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Staphylococci in noses and streptococci in throats of isolated and semi-isolated Antarctic communities*

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Antarctica is one of the few places left on earth where small groups of men are cut off from physical contact with other communities for long periods of time. Despite recent advances in aerial transport to the south-polar regions, it is still possible to study men who are completely isolated for 6–12 months. This provides unusually simplified conditions for the study of the persistence and exchange of micro-organisms of the respiratory tract (Sladen, 1961).

The only previous Antarctic work on the microbiology of the human upper respiratory tract was done by McLean (1919), the medical officer of the Australasian Antarctic Expedition of 1911–14. He cultured bacteria from the nose and throat of four members of the expedition, two of them for 9 consecutive months, to observe whether there was any diminution or disappearance of organisms. The period extended from the time of leaving Tasmania, December 1911, until the end of the first Antarctic winter. He noted that *Staphylococcus albus* persisted throughout the period, but *Staph. aureus*, though present during the first 3 months, did not appear again during the last 6. McLean identified his staphylococci only by morphological and staining characters. Streptococci also showed a tendency to decrease, but no differentiation was made as to species.

This possibility of a decrease in the numbers of potentially pathogenic organisms in the upper respiratory tract of men living for prolonged periods in Antarctica was investigated in more detail at Hope Bay, Antarctic Peninsula, and at Signy Island, South Orkney Islands. These investigations, carried out during 5 years with the Falkland Islands Dependencies Survey (FIDS), now British Antarctic Survey, have been reported briefly at a meeting of the Pathological Society of Great Britain and Ireland, in July 1952. A more detailed study, which included respiratory viruses, was made with the United States Antarctic Research Program (USARP) at the end of the International Geophysical Year (IGY) on the icebreaker U.S.S. *Staten Island* (Sladen & Goldsmith, 1960). Several hundred bacterial cultures from nose and throat were collected when with FIDS and 2660 cultures during the USARP investigations. Work on respiratory viruses and methods for their study in Antarctic communities will be dealt with elsewhere.

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METHODS AND MATERIALS

The subjects

All were young males with the exception of three at Wilkes Station who were over 40 years. They were picked for Antarctic duties because of their physical fitness. Seven men were studied at Hope Bay in 1948–49 for a period of 9 months, during 7 of which they were completely isolated from the outside world. At Signy Island six men were studied for periods of 1–3 years between 1949 and 1952. Three of these men spent over 2 years in Antarctica with periods of complete isolation of 9 and 8 months each and intervening periods of semi-isolation when *the supply ship was visiting the base. Two others spent 9 months, including the* first winter, in complete isolation; the sixth man was isolated for 8 months, which included the second winter.

Three groups of men were studied during the USARP investigations in 1958–59:

(i) Fifty-six volunteers from 232 men aboard the icebreaker U.S.S. *Staten Island* during its Antarctic tour. Two of them were civilian medical officers; one of whom (W.S.) had been a member of the Hope Bay and Signy groups. The study of the group began when they left Seattle, U.S.A., in October 1958, and continued during the voyage via New Zealand, McMurdo, Little America, Hallett, Wilkes and Australia, until the return to U.S.A. in April 1959. The icebreaker was in the Antarctic for over 3 months, and at sea for all but 3 weeks of the remaining period. The longest time in port was 6 days at New Plymouth, New Zealand, in November 1958, and this group could therefore be regarded as a semi-isolated community. Thirty-two of these men were finally swabbed at Point Barrow, Alaska, nearly 10 months after the first swabs were taken.

(ii) Twenty-five men who had been completely isolated at Wilkes for 12 months were studied intensively ashore and aboard *Staten Island* during the first month after the arrival of the ship. During this period an average of nine swabs was taken from the nose and ten from the throat of each man, the first samples being obtained on 24 January 1959 before contact with incoming personnel from the ship.

(iii) Sixteen men from Hallett were examined after 9 months of complete isolation and then a period of semi-isolation during the summer. It was not possible to collect more than one or two swabs from these men before they left the Antarctic.

