VIRAL RESPIRATORY DISEASES IN ISOLATED COMMUNITIES: A REVIEW

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ABSTRACT. The pattern of viral respiratory disease in isolated communities has tended to be one of severe epidemics occurring when isolation is broken. Only occasional mild colds occur after the first 6 weeks of isolation. Large communities appear to perpetuate and spread virus by person-to-person contact but in small communities, where homeostasis is likely to be quickly achieved, virus may be preserved in the environment, for example, in the water supplies. The severity of epidemics is determined by the isolation itself while other environmental factors such as low temperatures play only a minor part. The recent work on experimentally induced viral respiratory disease in small isolated communities shows the potential for further studies.

IN the past most of the studies of viral respiratory diseases in isolated communities have consisted of epidemiological and immunological surveys, and these continue to the present day. Recently, however, use has been made of the unique polar environment in the study of experimentally induced viral respiratory diseases.

Facilities for work are now much better than they were in the past, but as communications improve so the degree to which viral respiratory diseases can be studied under isolation conditions is inevitably diminished. There are, however, still a number of places where small groups of men are isolated for many months at a time. The Antarctic continent is particularly valuable in this respect, as the men who winter there do so at widely separated stations and generally have no physical contact with the outside world for periods of up to a year.

This paper reviews work pertaining to viral respiratory diseases in the Antarctic and the Arctic, and also comments briefly on research carried out in non-polar communities which appears to have some relevance to the polar situation.

WORK IN THE ANTARCTIC

Microbiology has been included in medical field work in the Antarctic from the turn of the century to the present. Most field workers have noted the same problems, namely contamination of samples (particularly by yeast on baking days), and the limitations imposed by available time, space and equipment (e.g. McLean, 1919).

The early workers were mainly concerned with bacterial flora in the local fauna and terrain, though they noted in passing the presence of apparent human pathogens (Charcot, 1906, p. 463–65; Ekelöf, 1908; Tsiklinsky, 1908; Gazert, 1912; Atkinson, 1913; McLean, 1919; Darling and Siple, 1941). Human pathogens in the respiratory tract were first investigated by McLean (1919), who showed a decrease in nasal and pharyngeal staphylococci over the year in isolation. This has been confirmed by later workers (Sladen, 1953; Adams and Stanmeyer, 1960).

Human viral diseases were given little attention until recently, though an influenza epidemic at Stanley in the Falkland Islands was reported in 1937 (Cheverton, 1937).

Work on respiratory virology was begun in 1958–59 with "Operation Snuffles" based on the icebreaker U.S.S. *Staten Island*. This programme involved taking blood samples from the entire ship's complement at the beginning and end of the 6 month voyage, and taking regular serum and throat swabs from volunteers. Serum and throat swabs were also collected from parties wintering at Hallett, Wilkes and McMurdo stations. Less than half the ship's complement suffered upper respiratory tract infections and a few minor symptoms were reported by the Wilkes party (Sladen and Goldsmith, 1960; Sladen, 1965). No evidence of infection was shown in tests on the sera against a variety of respiratory antigens.

Information is also available from several stations where the medical officers were not following planned virus studies. A severe outbreak of influenza, identified as A2, was recorded at Scott–Amundsen station at the South Pole in 1957, following the visit of an aircraft in October. Upper and lower respiratory symptoms were seen and the crew of the aircraft were also ill (Siple, 1960). Two workers at McMurdo established that waves of respiratory tract infections followed the arrival of newcomers, who themselves became affected (Taylor, 1960).

In addition, upper respiratory tract infections did occur during the winter, though they were generally mild and affected fewer people: 16 cases out of 80 men wintering, against 134 out of 170 when the flying season started (Hedblom, 1961). McMurdo is not as isolated as many of the other Antarctic stations, since it is the main staging post for all American activity around the Ross Ice Shelf and inland. At Mawson, the Australian Antarctic mainland station, a polio-like illness was described in one man 16 days after contact with the U.S.S.R. vessel *Ob*. Apart from this contact, the station had been isolated for a full year and *Ob* herself had been at sea for 3 months. One other man suffered a brief episode of muscle pains. No virus was isolated from the patient but a process of elimination implicated Coxsackie A7 as a possible cause. The same observer made a detailed study of the parameters of the environment on the station (Budd, 1962, 1964).

A specific virus study was made at SANAE (South African National Antarctic Expedition) station in 1961–62 with a systematic antibody survey of monthly sera. The year's results were completely negative; there was no evidence of any infection by the agents tested (Gear, 1961–62, quoted by Cameron and Moore, 1968). Later, a clinical record of upper respiratory tract infections showed that none occurred after the first 6 weeks of isolation of the wintering party (Wilson, 1965). Wilson also quoted Goldsmith's account of the wintering party at Halley Bay in the Weddell Sea, who had "severe colds" after contacting the relief ship, but when a few days later they and the ship visited Shackleton station farther down the coast, none of the new contacts developed overt infection.

