Middle Articles

Factors in Human Endurance

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Edward Wilson, one of the greatest Antarctic explorers, was "almost an invalid" when he was chosen as second doctor for the *Discovery* Expedition in 1901. Only a year before that he was recovering from tuberculosis at Davos, and yet he was to become Captain Scott's right-hand man.¹ When Scott, Shackleton, and he went on the sledge journey farthest south on that expedition Shackleton survived only because of his companions' efforts. In 1910 Wilson went in the *Terra Nova* on Scott's last attempt on the South Pole itself. On this expedition he took part with Cherry-Garrard and Bowers in "the worst journey in the world."² His last journey was to the Pole itself, and, after both the disappointment of finding Amundsen's Norwegian flag already there and of the tragic deaths of Evans and Captain Oates, Scott, Bowers, and Wilson were caught in a snow blizzard and died of starvation.³

It was not a strong physique which made Wilson a great explorer: he stood out because, as Scott said: "He really is the finest character I ever met . . . every quality is so solid and dependable." It was the quality of the man which counted. This was true of Scott himself, as Apsley Cherry-Garrard recalls: "Scott was the strongest combination of a strong man in a strong body that I have ever known. And this because he was so weak! Naturally so peevish, highly strung, irritable, depressed, and moody. Practically such a conquest of himself, such personal and magnetic charm. . . . His triumphs are many—but the Pole was not by any means the greatest of them. Surely the greatest was that he conquered his weaker self and became the strong leader whom we went to follow and came to love."⁴

"The overriding importance of morale" is stressed also by a recent Working Party on Accident Prevention, though rather more prosaically.⁵ To conclude, however, that survival in difficult conditions depends on courage alone would be a distortion, since there are individual variations in physical capacity and adaptability in different situations. Limiting factors include the individual's physical characteristics, the extent to which the environment imposes difficulties, and the extent to which physiological mechanisms can adapt themselves. I shall consider the influence of these factors on performance and also other causes of accidents which may occur in athletic pursuits.

Factors Altering Individual Responses

The ability any person has to survive depends, among other things (Table I), on his racial group, his degree of acclimatization to his environment, his physique, and his character. A man's character, as I have already suggested, may be of over-

riding importance, and raises the difficult problem of the extent to which it may be altered by experience.

TABLE I.—*Factors Altering Individual Responses*

1. Genetic adaptation.	5. Physique (e.g., height and strength)
2. Acclimatization to environment.	6. State of health.
3. Conscious adjustments (e.g., clothing)	7. Age and experience.
4. Sex differences.	8. Psychological factors.

Differences occur in physiological responses as a result of differences in racial genetic structure. It is difficult, however, to assess the importance of genetic factors in causing physiological differences compared with the importance of acclimatization as a result of living continuously in a particular environment. One group which may exhibit racial adaptation is the South American Indians of Bolivia, who work in mines at least 17,500 ft. (5,335 m.) above sea-level. They have values of haemoglobin which are higher than those found in mountaineers, even though some mountaineering groups, such as the Himalayan Scientific and Mountaineering Expedition in 1960-1, have spent up to eight and a half months at higher altitudes.^{6,7} Another group which may show racial adaptation is the Aborigines of Central Australia. Sir Cedric Hicks, who was professor of physiology at Adelaide, observed that these natives could sleep comfortably at night in conditions of severe cold, though they were naked. On the other hand, Europeans shivered and were unable to sleep. Aborigines appear to have an adaptation not possessed by Europeans, so that their central temperature can fall when the environmental temperature falls, and though they are far from being poikilothermic—that is, with their temperature varying directly with that of the environment—they nevertheless do not shiver so quickly and can withstand cold conditions without discomfort.⁸

Some Examples

The following examples show that acclimatization may possibly develop in some members of a racial group compared with others. One of these is the Ama women of Southern Korea, about 30,000 of whom regularly dive to the bottom of the sea to search for edible seaweeds and shellfish on which to feed their families. For their families to survive they must do this all the year round, and in winter the water is very cold indeed. The basal metabolic rate of these women is higher in winter than in summer. It is higher, moreover, than that of those members of their families who do not dive and who maintain a constant basal metabolic rate throughout the year.⁹ The increased rate of metabolism helps them survive the cold, but its cause is uncertain. It may be that the divers eat different food from that eaten by the rest of the family. The high fat and protein content of the food eaten by Eskimos is the prob-

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able explanation of their raised basal metabolic rate compared with that of other racial groups.