Collection of material and culture methods

All nose swabs were collected by rotating a sterile cotton-tipped applicator in both anterior nares; throat swabs, by stroking firmly both sides of the fauces in the tonsillar region. Swabs were discarded after inoculation on to the culture or holding media.

Cultures from the nose. The FIDS cultures were made under a variety of conditions, often quite primitive. Control swabs taken aboard the expedition ship before it sailed from England, on both occasions December 1947 and October 1949, were inoculated a few hours later on blood agar plates at the Middlesex Hospital, London. All organisms isolated were dry-frozen by the Rayner (1943) method, for later comparison with the Antarctic material. Direct primary cultures on Loeffler

slopes taken during the voyage south in 1948 were incubated in the ship's engine room. Most of the swabs collected in the Antarctic were inoculated immediately on to slopes of Loeffler medium in small screw-capped vials, incubated at 37° C. in a kerosene-heated incubator for about 24 hr. and stored at 4° C., or lower, as direct primary cultures. When time and conditions permitted, swabs were also streaked directly on to 10% human blood agar plates, subcultured on to Loeffler and stored in the same way. The biology laboratories at Hope Bay and Signy Island needed considerable reconstruction and insulation before they could be used for microbiology. It was necessary to work at night to prevent contamination from other activities, such as cooking, in adjacent rooms. On sledge trips during the Antarctic winter, the culture media had to be thawed before inoculation. A primus cooking stove was used instead of a conventional bunsen burner during inoculation. The screw-capped vials were either handed back to the donors for incubating overnight in their sleeping bags, or suspended for several hours at the peak of the tent, where heat from the primus stove raised the temperature to approximately 37° C. When the expedition returned to England, all the cultures were revived by the addition of 1 ml. of 10% blood-broth to each vial, incubated for 24 hr., and plated on to blood agar.

The USARP investigations were conducted in a small laboratory 10×8 ft. on the main deck of the U.S.S. *Staten Island*. It was not possible to make blood agar plates under these conditions, so, as in much of the FIDS work, each nasal swab was inoculated as a direct primary culture on to a Loeffler slope in a $\frac{1}{4}$ oz. screw-capped vial. As an additional precaution, the same swab was afterwards inoculated on to a mannitol salt agar (Baltimore Biological Laboratories) slope, also in a screw-capped vial. The Loeffler slopes were incubated for 12–18 hr. and the mannitol salt agar for 24 hr., at 37° C., and then stored at 4° C. until the ice-breaker returned to U.S.A. Staphylococci were later isolated from these cultures on blood agar plates in the Clinical Bacteriology Laboratory at Johns Hopkins Hospital.

All staphylococci isolated in pure culture were tested for coagulase properties by the method of Fisk (1940) using pooled human plasma. All staphylococci which proved coagulase positive will be called *Staph. aureus*, those that were coagulase negative, *Staph. albus*. The *Staph. aureus* were bacteriophage typed; those from FIDS men by Dr R. E. O. Williams at the Staphylococcal Reference Laboratory, Colindale, London (Williams & Rippon, 1952), and those from USARP men at Johns Hopkins Hospital with routine test dilution (RTD) using methods recommended by Blair & Carr (1953). Antibiotic-sensitivity tests were done by the disk method (Baltimore Biological Laboratories) and are reported in this paper for penicillin (2 units) only.

Cultures from the throat. All throat cultures collected and recorded at Hope Bay were lost in a fire which destroyed the hut in November 1949 (Fuchs, 1951). At Signy Island, streptococci were isolated either by plating a throat swab directly on to blood agar or by inoculating a Loeffler slope and incubating, storing and reviving in the same way as described for the staphylococci. In the USARP investigations two throat swabs were collected simultaneously at each examination. One was mixed in virus-holding medium for a separate inquiry; the other

in 5 ml. of streptococcal holding medium of trypticase broth containing 15% of glycerine in screw-capped vials. These samples were frozen within 30 min. to minus 60° C. and held in this state until worked on in the following manner at the Johns Hopkins laboratory. The contents of the vials were allowed to thaw at room temperature for about 30 min. and then shaken thoroughly. Two plates (deep pour sheep's blood agar plate and human blood agar streak plate) were then inoculated immediately with one loopful of contents for each plate and the vials promptly refrozen to minus 60° C. Techniques recommended by Schaub *et al.* (1958) for the isolation of β-haemolytic streptococci were used. All pure subcultures were held on Loeffler slopes and sent to Dr Roger Cole, National Institutes of Health, Bethesda, for grouping.