The third specifically virological programme was a sero-epidemiological study at Mawson during 1965–66, where clinical histories, nose and throat swabs, serum and faecal samples were taken. No viruses were isolated and no specific rises in antibody titre were detected (Cameron and Moore, 1968).

The fourth virus project was marred by loss of the viruses taken for use in a clinical trial, when the ship's refrigeration system failed. Sera were examined for changes in titre to a group of respiratory viruses and none was found, antibody levels being largely maintained over the year (Williams, 1967).

A fuirther study on men wintering on a British Antarctic Survey station involved the adminstration of Coxsackievirus A21 and influenzavirus A2. Monthly sera were collected for antibody estimations, and results suggested that repeated re-infection with Coxsackievirus A21 occurred, and that the virus persisted in the community for most of the period of isolation (Holmes and others, 1971).

More work arising out of these findings is in progress in the Antarctic.

Work in the Arctic

The Arctic, with its permanent aboriginal population and relative accessibility, has been the locale of more work than the Antarctic. Some of the earliest epidemiological studies carried out on isolated populations were made there, and a number of Scandinavian medical officers in Greenland and Spitsbergen have recorded the spread of disease among their patients. Before communications developed, the isolation of the Eskimos gave them "antigenic virginity" to all non-endemic disease, and their primitive hygiene ensured a high incidence of antibody to all diseases which were endemic.

The epidemiology of respiratory tract infections began at the end of the last century in the Arctic. At that time one-third of all deaths in Greenland were due to respiratory disease, and two statistico-epidemiological studies were made by one worker in 1867–68 and in 1897–1903 on influenza and "epidemic catarrh" (Meldorf, 1907, 1912). He found that the epidemics were seasonal, occurring in spring and autumn, and that they coincided with periods of high humidity followed by cold spells. However, the epidemics also tended to follow visits from ships, so he decided that ships brought the infection, wet weather "activated" it, and the disease then spread through the community. Somewhat later it was recorded that Eskimos were more vulnerable to the common cold than Europeans, but that they appeared to have "natural immunity" to a variety of bacterial infections (Heinbecker and Irvine-Jones, 1928).

The next contribution in this field came from a worker in Spitsbergen, who was interested in respiratory disease amongst the miners (Abs, 1930). He also found that respiratory tract

infection epidemics coincided with the arrival of the relief ship in late spring each year. He further noted that ships without new employees on board were less likely to start an epidemic, that the epidemics did not have a clear peak but tended to persist until the ships left the area in the autumn, and also that the occasional minor winter epidemics coincided with periods of high humidity. He also noted that workers tended to have gastro-intestinal symptoms with their upper respiratory tract infections and those who stayed ashore a long time tended to get upper respiratory tract infections of increasing severity every season.

Shortly afterwards, two more workers in Spitsbergen made a detailed and elegant study of respiratory disease there (Paul and Freese, 1933). They traced the epidemics following the arrival of the ship, also noting that many of the respiratory cases suffered from transient diarrhoea. They kept extensive meteorological records but were unable to show a correlation between the weather and the prevalence of disease. Comparing two communities, they found that the more crowded one was much more susceptible to disease and deduced short-chain person-to-person spread as the cause. They further discovered that, though an individual might suffer several respiratory tract infections, there was an interval between each one averaging 7 weeks, and therefore decided that immunity lasted for this length of time. Paul and Freese also defined the "incubation" period of the disease as 48 hr., and felt that bacteria had little to do with the production of upper respiratory tract infections. These authors put forward two hypotheses which have still not been fully confirmed. The first was that stress might precipitate a cold by activating an agent latent in the host's tissues following a recent infection or recent contact. The second was that a population must reach a "critical number" before a disease can become endemic. They also showed that the development of an epidemic is not necessarily dependent on the occurrence of unfavourable environmental factors such as sudden drops in air temperature.

The next study was made in the Canadian Arctic on two communities undergoing the same respiratory epidemic in similar environments, but with medical care available in one and not in the other (Pettit and others, 1936). The results showed an inverse relationship between the availability of medical care and mortality in the two isolated settlements. Similar findings were made in the Pacific after an influenza epidemic affecting some isolated atolls, though other factors may also have been in operation there (Brown and others, 1966).

Little was done during the second World War except a retrospective analysis of the 1846 measles epidemic in the Faroe Islands, which demonstrated the severity of an outbreak of disease in a non-immune population (Panum, 1940). The data were, however, incomplete.

