

symptom of acute symptoms over a period of half an hour to three days. Frequency of micturition during this phase is a significant feature.

According to Brunt (1945), for nude men resting indoors the limiting environment in a hot dry climate is 113° F. for a relative humidity which is nil, or 106° F. for a 20 per cent. relative humidity, when the air movement is 17 feet per minute. In a hot wet climate, with the same rate of air movement, and a relative humidity of 100 per cent., 88° F. is regarded as the upper limit, above which heat stroke occurs; or 93° F. when the relative humidity is 80 per cent. The author has been taken to task for these figures, which some would regard as too low.

It is probable that both heat stroke and syncope from heat exhaustion were responsible for most of the deaths in the Black Hole of Calcutta incident. The mortality rate is high in cases of heat stroke (hyperpyrexia), and there is some evidence that European survivors are rendered permanently unfit for further tropical service, from an acquired sensitivity to the heat.

Heat cramps constitute the third well-known effect of raised temperature. The latest review of the subject, by Sneddon, deals with its occurrence

in units of the British Pacific Fleet during the war 1939-45.

Psychological Effects of Tropical Residence

Although these are denied by many tropical residents, it is nevertheless a common experience that persons visiting the tropics for the first time may note certain prominent traits or features in the residents: undue irritability, sometimes directed particularly against the indigenes; alcoholic habits which surprise the newcomer; mild hypochondriacal preoccupation; feelings of frustration, or resentment, which have a very paranoid flavour. The combination of mild bodily malaise with general mental and physical lassitude was recognized by Castellani and dubbed "cacophoria tropicalis."

Such changes were very commonly encountered during the war 1939-45 among personnel of the fighting Services. In the Services stationed within the tropics, such personality-trends were a topic of common discussion, often in a facetious vein. It was commonly believed, or at any rate proclaimed, that after a year there would develop a deterioration in drive, alertness, keenness, memory, capacity and speed of thought, and the power of making decisions. Accompanying these features there might be a certain slackness, procrastination, irritability, and sometimes bibulousness. Ratings and other ranks might drift into a slovenliness in dress and appearance quite foreign to their practice in European stations. This, coupled with uninhibited conduct in public with incorrect, unrestrained, and often violent conduct toward the natives, might become a matter of concern to the authorities. Such phenomena might be both subjective and objective; that is, the victim might be aware of his changed personality, just as it might be conspicuous to others.

There can scarcely be any reasonable doubt that very real changes occur in personality, mood, and conduct. Whether these are accompanied by any actual and measurable falling-off in efficiency is less clear, though it is very likely. The problem differs according to the circumstances. That is, the causation of these psychological changes may be very different in war service personnel sent to a foreign station against their inclinations, from what it is in the tropical resident who has deliberately embarked upon his career in that particular climate. In the former case, any change in personality is more likely to belong to the category of the neurosis, with hysterical features motivated by a strong, though perhaps veiled, desire to return home; a nostalgic reaction in fact. In the case of the tropical business man or civil servant, the psychopathology may be quite different.

Climate is not, of course, the sole environmental factor responsible for psychological changes. The association with indigenous subordinates, with their own often inscrutable ways; chronic ill-health; a sense of frustration and exasperation with authorities and the organization at home; flies; defective sleep; isolation; boredom; unnatural social life; these may all play a part. In the armed forces there are additional factors such as family domestic anxieties and perhaps financial ones; lack of amenities; uncomfortable quarters; unfamiliar diet; the strain of enemy action in wartime.

The literature has much to say on the question of so-called "tropical neurasthenia," but it must be admitted that the subject has not been considered adequately. Originally this form of neurosis was thought to be very common and to be due mainly to the ill-effects of climate. Later there came a tendency to decry the status of this affection; to regard it as relatively rare; and to ascribe its existence, where it did occur, not so much to climate as to sociological factors. During the war 1939-45 the pendulum swung back, and service personnel begun to regard neurotic symptoms as the expected concomitants of tropical residence, and to attribute them to the effects of heat, whether dry or humid.

The time is ripe, therefore, for a more scientific evaluation of this subject. Its relationship to climatic factors would be strengthened if it were possible to demonstrate certain phenomena: (1) if tropical civilians were liable to the same symptoms as naval and military personnel stationed in the Far East, this would implicate the factor of climate as opposed to homesickness; (2) this would also be so if psychological symptoms were found to be cured by leave periods up country, or prevented by regular spells of that sort; (3) if certain clinical differences were to be found between tropical neurotics and neurotics in the home country, it might be argued that the heat had something to do with the determination of the particular symptoms; (4) if there were found to be a parallelism between fluctuations in the weather and the clinical waxing and waning of psychiatric symptoms, the inference would be suggestive; and (5) if it were capable of proof that those born in the tropics improved in mental efficiency when they emigrated to a cool climate, the ill-effects of environmental heat would be still further suspected.

These points are worth examining.

1. Despite the occasional and perhaps over-emphasized disclaimers, it is hard to escape the conclusion that neuroses are commoner in the tropics than at home, in European and North American settlers at any rate. It is granted that civilians are probably less affected in this

way than members of the armed forces. Few would deny that in time, that is, after a year or two, a state of apathy, or inertia, or perhaps actual inefficiency develops, associated with anhedonia or mental malaise. That such manifestations are temporarily improved by a sojourn in a more temperate hill station seems indubitable; better still by a period of leave at home. The common practice of firms and government offices insisting that their employees take long and frequent periods of leave is eloquent testimony here.

