ADAPTATION TO WARM CLIMATES

Surgeon Rear-Admiral S. Miles, M.D., R.N.
Royal Naval Hospital, Plymouth.

1. THE HOT CLIMATE

It is convenient to divide the hot climate into two major groups (i) the warm and moist (jungle climate) and (ii) the hot and dry (desert climate). There are, of course, intermediate areas particularly by the sea where the climate falls between one or other of these two.

(i) THE WARM MOIST CLIMATE (JUNGLE)

This is characteristically found in the rain forest belt which more or less follows the Equator round the world through Central Africa, India and the Pacific Islands and South America. It is a monotonous climate with little variation in temperature day or night or thoughout the year. The dry bulb temperature rarely exceeds 90°F. and a wet bulb is not far behind it and frequently at night the humidity may be 100%. Rain forest protects the area from wind and the air is invariably still. Because of the high humidity man cannot lose heat through evaporation and must rely on conduction, convection and radiation, which are slow processes and thus after exercise many hours elapse before the body temperature returns to normal. It is a climate too which discourages activity and the inhabitants are quite naturally lazy especially as there is often an abundance of food. Furthermore the lack of contrast between day and night and winter and summer removes the stimulus of change which monotony in practise leads to a much higher incidence of psychiatric disease. In a serious of experiments comparing the stress of the jungle and desert climates it was found that the excretion of 17 keto-steroids in the urine was increased. In the Service during the war the invaliding rate from this climate for psychological upset was much higher than elsewhere.

Where there is some difference between the wet bulb and dry bulb temperature limited sweating can take place with advantage. To make the most of this the maximum amount of the body should be exposed. It is for this reason therefore that natives are happier running about naked.

(ii)THE DESERT CLIMATE

To the North and South of the tropical rain forest belt are found in the North, the deserts of the Sahara, Middle East, India, China, Mexico and to the South, Northern parts of Australia and the Southernmost ends of Africa and South America. These areas are characterised by a very high, dry belt temperature sometimes reaching 110°F, a large degree of radiation but a low wet bulb temperature giving a dry atmosphere. The nights are cool and in both North and South there is a winter season which is comfortable and temperate. The stress of this climate lies in the extreme heat so that work in the day can be particularly exhausting. The dry atmosphere allows evaporation of large quantities of sweat which

may be as much as one litre per hour. If this is not replaced dehydration rapidly occurs. Exhaustion of sweat glands too may lead to cessation of sweat and acute heat illness. During the heat of the day the body must be covered to avoid the burning affect of excessive radiation and a white reflecting cloth is to be preferred. It should be porous to allow the evaporation of sweat to take place freely. Where possible, work and travel should be done during the night and rest in the shade during the day. Evaporative cooling is rapid so that for this reason an energetic life can be maintained in this environment.

2. ASSESSMENT OF CLIMATES

Man's comfort and therefore his working efficiency depend on his ability to accommodate unconsciously to environmental conditions. The human heat controlling mechanism is so geared to maintain body temperature within the relatively short range of 98.4°F. Extreme variation from this results in loss of efficiency and ultimately, death.

The body however is not able to analyse the constituents of the environmental make-up and only a response to heat, either the direct effect of the blood temperature (deep body heat) on the temperature regulating centres in the thalamus or on signals received from peripheral thermoreceptors i.e. a register of surface temperature. These sensing organs are in fact sensory nerve endings in the small veins draining the peripheral capillary beds in the skin. Thus two temperatures are recorded, deep body temperature and skin temperature. As has already been stated the immediate response to an increase in temperature is hyper-ventilation peripheral vasodilation followed by sweating, this being modified by acclimatization in due course.