Another example of apparent acclimatization is the Nepalese pilgrim who was studied by the Himalayan Scientific and Mountaineering Expedition. The pilgrim, a man aged 35, visited the expedition's camp at an altitude of 15,300 ft. (4,665 m.), at which the air temperature was below freezing-point. He had no shoes or gloves and was wearing thin cotton trousers and upper garments. He spent four nights above the camp near one of the glaciers at an altitude of 17,500 ft. (5,335 m.), and on one of the nights there was a snowstorm with winds of gale force and temperatures as low as -15°C . The expedition searched for him and he was found alive and well just below the level of the camp. Physiological investigations showed that in the cold he shivered little and experienced little discomfort even while maintaining his body temperature by a rise in metabolism, and his extremities remained warmer than those of unacclimatized subjects would have done.¹⁰

Physique and Age

The physique of an individual has a considerable effect on his performance. This may best be shown by those who perform well in difficult pursuits—for example, channel swimmers, who are able to swim for 22 hours in water at 15°C ., whereas most of us would have died in less than five hours. Physiological studies of swimmers in the cross-Channel race of 1955 between Cap Gris Nez and Dover showed that the swimmers had subcutaneous fat which was much thicker than usual, though several had a total body fat content which was well below the average for their size. A greater thickness of subcutaneous fat improves insulation and prevents the development of hypothermia. The physiologists carrying out these investigations drew attention to the considerable difference in physique between the good Channel swimmers and good runners, who have unusually little subcutaneous fat. From this it appears possible that physique is important in one's choice of pursuit.¹¹

Another important factor appears to be age. Sir Vivian Fuchs tended to choose men of 30 to 40 years of age for Antarctic exploration because of their greater experience and because their qualities had been tried.¹² With Dr. Pugh and Dr. Corbett I have recently been studying runners in a marathon race—over a distance of 26 miles 385 yards (42.2 km.).¹³ These athletes also tend to come from an older age group, and in the race that we studied the average age of those who finished was 33, and one of them was nearly 60.

Among other factors which determine performance are sex differences, which include different physique and thickness of distribution of subcutaneous fat and hence insulation. There are some women, for example, who are good long-distance swimmers. Nutrition can also be very important. For example, one of the factors limiting the abilities of early Everest climbers was almost certainly the fact that the calorific value of their food intake was far below that required by men exerting themselves as severely as they were, and many of them became emaciated. Much of the work of explorers over 50 years ago was also limited by lack of knowledge of good dietetics and the importance of vitamins, which were not described until 1912.

Environmental Conditions

Some environments give rise to particular problems, which include those of climbing at high altitudes and of underwater swimming, as well as the extremes of temperature from the heat of deserts and tropical rain forests to the cold of glaciers, the poles, and sometimes of the sea itself (see Chart). Mountain climbers at high altitudes may suffer in various ways from failure to adjust, such as mountain sickness, and they can

experience severe fluid loss owing to the intense solar radiation. These and other changes which may occur at high altitudes are complex, and many are still far from being clearly understood, but the chief problems are those of cold, which is considered below, and of hypoxia. Under normal conditions respiration requires the stimulus of carbon dioxide in the blood, and it is only at the levels of oxygen found at high altitudes due to the low atmospheric pressure that a hypoxic stimulus to respiration also occurs. The stimuli of carbon dioxide and of oxygen

lack are not, however, additive, and the low level of oxygen in the blood results in increased sensitivity to carbon dioxide. Respiration is therefore increased at high altitude as against respiration at sea-level during the same amount of work. A further complication is that there is a progressive fall in arterial oxygen saturation with increased work at high altitude owing to the diffusion limitations of the lungs.^{14 15}

In the extremes of heat and cold the chief problem for the body is the maintenance of a normal temperature. In hot climates this is achieved mainly by an increase of sweating, a process which may show acclimatization, as sweat has much lower salt content in those who have dwelt for long periods in hot climates compared with those who have not.¹⁶ Sweating produces considerable fluid loss, and, though Arabian explorers have reported that the Bedouin are able to withstand the heat and limitation of water which may occur during desert journeys to an extent which a European cannot withstand, there has so far been no evidence of racial adaptation or individual acclimatization of fluid control. Dr. John Corbett and I have recently been investigating water balance in the North Arabian Desert of Jordan, and we have failed to find any marked difference between the renal mechanisms of Bedouin and of non-Bedouin Arabs. We did, however, find that the work performance of the Bedouin was better than that of Europeans or of non-Bedouin Arabs, and further studies are therefore required, particularly of sweating regulation as this may be relevant to the problem.