We may turn, in this connexion, to the invaliding statistics from tropical stations, based upon European personnel who originally passed a rigorous physical test, and who elected to leave the home country to make their career in isolated and unsalubrious regions of the tropics. Here the Colonial Office figures are suggestive. Psychiatric disorder was responsible for 1 out of every 3 invalidings from East Africa and 1 out of every 2.7 from West Africa. Alcoholism was responsible for 1 out of every 24 and 30 respectively. (Tropical disease proper, for example, malaria, dysentery, etc., accounted for 1 out of 9 and 1 out of 10 respectively.) One of 6 and 1 in 3.8 deaths were directly due to tropical diseases in East and West Africa respectively, while 1 in 11 and 1 in 13 were suicides. Some early figures are available for the United States Army. Of 166 psychotic soldiers recorded in 1901, 120 were stationed in the Philippines. In 1902 the figures were 114 out of 186. In 1903 the suicide rate was 7 per 100,000 in the U.S.A. and 16 per 100,000 in the Philippines for Army personnel. Out of 189 cases of sickness in the Dutch East Indies in 1920, for which leave was granted, 111 were instances of psychological disorder.

2. It would be interesting to study records of the incidence of neurosis in tropical employees before and after the installation of air-conditioning plant in the homes, offices, and factories. Unfortunately, no such figures appear to be available as yet.

3. Comparison of the clinical features of the neurotics in temperate climates and in the tropics is important, and seems to show some minor differences. Anxiety and depression, in various degrees of association, are the characteristics of commonplace psychogenic disorders at home; next in frequency and importance come psychosomatic affections, with their predominant cardiac, gastric, colonic, or aphalic reference. In the tropics, however, the picture seems rather different. Intense irritability, poor memory, and mental and physical lassitude are more conspicuous. How far these clinical differences depend upon the factor of climate is, of course, another matter.

It might be helpful to compare the clinical features of the psychotic illnesses in the tropics with those occurring at home. As regards service personnel, short-lived schizophrenic episodes seemed conspicuous, independent of geography and of climate. The bizarre psychoses that have been described under the terms *latah*, *amok*, *koré*, *uas-uas*, are quite outside psychiatric experience at home, but racial factors are more likely to be significant than climatic.

4. More directly related to weather influences are the well-known mood changes associated in the tropics with dry winds and high velocity. Such meteorological phenomena may induce symptoms of their own, or may

exaggerate any pre-existing neurotic or psychotic features. The *mistral* of the South of France leads, as is well known, to the curious irritability known as *le cafard*. The *Kkamsin* of the Levant, the *harmattan* of West Africa, and the *Xirocco* of Malta are all notorious climatic phenomena closely bound up with psychiatric effects. To these may be added the *solano*, the *pamperos*, the *ghibli*, the *föhn*, and the *samum*. We may even quote Dexter's observation that Denver school-children were more unruly when strong southerly winds were blowing.

5. Though the problem is difficult to establish scientifically, there is an impression that when Indians, Chinese, negroes, and other tropical indigenes leave their homes and emigrate to cooler parts, their capacity for efficient mental work improves. The only scientific observations of this kind were made by MacKinnon upon European children born in Kenya. At first they seem to develop intellectually at a superior rate to those at home, but after the age of 10 or so a gradual mental tiredness and deterioration seemed to set in.

Morbid Effects of Cold

Considerably less is known on this subject, and it seems probable that on the whole the frigid regions of the globe are healthier as dwelling-places for man than are the tropics.

Specific Cold Effects.—These need only be mentioned. They include such conditions as chilblains and frostbite (and the related disorders of immersion foot and trench foot). There is the question of the deleterious effect of cold environments upon pre-existing cardiac, cardiovascular, and cerebrovascular affections. Perhaps (as will be discussed later) the responsible trauma is not so much the question of cold, as an abrupt transition from one temperature to another, or one kind of climate to another.

The question of how far cold climate or cold exposures can precipitate the symptoms of other types of disease is unsettled. The tendency to relate acute respiratory infections (upper or lower) to sudden exposure, is less prominent now than formerly. Even rheumatic and pararheumatic disorders are less often ascribed to low temperatures nowadays. The experience of shipwrecked personnel during the last war showed clearly that men may endure astonishing degrees of cold exposure without developing such sequelæ as pneumonia, nephritis, fibrositis, or even simple head colds. The beliefs of the last century that certain organic spinal diseases were somehow related to cold exposure—myelitis, tabes, sclerosis—is now almost entirely discredited. What has been said earlier regarding the cause of death from cold suggests that the ill-effects can be narrowed in all probability to those of cardiac or circulatory origin.

Arctic and Antarctic Diseases.—Specific arctic and

antarctic diseases cannot be identified in the way that tropical affections can, largely because of the comparative rarity of insect and bacterial life and other potential parasites. The mosquitoes so common in the subarctic summer are probably non-pathogenic.

Sickness Rates in Cold Climates.—These have probably been studied even less than in the tropics. According to Lind (1774), "An intense degree of cold, if the air is at the same time pure and dry, is productive of few diseases, when seamen are sufficiently clothed and kept in due exercise." It is almost certain that the man-days lost by sickness are less than in hot climates, and perhaps even less than in the temperate zones, so long as overcrowding is avoided. Probably the bulk of the loss in man-days is made up of upper respiratory infections, and it is a matter for discussion why severe cold *per se* should be ineffectual in precipitating such types of illness, whereas the winter incidence in temperate or temperate-frigid regions should rise. Very many other epidemiological factors besides cold are concerned. Few nowadays would agree with the opinion expressed by Kane that "An arctic night and an arctic day age a man more harshly than a year anywhere else in all this weary world."