Thus the body is unable to distinguish between hot dry climate and the warm, moist one. It is for this reason that an individual in a very warm saturated atmosphere will sweat profusely even though no sweat will evaporate. In such circumstances the sweating is of little value for evaporative heat loss and is physically seen to accumulate on the skin, moisten clothing and ultimately even drip on to the floor. The same temperature in a hot dry climate will cause the same amount of sweat production but because it evaporates immediately it is not visible on the skin which remains dry. The cooling effect is most effective. Evidence of this profuse sweating is found if the skin is licked when a salt taste is present or in extreme circumstances by an actual deposit of salt on the skin from evaporated sweat.

This principle of evaporative cooling is used in many other ways e.g. cooling of drinks and the conventional oriental practise of keeping water cool in a porous container.

The constituents or variables which go to make up the climate as man feels and responds to it are:-

a. Dry bulb temperatures.

b. Wet bulb temperatures.

c. Radiant temperature.

d. Air Movement.

These have been collated to give a single index known as the Corrective Effective Temperature (CET) which can be used as a comfort and efficiency index. For example when this environment exists 78°F. conditions are becoming adverse, heat stress is possible and efficiency drops. Temperature measurements are carried out with conventional thermometer, a black globe theromometer being used for the radiant temperature. Air movement can be measured by using a Kata thermometer or an anemometer. Measurement of air movement is time consuming and needs somewhat complicated apparatus. It is, however, of great value in a professional survey of environmental situations.

In recent years a new index has been developed which shows a close correlation with the Corrective Effective Temperature and is of the greatest practical value for field use. This simply uses the wet bulb dry and globe temperatures in the following formula:-

WBGT INDEX = (0.7 WET BULB) + (0.2 GLOBE) + (0.1 DRY).

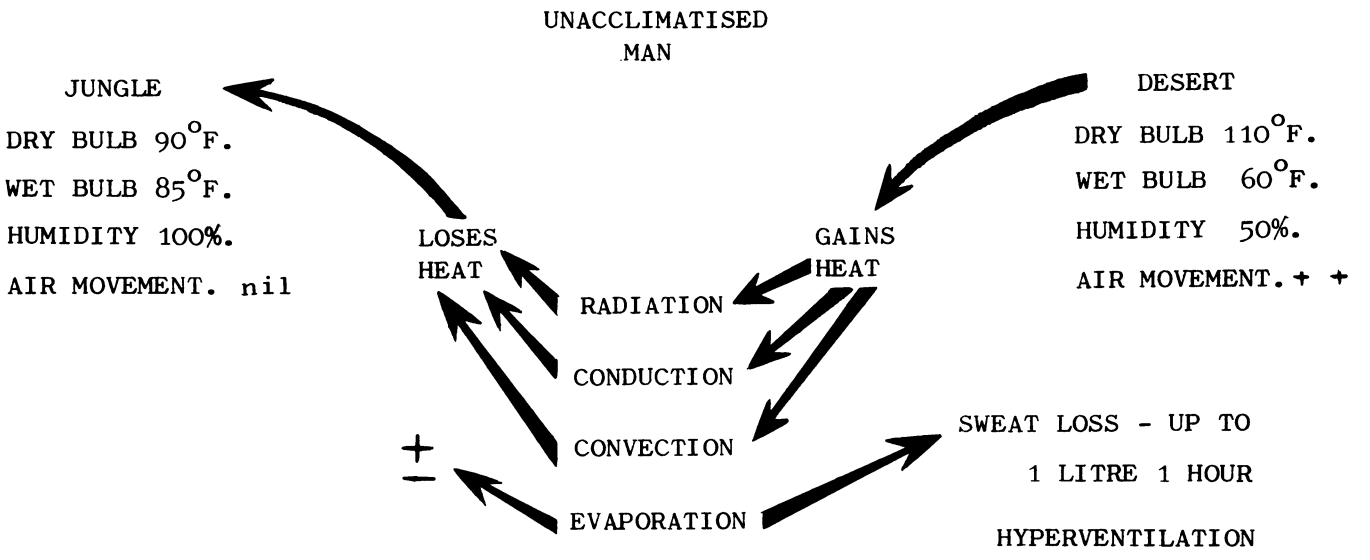
If this exceeds 88°F. there is real risk of heat casualties.

