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PHYSIOLOGICAL ADAPTATION AND HEALTH OF AN EXPEDITION IN ANTARCTICA, WITH COMMENT ON BEHAVIOURAL ADAPTATION*

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Davis from the sea ice, September 1963
(Photograph by B. Eyre)

C O N T E N T S

PHYSIOLOGICAL ADAPTATION AND HEALTH OF AN EXPEDITION IN ANTARCTICA, WITH COMMENT ON BEHAVIOURAL ADAPTATION

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ABSTRACT

Antarctica is the harshest and most isolated continent, and members of the Australian National Antarctic Research Expeditions (ANARE), who come from densely populated temperate and tropical regions, form an ideal population in which to study human adaptability. In this age of space exploration and the current evaluation of man's impact on the world and of the world on himself, medical research on small groups in Antarctica is appropriate as human adaptation is the central problem in environmental epidemiology.

This study consists of a number of interrelated observations on physiology, thermal comfort, cold exposure, activity, health and behaviour of a nine-man expedition at Davis, Antarctica, in 1963, and a health survey of the Australian expeditions from 1947 to 1972. Medical practice and research in Antarctica are reviewed, and descriptions are given of the environment, and cold exposure experienced; expedition organisation and programs are given. These are important to an understanding of the present study, and also enables comparisons to be made with expeditions of other nations.

The men were exposed to the meteorological climate for 20 per cent of their time. However, adaptation was influenced by behavioural response as the exposure climate was found to be 12 - 28°C above the meteorological climate and independent of it. At all dry bulb temperatures between 5.6°C and 27.2°C all men were comfortable, but the preferred indoor temperature was 14.2°C. The results are compared with those for tropical and temperate regions. The absence of thermal discomfort and the low value of the preferred temperature are shown to be due to adjustments in clothing, clothing being shown to play a larger part in determining the thermal sensation than the indoor air temperature.

The amount of clothing worn outdoors did not increase as winter approached, yet the men maintained a higher level of thermal comfort. A comparison of the thermal comfort and the clothing worn, both indoors and outdoors, in periods before and after midwinter strongly suggests that acclimatisation to cold had occurred.

Throughout the year there was a high degree of activity which was reflected in an absence of seasonal weight changes. The human adaptation is related to changes in the physiological variables although the biological significance of a number of these changes is not clear.

Observations of men on field traverses showed a complex interaction between activity, calorie intake and energy expenditure, with dehydration being considered the most important factor influencing the substantial weight losses that occurred.

The group adjusted readily to the climate, isolation, work, stress and to each other. This is emphasised by the low incidence of mental illness. Comment on behavioural adaptation is made. Although physiological adaptation in the form of acclimatisation to cold is suggested by the Davis study, it is concluded that overall adaptation of the group is more influenced by behavioural than by physiological factors.

The ability of the men to function effectively is shown by the low incidence of illness, for the maintenance of health implies adaptation to man's environment. An analysis of the health, including mortality and medical evacuations, of 60 Australian expeditions shows the Davis group to be a typical expedition. Factors influencing health are discussed.

It is the aim of this study to add to the knowledge of man in polar regions and human adaptability in Antarctica in the areas of local acclimatisation, thermal comfort, health, morbidity, medical practice and behaviour, all of which are basic to a complete understanding of Antarctic environmental epidemiology.

1. INTRODUCTION

1.1 THE ANTARCTIC

1.1.1 History of exploration and scientific expeditions

Ancient Greek philosophers speculated on the existence of a southern continent about the fourth century B.C. Their liking for order and symmetry in nature led them to place a land mass in the south to balance the known lands of the Northern Hemisphere.

Raratongan legends dating back to 650 A.D. (Roberts, 1958) leave little doubt that Ui-te-Rangiora and other Polynesians sailed as far south as the frozen pack ice. Fifteenth century cartographers marked the continent of Antarctica on their maps, calling it "Terra Australis". Captain James Cook modified the theory of "Terra Australis" extending to temperate latitudes when he sailed as far south as 71°10', crossing the Antarctic Circle for the first time and circumnavigating the Antarctic continent. This occurred during his voyages in two tiny ships, the *Resolution* and the *Adventure*, in the years 1772-75.

Although Cook failed to see the actual Continent, he thought that such a land did exist. He records in his diary (Cook, 1777):

> *'That there may be a continent or large tract of land near the Pole I will not deny; on the contrary, I am of opinion there is, and it is probable that we have seen a part of it. The excessive cold, the many islands and vast floats of ice all tend to prove that there must be land to the south....'*

Cook reported sightings of large whale and seal populations in the southern waters and at South Georgia, and in 1778 British sealers started working on this island. American sealers followed the British in order to share in the financial reward from the slaughter of the fur seal. As the seals on known beaches decreased, the hunters sailed further southward looking for new beaches and more seals.

In 1820, men of three different nations all recorded seeing the Antarctic continent. An Englishman named Captain Edward Bransfield discovered Graham Land and was the first man to chart a portion of the Antarctic mainland (Anon, 1946). At about the same time an American sealer, Nathaniel Palmer (Martin, 1940) sighted that portion of the continent. A Russian expedition commanded by Thaddeus Bellingshausen (Debenham, 1945; Armstrong, 1950, 1951) almost certainly sighted, but did not recognise as land, two coastal areas on the opposite side of Antarctica two days before Bransfield's discovery.

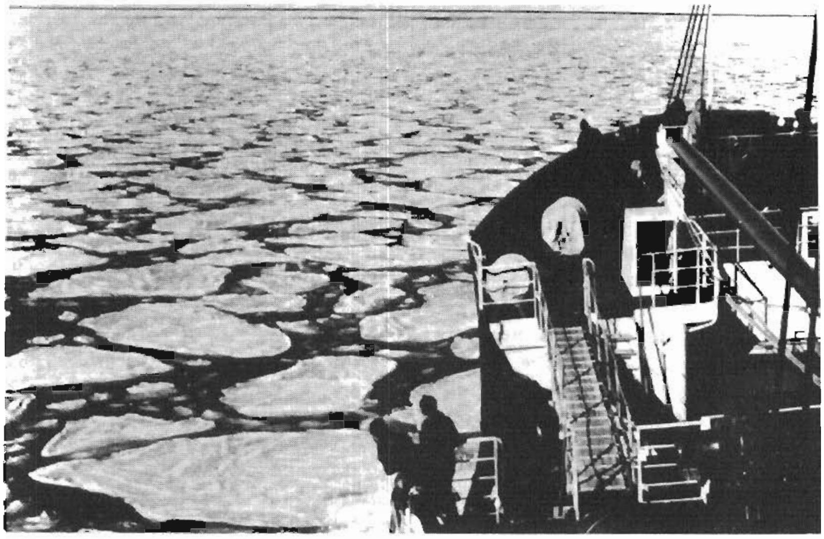

Plate 1. M.V. Nella Dan *passing through pancake ice on the voyage to Davis, February 1963. This ice is the start of the formation of pack ice through which the early expeditions had to force their way. (Photograph by D. J. Lugg)*

The success of the commercial sealing and whaling ventures stimulated many expeditions and near the end of the nineteenth century the coastal limits of the Antarctic continent had been roughly defined. Small wooden ships were sailed by brave seamen through the pack ice to make sightings of the land mass encompassing the whole circumference of Antarctica. Men such as Weddell, Biscoe, Kemp, Balleny, Dumont d'Urville, Wilkes and Ross contributed to the discoveries in this maritime era of Antarctic exploration. Roberts (1958) and Kirwan (1962) have reviewed the history of polar exploration.

The interest in Antarctic exploration waned as major efforts were made to discover the North-West Passage in the Arctic. However, shortly after 1890, interest in the Antarctic revived. The two principal reasons for this were new methods of whaling, which allowed greater catches to be made more efficiently, and the conviction of scientists that the south polar regions were important for discovering more about the universe.

The influence of whaling on the renewed exploration is obvious from the writings of Bull (1896). He led the first expedition to make a landing in 1895 on the Antarctic continent at Cape Adare in Victoria Land. This private expedition was financially supported by the Norwegian, Svend Foyn, the inventor of the modern harpoon gun, and sailed in the whaler *Antarctic* under the command of Captain Leonard Kristensen.

Bull (1896) wrote of the first landing:

> *'The sensation of being the first men who had set foot on the real Antarctic mainland was both strange and pleasurable, although Mr. Foyn would no doubt have preferred to exchange this pleasing sensation on our part for a Right whale even of small dimensions.'*

The first discovery at Cape Adare of living plants aroused much excitement and was a further stimulus to the efforts of Sir Clements Markham, Sir Joseph Hooker and Sir John Murray at the Sixth International Geographical Congress in 1895 to have more extensive scientific investigations carried out in Antarctica.

During the winter of 1898, the Belgian Antarctic Expedition under Adrien de Gerlache (1902) found its ship frozen fast. All winter, the *Belgica* drifted with the ice until the following summer. This was the first expedition to winter, though unintentionally, in Antarctica.

A small well-equipped British expedition led by Carstens Borchgrevink (Borchgrevink, 1901) sailed south in the *Southern Cross* in 1898. A station was successfully established at Cape Adare and the first planned wintering expedition remained on the Continent while the ship sailed to New Zealand, returning the following year to pick up the party.

These two expeditions began the heroic era of Antarctic exploration. During this era men penetrated the Continent as far as the South Pole. Facing unknown dangers with unproved equipment, these explorers showed great courage and determination as they laid the foundation of techniques which future expeditions followed. In 1901, German, Swedish and British expeditions under Drygalski (Drygalski, 1904), Nordenskjöld (Nordenskjöld and Andersson, 1905) and Scott (Scott, 1905) respectively commenced scientific studies in Antarctica. From 1901, expeditions were in the region nearly every year.

On 15th December 1911, Amundsen reached the South Pole. This Norwegian expedition used dog-teams and a vivid account of the journey was written by the leader (Amundsen, 1912). Captain Scott and his party arrived at the same objective one month after Amundsen. Scott's diaries (Scott, 1968) describe the hardship and misfortunes that occurred on this expedition. Scott and his four companions died on the return journey but their scientific records including 14 kg of geological specimens were carried until the end, and were later recovered by other members of the expedition.

The 1911-1914 Australasian Antarctic Expedition (AAE) led by Sir Douglas Mawson was most successful scientifically and the general account of this expedition (Mawson, 1915) was widely read. Sir Ernest Shackleton's British Imperial Trans-Antarctic Expedition 1914-1916 became one of the greatest adventures in the history of exploration as his ship *Endurance* was crushed by ice. His men escaped to Elephant Island in small boats following which six men travelled

1300 kilometres in an open boat to get help from South Georgia (Shackleton, 1919). This expedition ended the heroic era of exploration.

Aircraft were used for the first time in 1928 by Sir Hubert Wilkins. Richard Byrd also used aircraft on his three expeditions. The importance of aviation to Antarctic exploration was stressed in the accounts of these expeditions (Byrd, 1930, 1935).

Prior to World War II, other important expeditions were Mawson's British, Australian and New Zealand Antarctic Research Expedition (BANZARE) (Grenfell Price, 1963) and Rymill's British Graham Land Expedition (Rymill, 1938).

In 1943 Britain began to send expeditions to permanent bases. These later became the Falkland Islands Dependencies Survey (now called the British Antarctic Survey). The modern mechanised era was initiated by the United States in 1946 with 'Operation High jump' which photographed large coastal areas from the air.

The Australian National Antarctic Research Expeditions (ANARE) began in 1947. The Norwegian-British-Swedish Expeditions 1949-52 carried out valuable scientific work (Giaever, 1954) and the French manned a station in Adélie Land from 1950 (Victor, 1964).

The International Geophysical Year 1957-58, involving twelve nations and fifty scientific bases, allowed scientists to obtain vast amounts of scientific information unprecendented in Antarctic research. During this period the Continent was crossed from the Weddell Sea to the Ross Sea (Fuchs and Hillary, 1958).

The foundation for the future of science in Antarctica was laid in 1959 when twelve nations signed the historic Antarctic Treaty. The evolution of twentieth-century man against Antarctica has been reviewed by Priestley (1956). He traces the changes from private explorers and scientific society sponsorship to complete government control, and shows how the initial emphasis on exploitation has now moved to scientific research, although less and less scientific result has accrued per unit of energy and money expended.

1.1.2 Geography, topography and climate

Antarctica is the great continent covered with ice and snow that surrounds the South Pole. The limits of this continent, which has an area of nearly fourteen million square kilometres, lie for the most part within the Antarctic Circle (latitude 66°33'S). It has a vast coastline. Off-shore are numerous islands which are also ice-covered. These are considered to be part of the south polar region called the Antarctic. Scientists recognise as the Antarctic boundary that zone around the continent where the cold waters flowing northwards meet the warmer waters of the Temperate Zone. This is known as the Antarctic Convergence. The Antarctic waters and the temperate waters support different sea life, as the waters differ in density and chemical composition.

During negotiations for the Antarctic Treaty the Antarctic was defined as the land and water south of the sixtieth parallel south. This precise definition of 66°33'S will be used in this thesis.

Approximately 98 per cent of Antarctica is covered by ice, the mean thickness being about 1800 metres (maximum thickness 4800 metres). The ice thickness at the South Pole is 2800 metres. The ice in general flows from the centre to the sea. Coastal floating ice shelves are fed by glaciers and snowfall, and pieces break off at the edge forming flat-topped characteristic "tabular" icebergs which float northwards. When the seas freeze during winter, ice is present for many hundreds of kilometres off-shore. During summer this breaks up to form pack ice.

Areas of exposed rock do occur and the mountains rise to heights of over 5000 metres above sea level. The peaks generally rise 200 to 2000 metres above the ice surface of the plateau.

Lamb (1964) and Rubin and Weyant (1965) have described the climate of Antarctica. It is the coldest on earth, with the temperature decreasing with altitude and distance from the coast. Temperatures as low as -88°C have been recorded.

Antarctica is a continent of high winds. Due to the slope of the ice the cold air at the centre flows outwards towards the coast. As it accelerates down the steeper ice slopes near the coast it may reach gale force. These winds are known as katabatic winds.

The high plateau that covers most of the Continent is the world's largest and driest desert. Over much of the whole area the mean annual snow accumulation is the equivalent of only 5-12 cm of water. However, this increases to 20-50 cm near the coast.

1.1.3 Flora and fauna

The waters encircling Antarctica support large populations of a few species and are one of the richest biological areas on earth. The myriads of phytoplankton and zooplankton support directly or indirectly life varying from sponges, echinoderms and molluscs to birds, seals and whales (Dell, 1965).

The terrestrial life is as poor as the oceans are rich. There are no terrestrial vertebrates and only three flowering plants. The fauna is made up of tiny invertebrates and the flora of primitive bacteria, fungi, algae, lichens, mosses and liverworts (Greene, 1964; Llano, 1965).

The herb *Colobanthus crassifolius* D'Urville and two species of the grass *Deschampsia (D. parvula* and *D. elegantula)* are flowering plants that grow no farther south than latitude 64°. The subzero temperatures, exposure to violent winds and long months of darkness limit the plant growth on the Continent to hardy plants. The plant that best withstands the desiccation is the lichen and this is found on many inland peaks and rock outcrops at high latitude. Contrary to popular belief the Antarctic is not devoid of micro-flora, and Llano (1965) has summarised the investigations of the microbial content of ice, snow, soil and air.

The terrestrial invertebrates of Antarctica inhabit the sparse soil, the vegetation and accumulations of freshwater that occur during the warmer months of the year. Invertebrates are also found as ecto- or entero-parasites of the higher animals. Gressitt (1965, 1967) has described these invertebrates.

Although eight species of seal are found in Antarctic waters, only four breed in Antarctica (Stonehouse, 1965). These are the Weddell, Ross, leopard and crabeater seals. The southern elephant seal *Mirounga leonina* visits the Continent, and a colony of mainly bachelor bulls is present near Davis during most of the year. No mammal, other than man, ranges as far south as the Weddell seal *Leptonychotes weddelli* which is the commonest seal of the Antarctic coast. Ross seals *Ommatophoca rossi* are rare, while the crabeater seals *Lobodon carcinophagus* and leopard seals *Hydrurga leptonyx* live in the pack ice and are occasional visitors to the coastal stations. Bonner and Laws (1964) have described the current status of seals in the Antarctic.

During a year at Davis many species of birds may be seen. Snow petrels (*Pagodroma nivea*) are one species that have been described at Davis (Brown, 1966). Other species breeding close to the station are the Wilson's storm petrel (*Oceanites oceanicus*), McCormick's skua *Catharacta maccormicki*), giant petrel (*Macronectes giganteus*), and cape pigeon (*Daption capensis*).

The largest penguin, the emperor penguin *Aptenodytes forsteri* is the only bird remaining in large numbers near the Continent during winter. These birds breed in winter in the most extreme conditions, on floating ice or on rock-based ice.

Near Davis 250 000 Adélie penguins *Pygoscelis adeliae* breed (Lugg, unpublished data). This creature of the Antarctic seas comes ashore in the southern spring establishing rookeries on the exposed rock of continental cliffs or offshore islands.

1.1.4 Human populations

Antarctica is unique in that no industrial or commercial activities take place there, and no indigenous peoples inhabit the area. Wilson (1965) has pointed out that man is a newcomer and a transient visitor only. The men mostly come from temperate regions or a warm environment and go South for a specific term of one or two years. The wintering expeditions in Antarctica, which comprise healthy male groups* of up to 150 men, contrast with the Arctic polar communities. In the Arctic, indigenous Eskimo people have lived in family communities for millenia.

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*In recent years, women have been included in both United States and Australian wintering expeditions.

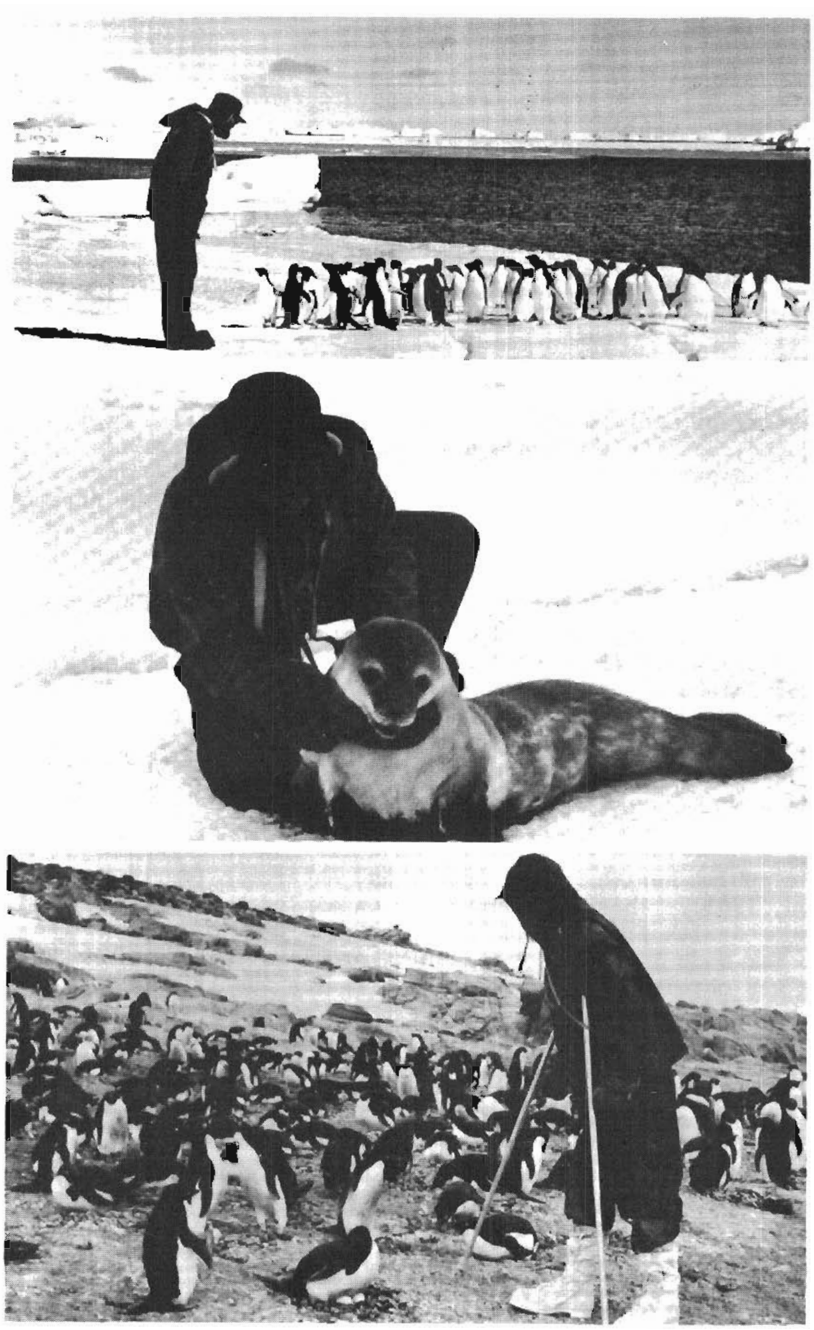


Plate 2. ***The close contact of the men with the local fauna was** a potential source of disease. (a) The author with Adélie penguins* (pygoscelis adeliae) *on the sea ice near Davis. (b) A Weddell seal pup* (leptonychotes weddelli) *being inspected for lice. (c) A patient whose fractured leg is in plaster exercising at a nearby penguin rookery. (Photographs by D. J. Lugg)*

In recent times, all-male groups from temperate zones live in military and oil and mineral exploration establishments in the Arctic but these are not totally isolated, and the men have frequent opportunities to travel to large cities and towns.

1.2 MEDICAL PRACTICE AND RESEARCH IN ANTARCTICA 1775-1962

1.2.1 Medicine

The history of medical work in south polar regions is a most interesting one, despite the absence of an indigenous Antarctic population. The early expeditions had one or more medical officers, many of whom described medical practice and the hazards of the Antarctic. The standard of medical care has been high, with possibly the highest ratio of doctors to population to be found anywhere - an average of one doctor to twenty-five men.

An historical review has been made of Antarctic medical practice in the period 1775-1975 (Lugg, 1975a, 1975b). The review begins with the primitive shipboard practice of doctors accompanying Captain James Cook around 1775 and concludes with the modern era of permanent stations and vast scientific endeavour. Medical practice in the heroic era and the highly mechanised transition period are contrasted with the present day.

In 1962 a conference was held by the World Health Organisation on medicine and public health in the Arctic and Antarctic (World Health Organisation, 1963). This conference was an exploratory one to exchange experiences on health problems in high latitudes and to evaluate the progress so far made in coping with health problems in cold climates. No evidence was obtained that there were diseases specific to high latitudes, but it was concluded that there was a need for specific research in environmental health and mental health of transient populations, as well as for more detailed work on human physiology.

1.2.2 Medical research programs

Medical research was not a feature of the early Antarctic expeditions. Although up to three doctors accompanied many of the expeditions and these doctors usually took a very active part in scientific research, they did not perform much medical research.

Microbiology was one exception to this and, although much of the work was done on animal life, it was continued over a number of expeditions. Gazert (1901) conducted the first observations in which he isolated bacteria from the intestines of seals but reported bacteria-free specimens of birds. Ekelöf (1904, 1908) also reported bacteriologically sterile birds but proposed that bacteria which grew on exposed culture plates were carried by soil particles. Charcot (1906) and Pirie (1912) furthered this work of isolating the various bacteria present.

McLean (1919) who cultured bacteria from the upper respiratory tract of men on his expedition, began the human studies which are now such a feature of the modern expeditions.

Darling and Siple (1941) isolated bacteria from ice and snow while Sladen (1953, 1962), Sladen and Goldsmith (1960) and Adams and Stanmeyer (1960) made a number of surveys of the pathogenic bacterial and viral flora of the upper respiratory tract of men wintering in Antarctica. Among their findings they showed that *Staphylococcus aureus* and *S. albus* remained in the noses of men isolated for long periods.

As early as 1899 Klovstad (Borchgrevink, 1901) tested pulses on a pulsometer, which was quite sophisticated for that era. He also measured hand strengths and lung capacities but the results, which were obtained under great difficulty, were never widely published, probably because the random measurements provided insufficient information from which to draw reliable conclusions. This was the fate of many of the early medical research observations.

1.2.3 Physiological research

> *'Later on, with our snow-tight walls, the temperature kept pretty constant, remaining at a few degrees below freezing point, a degree of comparative warmth to which we soon grew quite accustomed, so that we could sit working or chatting in our jerseys, with naked hands and uncovered heads.'*

Thus wrote Nordenskjöld and Andersson (1905), when describing their reaction to the low temperatures of their indoor environment on the Antarctic continent during the Swedish Antarctic Expedition of 1902 to 1903. Although, in the sixty years which have passed, many other explorers have made similar observations (Mawson, 1915; Shackleton, 1919), quantitative evidence of acclimatisation has been lacking until quite recently, when records of the amount of clothing worn by several polar parties suggested that improved thermal tolerance or acclimatisation did in fact occur (Frazier, 1945; Butson, 1949). Later Goldsmith (1960) and Palmai (1962a) studied the changes in clothing together with the associated thermal comfort of men wintering at Antarctic and sub-Antarctic bases and obtained by this means more exact evidence of improved thermal tolerance. However, there is still much to be learnt concerning factors which determine thermal comfort in extremes of cold.

Many attempts have been made to detect physiological evidence of acclimatisation to cold. These have been done in both the Arctic and the Antarctic, and the results obtained have conflicted in many cases. Edholm and Lewis (1964) and Wilson (1965) have summarised much of the work done in the period of this review. Edholm and Lewis (1964) consider that there is meagre evidence for general bodily adaptation to cold in contrast to the substantial evidence for adaptation of local sites, such as hands and face, to the cold.

Cold adaptation of the hands, which had been demonstrated in the Arctic by use of a simple two-point discrimination test (Mackworth, 1953, 1955), was confirmed by Massey (1956, 1959) in the Antarctic, where he conducted experiments for twelve months on a group of new arrivals and a group who had already been in Antarctica for a year. Massey also observed that frostbite occurred more often in the men who were spending their first year at the base than in those who were in their second year. This phenomenon had been recorded by Frazier (1945) during the U.S. Antarctic Service Expedition 1939-1941.

Lewis and Masterton (1963), who were the pioneers of modern polar physiology, on the 1952 British North Greenland Expedition (Hamilton, 1958) investigated the important question of the cold stress actually occurring. They concluded that

> *'at this stage of our studies in polar physiology, we are reasonably sure that the effects of cold are small, usually identifiable, and not of great significance on a successful polar expedition.'*

Norman (1965), following a study in 1959 at Halley Bay, concluded that at stations where there is little or no sledging, the exposure is not sufficiently severe or prolonged to produce any significant physiological change. Norman also studied patterns of exposure, calorie intake and energy expenditure.

Norman (1965) used a temperature-sensitive vest (Wolff, 1958) to investigate the micro-environment of his subjects. The temperature of the micro-climate beneath the clothing was almost identical with the skin temperature. This was found to be between 32 and 33^{o}C at base with a lower range occurring on sledging journeys away from base. Other investigators (Milan, 1964; Hampton, 1964, 1969) agreed with Norman that the skin temperature falls when men go outside but this does not always indicate cold stress as other factors, including activity and sweating, may occur and alter the actual stress.

The investigations of micro-climate of the body led to the assessment of activity patterns which could also be related to the environmental conditions. These studies were done in the period 1957-59. Milan and Rodahl (1961) observed that a group of scientists spent 13-15 per cent of the time outside in the autumn and spring, but only 6 per cent in the winter. A group of support personnel averaged 20 per cent in the spring. Cumming (1961) calculated that the average time spent outside at Halley Bay was 13 per cent in summer and 5 per cent in winter, while Wyatt (1963) at a sledging base spent no more than 17 per cent of his time outside the hut or tent.

The physiological measurement that has been most recorded on expeditions has been body weight. Ekelöf (1904) weighed his men every fortnight. One early assumption was that an increase in body weight in polar regions was accompanied by an increase in body fat thickness as a direct response to cold and that this had biological significance by increasing insulation.

Body weight measurements taken by Marshall (1909) showed little change during the year but one man had '*well-marked linear albicantes on both upper arms as a memento of the adiposea of the south*'. Reports in later years (Goldsmith, 1959; Wilson, 1960) did not substantiate the presence of 'the southern adiposea' and suggested that body weight and subcutaneous fat vary, not as a response to cold but with changes in activity.

The variation in the results of measurements of body weight from expedition to expedition and in the interpretation of these results is apparent when the figures from SANAE 1961 are examined. In this study tissue insulation was said to be due to weight gain (Wyndham and Plotkin, 1963; Wyndham, Plotkin and Munro, 1964).

Budd (1962b, 1964) who carried out whole body cooling studies on four men at Mawson in 1959 suggested tissue insulation increased as a result of vasomotor changes. The ability of the four men to maintain rectal temperature during acute cold stress was attributed to general acclimatisation to cold. Milan, Elsner and Rodahl (1961) also found evidence of general acclimatisation in their study, which investigated the thermal and metabolic responses of men exposed nude for two hours to a standard cold stress (17°C) after varying intervals of time in Antarctica.

Of serial basal measurements performed, blood pressure is another variable that has been shown to differ from expedition to expedition. Wilson (1965) has summarised these changes which have included decreased systolic and diastolic blood pressures at Vostok in 1959 (Tikhomirov, 1963), decreased diastolic blood pressure (Pace, 1960) and increases in both diastolic and systolic blood pressures in relation to a cold stress (Frazier, 1945; Butson, 1949).

Field studies on sledging teams have included food requirements for sledging. It has been estimated that from 3500 to 5500 kcal are necessary for this activity. Fuchs (1952) studied ration scales for British dog-sledging parties and adopted a scale giving a daily calorie intake of slightly above 4000 kcal. Rogers (Rogers and Sutherland, 1971) measured the food intake of one member of the Trans-Antarctic Expedition for 7 days and it averaged 4100 kcal. Energy output was the same. Sapin-Jaloustre (1955) and Rivolier (1955) have reported on the nutritional requirements of the Expéditions Polaires Francaises and the daily calorie intake has been almost identical to the British calculations. Lewis (1963) has described nutritional research in polar regions and the development of modern sledging rations. He has also discussed calorie requirements of men in Antarctica.

Nutritional studies are closely allied with changes in body weight of men in the field and these have been studied by Massey (1956), Wilson (1960) and Orr (1965). Weight losses have been found by most workers but there has been considerable disagreement as to the specific mechanism for this.

The overall evaluation of the research in physiology up to 1962 is difficult as there are so many contradictory findings. However, as Wilson (1965) points out, the steady accumulation of evidence from many expeditions can be expected ultimately to clarify the problem of how man adapts physiologically.

1.2.4 Psychological studies

The study of psychological problems and the adaptation of men on Antarctic expeditions is most important both for the successful running of the expeditions and for gaining insight into man's behaviour in total isolation. From the earliest expeditions descriptions have been given of the feelings of the wintering expeditioners. Cook (1900) described the return of the sun after the period of winter darkness as follows:

> *'After so much physical, mental and moral depression, and after having our anticipations raised to a fever heat by the tempting increase of dawn at noon, it is needless to say that we are elated at the expectation of actual daylight once more... Their* (Lecointe and Amundsen) *eyes beamed with delight, but under this delight there was noticeable the accumulated suffering of seventy dayless nights'.*

On a number of early expeditions psychiatric problems were experienced, but only vague reference was made to them. An example of such a case and the attitude of the doctor treating it occurred in the reports of Mawson's Australasian Antarctic Expedition 1911-14. McLean (1915) wrote:

> *'Adélie Land can only be regarded as an intolerable country in which to live, owing to the never-ceasing winds. Usage and necessity helped one to regard the weather in the best possible light; for the sake of a few hours of calm which might be expected to occasionally intervene between the long spells of the blizzards. It is, therefore, with regret and some diffidence that I speak of the illness of Mr. S.N. Jeffryes, who took up so conscientiously the duties of wireless operator during the second year (1913); but upon whom the monotony of a troglodytic winter life made itself felt. It is my hope that he is fast recovering his former vigour and enthusiasm'.*

A footnote to McLean's report has been added by Sir Douglas Mawson:

> *'With the advent of summer, Jeffryes became normal, but unfortunately suffered a temporary relapse upon his return to Australia'.*

Priestley (1921) was one of the first to write on the psychology of polar exploration. He was a member of Shackleton's *Nimrod* expedition of 1907-09 and was also one of the six-man party that wintered as Scott's Northern Party. During this expedition Priestley (1914) spent the winter of 1912 in an ice cave scooped out of the snow on Inexpressible Island. An account of the survival of this party against incredible odds has been given by Priestley (1969).

The compatibility of the men, the factors of the environment, such as hunger, thirst, lack of sleep and '*monotony of colour, of occupation and of companionship*', the nature of polar work and the dangers such as crevasses are all discussed. Dreams which were one of the men's few relaxations are vividly described.

Shurley (1970), a psychiatrist who has studied the dreams of isolated explorers, has analysed the dreams described by Priestley some 60 years later. Shurley considered that

> '*food was the hallucinated gratification of their growing hunger; rescue fantasies were the nourishment of their ego's will to survive*'.

He added that

> '*...in another sense their dreams could also be taken as evidence of the strong, emotional working of their minds in presenting possible solutions to their direct problems*'.

Priestley concludes his article with the following:

> '*Before closing the subject, short reference should be made to that very real danger to the polar expedition, the peculiar mental trouble which might perhaps best be called* polar *madness. It is a well-established fact that men mentally unsuited for polar exploration are liable to suffer from temporary mental aberration either during or immediately after an expedition. Cases have occurred in nearly all recent expeditions where real hardships have been incurred. The most extraordinary hallucinations afflict the patient and for the time being he is quite irresponsible. It is a merciful fact that this aberration is apparently temporary only, though in extreme cases it may last for months and even years. One factor worth mentioning is that it appears to be the most inelastic temperaments and minds that succumb. The higher strung and more sensitive the organisation, the better it will withstand extraordinary strain*'.

Evans (1937), who wintered with Scott in the *Discovery* Expedition, agreed with Priestley on the importance of psychology and mental illness. He wrote:

> '*Psychology plays an important part in Polar exploration as well as in war, and during the winter darkness one has to be constantly watching one's subordinates. Many men have gone mad after their return to civilization. Few go mad during the expedition, when the tension is not relaxed. Looking back, I calculate that 13 per cent of Scott's men were mentally deranged after the expedition*'.

Further reports of psychological aspects of wintering groups were published as more expeditions returned to their homelands from taking part in the modern era of exploration. Rivolier (1954) wrote of the problems of the doctor on such an expedition, based on his experiences on the Adélie Coast in 1950. Law (1960), who had never wintered in Antarctica, described in general terms the Australian experiences of personality problems. These were based on leaders' and medical officers' reports from the wintering groups and his own involvement in the dispatch of thirty expeditions from Australia. Law stated that Antarctica

> '...*is an environment in which men and their behaviour can be subjected to searching scrutiny*',

and he felt

> '...*that observations which are made and lessons which are learnt must have important implications for the more complicated urban environment* ...'

The United States Naval Medical Neuropsychiatric Research Unit has collected, analysed and published psychiatric screening and sociometric data since 1955 and American investigators in Antarctica have done a considerable amount of work on mental stress factors, psychological reactions and adjustment (Gunderson, personal communication). Aspects of isolated living at several U.S. Antarctic stations were reported on by Mullin, Connery and Wouters (1958).

Mullin and Connery (1959) found that the lack of female company did not cause any serious problem in men wintering over, while Rohrer (1959, 1960) reported that there was an increased sensitivity to physical and social stimuli with the onset of winter. Mullin (1960) postulated that psychological factors were most likely to be the cause of midwinter insomnia.

McGuire and Tolchin (1961) reported on group adjustment at the South Pole, where much friction existed between the civilian and service sub-groups forming the wintering expedition.

Despite the increases in the psychological and psychiatric studies in the late fifties, Palmai (1963a) stressed the lack of literature on the subject of psychological problems in Antarctica.

Smith (1961) who studied the recruitment, selection and performance of scientific personnel in Antarctica during the IGY, also commented on the data available. He wrote

> '*The literature on personnel selection is considerable but little of it is aimed specifically at selection for polar regions. Of the few studies done, most have been conducted by the armed forces and concern service personnel*'.

Following the WHO conference on Medicine in the Antarctic in 1962 at which a number of unpublished papers was presented on psychiatric and psychological topics (World Health Organisation, 1963; Nelson, 1963a, 1963b) further research has been reported and this has been summarised by Wilson (1965).

1.2.5 Cold injury

Although most of the information and research of cold injuries has been obtained from studies in the Arctic and northern hemisphere it is pertinent to review cold injury briefly, as the prevention of cold injury has been of great importance to all Antarctic expeditions. From reviewing the medical literature of Antarctica it is apparent that cold injury of a minor nature occurs frequently, but the incidence of serious conditions leading to gross gangrene and tissue death is very low.

Atkinson (1915), writing of his experiences in Antarctica compares frostbite with the effects of a scald. The occurrence and attitude of the men to minor cold injury which Atkinson described as '*frost-bites of first degree*' can be seen from the following:

> '*While out of doors, it was quite a common and even laughable experience to see a patch of white on the nose or cheek of a companion, who at the time was unconscious that anything was wrong*'.

Cold injury has been with man since his earliest days in the glacial era and his survival is due to his behavioural adaptation and skill in combating the cold weather. Cold injury does occur among civilian populations, but the classical descriptions of this condition have followed military campaigns beginning with Alexander the Great, king of Macedonia, whose campaigns were recorded by Xenophon. Baron Larrey (1817) has written of the role of cold injury in the retreat of Napoleon's army from Moscow and subsequent defeat in Poland in 1812.

Further descriptions have come from the Crimean War and both World Wars I and II in which cold injuries have been given names such as trench foot, shelter foot and immersion foot. A recent monograph by the United States Departments of the Army, the Navy and the Air Force (1970) gives the total incidence of time-lost cold injuries during World War II as 90,535. This figure included trench foot and frostbite in ground troops, and high altitude frostbite in air crews. In Korea more than 9 000 cases of cold injury were experienced by United States troops, 8 000 of these occurring in the winter of 1950-51. The experiences of the U.S. Military Services are described in an official publication - *Cold Injury, Ground Type* (1958).

The *Cold Injury Series* of the Josiah Macy, Jr. Foundation (Macy Foundation, 1951-60), Washburn (1962) and the *Proceedings* of the Symposium on Arctic Medicine and Biology (Viereck, 1964) detail cold injury of military, polar and high mountain explorations. These publications also describe the management of cold injury and the various theories of the poorly understood pathogenesis of tissue injury resulting from cold exposure.

1.3 THE PRESENT STUDY

1.3.1 General

Living for a year on an Antarctic station is an unusual experience with its complete isolation, confinement, restricted activity, enforced intimacy and social deprivation. Although many of these conditions do exist in urban life in such establishments as prisons, and in remote survey, mining and military camps, none of these situations have the total isolation of Antarctica. Voyages of nuclear submarines as described by Weybrew (1963) are isolated but the duration of these voyages is only several months.