Psychological Effect of Prolonged Residence in the Cold.—This subject arises out of the question, already touched upon, as to the possible deterioration in efficiency in cold environments. As in the case of the tropics, cold alone does not enter so much into the mood and personality changes which occur in the far north, as the total situation—boredom, isolation, long hours of darkness, monotony of diet, etc. During the war it was sometimes asserted that personnel stood up better to conditions in the extreme north than in the tropics—not only as regards their physical health, but also in respect of morale. Nevertheless, troops in the arctic were liable to show psychiatric changes. The Germans occupying the extreme north of Norway described a sort of "barrack fever," mainly psychiatric in its manifestations. In Finland they used to speak of a "spring-tiredness" which they ascribed to deprivation of sunlight and which disappeared in the summer. This condition is comparable with the Russian "light-hunger," or "sun-thirst."

Dr. F. A. Cook of polar notoriety spoke of "the awful mental depression affecting arctic explorers, the suppression of bodily functions, somnolence, melancholia, and the desperation of the sufferers." Burton's *Anatomy of Melancholy* also referred to the depression of those dwelling in "Iceland, Muscovy, or under the Pole itself."

In these high latitudes the mood-changes usually comprise depression, and are different in clinical appearance from the tropical neuroses. Even the arctic psychoses seem to comprise an undue proportion of melancholia. Otherwise there are points of resemblance between some of the alcoholic

outbursts common both in the arctic and in the tropics: the queer specific psychoses of the north (*piblokto*, *miryachet*, *wihtiko*) are not very unlike some of the mental disorders of the tropical indigenes already mentioned.

Effects of Sudden Change from one Climatic Extreme to Another

Here is a situation which may be of even greater moment than prolonged residence in one type of climate. While it is well realized that a change of air or of climate proves refreshing and beneficial, physically and mentally, the change must obviously entail not too great a difference. As already stated, acclimatization to the heat entails one type of physiological adjustment; and to the cold another, quite different. Too abrupt a transition to another climate brings about a certain strain, which falls chiefly upon the circulation and the heart. Consequently, it is in the debilitated, the aged, the hypertensive, and the arteriopath that these transitions are worst endured.

Barcroft and others (1923) have dealt with the vicissitudes which occur in the blood volume and their probable ill-effects. Bazett too has described the possible role of sudden changes in weather or climate in the aetiology of cardiovascular and archovascular accidents. The subject is by no means a novel one. Hippocrates wrote: "For when an old man has been heated in the head and brain by a large fire, and then comes into the cold and is chilled, or if he leaves the cold for warmth and a large fire, he experiences the same symptoms and has a seizure." In another place he lays down that "it is chiefly the changes of the seasons which produce diseases."

The early records of maritime medicine also contain references to this danger. We find Armstrong (1843) ascribing the premature appearance of old age so common in seafaring people to the extreme vicissitudes of climatic conditions. James Lind in 1774 wrote "it is not the degree of cold in the air which affects health so much, as the sudden changes from heat to cold, or from cold to heat."*

The subject, if not novel, is at least interesting and rather obscure. A few scientific enquiries have been made to correlate meteorological factors with disease incidence, or the periodicity of recurring affections. Ernest Jones (1905) studied figures for the occurrence of apoplexy with the existing weather conditions, but without finding much correlation. Petersén's monograph

* "Transition, especially if quick, from cold to extreme hot weather, generally causes a plethoric disposition. The signs are, a pain and giddiness of the head, a heaviness and dullness of the eyes, which sometimes appear slightly inflamed; there is usually a sense of fullness and weight in the breast, the pulse becoming quick and oppressed. Some, at this season, are seized with fevers; a few with fluxes. In such cases, blood-letting is plainly indicated."

(1935) upon *The Patient and the Weather* forms an ambitious if not altogether convincing analysis of this subject.

Palmer (1730), working in Boston, also attempted to associate the occurrence of cerebral hæmorrhage with seasonal changes in weather.

Personnel Selection and Rejection for Foreign Residence

One of the most promising methods whereby successful habitation of unpropitious regions might be effected would be by the judicious elimination at home of those unfitted to live either in extremely cold or extremely hot climates, coupled with the selection of those pre-eminently suited. Unfortunately it cannot yet be said that our methods of selection and rejection rest upon a sure basis, though we are more advanced in the matter than we were. The problem is not insoluble; nor is it even a particularly difficult one, and promising lines of investigation can already be clearly discerned.

In the first place, some attention is deserving to the subject which has been termed by Minding "nosochthonology," or the study of the influences of geo-physical environment upon the human. This question has been discussed and debated for centuries, indeed ever since the days of Hippocrates, who was probably the first to discern a relationship between geography, climate, and the personality of the inhabitants. "For when the seasons exhibit the most violent and frequent changes," he taught, "there the land is wild and uneven. But when the seasons do not alter much the land is apt to be more uniform and so too will be the inhabitants. For the denizens of these regions ultimately come to resemble the lands in which they are reared." The same theme was advanced in the sixteenth century by the philosopher-economist, Jean Bodin. But it is Montesquieu whom we particularly associate with this belief. He contrasted the habits and temperaments of peoples dwelling in the north from those of the south, drawing an analogy with the contrasting climates. Northern peoples campaigning to a southern region, he claimed, did not perform such exploits as the local populace. Climate also affected the intellect, and in hot parts of the world he finds . . . "aucune curiosité, aucune noble entreprise, aucun sentiment genereux; les inclinations y seront toutes passives; la paresse y fera le bonheur; la plupart des chatiments y seront moins difficiles a soutenir que l'action de l'âme, et la servitude moins insupportable que la force d'esprit qui est necessaire pour se conduire soi-même."†

† Montesquieu's views upon English climate and character are of interest: "Ce caractère (d'impatience), dans une nation libre, seroit très propre de deconcerter les projets de la tyrannie, qui est toujours lente et foible dans ces commencements, comme elle est prompte et vive dans sa fin; que ne montre d'abord qu'une main pour secourir, et apprime ensuite avec une infinité de bras. La servitude commence toujours par le sommeil. Mais un peuple qui n'a de repos dans aucune situation, qui se tâte sans cesse, et trouve tous les endroits douloureux ne pourroit guère s'endormir. La politique est une lime sourde qui use et qui parvient lentement à sa fin. Or les hommes dont nous venons de parler ne pourrissent soutenir les lenteurs, les détails, le sang-froid des négociations; ils y réussiroient souvent moins que toute autre nation; et ils perdroient, par leurs traités ce qu'ils auroient obtenu par leurs armes."