More recently, an influenza epidemic was traced in a group of communities in the North-west Territories and the rate of spread determined (Anonymous, 1949). Little original material was included but it marked the revival of interest in polar work. This epidemic affected mixed Eskimo and European communities, and provided a striking illustration of the relative vulnerability of the Eskimo to respiratory disease. The agent was identified as an influenza A strain (Nagler and others, 1949).

One of the paradoxes of polar life, which makes it particularly suitable for epidemiological studies, is that though communities are small and isolated each one tends to be crowded. This results in more limited dissemination of disease between communities, but, once introduced, a high percentage of the community is usually infected. Individual communities are in any case likely to be susceptible because of their isolation. This is borne out by descriptions of explosive outbreaks of enterovirus disease in the north (Paul and others, 1951; Eklund and Larsen, 1959).

Carrier states for particular viruses have been demonstrated for relatively long periods, and make the isolation of polar communities a less effective barrier to continued enterovirus infection. For example, one group of workers was still recovering Coxsackievirus A21 when their study finished 40 days after infection (Johnson and others, 1962). This slows down the passage of virus and lengthens the possible time for transmission. Coxsackievirus in 10 per cent sewage at 10° C survived 44 days (Clacke and Chang, 1959). Water supplies in most of the primitive Arctic communities and most Antarctic communities are generally locally contaminated and at low temperatures all the time.

Arctic epidemiology has been treated on a much broader basis, including bacteriology, by some workers (Pauls, 1953). They felt that the environment favours diseases which spread

by direct contact or via an intermediate host. Others have gone further and suggested that even where diseases are normally spread through food and water elsewhere, in the Arctic spread is by direct contact (Fournelle and others, 1959; Gordon and Babbott, 1959; Gordon and others, 1961).

Many viruses are certainly present in the Arctic. One of the serological studies showed that neutralizing antibodies to polio, Coxsackievirus, psittacosis, ECHO, herpes, influenza and adenoviruses were distributed throughout the native population (Hildes and others, 1959).

Early workers were unable to compare morbidity and mortality rates in the epidemics of respiratory disease in polar communities because techniques had not been developed to identify the agent responsible. Later, as influenza viruses began to be differentiated, the emphasis of the work began to shift to identification of the agents responsible rather than straightforward clinical studies, though these still continued in Alaska (Veterans Administration, 1953).

After the 1957 pandemic of Asian influenza, spread of the virus to the Canadian Arctic became of particular interest. A study was made of two remote Bering Sea communities which were affected in October 1957. In both communities the outbreaks followed the return of a serviceman. Attack rates were found to be higher among the Eskimos than the Europeans. The disease itself, however, was found to be no more severe than elsewhere. Complications were more frequent but they were mainly bacterial. There was a high pre-existing level of influenza A and A prime antibody in the populations, but this in no way appeared to mitigate the disease (Philip and others, 1959). This group also made a retrospective serological study of the 1918–19 influenza pandemic, which caused very severe morbidity and mortality in the Arctic Eskimos. It included a comparison and evaluation of European and Eskimo mortality in mixed communities, where it was found that over seven times more Eskimos than Europeans died. The serological data, when compared to that from other areas, were found to be similar to mid-western urban communities in the United States (Philip and Lackman, 1962). A further comparative study was made on Eskimos who had been vaccinated against influenza, and those who caught it in the 1957 pandemic. This was of interest since the Eskimos were judged to have less naturally acquired anti-influenza antibody than other ethnic groups, so a clearer picture of the immune response to a vaccine strain and a wild strain of influenza could be obtained (Reinhard, 1962).

European military personnel stationed in the Arctic provided some contrasting data in a series of studies by the Arctic Aeromedical Laboratory. These were largely concerned with respiratory disease. One study, tracing the incidence of upper respiratory tract infections amongst this group, showed that the frequency and severity of disease was not changed by the Arctic environment. Serology showed evidence of adenovirus and influenzal infections, the most commonly occurring being influenza A (Treece and Schmidt, 1960). A further study was then made covering the Asian influenza pandemic and upper respiratory tract infections the following year (Metcalf and Schmidt, 1960). Both studies included vaccine trials, the former using a mixed influenza and adenovirus vaccine, and it was shown that this gave a significant degree of protection against respiratory tract infections. The second trial showed that the vaccine was at its most effective when give 3–6 months before a wild infection.

A further study of three new influenza vaccines was made by the same group, who found four times as much morbidity in their controls, and also demonstrated serologically the widespread presence of influenza A2 antibody in the population (Metcalf and others, 1961).

Yet another indication that the native population was more prone to suffer severe disease than immigrant urban Europeans was provided by the study of an influenza B outbreak at Fort Yukon in a mixed population of Americans and Indians (Maynard, 1962).