Wilson (1966) attempts to describe the isolation in Antarctica in an entry in his diary for Thursday 22 May 1902:

> *'The stillness was almost uncanny. One could imagine oneself in another dead planet. I could easily imagine we were standing not on the Earth but on the Moon's surface. Everything was so still and dead and cold and unearthly. We had some nights like it in Davos, (Switzerland) but they were noisy compared with the absolute silence here, which one felt as a thing that had been broken by nothing but wild nature's storms, since the beginning of the world. I can't describe it.'*

This isolation is also apparent in Amundsen's (1912) description of a gramophone concert at Framheim. He describes it thus:

> *'As the notes rang clear and pure through the room, one could see the faces grow serious. No doubt the words of the poem affected them all as they sat there in the dark winter night on the vast wilderness of ice, thousands and thousands of miles from all that was dear to them.'*

Allied with the isolation factor is the different thermal environment encountered. Most men wintering in Antarctica come from the densely populated temperate and tropical regions.

The historical review in section 1.2 shows the diverse nature of researches in human biology, many of which have necessarily been of a simple nature. This simplicity was necessary because polar medical research was an additional project for the medical officers, and laboratory facilities were primitive compared with those provided for the natural sciences.

The totality of the medical observations up to 1962 constituted a substantial body of knowledge but these observations were fragmented, with only one topic being described in most reports; in few cases has any synthesis been attempted. Many of the investigations assume that the environmental stresses encountered in Antarctica adversely affect physical and mental health. These underlying assumptions are due to the abundance of anecdotal reports.

Anecdotal reports have not all given false impressions, and many have made valuable contributions to our knowledge. Much observed in early years has remained to be explained later. An example of this is Mawson's (1915) observation of the serious illness suffered by himself and the death of Mertz while dog-sledging on the Australasian Antarctic Expedition. It was not until more than forty-five years later that further work (Cleland and Southcott, 1969; Southcott, Chesterfield and Lugg, 1971) has suggested that the illnesses were due to hypervitaminosis A after eating liver from the husky dogs, which were killed following the loss of most of the food supplies.

My appointment as medical officer with the 1963 Australian National Antarctic Research Expeditions to Davis enabled me to exploit a situation where observations could be made on a nine-man isolated group over a year. It was decided to undertake a broadly-based series of investigations which could be used as the means of providing an integrated picture of life in Antarctica. Many topics had been examined previously in "isolation", but no one had attempted a study in breadth nor assessed the totality of the adaptation in an Antarctic environmental epidemiological study, human adaptability being the central problem in environmental epidemiology.

The results of the study suggest that some physiological adaptation takes place, but the overall adaptation of the group was influenced to a greater degree by behavioural and psychological factors.

Constraints imposed by the environment on the previous studies also limited the Davis study. These constraints included the lack of a sophisticated laboratory, the small number of men, and their availability as subjects due to other tasks they were called upon to perform. It was originally intended to do a comprehensive time and motion study on all nine subjects, but when a pilot program was commenced during the voyage south it was apparent that such a program was impracticable. It was therefore abandoned. The other individual programs were completed as planned.

1.3.2 Monthly physiological measurements

Physiological measurements were carried out at monthly intervals and included assessment of body weight, skinfold thickness, arm circumference, pulse rate, blood pressure and oral temperature. Both basal and casual levels of these variables were taken.

The monthly measurements were a good index of the physiological status of the men as many of the variables had been measured on other polar expeditions which made comparisons possible between this study and others.

1.3.3 Field studies

Loss of body weight by men sledging in Antarctica has been observed on many occasions (Ekelöf, 1904; Massey, 1956; Wilson, 1960). The weight lost is rapidly regained after return to base. Although the weight changes form a standard pattern, the cause for these changes is not known.

On the major field traverses inland, in addition to observing the changes in body weight and skinfold thickness that resulted from these field projects, the calorie intake and energy expenditure were calculated so that any resultant changes could be assessed in relation to dietary intake and energy expenditure.

1.3.4 Cold exposure and activity

The men on polar expeditions spend only a portion of each day out of doors. It is necessary in a study of acclimatisation and thermal comfort to analyse the amount of time that the men are exposed to the varying thermal environments. It is possible that the cold exposure is low at modern Antarctic stations and this fact together with the effective clothing worn may mean that the stimulus provided by the environment is not enough to cause cold adaptation. The importance of the climatic stress and activity patterns, especially in relation to the environment, has been discussed by Norman (1962) and Lewis and Masterton (1963).

The Davis study proposed to ascertain what cold stress actually occurred and what activity the group experienced. An additional aspect involved assessing the time spent by the medical officer in all phases of his work, as no previously published reports were available with this information.

1.3.5 Thermal comfort studies

The results of thermal comfort investigations done in Antarctica up to the time of this study have been reviewed in section 1.2. Observations such as those of Wilson (1966) in 1902 -

> *'At freezing point, so acclimatized have we all become to the cold, we feel quite warm and can work in absolute comfort with wet fingers for hours. When the temperature out of doors goes above zero, as it is beginning to do nowadays, we feel it just as comfortable as a warm sunny day at home'* -

have resulted in further studies (Frazier, 1945; Butson, 1949; Goldsmith, 1960). Despite these more objective investigations there is still much to be learnt concerning factors which determine thermal comfort in extremes of cold.

In the present study an attempt was made to define the limits of indoor temperature and the clothing worn indoors, and the environmental temperature and the clothing worn out of doors, and to evaluate the evidence for acclimatisation which changes in these with time might provide.

1.3.6 Health of the expedition

The expeditioners wintering at Australian stations are physically healthy and mainly in the age group 20-45 years. They are motivated people who have volunteered to accept a strenuous life in Antarctica for 12-15 months. No complete account of clinical observations from a wintering Australian expedition has previously been published.

In an epidemiological study clinical aspects are considered important despite the likelihood of a low incidence of disease. The health and morbidity study was undertaken to see whether changes of clinical importance occur during a year in Antarctica, what the injuries and illnesses are, and when they occur.

1.3.7 Psychological adaptation

The interaction of psychological changes resulting from stresses, with the physiology and health of a small group and their behavioural adaptation, are still largely unknown. The WHO conference (World Health Organisation, 1963) considered that mental health difficulties were probably the most important of all health problems and that assessment of performance in the field was necessary.

The psychological investigation was undertaken to study the Davis group's responses to situations and stress, interpersonal adjustments, group adjustive behavioural phenomena, and the general pattern of psychological adaptation.

1.3.8 Morbidity and mortality at Australian stations, 1947-72

Preliminary information on morbidity and deaths by Hedblom (1961) has shown that the risk of injury or psychiatric disorder for United States naval personnel in Antarctica is low, but somewhat higher than elsewhere. No corresponding figures were available for ANARE and so a survey of all expeditions was undertaken following the Davis study to give a factual report on the health of ANARE personnel.

The analysis of medical records at Australian stations over a period of years enables the risks of different types of illness or injury to be objectively established, as well as the patterns of illness from different geographical locations, and the seasonal trends. A further aspect was the testing of the hypotheses that health problems appear to be concentrated in a relatively small proportion of the population (Hinkle, Pinsky, Bross and Plummer, 1956), and that individuals having multiple illness episodes tend to have them concentrated during periods characterised by unusual life stress (Hinkle and Wolff, 1958).

1.3.9 Comparison studies in the Arctic

It was decided to confine the clinical studies of health, psychological adaptation, morbidity and mortality to Antarctic and sub-Antarctic populations, and not to compare them with Arctic groups. Most of the work done in the Arctic has been of an anthropological nature and has concerned itself with the indigenous inhabitant and not the non-native group. These two groups have also created problems between their two cultures. It was therefore considered that these cultural differences, the presence of women, the presence of endemic and chronic diseases, and the lack of total isolation made comparisons between the Arctic and the Antarctic invalid.

2. THE ENVIRONMENT

2.1 DAVIS STATION

2.1.1 General

In 1947 the Australian Government established the Australian National Antarctic Research Expeditions (ANARE). Since that time Australia has continuously maintained stations on the Antarctic

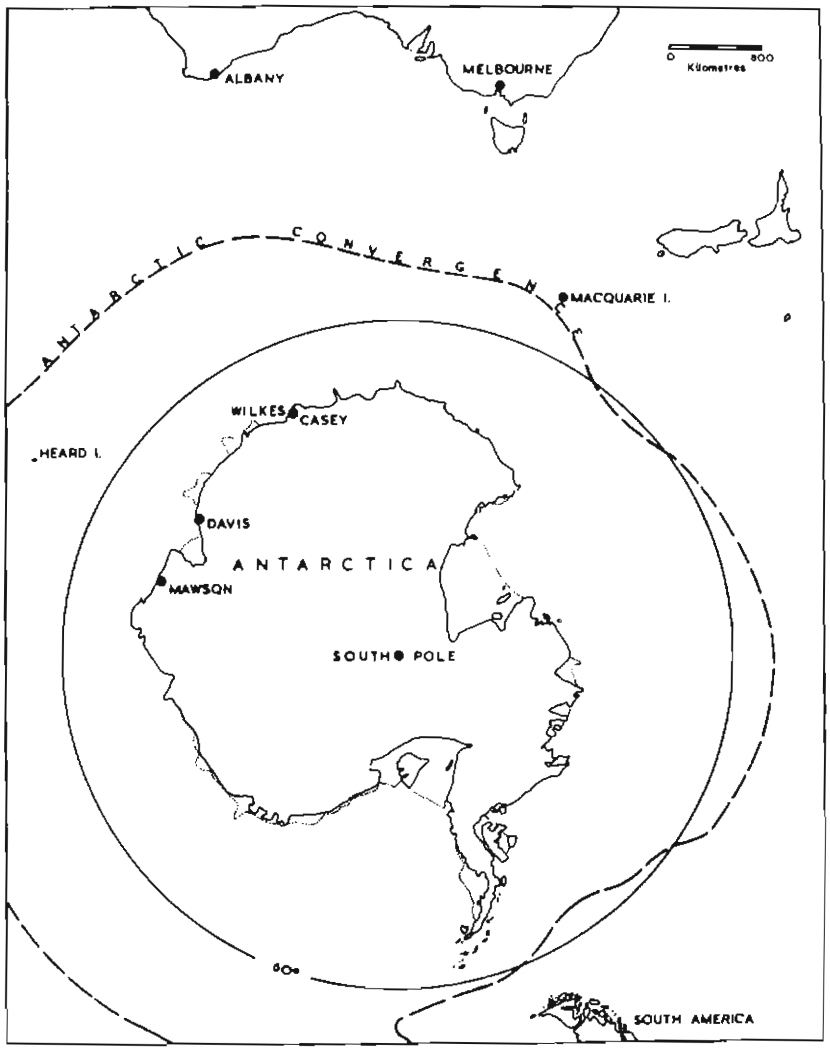


Figure 1. Antarctica and the Southern Ocean

continent and sub-Antarctic islands. Figure 1 shows the locations of the stations, and a list of expeditions and the number of personnel wintering at each station is incorporated in Appendix 6. Law and Béchervaise (1957) and Swan (1961) have published general accounts of ANARE.

Davis (68°35'S, 77°58'E) is situated in the Vestfold Hills on the east side of Prydz Bay in Princess Elizabeth Land, Antarctica. Princess Elizabeth Land was discovered and named by Sir Douglas Mawson's BANZAR Expedition of 1929-31 (Mawson, 1931). Captain Klarius Mikkelsen (Mikkelsen, 1935), master of the Norwegian ship *Thorshavn* first sighted and named the Vestfold Hills on 20 February 1935 when leading an expedition for Lars Christensen. The hills were named after an area in Norway because of the striking resemblance between the two localities.

In 1954 and 1955 members of the ANARE made landings in these hills, and in 1957 the station Davis was established. It was named in honour of the Antarctic navigator, Captain John King Davis.

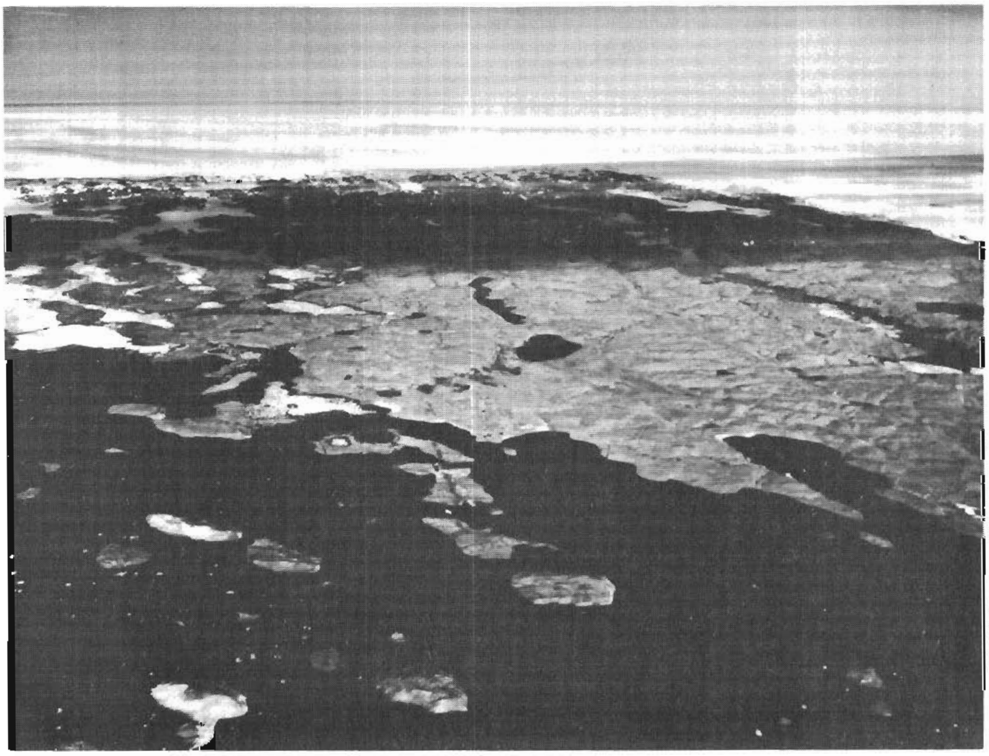


Plate 3. Aerial view, taken in January, of the Vestfold Hills looking in a south-easterly direction. The continental ice of the polar plateau surrounds the Vestfold Hills. The Sørsdal Glacier is to the right. The numerous offshore islands, lakes and winding fjords which run to the polar plateau are clearly shown. To the left the white fast sea ice is still present in Long Fjord. (Photograph by P. G. Law)

2.1.2 Station site

The station is built on the edge of the 500 square kilometre triangular ice-free rocky area forming the Vestfold Hills (Plate 3). This rocky region, which has the inland ice sheet to the east, the Sørsdal Glacier to the south and numerous offshore islands has been described by Law (1959). The hills are hummocky in nature, rising to a maximum height of 158m, and are indented by moraine-filled valleys, long narrow fjords and numerous lakes (Figure 2). McLeod (1963) has described these lakes the water content of which varies from fresh to extreme salinity.

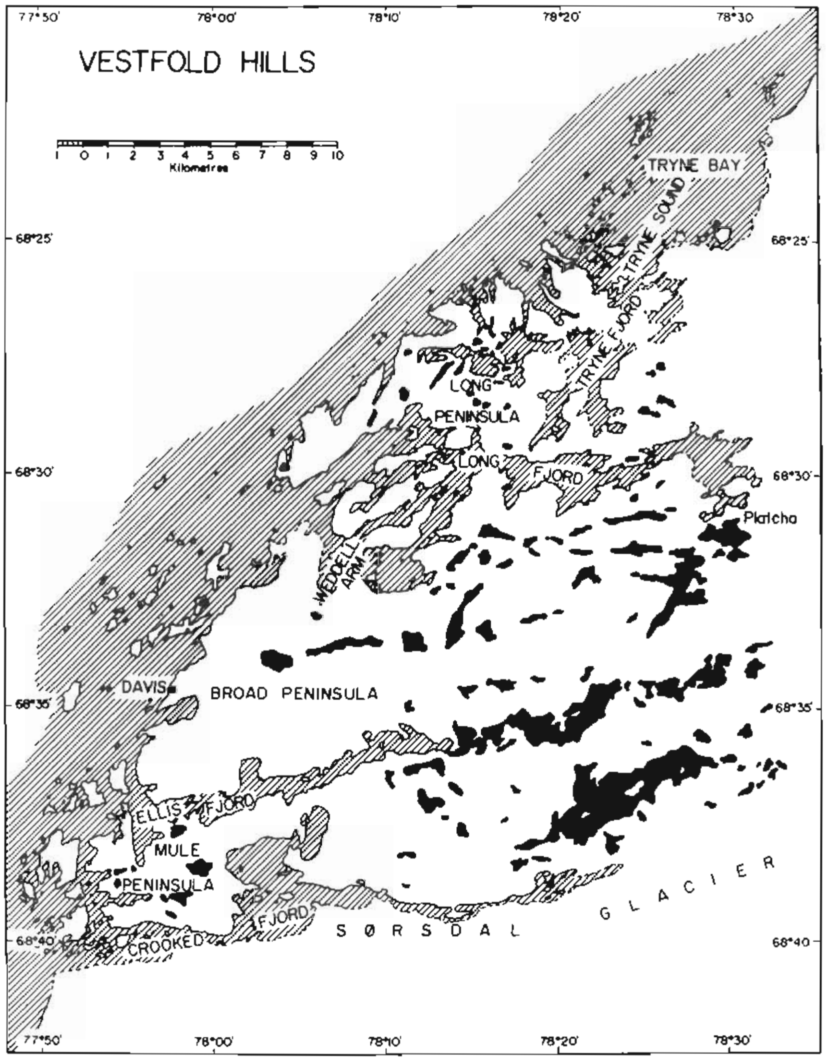


Figure 2. Map of the Vestfold Hills, Antarctica.

The main local rock is gneissic granite, criss-crossed with broad black dolerite dykes (Crohn, 1955, 1959). The Vestfold Hills area is one of several ice-free "oases" on the Antarctic continent.

2.1.3 Station construction

The main building complex at Davis is sited along a line across the

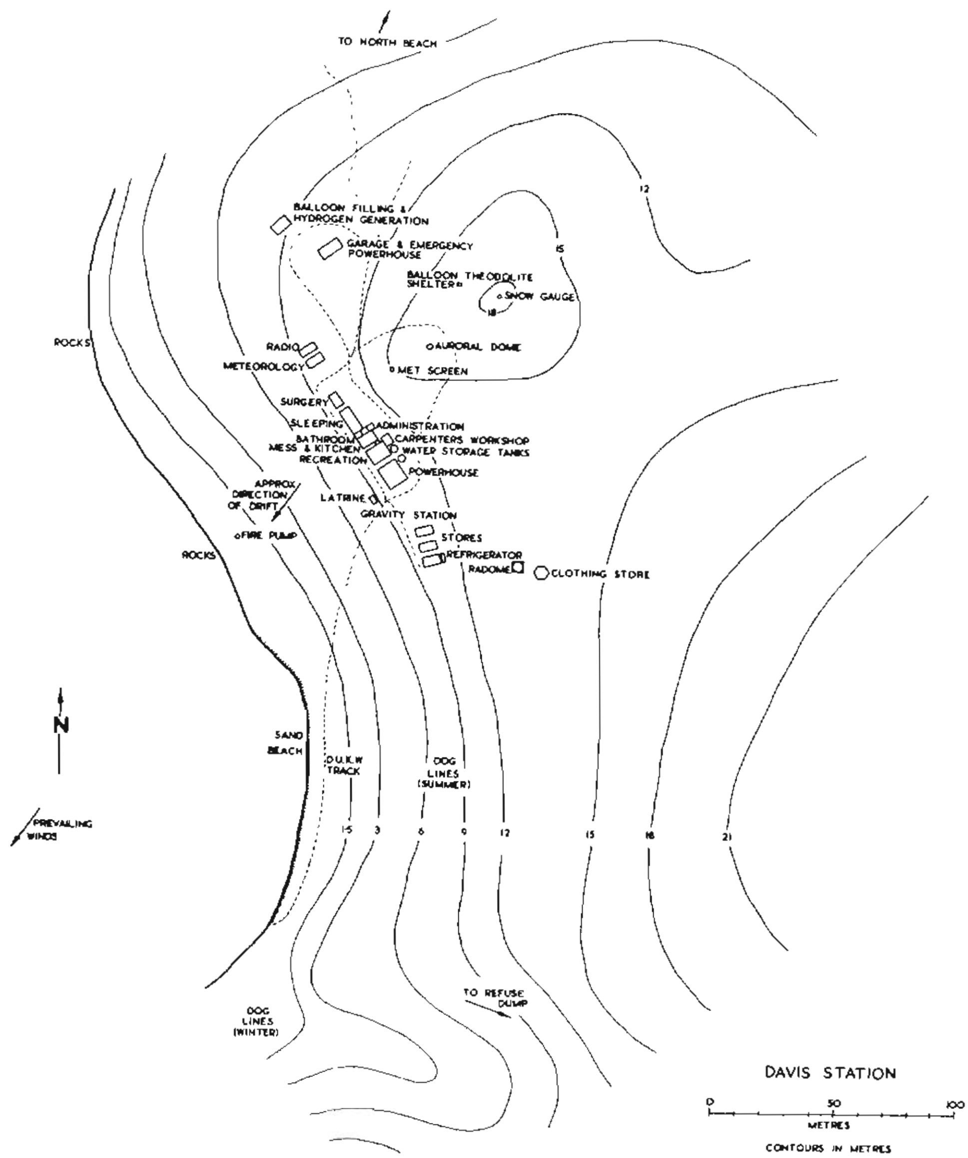


Figure 3. Plan of Davis station 1963.

prevailing wind and close to the shore. The site plan (Figure 3) shows the station buildings and the irregular contours of the rock surface on which they are built. The buildings were separated where possible to diminish the risk of fire.

The basic building design of Australian stations has been discussed by Styles, Brown, Smith and Lukinovic (1963). The flat-topped box-like buildings were constructed by clamping together prefabricated wall panels of either plywood, steel or aluminium with a core of insulating foamed rigid polystyrene. The buildings rested on wooden stumps or scaffold piping and were firmly tied down to the rock by cables rigged to roof brackets. This type of construction had been used for rapid erection by the expeditioners themselves.

During winter, drifts formed in both the lee and upwind sides of the buildings and this caused access problems, but in summer all the snow ablated.

The buildings were heated by oil, electricity or an integrated-energy central heating system (Brown, 1968), which utilised waste heat from the two diesel-electric generators. The more modern of the buildings had entry porches which acted as a trap to prevent the entry of wind and snow, or loss of heat when the inner door was opened. Such porches were uninsulated and, since they remained cold, snow-covered outer clothing hung in them did not thaw nor become wet.

2.2 THE 1963 EXPEDITION

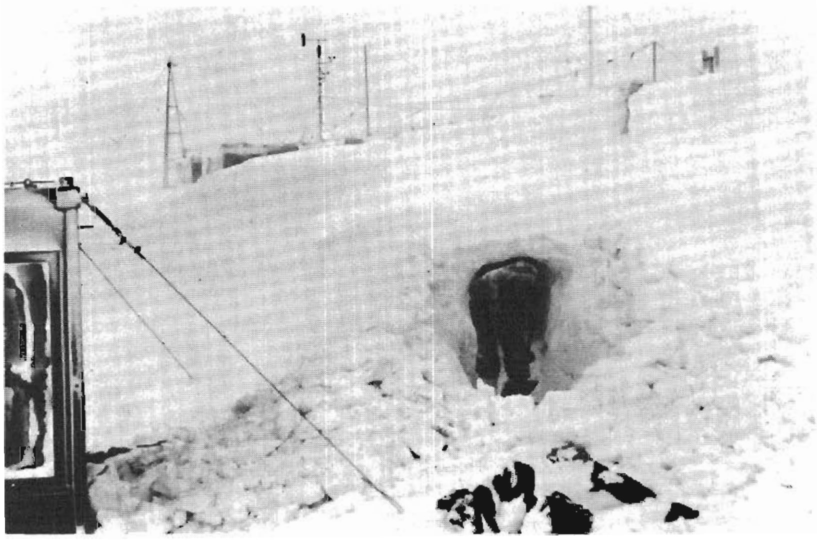
2.2.1 Relief voyages

The 1963 wintering expedition departed from Melbourne on 9 January 1963 aboard the Danish ice ship M.V. *Nella Dan*. The Davis expedition was one of three on board, the other two being a summer group for Heard Island and the 1963 wintering expedition for Mawson. The planned itinerary was changed during the voyage as one of the men going to Mawson developed appendicitis. The *Nella Dan* returned to Albany in Western Australia where it stayed for twenty-four hours.

Heard Island was reached on 26 January and four days were spent in this area. On 2 February the Mawson changeover began. This involved about nine days of hard physical labour. The stores for the following year were unloaded from the ship and transported ashore by amphibious Army DUKWs.

On 15 February, three days after leaving Mawson, the *Nella Dan* arrived at Davis and six days were spent unloading equipment and supplies for the Davis expedition. Following the departure of the *Nella Dan* on 21 February 1963 the nine men were completely isolated until the ship returned on 29 February 1964.

(a)



(b)

Plate 4. The road in front of the main building complex at Davis. (a) A view taken during summer following the first snowfall. (b) A member of the expedition clearing the entrance to the access tunnel following a winter blizzard. (Photographs by D. J. Lugg)

The nearest occupied stations to Davis are the Russian base Mirny, 670 km to the east, and Mawson, 610 km to the west.

2.2.2 Personnel

The nine men who made up the 1963 Davis expedition were:

Officer-in-Charge

Cook

Medical Officer

Radio Operator

Radio Technician/Operator

Three Weather Observers

Weather Observer (Radio)

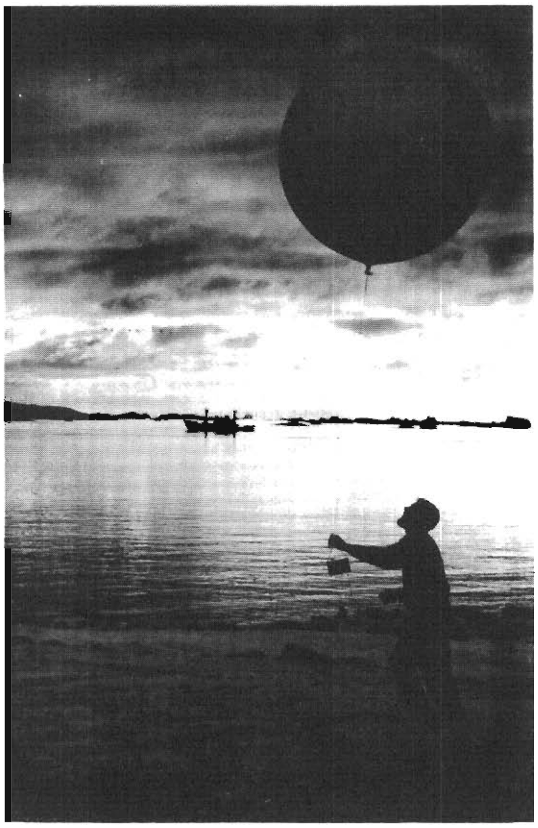
2.2.3 Station duties

As is the case on all small expeditions, the men not only performed their own special duties but did other tasks as well. The Officer-in-Charge (OIC) ran the powerhouse and was responsible for the power, heating and water reticulation as well as the construction program, while the cook did most of the carpentry and assisted with all construction works, as well as doing the engine maintenance while the OIC was absent. The care of the fire-fighting equipment and the preventive measures associated with this were the responsibility of the radio technician. The radio operator and one of the weather observers cared for the dogs, while the photographic work and some aspects of the construction were done by the weather observers. The medical officer attended to the administration in the absence of the OIC, acted as messing officer, storeman, biologist and assisted in general construction and labouring.

In addition to the work outlined above, general station duties were shared by all men. These duties were mainly manual in nature as the station did not have mechanical facilities for the work. All fuel for Davis was in conventional 44-gallon drums and had to be dug from snow drifts and rolled over the snow to the powerhouse for pumping into the reserve tanks. This was intense physical labour. Construction work and building maintenance also had to be done.

The digging of tunnels and steps to gain access to the buildings was a task that was present throughout winter. The author spent at least thirty minutes of most days digging out supplies or the doorways.

Waste disposal necessitated loading a trailer or sledge and driving either the Snow-Trac or the tractor to the summer dump on rock or on to the sea ice during winter. Water was gathered in the form of small



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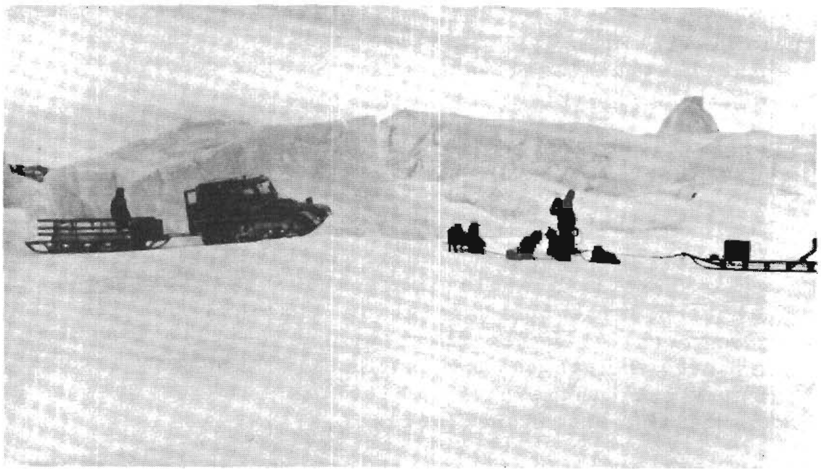


(b)

Plate 5. Station duties at Davis included meteorological balloon flights and the collection of ice from icebergs for water. (a) A radio-sonde balloon being released during changeover. The relief ship can be seen in the background. (b) Men about to break ice from a grounded iceberg. The dog team and Snow-Trac travelled over three kilometres across the sea ice to reach these icebergs. (Photographs by D. J. Lugg)

pieces of iceberg which were washed up on the sandy beach during summer. When the sea ice became solid many hours a week were spent in driving vehicles or dogs to icebergs 3-4 km from the station where picks and crowbars were used to break up the grounded icebergs for melting into water.

Sealing was one unpleasant task that was necessary to feed the husky population. Occasionally seals were shot and flensed on the sea ice near Davis, but most times journeys of 10-30 km were necessary to the Weddell Arm area or Crooked Fjord (Figure 2).

Night-watch occurred for each man once every nine days, or more frequently whenever men were absent in the field. Night-watch duties consisted of cleaning up the kitchen, the mess and the recreation room, doing meteorological observations at 0200 (Davis time), ensuring that the buildings were being heated and that the powerhouse fuel tanks had sufficient fuel. Following night-watch all men slept in and did not get up for breakfast. Duty cook was another task in which all men took turns cooking for the group on a Sunday when the cook was given a day off.

2.2.4 Recreation

The station had an excellent library, record player, records and taped music, a variety of indoor games such as darts and table tennis, and fifty 16mm feature films. Films were shown several times a week and were most popular. 'Ding' nights were held on birthdays, at mid-winter and on other special occasions, and on these nights additional beer and wines were provided above that issued weekly to each man.

Model aeroplane flying, motor cycling, football and walking were pursued on the sea ice at one time or another. Most men were interested in photography, and ham radio and skiing were popular with several. The training of the huskies was one strenuous form of relaxation and all men enjoyed this greatly.

2.2.5 Clothing

One of the most important factors in man's ability to survive in Antarctica is efficient clothing. The simple but efficient use by the Eskimos of a tent-shaped garment of warm fur which can be opened either at the top or bottom has been shown by Milan (1962) to provide this race with almost total protection against cold exposure. Siple (1945) and Law (1965) have discussed the general principles governing the selection of modern polar clothing. This clothing is, however, still less efficient than that of the Eskimos (Rodahl, 1960).

Linton-Smith (1968) has described the clothing worn by Australian expeditioners. The Davis group was equipped with such clothing. The principle of this clothing is to clothe the body with a number of layers of warm material of a cellular, permeable type and to cover these externally with a light windproof envelope. During the year, the clothing worn by the men in the vicinity of the station was fairly standard despite individual preferences and this agreed with other workers' assessments of men working in polar climates (Masterton, 1958; Edholm and Lewis, 1964).

Plate 6. Clothing worn by men travelling away from the station. The man in the centre is wearing light windproof parka and trousers; the others heavier Ventiles. (Photograph by D. J. Lugg)

The significant feature of the clothing assemblies at the station was the universal way in which all members of the expedition refused to wear extra outer clothing in their movement from one heated building to another, unless there was a blizzard. As all the work huts were distant from the main living complex (see Figure 2), this meant that all nine men frequently were cooled each day, during their movement from one area of the station to another.

When men left the station area for short periods of time, light windproof parkas were usually worn with cotton combination overalls or windproof trousers, but when the field work involved greater distance or when on the polar plateau, heavier Ventile clothing was worn (Plate 6). Similarly, cold-wet leather boots which were worn in summer months were changed to mukluks (a rubber-soled loose-fitting vapour-permeable nylon or canvas boot worn over woollen and duffel socks) or thermal vapour barrier boots in winter.

2.2.6 Food

The occurrence of both hypovitaminosis (Kendall, 1955; Paleev, 1959) and suspected hypervitaminosis (Cleland and Southcott, 1969; Southcott *et al.*, 1971) in Antarctic expeditions outlined one of the many problems that have occurred in the victualling of polar groups.

Bell (1957) reviewed rations used in polar areas and described the organisation of the ration scales for the New Zealand Trans-Antarctic Expedition. Work such as Bell's and that of Law (1957) and Csordas (1958), who have discussed aspects of the victualling at Antarctic stations, have resulted in excellent food being available at Australian stations.

At Davis, bread was baked frequently and there was a plentiful supply of meat. Fresh frozen meat was eaten at least one meal per day with the balance coming from tinned and preserved supplies. Early in the year fresh fruit and vegetables were available, but later deep-frozen, tinned and dehydrated supplies were used. The fresh vegetables deteriorated earlier than expected due to the rapid growth of a mould (genus *Penicillium*) when the fresh supplies were put in the warmed food store. Even in Antarctica the preservation of food is important, as Kefford (1956) outlined in his report of food storage in Antarctica.

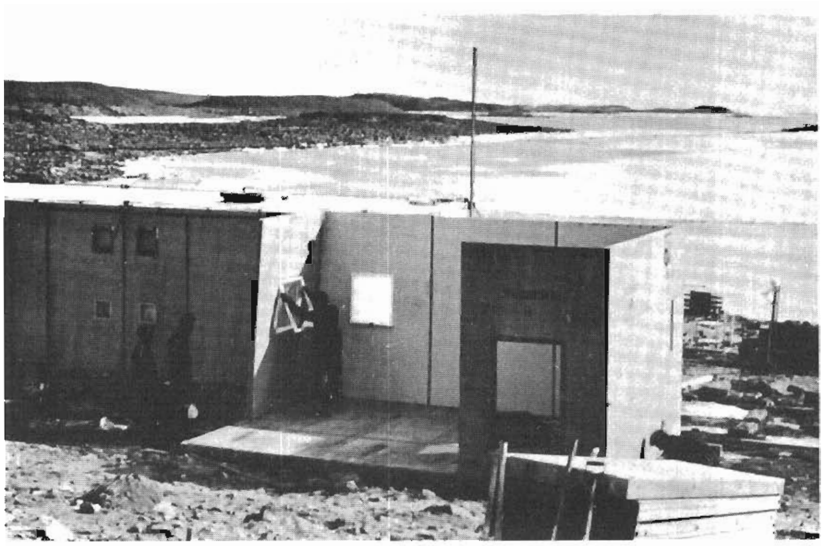
Vitamin supplementation was given to those who desired it at the station as this was the Antarctic Division's policy, but in the author's opinion it was not necessary. Vitamin tablets were, however, necessary in the field rations which, although of satisfactory calorie value, were very limited in variety because of weight considerations. These rations were mainly concentrated meat blocks like pemmican and HF6 (Horlicks), rolled oats, biscuits, egg powder, dehydrated vegetables and chocolate. In general it was considered by the author that most expeditioners ate better in Antarctica than they did in Australia.

2.2.7 Medical establishment

The surgery at Davis in 1963 was still fairly primitive compared with the modern surgeries that have been erected at all ANARE stations in the last few years (Smith and Lugg, 1968). The standard of medical practice was therefore not as high as the present practice described by Lugg (1966b, 1970, 1972).

The surgery building, which was relocated and improved during 1963, (Plates 7 and 8) was a single room 5.5 x 3.7 metres. It housed a small medical library, essential surgical instruments and medical and dental equipment and supplies. An examination couch doubled as an operating table and a portable x-ray plant was a valuable diagnostic aid. There was no autoclave, but a small steam steriliser and a household pressure cooker were used for sterilisation. A small ether-air anaesthetic machine completed the equipment.

Three of the station personnel were trained in the administration of anaesthetics and in operating-theatre techniques before leaving Australia and were available to assist the medical officer in emergencies.