His great protagonist was David Hume, whose essay on *National Character* asserts, "Nor do I think that men owe anything of their temper or genius to the air, food or climate. . . . Physical causes have no discernible operation on the human mind."

It is obvious that much individual variability exists in suitability or otherwise for service or residence abroad under climatic extremes. While some subjects adjust themselves well both physically and mentally, others completely fail. Any system of "artificial acclimatization" practised at home or in a temperate climate would, therefore, have the additional merit of acting as a filter, isolating those who are incapable of adjustment. The system of acclimatization formerly carried out in the Rand gold mines has already been mentioned, and its role as a selection process noted as an important side-effect.

The status of personnel selection for tropical or subarctic residence does not yet rest upon very sure or scientific foundations. A strict medical examination, and perhaps a preliminary psychiatric interview, might probably identify those who are obviously unsuited, but there will be many potential misfits who will pass these preliminary tests.

Physical Health.—A number of minor or chronic maladies become much exaggerated in unpropitious climatic environments. One would, therefore, look askance at a candidate with mild arthritis, chronic bronchitis, arrested tubercle, or some intractable skin disorder. Though able to continue at useful work in temperate climates, such persons might well become incapacitated in extreme heat or intense cold. The initial medical examination would, therefore, be an unusually strict one, and the standards for acceptance set very high.

Psychological Aspects.—It might be expected that individuals who elect to go abroad and work in isolated and inclement regions will stand up better to the conditions than those, like service personnel, who are conscripted and sent abroad irrespective of their inclinations. Broadly speaking this is true, and the breakdown rate is probably much lower in civilians than in soldiers and sailors (conscripts, not regulars). Missionaries show a relatively minor rate of neurotic illness compared with commercial employees and civil servants, but the rate is high enough to cause comment. It must be remembered that there may be very definite psychiatric reasons for volunteering to live and work in the tropics or polar regions which would facilitate and not prevent subsequent breakdown. Certainly psychopaths, both of the inadequate and of the aggressive varieties, are apt to fare badly. The boredom of isolated assignments cannot be well endured by those of poor

intellectual calibre or educational status. Alcoholic tendencies should be regarded as an absolute contraindication to employment in the tropics or colder regions. A previous history of a nervous breakdown should also preclude a candidate. In the Services it was found desirable to recommend that none with a bad crime record should be sent to a station where the climate is unpropitious.

There is a good case, therefore, for a preliminary psychiatric interview in selecting candidates, though the psychiatrist himself needs to be carefully chosen, and should be one who himself has experience of the conditions of life abroad.

Age.—Obviously the elderly do not tolerate the extremes of heat and cold as well as the younger adults, whose cardiovascular system is more elastic and adjustable. This especially applies to those who have not lived abroad before under climatic extremes. Nevertheless one should not exaggerate this point, and experience has shown that if the elderly candidate is in robust health, is keen and ready to put up with discomfort, and has been experienced in hardening experiences of other kinds in the past, he may make the grade excellently. Scott's last letter from the South Pole said, "I want to tell you I was not too old for this job (he was 43). It was the younger men who went under first."

Body Build.—Tropical exigencies are less well tolerated by those of pyknic habitus than by the spare or by the tall lean types. When working in humid atmospheres a big man is perhaps at a disadvantage compared with a small one, for both will produce heat in proportion to their weight and dissipate it according to the ratio of body weight to surface area. Such was the case in Robinson's (1942) comparison of two subjects, but Weiner's analysis of over two hundred miners showed only a slight correlation between heat tolerance and surface area. A poor musculature is not a handicap. In the case of cold climates, a generous amount of subcutaneous fat is of benefit short of a pathological obesity with its attendant circulatory strain. Apart from the factor of fat-insulation, big persons on the whole tend to endure cold better than the small, just as the larger mammals are the ones to survive in the arctic. Exceptions occur, of course, as in Scott's party, where they found "strength of will" more significant than physical constitution.

Physical Efficiency Tests.—These might be most helpful if standardized. A step test has proved useful in the selection of recruits, and correlates well with subsequent performance in the heat. The virtues of any selection procedure which reproduces closely the actual conditions of work are obvious, and it should be developed farther.

Pigment.—There is some relationship between the pigmentation of an individual and his tolerance towards tropical life, though few would go all the way with Woodruff (1905), who said that recruits for tropical service should be limited to brunettes of short stature—the Mediterranean type, in fact. This same author tried to demonstrate a predominance of the blond in cooler climates and of dark-skinned in the heat. Regarding sailors as essentially encompassed by a low-temperature environment (which of course is not the case), Woodruff has written "The blond type of man is now and always has been the best sailor. He takes to water like a duck . . . he is the yachtsman of the world, the boat-builder, and rules the sea at the present time." For arctic service, cutaneous pigment is unlikely to influence the selection test, despite Woodruff's beliefs.

But certainly tropical service is not for those who have such congenital defects of pigment as leucoderma. Albinos fare very badly in hot climates, and those rare cases of albinism in coloured people seldom attain adult age. Vitiligo, if sufficiently extensive, is a handicap. Persons who are of excessive or "platinum" blondness, especially if showing a tigroid fundus on ophthalmoscopic examination, are doubtful candidates for the tropics. Even the red-heads are suspect, by virtue of cutaneous intolerance towards the sun's rays. It has been said that the French Foreign Legion used to debar such candidates, but considerations other than photosensitivity might have been in mind.