The apparatus required for this measurement is simple and apparatus is now available to give a direct reading of this index. Another index which is of great value but again requires special measuring facilities is the "predicted four hourly sweat rate".

When exposed to a hot climate the athlete has no advantage over the untrained individual other than the benefit likely to be achieved by his expected higher standard of physical fitness. In adapting to a hot climate physical fitness is an important factor. Equally so is a high morale.

Although there are basic physiological changes which are essential if maximum efficiency is to be reached, these alone are not capable of producing the maximum adjustment. Experience has found that in sending men to work in the Tropics much better result is obtained (a) if they are physically fit and (b) if they are quite happy to undergo the project. Fit volunteers therefore make better candidates than the depressed, unhealthy individual.

3. PHYSIOLOGICAL PROCESSES IN ACCLIMATISATION



The maintenance of heat balance can be gained from the environment by radiation, convection and conduction, or created by internal metabolic processes. It can similarly be lost to the environment by conduction, radiation and convection but more imporant to man, by the evaporation of sweat. As has been said man's mechanism for assessing the climate to which he is exposed is by and large unable to distinguish between a hot, dry climate, and a warm, moist one. When an individual is exposed to a hot environment a three-fold response occurs.

(i) There is hyper-ventilation.

(ii)Peripheral Capillary Dilation.

(iii)As the temperature rises, sweating.

In a hot, dry climate loss of heat from sweating is extremely efficient and recovery after exercise is relatively rapid. On the other hand, in the warm, moist or jungle climate where sweat does not evaporate cooling can only take place by radiation, convection or conduction. This must, of necessity, be a slow process and the return to normal after exercise in these conditions is considerably prolonged. It is this climate which produces the greatest stress and to which the adjustment of acclimatisation is minimal.

4. PROCESS OF ACCLIMATISATION

Changes which take place in the ten days or so during which an individual acclimatises to his environment involve:-

(i) A lowering of the sweating threshold.

(ii) A dilution of the blood.

The latter involves an increase in blood volume which enables a greater percentage of the available blood to be diverted to the peripheral circulation for cooling purposes leaving an adequate supply for essential basic internal processes. In time also the amount of chloride lost in the urine and sweat also increases.
As these changes occur there is a return of respiratory ventilation rate to normal and a lowering of the pulse rate in response to exercises. These changes are much more marked in the hot, dry climate than the hot, moist one. Process of acclimatisation can be speeded up if controlled exercises are carried out during the initial period. Seventy five per cent of the process is complete in the first 48 hrs.

(iii)Pyschological adjustment.

Perhaps one of the most important features is the mental adaptation to the tempo of life current in the particular area and an acceptance that Western ways are not always acceptable.

5. DEHYDRATION

To maintain fitness in the tropics water lost by sweating must be replaced by drinking. Hot work in the desert may produce a litre of sweat per hour, and under such conditions to cover work and rest periods as much as 20 pints a day may be needed. It is better to take fluid in small and frequent quantities. It is not always easy to assess in the field conditions the actual fluid lost by sweat but men can easily be taught to measure their urine output which should be at least one pint per day for safety. It is possible to work out a simple index of balanced fluid intake against man's urinary output.

Thirst itself is not a reliable guide. It is also important that drinking water should be cool and palatable. Flavouring powders such as Glucose and Lemon may be added with advantage.

6. HEAT ILLNESS

Heat Illness in its simplest form may be an uncomplicated faint or syncope which is common in the unacclimatised individual particularly when standing in radiant heat which causes marked peripheral vaso-dilation and blood pools in the lower extremities draining away from the head producing a cerebral anoxia which is of course worsened by other stresses e.g. fatigue, hunger, etc.