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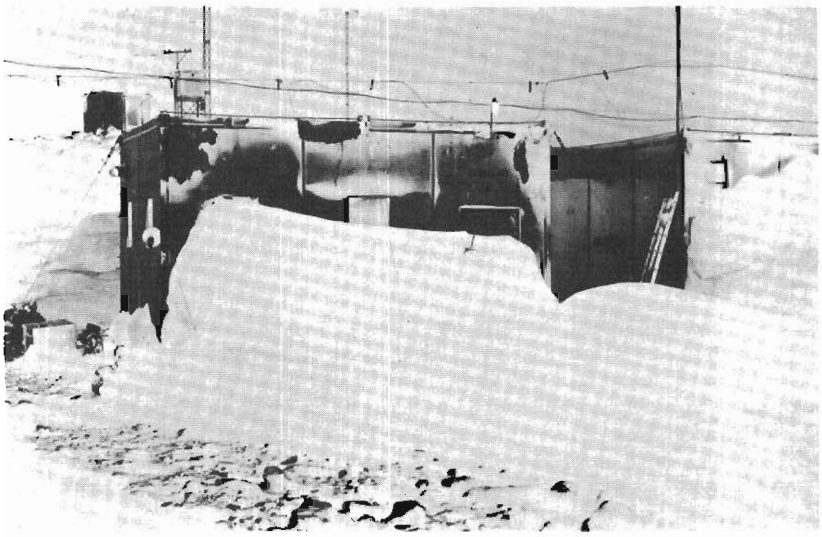


(b)

Plate 7. The Davis medical building. (a) The surgery being rebuilt during January 1964. The prefabricated style of building construction is shown. (b) The building during winter 1963. (Photographs by D. J. Lugg)

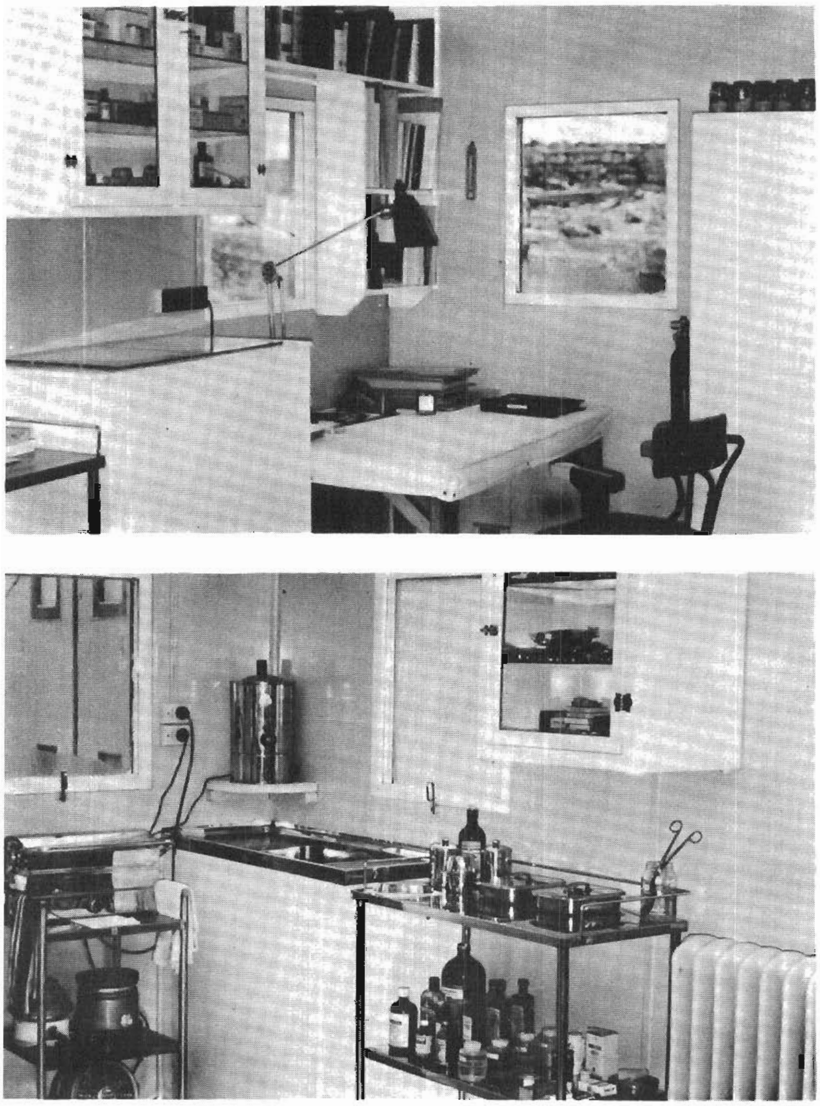


Plate 8. The Davis building: Interior views of the rebuilt surgery. (Photographs by D. J. Lugg)

2.2.8 Communications

Radio was the only form of communication between Davis, Australia and other Antarctic stations. The traffic to and from Davis was relayed via Wilkes and Mawson. On a number of occasions a radio "blackout" occurred as the result of atmospheric PCA (polar cap absorption) events, preventing communications for periods of several days at a time.

2.2.9 Transport

The four means of transport used at Davis were tractor, Snow-Trac (Smith, 1962), motor cycle and dog teams. Vehicles could only be used on the tracks and roads in the Davis environs in summer and on the sea ice during winter. On the mainland outside the station area, walking was the only manner of travel. The husky population of between twenty and thirty dogs covered over 2000 km on sea ice and plateau journeys during the year. The Snow-Trac covered 3000 km during the period from April 1963 to January 1964.

2.3 EXPEDITION PROGRAM

2.3.1 Construction

The 1963 expedition had a large construction program. Among the new buildings constructed in 1963 were a kitchen and mess, bathroom, emergency power house and administrative office, while the old engine room was converted into a recreation and library building.

New generators, diesel engines and distribution boards were installed. The power reticulation was changed from overhead wires to mineral-insulated copper-covered cables buried under the rock and "permafrost".

2.3.2 Science

The following research projects were done in addition to the medical research as described in this thesis. The meteorological program will be described in detail because of the use made of these observations in this study.

(a) Meteorology

Surface observations were taken at Davis at three-hourly intervals starting at 0200 (local standard time). Davis time was GMT + 5 hours. Upper wind observations were normally made three times daily by visual means following either a pilot balloon or a radio sonde balloon, or by electronic means using a radio theodolite following either a radio sonde or a radio transmitter used for wind finding only. Radio sondes were released once daily.

Temperatures were recorded by dry bulb thermometers (^{o}F) and thermographs mounted in a Stevenson screen, the thermographs being used to obtain the daily temperature extremes. A hygrograph provided a continuous record of relative humidity.

Wind records of speed and direction were obtained from Davis anemometers which were 6 m above the station building and about 9 m above the ground.

Precipitation was measured by a shielded snow gauge, but it was not possible to record all snowfall accurately. Daily duration of sunshine was observed using Campbell-Stokes sunshine recorders. Measurements of temperature and humidity in various buildings at Davis were measured using hair hygrographs, sling psychrometers and dry bulb thermometers. During field work, temperatures and wind speeds were observed using hand-held instruments.

(b) Biology

The author was responsible for the execution of the biological program with the assistance of all members of the group. Appendix 4 shows the amount of time spent on this work throughout the year. It ranged from 0.4 hours/day in February to 3.5 hours/day in November.

The completed work has resulted in new information on the location and breeding behaviour of both birds and mammals (Lugg, 1966a; Shaughnessy, 1971; Johnstone, Lugg and Brown, 1973). In December 1963, the author found the most southerly known breeding location (68°38'S) for the giant petrel. This rookery is one of only four in Antarctica. Further field work in which the skin temperatures of elephant seals were measured has been used by Murray, Smith and Soucek (1965) in their study of the louse *Antarctophthirus ogmorhini* Enderlein.

Late in 1963 the author discovered a new species of prostigmatic mite *Tydeus erebus*. This has been described by Gressitt (1967), Strandtmann (1967) and Rounsevell (1976).

(c) Field program

The major field program was a topographical survey from Davis to the Amery Ice Shelf and the Munro Kerr Mountains (Figure 4). The work included astrofixes of the mountains, a preliminary glaciological survey and meteorological observations. The logistic support for this entailed numerous reconnaissance and depot trips and, although the objective was not reached, valuable information was obtained.

2.3.3 Satellite station

A satellite station Platcha (68°31'S, 78°31'E) (Plate 9 (b)) lies near the eastern margin of the Vestfold Hills, at the head of Long Fjord, about 23 km east-north-east of Davis (Figure 2). This was used as a base for all field work on the plateau.

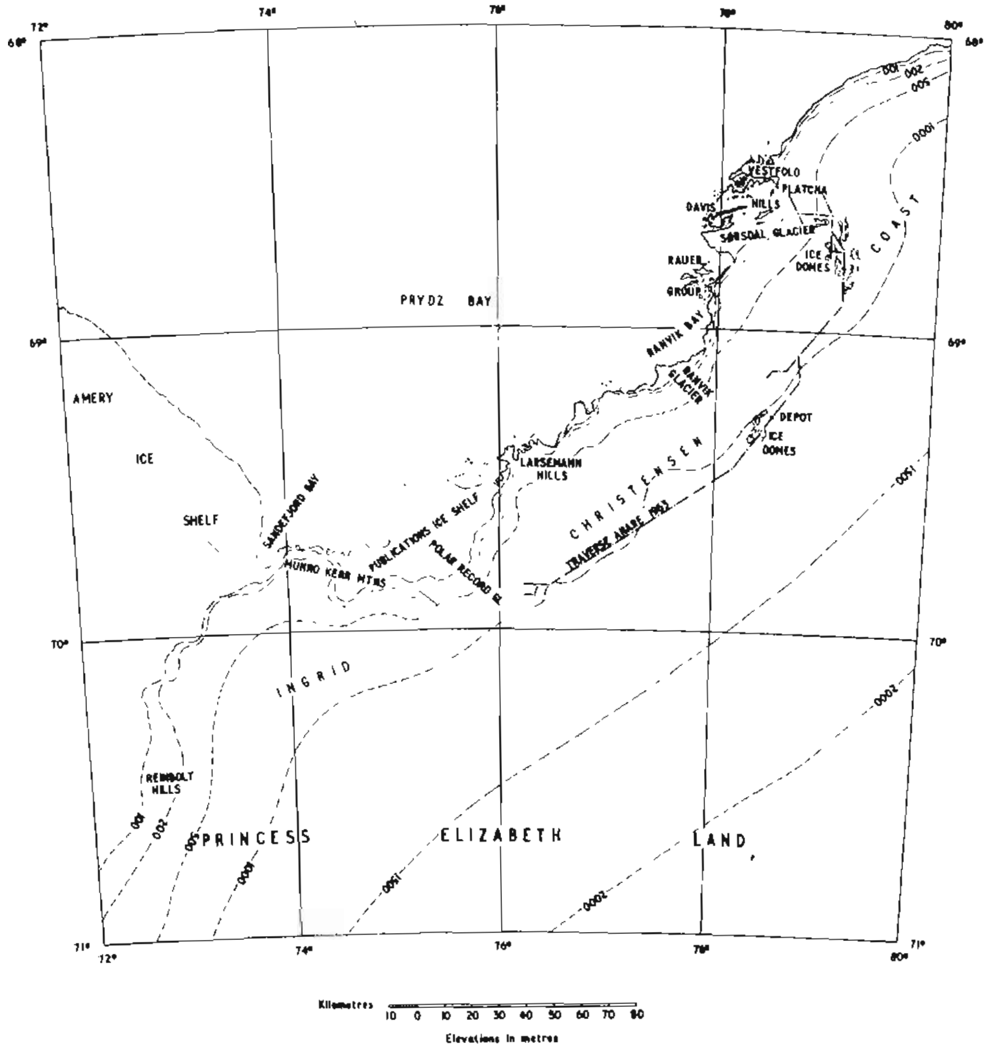


Figure 4. Map of the Ingrid Christensen Coast, showing the main routes of the inland field traverses.

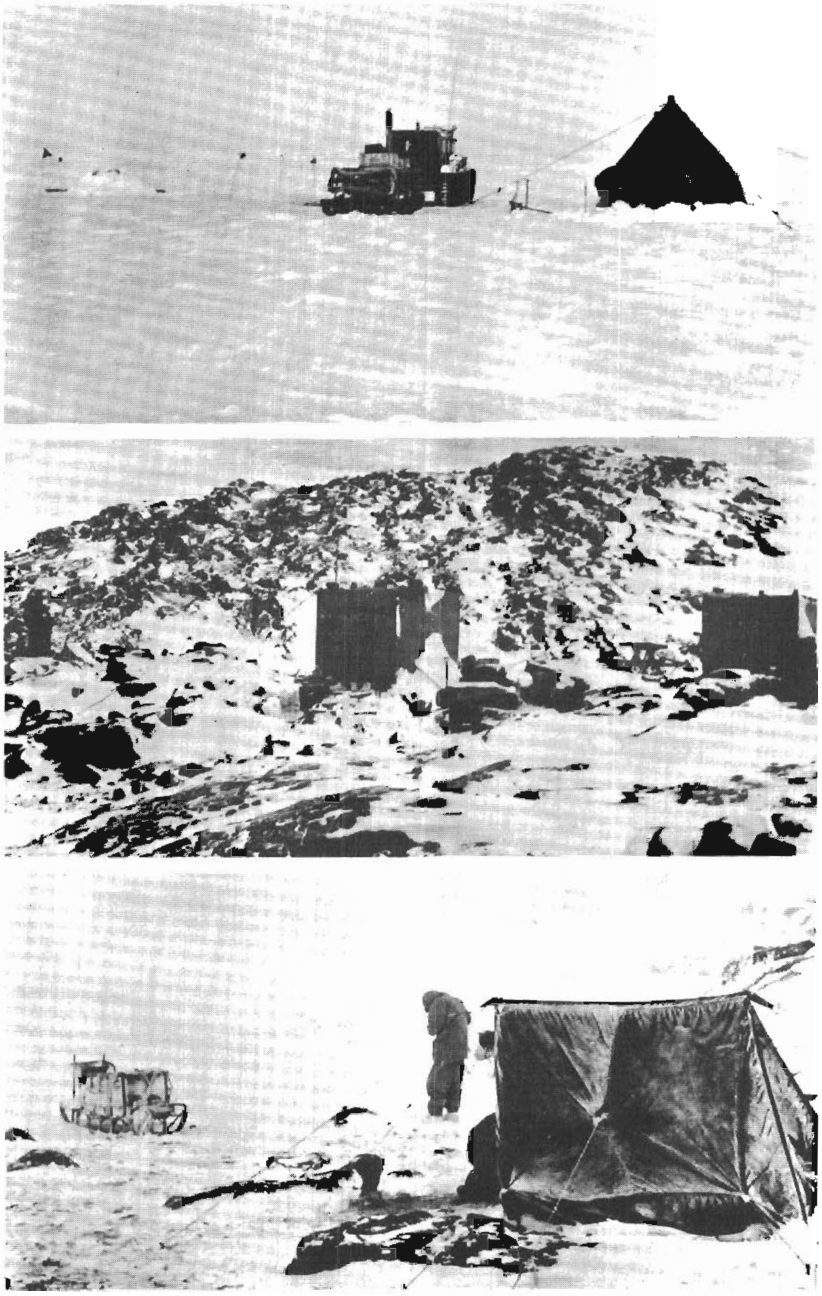


Plate 9. Overnight camp sites used during field programs. (a) The Depot Camp 160 km from Davis. Supplies left for the main dog traverse group are beneath the partly-built cairn to the left of the photograph. (b) The satellite station at Platcha. (c) A sudden blizzard caused a two-man dog-sledging team to make a stop in the area of Long Fjord. The men remained at this camp for three days and nights. (Photographs by D.J. Lugg)

2.4 CLIMATIC FACTORS

2.4.1 Vestfold Hills climate

The climate on the coast at Davis is much milder than that experienced on the plateau, due to the 20 km ice-free land mass breaking up the regular katabatic winds. Lied (1963, 1964) has discussed aspects of this climate and the influence of Prydz Bay on the Davis climate. Stretton (1968, 1969) has made comparisons of the winds at Davis with those in other areas.

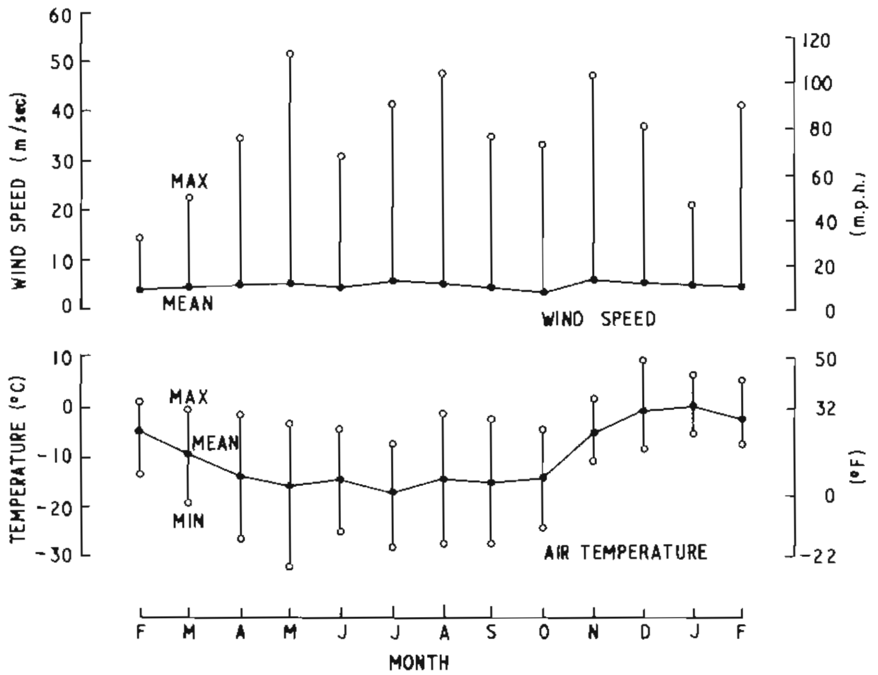


Figure 5. The climate at Davis during the period from February 1963 to February 1964. The mean wind speeds and the temperature were taken from the three-hourly observations and the maximum gust that is recorded each month.

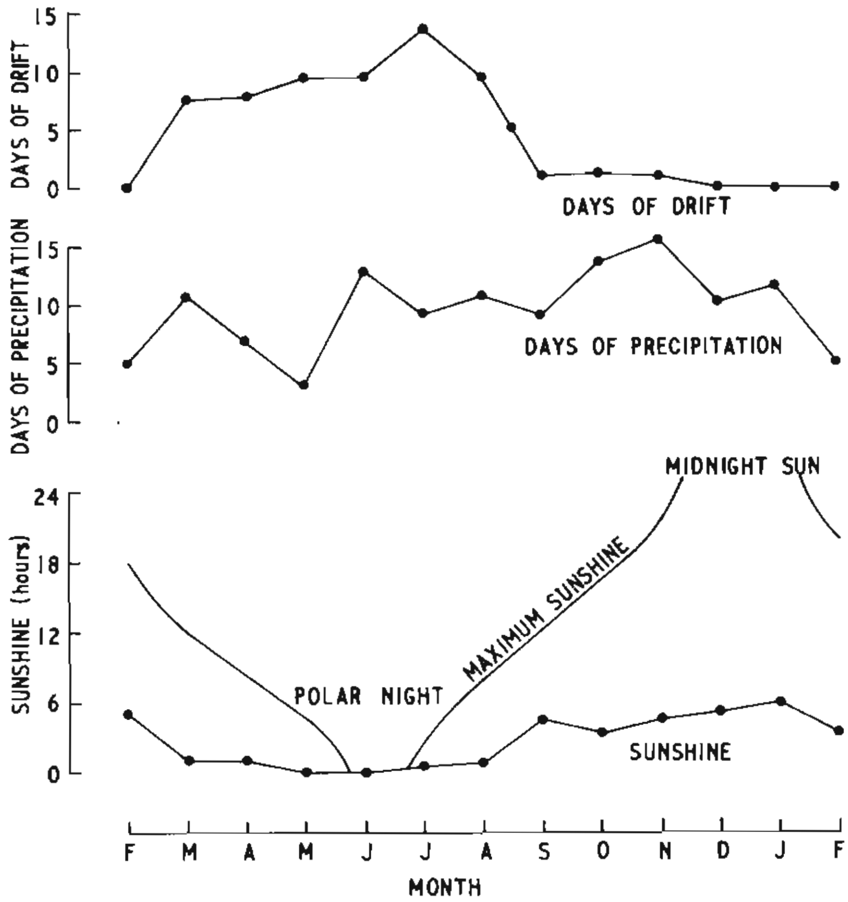


Figure 6. The climate at Davis during the period February 1963 to February 1964. Precipitation of snow was measured by a shielded snow gauge, while the days on which drift occurred were taken from the three-hourly observations. Sunshine means were taken from continuous recordings of sunshine as compared with maximum duration.

Figures 5 and 6 and Appendix 1 summarise the Davis climate. The annual mean air temperature for the period February 1963 to February 1964 was -9.5^{o}C, with a maximum of 9.5^{o}C in December and a minimum of -32.3^{o}C in May. The annual mean wind speed was 5.2 m/sec and the maximum gust of 51.9 m/sec was recorded in May. Drifting snow was recorded on 65 days and precipitation of snow occurred on 124 days. Rain has been recorded in summer.

Fast sea ice is present from March or April until December or January each year. Excessive winds and ocean swells may cause breakouts of this sea ice during the winter months, and in the areas near the Sørsdal Glacier open water is never more than a few kilometres from the land. Sea ice conditions have been recorded by Mellor (1960) and McLeod (1967). In the fjords, sea ice may remain fairly solid during some summers, while in others it breaks up leaving large leads of open water.

The amount of daylight present throughout the year at Davis is shown in Figure 6. It will be noted that the sun was absent for about one month, while twenty-four hours of sunlight was present for over twice this time.

2.4.2 Indoor thermal environment

Appendix 5 shows the indoor thermal environment to which the subjects were exposed. There are gross variations between buildings. The overall temperature was lower than at other Australian stations where studies have been done (Cameron, 1968a).

The relative humidity taken at the time of the thermal vote records was 53 per cent but the mean value for the whole station was 35 per cent. This latter value was recorded on portable hair hygrographs.

2.4.3 Cold exposure of subjects

The station organisation and programs as described in sections 2.2 and 2.3 show that all subjects spent long periods of time outside their heated buildings. The mean number of nights spent away from Davis in tents and at the remote station for the nine men was 30. The author was absent from Davis on daily excursions on 81 days. The time away from Davis on these daily trips ranged from 3 - 4 hours to 20 hours. As all journeys were made by dog teams and in unheated vehicles the cold exposure was considerable.

As stated in section 2.2, the movement and behaviour at the station involved in daily chilling in addition to the cold exposure resulting from sealing, gathering ice and fuel, biological work and construction tasks.

The weather observers spent considerable time out-of-doors preparing for balloon flights and observing the released balloons. The radio staff, in the repair of installations, were subjected to long periods of cold exposure. The collapse of a radio mast in a blizzard resulted in many days of work in the open. The other members (OIC, MO and cook) of the group also spent lengthy periods outside, as their tasks demanded. All of the men spent time outdoors during blizzards, either in the course of their work or to inspect the huskies several times a day.

In summation, the study shows that the Davis 1963 group were exposed more than other groups as described by Soucek (1963), Budd (1964) and Cameron (1968a). This is borne out by the time and motion study.

3. SYSTEMATIC INVESTIGATIONS

3.1 MONTHLY PHYSIOLOGICAL MEASUREMENTS

3.1.1 Materials and methods

(a) General

The experimental situation and the environment have been outlined in sections 1 and 2. The nine men participating in this study were fit, active members of the 1963 wintering expedition at Davis. They were aged between 24 and 33 years (mean age 27.4 on 1 January 1963), weighed between 79.14 and 56.10 kg (mean, 70.34) and their heights ranged between 160 and 183 cm (mean, 175).

Six of the subjects were Australian, one of whom was of Chinese extraction, two were English, and one was born in New Zealand. Of the nine men, one Australian and one Englishman had previously wintered at Mawson in 1961 and the New Zealander had wintered in 1961 at the sub-Antarctic station on Macquarie Island.

Table 1 shows the physical characteristics of the nine subjects all of whom were examined in Australia prior to leaving for Antarctica. This examination gave an initial set of casual physiological variables, but it was not possible to measure the skinfold thickness at this stage.

The standardised measurements at monthly intervals were designed to detect seasonal variations in a number of physiological variables which also would indicate the physiological status of the 1963 expedition. The results, too, could be used in continuing programs at widespread localities where personnel are subjected to differing environments, activities, diets and other factors.

The measurements of all variables were continued for a period of thirteen months on eight subjects at Davis under standard conditions. The ninth subject was the Medical Officer who performed the examinations, and some measurements (for example, skinfold thickness, blood pressure) were not made on him.

The mean temperature in the surgery where the casual observations were made was 14°C for all observations. The air movement in the surgery was minimal. Despite variations in the temperature range in the sleeping huts throughout the study, the mean temperature was near 14°C at the times when recordings were made.

The time of determination was within a period of twenty-four hours around the twenty-eighth day of each month. Slight variations were made in these arrangements to cope with unusual station routines or the absence of the men on field trips.

Table 1. The physical characteristics of the Davis subjects

Subject	Age* (yr)	Height (cm)	Weight+ (kg)	Occupation
1	34	165	62.74	Radio Technician/Operator
2	33	178	70.53	Officer-in-Charge
3	31	183	76.88	Cook
4	27	160	57.09	Weather Observer
5	26	182	74.03	Radio Operator
6	25	183	74.52	Medical Officer
7	24	178	76.83	Weather Observer-in-Charge
8	24	178	76.93	Weather Observer (Radio)
9	24	167	67.61	Weather Observer

* Age in years on 1 January 1963

\+ Average body weight for monthly series February 1963 - February 1964

(b) Basal observations

The individual subject was observed within the same period of each month, but not necessarily at the same time due to the fact that all men were rostered for a night-watch duty. In addition to night-watch the meteorological and radio personnel were rostered for their specific tasks. Generally the rostered meteorological staff were measured between 3.30 a.m. and 4.00 a.m., the man on night-watch at 11.45 a.m., shortly before the midday meal, and the other five between the hours of 6.30 a.m. and 9.00 a.m.

After being awakened, the subject was allowed to lie supine for at least five minutes to relax. After this resting period, oral temperature, pulse rate and blood pressure were estimated.

(c) Casual observations

Casual observations were made between 2.00 p.m. and 6.00 p.m. on the same day on which basal recordings were made. The subject, having emptied his bladder, entered the heated surgery and after an interval of ten minutes he undressed to his undergarments (for most, socks and cotton underpants). After being weighed, the subject lay supine on an examination couch, and was given a further period of at least five minutes to relax before further measurements of blood pressure, pulse rate, arm circumference, skinfold thickness and oral temperature were taken.

(d) Body weight

Each subject wore the same type and amount of clothing each month for the weighing which was done on a beam balance. This balance was accurate to 10 g.

Wilson (1960) has stated that marked dehydration may occur on polar field trips, thus causing an apparent loss in the total body weight. Additional weight records were kept of men engaged in field work so that an assessment of the regaining of weight lost on such traverses could be made. The body weights used in the monthly measurements were not recorded for several days after return if the subject had been absent in the field. This practice was adopted by Lewis, Masterton and Rosenbaum (1960).

(e) Skinfold thickness

Skinfold thickness measurements were made using Harpenden spring-loaded calipers (Tanner, 1959). The gauge was read to the nearest 0.1 mm. The measurements were taken at the conclusion of the other casual measurements with the subject standing and arms hanging loosely to the sides of the body. International standard measuring sites were used.

The two sites were (i) Subscapular - just below the angle of the left scapular, picking up the fold parallel to the natural cleavage line of the skin (Lewis *et al.*, 1960);

(ii) Triceps - the posterior fold passing directly up the left arm from the tip of the olecranon at the point midway between the olecranon and the surface marking of the head of the humerus (Brozek and Keyes, 1951; Keyes and Brozek, 1953).

The site having been located, a small fold of skin and subcutaneous tissue was picked up and pinched clean from the muscle allowing the calipers to be applied. The technique was that recommended for use with the Harpenden skinfold calipers. Three measurements were made with the site being relocated each time, and all results were recorded. Five of the subjects who were engaged on field work had extra skinfold thickness measurements done before their departure from Davis and following their return.

The skinfold thickness measurements were converted from millimetres to transferred units (Edwards, Hammond, Healy, Tanner and Whitehouse, 1955) for the purpose of statistical analysis.

(f) Pulse rate and blood pressure

The pulse rate was counted from the radial pulse of the left wrist for a full minute. The blood pressure was estimated with a mercury sphygmomanometer on the left arm in the manner described by Wood (1959), the diastolic pressure being taken as the point at which diminution of the sound occurred.

Arm circumference was taken as the circumference of the relaxed left arm in the middle of where the sphygmomanometer was placed, but corrections for this variable were not considered necessary (Palmai, 1962b).

(g) Oral temperature

Oral temperatures were determined with standard clinical thermometers (read to 0.1°F) which were standardised before the expedition left Australia, and rechecked upon return. The results were corrected accordingly.

The thermometer was placed sublingually, and at one-to two-minute intervals the oral temperature was checked until succeeding readings were the same.

(h) Analysis of results

During thirteen months of observations in Antarctica only three subjects of the eight under study missed one set of observations when they were absent on a dog-sledging traverse. The physiological measurements of the entire group for the month of November were therefore deleted from the analyses.

The results were examined statistically for relations between the variables with respect to time. The analysis of covariance (Wishart, 1950) was used to examine variation caused by the differences in subjects, while the relation that existed between two variables within a subject over a period, but with the variations due to time taken out (residuals), was measured by the same method. Correlations between variables were tested for significance in each group.

The initial analyses were made on two groups, subjects 3, 4, 5, 7, 8 being called a base group and subjects 1, 2, 9 being classified as a field group. These latter three were absent in the field in November.

The separation into base and field groups was considered to be of little value when only three were in the field group and five in the base group. The analyses were therefore done on all eight subjects and the casual and basal readings were analysed for twelve readings over a period of thirteen months.

3.1.2 Results and discussion

Appendix 2 contains the mean monthly values for all the variables measured in this program. The results for both basal and casual levels are presented in Figures 7 and 8.

(a) Body weight

Figure 7 illustrates the mean monthly values of body weight for the Davis group. The mean body weight decreased in the period February to March 1963, remained fairly constant until August when a decrease occurred, and then rose steadily until January 1964. A decrease corresponding to the February - March decrease in 1963 occurred in the period January - February 1964 and the final reading was 0.9 kg below that of the first Antarctic reading, and almost identical with the Australian reading.

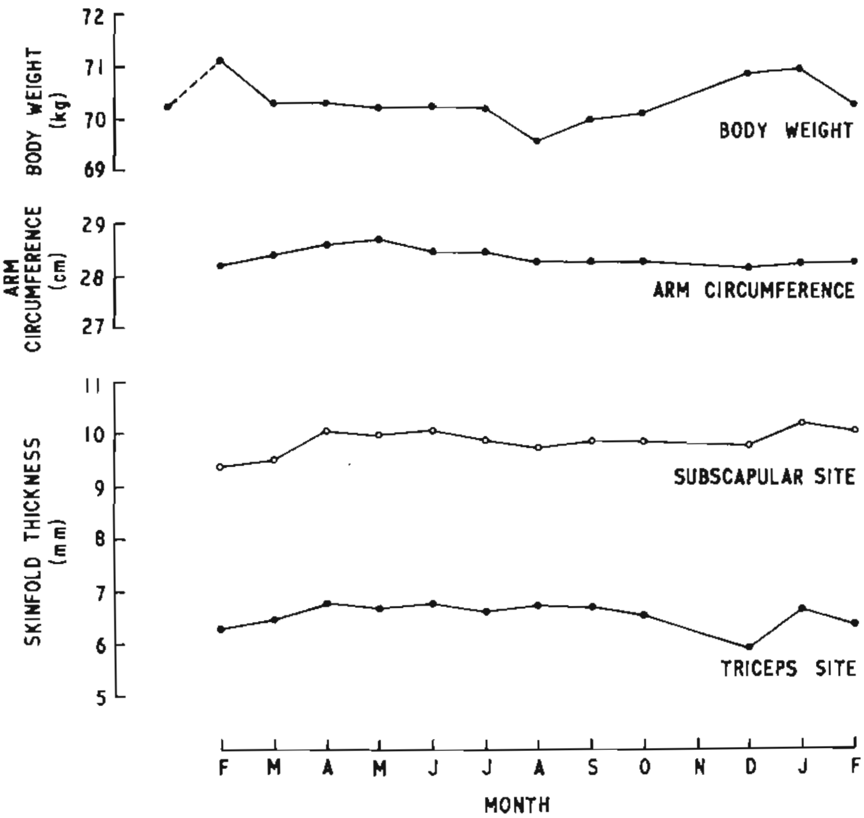


Figure 7. Mean monthly body weight, skinfold thickness (triceps and subscapular sites) and arm circumference.

Early expeditions (Marshall, 1909; McLean, 1915) reported weight gains of over 4 kg during the winter months, and similar results were also obtained by Lewis *et al.*, (1960), Wilson (1960) and Cameron (1968a). The present study contrasts with these previously-described studies. As the changes in weight for the year were not statistically significant, the Davis results were nearer to those of Palmai (1962b) at Macquarie Island, Massey (1956), and Goldsmith (1959).

Various theories have been put forward to account for the increase of body weight. It was initially thought to be an insulative adaptation to the increased cold of the winter months. Other theories (Mitchell, Glickman, Lambert, Keeton and Fahnestock, 1946; Massey, 1956) suggested that a high fat intake caused deposition of dietary fat in subdermal tissues, and lack of exercise during the winter, when activity decreased, were the causes of the weight increases. Lewis *et al.* (1960) suggested that cold and darkness influenced physiological changes by restricting activity together with promoting over-eating. Rohrer (1960) suggested that eating was a compensatory factor due to the deprivation of more basic gratifications and boredom.

The level of activity at Davis did not change greatly throughout the year. In the period October to December three men were engaged on dog sledging but, despite short term changes in weight, there was no marked effect on the body weight changes. The activity remained high in the December - January period when the most marked rise in body weight for the year was seen.

Boredom and increased eating were not generally observed at Davis. Minor increases in appetite did occur following the main sledging trip and this will be commented on in section 3.2. The lack of seasonal weight changes could therefore be due to this maintenance of activity, reinforcing the theory (viz., increased weight results from a restriction of activity) of other authors.

Skinfold thickness was measured by Lewis *et al.* (1960) and they found that it varied in a similar manner to body weight. This supports the view that fat was the cause of the weight gain.

(b) Skinfold thickness

The mean skinfold thickness at both sites increased during the first two months at Davis, but remained steady for the next six readings (Figure 7). In December there was a fall in the skinfold thickness at the triceps site but it remained steady at the subscapular site. Both sites showed a rise in January with a fall in February. The triceps reading showed no marked changes between readings taken at the beginning and the end of the expedition, while the subscapular site increased by 0.68 mm over this period. The changes in skinfold thickness at both sites over the year were statistically significant ($P < 0.05$).

These results are not consistent with some workers who found seasonal variations of rises in winter and falls in summer (Lewis *et al.*, 1960), but the measuring of skinfold thickness in polar regions has produced widely differing results. Massey (1956) found an initial loss in his skinfold thickness recordings with a rise during the winter months and a partial reduction in the summer months. Hicks (1966) and Cameron (1968a), on the other hand, noted rises initially, with varying decreases in the latter months of the year, to values near the levels measured before leaving Australia.

Allied with weight changes have been the changes in skinfold thickness, as skinfold thickness has been found to correlate with the total fat content of the body (Edwards, 1950; Keyes and Brozek, 1953).

(c) Correlation between body weight and skinfold thickness

The mean skinfold thickness during the whole year showed no correlation with weight in individuals or in time, but it did in 'residual' terms, indicating that a weight increase with a subject under controlled conditions was accompanied by an increase in skinfold thickness (Table 2).

The calculation of the correlations associated with differences between subjects, between months, and between the residual fluctuations not associated with either of these factors has been discussed by Hicks (1966). Hicks did a similar physiological study during 1963 at the Australian station Wilkes, and the results of the two sets of observations are almost identical.

Table 2. The coefficients of correlation of body weight with skinfold thickness of the triceps and subscapular sites, in the subjects, months and residual terms of the analysis of covariance

Factor	Skinfold thickness	
	Triceps	Subscapular
Body weight		
Subjects	n.s.	n.s.
Months	-0.566	n.s.
Residuals	0.308*	0.290*

n.s. Not significant

* $0.01 > P \geq 0.001$

The significance of the findings in the Davis and Wilkes studies is not clear, but it may reflect the small sample or factors of physique other than body fat. Hicks (1966) considered that the weight changes could have been due to variations in body fluids or muscle mass. Palmai (1962b) suggested variations in physical activity to account for his similar findings on Macquarie Island. The absence of correlation between monthly changes in body weight and skinfold thickness has also been reported by Orr (1965) and Easty (1967).

Massey (1956) postulated that shrinkage in skinfold was due to loss of fluid from the circulation and skin due to cold, and that increases were due to the temporary deposition of subdermal fat. Burton and Edholm (1955) doubted the existence of this increase due to cold, and the Davis results would reinforce this finding. Men did show changes in their thermal reaction to cold (see section 3.4) but there was no increase in skinfold thickness or body weight. Edholm (1964), commenting on the importance of subcutaneous fat for insulating man against cold water, stated that the changes in body weight and fat thickness are small and the increased insulation so gained is also small. If it is an adaptation it is not a very effective one. The possibility of vascular changes cannot be overlooked in this study.

(d) Arm circumference

Figure 7 shows the variations during the year in arm circumference. A rise occurred in the period February to May but then declined over the rest of the year to a value below that of the first reading. The changes during the period at Davis were statistically significant to the 0.1 per cent level.

(e) Correlations of arm circumference with other variables

The Davis results show a correlation between arm circumference and body weight in both subjects ($P < 0.05$) and residual ($P < 0.10$) terms, showing that changes in body weight are accompanied by corresponding changes in arm circumference and that heavier men have larger arms. Over the year a high correlation occurred between arm circumference and triceps skinfold thickness ($P < 0.05$). The lack of residual and subject correlations between arm circumference and triceps skinfold thickness substantiate the fact that arm circumference combines the measurement of muscle bulk as well as fat thickness.

(f) Pulse rate

The changes observed in both the mean monthly basal and casual pulse rates are shown in Figure 8. The casual pulse rate was higher in all months by from one to twelve beats per minute. The basal pulse fell steadily from February to September and then rose to a maximum in December. Another fall occurred in January followed by a rise shortly before the group left Davis in late February. These variations for basal pulse, unlike the casual pulse, are highly significant ($P < 0.001$)

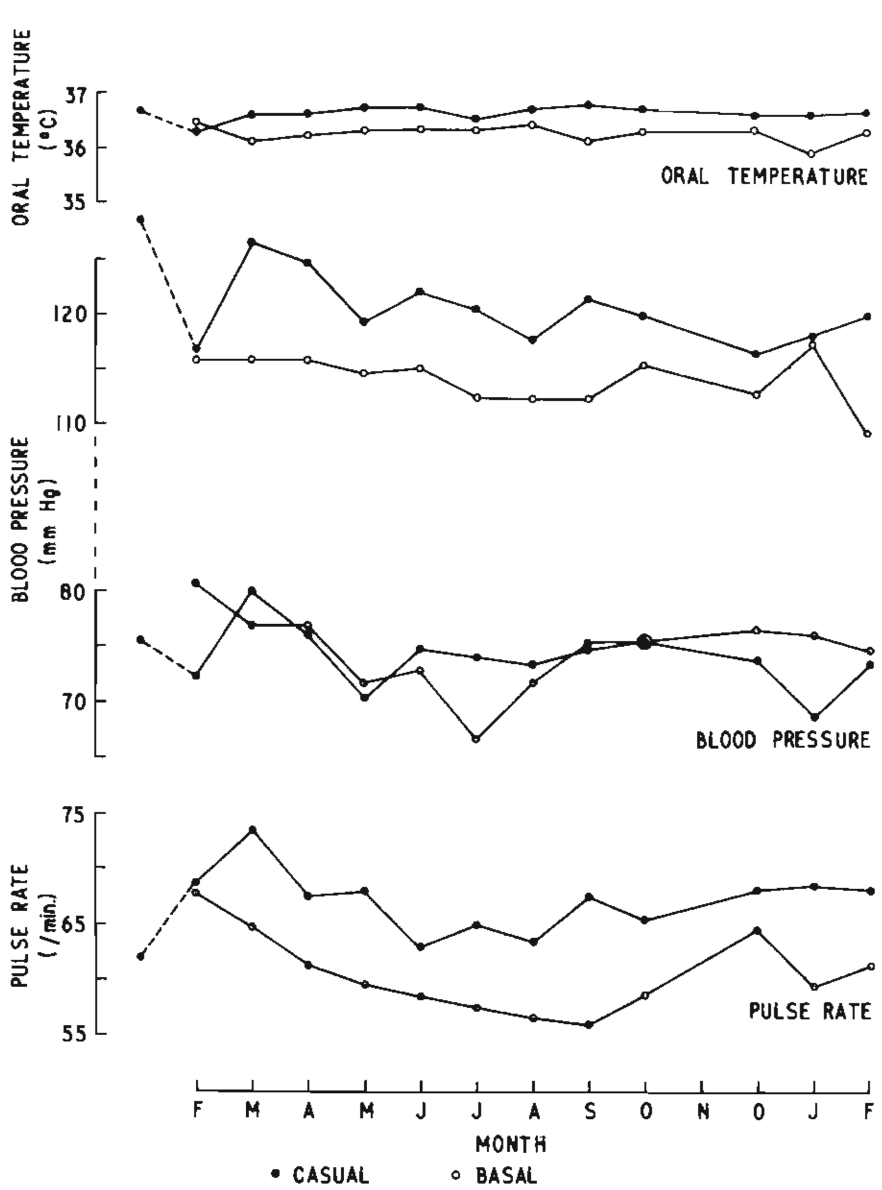


Figure 8. Mean monthly values for casual and basal blood pressure (systolic and diastolic), pulse rate and oral temperature. The value obtained in Australia prior to sailing to Antarctica is also included.

and reflect the satisfactory adaptation of the men to the Antarctic environment. The changes in the period September to February probably reflected emotional causes as preparations for field work were begun and were carried out, and the men prepared for their return to Australia.