Possible Biochemical Factors.—Experience both in the tropics and in the far north shows that there are certain rare persons who are conspicuously intolerant of the heat, and others of the cold. Such heat-sensitive and cold-sensitive subjects are not conspicuous to ordinary medical tests; nor do they stand out by virtue of any feature of age, build, or colouring. It would be a convenience, at the very least, if it were possible to devise some test or criterion whereby these rare cases could be identified at home. No such hall-mark is yet known, though a close physiological study is projected of all naval ratings who are invalided from the tropics to the United Kingdom as being heat-sensitive. Alterations in the blood lipid-phosphorus level and in the suspension stability test have been suspected, but not demonstrated, in such cases. It is possible that some inherent dysfunction of the sweat glands or of chloride metabolism, or both, may be a feature of the heat-sensitive. A fairly wide variation in the chloride content of the sweat is known to occur, but no serious attempt has yet been made to correlate the biochemical with the clinical data. The pro-

portion of eccrine to apocrine glands may be significant in this connexion, as suggested by the known racial differences. Still more likely is a link between the total number and distribution of eccrine glands and heat tolerance. Unreadiness to sweat in hot atmospheres may be a factor in determining heat sensitivity. Thus Borchardt (1934) closed up fifteen subjects for two or three hours in a hot room at 33° C. (91.4° F.) with a relative humidity of 90 per cent. Seven of them sweated much less than the others, and these developed various distressful symptoms, their body temperatures rising considerably. Kuno (1935) regards those hypohidrotic persons as probably unsuited for tropical residence.

There are several possible causes of constitutional deficient sweating; there may be a relative insensitivity of the sweat centres in the hypothalamus, the medulla, or the spinal cord; or the sweat glands themselves may be abnormally sluggish in action or too few in number. With regard to the last point, it is important to note that those very rare persons with congenital absence of sweat glands should be absolutely precluded from the tropics.

Sensitivity towards high temperatures may increase as the result of a previous attack of heat stroke. For this reason, firms usually transfer an employee to the United Kingdom permanently on his recovery from such an illness.

The phenomenon of cold sensitivity exists in a small proportion of the population. Such display considerable distress and even syncope when exposed to low temperatures which would not incommode the average. Horton and Roth (1937) believe they can detect such cases in the laboratory. Five minutes' soaking of the hands in water at 8 to 10° C. (46.4 to 50° F.) will bring about flushing of the face, rapid pulse, and a fall in blood pressure. They believe that such can be desensitized in either of two ways: (1) by immersing the hand in water at 10° C. (50° F.) for one or two minutes twice a day for three or four weeks; or (2) by the subcutaneous injection of 0.1 mg. of histamine twice a day for two or three weeks.

An acquired sensitivity to cold may develop in those surviving severe exposure—as, for example, sailors who have been immersed for long periods in the sea or who have been adrift in waterlogged boats. A local hypersensitivity to cold is, of course, one of the characteristic sequelæ of immersion foot.

The subject of selection and rejection, in so far as it was illustrated by personal sensitivity to cold, was well expressed a hundred and twenty years ago by Moricheau-Beaupré, whom we have already quoted in full.

Protection Against Extremes of Heat

Johnson (1815) wrote that "man, by the exertion of his mental faculties, can raise up a thousand barriers round him, to obviate the deleterious effects of climate on his constitution." It must be admitted that this science of protection has not yet been prosecuted with sufficient thoroughness or enthusiasm. The pressing exigencies of the war, flinging millions of white men into tropical warfare, considerably stimulated research into those aspects of hygiene, but the war ended with many projects left unanswered. The advisability of continuing these studies scarcely requires emphasis.

Clothing.—One of the chief problems for tropical residents is that of clothing. Herein we can witness a considerable change of front over the course of the past century. We recall the times, not yet beyond living memory, when soldiers campaigned in heavy scarlet uniform, and when sailors wore high-necked uniform with flannel underclothing even in the summer months in the Persian Gulf. Concessions to a scientific protection against the sun were found in solar topees, spine pads, and woollen cummerbunds or cholera belts. It is obvious that tropical dress in those days was influenced by three medico-scientific beliefs, two of which were certainly unsound and the other possibly so. On the one hand it was considered that the major ills of the tropics were due to the direct rays of the sun (rather than simple heat effects). On the other, there were visualized ill-effects from sudden chilling of the abdominal wall (e.g. after sundown, in draughts from evaporated sweat). Thirdly, danger was visualized after the tropical sun had set, and this was freely ascribed to the chill and dank miasmata arising from marshes, lakes, rivers, and swamps.

Nowadays, tropical dress is largely governed by two medico-scientific considerations: protection of the skin against biting, disease-carrying insects; and avoidance of heat effects. During wartime the first of these assumes the greater importance, in order that man-day wastage from malaria, dengue, and so on may be avoided. Civilian residents within the tropics usually adopt their own methods of protection, and appropriate dress looms less prominently.

The science of clothing advanced more rapidly during the last war years, so that by about 1944 it was possible to enumerate a large number of considerations which had to be filled by an ideal fabric. There are at least twelve points which come up for discussion.

1. The textile should impose the least possible physiological burden, so that avoidable heat-effects may be countered. This virtually means that the textile should

be of the lightest possible weight. Hence loosely woven cottons or closely woven silk, nylon, cotton, or mixtures thereof are indicated. The degree of physiological load is readily tested by the use of human subjects working on a treadmill at a standard task, in a hot room where temperature, humidity, and air movement are established. The subject works nude, and afterwards he wears the various experimental garments to be tested. Rectal and skin temperatures, heart rate, blood pressure, and volume of sweat loss are recorded.

2. The cutaneous surfaces should be protected, to some extent at least, against the direct rays of the sun. That is to say, until a person is tanned and acclimatized there should not be an undue exposure of too great a skin-area. This consideration influences the pattern and design rather than the material for clothing.