Later, a survey of lower respiratory disease in Eskimo children showed that they were particularly vulnerable, and indeed, that the relatively high infant mortality amongst them was largely attributable to this cause (Brody, 1965).

A variety of epidemics of other diseases has been reported, usually on a comparative basis with less isolated communities, or with a view to improving public health measures in native populations. These have been by no means confined to the Canadian Arctic. The general pattern is again one of sudden explosive outbreaks with high morbidity rates and complications,

which parallel the respiratory epidemics. For example, very severe measles was reported in Greenland (Fog-Poulsen, 1958).

Low temperatures, though they dictate the way of life in a polar or sub-polar environment, may not be the main reason for the severity of disease there. The only direct effect that they can have is to modify the survival rate or infectivity of viruses, and there is little evidence to suggest that this occurs, except in the preservation of infected material in frozen waste. Polar clothing and adaptive modes of life preserve essentially the same micro-climate and body temperature that a human host would have in a temperate climate (Babbott, 1963). A comprehensive study of the effect of weather on the incidence of upper respiratory infections showed that low temperatures *per se* had only a small influence upon the frequency and severity of disease in England (Lidwell and others, 1965). There was, however, a significant correlation between a drop in temperature and an increased number of respiratory tract infections. Lidwell and others decided that a drop in temperature in some way encouraged the transmission of virus.

The very low relative humidity which accompanies very low temperatures may have more influence on the survival of virus in an infective form, though this works both ways. The survival of myxoviruses, which possess a lipid fraction, is enhanced by low relative humidity. The survival of picornaviruses such as rhinoviruses and enteroviruses, on the other hand, is prejudiced by low relative humidity (Hemmes and others, 1960; Buckland and Tyrrell, 1962). This, of course, can apply only to the outside environment. The relative humidity inside a building is markedly affected by the number of occupants relative to its size, the ambient temperature gradient from outside to inside, and the ventilation rate (Hutcheon, 1960).

Whether people are more prone to overt respiratory disease in a polar environment is not so clear. It has been known for a very long time that cold-stressed animals suffer more severe disease than animals in a normal environment (Pasteur and others, 1878), but whether or not this is true of cold-adapted animals is open to doubt. More recent animal studies have shown that mice acclimatized to 2° C for 45 days largely survived a dose of Coxsackievirus B5 which was lethal to controls and even more rapidly lethal to a group of mice acutely stressed by exposure to a temperature of 2° C (Marcus and others, 1965).

A further effect which may be a mechanism by which cold could theoretically influence host susceptibility is the increased acidity of saliva of chilled subjects—with the possibility that the nasal mucus may also be affected. Rhinoviruses grow better in slightly more acidic conditions than the normal human milieu (Andrewes, 1963). Chilling of the extremities does cause nasal ischaemia (Mudd and Grant, 1919; Bobrov, 1963), but whether this could cause a decreased pH of nasal mucus as well as a lower nasal temperature is not established.

Factors likely to prolong the survival of viruses under polar conditions, such as intermediate hosts or animal vectors or carriers, are of particular interest. A study made on dogs in central Alaska, to see if they carried human pathogens, implicated family pets as possible vectors but not the husky dogs, since they were not allowed access to family dwellings (Butler and Herd, 1964). The rather different treatment huskies enjoy at Antarctic stations does not similarly disqualify them.

Another major source of infection is contaminated waste, with spread of disease by the faecal-oral route, and the prolonged survival of enteroviruses in waste was reviewed by Le Gros and Probay (1966) from a public health viewpoint. Their findings indicated that waste disposal methods were inefficient and provided good sources for the preservation of enteroviruses, and that with the methods then in use the contamination of water supplies was likely. This factor may be even more important at an Antarctic station with a large dog population, where preserved enteroviruses may be available to the huskies, which are then quite likely to contaminate the areas of snow and ice used for drinking water, the evidence being hidden by subsequent snowfall.

Respiratory Disease in Other Isolated Communities

Differences in climate do not appear to influence the annual rate of respiratory infections (Taylor-Robinson, 1965), and the actual number of infections experienced by a tropical community shows no significant difference from that experienced by a temperate one (Sutton,

1965). Epidemic influenza can be as severe in an isolated tropical community as in a polar one (Brown and others, 1966).

Isolation appears to be the environmental condition of prime importance in determining the susceptibility of a community to respiratory disease. The length of time visitors to the community have themselves been out of contact with the outside world is another important factor (Heyerdahl, 1958, p. 58; Hope-Simpson, 1958; Wooley, 1963).

High or low environmental temperatures therefore, except possibly during an undefined period of acclimatization, do not appear to markedly affect the severity of respiratory virus disease.