RESULTS

Nasal staphylococci

The staphylococci survived extremely well on the Loeffler slopes no matter how they were collected. *Staph. aureus*, if present, often overgrew other organisms, thus leaving a pure growth. Table 1 summarizes the results of the first year of study

Table 1. *Summary of nasal staphylococci from seven men at Hope Bay, before and during complete isolation in Antarctica*

		Staph. aureus carriers			*Staph. albus* carrier	Insufficient data		
Date	Place and occasion	W. S.	B. J.	S. M.	M. G.	O. B.	J. O.	F. E.
Dec. 1947	England	A1	A3	a	ng	—	a	—
Jan. and Feb. 1948	Aboard ship at sea	A1	A3a	A4	ng	—	—	a
Complete isolation*								
April	Hope Bay, before sledging	a	A3	A4	a	ng	a	A2
June	Hope Bay, after sledging	A2	A3	A4	a	A2a	a	a
July	Hope Bay, before sledging	A3	A3	—	ng	a	—	ng
Aug.	Hope Bay, after sledging	A2	A3	ng	a	ng	A3	ng
Sept.	During 4th sledge journey	A2	—	—	a	—	—	—
Sept. 1948	Hope Bay, after sledging	A2	A3a	ng	a	a	—	—

a = *Staph. albus* isolated; ng = no staphylococci isolated from original culture; — = no swab taken.

A = *Staph. aureus* isolated. Phage patterns: A1 = 3A/3B/3C/51; A2 = 53, or 42B/53/54; A3 = 6, or 6/47, or 47/53; A4 = 29, or 29/79.

* Complete isolation was from 1 March to end September 1948 (7 months).

at Hope Bay. Two men (W. S. and B. J.) and probably a third (S. M.) carried *Staph. aureus*, and one man (M.G.) *Staph. albus*, consistently throughout 6–9 months. There are insufficient data from the other three members of the party, but they carried both *Staph. aureus* and *Staph. albus*, at one time or other. *Staph. aureus* persisted in at least two individuals (W. S. and B. J.) for at least 7 months of Antarctic isolation at Hope Bay. These observations differ from those of McLean (1919), who was unable to isolate *Staph. aureus* from noses after the first 3 months of isolation.

Each *Staph. aureus* carrier kept the same phage type in his nose for a long period of time. This shows well in B. J., who held his for 9 months, and fairly well in the other two subjects. W. S. carried phage type 3A/3B/3C/51 before leaving England in December 1947 and kept this during the voyage out. Sometime between January and June 1948 the phage type changed to a completely different one. W. S.'s first sample of phage type 3A/3B/3C/51, collected in December 1947, was dried independently of the second sample collected at sea in January 1948.

Table 2. *Summary of nasal staphylococci from six men at Signy Island, South Orkney Islands, before, during and after complete isolation in Antarctica*

Date		Place and occasion	*Staph. aureus* and *Staph. albus* carriers					
			W. S.	J. C.	R. W.	E. S.	J. B.	D. D.
Oct. 1949		Before leaving England	a	A5a	ng	A7	.	–
Sept. 1950	Complete isolation	During sledge journey	A2	A5a	A6	–	.	–
Sept.		Signy, after sledging	A2	A5	ng	A7	.	A2a
Nov.		Signy, before relief ship	A2a	A5 & A2	A6	A7a	.	a
Dec.	Semi-isolation	Signy, after relief ship	–	A5	–	A7	A8	–
Jan. 1951		Signy, before 2nd ship	A2	A5a	ng	–	A8a	–
April		Signy, during 3rd ship	A2	A5	A6	–	A8	–
Dec.		England	A2*	–	–	–	–	–
Mar. 1952		England	A2	–	–	–	–	–
Jan.–May		Falkland Islands	–	A5†	a†	a†	A9‡	A10‡
May–July		England	A2	A5	A6a	–	–	A10
Sept. 1952		England	A2	A5a	a	–	–	–