3. Both the design and the textile should be comfortable. That is to say, the clothing should be loose, rather than tight; high collars and other such features may prove undesirable. During the war this was largely a problem of the comparative merits of shorts versus long trousers; bush shirts versus blouses; two-piece as opposed to one-piece garments. There is some merit, too, in a slight starching of a tropical garment so as to produce a sort of bellows action. It is highly important to avoid as far as possible any constricting band, e.g. a belt, which is liable to produce a severe local crop of prickly heat. The material itself should be smooth and "cool" to the touch, and when impregnated with sweat should not cling clammy to the skin. In this last respect, loosely woven materials are best.

4. The textile should be impermeable to the bites of stinging insects, such as mosquitoes. This is a quality which can be tested in a laboratory, though it must be borne in mind that mosquitoes differ with regard to the length and delicacy of their probosces. Tightly woven cotton, silk, or artificial silk fabrics are the best protection.

5. The material should, if possible, be water-repellent. There is a risk that this quality may be gained by chemical proofing in such a way as to prevent the evaporative cooling of sweat from the body. There are certain fabrics, however, which combine a fair degree of water-repellency with adequate ventilation, so that evaporation is not inhibited and no chemical treatment is required.

6. The colouring of the garment should be such as to reflect the heat-rays of the sun. For this reason whites are best. Woodruff some years ago (1905) advocated the use of black undergarments (or linings) beneath an outer white layer.

For service personnel in wartime, other considerations come into play.

7. The design of the dress (uniform) should be such that there are no avoidable gaps or openings which might permit the entry of such parasitic pests as ticks, mites (vectors of typhus), or of leeches.

8. The material should be durable and be able to stand up not only against very hard wear but also against the tropical deterioration due to moulds and fungi. At the same time the textile should not be unduly friable,

and here the closely woven stuffs are at a relative disadvantage.

9. The textile should be sufficiently thermal-resistant to protect the skin against flash burns.

10. The colour of the fabric should not be determined solely by its reflective properties, for visibility to enemy aircraft must be considered. Hence whites, ideal in many respects, are perhaps contraindicated. A compromise may have to be reached, as in the jungle green of S.E.A.C. personnel

11. Lastly, the textile should be such that it is capable of taking up various chemical substances, of an anti-gas, insect-repellent, flash-proofing, or water-resistant character.

By the end of 1944 it seemed as though the tussle between loose cellular weaves and tightly woven fabrics was being solved in favour of the latter. This was largely due to the priority placed upon anti-malarial measures, and insect-permeability dominated the counsels. But early in 1945 the situation was shifting slightly; the efficacy, and the increased availability of the newer insect repellents (dimethyl—dibutyl—phthalate), the organized employment of suppressive mepacrine, made it less essential to insist upon an impermeable textile. There were the beginnings of a swing of the pendulum back to the cooler, cheaper, and more comfortable loose-weaves. These latter have yet another advantage; they are somewhat more heat-retaining, so that if there is a sudden drop in temperature they are rather better than the tightly woven fabrics (provided there is but little air movement).

Housing

The problem of the ideal type of architecture suitable for tropical residents has, of course, many medical aspects, but the problem lies outside the scope of this review. One or two important features may be mentioned, without undue elaboration. With wartime exigencies, and sudden entry of large numbers of white personnel, the difficulties increase.

1. There is a wide variation in the style of tropical dwellings, including selection of building materials, between the differing nations. Thus, British colonial architecture differs in many particulars from the American preferences, and more so from the Portuguese, French, and Spanish styles adopted in their tropical empires. These again differ from the models selected by indigenous peoples. Herein an outsider might see the advantage to be gained by pooling and exchanging experiences. Medical opinion upon the purely hygienic characteristics should not be a matter of serious dispute.

2. The advantages of air-conditioning in houses, offices, and factories appear obvious, though medical details as to optimum standards etc. need perhaps to be studied further.

3. Fly-screening of buildings may be a matter of considerable importance, especially in barracks and camps, as the Americans demonstrated so clearly during the war 1939-45. The matter is by no means beyond debate and there is at times a considerable prejudice against such a practice by some tropical dwellers.

4. The correct siting of European-occupied dwellings and offices with relation to indigenous habitations may be a very delicate problem. There is an *a priori* case for putting white and coloured dwellings at a respectable distance from each other, because of the reservoir of infection which is apt to be constituted by the coloured folk, and especially the young ones. Such a policy of segregation or separation, albeit medically desirable, is apt seriously to offend official policies of a "non-discrimination" character.

Food and Drink

Text-books of tropical hygiene traditionally recommend a modification of the alimentary habits usual in the temperate zone. A reduced global intake, a relative reduction in high calorific food-stuffs, an avoidance of highly spiced dishes, and an economy in the use of condiments are the conventional pieces of advice. But common experience shows how often such counsels are flouted, and apparently with impunity. During the last war the tendency was for troops in the tropics to adhere as closely as possible to the sort of diet they would select at home. Sailors were particular offenders in this respect, and they insisted, as far as lay within their powers, on hot roast joints, potatoes, greens, and suet puddings even in the Persian Gulf in summer time. Their conservative tastes led them to eschew fish, salads, and local vegetables. And yet it was difficult to demonstrate any detriment which they suffered as a consequence, save possibly a heightened proclivity to prickly heat. Partly, of course, this peculiar dietary has a sociological explanation, and daily roast meat might represent to them a measure of social superiority beyond their civilian status.

But even the tropical civil resident has his own peculiar predilections, and we find some highly seasoned dishes much in favour in the tropics, e.g. the palm-oil chop of West Africa, and the curries of the Far East. Just how such a choice can be excused on dietetic, hygienic, or physiological grounds is difficult to say. Similarly, the consumption of alcohol in excess of what is the habit in temperate zones is not only common but is often rationalized as a means of preventing fever.