Tristan da Cunha proved a particularly fruitful field for study when the inhabitants were evacuated *en bloc* after the volcanic activity of 1961. This made it possible to study the course of respiratory viral disease in a highly susceptible group brought into contact with the inhabitants of suburban England (Taylor-Robinson and Tyrrell, 1963). The serology and clinical data showed a lack of immunity to respiratory viruses but, when antibody was present to a virus, it was usually found in high percentages of the sera examined. This "all or none" serological pattern seems to be mirrored by most other investigations in isolated communities.

Further work on the Tristan da Cunha islanders concerned their reactions to respiratory disease during their stay in England (Tyrrell, 1967). Nearly all of the islanders acquired antibody against influenza B and C. Adults also caught para-influenza 3, an infection normally seen only in infants. Rising serum antibody titres against para-influenza 1 and 3 preceded those against para-influenza 2 in the group. This recapitulates the pattern seen in children (Stark and others, 1964). Here it was seen in both children and adults, and the suggestion was made that the islanders might be acting as a "sentinel population" with their non-immune status to many common United Kingdom viral pathogens. This would predispose them to infection by almost any virus currently circulating, and to be infected most frequently by those affecting local children. Later during their stay, antibody levels against influenza C and the para-influenza viruses declined. The reverse was found in a study at an Antarctic station where the opposite parameters of environment were present, that is, an urban group of Englishmen in total isolation instead of an isolated group brought into free contact with others, and antibody levels were largely maintained throughout the year (Holmes and others, 1971).

Since the return of the islanders to Tristan da Cunha, further epidemics of respiratory disease have been observed which resemble those reported by Paul and Freese (1933) in Spitsbergen, and give fairly clear evidence that acute respiratory disease in a very isolated community behaves as an infectious disease introduced from outside (Shibli and others, 1971). The islanders suffered fewer colds than those in less isolated communities, and this has been supported by evaluation of the data in a mathematical model which suggested that the threshold for initiation of an epidemic of common cold was almost twice the level of the theoretical threshold (Hammond and Tyrrell, 1971).

The increasing use of nuclear submarines and space vehicles in the past few years has produced a different kind of isolated community. In closed, re-cycled and artificially replenished atmospheres men have started to seal themselves off for long periods of time. This has led to studies on the microbiological ecology in such vehicles, and so to a study, in the "closed cabin environment", of the epidemiology of viral respiratory disease (Sawyer and Sommerville, 1966; Gordon, 1970).

Conclusions

The pattern of respiratory disease occurring in isolated communities has tended to follow that outlined by Paul and Freese (1933), with epidemics occurring after the arrival of relief ships, and the freedom from epidemics after the first 6 weeks of isolation.

Occasional colds have been reported during the isolation periods, especially in large isolated communities where person-to-person contact seems to be the most likely means of perpetuation and spread. This is not necessarily so in small isolated communities, where homeostasis is likely to be quickly achieved between members in the crowded and intimate living conditions. In this case it seems more likely that continued re-infections or sporadic outbreaks during the isolation period might be due to preservation of virus in the environment, for example in the

water supplies in polar communities, and then subsequent re-infection of the community members when the local conditions are opportune.

Respiratory infections occurring during isolation periods have tended to be mild, and may represent infection with endemic viruses but outbreaks occurring after contact with new virus strains, introduced by relief vessels, have tended to be severe, resembling the severe epidemics first seen in early studies amongst Eskimos, with their "antigenic virginity" to non-endemic disease.

Comparison of the different types of isolated community has shown that it is the isolation itself that determines the severity of viral respiratory disease, and that environmental factors such as cold play only a minor part.

The recent work on experimentally induced respiratory viral disease in small isolated communities shows the potential for further studies. These are taking place at present in the Antarctic and should yield increasingly exact information on the interaction between Man and virus in isolated communities.

MS. received 21 September 1972

REFERENCES

ABS, O. 1930. Über Epidemien von unspezifischen Katarrhen der Luftwege auf Svalbard. *Skr. Svalbard Ishavet*, No. 32, 1–27.

ADAMS, R. J. *and* W. R. STANMEYER. 1960. Effects of prolonged Antarctic isolation on oral and intestinal bacteria. *Oral Surg.*, **13**, No. 1, 117–20.

ANDREWES, C. H. 1963. Influence of cold on host–parasite interactions. (*In* VIERECK, E. G., *ed. Proceedings of symposia on Arctic biology and medicine. III.* Fort Wainwright, Alaska, Arctic Aeromedical Laboratory, 301–17.)

ANONYMOUS. 1949. Influenza epidemic at Cambridge Bay. *Arct. Circ.*, **2**, No. 6, 66–69.

ATKINSON, E. L. 1913. [A bacterium in the snow.] (*In* HUXLEY, L., *ed. Scott's last expedition.* London, Smith, Elder & Co., **1**, 269.)