a = *Staph. albus* isolated; ng = no staph. isolated from original culture; – = no swab taken.
A = *Staph. aureus* isolated. Phage patterns; A2 = 53; A5 = 3C or 55 or 3C/55; A6 = 3A; A7 = 29 or 29/75 or 29/47/75; A8 = 42B; A9 = 42E/47; A10 = 52.
Men returned to civilization after: * = 16 months in Antarctica with 9 months complete isolation; † = 27 months in Antarctica with two winter periods of 9 and 8 months each of complete isolation; ‡ = 12 months in Antarctica with 8 or 9 months complete isolation.

The second year of work at Signy Island is summarized in Table 2. All six men were *Staph. aureus* and *Staph. albus* carriers. J. C. carried his *Staph. aureus* phage type consistently throughout 12 months of complete and semi-isolation in Antarctica and still carried it 4 months after returning to Britain after completing a second year in the Antarctic. R. W. was nearly as consistent a carrier as J. C. The staphylococci from W. S.'s nose, continuing from Table 1, are followed for a total of nearly 5 years. The only change in phage type from June 1948 to September 1952 was recorded in July 1948 when he was carrying the same type (6/47) as found in B. J.'s nose. However, on this date W. S.'s usual type (53) was isolated from his throat. It can therefore be concluded with reasonable certainty that W. S. carried one phage type of *Staph. aureus* consistently for over 4 years.

Staphylococci were grown from 773 swabs collected from volunteers aboard U.S.S. *Staten Island*, *Staph. aureus* being grown from 415 swabs and *Staph. albus* from 581. All fifty-six volunteers (100 %) carried *Staph. albus* at one time or other and over half of them persistently throughout the voyage. From the twenty-five

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Wilkes men returning from 12 months complete isolation, staphylococci were grown from 223 swabs, 200 of which grew *Staph. albus* and only fifty-seven *Staph. aureus*. Like the *Staten Island* community, the Wilkes men showed a 100 % carrier rate of *Staph. albus*, but more of them (76 %) were persistent carriers.

Table 3. Staphylococcus aureus *from noses of men on U.S.S.* Staten Island *and at two Antarctic stations after isolation; compared with data from medical students*

	Total men swabbed	Total swabs growing *Staph. aureus* and/or *albus*	Av. no. swabs per person	Av. period (weeks) followed	*Staph. aureus* carriers: Pers.*	Int.* and occas.	Total carriers	Total swabs growing *Staph. aureus*	Total *Staph. aureus* penicillin resistant
U.S.S. *Staten Island* volunteers	56	773	14	33	8 (14 %)	39 (70 %)	47 (84 %)	415	106 (26 %)
Wilkes	25	223	9	4	4 (16 %)	5 (20 %)	9 (36 %)	57	2 (4 %)
Hallett	16	27	2	1	Not followed for long enough		6 (38 %)	8	1
Medical students†	520	—	—	37	(24 %)	(57 %)	(81 %)	503	(24 %)

* Persistent carriers: number of men from whom *Staph. aureus* was isolated from at least 90 % of their swabs. Occasional carriers: number of men from whom *Staph. aureus* was isolated from less than 10 % of their swabs. Intermittent carriers: between persistent and occasional carriers.

† From Gould & McKillop (1954*a*, *b*).

Staph. aureus carriage is summarized in Table 3. In accordance with Gould & McKillop (1954*a*), these carriers have been divided into three types.

(i) *Occasional carriers* from whom *Staph. aureus* was isolated from less than 10 % of the swabs in any one individual.

(ii) *Persistent carriers* from whom the organism was isolated from 90 % or more of the swabs in any one individual.

(iii) *Intermittent carriers* showed a carrier rate of between 10 and 90 %. Gould & McKillop stressed that persistent and intermittent carriers usually held the same phage type, whereas the occasional carriers did not. Our experience (Sladen *et al.* in preparation) does not fully support this, so for the present it is best to describe the carrier rates on a percentage basis only.