Another condition in the unacclimatised found particularly in those who have limited exercise and stand on hot decks etc. is swelling of the ankles or heat oedema. This condition is of little significance and disappears with acclimatisation.

Heat Exhaustion may result from inadequate water intake and or excessive salt loss without replacement and is recognised by fatigue, goddiness, rapid pulse and rising temperature. It is a progressive condition unless treated. Death is likely if 15% of the body weight is lost through water depletion. Lack of salt can also produce excessive muscle cramps.

The most serious of all heat illness is Heat Stroke or Heat Hyperexia which is a result of a failure of the heat controlling mechanism characterised by the cessation of sweating, a rapidly rising body temperature (105°F, or more) and changes in consciousness, delirium feeling or coma. It has a very high mortality.

7. TREATMENT

Treatment is urgent and cooling must be introduced. The most satisfactory method is to get the patient in the shade if possible and replace the faulty sweating mechanism artificially by sprinkling with tepid water and encouraging evaporation by fanning. This evaporative cooling is the most effective method. Cold water or ice should not be used as this has the affect of excessive cold on the skin causing vaso-constriction which lessens the flow of blood to the superficial surfaces.

Care must be taken to ensure that the temperature is not lowered beyond a safe limit. When it drops to about 100°F. treatment should be reduced or even stopped. Failure to do this may result in over cooling the body producing the features of shock.

Patients who have suffered this extreme heat stroke should be returned from the tropics to a temperate climate and be discouraged from visiting there again.

THE PREVENTION OF HEAT CASUALTIES

The common predisposing causes of heat illness are:-

(i) Lack of acclimatization.
(ii) Poor physical condition and ill health.
(iii) Low morale.
(iv) Dehydration from inadequate fluid intake.
(v) Lack of salt.
(vi) Sunburn.
(vii) Exhaustion.
(viii) Extreme climatic stress.
(ix) Inadequate or unbalanced diet.
(x) Poor hygiene.
(xi) Incorrect dress.
(xii) Inadequate medical services.

ACCLIMATIZATION

This is a process whereby the body by alterations in blood volume, increased ability to sweat and diminished salt content of sweat becomes better able to withstand severe heat.

The process takes from seven to ten days but is generally three quarters complete in the first forty-eight hours. It is lost within a few weeks of leaving the hot climate.

Acclimatization can be achieved more rapidly if moderate and controlled work or exercise is carried out during the period. Some advantage may be gained by exercising for at least four hours daily in a hot chamber in the temperate climate for several days immediately prior to departure for the tropics.

Local acclimatization is important as re-adjustment is necessary for the variations in hot climate, i.e. between desert and jungle.

During the period of acclimatization activity should be moderate and limited in time. Where operational demands necessitate the use of unseasoned men heat casualties must be expected.

PHYSICAL FITNESS

This is probably the best safeguard against heat illness as the processes of acclimatization are more rapidly and more efficiently completed in fit men. Care should be taken that periods of leave given immediately before emplaning for the hot climate and the delays, irritations and lack of rest associated with air transport do not impair this.

Freedom from common ailments is equally important.

MORALE

There is no doubt that psychological factors are of great importance. Under heat conditions of active service with good motivation there will be fewer heat casualties than with routine exercises.

Great care must be taken with instruction to men visiting hot climates to avoid overstressing the risk of heat illness lest they come to expect it. They should be confidently assured that heat casualties need never occur.

WATER SUPPLY

This may be the most difficult problem and may depend entirely on logistics. The nearer the water supply can approach the physical requirements the fewer will be the casualties.

Water is required to replace that lost by sweating and to produce an adequate flushing out of the body's waste products through the kidneys.

Hard work in a hot dry (desert) climate may result in a sweat loss of 1 litre per hour ($1\frac{3}{4}$ pts.). Thus under extreme conditions, to cover work and rest periods, as much as 20 pints a day per man may be needed.