BABBOTT, F. L. 1963. Aspects of Arctic epidemiology. (*In* VIERECK, E. G., *ed. Proceedings of symposia on Arctic biology and medicine. III.* Fort Wainwright, Alaska, Arctic Aeromedical Laboratory, 25–45.)

BOBROV, N. I. 1963. Changes in the nasal mucous membrane during cold adaptation in the north. *Gig. Sanit.*, **28**, No. 1, 97–99.

BRODY, J. A. 1965. Lower respiratory illness among Alaskan Eskimo children. *Archs envir. Hlth*, **11**, No. 5, 620–23.

BROWN, P., GAJDUSEK, D. C. *and* J. A. MORRIS. 1966. Epidemic A2 influenza in isolated Pacific island populations without pre-epidemic antibody to influenza virus types A and B, and the discovery of other still unexposed populations. *Am. J. Epidem.*, **83**, No. 1, 176–88.

BUCKLAND, F. E. *and* D. A. J. TYRRELL. 1962. Loss of infectivity on drying various viruses. *Nature, Lond.*, **195**, No. 4846, 1063–64.

BUDD, G. M. 1962. A polio-like illness in Antarctica. *Med. J. Aust.*, **49**, No. 1, 482–86.

————. 1964. General acclimatization to cold in men studied before, during, and after a year in Antarctica. *A.N.A.R.E. Rep.*, Ser. B, **4**, No. 70, 84 pp.

BUTLER, E. *and* B. R. HERD. 1964. Human enteric pathogens in dogs in central Alaska. *Tech. Document. Rep., Arct. aeromed. Lab.*, No. 64–10.

CAMERON, A. S. *and* B. W. MOORE. 1968. The epidemiology of respiratory infection in an isolated Antarctic community. *J. Hyg., Camb.*, **66**, No. 3, 427–37.

CHARCOT, J.-B. 1906. *Le "Français" au pôle sud. Journal de l'Expédition Antarctique Française, 1903–1905.* Paris, Ernest Flammarion.

CHEVERTON, R. L. 1937. An influenza epidemic in the Falkland Islands. *Br. med. J.*, **1**, No. 3967, 135–37.

CLACKE, N. A. *and* S. L. CHANG. 1959. Enteric viruses in water. *J. Am. Wat. Wks Ass.*, **51**, No. 10, 1299–317.

DARLING, C. A. *and* S. L. SIPLE. 1941. Bacteria of Antarctica. *J. Bact.*, **42**, No. 1, 83–98.

EKELÖF, E. 1908. Bakteriologische Studien während der Schwedischen Südpolar-Expedition, 1901–03. *Wiss. Ergebn. schwed. Südpolarexped.*, Bd. 4, Lief. 7, 1–120.

EKLUND, C. M. *and* C. L. LARSEN. 1959. Outbreak of type 3 poliomyelitis on St. Paul Island, Alaska. *Am. J. Hyg.*, **63**, No. 1, 115–26.

FOG-POULSEN, M. 1958. Maeslingeepidemer i Grønland. *Grønland*, 1958, 210–23.

FOURNELLE, H. J., RADER, V. *and* C. ALLEN. 1959. Seasonal study of enteric infections in Alaskan Eskimos. *Publ. Hlth Rep., Wash.*, **74**, No. 1, 55–59.

GAZERT, H. 1912. Untersuchungen über Meeresbakterien und ihren Einfluss auf den stoffwechsel im meere. *Dt. Südpol.-Exped.*, **8**, 235–96.

GORDON, F. B. 1970. The microflora of Man in confined, controlled environments: review and analysis. (*In* SILVER, I. H., *ed. Aerobiology. Proceedings of the third international symposium, University of Sussex, 1969.* London, Academic Press. 167–90.)

GORDON, J. E. *and* F. L. BABBOTT. 1959. Acute intestinal infection in Alaska. *Publ. Hlth Rep., Wash.*, **74**, No. 1, 49–54.

———., FREUND, E. A., BROWN, E. W. *and* F. L. BABBOTT. 1961. Endemic and epidemic diarrhoeal disease in Arctic Greenland. *Am. J. med. Sci.*, **242** (Progress of Medical Science Section), 374–90.

HAMMOND, B. J. *and* D. A. J. TYRRELL. 1971. A mathematical model of common-cold epidemics on Tristan da Cunha. *J. Hyg., Camb.*, **69**, No. 3, 423–33.

HEDBLOM, E. E. 1961. The medical problems encountered in Antarctica. *Milit. Med.*, **126**, No. 11, 818–24.

HEINBECKER, P. *and* E. I. M. IRVINE-JONES. 1928. Susceptibility of Eskimos to the common cold and a study of their natural immunity to diphtheria, scarlet fever and bacterial filtrates. *J. Immun.*, **15**, No. 5, 395–406.