The mean monthly casual pulse rate showed no significant change during the year.

(g) Blood pressure

The blood pressures recorded under both basal and casual conditions showed changes during the year (Figure 8), with the changes in the casual systolic blood pressure being the most significant ($P < 0.001$). The basal diastolic blood pressure changes were significant at the 1 per cent level while the basal systolic and casual diastolic pressures were not significant. The mean casual blood pressure reading at the end of the year was a little higher than the first reading, while the mean basal blood pressure readings were lower at the end of the study period.

These results vary slightly from blood pressures taken under similar conditions at other ANARE stations (Hicks, 1966, 1967; Cameron, 1968a) but no constant pattern has been found for men wintering in Antarctica (Wilson, 1965).

(h) Correlations between blood pressure and other variables

When both basal and casual recordings were analysed, systolic and diastolic blood pressures were correlated with each other, in the month, subject and residual terms. There are no highly significant correlations between changes in blood pressure and body weight and this agrees with earlier reports (Palmai, 1962b; Hicks, 1966).

However, no substantiation of Palmai's close correlation between skinfold thickness and blood pressure could be found and, as Hicks (1966) reported, negative correlations were obtained between skinfold thickness at both sites and basal systolic blood pressure ($P < 0.05$). Hicks postulates that a psychological factor may be responsible for this difference between the sub-Antarctic and Continental stations.

(i) Oral temperature

Figure 8 shows the mean monthly basal and casual oral temperatures. The mean basal reading varied over 0.6°C during the year and the casual reading 0.5°C. The mean basal oral temperature during the year was 36.2°C and the casual reading 0.5°C higher. Both the basal temperatures ($P < 0.01$) and the casual temperatures ($P < 0.05$) were significant over the year.

These results agree with other workers (Wilson, 1965; Hicks, 1966) but do not confirm Palmai's work (1962c) which recorded a seasonal change in the mean daily oral temperature during a year at Macquarie Island.

3.2 FIELD STUDIES

3.2.1 Materials and methods

(a) General

On the three major dog sledging and vehicle traverses, in addition to observing the changes in body weight and skinfold thickness that resulted from these field projects, the calorie intake and energy expenditure were calculated so that any resultant changes could be assessed in relation to dietary intake and energy expenditure.

Three were involved in each journey, five different subjects taking part: subject S1 on all three journeys, subjects S3 and S9 on two, and subjects S2 and S6 on one. Table 3 summarises the traverses, the distance travelled and duration, the mode of transport used and the subjects taking part. The extent of the journey is shown in Figure 4.

Table 3. The subjects studied on the three major traverses from Davis, together with the mode of transport, distance and duration of the trip

Field traverse	Mode of transport	Subjects	Distance travelled (km)	Duration (days)	No. days travelling prevented
Reconnaissance Trip	Snow-Trac	S1,S3,S9	117.5	5	1
Depot Trip	Snow-Trac	S1,S3,S6	370.3	7	0
Main Trip	Dog team	S1,S2,S9	558.5	52	29

(b) Body weight and skinfold thickness

The body weight and skinfold thickness were recorded as described in section 3.1. The subjects were weighed on the day before leaving Davis. Following their return from the initial two short journeys, the men were allowed to rehydrate over a period of six to eight hours before the weighing was done. After the main trip, however, the men were weighed as soon as they reached the station and had emptied their bladders, and the following day further recordings were taken under the conditions of the casual observations, after rehydration had occurred. Further readings were taken one week later. Skinfold thickness readings were taken both before and after the depoting and main journeys.

(c) Daily field activity

The daily activities were recorded on the Depot Trip as part of the cold exposure and activity study as described in section 3.3, while on the other two journeys the comprehensive logs, records and twice-daily radio reports were used to calculate accurate daily activity patterns of the men.

The five grades (rest, personal administration, light work, light-moderate work, moderate-heavy work) as described in section 3.3 were used to classify the men's activity.

It was found during short dog sledging trips early in the year that all men shared the work load very conscientiously. As they spent similar periods of time at common tasks, for the purpose of this study the hours per day spent by the three men in various activities were given as single totals.

(d) Daily energy expenditure

Daily energy expenditures were calculated using the most appropriate estimates for energy expenditure of the five grades of activity. The estimates, obtained from Passmore and Durnin (1955), Masterton, Lewis and Widdowson (1957), Consolazio, Johnson and Pecora (1963) and Budd (1966), used in the present study are as follows:

	kcal/min
Rest	1.2
Personal administration	2.0
Light work	3.2
Light-moderate work	5.6
Moderate-heavy work	8.0 (vehicle traverses)
	10.0 (dog sledging)

The moderate-heavy work activity was given separate values for the two forms of transport used on field trips as it was observed that the physical effort involved in the two differed as more efficient aids were available when working from the vehicle.

(e) Food intake

The total food intake while on traverse was known as the rations were packed in twelve man-day packs the calorie values of which had been determined in Australia (Law and McMahon, 1963). Table 4 gives the ration scales and the calorific values of the ANARE pack. The pack provided 143 g/day of protein. Sometimes the contents of the pack were changed before the field groups set out, but the values of the deletions and the additions were accurately determined and no extra rations were taken that were not accounted for.

Table 4. The ration scales of the ANARE twelve man-day field ration pack used in 1963

Item	Weight/Man-day (g)	Total calories
Pemmican	227	1372
Butter	113	945
Biscuit	142	662
Sugar	113	446
Egg powder	28	170
Milk powder	71	354
Cocoa	28	128
Potato powder	43	157
Chocolate	57	310
Onion	9	28
Coffee	9	
Vegemite	5	
Rolled oats	57	224
Salt	5	
Total	907	4796

Each man took one third of the daily ration and inevitably there were small day-to-day inaccuracies and variations, but over the whole period of the journeys an accurate record was kept of the food intake.

3.2.2 Results and discussion

(a) Body weight and skinfold thickness

The changes in body weight and skinfold thickness of the five subjects involved in field traverses from Davis are shown in Table 5. In the three traverses loss of weight occurred and this is illustrated in Figure 9. The weight changes of one man (S4) who did not leave the station is included for purposes of comparison. After allowing for rehydration to occur the mean weight losses of 1.59, 2.21 and 1.62 kg respectively were recorded. The losses of weight in the Davis group agree with previous reports (Massey, 1956; Wilson, 1960; Hicks, 1966). Massey weighed his subjects immediately upon return to base and 1.4 kg of the loss of 5.0 kg was regained within the first twenty-four hours. Figure 9 illustrates the rapid regaining of weight in the Davis men in the first twenty-four hours of their return from the Main Trip.

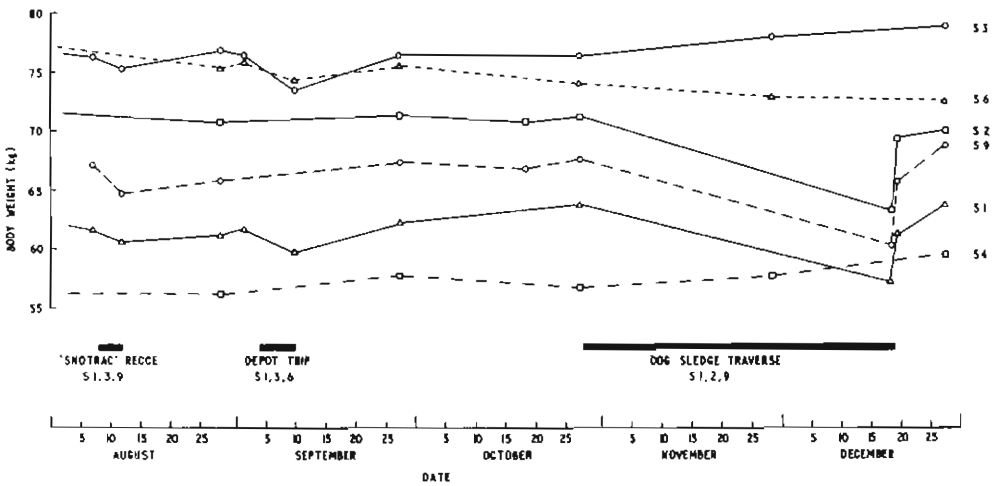


Figure 9. Body weight changes resulting from field trips. The times and duration of the field trips are also indicated. Subject S4, who did not participate in the field trips, is included to enable a comparison to be made between base and field subjects.

Subject S1 lost 6.42 kg over 52 days, 4.27 kg of this being regained in the first twenty-four hours, and the balance over the next week. Subject S2 (7.55 kg loss and 6.12 kg regained in first twenty-four hours) took longer to regain his loss, while subject S9 (7.27 kg loss, 5.98 kg regained in first twenty-four hours) regained his pre-trip weight within a week. Similar rises in the first twenty-four hours were seen in all three subjects and these dramatic rises were more marked than those reported previously by Massey (1956), Wilson (1960), and Orr (1965).

Skinfold thickness (Table 5) was also decreased in subjects who took part in the field work. At the conclusion of the Main Trip the mean skinfold thickness lost was 1.1 mm (range 0.6 mm to 1.4 mm). Following the journey when the body weight increased sharply, there was a much slower and more gradual regaining of skinfold thickness. This confirms the observations on a similar number of subjects at Hope Bay (Orr, 1965) and also those of Wyatt (1963).

(b) Daily activity

On most traverses, blizzards caused the men to spend considerable amounts of time in their tents. The short Depot Trip was an exception. On this trip the weather, although marginal on most days, did not prevent the planned work being done. In contrast, during the Main Trip travelling was possible on only 20 days, as blizzards, whiteout and poor weather caused the three men to lie-up in their tent for 29 of the 52 days they were absent from Davis. During this trip a blizzard struck with such force that the poles of the polar pyramid tent broke and the men had to brace the tent with their backs for a twenty-four hour period until the fury of the blizzard passed.

Table 6 shows the daily activity of the men on the three journeys, and the variation between travelling days and days on which they were tent-bound. The number of hours per day spent working while on the two minor journeys was higher than expected. Due to the nature of these journeys, time was at a premium and much manual labour was needed to accomplish tasks which, on large tractor traverses, would be more mechanised. Even on the Main Trip, the men spent five hours per day working despite their being prevented from travelling. This work included digging out the tent, the sledges and stores, checking the tent guys, feeding the dogs and checking them, making weather and glaciological observations, cooking and cranking the hand radio-generator. The accumulation of snow and drift at most of the camps on the plateau was very high, and at times the sledges were completely buried.

On days when travelling was possible, the mean distance travelled with the dog teams was 27.9 km (range 8.1 to 61.2). Over these distances, the mean daily work period increased from 5.0 hours on 'tent-bound' days to 12.1 hours on a day when travelling was possible. The mean daily rest and personal administration periods together totalled 11.9 hours on travelling days, but this increased to 19 hours on days when the men were unable to move. On such days the men spent long hours in their sleeping bags. During the two trips using the Snow-Trac the daily mean time for rest and personal administration totalled 15.4 hours and

Table 5. Changes in body weight and skinfold thickness of the five subjects who were involved in field traverses from Davis

Subject	Station average (Feb-Jun)	Date 28/7	7/8	12/8	28/8	3/9	10/9	28/9	18/10	27/10	28/11	19/12	20/12	28/12
							Body weight (kg)							
S6	75.51	76.95	-	-	75.15	75.67+	73.86#	75.15	-	73.80	72.90	-	-	72.45
S3	77.14	76.65	76.38+	75.21#	76.70	76.15+	73.32#	76.10	-	76.11	77.93	-	-	78.54
S1	62.09	62.28	61.88+	60.62#	61.47	61.91+	59.92#	62.32	-	63.52+	-	57.10#	61.37	63.57
S9	67.62	66.80	67.00+	64.65#	65.91	-	-	67.13	66.75	67.52+	-	60.25#	66.23	68.86
S2	70.15	71.55	-	-	70.45	-	-	71.20	70.90	70.95+	-	63.40#	69.52	70.00
							Skinfold thickness (mm)*							
S3	9.5	9.5	-	-	9.5	9.6+	9.0#	9.5	-	9.4	8.9	-	-	8.6
S1	7.4	7.4	-	-	7.4	7.5+	7.4#	7.4	-	7.1+	-	-	6.5#	6.6
S9	8.9	8.8	-	-	8.8	-	-	8.9	8.9	9.0+	-	-	7.7#	8.3
S2	6.7	7.3	-	-	7.4	-	-	7.4	7.4	7.4+	-	-	6.0#	6.9

* Average skinfold thickness of both subscapular and triceps sites. No skinfold thickness measurements were available for S6 who was the observer.
\+ Measurement made on day prior to departure from Davis.
\# Measurement made on day of return from the field.

Table 6. The activity, daily food intake, daily energy expenditure and weight losses during three traverses from Davis

	Reconnaissance Trip			Depot Trip		Main Trip	
	Total	Travelling	Tent bound	Travelling	Total	Travelling*	Tent bound
Activity (hours/day)				(Total)			
Rest	12.2	10.7	18.0	10.8	11.4	8.9	13.3
Personal administration	3.2	3.3	3.0	3.0	4.5	3.0	5.7
Light work	4.6	5.3	2.0	4.5	4.1	5.0	3.4
Light-moderate work	1.5	1.7	0.5	1.4	0.8	1.5	0.3
Moderate-heavy work	2.5	3.0	0.5	4.3	3.2	5.6	1.3
Daily food intake (kcal)	4360			4460	4860		
Daily energy expenditure (kcal)							
Mean	3850	4200	2450	4500	4350	5830	3180
Range	2450-4510	3720-4510	-	3770-5420	2780-6910	3950-6910	2780-4850
Weight loss (kg)							
Mean	1.59			2.21	1.62 (7.08)+		
Range	1.17-2.35			1.81-2.83	1.29-2.15 (6.42-7.55)+		

* Includes three days on which astro fixes were done, but camp not moved.
\+ Actual weight losses before rehydration had taken place.

13.8 hours, and this reflected the easier nature of the traverse compared with the more arduous dog sledging.

The comparison of traverses of different expeditions is very difficult as no two expeditions have identical programs or methods of transport, and the terrain and the weather are so variable. However, the mean daily activity of the men engaged on the Davis dog trip is comparable with the results of the few other studies that have taken place (Masterton *et al.*, 1957; Wyatt, 1963; Budd, 1966) that have taken place. This is important for assessing energy expenditure and food intake.

(c) Daily energy expenditure

The estimated daily energy expenditure for all trips is shown in Table 6. On the vehicle traverses the mean daily energy expenditures on travelling days were 4 200 kcal (range 3720-4510) and 4 500 kcal (range 3770-5420), but on the dog trip this expenditure rose to 5830 kcal (3950-6910).

On the day when travelling was impossible during the vehicle traverse, the mean daily energy expenditure was 2450 kcal, but under similar conditions while dog sledging this mean daily value was estimated at 3180 kcal (range 2780-4850).

The mean daily energy expenditure for four polar sledging trips is given in Table 7. Edholm (1964) sums up a number of British sledging expeditions as follows:

> *'When all these results are considered together, it becomes clear that the energy expenditure during sledge journeys is in excess of 5,000 kcal/day.'*

The lower estimate of the daily energy expenditure on the Davis Main Trip reflects the large number of lie-up days, but overall the figures from the Davis field studies are in agreement with other expeditions.

At Halley Bay in 1967 a further study was done on the energy cost of a wide range of outdoor activities in a typical polar environment (Brotherhood, 1973). Brotherhood found that energy expenditure was higher than would be predicted from the energy cost of comparable activities in temperate zones reported in the literature. The average outdoor heat output was 7 kcal/min with the energy cost of walking or skiing averaging approximately 9 kcal/min. Brotherhood's figures confirm the previous less accurate studies of energy expenditure in Antarctica.

Table 7. A comparison of food intake, energy expenditure and mean weight changes of polar sledging expeditions

Reference	Masterton *et al.* (1957)	Norman (1965)	Orr (1965)	Budd (1966)
Food intake (kcal)	4800	4430	5600	4800
Energy expenditure (kcal)	5200	5050	+	5100
Mean weight changes (kg)	*	-1.25	No change	-4.1

+ No figure given but 18 days of hard travelling.
* Weight loss occurred but no figure given.

(d) Food intake

The daily food intakes for the three field trips were as follows:

Reconnaissance Trip - 4360 kcal

Depot Trip - 4460 kcal

Main Trip - 4860 kcal

Wilson (1965), who has summarised the daily food requirements for sledging in polar regions, quotes values ranging from 3500 kcal to 5500 kcal.

(e) Role of food, fluid and activity in loss of body weight and skinfold thickness

It is a common observation on polar expeditions that body weight decreases during sledging (Massey, 1956; Wilson 1960). On earlier expeditions (Ekelöf, 1904) this loss was mostly attributed to hardship and limited f od supply. Weight losses, however, have also been described on field trips with adequate food supply (Hicks, 1966).

Hicks has described the ANARE field expeditions from Wilkes. These occurred in the same year as the present study but, in contrast to the Davis field work, where the food intake was provided from a basic ration pack, the expeditioners from Wilkes had no lack of "luxury" items and, as Hicks stated, '*the type and quality of the food available in the field on these expeditions differ little from those at the station*'.

On all three Davis trips weight losses occurred. On two of the trips the mean daily energy expenditure was less than the mean daily calorie intake, while on the third trip the mean daily energy expenditure was calculated at only 40 kcal above the food intake.

Hicks (1966) postulated that, although it appeared unlikely, calorie imbalance may have been partly responsible. Possible causes for this imbalance may have been tiredness, discomfort or less appetising cooking. On the Main Trip inland from Davis, where movement was possible on only twenty days and conditions were extremely poor, boredom, discomfort and monotony of foodstuffs all may have played parts, even though the calorie intake was accurately calculated and was in excess of energy output by 500 kcal/day. Despite the positive calorie balance the men did not increase their body fat or weight.

The imbalance between calorie intake and energy expenditure may be due to the weight of clothing and footgear worn. Consolazio, Johnson and Krzywicki (1970) who reviewed energy metabolism during exposure to extreme environments commented on the influence of clothing, and Welch, Levy, Consolazio, Buskirk and Dee (1957) suggested an increase of 2-5 per cent in energy requirements for the wearing of heavy clothing and footgear. The average weight of clothing worn by the field groups was 10 kg and although the values chosen for energy output should take into account the clothing worn, it is possible that in some instances they do not.

The ANARE sledging rations were high in protein, and high protein diets have been shown to increase the metabolic rate in men in polar regions (Heinbecker, 1928; Rodahl, 1952). The discrepancy between energy expenditure and calorie intake in this study may be explained in part by the high protein diet.

A similar study was made at Davis in 1970 (Boyd, 1975). Three subjects travelled 900 km by motorised toboggans in a period of 42 days over the same terrain as this present study. The mean calorie intake on this trip was 4050 kcal/day and the energy expenditure 3500 kcal/day. Despite an excess of 550 kcal/day, mean body weight losses of 7.2 kg were recorded.

Boyd points out the similarity of the two results obtained using both modern mechanised transport and traditional dog teams, and the influence of heavy polar clothing, cold and the high protein diet on the calorie requirements. The possibility of a thermogenic response to the cold as described by Keatinge (1969), and evident in Boyd's study, cannot be discounted in the present study, although Brotherhood (1973) found in his Halley Bay study that '*there was little evidence of increased metabolic rates due to* involuntary thermogenesis'. However, in Brotherhood's study shivering was never observed but increased metabolic rates were found in situations where activity was restricted, and a heat output of approximately 220 kcal/m^2/hr was required in order to maintain thermal comfort.

Brotherhood also commented on the desire to complete some tasks quickly as a factor in the high energy expenditure. This desire has been observed in a number of wintering expeditions by the author. The Davis group was no exception to these groups, especially in the category of moderate-heavy work.

On weighing the men immediately on return to Davis, it was found that the mean weight loss of the three subjects for the trip was 7.08 kg. In the first twenty-four hours an average of 5.46 kg was regained by the three men.

This rapid early regaining of weight has been observed on a number of occasions. Wilson (1960) and Massey (1956) attributed it in their subjects to replacement of body water. All Davis men experienced considerable thirst following a field journey, and agreed with Nansen's (1892) vivid description of "polar thirst" following his crossing of the Greenland Ice Cap. This was in part due to excessive sweating, especially when sledging with the dogs, but also due to the men being very conservative in the use of fuel for melting snow and ice to obtain water, thus decreasing the amount available for their fluid intake. Edholm (1964) comments that water intake during sledging from British bases averaged between 2.5 and 3.5 litres daily. The daily fluid intake of the Davis men although not accurately measured, was calculated to be much less than this. Young (personal communication) estimates that the mean daily intake was around 1.5 litres. Boyd (1975) found his subjects in 1970 became dehydrated on a daily fluid intake of 2 litres.

The question of dehydration is not fully answered as Orr (1965) found no evidence of dehydration in men sledging from Hope Bay, Antarctica.

Of the three subjects following their return from the main Davis traverse only one man had the voracious appetite as described by Wilson (1960). Several years after Wilson's study, Edholm (1964) summed up British polar research and stated that, provided the daily food intake on sledging trips is over 5 000 kcal, there will be no weight loss. Table 7 shows weight changes, food intake and energy expenditure of four sledging parties. These figures support the estimated value for food intake below which calorie imbalance occurs.

It is possible that the Davis weight losses were in part due to inadequate food, but the regaining of 5.6 kg in twenty-four hours would appear to be due more to dehydration, and the subsequent retention of fluid following return to base, than to food. These results disagree with the views of Edholm (1964) and Orr (1965) who considered that the weight losses on sledging trips were due essentially to food deficit, with dehydration appearing to be of minor importance.

The decrease in skinfold thickness (Table 5) in men engaged in field work could point either to calorie imbalance and a depletion of body fat or to a possible reflection of changes in fitness. The losses in skinfold thickness although small, did return, but these took longer than the body weight to return to normal.

It is probable that fitness played a part in the skinfold thickness variations, and that the effects of clothing, diet and cold may have reduced the calculated positive calorie balance to a negative one, this being reflected as a loss of skinfold thickness. From this study the interaction of energy and calorie balances, fluid and fitness can be seen to be complex, with the most significant single factor being fluid balance.

3.3 COLD EXPOSURE AND ACTIVITY

3.3.1 Materials and methods

(a) General

The degree of cold exposure to which all Davis men were subjected in terms of meteorological climate has been described in section 2.4. The importance of the amount of cold exposure has been discussed by Norman (1962) and Edholm and Lewis (1964) and this study was proposed to ascertain the cold stress occurring and the activity the group experienced.

(b) Subject

The investigation of cold exposure and activity was limited to Subject 6. In Australia before departure it was planned to do a comprehensive time and motion study on all nine subjects, but as a pilot program was commenced on the voyage south it became apparent that the proposed comprehensive program was not feasible on an expedition of nine men because of the time needed to record all the observations accurately. As all the expeditioners had more than one specific task to carry out, the time involved each day in the study would have led (as in the pilot study) to inaccurate reporting.

(c) Recording of daily activities and cold exposure

The subject recorded his daily activities and exposure times each evening as he retired, whether he was at Davis or in the field.

The activity was classified in five grades:

1. Rest

2. Personal administration

3. Light work

4. Light-moderate work

5. Moderate-heavy work

Time spent in bed or in a sleeping bag, including sleeping time, was taken as rest. The actual sleep times were not recorded. Personal administration included dressing, washing and personal domestic duties, talking, eating meals, coffee breaks, parties or "ding" nights, recreational pursuits such as reading, playing darts or table tennis, watching movies, photography and other hobbies.

Light work included medical, dental, scientific and administrative work, writing records and logs, station tasks such as cooking, light manual tasks and driving the light farm tractor and Snow-Trac. The category light-moderate was used for tasks such as disposal of refuse, labouring work, carrying light stores and cleaning huts.

Activities such as digging snow, obtaining ice from icebergs for melting into fresh water, digging out 44-gallon drums of fuel from snow drifts and manhandling them to the power house, carrying heavy stores and crates, flensing seals for dog food, dog sledging, manhauling, construction work, labouring tasks, such as digging trenches and concreting, were categorised as moderate-heavy work.

The activity was further broken down into the type of work, viz., medical, dental; medical research; biology research; station and field work-manual, etcetera.

The environmental exposure time was recorded under three categories:

1. Indoors

2. Shelter - unheated

3. Outdoors.

The "indoors" category included all time spent inside heated buildings. "Shelter-unheated" included the periods of time spent in unheated stores, cold porches, workshops, tents in the field, huts at the remote station Platcha, and inside the cabin of the Snow-Trac. Any time spent outdoors was recorded under "outdoors".

(d) Meteorological measurements

The routine meteorological observations were recorded as described in section 2.3. Additional indoor measurements of temperature and humidity were made during the year in all of the Davis buildings, which were part of the subject's indoor or sheltered environment. When the subject was absent in the field additional recordings were taken in vehicles, tents and huts. Outdoor meteorological readings using portable instrumentation was also made at these remote areas.

3.3.2 Results and discussion

(a) Comparison of group with subject studied

During the period in Antarctica, records of cold exposure and activity were kept on 377 days, measurements not being taken on two days. Although the study was limited to one subject, it was found during the year that the subject chosen spent time at both indoor and outdoor work in periods which were comparable with most members of the group. His tasks were both scientific and support and, as well as station work, he was absent from Davis on field work on over 100 whole or part days.

The results of this study cannot therefore be considered atypical of the cold exposure and activity of all nine men in this group.

(b) Cold exposure

Throughout the study the mean daily time spent "outdoors" was 4.8 hours (range 1.0 - 14.0 hours), under "shelter-unheated" 2.3 hours (range 0 - 22 hours), and "indoors" in a heated atmosphere 16.9 hours (0 - 23.0 hours). Appendix 4 gives the mean daily duration of cold exposure for each month of the study, and Figure 10 shows the results in a histogram. Thirty per cent of the time that Subject 6 was in Antarctica, he was exposed to outdoor temperatures and 20 per cent of the time he was exposed to meteorological conditions such as wind, drift and snow.

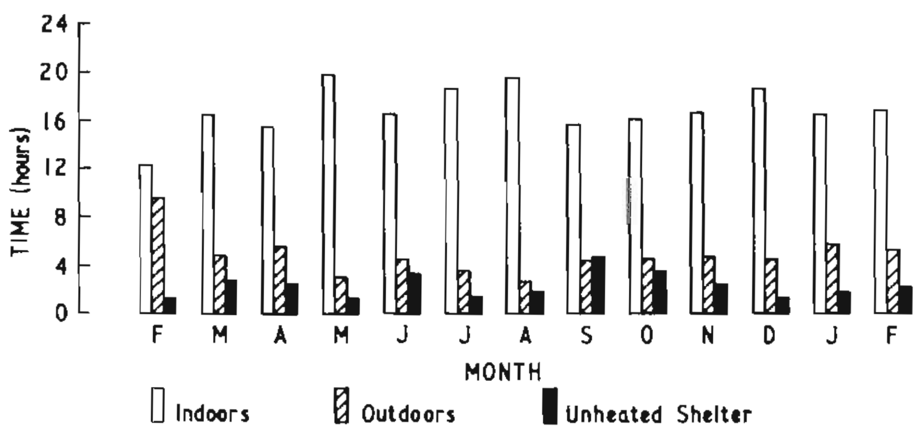


Figure 10. The mean daily duration of cold exposure for each month of the period at Davis.

(c) Comparisons with other expeditions

A number of time and motion studies have been carried out in polar regions both before and after this study (see Table 8). Some of these studies, such as Norman's (1965) manhauling and Budd's (1966) dog sledging trips, have been conducted over limited periods. Previous workers, Milan and Rodahl (1961) and Norman (1965), used more accurate methods than the present study, but their sampling of data from one twenty-four hour period per week or per month leads to insufficient samples for valid statistics over a prolonged period.

Table 8. Comparison of the time spent outdoors by Antarctic expeditions in different localities

Expedition	Locality	Lat.S.	Time spent outdoors Hour/Day	Activity	Ref.
Deep Freeze 1957	Little America V	78°16'	2.6	Base scientists (autumn, winter, spring)	Milan and Rodahl (1961)
			4.8	Base naval support (spring)	
F.I.D.S. 1958	Stonington Island	68°11'	3.6	Sledging from base for six months	Wyatt (1963) In Edholm (1964)
F.I.D.S.	Halley Bay	75°31'	2.2	At station	Norman (1965)
			9.4	Manhauling for one week	
F.I.D.S. 1959	Argentine Island	65°15'	2.2	At station	Cumming (1961) In Edholm & Lewis (1964)
ANARE 1959	Mawson	67°36'	9.2	Dog sledging for 12 days	Budd (1966)

8 (continued)

Expedition	Locality	Lat.S.	Time spent outdoors Hour/Day	Activity	Ref.
ANARE 1962	Wilkes	66°16'	2.4	At station	Soucek (1963)
			3.2	Tractor traverse (Wilkes - Vostok)	
ANARE 1963	Davis	68°35'	4.8	Total survey	
			7.6	Dog sledging	This study
			5.9	Snow-Trac traverse	
J.A.R.E. 1967-68	Syowa	69°00'	3.2	Tractor traverse	Hirose (1969)
J.A.R.E. 1968-69	Syowa	69°00'	7.2	At station	Okubo and Kobayashi (1971)
			3.2	Tractor traverse (Syowa - South Pole)	

Table 8 shows the comparison of time spent outdoors by various Antarctic expeditions. The mean daily exposure time of 4.8 hours at Davis is higher than most other base studies. The figure for the naval support group studied at Little America V over the spring period (Milan and Rodahl, 1961), is identical to the Davis annual figure, and illustrates the fact that the Davis subjects spent more time outdoors over the whole year than the average Antarctic expedition. The Davis results of 7.6 hours and 5.9 hours for dog sledging and the Snow-Trac traverse are comparable with figures for manhauling, tractor traverses and sledging at other bases.

Okubo and Kobayashi (1971) found that 7.2 hours per day was the mean period of time spent outdoors at the base by the Japanese group who travelled from Syowa to the South Pole. This figure dropped to 3.2 hours on the inland journey. The combined Davis results of 4.8 hours per day spent outside and 2.3 hours per day spent in unheated shelters and vehicles total 7.1 hours per day, which is almost identical with the Japanese results. In contrast to the base group at Syowa who were mainly scientists, the Davis station personnel spent more time outdoors.

A comparison is made by Okubo and Kobayashi (1971) with Milan and Rodahl's (1961) study and they conclude that the daily routine in the Antarctic is similar at all stations. This is not borne out by the present study nor by the review of the results from other authors. Davis is considered less a field station than is Wilkes, but the outdoor exposure at Davis is much higher than the base group at Wilkes (Soucek, 1963). It is concluded that, for comparisons to be made between cold exposures and the amount of cold stress undergone at different bases and localities, accurate reporting must be made on activities both at base and in the field, and time and motion studies are necessary.

Men on tractor journeys into the Antarctic inland such as described by Somov (1962), Hirose (1969) and Thompson (1969) may, in terms of time, be exposed for short periods, but in these short exposures the conditions experienced may be extremely difficult and almost unbearable.

(d) Meteorological climate

Appendix 1 shows the monthly mean values of temperature, relative humidity, windspeed, windchill, sunshine, days of drift and days of snow precipitation, and Figures 5 and 6 graphically represent these results.

The factors of air movement and temperature which reflect the cooling power of the atmosphere of the Davis climate are tabulated in Table 9. This double frequency table of air temperature and wind speed is expressed in terms of the percentage of time during which the various combinations of temperature and wind speed occurred during the period at Davis.

In Antarctica generally, it is usual to associate higher winds with higher temperatures. The double frequency table shows this to be so part of the time, but higher winds did occur with lower temperatures on a number of occasions. This may reflect the position of Davis which is on low hills distant from the plateau and free from the influence of the katabatic winds. The fjord system may also influence the weather at Davis.

In a polar climate the environmental stress consists of a combination of wind, air temperature and radiation which determine the relative comfort sensation. These combinations may also cause injury such as frostbite, snowblindness and sunburn.

Table 9. Double frequency table of temperature and wind speed expressed in terms of the percentage of time during which the various combinations of temperature and wind speed occurred during the period at Davis

WIND SPEED M/SEC	TEMPERATURE (°C) 10	5	0	-5	-10	-15	-20	-25	-30	-40	Total
0		0.38	1.05	1.33	2.41	2.76	2.00	0.67			10.60
5	0.10	5.14	11.26	9.89	10.43	9.73	5.11	1.46	0.29		53.41
10	0.22	3.96	6.11	4.12	3.68	2.00	1.11	0.19			21.39
15	0.03	1.17	2.60	2.67	1.33	0.29	0.32				8.41
20		0.35	1.78	1.43	0.89						4.45
25		0.10	0.45	0.41	0.29						1.25
30			0.07	0.16	0.07						0.30
35			0.03	0.03	0.13						0.19
Total	0.35	11.10	23.35	20.04	19.23	14.78	8.54	2.32	0.29		100.00

Chrenko and Pugh (1961) have estimated the importance of direct polar solar radiation which is high due to the clear air. Humidity is of minor importance at temperatures below freezing, but if snow is blown by high winds into clothing, it may cause heat loss by reducing the insulation of clothing. Heat loss is the main factor concerned with relative discomfort and the mechanisms of this have been described in detail by Burton and Edholm (1955). Altitude is another important factor, but this did not influence the Davis group to any degree, as on field trips the highest altitude encountered was 1200 metres. Various authors (Edholm and Lewis, 1964; Norman, 1965) have pointed out that conventional meteorological observations such as maximum and minimum values of temperature and windspeed have been inadequate for measuring man's thermal environment, and detailed meteorological information and analyses have been necessary to correlate climatic conditions with their effects on man.

(e) Indoor environments

The inside environmental temperatures to which the subjects were exposed at Davis are shown in Appendix 5. As Subject 6 was exposed to indoor environments for 16.9 hours daily for the year (Figure 10) these temperatures would have contributed to his adaptation.

The variation of the indoor temperature range (2^{o} - 30^{o}C) reflected changes in the station design and heating system as described in section 2.1

(f) Exposure climate

By using conventional meteorological data together with more specialised recordings and analysis it was possible to describe the exposure or environmental climate at Davis. This is the climate that surrounds the human body.

The mean monthly temperatures of the exposure climate are shown in Table 10. The exposure climate was adjusted by allowing for the time spent by the subject under certain environmental conditions around the station. The exposure climate was 12 - 28^{o}C above the meteorological temperature, and the exposure temperature found for Subject 6 was similar to Norman's (1965) results at Halley Bay; however, the temperatures at Halley Bay are lower than those for Davis.

Table 10. Monthly mean values of the temperature of the exposure climate to which Subject 6 was exposed during the year

Month	Temperature of exposure climate (°C)
February	7.6
March	8.8
April	6.6
May	11.9
June	7.6
July	10.0
August	7.5
September	5.6
October	7.1
November	10.8
December	13.3
January	12.2
February	11.7

The face and hands were often uncovered and so were subjected to the meteorological temperature more often than the rest of the body.

The micro-climate (which is the climate surrounding the skin) was not measured as other studies (Adam, 1958; Norman, 1962; Budd, 1966) are in close agreement that the micro-climate is 32° - 33°C, with lower readings while sledging (around 27°C).

(g) Influence of meteorological climate

Figure 11 shows the mean daily time spent outdoors for each month and the mean monthly outdoor temperature, windchill and exposure temperature. Man's intuitive behaviour causes him to seek shelter and avoid extreme exposure, thus avoiding the meteorological climate to a large degree. The exposure climate was independent of the meteorological climate.

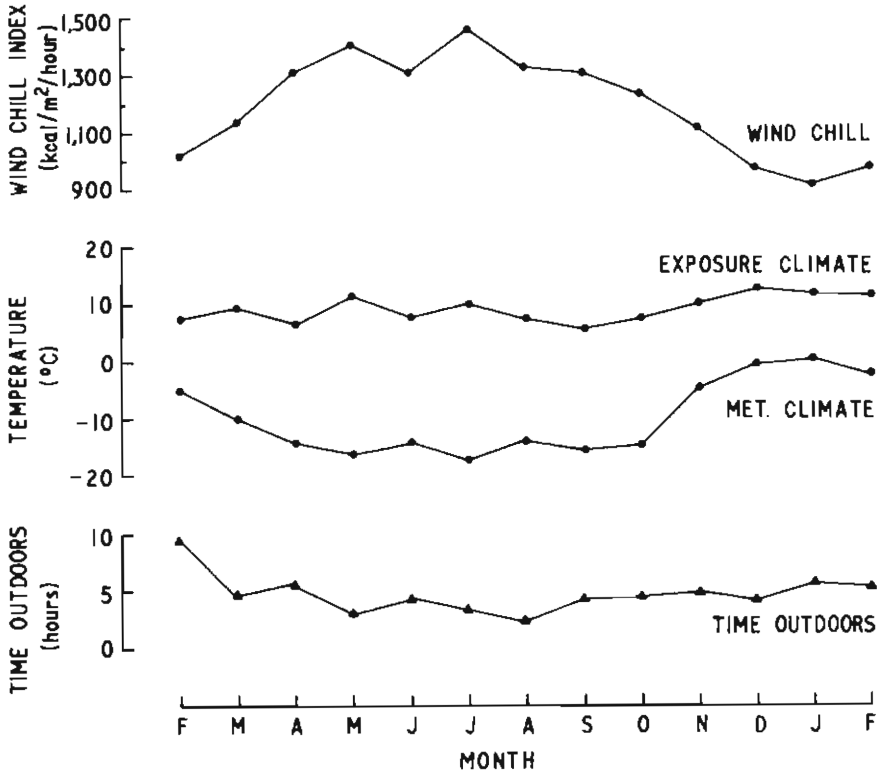


Figure 11. Mean monthly values of the temperature of the meteorological climate, the exposure climate, the windchill factor and the time spent outdoors.