There are some interesting contrasts between the ship's population and the Wilkes men. Forty-seven (84 %) out of fifty-six *Staten Island* men carried *Staph. aureus* on one occasion or more throughout the voyage, whereas only 36 % of the Wilkes men carried them during the month of intensive swabbing after 12 months of complete isolation. Persistent carriers were about the same in both communities (14 % for *Staten Island* and 16 % for Wilkes), but the combined intermittent and occasional carriers were much reduced in the Wilkes group (20 %, in contrast to 70 % aboard *Staten Island*). Sixteen men from Hallett, a group of men who had been mixing a little with a few personnel from relief planes during summer

but who were essentially still isolated after 9 months of complete isolation, had but six individuals (38 %) from whom *Staph. aureus* was cultured, much the same total carrier rate as in the Wilkes men.

Bacteriophage typing showed that over half of the persistent and intermittent carriers aboard the *Staten Island* (22 out of 40), and all six of the Wilkes men, were consistently carrying their own strain within the broad classification of the groups. The typing is now being repeated with concentrated bacteriophage (1000 × RTD).

From a total of 415 swabs which grew *Staph. aureus* in the *Staten Island* volunteers there were isolated 106 (26 %) resistant to penicillin, whereas only two (4 %) out of fifty-seven isolated from the Wilkes men were resistant. These two strains from Wilkes were from two individuals who were occasional carriers, so from none of the four persistent carriers could resistant *Staph. aureus* be isolated. Five out of the eight persistent carriers aboard *Staten Island* carried resistant strains, though only two of these carried them consistently. One of these two men (W. S.) who in 1947–52 had been a penicillin-sensitive *Staph. aureus* carrier was now a persistent resistant carrier. More will be written about his nose, which has been studied for 15 years.

Table 4. *Haemolytic streptococci from throats of men on U.S.S.* Staten Island *and at Wilkes Station*

	Total men swabbed	Swabs: Total	Swabs: Av. per man	β-Haemolytic streptococcal carriers*: All groups	β-Haemolytic streptococcal carriers*: Group A	β-Haemolytic streptococci isolated: All groups	β-Haemolytic streptococci isolated: Group A
Staten Island	56	681	12	20 (36 %)	8 (14 %)	129 (19 %)	47 (7 %)
Wilkes	25	251	10	4 (16 %)	1 (4 %)	5 (2 %)	1 (0·4 %)

* One or more swabs positive per person.

Throat streptococci

McLean (1919) did not differentiate between the α-haemolytic and β-haemolytic streptococci. He reported that streptococci diminished during Antarctic isolation.

α-Haemolytic streptococci. FIDS and USARP collections showed that these streptococci could be cultured from the throats of all personnel before, during and after Antarctic isolation and semi-isolation.

β-Haemolytic streptococci. No attempt was made to culture these organisms during the FIDS investigations. However, good results were obtained from the frozen material collected with USARP (Table 4). Of fifty-six *Staten Island* volunteers there were twenty (36 %) from whom β-haemolytic streptococci were grown on one occasion or more, five of these individuals being consistent carriers (75 % or more of the swabs were positive) throughout the voyage. Group A streptococci were grown from eight (14 %) men and two of these were consistent carriers.

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From 681 swabs (averaging 12 swabs per man) collected, there were grown 129 (19%) β-haemolytic streptococci, of which 47 (7%) were group A.

There was a marked difference in the Wilkes men, from whom 251 swabs were taken (averaging 10 per man). Only five (2%) of the swabs grew β-haemolytic streptococci, and only 1 (0·4% of the 251 swabs) grew a group A organism. These five positive swabs were from 4 (16%) of the 25 men. No β-haemolytic streptococci were found on 24 January, the day the men broke their 12 months of Antarctic isolation. Two were grown from swabs taken on 27 January (one group C and another of an unidentified group), one from swabs taken on 8 February (group C) and two from swabs taken on 16 February (groups A and B). There was also an appreciable difference between the number of colonies grown from the four Wilkes men and from the twenty *Staten Island* volunteers. The two consistent carriers of group A on the ship gave colony counts of usually between 10 and 100, occasionally over 100, while the Wilkes cultures, collected, stored and revived in the same way, grew single colonies per plate, or at most seven. Moreover, three of the five positive Wilkes cultures were grown from swabs collected 2 weeks or more after isolation had been broken, and at a time when the men were freely mixing with the men of the icebreaker. Thus, from this small Antarctic Station there seems to be good evidence of a greatly reduced carrier rate, probably amounting to total absence of β-haemolytic streptococci, and certainly of group A streptococci, in men returning after complete isolation from the outside world.