HEMMES, J. H., WINKLER, K. C. *and* S. M. KOOL. 1960. Virus survival as a seasonal factor in influenza and poliomyelitis. *Nature, Lond.*, **188**, No. 4748, 430–31.

HEYERDAHL, T. 1958. *Aku-Aku*. London, Allen and Unwin.

HILDES, J. A., WILT, J. C. *and* W. STACKIW. 1959. Neutralizing viral antibodies in eastern Arctic Eskimos. *Can. J. publ. Hlth*, **50**, No. 4, 148–51.

HOLMES, M. J., ALLEN, T. R., BRADBURNE, A. F. *and* E. J. STOTT. 1971. Studies of respiratory viruses in personnel at an Antarctic base. *J. Hyg., Camb.*, **69**, No. 2, 187–99.

HOPE-SIMPSON, R. E. 1958. Discussion on the common cold. *Practitioner*, **180**, No. 1077, 356–58.

HUTCHEON, N. B. 1960. Humidity in Canadian buildings. *Can. Bldg Dig.*, No. 1, 1–4.

JOHNSON, K. M., BLOOM, H. H., MUFSON, M. A. *and* R. M. CHANOCK. 1962. Acute respiratory disease associated with Coxsackie A21 virus infection. *J. Am. med. Ass.*, **179**, No. 2, 112–19.

LE GROS, P. G. *and* N. L. PROBAY. 1966. Viruses in polar sanitation. A literature review. *Tech. Rep. U.S. nav. civ. engng Lab.*, No. R505, 14 pp.

LIDWELL, O. M., MORGAN, R. W. *and* R. E. O. WILLIAMS. 1965. The epidemiology of the common cold. IV. The effect of weather. *J. Hyg., Camb.*, **63**, No. 3, 427–39.

MCLEAN, A. L. 1919. Bacteriological and other researches. *Scient. Rep., Australas. Antarct. Exped.*, **7**, Pt. 4, 5–130.

MARCUS, S., MIYA, F., PHELPS, L. J. *and* L. SPENCER. 1963. Influence of low ambient temperature on resistance of mice to experimental Coxsackie virus infection. *Tech. Document. Rep. Arct. aeromed. Lab.*, No. 62–56.

MAYNARD, J. E. 1962. Influenza B at Fort Yukon. Report of outbreak, 1961. *Alaska Med.*, March 1962, 1–6.

MELDORF, G. 1907. Epidemiske sygdomme i Grønland; influenza og epidemske katarrhalske affektioner af luftvejs-slimhinderne. *Meddr Grønland*, **33**, No. 7, 129–304.

———. 1912. Epidemske sygdomme i Grønland; influenza og akute affektioner af luftvejsslimhinderne ikke medregmede. *Meddr Grønland*, **50**, No. 6, 187–347.

METCALF, T. G. *and* J. P. SCHMIDT. 1960. Immunologic study on respiratory viruses isolated in Alaska. *Tech. Rep. Arct. aeromed. Lab.*, No. 60–37.

———., SCHMIDT, J. P. *and* R. E. BECKER. 1961. A study of upper respiratory disease of personnel stationed at 18 remote radar sites in Alaska. *Tech. Rep. Arct. aeromed. Lab.*, No. 60–42.

MUDD, S. *and* S. B. GRANT. 1919. Reactions to chilling of the body surface. *J. med. Res.*, **40**, Pt. 174, 53–101.

NAGLER, F. B., VAN ROOYEN, C. E. *and* J. H. STURDY. 1949. An influenza epidemic at Victoria Island, N.W.T., Canada. *Can. J. publ. Hlth*, **40**, No. 11, 457–65.

PANUM, P. L. 1940. Observations made during the epidemic of measles in the Faroe Islands in the year 1846. (*In Dissertations of the American Public Health Association*. New York, Delta Omega Society.)

PASTEUR, L., JOUBERT, J. S. *and* C. CHAMBERLAND. 1878. La théorie des germes et ses applications à la médecine et à la chirurgie. *Bull. Acad. Méd.*, 2ème sér., **7**, 432–53.

PAUL, J. H. *and* H. L. FREESE. 1933. An epidemiological and bacteriological study of the "common cold" in an isolated Arctic community (Spitsbergen). *Am. J. Hyg.*, **17**, No. 3, 517–35.

PAUL, J. R., RIORDAN, J. T. *and* L. M. KRAFT. 1951. Serological epidemiology: antibody patterns in north Alaskan Eskimos. *J. Immun.*, **66**, Pt. 6, 695–713.

PAULS, F. P. 1953. Enteric diseases in Alaska. *Arctic*, **6**, No. 3, 205–12.