There is no significant relationship between either the mean monthly outdoor temperature or the mean monthly windchill and the mean daily time spent outdoors. A man at Davis was subject to cold exposure which was related only to a limited degree to the meteorological climate. This contrasts to Cumming's (1961) results where the time out-of-doors was related to both outside temperature and windchill, the relationship being closer in the latter factor. It was stated that as soon as the wind speed reached 8 m/sec, outside activity usually ceased. Although the men at Davis did avoid extreme conditions where possible it was not my impression that outdoor activity stopped when the wind was above 8 m/sec.

(h) Activity patterns

The monthly means of the daily records of activity are shown in Appendix 4 and the mean results for each category for the period February 1963 to February 1964 are presented in the form of a histogram (Figure 12). During the study, light work averaged 5.8 hours daily (24 per cent of time), light-moderate work 2.7 hours (11 per cent), moderate-heavy work 2.8 hours (12 per cent), rest 8.2 hours (34 per cent) and personal administration 4.5 hours (19 per cent).

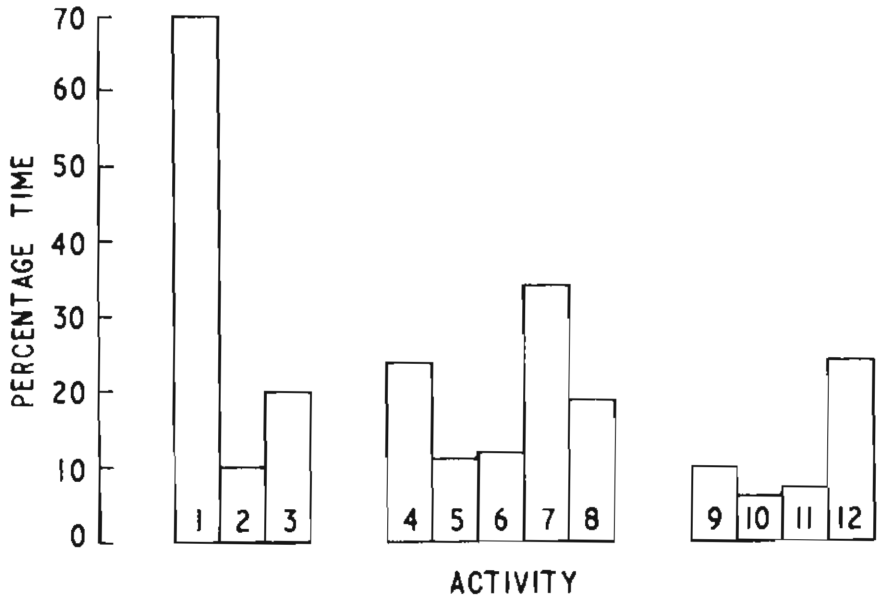


Figure 12. The percentage time spent in the various activities during the year. 1. Indoors - heated. 2. Shelter - unheated. 3. Outdoors. 4. Light work. 5. Light-moderate work. 6. Moderate-heavy work. 7. Rest. 8. Personal administration. 9. Medical - dental. 10. Medical research. 11. Biological research. 12. Station and field work, etcetera.

The categories of activity were different from those used by Masterton *et al.*, (1957), Soucek (1963) and Norman (1965), but the results show the greater degree of physical activity over the year at Davis than on the previously described studies. The increase in the "moderate-heavy" category in February and March 1963 is due to the unloading of the ship and the heavy construction work necessary to prepare the station for the wintering period. The September rise in this same category shows the preparations for the spring field program, while the rise in January 1964 indicates further construction work and preparations for the relief of the station.

The mean daily period of rest varied from 6.3 hours in February to 9.1 hours in August, and the mean for the whole study was 8.2 hours. The actual sleep times were not recorded, but would be proportionately less than rest time, depending on whether the subject was at the station or in the field. On field journeys considerable time was spent resting due to poor weather which kept men confined to their tents for days on end. Sleep times on these journeys were much more variable than at the station.

Sleep rhythms have been studied in the Antarctic. Wilson (1965) quotes the average sleep per night as 8.2 hours, and the mean duration was not found to differ during the various seasons of the year. This duration is higher than that for Davis, but as Wilson points out, the disruption of sleep occurring during the periods of continuous polar day and night varies considerably between bases and is markedly affected by social organisation. Soucek (1963) found that the mean sleep per night at Wilkes was 7.67 hours, while Shurley, Pierce, Natani and Brooks (1970) found that men at the South Pole spent 31.5 per cent, or 7.55 hours per day in sleep during the very busy early Antarctic summer season, with a range of 5.6 to 10.5 hours.

At Davis there was a regulated daily routine and this social factor had a subjective influence on the rest patterns. Although Sunday was considered a "rest" day and people were free to do as they chose, most men used the day for ordinary work tasks and therefore the pattern of this day remained the same as the other days of the week. On working days all men were required to be out of bed by a definite time.

Despite this regulated social behaviour, the light factor had an influence on the rest pattern and this is shown in Figure 13. This broadly disagrees with the British studies quoted by Wilson (1965) where the mean duration of sleep did not differ with the various seasons of the year. As these results are for rest and not sleep it is probable that the Davis results do agree with the British studies and the sleep times were not influenced by the polar light regimes, but that the men tended to rest more in the darker months.

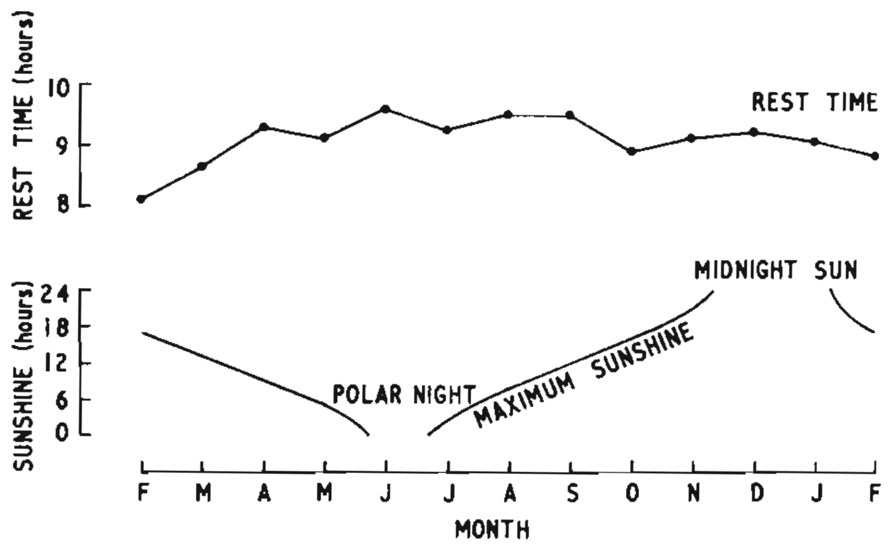


Figure 13. Mean monthly values of the daily period of rest. The maximum hours of sunshine are also included.

Appendix 4, which records the monthly means of the daily record of the type of work performed by the medical officer, shows some unexpected results. Over the year 2.3 hours per day (range 1.2 - 2.9 hours) were spent on medical and dental work while 5.8 hours per day (range 3.4 - 10.2 hours) were spent on general station and field tasks. Medical research occupied 1.5 hours per day (range 0.6 - 2.1 hours) and biological research 1.7 hours daily (range 0.4 - 3.5 hours). The small number of men at Davis was one reason for the high output of support work, as their existence depended on such tasks as gathering snow and ice for water, fuel for power and other menial tasks.

A detailed assessment of the medical officer's biological research times indicates that the time spent on this study was directly related to the presence of the wildlife under study. The summer months were the busiest for biology.

3.4 THERMAL COMFORT STUDIES

3.4.1 Materials and methods

(a) General

The basis of the investigation was the use of the now familiar "comfort vote" technique of Bedford (1936). In the present form of this technique the subject is required to record his assessment of his thermal sensations on a card (the comfort vote), on which the investigator later enters details of the environmental conditions, such as the temperature, the humidity and the air movement. Space is also provided on the card for entering the date, the place, the time, the subject's identification and any other details thought relevant to the investigation.

Two types of card (Plate 10) were used in the present investigation, one for indoor use and one for out-of-doors. The indoor voting card had provision on one side for entering details of the subject's activity, the presence of any radiant heat source and thermal sensations in the following categories: "much too hot", "just too hot", "warm", "neutral", "cool", "just too cool", "much too cool". These categories were numbered from +3 for "much too hot" to -3 for "much too cool". The range of -1 to +1, which represented the thermal sensations of cool, neutral and warm respectively, was classed as the comfortable range.

The reverse side of the card allowed for a record of the amount of clothing worn on the trunk, the feet, the head and the hands. Each garment was recorded as a layer of clothing, paired items such as gloves and socks being regarded as one.

The outdoor voting card had provision for entering the same range of thermal sensations as the indoor card, but, in addition to trunk recordings, the thermal sensations of the head, the hands and the feet were recorded. The men also recorded whether they were out of the wind, being warmed by the sun or exposed to drifting snow. The amount of clothing was recorded in the same way as on the indoor voting card.

(b) Indoor votes

The votes were cast at weekly intervals throughout the study. The indoor recordings were taken in the mess before the evening meal, three hours after food had been taken, or in the recreation room adjoining this during one of the intervals in the evening film show, three hours after the evening meal. On the sea voyage from Australia to Davis, votes were cast in the ship's saloon just before lunch or in a cabin later in the day. At all times the men were either resting or engaged in light sedentary activities. The medical officer recorded the indoor temperature and humidity by means of a sling psychrometer, after he had cast his vote. None of the subjects knew the prevailing temperature when casting their votes.

INDOOR COMFORT VOTE

Station____________________

Name________________ Date____________ Time________ Place______________

Activity__________________________

Dry-bulb________°F. Wet-bulb________°F. Air movement________ E.T.________°F.

Are you being warmed by radiation ? No________ slightly________

moderately________ strongly________

Comfort Vote		Trunk
TOO HOT (T.H.)	Much T.H.	
	Just T.H.	
NEITHER T.H. nor T.C.	Warm	
	Neutral	
	Cool	
TOO COOL (T.C.)	Just T.C.	
	Much T.C.	

Are you sweating ?________

Are you shivering ?________

Have you gooseflesh ?________

OUTDOOR COMFORT VOTE

Station____________________

Name________________ Date____________ Time________ Place______________

Activity__________________________

Temp________°F. Wind________kt. Drift________ Wind chill________

Are you out of the wind ?________ Are you exposed to drift ?________

Are you in shade ?________ or in sunshine ? (strong________ moderate________ weak________)

Comfort Vote		Trunk	Head	Hands	Feet
TOO HOT (T.H.)	Much T.H.				
	Just T.H.				
NEITHER T.H. nor T.C.	Warm				
	Neutral				
	Cool				
TOO COOL (T.C.)	Just T.C.				
	Much T.C.				

Are you sweating ?________ Shivering ?________ Have you gooseflesh ?________

CLOTHING

Note number of each item worn (number of *pairs* for foot and hand wear)

FEET	
Boots	
Leather	
Wool-lined	
Mukluks	
Vapour barrier (white)	
Vapour barrier (black)	
Gumboots	
Sox	
Mukluk inners	
Lauge-Koch inners	

TRUNK	
Pyjama pants	
Long underpants	
Trousers	
Windproof pants	
Singlets	
Shirts	
Sweaters	
Down jacket	
Anare jacket	
Windproof jacket	

HEAD	
Ski cap	
Balaclava (as cap)	
Balaclava (as helmet)	
Blizzard mask	
HANDS	
Mitts, windproof	
Mitts, wool	
Wristlets	
Fingered Gloves	
Leather (lined)	
Leather (unlined)	
Wool	
Silk	

Additional items :________________________________

Plate 10. Comfort vote cards.

(c) Outdoor votes

The outdoor recordings were made at 2 o'clock in the afternoon and coincided with one of the routine meteorological observations. The men, who did not know the result of the meteorological observation, had been out-of-doors for a period of at least ten minutes before recording their votes. The activity outdoors was more variable than that inside, and ranged from walking to heavy manual labour.

Whenever men were engaged in work away from the station, indoor and outdoor votes were cast on the usual voting day. The indoor votes were registered in tents, vehicles and the huts of the remote station, while the outdoor votes were recorded in the same manner as that used at the main station.

3.4.2 Results and discussion

(a) Analysis of indoor votes

The distribution of indoor votes cast according to air temperature and thermal sensation are shown in Table 11. The total number of votes cast was 587 but, of these, eleven votes did not have a temperature recorded on them and therefore could not be included in the survey.

Table 11. Distribution of indoor votes cast according to air temperature and thermal sensation

Dry-bulb temp.		Number of votes					Total
(°F)	(°C)	Just too hot +2	Warm +1	Neutral 0	Cool -1	Just too cool -2	
< 25	< -4	0	10	10	4	3	27
41-45	5.0 - 7.2	0	0	1	3	5	9
51-55	10.6 - 12.8	0	2	4	2	1	9
56-60	13.3 - 15.5	1	10	13	4	0	28
61-65	16.1 - 18.3	1	26	43	5	3	78
66-70	18.9 - 21.1	9	74	62	10	2	157
71-75	21.7 - 23.9	16	74	26	2	0	118
76-80	24.4 - 26.7	27	81	24	1	0	133
81-85	27.2 - 29.4	2	10	5	0	0	17
Total		56	287	188	31	14	576

A further small group of votes was cast some time after the actual voting time and, because of discrepancies occurring due to the inability of the men to remember details of thermal sensation or clothing, these votes were discarded.

The original intention of the indoor study was to relate thermal sensation and clothing to all components of the thermal environment, but under the prevailing conditions it was only convenient to measure dry-bulb and wet-bulb temperatures. The analysis was therefore restricted to those votes cast under "normal" indoor conditions, in "still" air and in the absence of direct radiant heat. All the votes other than those cast at Davis station therefore had to be discarded, because they failed to comply with one or more of these restrictions. A large vertical temperature gradient (0°C at floor level to 38°C at ceiling level, 2.3 m higher) in the hut at the remote station produced an "abnormal" thermal environment, while votes cast under field conditions were affected by radiant heat from cooking stoves or heaters.

The "just too hot" (+2) and "just too cool" (-2) votes had all to be discarded, for one or other of the reasons outlined above. Radiation was the major cause for invalid "hot" votes, while either abnormal environment or doubt concerning accuracy invalidated the few which were "too cool".

Table 12. Number of votes cast in each quarter of the year, and number and distribution of those analysed

Time of casting of votes	Number of votes				
	Total cast	Analysed			
		Warm (+1)	Neutral (0)	Cool (-1)	Total analysed
1. Shipboard	108	32	48	10	90
2. March to May	126	44	55	11	110
3. June to August	126	69	18	0	87
4. September to November	116	54	29	2	85
5. December to February	111	65	25	2	92
Total	587	264	175	25	464

The number of votes cast in each quarter of the year and the number and distribution of those suitable for analysis are shown in Table 12. The votes analysed for each quarter were comparable in number.

Figure 14 shows the monthly outdoor and indoor air temperatures at the times when the votes were cast, the mean monthly values for the comfort vote, and the mean number of garments worn on the trunk. Dry-bulb temperature has been used rather than effective temperature (which takes into account humidity and air movement), because the air movement was slight and the relative humidity was constant and low (35 per cent). Moreover, there is evidence that, within the range of air temperatures encountered in this study, humidity has little effect on the comfort of sedentary men (Koch, Jennings and Humphreys, 1960). The changes in the mean values of indoor air temperature over the period from May to August reflect the performance of a new heating system, which was installed during April and May, but which did not function properly until August.

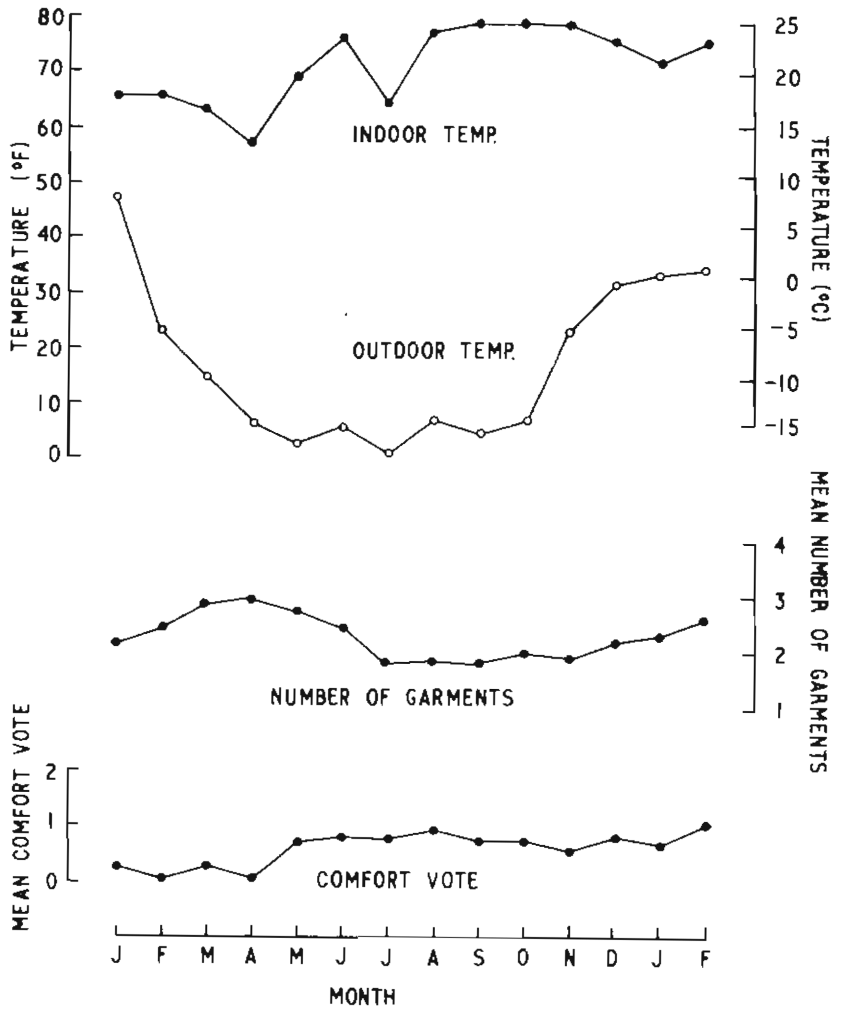


Figure 14. Monthly mean values for the indoor and outdoor temperatures, the number of garments worn on the trunk indoors, and the indoor comfort vote.

(b) Range of comfort

The analysis of the 464 votes, the distribution of which is shown according to air temperature and thermal sensation in Table 13, illustrates the fact that none of the men casting votes was uncomfortable in the observed temperature range. Hence the variations in the mean comfort vote, as shown in Figure 14, all fell within the range of comfort. This finding (namely, that all men felt comfortable within the temperature range from 5.5°C to 27.2°C) is in agreement with Palmai's results (1962a) for men at Macquarie Island in the sub-Antarctic, where no comfort zone could be determined. (A "comfort zone" is defined as the range of temperatures within which an arbitrary percentage of subjects experiencing these temperatures are comfortable.)

Table 13. Distribution of indoor votes analysed according to air temperature and thermal sensation

Dry-bulb temperature (°F)	Dry-bulb temperature (°C)	Number of votes: Warm (+1)	Number of votes: Neutral (0)	Number of votes: Cool (-1)	Total
41-45	5.0 - 7.2	0	1	3	4
51-55	10.6 - 12.8	2	4	2	8
56-60	13.3 - 15.5	9	13	4	26
61-65	16.1 - 18.3	24	42	5	71
66-70	18.9 - 21.1	70	61	9	140
71-75	21.7 - 23.9	71	26	1	98
76-80	24.4 - 26.7	79	24	1	104
81-85	27.2 - 29.4	9	4	0	13
Total		264	175	25	464

Although the men at Davis were comfortable, they could still appreciate changes in temperature, and this is illustrated in Table 13, in which a trend towards warmer thermal sensations as the temperature increased is clearly shown.

Loots and Krüger (1971) have confirmed the findings that narrow comfort zones are not discernible in polar regions, as the men at Sanae base were comfortable in a wide range of temperatures.

(c) Preferred temperature and comfort zone

The temperature at which the maximum number of subjects experienced "neutral" thermal sensation was considered to be the preferred temperature for Davis. This was 14.2°C. At some Australian stations the temperatures of the buildings are adjusted by members of the expedition, and the average air temperature has been taken as an estimate of the "preferred temperature". The heating of the study area at Davis did not have controls which could be adjusted manually, and it is considered that the method of calculating preferred temperature at Davis and Sanae is more accurate than that based on varying thermostat readings.

Since thermal comfort depends on many variables, such as weather, season, activity, age, sex, race, diet, acclimatisation and clothing, the definition of comfort zones varies considerably with different workers in different regions. Macpherson (1964) has discussed the difficulties in attempting to compare results from different regions. Table 14, which also shows the percentage of subjects comfortable in each of the comfort zones defined, illustrates these variations in definition. However, despite the variations in definition, comfort zones are recognisable in temperate and tropical regions, in contrast to the lack of similar zones in Antarctic and sub-Antarctic regions.

Table 14. Comparison of the ranges of comfort and the preferred temperatures for different localities

Locality	Latitude	Comfort zone (°C Dry-bulb)	Proportion of subjects comfortable	Preferred temperature (°C Dry-bulb)	Reference
Singapore	1°N	24.4 - 27.2	66%	25.9	Webb (1959)
New Guinea	4°S	*	*	25.6	Hindmarsh and Macpherson (1962)
Calcutta	23°N	23.3 - 28.3	100%	25.8	Rao (1952)
Sydney	34°S	18.9 - 27.2	50%	22.9	Hindmarsh and Macpherson (1962)
London	51°N	12.8 - 23.9	70%	18.2	Bedford (1936)
Macquarie Island	55°S	10.6 - 21.7+	100%	-ø	Palmai (1962a)
Davis, Antarctica	69°S	5.5 - 27.2+	100%	14.2	This study
Sanae, Antarctica	70°S	3 - 16	100%	13.4	Loots and Krüger (1971)
Maudheim, Antarctica	71°S	-*	-*	13.5 - 14.5	Wilson (1965)

* No figures available. + All persons comfortable in ranges over which study done. ø No temperature reported.

The lowering of the preferred indoor temperature with increasing latitude is also shown in Table 14. This result confirms the observations of Nordenskjöld and Andersson (1905), Mawson (1915), Shackleton (1919), and Wilson (1966) who all described men as working quite comfortably in low indoor temperatures in Antarctica. Acclimatisation is one possible factor causing comfort to be maintained at these low temperatures, but the effects of clothing must first be considered.

(d) Effect of clothing

Figure 15 shows, for men indoors, the relation of the mean number of garments, and of the mean comfort vote to the prevailing temperature. The regressions were significant at the 0.1 per cent and 1 per cent levels respectively, and show that, although the men were comfortable, they could still appreciate changes in temperature.

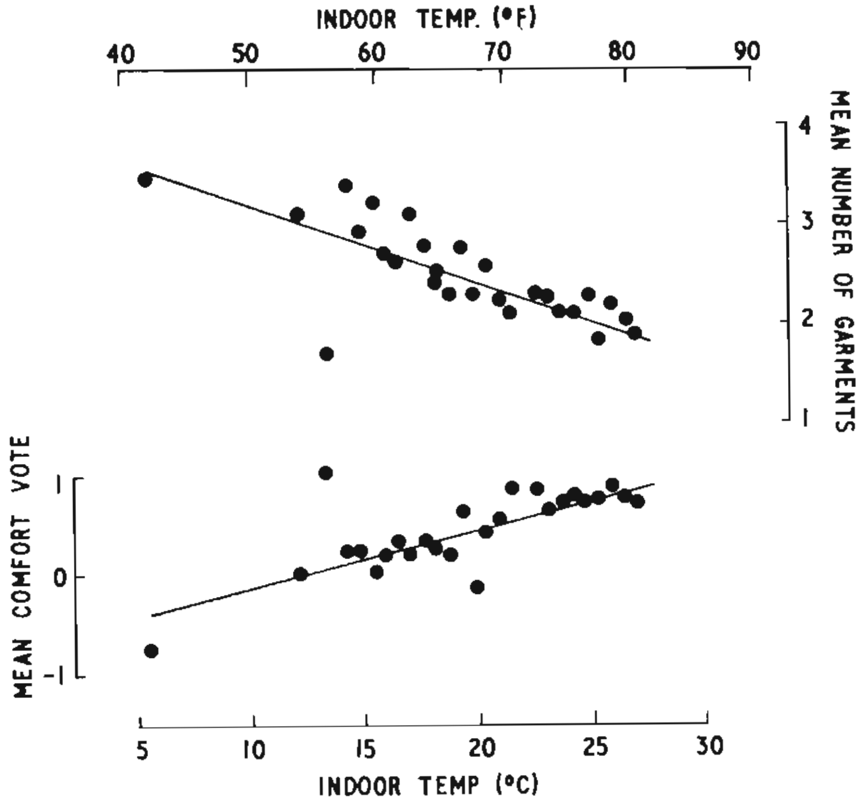


Figure 15. Relation between the mean number of garments on the trunk and the temperature indoors, and the mean indoor comfort vote and the indoor temperature.

Comfort was maintained by changes in the number of garments worn. Compensation, reflected by the clothing changes and the levels of comfort, was not so readily achieved for high temperatures as for low temperatures. After removing one layer of clothing as the temperature rose, the men did not remove the second as readily, probably because of the difference in the nature of the outer garments and those nearer the skin, with the result that warmer comfort votes were cast at the higher range of temperatures.

The difficulties of comparing the insulation of various garments and materials has been pointed out by Goldsmith (1960). Previous workers (Goldsmith, 1960; Palmai, 1962a) have expressed the insulation of clothing simply in terms of the numbers of layers of clothing, and this method has been followed here. The basis for using layers as the unit of measurement is to be found in the principle expressed by Fourt and Harris (1949) who state:

> *'Investigations of the thermal character of cloth agree in showing that the main factor in insulating value is thickness'.*

The inverse relation between clothing and indoor temperature observed in this investigation confirms Palmai's (1962a) suggestion that '*in the absence of social convention with respect to dress, they* (the Macquarie Island Expedition) *adjusted their clothing to the existing temperature*', but the mean clothing level at Davis changed only about half as much as it did in the Macquarie Island study. The difference in climate may have been an influencing factor here, although the clothing worn indoors was independent of the outdoor temperature (Figure 14).

The regression linking all three variables of mean thermal sensation (Y, in units of -1 to +1), indoor temperature in degrees Celsius (x_1), and mean number of garments on the trunk (x_2) was

$$Y = 0.435 + 0.029\ (x_1 - 19.57) - 0.394\ (x_2 - 2.50).$$

This multiple regression suggests that the thermal sensation was influenced to a much greater degree by clothing than by temperature, which adds support to the view that dress plays a large part in the maintenance of thermal comfort at low temperatures in polar regions.

(e) Acclimatisation to cold: Indoor study

In order to discover whether any changes in clothing and comfort occurred that might be attributable to acclimatisation to cold, the votes cast after midwinter were compared with those cast before. Goldsmith (1960) and Palmai (1962a) have both used this method, on the assumption that acclimatisation would be more fully developed after midwinter than before. The results of the indoor comparison are presented in Figure 16. This shows that, for temperatures common to both periods, after midwinter the subjects felt warmer than they had in the same air temperature before midwinter, even though they wore much the same number of garments. The conclusion that a degree of acclimatisation has occurred seems logical.

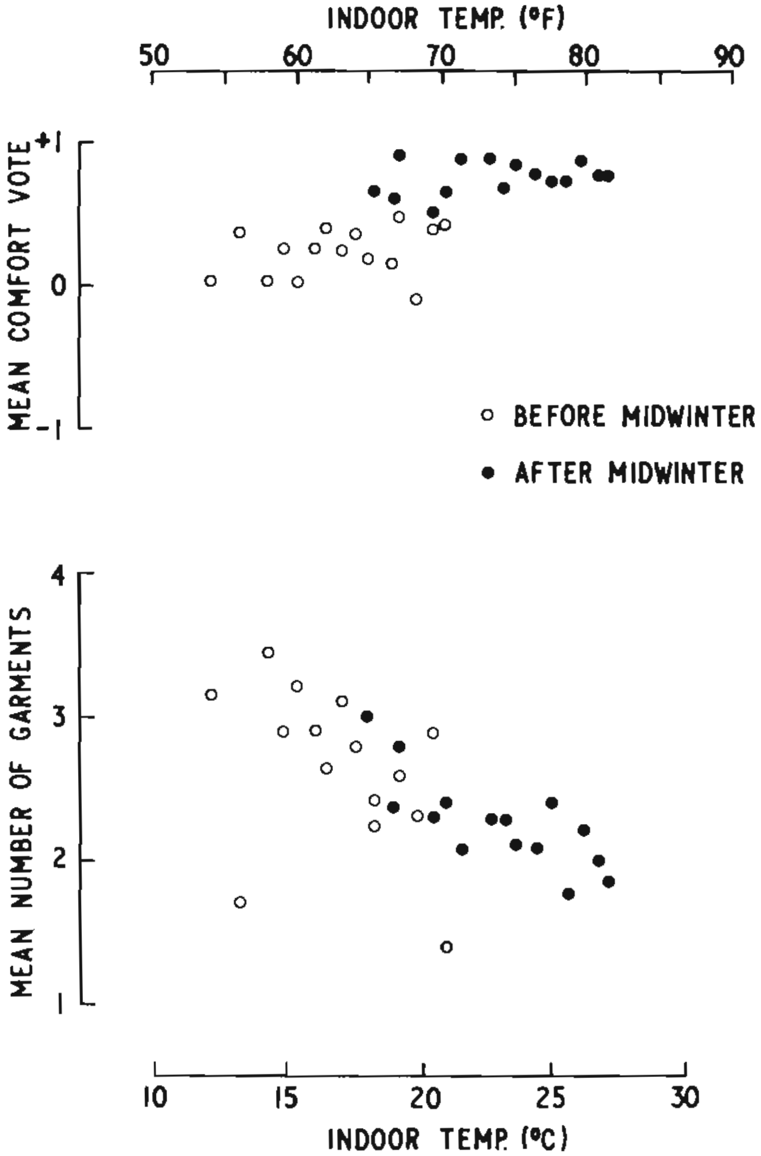


Figure 16. Relation of the mean indoor comfort vote and of the mean number of garments on the trunk to the indoor temperature for the periods before and after midwinter.

(f) Outdoor votes

The votes cast over the whole period of 54 weeks in the outdoor study, together with the activity of those voting and the presence of sunlight, are shown in Table 15.

Table 15. Activity of men and influence of sunshine on those voting in the outdoor study for the 54 weeks, for the 17 weeks before and the 17 weeks after midwinter

	Number of votes		
	Yearly	Before midwinter	After midwinter
Activity:			
(a) Moderate to heavy manual labour	278	89	95
(b) Light work	196	63	58
Sunlight:			
(a) Present	183	58	49
(b) Absent	291	94	104
Total	474	152	153

All of these votes were used in order to examine the relation between comfort, the amount of clothing worn and the thermal environment. More men were engaged in manual labour than in light work, but the general level of activity did not vary greatly throughout the year. More votes were recorded in conditions unaffected by solar radiation than in conditions affected by it, but these also were evenly spread throughout the year. In order to compare the various outdoor conditions of wind and temperature, windchill (Siple and Passel, 1945) was used as the index of outdoor climatic stress. This incorporates temperatures and wind speed in the one figure and is generally considered (Burton and Edholm, 1955) to correspond quite well with the discomfort of men in cold climates.

Line charts and tables (Consolazio *et al.*, 1963) have been drawn up enabling one to derive the windchill from the wind velocity and ambient temperature and to estimate at the same time the degree of discomfort in the environment. The equation of Siple and Passel (1945) used in this study is

Windchill (k cal/m^2/hr)

$$= (\sqrt{WV \times 100} - WV + 10.45) \times (33 - T_A),$$

where

WV = wind velocity in m/sec

10.45 = an arbitrary constant

33^oC = average skin temperature

T_A = ambient dry bulb temperature, ^oC.

(g) Clothing and thermal comfort

Figure 17 shows the mean number of garments worn on the various regions of the body, and the mean windchill on the 54 days on which outdoor observations were made. The mean values of each for the successive three-month periods are also shown. At Davis, as the weather became slightly colder with the onset of winter, less clothing was worn on the trunk and the feet, while more garments were worn on the hands. The improvement in the weather with the approach of summer resulted in less clothing being worn on all areas of the body.

The increase in the number of hand coverings during winter reflects the nature of the outdoor activity. In many cases this involved the handling of metal objects, such as fuel drums and hydrogen cylinders. As outdoor temperatures fell, the temperature of these objects also decreased, but this decrease in temperature is not necessarily represented by the prevailing value for the windchill. This index, which is designed to measure physiological effects, takes into consideration both air temperature and air speed. A fall in air temperature therefore can be compensated for by a fall in air speed which would, of course, not affect the temperature reached by metal objects, which in turn would determine the amount of hand coverings necessary.

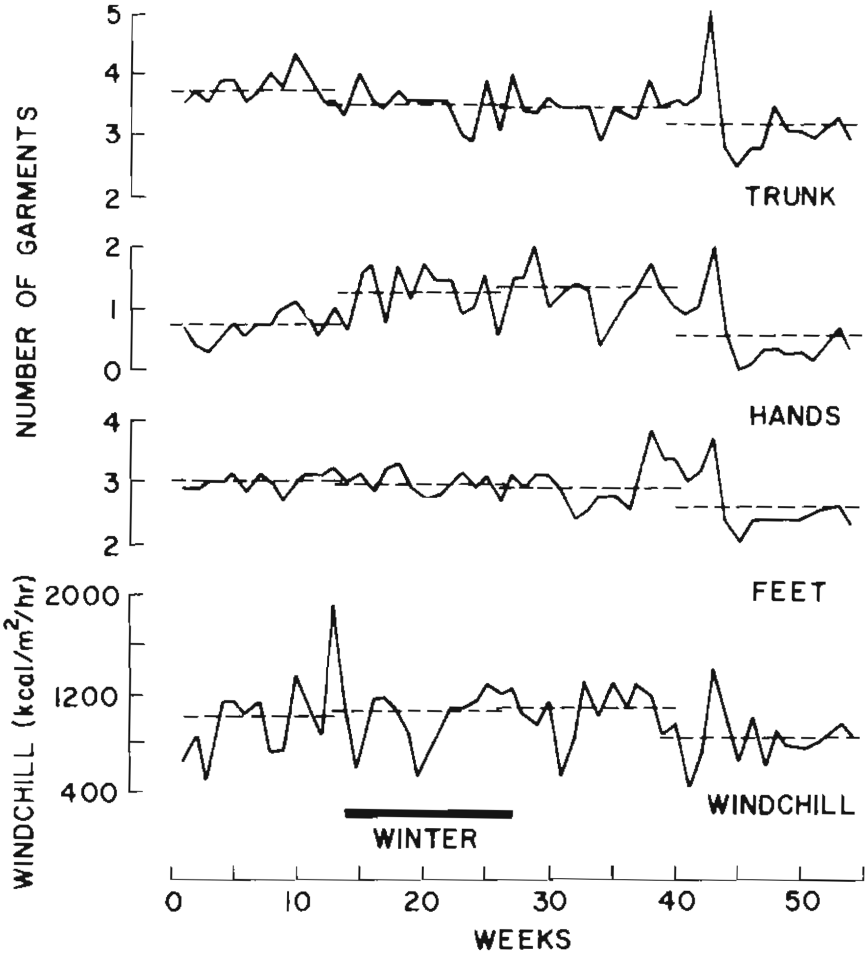


Figure 17. *The mean number of garments worn on the trunk, hands and feet out-of-doors and the mean windchill on days on which outdoor votes were cast. The dotted lines represent the mean values for successive three-month periods.*

Figure 18 illustrates the changes in the mean comfort vote of the feet, the hands and the trunk for the 54 outdoor observations. The quarterly mean values are also shown. Despite slightly colder weather during winter, the mean comfort vote for the feet, the hands and the trunk rose. With the coming of summer and the lowering of the windchill, the comfort vote rose further. In both these periods less clothing was worn on the feet and the trunk than at the beginning of the year.

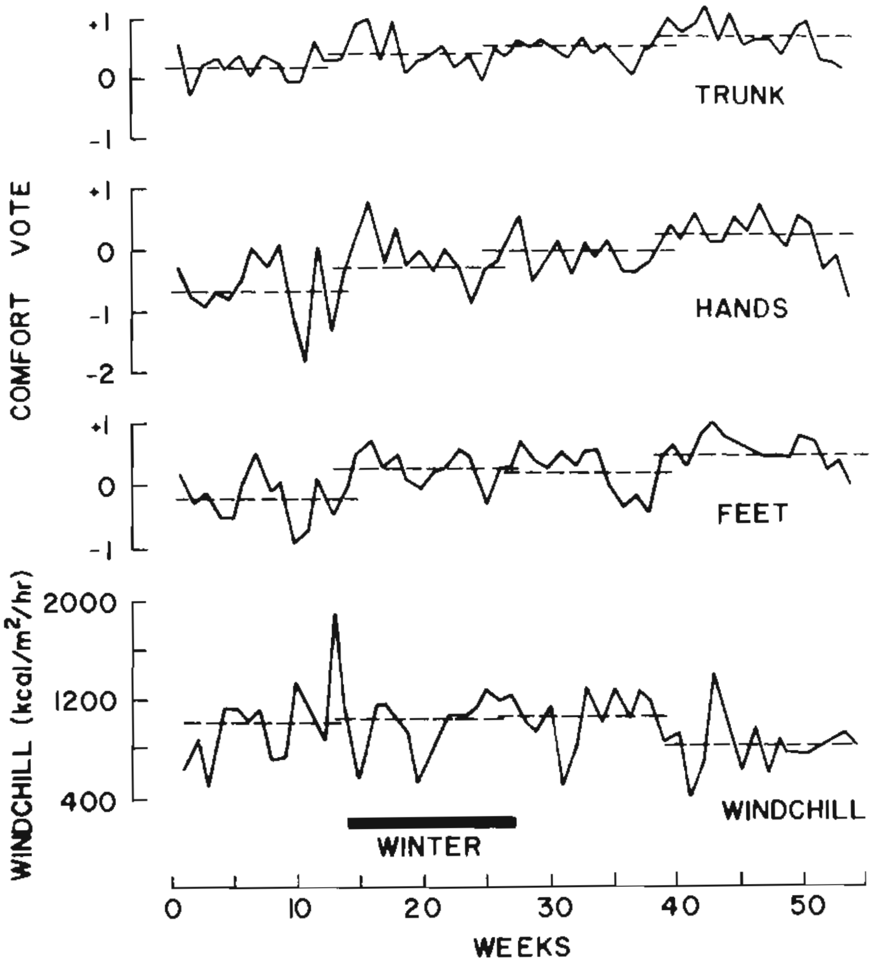


Figure 18. The mean comfort vote for the trunk, hands and feet out-of-doors, and the mean windchill on the days on which outdoor votes were cast. The dotted lines represent the mean values for successive three-month periods.