Hypothermia

In a cold environment the body's ability to maintain central temperature depends on several factors, including the degree of insulation. I have already drawn attention to the importance of subcutaneous fat as insulation, and thin people can suffer a very rapid fall of temperature. For example, in cold water there is a considerable loss of heat by conduction, and the body temperature may fall by 3°C . in less than half an hour¹⁷; it is for this reason that deaths often occur rapidly after shipwreck. Another factor which can increase the rate of development of hypothermia after shipwreck is whether or not a person is wearing much clothing and moves when in the water. This was confirmed by the *Lakonia* disaster in 1965, after which those who were clothed and who kept still were shown to have had a higher rate of survival than those who made swimming movements.¹⁸ Hypothermia is a danger not only during the actual period of exposure to cold but also in the hour or so immediately after it. The terrible experiments at Dachau in which inmates of the concentration camp were immersed in

ice-cold water showed this clearly, for their body temperatures fell considerably after removal from the water because of the recirculation of cold blood from the cooled skin even after their removal from the water. It has been suggested that this further drop can be a contributory factor to exposure deaths in the period after rescue.¹⁹

A cold environment may become dangerous in any situation in which the insulation from the subject's clothing fails, and this may happen even in the climatic conditions to be found in Great Britain. During the Four Inns walking competition in Derbyshire in 1964 three scouts died and four had narrow escapes when there was a sudden change in the weather conditions. The 240 scouts taking part had to walk 45 miles (72.4 km.) over the Peak District at altitudes varying between 650 and 2,000 ft. (198 and 610 m.), the record time being seven and a half hours. The weather deteriorated throughout the day, and about seven hours after the start word was received that some competitors were in difficulties, and before they were found two scouts had died and one was in such a state of collapse that he died while being carried down.²⁰ Some of the clothing worn by one of these boys was studied by Dr. Pugh, who showed that when it was wet its insulation fell to a level below that of clothing worn by city dwellers on a warm summer day. The combined effect of exercise, wind, and wet clothing could therefore result in severe heat loss and possibly the development of hypothermia.²¹

In order to investigate the physiological changes which may occur in wet conditions compared with dry ones, Dr. Pugh, Dr. Cooper, and I later examined a group of scouts covering the same ground.²² We found that central temperatures tended to fall when the scouts' clothing was wet, and, incidentally, that they rapidly developed ketosis. As this was not observed in the severe exercise of marathon running,¹³ it appears that biochemical processes may be facilitated or altered by the training programme of athletes, and this problem requires further study. There is also a danger that the circulatory system may become unable to compensate normally, and it is possible that the death of the boy who died subsequently to being reached was precipitated by cerebral hypoxia resulting from a fall in blood pressure while he was being carried down the hillside in a foot-down position. This would explain the account that: "While they were carrying him along a narrow steep slope he had a convulsion which threw the rescuers off balance and one of them fell 20 ft. and hurt his chest."²⁰ Such accidents suggest that the problems of hypothermia and of the lowering of blood pressure with changes of posture need to be carefully considered by mountain-rescue units.

Immersion in Water

Hypothermia also constitutes a potential danger for the deep-sea diver and the underwater swimmer, whether it is in the sea, lakes, or the sumps of caves. When caving, the development of hypothermia due to wet inadequate clothing, which has been known to lead to death within four to five hours of entry into the cave system,¹⁹ is a danger which is not appreciated by the inexperienced, and the development and use of suitable clothing, such as wet suits, is essential.^{23 24} Immersion in water produces changes in physiological mechanisms, including heart rate and distribution of blood flow,^{25 26} and breathing air while diving into great depths, and therefore at great pressures, may result in the "bends" (Caisson disease) if the diver returns too rapidly to the surface. This is because of the high solubility of nitrogen under increased pressure and the fact that it comes out of solution as bubbles in the blood stream if the pressure is reduced quickly. If, however, oxygen is substituted for air there is a danger of oxygen toxicity, notably convulsions, and it is common for deep-sea divers to breathe an oxygen-helium mixture. As helium has a lower solubility than nitrogen, neither oxygen toxicity nor the "bends" is then likely to occur.

Diving in shallow water can lead to dangers, including the effects of overbreathing before diving. This may result in unconsciousness owing to a low oxygen tension of the blood developing before the carbon dioxide levels are reached that would normally cause the divers to return to the surface. Unconsciousness can also occur if a diver without a respiratory gas supply strains while trying to overcome his urge to breathe, so preventing the normal return of blood to the heart (Valsalva's manœuvre). One of the chief problems, however, is the failure of equipment, which is even more serious in cave-diving because of the restricted space and lack of visibility.