PETTIT, H., MUDD, S. *and* D. S. PEPPER. 1936. The Philadelphia and Alaskan strains of influenza virus. Epidemic influenza in Alaska 1935. *J. Am. med. Ass.*, **106**, No. 11, 890–94.

PHILIP, R. N. *and* D. B. LACKMAN. 1962. Observations on the present distribution of A-Swine antibodies among Alaskan natives relative to occurrence of influenza, 1918–19. *Am. J. Hyg.*, **75**, No. 3, 322–34.

———., WEEKS, R. J., REINHARD, K. R., LACKMAN, D. B. *and* C. FRENCH. 1959. Observations on Asian influenza on two Alaskan islands. *Publ. Hlth Rep., Wash.*, **74**, Pt. 8, 737–45.

REINHARD, K. R. 1962. The serologic sequelae of an influenza A2 epidemic modified by intercurrent vaccination in an insular Eskimo population group. *J. Immun.*, **88**, No. 5, 551–55.

SAWYER, R. *and* R. G. SOMMERVILLE. 1966. An outbreak of mycoplasma pneumoniae infection in a nuclear submarine. *J. Am. med. Ass.*, **195**, No. 11, 958–59.

SHIBLI, M., GOOCH, S., LEWIS, H. E. *and* D. A. J. TYRRELL. 1971. Common colds on Tristan da Cunha. *J. Hyg., Camb.*, **69**, No. 2, 255–62.

SIPLE, P. A. 1960. Living on the south polar ice cap. (*In* HORVATH, S. M., *ed. Cold injury. Transactions of the sixth conference. 1958*. Fort Knox. New York, Josiah Macy Jr. Foundation, 89–115.)

SLADEN, W. J. L. 1953. *Bacteriological work in the Antarctic*. Vol. 1. M.D. thesis. University of London, 84 pp. [Unpublished.]

———. 1965. Staphs in the nose and streps in the throats of isolated and semi-isolated Antarctic communities. *J. Hyg., Camb.*, **63**, No. 1, 105–16.

———. *and* R. GOLDSMITH. 1960. Biological and medical research based on U.S.S. *Staten Island*, Antarctic, 1958–9. *Polar Rec.*, **10**, No. 65, 146–48.

STARK, J. E., HEATH, R. B. *and* S. PETO. 1964. A study of the antibodies against para-influenza viruses in children's sera. *Arch. ges. Virusforsch.*, **14**, No. 2, 160–68.

SUTTON, R. N. P. 1965. Minor illness in Trinidad: a longitudinal study. *Trans. R. Soc. trop. med. Hyg.*, **59**, No. 2, 212–20.

TAYLOR, I. M. 1960. Medical experiences at McMurdo Sound. (*In* HORVATH, S. M., *ed. Cold injury. Transactions of the sixth conference*. 1958. Fort Knox. New York, Josiah Macy Jr. Foundation, 117–40.)

TAYLOR-ROBINSON, D. 1965. Respiratory virus antibodies in human sera from different parts of the world. *Bull. Wld Hlth Org.*, **32**, No. 6, 833–47.

———. *and* D. A. J. TYRRELL. 1963. Symposium on problems encountered by the Tristan da Cunha community. 2. Virus disease on Tristan da Cunha. *Trans. R. Soc. trop. med. Hyg.*, **57**, No. 1, 19–22.

TREECE, E. L. *and* J. P. SCHMIDT. 1960. Incidence of U.R.D. among military populations in Alaska. *Tech. Rep. Arct. aeromed. Lab.*, No. 57–44, 3–46.

TSIKLINSKY, E. 1908. Flora microbienne. (*In* Expédition Antarctique Française (1903–05), Sciences naturelles: documents scientifiques, **3**, last section, 1–33.)

TYRRELL, D. A. J. 1967. Serological studies on infections by respiratory viruses of the inhabitants of Tristan da Cunha. *J. Hyg., Camb.*, **65**, No. 3, 327–41.

VETERAN'S ADMINISTRATION. 1953. Influenza on an Arctic Island. *J. Am. med. Ass.*, **152**, No. 4, 349.

WILLIAMS, R. A. 1967. Medical report, Stonington Island (B.A.S. No. M/1967/E), 7 pp. [Unpublished.]

WILSON, O. 1965. Human adaptation to life in Antarctica. (*In* OYE, P. VAN *and* J. VAN MIEGHEM, *ed.* Biogeography and ecology in Antarctica. *Monographiae biol.*, **15**, 690–752.)

WOOLEY, E. J. S. 1963. Symposium on medical problems presented by the Tristan da Cunha community. Discussion. *Trans. R. Soc. trop. med. Hyg.*, **57**, No. 1, 24–25.