DISCUSSION

Nasal staphylococci

The FIDS results demonstrate, contrary to McLean's (1919) findings, that the potential pathogen *Staph. aureus* can be carried in the anterior nares throughout Antarctic isolation and, in certain individuals, with remarkable persistency. Though the number of swabs collected at Hope Bay and Signy was small, we can be reasonably certain that three (W. S., B. J. and J. C.) out of twelve men were persistent carriers. FIDS men were isolated as a community, but were also living in extremely close contact with each other. A persistent *Staph. aureus* carrier (W. S.) shared a tent with a persistent *Staph. albus* carrier (M. G.) at Hope Bay for 1 month of sledging. W. S. also shared tents with *Staph. aureus* carriers J. C. and R. W. during Signy sledge journeys, yet there was no exchange of strains among them. When at base there were four examples of W. S.'s strain and one of B. J.'s strain being picked up in the anterior nares of other men at Hope Bay and Signy, but they were not held more than once. It is interesting to note that in November 1950 J. C. held W. S.'s strain (76/77) as well as his own (3C). However, 76/77 was subcultured from the original blood agar plate as a single colony, whereas 3C was picked from a different-looking colony growing profusely on the same plate. We can conclude, therefore, that the true inhabitant of J. C.'s nose was a *Staph. aureus* of phage type 3C which he held consistently during $2\frac{1}{4}$ years in Antarctica and for another 9 months back in civilization. This would fit Gould and McKillop's (1954*a*) definition of a persistent carrier, but W. S. would not. W. S.

changed from a group I phage type (3A/3B/3C/51) to a group III phage type (53) and then held the latter consistently throughout two winters of complete isolation and for varying periods back in civilization, for a total of nearly 4 years. Six years later, when aboard U.S.S. *Staten Island*, he changed his phage type at least once (Sladen, in preparation). Yet all of the sixteen swabs taken during this voyage grew profuse colonies of typical golden-yellow coagulase-positive *Staph. aureus*. It seems that, the longer an individual is followed, the more chance there is of recording a change in the phage patterns of his commensal staphylococci. I therefore believe that a persistent *Staph. aureus* carrier should be defined as one who carries this potential pathogen in his anterior nares for 90 % or more of the swabs, regardless of occasional changes of phage type.

Table 3 points to some interesting similarities and contrasts between the *Staten Island* and Antarctic communities when compared with medical students studied by Gould & McKillop (1954*a*). The total carrier rate was about the same for the *Staten Island* men as it was for the Scottish medical students (84 and 81 % respectively) but it was appreciably lower (36 and 38 %) in the Wilkes and Hallett men after Antarctic isolation. The period for which these different groups were followed varied, and it could be argued that 4 weeks with an average of nine swabs per man for Wilkes Station was hardly sufficient to obtain a true comparison with the *Staten Island* and medical student groups. However, data from twenty-two staff members of an English hospital whose noses were swabbed on 8 consecutive weeks gave a carrier rate of 82 % (Williams, 1946), and 104 Australian nurses followed for 16 weeks, but with only four swabs taken per person, also gave an equally high total carrier rate of 85 % (Rountree & Barbour, 1951). Thus the total carrier rate of the volunteers aboard the icebreaker differs little from that of other urban groups followed, whereas there appears to be a marked decrease among men who have been isolated for a long period in Antarctica.

This low carrier rate is of great interest medically, because recent surveys of adults in hospitals and clinics have shown opposite trends. For example, within 5 weeks of trainee nurses entering hospital wards, the nasal carrier rate, based on two examinations per person, rose from 53 to 71 %, and the rate of penicillin resistance from 4 to 32 % (Rountree & Barbour, 1951). Williams *et al.* (1959) give similar figures from patients during their stay in surgical wards. Of 602 patients swabbed within a few days of admission, 38 % carried *Staph. aureus* and 13 % carried penicillin-resistant strains. Of twenty-five swabbed after 8 weeks in the wards, 68 % were carriers and 52 % had resistant strains.