Alterations in Physiological Mechanisms

The body has remarkable abilities to maintain relatively constant internal conditions (see Chart). For example, body temperature in the tropics is similar to that in temperate zones. Exploration and athletics may, however, impose a considerable strain on these mechanisms, some examples of which have already been given. A further problem is that of water and electrolyte loss in severe exercise, particularly in hot conditions. Hyperpyrexia may also be a problem during exercise. When Jim Peters collapsed in the Commonwealth Games marathon in Vancouver in 1954 the cause was probably his considerably raised body temperature. In the group of marathon runners which we have studied¹³ the winner had a temperature of 41.1° C. (105.6° F.) even though this was a comparatively slow marathon and the winning time was two hours 38 minutes. We were fascinated to find that these runners had developed acclimatization of their sweating mechanisms, presumably as a result not of external heat but of their raised body temperature during training. If, as has been predicted, the record for the marathon comes down to two hours two minutes²⁷ the danger of hyperpyrexia could be considerable, and it would then be necessary to consider carefully the climatic conditions under which the race is run. Fluid loss during exercise can be severe, and the winner of the marathon race we studied lost 5.23 kg., which was 6.7% of his body weight. There is the additional danger of circulatory collapse as a result of a fluid loss of this order.

Factors Producing Accidents

The preceding discussion indicates that accidents may occur when physiological mechanisms can no longer withstand the stress imposed on them by environmental conditions, and I shall now consider other factors which may contribute towards accidents (Table II). These include fatigue and injury, as

TABLE II.—Factors Producing Accidents

1. Fatigue—mental and physical effects.	5. Lack of organization.
2. Trauma.	6. Improper assessment of conditions.
3. Drugs.	7. Psychological factors.
4. Failure of equipment.	

will be obvious to anybody who has been on a mountain or on ice with an injured person: it is not just the injured man but the whole group that is endangered. Wilfred Noyce in *They Survived* instances the account of a climb on Haramosh II in the Himalayas when this was the case and only half of the party survived.²⁸ Perhaps even more sad are those accidents which later analysis shows to have been avoidable. Such are recent deaths due to the taking of drugs to improve athletic performance—for example, that of Tommy Simpson on 12 July 1967 while cycling in the Tour de France²⁹ and that of another cyclist 18 days later in the Spanish National race. Simpson was reported in the press as being "so doped that he did not know he had reached the limit of endurance," and according to one of the participants all the cyclists riding in the Tour de France were taking chemical stimulants.³⁰

There may, however, occasionally be advantages in using drugs. During the 1939–45 war men on the bridges of destroyers sometimes had to stay awake for many hours, and this was achieved by taking methylamphetamine. Under certain conditions the naval tot of rum may also be valuable. It is true that alcohol in some situations may produce dilatation of skin blood-vessels and therefore the danger of excessive heat loss. Nevertheless, if the sailors' clothing and boots provide good insulation the rum produces a feeling of warmth and comfort, the beneficial effects of which on morale far outweigh the small heat loss. Accidents may also occur if people fail to prepare themselves with adequate equipment for their chosen activity. It is worth remembering that in a recent investigation of life-jackets of 24 tested only two had minimum safe buoyancy.⁵

A careful assessment of the abilities of all the members of the party is obviously essential, and failure to make this may be the explanation of the experiences of a master who was in charge of a group suffering from exposure and who was reported as saying that he had very bad luck in these matters, as accidents had befallen two earlier parties in his care.³¹ Even in this country great care is needed, as every year there are about 200 accidents of all kinds on mountains in England and Wales and a further 60 in Scotland.³²

In spite of all the possible causes of accidents it is on the qualities of a man's personality that his ability to survive ultimately depends. When Cherry-Garrard, Wilson, and Bowers returned from the expedition to Cape Crozier^{2 3} Scott wrote in his diary for 2 August 1911: "Cherry-Garrard . . . still looks worn. It is evident that he has suffered most severely—but Wilson tells me that his spirit never wavered for a moment. Bowers has come through best . . . never was such a sturdy, active, *undefeatable* little man."

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NEW APPLIANCES

Self-clearing Acetabular Reamer

Mr. C. G. ATTENBOROUGH, consultant orthopaedic surgeon, Farnborough Hospital, Orpington, Kent, writes: A considerable number of instruments have been designed for deepening the acetabulum. Many of these, though of excellent engineering design, seem to be ineffective either because they clog easily or because they rapidly become blunt. It is probable that the loss of sharpness is due to the type of steel that is used.

For some years I have used an acetabular reamer which is self-clearing, and, though it has a stainless-steel shaft, the blades themselves are manufactured from tool steel. This has been found to be extremely effective and cuts both articular cartilage and bone, even quite densely sclerotic bone. The blades retain their sharpness for a long period provided they are well cleaned and dried after use and kept oiled when in store.

These reamers were made for me by the London Splint Company and are available in 1½ and 2 in. (4.5 and 5 cm.) sizes.