Fluid should be taken frequently, every one or two hours.

It is impossible to calculate the requirements under field conditions but if the intake is inadequate the urine output will drop and what little

is passed becomes dark and concentrated. Men can be taught to be conscious of their urine output and should take enough fluid to ensure that they pass at least a pint a day. They should learn roughly how many seconds it takes them to pass a pint of urine and get into the habit of estimating their output.

Thirst itself is not a reliable guide.

Drinking water should wherever possible be made cool and palatable. Water containers should be kept in the shade, be insulated and if possible cooled by evaporation. Flavouring powders such as glucose and lemon may be added with advantage.

The usual purity requirements must of course be observed.

SALT

Salt is lost with the sweat and must be replaced. If food is well salted during preparation and a liberal addition is made on consumption it should not be necessary to issue salt tablets. Tablets should in fact only be issued under expert medical advice and then only with liberal quantities of water or other fluid. Sugar or chocolate coated tablets are of little value.

Excess salt, especially if concentrated, may cause nausea or even vomiting. Furthermore if more salt is taken than is lost in sweat there will be an increased demand on fluid intake to get rid of it which under the circumstances is undesirable.

The occurrence of cramp is an indication of salt deficiency.

In short, all that is necessary is for both cooks and men to use more salt then in a temperate climate.

ALCOHOL

In the tropics the capacity and desire for alcohol tends to increase. Alcohol quite definitely increases the susceptibility to heat illness and its consumption should be delayed until the day's activity is completed and then restricted to avoid hangover on the following day. Beer is a good way of restoring fluid balance but its alcoholic content necessitates moderation.

SUNBURN

A good tan is a safeguard against burning and many tropical skin conditions. It must however be achieved slowly with limited daily exposures to begin with. Reddening and burning of the skin greatly reduces the efficiency of the sweating and cooling mechanism. Light clothing, preferably of a colour which will reflect radiant heat should be worn by the susceptible.

Advantage should be taken at all times of any available shade.

EXHAUSTION

Fatigue is a predisposing factor to heat illness and in extremes of climate activity should be limited to essential requirements. Strenuous recreational activity should be left until early evening. This is particularly important in the hot humid climate where body cooling is relatively slow and early morning exercise may produce a heat load difficult to lose.

Where nights are cool and circumstances permit, consideration should be given to working at night with rest in shade during hotter daylight hours.

CLIMATIC EXTREMES

In spite of all precautions situations arise where prevailing conditions strictly limit human activity.

It is possible to anticipate these extremes if facilities are available to measure radiant heat, maximum temperature and humidity. See above page

DIET

The basic calorie requirement in a hot climate is 15 - 20% lower than in a temperate climate and the general discomfort may lessen appetite. The diet must be well balanced and above all attractive. Experience has shown that there is a tendency under field conditions for men to lose interest in conventional rations. This may result not only in inadequate calorific intake but in salt deficiency. More study is needed on dietetic problems in hot climates but much can be achieved by well trained and imaginative cooks.

HYGIENE

In hot climates it is essential to apply the well established principles of hygiene relentlessly. The importance of physical fitness and good health has been emphasised.

The most important single factor is the maintenance of a high standard of purity of food and drink. This will go a long way to reducing the frequent outbreaks of gastro-enteritis in which diarrhoea and vomiting result in dehydration, low morale and predispose to heat illness. In this respect too, fly control and refuse disposal must receive continuous attention.

Personal hygiene must also become second nature to men in these conditions.

DRESS

This must inevitably be a compromise between operational requirements, comfort tradition and protection from terrain, disease carrying insects, local hazards and climate.

For climatic protection loose fitting, porous clothing will allow free evaporation of sweat. In desert climate where there is a high radiant heat problem, light head gear is essential and covering of as much of body surface as possible with a material of heat reflecting colour is desirable. The humid climates where radiation is much less and sweat evaporates less freely the minimum possible clothing should be worn.