Previous workers in polar regions have disagreed on the pattern of clothing changes and the thermal comfort of wintering parties. The Davis findings that the men maintained their comfort at a higher level yet did not increase their clothing with the onset of winter, confirm the opinions of Frazier (1945) and Butson (1949) who observed that, as the weather grew colder, little if any additional clothing was needed by the parties at Little America III and in Grahamland. However, the results of Goldsmith (1960) and Palmai (1962a), who found that the number of garments increased as the weather became colder, and then decreased as it became warmer, contrast sharply with those obtained at Davis.

Rogers (1973) who accompanied the Trans-Antarctic Expedition, analysed the clothing worn and the relevant climatic data. He found that the clothing worn increased with lower temperatures and the passage of time, but did not decrease by the expected amount when higher temperatures occurred, or when similar conditions recurred after an interval of time. These findings also contrast with those from Davis.

The results of the outdoor study in the Vestfold Hills have been used in a more complex analysis of the thermal discomfort at ANARE stations in the Antarctic and sub-Antarctic (Budd, Hicks, Lugg, Murray and Wigg, 1969). The Davis group were very successful in keeping comfortable, and this result for thermal comfort of the trunk in the men working outdoors is compared with those of the pooled study (Table 16).

Table 16. Thermal comfort of the trunk in men working outdoors in Antarctica

Study	Number of observations	Frequency (per cent)		
		Too cold	Comfortable	Too hot
Davis	464	1	96	3
Antarctica	1 569	6	87	7

It is interesting, too, that only 1 per cent of the Davis "too cold" category were shivering and 4 per cent of the "too hot" were sweating compared with the pooled results of 2 per cent shivering and 9 per cent sweating. This variation is due to the more efficient use of the polar clothing, while working outdoors, by the Davis group.

(h) Acclimatisation to cold: Outdoor study

In order to compare the outdoor votes cast before and after midwinter, those taken over the 17-week period before midwinter and those obtained in the corresponding period after midwinter were used. The votes analysed are set out in Table 15.

Because there were no votes taken in weeks equidistant from midwinter with which to compare them, 169 votes were discarded. The votes were balanced in this way because in weeks equidistant from midwinter, the sun would have the same warming effect on men exposed to it at the same time of the day. The factors of radiation and activity are unlikely to have been the cause of any differences observed in comfort votes or clothing, since the votes affected by these factors were almost the same before and after midwinter (the few extra votes in the high-activity group after midwinter tended to be balanced by the fewer votes affected by radiation at that time).

The comparison between the mean windchill, the mean comfort vote of the exposed face and the trunk, and the mean number of garments on the trunk for the periods before and after midwinter are shown in Table 17. After midwinter, fewer garments were worn with a higher degree of comfort than in the period before it. This change in thermal sensation is very similar to that described by Palmai (1962a) for men working outdoors on Macquarie Island. From a consideration of the amount of clothing worn together with the degree of thermal comfort achieved in the periods before and after midwinter, it would indeed seem that increased thermal tolerance had occurred after exposure to cold.

Table 17. Comparison between the mean windchill, the mean comfort vote of the exposed face and the trunk, and the mean number of garments on the trunk for the periods before and after midwinter

Period	Mean windchill	Mean number of garments on trunk	Mean comfort vote	
			Exposed face	Trunk
Before midwinter	1010	3.73	-0.33	0.26
After midwinter	1020	3.41	-0.04	0.34

4. CLINICAL AND PSYCHOLOGICAL OBSERVATIONS

4.1 HEALTH OF THE EXPEDITION

4.1.1 Materials and methods

(a) General

All nine members of the expedition took part in the health and morbidity study. In order to retain anonymity the men were given subject identification A - I, which differed from that of the physiological studies (Subjects 1 to 9).

Three to nine months before the beginning of the study, all subjects had been examined by Commonwealth Medical Officers of the Department of Health, and the Department of Army had conducted psychological tests on the men (Law, 1962; Owens, 1966, 1967a, 1967b). Blood tests (group, serology, haemoglobin) and a chest x-ray had also been done.

(b) Illnesses and injuries

This study consisted of monthly examinations (done during the recording of the physiological variables as described in section 3.1), a half-yearly complete physical examination and records of all illnesses, diseases and injuries that occurred throughout the year. These were classified under fifteen categories, which were based on the *Manual of International Statistical Classification of Diseases, Injuries and Causes of Death* (World Health Organisation, 1955).

(c) Consultations

A record was kept of all visits to the surgery and reports to the Medical Officer from men working away from the station. The aim of this study was to demonstrate any seasonal variations that might occur both in the number of consultations made and also the diagnosis for which an opinion was sought.

(d) Cold injury studies

All cases of cold injury reported were recorded and the simultaneous climatic data were noted where this was possible. Cases of "light frost-bite" or "frost nips" of the finger tips that resulted from touching cold objects (such as metal instruments, tools, engine spares and ice) were not included in the study as all men tended to regard them as a trivial matter and did not report them. Included in this category are the small and unnoticed "frost nips" of the nose and cheeks which occurred on occasions and, apart from leaving small areas of peeling skin, caused no morbidity.

4.1.2 Results and discussion

(a) Illnesses and injuries

The classification of the medical diagnoses and their occurrence at Davis are recorded in Appendix 7. No illnesses were recorded in six of the fifteen categories. The absence of cases in the categories of neoplastic, allergic, metabolic and endocrine diseases, and diseases of bone, blood, nervous and genito-urinary systems is most likely attributable to the age group of the men, their excellent health and the selection procedures.

The environment had a much lower influence on the health statistics than might be expected for the severity of the climate, diseases related to the environment occurring in only 10 per cent of the total cases. The environment, however, may have been an important factor in the absence of illnesses in the category of infective diseases.

The occurrence of skin diseases, trauma, accidents and poisonings, and non-traumatic musculo-skeletal diseases are directly related to the type of work and the living conditions at Davis. The incidence of these (skin diseases 8 per cent, trauma and injuries 28 per cent, musculo-skeletal diseases 4 per cent), however, did not appear to be increased above that of a medical practice for a comparable group of males in Australia.

Dentistry accounted for 12 per cent of the treatments, while 23 per cent of the diagnoses were included under symptons and ill-defined diseases. In this category vague gastro-intestinal symptons were within normal limits, but the frequency of headaches and insomnia were atypical for a group of healthy males. This finding is not new as Mullin (1959), Palmai (1963a) and Nelson (1963b) have reported similar findings in Antarctica.

Psychiatric illness was rare and this contrasted with the expected findings in an isolated all male community.

(b) Seasonal variations in illnesses and injuries

Appendix 8 shows the occurrence of the illnesses and injuries in each month of the year. The maximum number (18) was recorded in the winter month of August, while the lowest numbers occurred in February 1963 (6 cases) and October (7 cases). The mean monthly rate was eleven and there was a significant rise in the number of incidents requiring attention in the last three months of the expedition.

During the summer, when there were twenty-four hours of daylight, the activity at Davis increased as both station and scientific projects were being completed before the arrival of the relief expedition. The rise in the category of ill-defined diseases and symptoms at this time may reflect the prospects of returning to civilization, a fact that loomed large in everyone's mind.

Seasonal variations of significance occurred in a number of the categories. In April the increase in ill-defined diseases may well have been caused by carbon monoxide poisoning. Although conclusive evidence in the form of actual measurement was lacking for this, the beginning of the winter snow build-up and the subsequent obstruction of ventilators, the inexperience of the men and the type of symptons reported, are all suggestive of the well documented polar problem of carbon monoxide.

The increase in the diseases related to the environment in April and September is closely correlated with the resumption of field work after periods of limited field activity. A higher incidence in August of injuries, such as back strain, was associated with heavy work in the power house and around the station. All nine men assisted in this.

In the period June-August there was an increase in respiratory diseases. This was unexpected and no reason could be found for the increase.

On examination of the records it would appear that there were seasonal variations in the dental category. These were, however, the direct result of the routine dental check-ups of all men, and no increase in fillings was associated with climatic changes. Dental fillings were necessary in some of the men after such routine examinations.

(c) Subject morbidity

The health statistics for each man are shown in Appendix 9. The mean number of illnesses and injuries for each individual over the year was 16 (range 6 - 34).

The morbidity was greatest in the three oldest men (aged 31 - 34 years) and least in the group of three whose ages were 25 - 27 years. The three youngest who were all 24 years of age had a morbidity rate between the above two groups.

Definitive conclusions on the various occupational groups were not possible because of the small number of subjects and the fact that no one subject limited himself to one work discipline only. The breakdown of morbidity figures into two groups representing those who spent most of their time outdoors and those who worked mostly indoors, showed that the outdoors group was more prone to illness and injuries.

The distribution in age and occupational groups have also been shown by the Tenth Soviet Antarctic Expedition 1956-66 (Matusov, 1971). Matusov found that morbidity increased with age on the expeditions, but

> '*the somewhat high morbidity rate in the youngest age group* (21 - 25 years old) *was probably due to inadequate training for the conditions of polar expeditions*'.

The highest morbidity rate occurred among personnel mainly working outdoors in both scientific and support groups.

(d) Consultations

The monthly medical consultations for each man are shown in Table 18 and the counselling calls over the year are analysed in Table 19. At Davis there were 141 new cases, 104 follow-up cases and 23 counselling calls.

Table 18. Analysis of medical consultations of all subjects for each month of the period at Davis

Subject	F	M	A	M	J	J	A	S	O	N	D	J	F	Subject total
A	-	3	8	2	2	4	6	2	1	1	2	6	4	41
B	-	1	1	-	-	-	-	1	-	2	2	3	2	12
C	-	1	2	2	3	1	3	7	-	7	3	3	6	38
D	-	1	1	1	1	2	5	11	5	6	2	3	4	42
E	-	1	1	1	5	7	3	-	1	4	1	2	3	29
F	1	5	2	1	2	1	1	-	-	-	1	1	1	16
G	2	-	-	1	1	4	1	-	2	-	3	-	-	14
H	1	5	1	-	1	-	1	4	1	-	2	-	-	16
I	4	1	2	2	-	-	-	-	9	7	8	2	2	37
Monthly totals	8	18	18	10	15	19	20	25	19	27	24	20	22	245

Table 19. Analysis of counselling calls of all subjects for each month of the period at Davis

Subject	Month													Subject total
	F	M	A	M	J	J	A	S	O	N	D	J	F	
A			1				1					1	1	4
B														0
C				1							1			2
D		1			1	2	1	1	1	1		2	1	11
E						1			1				1	3
F									1					1
G														0
H									1					1
I											1			1
Monthly totals	0	1	1	1	1	3	2	1	4	1	2	3	3	23

Palmai (1963a, 1963b) has published the only other figures from ANARE. Fourteen wintering men on Macquarie Island had 401 new cases, 317 follow-up cases and 667 counselling calls. Headache occurred in 25 per cent of the new cases, trauma in 21 and insomnia in 12.

The Davis figures show a marked contrast with those from Macquarie Island, especially in the rate of illness and also the counselling calls. Discussion with a number of ANARE medical officers leads to the conclusion that the Macquarie Island results are unusual and the Davis results more representative of an expedition.

The illnesses and accidents from Davis were in the majority of cases of a minor nature and, as Smart (1964) found with the Falkland Islands Dependencies Survey, although the health records seemed serious all men returned to their homelands in good health.

(e) Cold injury studies

Although Table 20 cites nine instances of superficial frostbite and two cases of unusual nonfreezing cold injury, as described later in this section, severe cold injury was not a common occurrence at Davis. More recent studies by Hunt (1968) and Youngman (personal communication) confirm the Davis results. Hunt wintered in 1966 with a group of 30 men at Byrd Station, the largest inland U.S. station and he commented that '*frostbite presented little problem*'.

The two cases of trench foot were incapacitating, but there were no gross or residual sequelae to the injuries. The cases were considered to be due to ignorance on the part of those sustaining the injury.

Analysis of the cases of frostbite occurring in April (see Table 20) shows that in every case it was one of the first times that the men involved found themselves in a potential cold injury situation. The other cases, apart from those of Subject D, were due to working in the field in adverse conditions. Subject D suffered frostbite because of not wearing gloves or using inadequate glove assemblies in calm or near calm conditions while running with the dog teams on the sea ice.

The wind speed and temperature were accurately recorded either simultaneously or close to the time of the occurrence of frostbite in seven of the nine cases. In all seven cases there was drifting snow. Massey (1959) conducted experiments in Antarctica and showed that frostbite often results from the added cooling effect of drift snow. The weather data for the other two cases (those of Subject D) have been estimated with a considerable degree of accuracy, and there was no drifting snow at the times of injury.

Wilson (1963) recorded 69 cases of frostbite in a study at Maudheim and found that no cases occurred when the temperature was above -8°C and the windchill less than 1380. He concluded that this was evidence in favour of Siple's assumption that exposed flesh begins to freeze at a windchill index of 1400 (Siple and Passel, 1945).

The small number of results from Davis broadly agrees with this assumption. Wilson (personal communication) considers it important that cases such as those from Davis are documented in order that clinical cases can better be correlated with the weather variable windchill, which is now used by both military and civilian organisations in planning outdoor activities where proper clothing and wind protection is essential (Falconer, 1968). Wilson (1967) states that, although there is some foundation for the empirical scale of the windchill formula which may allow prediction of the risk of frostbite in exposed skin under varying meteorological conditions in the field, windchill may not be equally valid for the different parts of the body. It is in this area that much observational work remains to be done.

The only doubtful case that did not fit the windchill criteria of 1400 was Subject D who sustained superficial frostbite of the hands in calm conditions at -18°C. As he was exercising vigorously it was likely that his bare hands cooled considerably due to the local air movement, and the calculated windchill index of 500 gave an inaccurate index of the cold stress on Subject D.

Table 20. Reported cases of frostbite, the subjects involved, their activity and location, and the climatic conditions occurring at the time of the injury

Date	Subject	Cold injury	Activity	Location	Wind speed (m/sec)	Temp. (°C)	Windchill Kcal/m²/hr)
24 April	F	Superficial frostbite face, ears	Tracking met. balloon by theodolite	Davis	11	-23	1800
"	B	Superficial frostbite face	Dog-sledging	Sea ice near Davis	13	-24	1900
"	I	"	"	"	"	"	"
12 August	G	Superficial frostbite face	Vehicle traverse	Plateau 48km from Davis	16	- 2	1200
5 September	H	Superficial frostbite face, hands	"	Plateau near Platcha	7-13	-28 to -32	1800-2200
"	B	"	"	"	"	"	"
"	C	Superficial frostbite hands	"	"	"	"	"
29 September	D	"	Dog-sledging	Sea ice near Davis	0	-18	500
10 October	D	"	"	"	2	-16	1100

The two cases of non-freezing cold injury to be discussed are unusual in that they occurred in well equipped men who had been given cold weather indoctrination before leaving Australia.

Three subjects (S1, S3, S6) travelled in the Snow-Trac for a period of seven days in September. They travelled 370.3 km and slept in a polar pyramid tent each night. Although polar whiteout and drift occurred, travel was possible on all seven days.

The traverse found a safe route inland (Figure 4) and left a depot of supplies which were used later in the year by a three-man group using two dog teams.

Throughout the journey marker poles and flags were placed at 2 - 4 km intervals. At each stop one man would leave the vehicle, drill a hole in the ice or sastrugi with a hand auger and place the marker pole in the hole. The whole operation took between five and ten minutes.

All men wore clothing assemblies as described by Linton-Smith (1968) and thermal boots which were designated for dry cold use. Thick woollen Norwegian ski socks and light woollen (Australian Army) socks were also worn. The socks were changed daily, foot powder was used and the boots were removed at night when the men slept in down sleeping bags.

The maximum altitude reached was 1200 m and the temperature varied between -15°C and -32°C. The windspeed range was 3.1 m/sec - 13.4 m/sec.

Clinical summary, Subject S3: Twenty-four hours after his return from the field trip he complained of aching feet. Four days later he went for a short run with the dog teams and the aching became more severe. Over the next day the aching in the feet became continuous and the patient was unable to stand on them for more than a few minutes at a time. Examination of the patient up till this time did not reveal any cause for this symptom.

On the seventh day after returning to Davis he awoke with intense burning pain in both feet which were hot and sweating profusely. On examination, both feet were hot, red, slightly swollen and hyperhydrotic with small clusters of vesicles and papules over both heels and soles. The patient was rested with the feet exposed to an even temperature of 20°C and analgesics were given as necessary.

The severe pain continued for a period of three days and during this time there were no changes in the appearance of the feet. The pain diminished over the next four days and on the fourteenth day after returning from the field there were no signs or symptoms.

The patient had no further problems with his feet but they were much more sensitive to cold exposure during the remaining time at Davis.

Clinical summary, Subject S1: Nine days after returning to Davis the patient complained of generalised aching in both feet. On examination of the feet there was no variation in skin temperature nor change in colour, and the only positive finding was slight swelling in both feet. Twenty-four hours later the aching changed to severe pain which was at first burning in nature and later throbbing. At this time the patient could not bear anything to touch his feet.

The severe pain persisted for four days before progressively decreasing and it was on the sixteenth day following his return from the field that the subject's symptoms ceased. No significant changes could be observed on examination of the feet at any stage of the illness.

The treatment given was the same as for Subject S3 and although no residual signs or symptoms occurred the patient felt that his feet were more sensitive to cold following this injury.

Footwear in Antarctica has always been a problem. The feet sweat and the moisture destroys the insulation of the socks thus exposing the individual to the risk of frostbite. The principle of the thermal boot is to keep the insulation of the foot covering dry by incorporating a layer of insulation of impermeable rubber on both the inside and outside of the boot. The vapour barrier produced prevents the sweat from escaping and although the foot is wet, the insulation remains dry and conserves the body heat so that the foot and sweat remain warm.

Law (1965) has pointed out the psychological adjustment necessary for the wearer to become accustomed to having wet feet. The boots are effective in dry-cold temperatures down to -50°C as well as in wet-cold and slush.

The cases of trench foot at Davis were associated with immobilisation and dependency of the feet in the cramped area of the Snow-Trac where prolonged sitting occurred without frequent foot or leg movement. The third member of the group (the author) did not sustain any cold injury. The probable reason for this was his greater activity as he placed more of the markers in position.

The cases described occurred despite regular changes of socks and drying of the feet. The boots caused sweating, and the retention of this sweat and the lack of movement which decreased the leg circulation and subsequent warming of the boot made a potential cold injury situation.

Trench foot results from prolonged exposure to wet-cold conditions and the injury is diffuse and poorly demarcated with multiple sequelae (pain, numbness, sensitivity and vasomotor instability). Mechanisms that possibly contribute to the pathogenesis of cold injury to tissue are:

(i) direct effect of cold on metabolism;

(ii) intracellular molecular changes due to crystallisation of extracellular water causing hyperosmolarity;

(iii) mechanical effect of freezing causing cellular and structural damage;

(iv) decreased tissue perfusion and tissue hypoxia resulting from vascular damage.

Non-freezing injury may cause pain, but numbness frequently occurs such that oedema and blistering may follow without the casualty being aware. The tissues may survive when the circulation returns or gangrene may occur if stasis remains. The pain is attributed to selective involvement of sensory nerves to anoxia or scar tissue (Bean, 1961).

The average duration of exposure resulting in trench foot is stated in *Cold Injury* (U.S. Department of the Army, the Navy and the Air Force, 1970) as three days in a temperature range 0°C - 10°C with a time range of from a few hours to fourteen days.

The more typical dry-cold injury (frostbite) differs from the wet-cold in that a brief exposure can result in injury which is well demarcated and has less sequelae.

Hedblom (1960) in his United States Navy *Polar Manual* draws attention to the avoidance of trench foot in expeditioners who wear thermal boots while doing jobs which require alternative periods of activity and inactivity. Hill (1918) similarly had discussed the science of clothing and the prevention of trench foot over fifty years ago, although the footwear and clothing available were far less effective in preventing cold injury than they are today.

Despite a full cold-weather indoctrination course being given to all Davis personnel in 1962 prior to leaving Australia, no mention was made of this potential cause of cold injury.

Bean (1961) sums up the causes of trench foot thus: '*trench foot has borne testimony to ignorance, unpreparedness or disaster as its cause*'. Ignorance could well be blamed for the Davis cases. The important aspect of cold injury is that it is preventable. As well as excellent protective clothing, indoctrination is most important to offset any departures from normal situations such as those described.

The low incidence of cold injury at Davis was due to preventive measures. The occurrence of injury could have been even less if adequate warnings about trench foot had been given, and if Subject D had adhered to the accepted procedures.

(f) Carbon monoxide poisoning

The hazard of carbon monoxide in Antarctica is well documented (Byrd, 1938; Pugh, 1959). One minor case of carbon monoxide poisoning was recorded at Davis, although it is probable that some of the ill-defined symptoms were due to the effects of carbon monoxide.

Random tests were carried out throughout the year and it was found that, on some days, constant low wind speeds caused exhaust fumes from the power house to be drawn into the air-cooling system of the diesel engines so that the atmosphere of the power house became lethal. This was rectified, leaving the Snow-Trac the only potential source of carbon monoxide poisoning.

(g) Infective illnesses

The low incidence of respiratory illnesses and the complete absence of infective diseases at Davis is not unusual among polar communities. Infective conditions, however, have occurred. Budd (1962a) has reported a polio-like illness, and malaria, chickenpox and rubella have all been recorded (unpublished Antarctic Division reports). Taylor (1960), Hedblom (1961), Cameron and Moore (1968) and Cameron (1970) have reported on respiratory infections.

Respiratory illness is the most common occurrence in summer at U.S. stations, but none of the Davis men contracted respiratory infections until April which was nearly two months after the relief vessel had left Davis. The occurrence of further cases in June, July and August is most unusual (Wilson, 1965; Cameron and Moore, 1968). Holmes, Allen, Bradburne and Stott (1971) studied respiratory viruses in personnel at the thirteen-man Stonington Island base and found that respiratory symptoms occurred in only one man during the year of isolation.

Following the arrival of the relief expedition no incidence of respiratory infection was recorded in the wintering Davis group. Cameron and Moore (1968) state that it is common for infections of low morbidity to occur at this stage in the acclimatised party. Allen (1973) has studied the common cold among groups of men in Antarctica and he has reported that during relief periods the incidence of colds has approached that of urban and rural communities, but after the first month in Antarctica colds have been rare.

The author has noted the difference between the 1963 changeover and two recent expeditions he has accompanied to Antarctica when severe respiratory infections have occurred. Lugg and Moore (1971, unpublished data) have attempted to isolate the viruses occurring in these clinical infections, but so far no isolations have been successful.

The close contact of man with the local fauna is a potential source of infective diseases. Cameron (1968b) has reported on the finding of an organism shown to be a member of the Psittacosis-Lymphogranuloma Venereum group from a dead emperor penguin collected at a rookery near Mawson, and evidence of Ornithosis and Psittacosis antibodies have been detected in

Antarctic birds (Sieburth, 1958; Sladen, 1962).

(h) Dentistry

The high incidence of dental fillings at Davis follows the normal pattern for personnel on Antarctic expeditions (Beynon, 1969, 1973). The men had all been examined thoroughly by dentists of the Royal Australian Navy before they left for Davis, and upon return to Australia about sixteen to eighteen months later most of the men required restorations. The author had received dental training prior to joining the expeditions as have most of the Antarctic Division medical officers.

Beynon (1969) summarised the number of cavities found in personnel of a number of expeditions. In thirty subjects at five British stations who spent either one or two winters in Antarctica, there was a mean increment of five cavities per head. The occurrence of cavities in the Davis men would appear to be close to the average for these expeditions, but less than the average increment of 6.4 cavities in ten subjects during one year at Stonington Island.

Five cases of gingivitis occurred during the year. One man had this complaint on three occasions at Davis, but on questioning, he had been receiving treatment for the same condition before leaving Australia. Poor oral hygiene was considered the cause in each case.

The other two cases were in two of the three men involved on the long dog trip. Although oral hygiene in the field was not ideal and may have been a contributing factor, the possibility of inadequate vitamin supplements, as found by Adams, Stanmeyer and Harding (1962), must be considered, as well as the high intake of carbohydrate.

In two subjects fine hairline cracks were observed during the final dental check in Antarctica, although the significance of these were not recognised. Beynon (1973) has observed the same phenomena, and he has made laboratory studies on this. He found that intra-oral temperatures may be reduced during exposure to cold by up to 20°C, to levels at which bacterial activity was markedly reduced. Tooth temperatures, however, were found to remain comparatively high, thus making it unlikely that the fine cracks were due to thermal effects alone.

(i) Mental ill-health

During the year the immature personalities of some members of the expedition were apparent, but on only one occasion could this have been regarded as pathological when one man refused to talk to any other member of the group for some days.

The only other condition in this category was a case of depression. This was far in excess of what could be considered a "normal" fluctuation, but responded rapidly without medication.

Blackburn, Shurley and Natani (1973) have presented a similar low incidence in mental ill-health in their report of an eight-man wintering station in 1967. They report:

> *'Several station members experienced minor psychological difficulties manifest by insomnia and mild depressive effect. Two station members were more severely psychologically distressed, as manifest in one case by constant dissatisfaction with his job and in the other case by an acute episode of anxious depression resulting in departure, from the main camp, for several hours'.*

Rasmussen (1961) has stated that the stresses of isolation appear to have a greater impact on individuals at small stations than at large stations, but the Davis observations are not in agreement with this, and would confirm Wilson's (1965) impression that the proportion of psychological problems can be overemphasised and that expeditions do exist with low incidences of psychiatric and psychological problems.

4.2 PSYCHOLOGICAL ADAPTATION

4.2.1 Materials and methods

(a) General

Observations of man in any climate shows that he is often distressed by changes in temperature. With such changes he is initially very inefficient, but after a time this improves. Part of this is behavioural, but another part is emotional or psychological, as he becomes accustomed to his surroundings.

Much of this study covers aspects of psychological adaptation but the specific psychological program was limited because of the size of the group and the limitations placed on the study by the medical officer being part of the group under study. As Taylor (1969) has pointed out:

> *'psychological data are not easy to obtain from the Antarctic because the men are tightly knit in small groups, and any psychologist who approaches them is likely to disturb their normal pattern of response no matter what role he assumes.'*

The medical officer was considered to have a minimal disturbing influence on the group's normal pattern, but he had the difficulty of keeping all his observations objective.

The program was designed to add factual data on the Australian expeditions, as the Australian research in psychology before 1962 had been mainly on the evaluation and establishment of selection criteria using rating scales and assessments by officers-in-charge and debriefing-type interviews supplemented by sociometric data (Owens, personal communication, 1966, 1967a, 1967b, 1968).

(b) Human adaptation

The medical officer kept detailed diaries of the expedition in order to summarise the Davis group's responses to situations and stress, inter-personal adjustments, group adjustive behavioural phenomena, and the general pattern of psychological adaptation. None of the men, apart from the author, knew that such records were being kept.

Palmai (1963a) considered that there was a lack of accurate data concerning the previous medical and sociological history of men engaged in polar exploration. In order to assess the histories of the present study group, previous medical and sociological data were compiled. However, analysis of the data was not begun until the expedition returned to Australia.

(c) Discussion topics

The topics that were discussed at length each week by the men were recorded. These discussions occurred during meal times and in the recreation room during recreational periods. The medical officer recorded the topics and none of the other eight men knew that this was being done.

The criteria used were very simple. Any subject that caused lengthy discussion was recorded; conversations between individuals were not recorded unless they proceeded to a full discussion involving many of the men. A departure from this occurred when a series of Antarctic books were read in turn by expedition members for ten to fifteen minutes after lunch and dinner to all who were at Davis. These were often controversial and provided much discussion. As these discussions were considered a departure from the normal way in which a subject came to be discussed, they were not included in the records.

All topics discussed were not recorded due to the doctor's absence from a particular meal or film evening or recreational period due to research efforts or work load at the station.

The topics were noted daily and the conversations for each week were summarised together with appropriate comment on the reason for raising a particular topic.

Conversation during the voyages to and from Davis in January 1963 and March 1964 were not recorded. Records were kept only of the nine men and they were discontinued following the arrival of the relief vessel in late February 1964.

4.2.2 Results and discussion

(a) Group adjustive behaviour

The group as a whole readily adapted to station life. Factors initially influencing this were the comfort of Davis, its palatial size by comparison with the *Nella Dan*, and the activity after the slow voyage of five weeks to Antarctica.

The problems of adaptation to long-range large-scale aerial troop deployments, where men have been subject to sudden environmental changes, have been discussed by the NATO Advisory Group for Aerospace Research and Development (AGARD/NATO, 1970). Many of the adjustments which have to be made are the same for men involved in both military operations and civilian Antarctic expeditions, but because of the slower movement of expeditions the overall response is easier adaptation for the Antarctic expeditioners.

The neatness and compactness of Davis compared with Mawson, which was visited en route, also facilitated the adjustment. This was in agreement with the work of Baeza (1963), who considered the major factor influencing human adaptive processes in Antarctica was the relative comfort of the base.

The construction program was one of the largest planned at Davis, and because the changeover was late in the season, much of the work was incomplete when the ship departed. This necessitated long hours of work to store supplies under cover and complete outside work as far as possible before the winter snows made it impossible. The work load also had an effect on the adjustment of the men to their new environment as it increased their motivation and made them very aware of the necessity for team work.

The adjustive behaviour of all men was influenced to a large degree by personal motivation and group accomplishment. Correspondence with all members of the expedition some years after their return to Australia emphasised the importance of group accomplishment to every member. Shear Shears and Gunderson (1966), in a later study of American personnel, comment on three stable attitude factors. These were social compatibility, personal motivation and group accomplishment.

The acceptance of the individual by the group depended on an interaction of work proficiency and social compatibility. This may be illustrated by the case of one man who at times became an isolate due to his low level of work proficiency but, because his social compatibility was considered by his drinking companions to be more important than his work proficiency, he gained overall acceptance.

Nelson (1963a) has described the criteria of adaptation in Antarctica as work proficiency, industriousness and social compatibility, and the observations of the Davis group agree with this. The interaction of the relation of acceptance to work proficiency and social compatibility has also been discussed by Nelson and Gunderson (1962).

The group adjustive behaviour at Davis confirm the findings of Gunderson and Nelson (1963) that the maintenance of group organisation, harmony and efficiency under conditions of long-term isolation and confinement at American bases, although difficult, is not impossible.

Other important factors were the composition of the group and the job skills of the individuals in the group. These two factors were found to be of equal importance in the adaptation.

Nardini, Herrman and Rasmussen (1962) in a five-year study of United States Antarctic bases judged vocational effectiveness to be the most important variable in adjustment to Antarctic isolation. This was considered more important than the group composition, and the variation between their results and this study reflects differences between the organisation and selection procedures of the U.S. Navy and of ANARE.

Later sociometric and adaptation research conducted at the South Pole (Natani, Shurley and Joern, 1973) suggested that job satisfaction, subjective feelings of competence and inter-personal relationships were the primary factors influencing human adaptation to isolation at small American Antarctic stations.

Sub-groups were formed at Davis because of the close association of work tasks. These sub-groups initially were comprised of the four men from the Meteorological Section, the two men from the Radio Section and the remaining three men (OIC, medical officer and cook). Changes in the relations between these sub-groups occurred from time to time with closer associations occurring among the six men in the Radio and Meteorological Sections.

Sub-group disruption did cause minor problems when situations were used by some men in order to decrease their work load, but there was no scientist/support group conflict as described by Law (1960) at other Australian stations.

The differences in attitudes between scientist and support groups that result from different social and educational backgrounds is very similar to the military/civilian groups on American stations (Gunderson, personal communication). The presence of two organisational sub-groups often leads to group disruption and conflict in Antarctica (Mullin and Connery, 1959; McGuire and Tolchin, 1961).

No gross personality changes were obvious but immature attitudes and childish behaviour occurred at times, and this often manifested itself in the humour of the Davis society. Jokes at other members' expense were common and one man in particular was designated "the clown". This behaviour was very similar to that described by Kinsey (1959) and Ebersole (1960) in confined nuclear submariners, who were also isolated from normal life patterns, but for much shorter periods of time.

(b) Adaptation to climatic factors

Adaptation to the climate appeared to be more of an individual variation than the other variables. The cold was not a problem to most of the men. Only one man did not adapt psychologically to the cold and made every effort to remain in the station. He later wintered over at another station, where he was the only man who did not spend a night away from the station during the whole year.

Initially problems were experienced in the use of clothing when inexperienced men had to go out into blizzards, but very soon man's intuitive behaviour remedied this. Although blizzards and drift snow caused occasional boredom in several men, group behaviour was relatively unaffected by the occurrence of this weather.

The cyclic adjustment especially to the winter darkness as described by Rohrer (2960) was noticeably absent. Some adaptation for the extra hours of darkness was necessary, but this did not affect the station routine and there was no rise in surgery consultations. On one day on which the weather was particularly bad the officer-in-charge found six of his eight men asleep in their work buildings during the day when he unexpectedly called on all men.

The Davis study, although on a small group, was in marked contrast to the study of Rivolier and Perrier (1965) where biometeorological factors such as severity of blizzards and changes of temperature and light could be correlated with psychosomatic manifestations.

Although the Davis monthly consultations varied more significantly from month to month than a later study by Perrier (1967), the results are in general agreement with Perrier's findings that the meteorological conditions at coastal Antarctic stations do not directly cause the appearance of morbid symptoms.

(c) Adaptation to isolation

All men adapted quickly to the complete physical isolation, and most men were not greatly concerned with happenings outside the station apart from the occasional important news items. One such item was the news that the President of the United States of America had been assassinated. Following receipt of this news, every effort was made to find out all details and much speculation occurred.

The weekly national radio broadcast from Australia titled 'Calling Antarctica' was well received and it became a social event as all men gathered in the radio building to listen to it. Despite the popularity of this program and the occasional use of amateur radio for social contact with Australia, the majority of the Davis group tended to shut themselves off psychologically from the outside world. This agrees with Nelson's (1963b) assumption that men on Antarctic stations isolate themselves psychologically from contact with the rest of the world.

The use of amateur radio, the only supplement to radio telegrams, caused a marked change in the mood of some men, who showed frustration following their inability to communicate intimate feelings or comments over a "public" system. Other men, however, responded well.

Rasmussen (1961) states that it appears that the stresses of isolation have a far greater impact on individuals at small stations than at large stations, but the Davis study did not confirm this finding.

(d) Interpersonal adjustment to a small group

Although some members of the group had very little in common and were not socially compatible with each other, adjustments took place and no gross problems arose throughout the year.

Several men had rather aggressive personalities, but during the whole period at Davis no physical outburst occurred. Gunderson and Nelson (1962) have commented on tension control and the presence of the same associates being two of the most stressful elements of wintering, while Law (1960) stated that the main stresses at Australian stations are the psychological ones between individuals, groups, and between the leader and his party.

Comments made to the author by all men reflect the prevalent attitude of tolerance and the necessity of controlling aggressive and emotional impulses towards each other, as there was no chance of changing the group at Davis. The capacity to control emotions was one of the most important attributes of the men. This finding is not confined to this expedition alone as Owens (1967b), in a study of a number of years of ANARE operations found that agreeableness, leadership, rigid defensiveness, group co-operation, self reliance and openness were all related to overall performance and to interaction between its three dimensions (task, intra-personal, inter-personal).

The factors of leadership and group co-operation were particularly strong at Davis and had a great influence on the adjustment of the party. Crocq, Rivolier and Cazes (1973) also found that these two local factors could improve or diminish the adjustment of small French groups in Antarctica.

It is probable that hard work was a means of releasing some of the pent-up aggressive feelings and one individual in particular, following disagreements, would always embark on projects requiring great physical effort.

Nelson (1964) studied three groups of American winterers and found no general change in the pattern common to all station groups or to the three interactions under study (work, formal communication, and off-duty friendship). It is the author's opinion from his association with a number of expeditions that there is no common pattern of interpersonal adjustment to the size of the group at Australian stations and the variation is great. The Davis expedition was better than the average ANARE group in its interpersonal adjustment.

(e) Adaptation to work

The distribution of activity followed the pattern of the classless society as described by Law (1960) and was shared by all men. At Davis there was a basic work output necessary for the safety and well being of the group and much of this was hard physical work.

The men with low work output never adapted to the work load, but the majority of the group did. This was most evident when three men were absent for over seven weeks on field work and five remaining fit men carried on the routine work.

Hebb (1930) has given experimental evidence that work is an important human need, but work more than any other aspect of life brought out the tendency for an exaggeration of injustices, most of which were imaginary, but which did have a minor disruptive influence on the station. One such case was the comparison by some men of the salaries obtained for the work being done.

(f) Morale

The morale of the men individually or as a group fluctuated throughout the year and was found to correlate closely with specific events, but there was no orderly dependence on season. Episodes of low morale were of short duration and resulted from such causes as infringement of the rights of an individual or the group, and news of serious mishaps at other stations. Examples of these were discussions on the amount of alcohol and cigarettes available for issue and where alcohol could be consumed on the station, and the loss of a vehicle through the sea ice at another station.

A specific event that had a major short-term influence on a man's morale was the first time that he slept out in the field. Several men were noticeably shocked by their experiences.

The group did not follow the pattern of a "midwinter low" in morale and no relation between fluctuations in morale and the work load or hours of daylight was observed. In late September irritability and annoyance with trivial matters were common and morale fell to the lowest level for the year. This occurred despite increased field activity, which usually raised morale, and was attributed to inadequate recognition of the efforts of the group by Head Office in Australia. This evidence confirms a similar finding in Palmai's (1963b) Macquarie Island study.

The fact that the Davis group did not follow the accepted pattern of morale at Australian stations (Law, 1960) emphasise the great variability in morale between both individuals and groups. Rohrer (1959) considered that an increase in the evidence of depression and apathy is related to a decrease in the work load and Palmai (1963b) considered that a direct relationship occurred between morale and daylight hours, but the study at Davis could not confirm either of these observations, although the high activity rate at Davis may have been responsible for the absence of depression.

Hicks (1965) has also reported that his wintering group maintained a fairly high level of activity throughout their year, and that the party was a happy one and no sign of emotional stress became apparent.

It is apparent that general adaptation patterns for small Antarctic stations are not as constant as those of nuclear submarines (Earls, 1969).

(g) Methods of facilitating adjustment

Individual men used different methods of facilitating their adjustment both to the life and to the environment; participation in field trips, hobbies, frequent showings of films, alcohol and celebrations all had a place. More than one hundred screenings of forty films were made. The films covered a wide range of topics and it is interesting that three of the four films rated most popular, by a voting system, were about social issues and family situations.

Parties or "ding" nights helped the men to socialise more readily and they were enthusiastic about the building of a bar where all men were able to drink and talk together. There was little abuse of alcohol, but some drinking habits did deteriorate due both to emotional factors and to the fact that the alcohol was provided free of charge.

It is interesting to note that the men at Davis enlarged their group to include the husky dogs and also established a mythical human population on the surrounding islands. These attitudes are considered to reflect attempts to compensate for the size of the group and its isolation.

Another action of the small group was to name members of the group according to their age. An example of this was that the officer-in-charge was always known as "Father". This is not an isolated case and is not confined to Australian expeditions alone as Matsuda (1964) discusses this in relation to Japanese Antarctic expeditions.

A "bitch session" where grievances were aired publicly was held on only one occasion, and this greatly relieved the tension present at that time.