The dietary habits of the indigenous coloured population are usually very different from that of the white settler, but it cannot be argued that the former are necessarily more rational or hygienic than the latter, as poverty and inadequate supply

play so large a part in native diets. One can hardly deny that there are still many gaps in our knowledge of tropical dietetics.

We may count among the few great means whereby tropical residence has been facilitated in recent years, first, the use of the refrigerator, and secondly, the development of canned foodstuffs. With these two innovations the white settler is able to choose his own foodstuffs, to be independent of the tainted or dubious local supplies; and to maintain his stocks pure and edible for long periods of time. These accomplishments can be attributed largely to the largesse and organizing ability of America, as well as to their higher national standards of cleanliness. Two other practices with regard to communal feeding in the tropics stand to their credit. When American forces came to West Africa during the war, they pushed fly-screening to a degree of perfection probably not witnessed before in that part of the world. The jaded European settler in the tropics too often gets tired of attempting fly-control, and lowers his hygienic standards as time passes. The other achievement was the routine search for, and elimination of, all dysentery-carriers among the natives who handled, cooked, or served foodstuffs. The task was a tremendous one, but proved well worth while.

It is probably true to say that the war years emphasized that on the whole people drink too little fluid in the tropics. The subjective sensation of thirst apparently does not provide a sure index of the presence or absence of dehydration. A water-intake over and above what seems to be required to assuage thirst is necessary to maintain maximum physiological and psychical efficiency. Enormous quantities of fluid may be required to offset the sweat loss, and in such cases it is often necessary to take deliberate steps to replace salt loss. Many minor forms of ill-health and fatigue, short of the well-known clinical picture of cramps and prostration, have been ascribed to a mild degree of salt and water depletion. The need for a large intake of water is even greater when drugs or medicines are being taken which are eliminated by the kidneys. An outstanding example is the danger of anuria from the use of sulpha drugs in the tropics unless very great amounts of fluids are also ingested. War experience in the desert has also shown that wounded men were more liable to shock and an inadequate resistance against infection if water-intake was not high.

The question arises whether the provision of iced water ready to hand in homes, offices, factories, etc., is the optimum method of avoiding dehydration in the tropics. Though this habit is deeply engrained

in American life, it is debatable whether it is physiologically sound. Lesser amounts of iced water are necessary to relieve thirst than of water which is merely cool or tepid. As thirst is known to be an unreliable guide in the question of hydration, it is possible that the iced water habit may allow minor degrees of dehydration to exist, without any subjective feeling of dry mouth or thirstiness.

The question of alcohol in the tropics—whether its effect is more or less deleterious than in cool climates, or equally so—is at present a matter of prejudice and guess-work rather than scientific knowledge. There is scope for controlled observation here, and an authoritative pronouncement is desirable.

Hours of Work : Seasonal Leave

Long experience has at last taught that the hours of work in tropical regions should be different from those practised at home; and that a mid-day break of some hours as practised by the native population has much in its favour. Furthermore, trading companies have learned that it pays to permit, or insist upon, their employees taking long holidays at home every year or two.

As long ago as 1905 Woodruff was writing on the need for curtailing the period of service in unpropitious climates, and the necessity for periodic breaks. He quoted the U.S. Naval practice in reducing the term of commission to two years at Cavite. The French served three years in the best of their colonies, but only two years in the less comfortable regions, and in the worst parts of Africa only twenty months. Woodruff quoted the following opinion laid down by the Inspector-General of the Philippines: "Few men in their third year of continuous service are in their normal condition of physical or mental vigor. This statement will be confirmed almost unanimously by medical officers who have served in the Philippines. It is further believed that a third year of continuous service will result in so great an increase in the number of officers invalidated home, or who return to the States broken in health, requiring months of leave and rest for recuperation, that no economy to the government will result. If one could break the period by a trip to the States for a few months, or could spend the hot seasons in the mountains, it might be different. Out of consideration for the almost unanimous wishes of officers affected, and in consideration of what is firmly believed to be for the best interests of the government, it is recommended that the duration of service in the Philippines for all officers be made two years."

So far, however, all such recommendations have been based upon a combination of empiricism and unscientific observation. There can be no doubt that planned studies of industrial human efficiency could be made in the field and in the experimental

psychological laboratory to determine such important points as : (a) the optimum length of a working day ; (b) the correct spacing of working hours in relation to periods of rest throughout the day ; (c) the most desirable times for taking meals, in relation both to rest periods and to working shifts ; (d) the number of working hours per week ; (e) the value of frequent spells in the cool (up country or at an altitude) and the optimum duration and periodicity of such spells ; (f) the question of seasonal leave.

Exercise

It is usual to advise physical exercise to be taken only in the cool of the day or after sunset. Early morning exercise is said to have the disadvantage that heat may be "stoked up" in such a way as to cause the body temperature to remain at an unduly high level for the rest of the day. As stated earlier, we do not altogether understand to what heights the body temperature can rise in tropical residents without morbid consequences. We recall that laboratory tests have shown that rectal temperature rises at a stage before psychological inefficiency begins to show itself. On the whole it is possible that many white settlers in the tropics indulge in an amount of exercise which is unnecessary, possibly even deleterious. Certainly there is a striking contrast between the habits of many native dwellers within the tropics and those that come to live among them. Which habit is biologically the sounder is a matter of opinion.