The FIDS results, based on small numbers followed for several years, provide strong evidence that persistent carriers of *Staph. aureus* remained so, before, during and after Antarctic isolation. Unfortunately, it was not possible to collect swabs from the Wilkes and Hallett men before and during their isolation. However, the persistent carrier rate remained much the same in these men after isolation as it did in the *Staten Island* men and the Scottish medical students (Table 3). It thus appears that the reduction in total carrier rate was due to a decrease in the intermittent and occasional carriers, and not in the persistent carriers.

Throat streptococci

During the voyage of U.S.S. *Staten Island* there were two distinct epidemics of upper respiratory infection (URI), and other spasmodic occurrences. None of these could be clinically attributed to acute streptococcal infection, nor could bacteriological findings from the eight group A carriers be correlated. In fact four of these men had no URI's at all, the others having one typical 'common cold' each, two with initial mild sore throats, two without.

The carrier rate of β-haemolytic streptococci and, when available, of the group A streptococci was much the same among the *Staten Island* volunteers as found in adults by other workers (e.g. Straker, Hill & Lovell, 1939; Zanen, Gaynor & van Toorn, 1959; Myers & Koshy, 1961). However, during the past three decades there have been no studies on isolated or semi-isolated communities. Working in the semi-isolated tropical Virgin Islands, Milam & Smillie (1931) reported 13% β-haemolytic streptococci and 5% group A streptococci from a total of 694 cultures, while Paul & Freese (1933) found that only 0·3% of the organisms isolated from a Spitzbergen community of Norwegians were β-haemolytic streptococci. Unfortunately, these and other papers published during this period give no precise data for the carriage of β-haemolytic streptococci throughout and immediately after isolation, so there is nothing to compare with the Wilkes results.

During a 5-year study of school children, Quinn & Martin (1961) showed that the carrier rates and serological types of group A streptococci changed from school to school and from year to year. They suggest that these changes involve complex mechanisms including type-specific immunity of the host, meteorological conditions and interactions within the community. Antarctic communities are characteristically free from acute URI's during their periods of complete isolation. The absence of group A streptococci in the throats of men returning from 12 months isolation suggests that these organisms disappear from the community despite the presence of susceptible hosts. Men cannot be reinfected until they return to civilization and mix with carriers. The same is possibly true for the respiratory virus agents.

What community size can maintain these potentially pathogenic agents? What time must elapse in a small isolated community before the agents disappear from the upper respiratory tract? Does the polar climate have any effect on the disappearance of β-haemolytic streptococci and the reduction of *Staph. aureus* carriers, or is this essentially the result of the isolation of a small community? How do the organisms regain a footing in the nose and throat? For answers to these and other epidemiological questions it will be necessary to study groups before, during and after isolation in several places, and to have better facilities for microbiological research.

SUMMARY

The Antarctic provides unusually simplified conditions for the study of the persistence and exchange of micro-organisms of the upper respiratory tract. The work reported here was done while the author was in the Falkland Islands Dependencies Survey and the United States Antarctic Research Program.

Staph. aureus and *Staph. albus* persisted in the noses, and α-haemolytic streptococci in the throats of men throughout long periods of isolation and semi-isolation in Antarctica.

On the whole, men kept their own strains (phage types) of *Staph. aureus* despite living in very close contact with each other.

Persistent carriers of *Staph. aureus* (90 % or more positive swabs per individual) continued to carry this organism for as long as 2 years in Antarctica. Data from men at Wilkes and Hallett IGY Stations indicated that there was a decrease in the intermittent and occasional carrier rates, resulting in a much lower total carrier rate after 12 months Antarctic isolation.

Evidence is presented to suggest that β-haemolytic streptococci had disappeared from throats after 12 months of isolation. It is thought that the absence of upper respiratory infections in these communities is due to absence of the bacterial or viral agents.