Regular journeys to the remote field station for short periods of time and daily field excursions were eagerly sought by most men, and was another method of assisting adaptation in that it allowed men to get away from the main station and provided differing companionship and scenery.

(a)

(b)

(c)

Plate 11. Recreation at Davis. (a) A seven-course dinner that began the celebration of Midwinter's Day. (b) During summer an outdoor barbecue was very popular. (c) The newly constructed bar which was built to encourage the men to socialise as a group. (Photographs by D. J. Lugg)

(h) Adaptation to stress situations

The Antarctic conditions of isolation, deprivation and hazards (Plate 12), and the absence of the usual sources of stimulation, diversion and emotional support, were not generally regarded as stressful by the men wintering there. This is considered to show a reduction of stress brought about by better engineering, selection and training. Behnke (1962) and Braun and Sells (1962) have discussed the reduction of stress at Antarctic bases, and Owens (1968) has reported on a number of biographical correlates of assessed performance in Australian expeditions which has led to improved selection techniques.

Simpson (1959) made a study of eosinophil counts to investigate the stress effects of the Antarctic environment. Falls in these counts seemed to be associated with both physical and mental stress in the Antarctic.

Although it is very difficult to assess reactions to stress, it appeared from the Davis study that this was very much an individual matter, rather than a group behavioural reaction. Many of the men gave no indication of any physical or mental adaptation to stressful situations, while others who reacted poorly early in the year to hazards, such as crevasses, later became ideal field men.

More recently in the Arctic, Simpson (1967) measured the output of 17 hydroxy cortico-steroids in men subjected to the stresses of sledging for a period of forty days, but no adaptation to stress occurred in this time.

(i) Previous medical and sociological history

A review of the past medical history of each man showed the mean number of illnesses and injuries suffered before joining the expedition was 2.4 (range 1 to 5). These were conditions such as tonsillitis, appendicitis, fractured bones, typhoid, mastoiditis, dermatitis and nephritis, but did not include minor problems such as the common diseases of childhood. The fitness of the men contributed to their adaptation to the environment, and previous medical history played little or no part in this.

Family history and other sociological data, which were gathered from personal interviews with all men, appeared to have little relation if any to the men's adaptation. It was obvious that factors such as finance and family background played a part in their motivation to apply for the expeditions, but were not important once the men reached Antarctica. Crocq *et al.*, (1973), however, have found a positive relationship between adjustment to the small group in the Antarctic and previous social adjustment in French expedition personnel.

One significant finding which possibly contributed to the easy adaptation was the low number of previous permanent occupations held by each man. The mean number of previous employers was 2.3 (range 1 to 4). This is lower than found on most expeditions.

(a)

(b)

(c)

Plate 12. Antarctic hazards. (a) Whiteout brought all operations at Moore Pyramid base camp to a standstill in February 1970. Although the rock faces on Moore Pyramid are visible in the background, the white snow and ice surfaces are not visible. (b) Tractors on a traverse to the southern Prince Charles Mountains trapped in crevasses. (c) A blizzard near Mawson. (Photographs by D. J. Lugg, A. Foster and R. Dovers)

Although it is difficult to make objective measurements of personal characteristics, nevertheless, from the data obtained it is valid to conclude that the men chosen for Davis were both healthy and stable.

(j) Discussion topics

The group discussion topics recorded during the year are shown in Table 21. The subjects discussed are categorised and the distribution in each month recorded. All topics were not recorded for at least a week in each of the months of February, April, June and September due to the doctor's absence in the field.

Law (1960) stated that

> '*the greatest obstacle to the building of a happy and well-adjusted party is the difference in cultural levels of various men*'.

He also questioned what topics of conversation could be common to all. Amundsen (1912) held the opinion that subjects of conversation must be very difficult to find on expeditions, but following his successful expedition he commented in his report that '*there was certainly no sign of any such difficulty here*'.

Although the nine men had diverse backgrounds the majority of conversations centred around topics that could be discussed by all. This may have resulted from the smallness of the group, and the isolation which caused the group to become preoccupied with their "closed society".

It is significant that the three subjects most frequently discussed by the group were Davis expedition matters and activities, the ANARE as a whole, and amenities at Davis. The next most common group discussions were on biology and sex. Biology included the husky population. These animals were considered members of the expedition and were regularly discussed.

It is the author's experience from association with a number of expeditions that the discussion of sex varies considerably between groups. The higher incidence in the early months would agree with most groups and seems to be a matter of ego among new associates. The lack of this topic later in the year might be accounted for by the fact that no mating behaviour of seals was observed. On Macquarie Island (Palmai, 1963b) the rise in discussions on sex coincided with mating behaviour of seals. Palmai found that sex accounted for 7 per cent of the conversation time of his study and the Davis results agree with this.

Food did not become a major discussion subject because the standard of the food and its presentation by the cook was always excellent. (It appears that only when food is poor does discussion follow.)

Table 21. The distribution of the subjects discussed at Davis according to the topic and month

Subjects discussed	Month												Total
	F*	M	A+	M	J+	J	A	S+	O	N	D	J	
Amenities -													
(i) general									3				3
(ii) alcohol		2		1	1			2	1	1			8
(iii) films and photography	1	1		1			2		2	1	1	2	11
(iv) library and records		2											2
(v) tobacco		1											1
ANARE -													
(i) Davis, field work and domestic issues	1	2	1	2	2	9	1	2	4	4	7	2	37
(ii) Other stations, expeditions and Head Office	1		1	2	2	2	7	2	1		2	5	25
Biology (inc. huskies)		3	3	1	1	2	1	1	2	2	4	3	23
Communications						2	1	1	2			1	7
Current affairs -													
(i) Australia					1			1					2
(ii) World				1		1				2			4
Education and science				2	2		1						5
Environment	1	3	1	1	1	1		2		1		1	12
Food	1	1				1		1		1		1	6
"Home" - families and Aust. issues		2	1						1	3	1		8
Law, authority and censorship		2			1								3
Medical and psychological		2	4	3	1		1		1		2	1	15
Miscellaneous		1			2		4						7
Money								1					1
Past experiences		1		1	1								3
Politics			1	3	1								5
Religion		2	1		1				1		1		6
Sex	1	6	2	4	2		1	1				1	18
Sport			1							1			2
Total													214

*Conversations recorded during one week only in February.
+Conversations not recorded during one week in these months.

The low incidence of sporting discussions is most unusual for an Australian expedition, but the lack of discussions on money, current affairs and families are representative of the expeditions. The lack of discussion on these latter subjects bears directly on the isolation and lack of communications.

The group was aware of the limitations in the medical establishment and often discussed these. In a number of medical discussions, it was obvious that some of the men had never had opportunities before for such discussions and were making use of the availability of a medical officer to gain knowledge.

The recording of the discussion topics illustrates one of the many ways in which the men adapt to life on a small station and confirms the need for more advanced measures of behavioural adaptation.

At the 1972 Symposium on Human Biology and Medicine in the Antarctic, Strange and Klein (1973), who summarised the emotional and social adjustment of recent U.S. wintering over parties, emphasised the importance of the isolated polar group for more detailed studies of individual and group adjustment processes.

It is concluded that the Davis group and its individuals adapted well both psychologically and behaviourally to life on an isolated Antarctic station.

5. ANTARCTIC EPIDEMIOLOGY

5.1 MORBIDITY AND MORTALITY AT AUSTRALIAN ANTARCTIC STATIONS 1947-72

5.1.1 Materials and methods

(a) Health survey

All available medical records from the Australian National Antarctic Research Expeditions were examined. The published accounts of illnesses (Budd, 1962a; Pardoe, 1965; Law, 1966) and deaths (Brown, 1957) were also reviewed, and aspects of the health of the expeditions were discussed with a number of doctors who had served as medical officers with ANARE.

The aim of the survey was to obtain a factual account of the illnesses, injuries, operations and deaths that have occurred in the period 1947-72. In order to retain anonymity, the figures for all years were combined so that no figures for one year alone were reported on apart from the findings of the Davis study as described in section 4.1

The figures for each station were examined for any differences that could be attributed to location, climate or season.

(b) Mortality

The deaths occurring at ANARE stations were reviewed. The ages and occupations of the men, the causes of death and the month and year in which they occurred were analysed for any seasonal or occupational trends.

(c) Appendicitis

The cases of appendicitis occurring in the period 1947-72 were examined and the method of treatment and course of the illness reviewed.

(d) Cold injury

The cases of frostbite and other cold injury were examined for both frequency and seasonal variations.

(e) Medical evacuations

Medical evacuations from the Antarctic and sub-Antarctic stations were reviewed. The ages and occupations of the men were analysed, together with the causes of the evacuations and the stations from which the evacuations took place.

5.1.2 Results and discussion

(a) Health survey

In the review period 1947-72, 1402 positions were occupied on wintering expeditions, and 1094 personnel travelled to the stations as summer expeditioners or supernumeraries. The actual number of men involved is less than the numbers of positions as some accompanied more than one expedition, one man for example having wintered on seven occasions.

The number of expeditions analysed, men wintering, and case histories reviewed are shown in Table 22. The records of sixty expedition years were analysed; a number of expeditions for which records were incomplete or not available were omitted from the study.

Table 22. The number of expeditions analysed, men wintering at each station, and case histories reviewed in the ANARE health survey 1947-72

Station	Number of expeditions analysed	Number of men wintering	Number of case histories reviewed
Macquarie Island	20	323	3223
Mawson	14	328	1622
Casey/Wilkes	12	289	1559
Heard Island	7	91	489
Davis	6	57	355
Total	60	1088	7248

It is apparent from the medical officers' logs that many minor conditions such as headache, insomnia and trauma not requiring treatment were not recorded, and expedition personnel did not report all their injuries. Despite these omissions, the analysis of over one thousand man-years is considered to show the main incidence of the medical conditions under their various categories.

Table 23 shows the distribution of the illnesses and injuries analysed according to classification and station. The total percentages for all categories at the five stations are also recorded.

Table 23. The distribution of the illnesses and injuries analysed in the ANARE health survey 1947-72 according to the classification and station. The figures are expressed as a percentage of the total for each station

Station	Heard I.	Macquarie I.	Mawson	Davis	Casey/ Wilkes	All stations
Classification						
I Infective and parasitic diseases	1.6	1.9	2.1	0.6	1.7	1.8
II Neoplastic diseases	0.4	1.4	2.0	0.6	2.1	1.6
III Allergic, endocrine, metabolic and nutritional diseases	0.7	0.9	0.8	0.3	1.2	0.9
IV Diseases of blood	-	-	0.1	-	0.1	<.1
V Mental, psychoneurotic, personality disorders	1.2	2.1	1.8	1.7	1.5	1.8
VI Diseases of nervous and sense organs	4.7	4.8	4.9	3.1	5.S	4.9
VII Diseases of circulatory system	2.5	1.4	2.0	3.4	1.4	1.7
VIII Diseases of respiratory system	2.7	4.9	5.0	5.1	8.1	5.4
IX Diseases of digestive system -						
Dental	11.0	6.1	13.1	10.1	8.6	8.8
Other	2.3	3.1	2.6	3.4	3.1	3.0
X Diseases of genito-urinary system	0.7	0.3	0.6	2.0	0.9	0.6
XI Diseases related to the environment	5.3	0.4	2.7	8.1	1.9	2.0
XII Diseases of skin	10.0	8.7	9.2	8.7	9.2	9.0
XIII Diseases of bone and musculo skeletal (non-traumatic)	3.7	4.1	3.6	3.9	4.0	3.9
XIV Trauma, accidents and poisonings	36.2	30.5	42.3	35.5	39.5	35.7
XV Symptoms, ill-defined diseases	16.8	29.4	7.2	13.5	11.2	18.9

The largest category (35.7 per cent) was that of trauma and accidents. The conditions ranged from abrasions, lacerations, burns, and dog and seal bites, to fractured bones and multiple injuries that resulted in death.

The next most common group (18.9 per cent) was that containing symptoms and ill-defined diseases. Headache, dyspepsia and vague symptoms referable to the gastro-intestinal system, and insomnia, were most frequently present in this group.

Dental and skin diseases each occurred in over 8 per cent of cases. The role of the environment in dental problems is largely conjectural, but it plays a considerable part in the occurrence of skin disease. In the early years of the expeditions skin infections such as boils and carbuncles were common. Dry skin and allied problems still occur frequently, while varying forms of dermatitis and dandruff require treatment from time to time. The incidence of pilonidal sinus was unexpected and would appear to be more frequent than in the male population at large.

The diseases related to the environment *per se*, such as frostbite, cold injury, sunburn and snowblindness, were much less frequently observed (2.0 per cent) than one would expect for such a climate. Respiratory diseases were mainly upper respiratory tract infections (URTI) which occurred most frequently following relief operations, only a small percentage occurring throughout the year. One case of staphylococcal pneumonia occurred at Macquarie Island and necessitated a long period of hospitalisation following the patient's return to Australia.

Rheumatic aches and pains were the major causes of the non-traumatic bone and musculo-skeletal group. Eye and ear conditions such as cerumen in the external auditory canal were the most common diseases of the sense organs. Other illnesses of interest in the low incidence categories included herpetic lesions, tinea, non specific urethritis, amoebic dysentery, gonorrhoea, hepatitis, polio and malaria.

The neoplastic category consisted chiefly of warts, sebaceous cysts, lipomas and naevae of long-standing duration. Many of these were removed by medical officers during the wintering period, although in most cases they were asymptomatic.

Drug sensitivities were recorded on a number of occasions. Suspected vitamin deficiencies were diagnosed in a small number of men. One case of gout occurred.

Anaemia which was diagnosed on two occasions was the only blood disease noted, while circulatory conditions ranged from relatively common haemorrhoids to thrombophlebitis and a ruptured intra-cranial aneurysm.

The genito-urinary category contains few cases, some six of these being circumcision operations.

Psychiatric problems were not a common feature of the survey. The most severe psychotic illness was that of paranoid schizophrenia. Acute anxiety states and depression were the most common of the psychoneurotic conditions.

No case of overt homosexuality was recorded.

Operations were performed at the stations for lacerations, appendicitis, reduction of fractures, craniotomy for ruptured intracranial aneurysm and amputation of frostbitten extremities.

Table 24 shows the most frequent conditions recorded at Macquarie Island 1960, Davis 1963 and for the total survey. The results from different expeditions show considerable variation and, as discussed in section 4.1, the Davis health survey would appear more representative of an Australian expedition than the previously published data of Palmai (1963b).

Table 24. The most frequent illness and injuries recorded on the health survey compared with Macquarie Island 1960 and Davis 1963

Group	ANARE	Macquarie Island	Davis
Period of survey	1947-72	1960	1963
Category (per cent of total)	Trauma and injuries 36	Trauma and injuries 21	Trauma and injuries 28
	Symptoms, ill-defined diseases 19	Symptoms, ill-defined diseases 46	Symptoms, ill-defined diseases 23
	Dental 9	Dental 7	Dental 12
	Diseases of skin 9	Diseases of skin 3	Diseases of skin 8
	Diseases of respiratory system 5		Diseases of respiratory system 6
			Diseases related to environment 10
		Diseases of digestive system 7	
	Diseases of nervous and sense organs 5		
		Non-traumatic musculo-skeletal and bone 6	

(b) Effect of location

The climate of the five stations reviewed range from the wet-cold sub-Antarctic climate of Macquarie Island and the wet-cold climate of glaciated Heard Island, which lies within the Antarctic convergence, to the dry-cold of the Antarctic continent.

As well as different climatic factors the station buildings vary considerably in design, Heard Island station being built in 1947 while Casey was opened in 1969, twenty-two years later.

Examination of Table 23 indicates only a few categories where location appears to have an obvious effect. This is most noticeable in the case of diseases related to the environment. For example this category is most prevalent at Davis and possibly reflects the method of transport at that station. Dog teams and motorised toboggans were used for most of the field work at Davis, contrasting with the larger vehicles and caravans of the other continental stations.

The low incidence of the same category at Macquarie Island (0.4 per cent) results from the absence of cold injury, sunburn and snow-blindness because of higher temperatures and overcast skies at the island.

The greater proportion of ill-defined diseases at Macquarie Island (four times the incidence at Mawson), however, is more difficult to understand. The ill-defined diseases and the lower incidence of trauma and accidents at Macquarie Island may be due to environmental factors, but the exact cause has not been elicited in this survey.

(c) Seasonal variation

The distribution of the total illnesses and injuries between the stations for each month of the year are recorded in Table 25 and represented graphically in Figure 19.

Incidence is high during the accelerated activity at the stations during changeover when more than twice the wintering population were on the station. Other occasions of high incidence occurred during periods of maximal outside activity such as preparing for and carrying out field work. This happened at Davis in September, to a lesser extent at Mawson in October and possibly at Heard Island in the same month.

Otherwise, the groups show a gradual decrease in incidence in illness and injury throughout the year. This progressive decrease indicates both job and climatic adaptation.

Table 25. The distribution of the illnesses and injuries analysed in the ANARE health survey 1947-72 according to the station and month. The figures are expressed as a percentage of the total for each station

Month	Station					
	Heard Island	Macquarie Island	Mawson	Davis	Casey/ Wilkes	Total
January	9.5	9.1	10.7	12.4	11.1	10.1
February	9.5	8.3	14.8	11.9	8.7	10.1
March	9.5	6.9	9.1	10.2	7.3	7.8
April	8.1	8.6	10.0	9.0	7.6	8.7
May	8.8	8.6	8.2	9.3	7.3	8.3
June	7.8	9.1	7.9	6.5	9.2	8.6
July	6.8	7.7	8.4	5.6	8.6	7.9
August	8.1	6.6	5.4	8.5	8.3	7.0
September	8.8	6.2	5.7	11.6	8.6	7.1
October	11.7	8.2	7.4	4.0	7.5	7.8
November	5.9	8.2	5.5	5.9	6.5	6.9
December	5.5	12.5	6.9	5.1	9.3	9.7

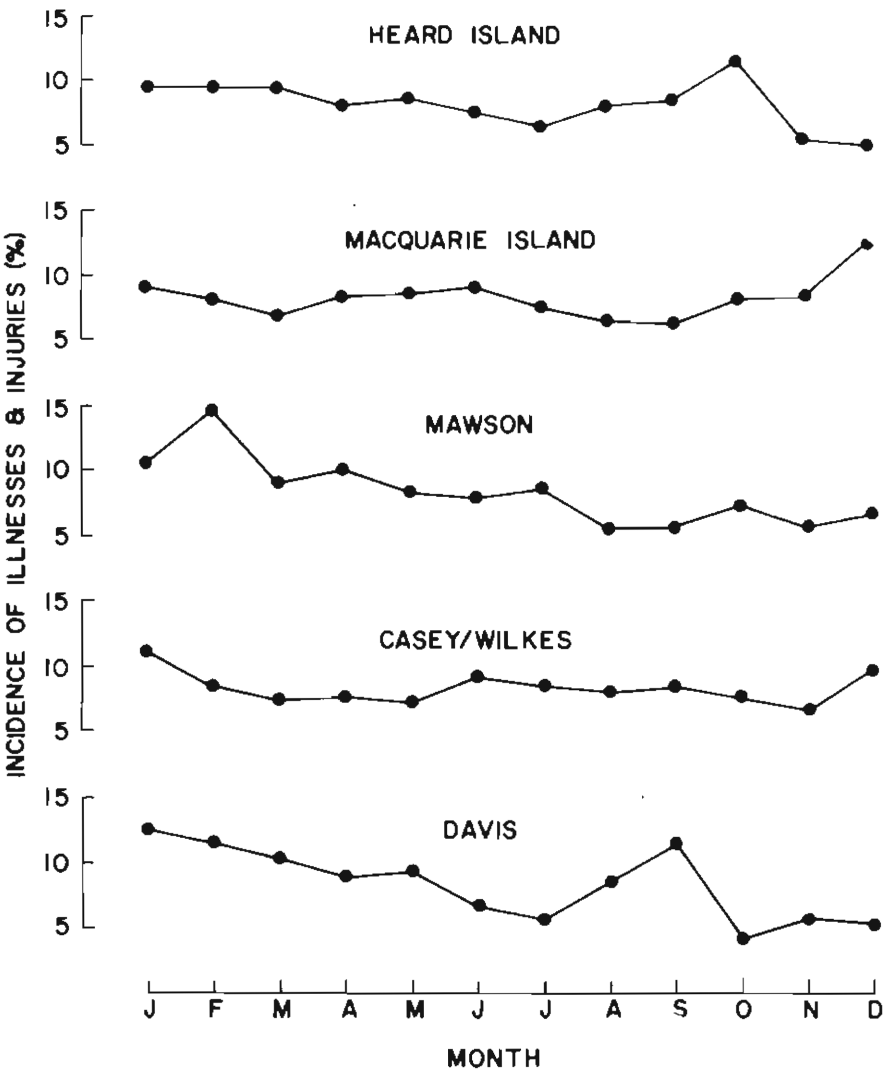


Figure 19. The monthly distribution of illnesses and injuries at all stations.

(d) Individual morbidity

Despite the large number (average 7 per man of cases reviewed) of illnesses and injuries reported, few men in any expedition were incapacitated. Gross variations occur from year to year, and expedition to expedition, but it would appear that only a small percentage of the men fall ill during their time in Antarctica. This confirms the impression of many doctors cited in the preceding chapters and agrees with the hypothesis that, in any population at risk, health problems appear to be concentrated in a relatively small proportion of the population (Hinkle *et al.*, 1956).

On a number of expeditions the medical officers have made comment of "accident prone" individuals and from an analysis of a number of expeditions it would appear that most groups have one or two who could be classed in this category.

Evidence was lacking, however, for support of the theory (Hinkle and Wolff, 1958; Schmale, 1966) that individuals having multiple illness episodes tend to experience them in time periods characterised by unusual life stress, although it may well be that the unusual life on the Australian stations was not stressful enough.

The incidence of illness and injury among the different occupations was also analysed. Men working with lathes, machinery and equipment were more likely to receive foreign bodies in their eyes, lacerations and strained backs than the meteorological staff who had a greater incidence of caustic soda burns and chemicals in their eyes.

However, no one occupation could be considered to be more predisposed to accidents or illness than another, and it appeared to be individuals and the job they were doing at the time of injury that were more significant. Cooks have cut their fingers on occasions both with utensils and when opening cases of food, but in most cases the frequency is low. One wintering cook however attended the surgery for 97 different ailments, the majority being lacerations and abrasions to the hands. This example emphasises the individual variation in the incidence of injury.

(e) Mortality

Appendix 10 shows the occupations and ages of the expeditioners who have died, the cause of death and the locality. In the period 1947-72 twelve men died. One of these was an Australian observer at Maudheim with a non-Australian expedition (the Norwegian-British-Swedish Expedition), while a second was a member of a relief expedition to Macquarie Island. The other ten men were wintering expeditioners. Since 1972 a further death has occurred due to trauma.

The cases of fatal appendicitis, cerebral haemorrhage, ruptured gastric ulcer and myocardial infarction are diseases that could have occurred anywhere, while the other cases were all accidents.

Beltramino (1965, 1966) has studied the overall mortality in Antarctica. He considers that the activities rather than the occupations of the men must be considered the underlying cause of death and that nearly all deaths have been of a purely accidental nature. The figures for the Australian expeditions would support Beltramino's findings.

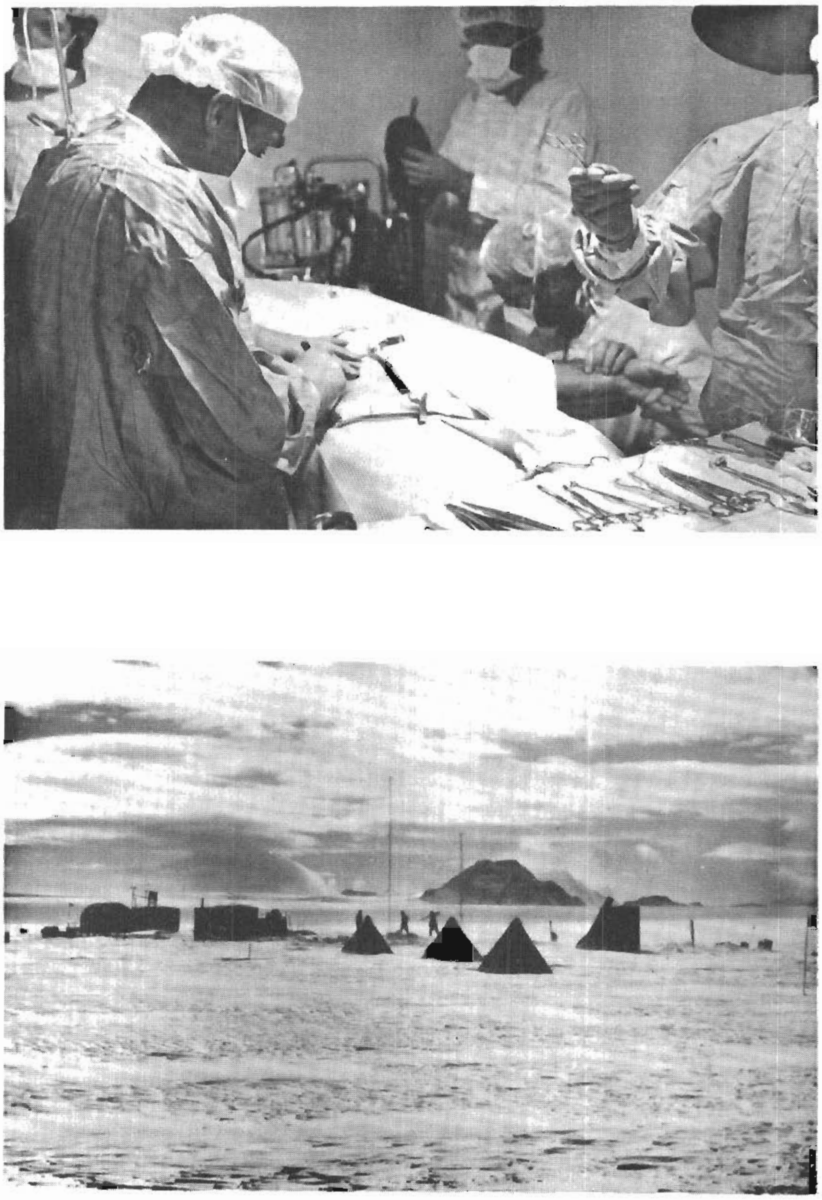
Table 26 shows the mortality rates for the various categories of the Australian expeditions. The rate is low. The mortality rate for Australia in the period 1946-70 has varied between 8.65 and 9.74 (Commonwealth Bureau of Census and Statistics, 1971). The crude death figures for the Antarctic continent as a whole are low (wintering expeditions 1951-64: 4.4; summer operations 1951-64: 0.7), probably lower than for any other continent, but it should be recognised that the Antarctic population is selective, and it is therefore difficult to make comparisons from one continent to another.

Table 26. Mortality on Australian National Antarctic Research Expeditions

Group	Number of members	Rate/1000
All expeditions	2496	4.41
All wintering expeditions	1402	7.13
Wintering expeditions on sub-Antarctic islands	492	12.20
Wintering expeditions on Antarctic continent	910	4.40
All summer expeditions	2496	0.40
Summer expeditions on sub-Antarctic islands	1041	0.96
Summer expeditions on Antarctic continent	1455	0

(f) Appendicitis

It has been mandatory, since the repatriation of a medical officer from an Australian expedition in 1950, for all medical officers to have undergone (usually prophylactic) appendicectomy before leaving for Antarctica. On some expeditions, such as the four-man expedition to the Amery Ice Shelf in 1968, all members have had their appendix removed. Appendix 11 lists the cases of appendicitis occurring at each station in the survey period. The month and year of occurrence, the occupations of the men and the method of treatment are also given.



(a)

(b)

Plate 13. Appendicitis. (a) An emergency appendicectomy being performed at Mawson. (b) The remote base camp at Moore Pyramid, 350 km southeast of Mawson. The patient in (a) was evacuated by helicopter from this camp. (Photographs by D. Parer and D. J. Lugg)

Twenty-three cases of appendicitis have occurred in the survey period, giving a morbidity rate for wintering expeditions of 15.7 per thousand. Ten cases were operated on at the stations or on the expedition ships. Complications occurred on four occasions. One operation took over eight hours, and during another the patient collapsed and resuscitation was necessary. A third patient had a suppuration in the post-operative wound, and the fourth patient died two days post-operatively. No medical records are available for the last case. A case treated conservatively was complicated by the patient having a drug sensitivity and the occurrence of thrombophlebitis. Since the survey, two further cases have occurred, and both of these were operated on.

Examination of the records of the cases of appendicitis show no significant seasonal or occupational trends.

(g) Cold injury

Cases of severe cold injury are noticeably absent from the records of ANARE station medical reports although the incidence rate of cold injury in the survey of over one thousand men was 81.3 per thousand. There were, however, only two cases of frostbite in which loss of phalanges of the fingers or toes occurred (Plate 14).

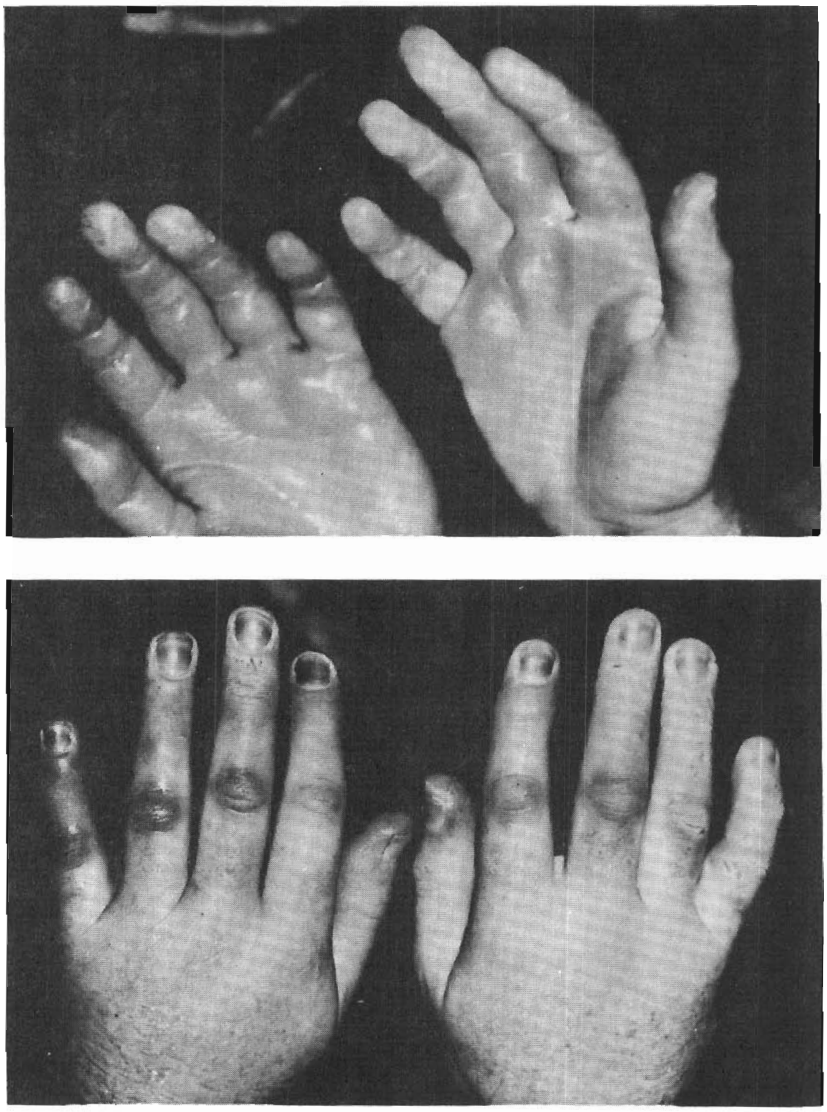
Cold injury has a greater incidence in two periods of the year. The first is the period March-May, when the field programs commence and the weather begins to deteriorate, and the second is the time of increased outdoor endeavour in September-November.

(h) Medical evacuations

Appendix 12 lists the statistics of medical evacuations from ANARE stations. There have been twenty men repatriated from Australian expeditions, and the reasons for these repatriations have been varied. Only five of the cases have come from the Antarctic continent, highlighting the difficulties of repatriating men from this area.

One case has been described by Pardoe (1965). Two of the continental medical evacuations were carried out by aircraft of the USSR and the USA, and three by Australian relief expeditions. Repatriations from the sub-Antarctic islands have been carried out by ten different ships.

It is apparent that some of the patients could have been managed at the stations by the medical officer but as a ship was either at the base or close by, advantage was taken of the situation in an effort to decrease morbidity and the patient was evacuated. This is shown by the much higher incidence of evacuations from Macquarie Island which is the station from which an evacuation is most easily accomplished.



(a)

(b)

Plate 14. *Cold injury. One of the two serious cases of injury recorded in the ANARE health survey. These photographs were taken several days after the injury when the patient had returned from the field. The patient later lost phalanges as the result of the cold injury. (Photographs by G. J. Merrill)*

(a)

(b)

Plate 15. Medical evacuations. (a) A patient who had suffered from a ruptured intra-cranial aneurysm being transferred from a 'Weasel' to a Russian Li-2 aircraft at the plateau ice airfield near Mawson. (b) The polar ship Nella Dan *moored to the fast-ice near Mawson. This vessel has been used during summer periods for the evacuation of personnel from the Antarctic continent and Macquarie Island. (Photographs by R. Wyers and D. J. Lugg)*

5.2 COMPARISON WITH OTHER ANTARCTIC EXPEDITIONS

5.2.1 General

Many of the doctors who accompanied early Antarctic expeditions wrote general accounts of their medical practice. Cook (1900), the first physician to winter in Antarctica, kept meticulous medical records of the mental and physical hardships of the men with him. Ekelöf (1904), Charcot (1911) and Wilson (1966) all described medical aspects of early Swedish, French and British expeditions.

Health conditions on Antarctic expeditions are in general good. Both Jones (1915) and McLean (1915), doctors who accompanied Mawson's Australasian Antarctic Expedition of 1911-14, opened their reports by stating this.

Since the International Geophysical Year more specific statistics have been reported (Hedblom, 1961; Matusov 1965, 1968, 1971; Gunderson, personal communication). Due to lack of standardisation, it is difficult to compare statistics from different stations as well as from populations of different nations, and it is even more difficult making comparisons for expeditions fifty years apart, because of advances in medical practice and technology. Up to the present, there are no standard categories of illnesses or injuries used for reporting Antarctic medical statistics and this causes further problems in collating the available data.

Morbidity is usually measured by the annual number of cases of injury or illness expressed as rates per 1 000 or 10 000 population but, due to the small numbers involved in expeditions, the categories of illness and injury are expressed in this study as a percentage of the total as had been done in the only previous survey (Hedblom, 1961) and the few other surveys (Matusov, 1965, 1971) reported since the present study.

In studying a specific group's adaptation in Antarctica it is, however, important to make comparisons with other polar populations.

5.2.2 Health statistics

The health of the men on Australian expeditions since 1947 compares favourably with other national expeditions who wintered in Antarctica before the inception of ANARE. This is also true of comparisons between the present survey and published reports from other contemporary expeditions.

The incidence of the most common illnesses and injuries vary between expeditions and localities. Table 27 compares the most frequent illnesses and injuries reported from Australian, United States and Soviet expeditions.

Table 27. Comparison of health statistics for ANARE, U.S. Navy and Soviet Antarctic expeditions

Group	ANARE		Soviet Antarctic expeditions				U.S. Navy 'Operation Deep Freeze'	
Period of survey	1947-72		1959-64*		1965-66		1955-60	
Most frequent illnesses and injuries (per cent of total)	Injuries and trauma	36	Injuries	16	Injuries	25	Injuries	29
	Respiratory	5			Respiratory	7	Respiratory	28
	Skin	9	Skin	7	Skin	15	Skin	14
	Dental	9	Teeth, oral cavity	21	Teeth, oral cavity	13		
			Peripheral nervous system	15	Peripheral nervous system	12		
	Symptoms, ill-defined diseases	19					Symptoms, ill-defined diseases	10
					Eye, ENT	9	Eye, ENT	6
	Diseases of nervous and sense organs (eye, ENT)	5	Neuroses	8	Neuroses	7	Gastro-intestinal	6
Reference	This study		Matusov (1965)		Matusov (1971)		Hedblom (1961)	

* Statistics for Mirny station only

The Soviet figures in Table 27 record the diagnostic data, the American figures the recorded sick calls, and the Australian statistics the reported illnesses and injuries. The figures for 'Operation Deep Freeze' do not include dental treatments, as the dental work is done by trained specialists, and not by the medical officers.

Hedblom (1961) analysed five years of operations of the United States Navy within the Antarctic Circle. This included over 16 000 men in the summer support groups as well as the wintering expeditions of about 1 000 men. Tyler (1968) confirmed that respiratory infections and accidents and injuries were still the most significant conditions treated by United States Navy doctors. Hunt (1968), who wintered at the American base Byrd, placed respiratory disease as the major summer illness and trauma the most common condition in winter.

Data from the Soviet Antarctic station Mirny over a six-year period has been reported by Matusov (1965). Matusov (1968, 1971) also records the medical statistics for all Soviet Antarctic expeditions with special reference to the Tenth Soviet Antarctic Expedition.

In the course of the present study, significant variations between Australian stations and those of other nations were observed. These include more trauma, less respiratory disease, and no peripheral nervous system diseases and neuroses among the most frequently recorded illnesses at Australian stations. The lack of specificity in the published data due to differences in classification does not permit other than general conclusions to be made on the health statistics.

At the large American and Soviet stations the number of men necessitated sick calls being separated into outpatient and inpatient groups. Taylor (1960) saw between five and ten patients daily in his wintering group of 93 men at the U.S. station at McMurdo Sound. The smaller number of men in ANARE did not warrant this differentiation as all men were seen and treated by one doctor only, and there were no para-medical aids to assist with the initial screening.

The comparisons of the Soviet inpatient treatments and the United States admission rates are shown in Table 28. The major variations between the results in this table and the data from the Australian survey is the high percentage of inpatient treatments for respiratory illness on both United States and Russian expeditions, and the admission rate for appendicitis, heart disease and hypertension at Soviet stations.

Table 28. Comparison of inpatient admissions on Soviet and United States Antarctic expeditions

Group	Soviet Antarctic expeditions				U.S. Navy 'Operation Deep Freeze'	
Period of survey	1955-66		1965-66		1955-60	
Most frequent illnesses and diseases (per cent of total)	Trauma	23	Trauma	11	Injuries	35
	Respiratory	21	Respiratory	22	Respiratory	18
	Appendicitis	22	Appendicitis	14	Gastro-intestinal	9
	Peripheral nervous system	6	Peripheral nervous system	14		
	Heart diseases, incl.hypertension	5	Heart diseases, incl.hypertension	8		
					Genito-urinary	12
					Skin	8
Reference	Matusov (1971)		Matusov (1971)		Hedblom (1961)	

5.2.3 Factors influencing medical statistics

Location of the station has a marked influence on the sickness rate. The Australian stations are all at sea level and there have been no reports of serious medical problems associated with altitude, apart from problems in high altitude flying. In contrast to these figures the 1965-66 medical statistics for Vostok, the inland Soviet station 3488 m above sea level, showed an incidence of 11 per cent for mountain sickness (Matusov, 1971). Although men from Australian stations go inland, they usually travel by slow tractor trains, thus allowing adaptation to the altitude on the way.