Air-Conditioning

As a means of maintaining health and efficiency in the tropics, the widespread use of air-conditioning in residences and places of work promises much. Although the initial outlay may be great, the enhancement in working output, in comfort, and reduced sickness-rate may easily prove to outweigh the expense. But up to now there is not enough evidence from industry to demonstrate clearly these suggested advantages from the use of air-conditioning within the tropics. The analogy of warships, both in the Royal Navy and the United States Navy, is promising, where greater comfort, less minor illness, and increased efficiency are recognized to be the rule in compartments where air-conditioning has been installed. The lesson has been particularly striking in the case of submarines serving in tropical waters. In the case of hospitals the benefits of air-conditioned operating theatres are obvious, for the risk of producing unhealthy rises in the body temperature of the patient is ordinarily not inconsiderable. Wards where febrile patients are nursed

may also with advantage be cooled, as was found when scrub typhus was treated near the front line in Burma. Should air-conditioning come into favour in the tropics a number of medical problems will arise. In a building or bungalow it may be feasible to air-condition one room only, and it will then be necessary to decide whether it is better to cool a bedroom—and so ensure a restful night's sleep—or an office or compartment where work is prosecuted throughout the day.

The optimum temperature and humidity levels need to be carefully determined with reference to the conditions of the ambient air. Abrupt transition from the heat of the outside atmosphere to the interior of a cold-storage room has been known to bring about what is called "cold shock" or "cold stroke." Possibly this risk has been exaggerated, but something similar might occur with personnel passing frequently from the outside heat into an air-conditioned room, and *vice versa*. If the atmosphere of an air-conditioned compartment is kept too dry, there may result an uncomfortable and an unhealthy condition within the mucous membranes of the upper respiratory passages. We know little of any possible ill-effect upon the resistance to bacterial and viral infections of frequent changes from one kind of climate to another ; or whether such changes affect the speed and completeness of acclimatization. It was said of the air-conditioned wards in the jungle hospitals that the patients were more comfortable, but that the nursing and medical staff who came and went were less appreciative.

There is a hypothetical risk, at any rate, that the fewer renewals of air within a cooled compartment may increase the incidence of airborne disease. The virulence of any pathogenic organisms might also be enhanced just as the relative immunity of the occupants might conceivably be decreased. Obviously such possibilities must be envisaged and checked, and if necessary chemical disinfectors incorporated with the ventilating system.

Certainly there has been at times a tendency to keep the temperature too low in some air-conditioned rooms. Perhaps an effective temperature of 78° F. is low enough when the atmosphere temperature is very high. Others would advocate no greater difference than 10° F. between the untreated and treated air, but this difference is probably too little and the rule too rigid. Mayer and Fittz have devised a formula for computing the optimum temperature.

The future of air-conditioning in a tropical country like India which is developing its industries may be enormous. We are reminded of a dictum made by Lawrence Lowell : "It is hardly an

exaggeration to summarize the history of 400 years by saying that the leading idea of a conquering nation in relation to the conquered was, in 1600, to change their religion; in 1700 to change their trade; in 1800 to change their laws; and in 1900 to change their drainage." Perhaps we could add, "in 2000 to change their climate."

Protection Against Direct Rays of the Sun

This, briefly, comprises the scientific utilization of adequate shade, correct clothing, sun-tan, and the wearing of dark glasses for the eyes.

Modern conceptions of the ill-effects of insolation are of interest especially as there has been some change in our beliefs. As already mentioned, the bogey of sunstroke has been laid, and it is known that this disorder is none other than heat stroke. The true morbid effects of injudicious and undue exposure of the skin surface are now better understood, as well as the mechanism of pigmentation of the skin. The recent valuable review on the physiological effects of sunlight on man by Blum (1945) should be mentioned. According to the author a white skin reflects about 45 per cent. of sunlight as compared with 16 per cent. by a black skin. This means that, though the negro's integument is less sensitive than a white man's to solar radiation, the absorption of heat is greater. The negro's survival in the tropics does not seem to be particularly due to his colouring.

Wartime experience has shown up one or two changes in social habits and prejudices. In the tropics the overclothing of the last century has given way to a cult of nudity, whereby service personnel now seek every opportunity of working and resting with the heads and torsos exposed. The development of a sunburned surface seems to be the first desideratum; secondly a mild "tonic" effect is claimed and an illusion of well-being and vigour; thirdly, a certain narcissistic self-display is not to be overlooked. The claimed health-giving effects of sun-tanned nudity during the war were difficult if not impossible to demonstrate, except in so far as it distinctly reduced the incidence of prickly heat, secondary septic infections of the skin, and also fungus disorders of the feet, ears, etc. To offset these advantages there are the possible risks of producing general tissue-reactions, fatigue, and lassitude, of lighting up latent foci of tubercle, and—remotely—of a possible carcinogenetic effect.

Another interesting fad or fashion in modern tropical life is the widespread popularity of sun glasses. Although without doubt tinted glasses, especially of the polaroid variety, protect the retina against tropical glare, especially when reflected off

water or white sand, there is a risk of lowering the photo-sensitivity of the eyes by their unnecessary and indiscriminate use. They are often worn as articles of sheer adornment (e.g. by coloured troops), as a protection against unsightly wrinkles around the eyes (by women residents), because of a neurosis (by victims of anxiety, or of lack of confidence), or as an outward and visible sign of a delicate nurture (as in Eurasians and Levantines). These points are borne out by the not uncommon observation that glasses are often worn indoors and after sundown.

Artificial protection of unshaded skin against the sun's rays was experimentally tested during the war by a variety of substances. Oily, fatty, and greasy media were found in the tropics to do more harm than good, for there was a tendency for the skin to become "fried." Preparations containing tannin were of greater service, as a certain degree of keratinization was produced. Benefit also followed the use of pigmented washes containing flavine or permanganate of potash.

While the pendulum is still swinging back and forth between sedulous self-exclusion from the sun and a kind of fanatical sun-worship, it is difficult to lay down authoritative rules for the tropics. Common-sense suggests, as usual, the happy mean.

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