There is an urgent need for further work on the carriage of micro-organisms in the present unique epidemiological conditions of the Antarctic, and for better laboratory facilities there.

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REFERENCES

Blair, J. E. & Carr, M. (1953). The bacteriophage typing of staphylococci. *J. infect. Dis.* **93**, 1.

Fisk, A. (1940). The technique of the coagulase test for staphylococci. *Brit. J. exp. Path.* **21**, 311.

Fuchs, V. E. (1951). The Falkland Islands Dependencies Survey, 1947–50. *Polar Rec.* **6**, 15.

Gould, J. C. & McKillop, E. J. (1954*a*). The carriage of *Staphylococcus pyogenes* var. *aureus* in the human nose. *J. Hyg., Camb.*, **52**, 304.

Gould, J. C. & McKillop, E. J. (1954*b*). *Staphylococcus pyogenes:* the antibiotic sensitivity of strains isolated from human carriers. *J. Hyg., Camb.*, **52**, 486.

McLean, A. L. (1919). Bacteriological and other researches. *Sci. Rep. Aust. antarct. Exped.* **7** (part 4), 127.

Milam, D. F. & Smillie, W. G. (1931). A bacteriological study of 'colds' on an isolated tropical island (St John, United States Virgin Islands, West Indies). *J. exp. Med.* **53**, 733.

Myers, R. M. & Koshy, G. (1961). Beta-hemolytic streptococci in survey throat cultures in an Indian population. *Amer. J. publ. Hlth*, **51**, 1872.

Paul, J. H. & Freese, H. L. (1933). An epidemiological and bacteriological study of the 'common cold' in an isolated Arctic community (Spitzbergen). *Amer. J. Hyg.* **17**, 517.

Quinn, R. W. & Martin, M. P. (1961). The natural occurrence of hemolytic streptococci in school children. A five-year study. *Amer. J. Hyg.* **73**, 193.

Rayner, A. G. (1943). A simple method for the preservation of cultures and sera by drying. *J. Path. Bact.* **55**, 373.

ROUNTREE, P. M. & BARBOUR, R. G. H. (1951). Nasal carrier rates of *Staphylococcus pyogenes* in hospital nurses. *J. Path. Bact.* **63**, 313.

SCHAUB, I. G., MAZEIKA, I., LEE, R., DUNN, M. T., LACHAINE, R. & Price, W. H. (1958). Ecologic studies of rheumatic fever and rheumatic heart disease. 1. Procedure for isolating beta hemolytic streptococci. *Amer. J. Hyg.* **67**, 46.

SLADEN, W. J. L. (1961). Medical Microbiology. In *Science in Antarctica. Part I: The Life Sciences in Antarctica*, p. 151. Publication 839. National Academy of Sciences, National Research Council. Washington, D.C.

SLADEN, W. J. L. & GOLDSMITH, R. (1960). Biological and medical research based on U.S.S. *Staten Island*, Antarctica, 1958–59. *Polar Rec.* **10**, 146.

STRAKER, E., HILL, A. B. & LOVELL, R. (1939). A study of the nasopharyngeal bacterial flora of different groups of persons observed in London and south-east England during the years 1930 to 1937, together with some observations on the occurrence of *H. influenzae* in the trachea. *Rep. publ. Hlth med. Subj. Lond.* no. 90, p. 7.

WILLIAMS, R. E. O. (1946). Skin and nose carriage of bacteriophage types of *Staph. aureus*. *J. Path. Bact.* **58**, 259.

WILLIAMS, R. E. O. & RIPPON, J. E. (1952). Bacteriophage typing of *Staphylococcus aureus*. *J. Hyg., Camb.*, **50**, 320.

WILLIAMS, R. E. O., JEVONS, M. P., SHOOTER, R. A., HUNTER, C. J. W., GIRLING, J. A., GRIFFITHS, J. D. & TAYLOR, G. W. (1959). Nasal staphylococci and sepsis in hospital patients. *Brit. med. J.* ii, 658.

ZANEN, H. C., GAYNOR, S. & VAN TOORN, M. J. (1959). A continuous study of hemolytic streptococci in the throats of normal children, adults and aged men. *Amer. J. Hyg.* **69**, 265.