The seasonal pattern at Australian Antarctic stations, where there was a gradual decrease throughout the year in the incidence of illness and injury from the high rate during changeover, was not observed in the Soviet reviews (Matusov, 1968; Bundzen and Matusov, 1969) where the sick call rate increased substantially with the onset of winter at Novolazarevskaya. The figures for the Tenth Soviet Expedition only showed an appreciable decrease in October. Despite these differences between groups there is evidence to support the theory that different diseases and injuries occur in different seasons (Matusov, 1968).

The 1963 Davis study showed a greater incidence of illness among those working outside, but in the total Australian study no one occupation could be considered to be more pre-disposed to accidents or illness than another. The observations of Matusov (1971), which showed a higher morbidity rate among engineers, technicians and personnel mainly working outdoors, support the Davis findings. Matusov also reported an increased morbidity with age, and this was also seen at Davis.

The influence of both age and occupation would appear to be further important factors which cause variations in the medical statistics. The increased incidence of heart disease and hypertension on Soviet expeditions (Matusov, 1971) is probably related to age, as the mean ages of men on these expeditions (Matusov, 1968; Matusov, Lukachev and Garshenin, 1968) is much greater than those of the Australian expeditions.

The assumption that previous polar experience influences morbidity would appear a reasonable one, but it is the author's experience that this is not the case. Russian groups have a high percentage of their men with previous polar experience, but Matusov (1968) found that morbidity was independent of previous experience.

The association of respiratory illness and the method of transport to Antarctica has been discussed by Hedblom (1961). Tyler (1968) states that 6 000 patients were treated during the austral summer 1967-68 and 28 per cent of these had upper respiratory infections in October. These infections were predominantly viral and responded poorly to treatment. Tyler reported that the true incidence of this type of illness is unknown as many perople treat themselves or put up with the symptoms.

Air travel, the large number of men, crowding of living quarters and the rapid exposure of people to the environment are factors that contribute to the greater incidence of respiratory infection at non-Australian stations.

Australian relief expeditions are all done by a single ship, the numbers of men are small and the slow journey allows gradual adaptation to the environment. The epidemiology of respiratory infection in an isolated Antarctic community has been discussed by Cameron and Moore (1968).

The influences of working and living conditions are significant. Crocq *et al.*, (1973) reported that there had been an increase in psychological problems at French bases as the bases were made more comfortable. Tikhomirov (1973), however, reported that both psychological and medical difficulties were reduced at Russian stations with successive physical improvements. Matusov (1965) reported a significant improvement in health in the last two years of the six-year Mirny survey.

The improvement in working and living conditions at ANARE stations appeared to have reduced the incidence of illnesses that were related to personal hygiene, but there was no correlation between new stations and changes in the rate of psychological problems or accidents.

5.2.4 Mental health

The incidence of mental, psychoneurotic and personality disorders at ANARE stations was 1.8 per cent. This incidence compares favourably with the published data for Antarctica, even allowing for the fact that Australian records for ill-defined diseases and symptoms include insomnia and headaches. It is probable that a small number of these could have been classified under psychological problems.

Hedblom (1961) reported an incidence of 0.9 per cent for psychological problems, those being admitted for treatment amounting to 2.3 per cent of total admissions. Gunderson (1968) reported that the incidence of diagnosed psychiatric disorders in United States Navy personnel in Antarctica was 3 per 100 each year. Most of these were seen on an outpatient basis only. Gunderson points out that, although the risk of psychiatric difficulties is a little higher in Antarctica, the incidence of gross psychiatric disturbances is very low. Nardini *et al.* (1961) reported that there were no documented psychiatric breakdowns of '*psychotic proportion*' at U.S. bases in the wintering-over groups in the period 1956-61.

The psychological problems on the Tenth Soviet Antarctic Expedition amounted to 7.1 per cent of all visits to the surgery (Matusov, 1971). The group treated as inpatients made up 5.6 per cent of the inpatient total, on this one expedition, but the figure was reduced to 3.2 per cent for all ten expeditions. Tikhomirov (1973) reported that recent investigations of the nervous system in men at Soviet stations '*have shown signs of gradual increase in fatigue, in some cases exhaustion, especially during the polar night*'. This has manifested itself by increases in various subjective complaints such as neurotic reactions and even by cases of acute psychosis.

The problem of insomnia or "big-eye" is less real on Australian expeditions than other expeditions and no reports can be found in ANARE records of examples such as 'Operation Deep Freeze 1' where insomnia was stated to be '*epidemic*' (Taylor, 1960).

5.2.5 Appendicitis

Although actual figures for cases of appendicitis are not available for all Antarctic expeditions, the morbidity rate of 15.7 per thousand for ANARE wintering expeditions in the period 1947-72 is much greater than that of the U.S. Navy Support Force (Youngman, personal communication), and the French expeditions (Rivolier, personal communication). The incidence at Soviet stations is higher (Matusov, 1971) than at the Australian stations.

There is very little reference to appendicitis in the early expeditions. Surgically and non-surgically treated cases were reported by Gazert (1914), and Evans (1937) commented that '*only one case of appendicitis had come to my notice in the South*', and that was on Byrd's 1929 expedition. The patient was successfully operated on by the doctor of a Norwegian whaler.

Taylor (1960) had two cases on the 'Deep Freeze 1,' and both methods of treatment were used. During the International Geophysical Year, a clinical case of acute appendicitis occurred in a member of the U.S. party wintering at the South Pole. Houk (1950) the medical officer, discussed the non-surgical management and outlined the problems of altitude, frozen anaesthetic agents, lack of trained help and total isolation at the South Pole.

Similar problems confronted the physician to the Sixth Soviet Expedition, who was forced to operate on himself for acute appendicitis in 1961 (Rogozov, 1964). The doctor was assisted by two co-workers who held the retractors and a mirror. The operation was successful.

5.2.6 Mortality

The mortality rates for the various categories of the Australian expeditions are tabulated in Table 26. The figure of 4.4 per thousand at Australian stations during the wintering periods 1947-72 is identical with the rate for all wintering Antarctic expeditions 1951-64 (Beltramino 1965, 1966). The records of the Antarctic summer operations of ANARE do not list any deaths and this compares with a rate of 0.73 for all Antarctic summer groups 1951-64. During the ANARE summer activities over 1.5 million passenger miles have been flown in small aircraft without fatality.

Beltramino (1966) found that deaths on the summer expeditions of all nations were associated with intensified field work by aircraft and vehicles, but the number was low in proportion to the number of men participating. Aviation accidents accounted for 60 per cent of these deaths.

The mortality rate for wintering expeditions 1904-64 was 5.36 per thousand but this figure contained the deaths in the heroic era. Beltramino (1965) found that, despite the increased number of men and activities over recent years, the mortality rate in almost all cases had declined.

The British Antarctic Survey has had 17 deaths in 29 years of operations (Fuchs, personal communication). Lloyd (1973) made a survey of medical and allied problems occurring on bases and sledging expeditions in the British sector of the Antarctic for the decade 1961-70. Table 29 compares the fatalities in his study with those of ANARE in the corresponding period. The British have had a higher mortality rate than the Australians during the decade under study.

Table 29. Comparison of fatalities occurring on the British Antarctic Survey stations with those on the Australian National Antarctic Research Expeditions for the period 1961-70

Expedition	BAS	ANARE
Number of men	850	741
Number of stations	7	4
Fatalities	7	3
Cause of fatality		
Medical	1	2
Accidental	6	1
Locality of fatality		
Station	1	2
Field	6	1
Reference	Lloyd (1973)	This Study

The increased incidence of deaths due to accidents on the BAS is associated with a greater number of deaths on field operations. This illustrates the importance of activity upon the mortality rate. The influence of activity can further be emphasised by the death of an Australian expeditioner in 1972. The man died of a perforated gastric ulcer, which occurred during a blizzard when he was confined for some days with his companions in a small hut, which was out of reach of medical attention.

The importance of medical support is also illustrated by this non-accidental death during a blizzard. At a number of the British bases small teams of men do not have a doctor, but they still do considerable sledging and field work. Although Lloyd (personal communication) stated that more medical problems and accidents occurred at bases where there was a doctor, the significance of the lack of a doctor cannot be under-estimated in the BAS study.

The Australian deaths in the study were due to carbon monoxide poisoning, cerebral haemorrhage and myocardial infarction. On the British expeditions three deaths were caused when a vehicle fell into a crevasse, two were thought to have died of carbon monoxide poisoning, and the other two were the result of drowning and ulcerative colitis.

Doury and Pattin (1973) reported that, during the French expeditions to Kerguelen, Amsterdam and Crozet stations in the years 1970-72, and to Adélie Land 1960-72, five deaths had occurred. Two of these were from unknown causes and three were the result of suicide.

From 1898-1962, 88 deaths were reported in Antarctica. Four of these resulted from medical causes, and occurred before 1903 (Hedblom, 1961; Wilson, 1965). In the next two years there were ten further deaths, two being medical in nature (Hedblom, 1965). Since 1964 additional medical deaths have been reported. Three of these have happened on Australian expeditions.

The increase in deaths due to medical causes is significant, as it has taken place despite better medical screening examinations by a number of nations (Doury and Pattin, 1973; Lloyd, 1973; Lugg, 1973a; Youngman, personal communication) on a young and highly selective group. This emphasises the fact that there is still much to be learnt and applied in medicine in polar regions, although great advances have been made in technology in these regions.

5.2.7 Cold injuries

The low incidence of serious cold injury on Australian expeditions is found on many Antarctic expeditions. Wilson (1965) reviewed ailments caused by the environment itself and found severe frostbites rare, occurring almost exclusively in connection with accidents under adverse circumstances. In the period since his review severe cold injury has continued to be an infrequent occurrence.

Hunt (1968), who wintered with a thirty-man group at the U.S. Byrd station, stated that frostbite presented little problem. Tyler (1968) commented on the incidence of environmental injuries on the U.S. Antarctic Support Force thus:

> '*contrary to what one might expect, the incidence of frostbite and other cold injury is very low*',

and this low rate was confirmed by Youngman (personal communication) for

'Operation Deep Freeze 1970-71'. Doury and Pattin (1973) stated that '*frostbite we observed in Polar regions was always benign*' when summarising French experiences.

5.2.8 Medical evacuations

The incidence of medical evacuations from Antarctica has not been reported by all the nations working there, and in many cases only the sensational repatriations have been commented on. The number of men who have been evacuated from ANARE stations is low by comparison with the personnel who have been returned from U.S. bases.

During 'Operation Deep Freeze 1970-71' over thirty men were evacuated by air from Antarctica (Youngman, personal communication). Tyler (1968) reported that during each operating season twenty-five to thirty U.S. personnel were evacuated from Antarctica for medical reasons. These trips are now routine, as flights are made in most months of the year from McMurdo to New Zealand.

Flights made for medical emergencies include two from Byrd station in April 1961 and September 1966 (*Antarctic J. of U.S.*, 1966a; Hunt, 1967) when cases of acute appendicitis and '*stomach ailment*' were flown out, and two from McMurdo station in December 1964 and June 1966 (*Antarctic J. of U.S.*, 1966a, 1966b) for spinal injuries and a ruptured bladder.

In December 1967 a U.S. Navy 'Hercules' aircraft repatriated the Halley Bay medical officer from his station to New Zealand via McMurdo (*Antarctic J. of U.S.*, 1968). He was suffering from severe facial fractures and broken vertebrae.

Other British evacuations (Fuchs, personal communication) have included cases of hepatitis, trauma, ulcerative colitis and intestinal obstruction, and both aircraft and ships from Britain, U.S.A. and the Argentine have been used.

The lack of published data on medical evacuations show the large amount of work that needs to be done on Antarctic environmental epidemiology. The cases illustrate the co-operation between the different nations in Antarctica, and also emphasise the difficulties in medical practice on this inhospitable continent.

6. SYNTHESIS

6.1 CONCLUSIONS

Human adaptability is dependent on the morphological, biochemical, physiological and behavioural characteristics of man. In this study despite the limitations of the research facilities and the difficulty of the author being a participating member of the group, the health and physiological and behavioural responses of nine men from a temperate region were studied. During a period of thirteen months the expedition was completely physically isolated in the Antarctic environment.

The men were exposed to the meteorological climate for 20 per cent of their time in Antarctica. A further 10 per cent of the time they experienced outdoor temperatures, as many of the huts, tents and vehicles were not heated. There was no significant relation between either the mean monthly outdoor temperature or the mean monthly windchill and the mean daily time spent outdoors. Comparison with other expeditions show that this group was exposed to the climate more than the average modern Antarctic expedition.

Despite the greater exposure, and the fact that all men were exposed to cold for varying periods every day, it is concluded that adaptation to cold was affected by the length of time spent in heated buildings, as man's intuitive behaviour caused him to seek shelter and avoid extreme exposure where possible, thus avoiding the meteorological climate. The exposure climate was found to be between 12° and 28°C above the meteorological temperature and this exposure climate was independent of the meteorological climate.

The actual microclimate of the subjects was not measured, as other studies have shown close agreement on the microclimate being 32° - 33°C, with lower readings being found on men sledging. The Davis observations are considered to be in agreement with these studies.

The men were comfortable at all dry-bulb temperatures between 5.6°C and 27.2°C, but the preferred indoor temperature was 14.2°C. The results were compared with those for tropical and temperate areas. The absence of thermal discomfort and the low value of the preferred temperature were shown to be due to adjustments of clothing; this finding reflected the tendency of isolated groups to disregard conventional habits of dress. Clothing was shown to play a larger part in determining the thermal sensation than the indoor air temperature.

The amount of clothing worn outdoors did not increase as winter approached, yet the men maintained a higher level of thermal comfort. A comparison of the thermal comfort and the clothing worn, both indoors and outdoors, in periods before and after midwinter strongly suggests that acclimatisation to cold had occurred.

The physiological variables that were examined did show some changes observed in other Australian expeditions, but the biological significance of a number of these changes is not clear. Throughout the whole year there was a high degree of activity by all men. Light work averaged 5.8 hours daily, light-moderate work 2.7 hours daily and moderate-heavy 2.8 hours daily. This activity is reflected in an absence of seasonal weight changes and is in contrast to the results of a number of expeditions. The maintenance of activity, the absence of boredom and of increased eating due to a successful behavioural adaptation to the environment are considered the causes of the negligible changes in body weight.

The satisfactory adaptation of the men is also shown by significant changes in the basal pulse rate. The significant negative correlations between basal systolic blood pressure and skinfold thickness may also reflect psychological factors. Blood pressure changes occurred but no relation was observed between blood pressure and body weight.

Skinfold thickness showed significant changes but no seasonal variations. Correlations of skinfold thickness records, associated with differences between subjects, months and residual fluctuations, may reflect the small sample or factors other than body fat. The men did show changes in their thermal reaction to cold, but there was no increase in skinfold thickness or body weight, and this may signify that vascular changes occurred as the result of adaptation to cold rather than fat deposition.

Significant changes in oral temperature were recorded over the year but no seasonal variation was detected.

Physiological changes occurring on field trips were recorded and analysed. The mean daily activity was considerably more than expected. On the main traverse where dog teams were used, travelling was possible on only 20 days out of a total of 52 days, blizzards, whiteout and poor weather causing the three men to lie-up in their tent for days. Despite not being able to travel, the men spent five hours pér day working.

The mean daily food intake for this trip was 4860 kcal while energy expenditure was calculated at 4350 kcal daily. The men returned to Davis with a mean body weight loss of 7.08 kg, 5.46 kg being regained in the first twenty-four hours. This rapid regaining of weight is considered to be due mainly to rehydration, but the influence of inadequate food and psychological factors cannot be completely discounted. Corresponding changes in skinfold thickness may be due to calorie inbalance or possibly a reflection of changes in fitness. Field studies on vehicle traverses showed smaller losses in body weight of those men taking part, but these traverses were of shorter duration.

The smaller number of men at Davis meant that there was a large amount of support work necessary for the existence of the group. The medical officer spent 5.8 hours per day on station and field work and only 2.3 hours per day on medical and dental matters. A large proportion of this time was taken in routine tasks that normally would be done by paramedical staff.

Health is a process of continuing adaptation to man's environment and the ability of the Davis expedition to function effectively in the hostile Antarctic region is reflected in the low incidence of illness at Davis. The environment had a much lower influence on the health statistics than might be expected for the severity of the climate.

The most frequent medical cases were trauma and injuries (28 per cent), ill-defined symptoms such as headaches and vague gastro-intestinal problems (23 per cent) and dental treatments (12 per cent). Although the list of illnesses appears serious, the majority were of a minor nature and all men returned to Australia in good health.

Nine cases of frostbite were recorded but all of these were superficial and no sequelae occurred. The absence of serious cold injury was due to preventive measures. Two cases of unusual non-freezing cold injury were caused through ignorance. From the survey of cold injury it is concluded that indoctrination is most important in the prevention of cold injury.

The Davis group as a whole readily adapted to station life. Important factors in the adjustment were personal motivation, group accomplishment, group structure and group co-operation. The adaptation of the men to the climate, isolation, work, stress and each other are reflected in the low incidence of mental ill-health. The meteorological conditions at this coastal station did not cause the appearance of morbid symptoms, and no obvious correlation was found between psychosomatic manifestations and biometeorological factors such as severity of blizzards and changes of temperature and light. Although sleep times were not recorded, it was concluded that rest time (mean 8.2 hours per day) was influenced by the light regimes; men rested more in the darker winter months.

The majority of the group tended to shut themselves off psychologically from the outside world and this was shown in the study of recorded conversations where the group discussed expedition matters, ANARE, and activities at Davis. Individual men used different methods of facilitating their adjustment to both the life and the environment, and compensations to the size of the group and its isolation were observed. The morale of the men individually or as a group fluctuated throughout the year and was found to correlate closely with specific events, but there was no orderly dependence on season. The pattern of morale at Davis differs from the two previously reported Australian studies and this emphasises the wide variations between different wintering groups. It is concluded that psychological adaptation is most important and there is need for more advanced measures of this at Australian stations.

Although physiological adaptation in the form of acclimatisation to cold is suggested by this study, it is concluded that the overall adaptation of the group was more influenced by behavioural than by physiological factors.

An analysis of the health of the Australian National Antarctic Research Expeditions from 1947 to 1972 shows the Davis study group to be a typical expedition. The categories of over 7 000 case histories from over 1 000 wintering men on 60 expeditions were analysed and it confirms anecdotal evidence that the health of the expeditions is very good. The largest category of illness and injury was that of trauma and accidents (35.7 per cent). The next most common group (18.9 per cent) was that containing symptoms and ill-defined diseases. Dental and skin diseases each occurred in over 8 per cent of cases. Severe cold injury is noticeably absent from the medical records although the incidence rate of cold injury in the survey was 81.8 per thousand. There were, however, only two cases of frostbite in which loss of phalanges of the fingers or toes occurred.

Despite the large number (average 7 per man of cases reviewed) of illnesses and injuries reported, few men in any expedition were incapacitated. The presence of "accident prone" individuals was confirmed but there was no one occupation that could be considered to be more predisposed to accidents or illness than another.

The results indicate only a few categories where location appears to have an obvious effect. The incidence of illness and injury is high during the accelerated activity at the stations during changeover when more than twice the wintering population are on the station. Other occasions of high incidence occured in periods of maximal outside activity such as preparing for and carrying out field work. Otherwise, the groups show a gradual decrease in incidence throughout the year. This progressive decrease indicates both job and climatic adaptation.

The Australian health survey is compared with other Antarctic expeditions as it is considered important to make comparisons with other polar populations. However, the difficulty in making comparisons from one continent to another, because of the selective population, is emphasised.

The mortality and medical evacuations from Australian stations are analysed and these compare favourably with the figures of other nations operating in Antarctica. The significant increase in deaths due to medical causes on both Australian and other national expeditions emphasises that there is still much to be learnt and applied in medicine in polar regions, despite the great advances that have been made in technology in these regions. The morbidity rate of appendicitis on Australian wintering expeditions, which is higher than French and American expeditions but lower than the Soviet expeditions, is another interesting finding.

The improvement in working and living conditions at Australian stations appear to have reduced the incidence of illnesses that are related to personal hygiene, but there is no correlation between new stations and changes in the rate of psychological problems or accidents.

The Australian survey is concluded to cover a typical Antarctic population but the lack of specificity in the small amount of published data, due to differences in classifications, does not permit other than general conclusions to be made on the health statistics.

This human study is one of few documented, of the large number of expeditions sent south by Australia, since 1947. As well as contributing to the physiology of local acclimatisation and thermal comfort of men from temperate regions in Antarctica, it includes records of health and behavioural adaptation which up till the present time have been anecdotal. This study assesses the totality of human adaptation in an Antarctic environment. The results of the health survey make an important contribution to the knowledge of morbidity, health and medical practice in Antarctica, which is basic to a complete understanding of Antarctic environmental epidemiology.

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APPENDIXES

APPENDIX 1: Davis climatological data 1963-1964

	Temperature (°C)					Relative humidity (%)
Month and year	Monthly mean	Maximum Highest	Maximum Mean	Minimum Lowest	Minimum Mean	Monthly mean
1963						
February	- 4.8	0.8	- 2.3	-13.3	- 6.9	59
March	- 9.6	- 0.6	- 7.2	-19.2	-12.4	59
April	-14.1	- 1.8	-11.9	-26.5	-16.2	62
May	-16.3	- 3.3	-13.7	-32.3	-18.9	69
June	-14.5	- 4.9	-11.7	-25.1	-17.3	70
July	-17.3	- 7.3	-14.4	-28.6	-20.3	73
August	-13.9	- 1.1	-11.8	-27.7	-16.4	68
September	-15.3	- 2.6	-11.9	-27.1	-18.6	61
October	-14.2	- 4.6	-11.1	-24.9	-17.3	63
November	- 5.2	1.7	- 3.0	-10.7	- 7.4	64
December	- 0.7	9.5	1.4	- 8.5	- 2.9	59
1964						
January	0.3	6.7	2.3	- 5.4	- 1.7	58
February	- 2.0	5.6	0.6	- 7.7	- 3.5	59

Data taken from published meteorological records of the Bureau of Meteorology (Commonwealth Bureau of Meteorology, 1966, 1967).

APPENDIX 1: Davis climatological data 1963-1964

Month and year	Windspeed (m/sec) Monthly mean	Windspeed (m/sec) Maximum gust	Windchill (Kcal/m^2/hr) Monthly mean	Sunshine (hr) Daily mean	Drift No. of days	Precipitation No. of days
1963						
February	4.4	14.9	1020	5.7	0	5
March	4.6	22.6	1150	1.7	8	11
April	5.2	34.5	1320	1.3	8	7
May	5.8	51.9	1410	0.0	10	3
June	4.9	30.8	1320	0.0	10	13
July	6.1	41.7	1460	0.1	14	9
August	5.4	47.8	1330	0.4	10	11
September	4.5	34.5	1310	5.0	1	8
October	3.9	33.4	1240	3.6	3	14
November	6.4	46.8	1120	4.3	1	16
December	6.0	37.0	980	5.2	0	10
1964						
January	5.2	21.1	920	6.7	0	12
February	5.2	42.7	980	3.4	0	5

Data taken from published meteorological records of the Bureau of Meteorology (Commonwealth Bureau of Meteorology, 1966, 1967).

APPENDIX 2: : Monthly means of the physiological variables studied at Davis during 1963-64

	Aust.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.*	Dec.	Jan.	Feb.
Body weight (kg)	70.26	71.12	70.31	70.33	70.18	70.24	70.22	69.58	70.03	70.07	72.09	70.89	71.01	70.23
Skinfold thickness (mm)-Scapular	-	9.42	9.49	10.06	10.01	10.08	9.92	9.78	9.86	9.87	10.20	9.80	10.24	10.10
Triceps	-	6.35	6.47	6.81	6.77	6.80	6.62	6.77	6.72	6.58	6.46	5.92	6.68	6.40
Arm circumference (cm)	-	28.3	28.4	28.6	28.7	28.5	28.5	28.3	28.1	28.1	28.0	28.0	28.1	28.1
Pulse rate/min -Basal	-	67.8	64.8	61.3	59.8	58.6	57.6	56.3	55.8	58.5	58.4	64.5	59.5	61.3
Casual	62.0	68.5	73.5	67.5	68.0	63.0	65.0	63.5	67.8	65.3	61.6	68.0	68.3	68.0
Blood pressure (mm Hg)- Diastolic Basal	-	80.6	76.9	76.9	71.5	72.6	66.9	71.9	75.1	75.4	72.4	76.3	76.0	68.5
Casual	75.6	72.1	80.0	76.5	70.4	74.9	74.0	73.1	75.0	75.4	71.0	73.8	68.8	73.4
Systolic Basal	-	115.9	115.9	115.8	114.5	115.0	112.3	112.1	112.1	115.5	111.4	112.8	117.3	109.1
Casual	128.6	116.8	126.5	124.3	119.4	122.0	120.1	117.3	121.3	119.9	121.4	116.1	117.9	119.8
Oral temperature (°C) -Basal	-	36.5	36.1	36.2	36.3	36.3	36.3	36.4	36.1	36.3	36.0	36.3	35.9	36.3
Casual	36.7	36.3	36.6	36.6	36.7	36.7	36.5	36.7	36.8	36.7	36.8	36.6	36.6	36.7

* Mean value of five subjects only.

APPENDIX 3: Monthly means of daily record of the duration of cold exposure, activity and rest of the Davis medical officer, 1963-64

Month and year	Duration cold exposure (hours)			Activity (hours)				
	Indoors heated	Shelter unheated	Outdoors	Light work	Light-mod work	Mod-heavy work	Rest	Personal admin.
1963								
February	13.3	1.2	9.5	3.7	3.8	5.9	6.3	4.3
March	16.2	2.9	4.9	4.8	3.4	3.5	7.3	5.0
April	15.6	2.8	5.6	5.3	2.3	2.8	8.6	5.0
May	19.9	1.1	3.0	6.6	2.0	2.1	8.3	5.0
June	16.5	3.2	4.3	5.0	2.0	2.7	9.2	5.1
July	18.7	1.7	3.6	5.8	2.4	2.8	8.5	4.5
August	19.4	1.8	2.8	5.3	2.7	2.6	9.1	4.3
September	15.2	4.5	4.3	5.9	2.0	3.0	9.0	4.1
October	16.0	3.5	4.5	6.9	3.0	2.2	7.8	3.6
November	16.8	2.4	4.8	7.4	2.7	2.0	8.3	3.6
December	18.2	1.4	4.4	7.3	2.2	1.3	8.4	4.8
1964								
January	16.4	1.7	5.9	4.6	3.7	3.3	8.1	4.3
February	16.7	2.2	5.1	6.7	3.4	1.9	7.7	4.3
Mean	16.9	2.3	4.8	5.8	2.7	2.8	8.2	4.5

APPENDIX 4: Monthly means of the daily record in hours of the type of work performed by the medical officer at Davis, 1963-64

Month and year	Medical-dental	Medical research	Biological research	Station and field work (non-medical)
1963				
February	2.2	0.6	0.4	10.2
March	1.2	1.0	1.1	8.3
April	1.4	0.9	1.9	6.1
May	2.4	1.1	0.8	6.6
June	2.4	1.4	0.6	5.2
July	2.5	1.5	1.1	5.7
August	1.9	1.7	1.6	5.3
September	2.3	1.6	1.4	5.6
October	2.7	1.8	2.8	4.8
November	2.6	2.0	3.5	4.0
December	2.5	1.5	3.4	3.4
1964				
January	2.9	1.5	1.5	5.7
February	2.7	2.1	2.2	4.9
Mean	2.3	1.5	1.7	5.8

APPENDIX 5: The inside environmental temperatures to which the subjects were exposed at Davis during 1963.

Most of the buildings had cold porches where the temperature remained at, or slightly above, the outdoor temperature

Building	Air temperature (°C) Mean	Range
Administration	15	13-17
Kitchen and mess	21	10-24
Sleeping	16	5-24
Recreation and library	20	5-30
Latrine	7	*
Meteorology	22	19-24
Balloon filling	≁	≁
Radome	≠	≠
Radio	21	19-25
Surgery	17	2-30
Powerhouse	5	2-26
Garage	≁	≁
Carpenter's shop	≠	≠
Food stores 1 and 2	7	1-10
Hardware store, field store and clothing store	≁	≁
Refrigerator	-10	*

≁ Air temperature inside was the same as the external temperature.

≠ Air temperature inside was always 1-5°C above the external temperature.

* No range available.

APPENDIX 6: Number of personnel wintering at Australian stations during the period 1947-1976

Year	Heard Island	Macquarie Island	Mawson	Davis	Repstat/ Casey	Wilkes	Amery Ice Shelf
1948	14	14*					
1949	11	12+					
1950	16+	17*					
1951	14	17					
1952	14	14					
1953	13	14					
1954	9	13	10				
1955		14	15				
1956		15	20				
1957		15	24	5			
1958		16	28	4			
1959		17	23	8		18	
1960		15	33	8		18	
1961		13	25	9		24	
1962		15	24	9		23	
1963		16	26	9		22	
1964		17	26	10		23	
1965		19	27			23	
1966		19	26			27	
1967		18	28			24	
1968		19	23		4	26	4
1969		22	28	10	33		
1970		18	22	10	24		
1971		16	24	12	26		
1972		16	24	12	25*		
1973		17	25	14	29		
1974		19	26	14	27		
1975		21	27	14	26		
1976		19	29	14	23		

* 1 man arrived during wintering period.

\+ 2 men arrived during wintering period.

APPENDIX 7: Classification and occurrence of illnesses, diseases and injuries at Davis, Antarctica, 1963-64*

I <u>Infective and parasitic diseases</u>°

II <u>Neoplastic diseases</u>°

III <u>Allergic, endocrine, metabolic and nutritional diseases</u>°

IV <u>Diseases of blood</u>°

V <u>Mental, psychoneurotic and personality disorders</u>

Depression
Immature personality

VI <u>Diseases of nervous system and sense organs</u>°

VII <u>Diseases of circulatory system</u>

Haemorrhoids (4)+
Varicose veins (2)

VIII <u>Diseases of respiratory system</u>

Sinusitis
Tonsillitis
U.R.T.I. (6)

IX <u>Diseases of digestive system</u> (including dental)

Dental fillings (13)
Repairs to dental prostheses (4)
Gingivitis (5)

X <u>Diseases of genito-urinary system</u>°

XI <u>Diseases related to the environment</u>

Chilblains
Frostbite of face and hands (9)
Snowblindness
Sunburn
Trench foot (2)

XII <u>Diseases of skin</u>

Acne
Cheilosis
Infection (bacterial) - Finger
Hair follicle
Sebaceous cyst
Skin

Ingrowing toenail
Ingrowing cilia eyelid
Pilonidal sinus
Pruritis ani (2)

XIII <u>Diseases of bones and masculo-skeletal (non traumatic)</u>

Fibrositis
Muscle cramps (5)

XIV <u>Trauma, accidents and poisonings</u>

Abrasions - Legs
Back strain (4)
Burns to hand, forearm (2)
Burns (Caustic Soda)-to hand (2)
to face
Carbon monoxide poisoning
Crushed hand (2)
Dog bite
Fluid on knee (2)
Foreign body eye (7)
Fractured patella
Haematoma-Hip
Shoulder
Subungal
Lacerations-Eyelid
Face
Finger (4)
Thumb
Splinder - Hand (2)
Tenosynovitis (3)

XV <u>Symptoms, ill-defined diseases</u>

Diarrhoea (3)
Headache (16)
Indigestion
Insomnia (5)
Nausea (2)
Pain - Abdominal (3)
Arm (2)
Chest

* Based on the International Statistical Classification of Diseases, Injuries and Causes of Death. The diseases and injuries at Davis during 1963-64 were used as a pilot study for the total ANARE figures.
o Denotes no occurrence in this category.
\+ Denotes number of occurrences in each category.

APPENDIX 8: The monthly occurrence at Davis of illnesses, diseases and injuries under their broad categories

Category of illnesses, disease or injury	Month													Total
	F	M	A	M	J	J	A	S	O	N	D	J	F	
I Infective and parasitic diseases														
II Neoplastic diseases														
III Allergic, endocrine, metabolic and nutritional diseases														
IV Diseases of blood														
V Mental, psychoneurotic, personality disorders					1		1							2
VI Diseases of nervous system and sense organs														
VII Diseases of circulatory system				1	2				1			1	1	6
VIII Diseases of respiratory system			1		1	2	4							8
IX Diseases of digestive system (including dental)	1	2	1	2				3	1	2	6	2	2	22
X Diseases of genito-urinary system														
XI Diseases related to the environment	1	1	3				1	6	1			1		14
XII Diseases of skin		1		1	2		1	1	1		1	2	1	11
XIII Diseases of bone and musculo-skeletal (non-traumatic)		1				1							4	6
XIV Trauma, accidents and poisonings	4	5	2	3	2	2	8		2	3	1	3	4	39
XV Symptoms and ill-defined diseases			4	1	1	3	3	1	1	5	5	6	3	33
Monthly totals	6	10	11	8	9	8	18	11	7	10	13	15	15	141

APPENDIX 9: The monthly illnesses, diseases and injuries for each subject at Davis, grouped under their broad categories

Month	Subject								
	A	B	C	D	E	F	G	H	I
February						D1 E1	T2	T1	T1
March	T2	T1	D1	M1	S1	D1 E1 T1		T1	
April	R1 T1 L2	E1	L2	T1		E1		D1	E1
May	C1 L1		D1	T1	S1	T1	T1		D1
June	R1 L1		T1	C2	S1	S1	P1	T1	
July	R2 L1		L1	T1	M1 L1		T1		
August	R1 T3 L1		L2	R3 T1	S1 T1	T1	E1	P1 T2	
September	S1 L1	D1 E1	D1 E2	D1 E1				E2	
October	C1			E1 L1	S1		T1	D1	T1
November	T1	D2	T1 L4	L1	T1				
December	D2 S1	D1 L1	D1 L2	L1	T1		D1 L1	D1	
January	S2 T1 L2	E1	D1 L1	T1 L2	C1 L1	D1			T1
February	C1 S1 M1 T1	D1 T1	D1 M2 L2	T2		M1			L1
Total	34	11	26	21	12	11	9	11	6

P - Mental, psychoneurotic and personality (V)
C - Circulatory (VII)
R - Respiratory (VIII)
D - Digestive (IX)
E - Environmental (XI)
S - Skin (XII)
M - Bone and musculo-skeletal (XIII)
T - Trauma, accidents, poisonings (XIV)
L - Symptoms and ill-defined (XV)

APPENDIX 10: Fatalities on Australian National Antarctic Research Expeditions 1947-75

Table 1. Causes of fatalities of ANARE expeditioners 1947-75

Cause of fatality	Number
Appendicitis	1
Carbon monoxide poisoning	1
Cerebral haemorrhage	1
Drowning*	3
Exposure	1
Myocardial infarction	2
Perforated gastric ulcer	1
Trauma - tractor accident	1
toboggan accident	1
fall while climbing	1
	13

* One case occurred at foreign base while person an observer

Table 2. Occupations of expeditioners

Occupation	Number
Carpenter	1
Diesel mechanic	2
Dog attendant	1
Medical officer	1
Meteorologist	1
Meteorological observer	1
Physicist	1
Radio operator	4
Technician (Electronics)	1
	13

Table 3. Ages of expeditioners

Age (years)	Number
20 - 25	3
26 - 30	2
31 - 35	3
36 - 40	2
41 - 45	1
46 - 50	1
51 - 55	1
	13

Table 4. Localities where fatalities have occurred

Station	Number
Heard Island	2
Macquarie Island	5
Maudheim*	1
Mawson	3
Wilkes	2
	13

* Base for the Norwegian-British-Swedish Expedition 1949-52

Table 5. Year in which fatalities have occurred

Year	Number
1948	1
1951	2
1952	2
1959	1
1963	1
1967	1
1968	1
1971	1
1972	2
1974	1
	13

Table 6. Months in which fatalities have occurred

Month	Number
January	3
April	1
May	2
July	3
August	1
October	1
November	1
December	1
	13

APPENDIX 11: Cases of appendicitis at Australian stations 1947-75

Table 1. Distribution of cases of appendicitis and the method of treatment

Station	Total cases	Surgical management	Conservative management	Complications
Casey	0	0	0	0
Davis	1	0	1	0
Heard Island	2	1	1	1
Macquarie Island	7	3	4	2
Mawson	6	2	4	0
Wilkes	5	3	2	1
Nella Dan	4*	3+	1ø	1
	25	12	13	5

* One case occurred in Danish crewman.
\+ One case operated on at Davis, a second at Mawson.
ø Case operated on after repatriation to Australia.

Table 2. Monthly incidence of cases of appendicitis

Month	No. of cases
January	3
February	3
March	2
April	2
May	2
June	2
July	2
August	0
September	3
October	3
November	1
December	2
	25

Table 3. Occupations of expeditioners suffering from appendicitis

Cook	3
Diesel mechanic	2
Electrician	1
Expedition assistant	1
Glaciologist	1
Medical officer	1
Meteorologist	3
Meteorological observer	1
O.I.C.	2
Physicist	2
Radio operator	5
Seaman (Danish)	1
Technician (Electronics)	1
Technician (Radio)	1
	25

Table 4. Year in which cases of appendicitis occurred

Year	No. of cases
1949	1
1950	2
1951	1
1953	1
1955	1
1958	1
1959	1
1960	1
1962	1
1963	2
1964	1
1965	1
1966	2
1967	3
1968	1
1970	1
1971	2
1975	2
	25

APPENDIX 12: Medical evacuations to Australia of members of ANARE 1947-75

Table 1. Causes of medical evacuations

Cause	Number
Amoebiasis	1
Appendicitis	3
Fracture - tibia and fibula	1
Fracture - medial malleolus	1
Haemorrhage - intra cranial	1
Migraine	1
Psychoneurosis	5
Psychosis	1
Renal calculus	1
Hydronephrosis	1
Tenosynovitis - wrist	1
Exostosis - humerus	1
Diagnosis not disclosed	2
	20

Table 2. Occupations of expeditioners

Occupation	Number
Cook	3
Diesel mechanic	5
Engineer (Electronics)	1
Expedition assistant	1
Medical officer	2
Meteorological observer	2
Plumber	1
Radio operator	2
Storeman/assistant cook	1
Technician (Electronics)	1
Technician (Radio)	1
	20

Table 3. Ages of expeditioners

Age (years)	Number
20 - 25	5
26 - 30	2
31 - 35	8
36 - 40	2
41 - 45	2
	19*

* Age of one man not available

Table 4. Station from which expeditioner repatriated

Station/Ship	Number
Casey	1
Heard Island	3
Nella Dan	1
Macquarie Island	11
Mawson	2
Wilkes	2
	20

Table 5. Year in which repatriations occurred

Year	Number
1949	1
1950	2
1951	2
1953	1
1954	1
1959	1
1961	1
1963	1
1964	1
1966	1
1967	1
1969	1
1971	2
1972	2
1973	1
1975	1
	20

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