Medical History (2025), 1–22
doi:10.1017/mdh.2024.39

CAMBRIDGE UNIVERSITY PRESS

ARTICLE

Germs, infections, and the erratic 'natural laboratory' of Antarctica: from Operation Snuffles to the Killer Kleenex

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Abstract

Historians have written copiously about the shift to 'germ theories' of disease around the turn of the twentieth century, but in these accounts an entire continent has been left out: Antarctica. This article begins to rebalance our historiography by bringing cold climates back into the story of environmental medicine and germ theory. It suggests three periods of Antarctic (human) microbial research – heroic sampling, systematic studies, and viral space analogue – and examines underlying ideas about 'purity' and infection, the realities of fieldwork, and the use of models in biomedicine. It reveals Antarctica not as an isolated space but as a deeply complex, international, well-networked node in global science ranging from the first international consensus on pandemic-naming through to space flight.

Keywords: Antarctica; Exploration; Field Work; Microbiology; Outer Space; Infectious Diseases

Through the end of the nineteenth century the creators and consumers of Western medicine gradually accepted the idea that infectious diseases were distinct entities caused by the ingestion of microorganisms.[1] Generally, these were bacteria or viruses that we breathed in, inadvertently ate or drank, or penetrated our bodies through wounds; in the case of the more politicised class of 'tropical diseases' sometimes more complex infections involved secondary organisms, including mosquitos and worms.[2] This shift in medical thinking first promised new preventative medicines in the form of vaccines and then, in the early twentieth century, the potential of cures as the first human-designed 'magic bullets' targeted specific microorganisms. Yet this 'new' germ theory and its consequences sustained older medical beliefs, including the fear of tainted air and the parallel passion for fresh air, as well as long-standing practices of exclusion and containment such as using mosquito nets or imposing forms of quarantine.[3]

Historians have written copiously about this moment, about the many spaces in which this revolution did (or did not) take place, from the metropolitan laboratory and its 'placeless' knowledge bolstered by technological innovations in visualisation and print, through to the microbially surveyed field site with

[1]Michael Worboys, *Spreading Germs: Disease Theories and Medical Practice in Britain, 1865-1900* (Cambridge: Cambridge University Press, 2000); Nancy Tomes, *The Gospel of Germs: Men, Women, and the Microbe in American Life* (Cambridge, MA: Harvard University Press, 1999).

[2]David Arnold (ed.), *Warm Climates and Western Medicine: The Emergence of Tropical Medicine, 1500-1900* (Amsterdam: Rodophi, 1996); Warwick Anderson, 'Immunities of Empire: Race, Disease, and the New Tropical Medicine, 1900-1920', *Bulletin of the History of Medicine*, 70, 1 (1996), 94–118.

[3]Rohan Deb Roy, *Malarial Subjects: Empire, Medicine and Nonhumans in British India, 1820-1909* Cambridge: Cambridge University Press, 2017); Alison Bashford, Alison (ed.), *Quarantine: Local and Global Histories* (Basingstoke, Hampshire: Palgrave Macmillan, 2016).

its crucial local workers, and the burgeoning of Pasteur Institutes and similar internationally connected scientific sites.[4] But despite all this work, *an entire continent* has been left out of the story: Antarctica. Antarctica makes obvious a fact that historians have begun to demonstrate: environmental medicine did not disappear with germ theory. While our historiography remains more focused on heat and the tropical regions, it is a fact that in the polar regions, the biggest threats to human survival are still environmental: temperature, landscape, lack of resources, and now climate change.[5] In Antarctica the very microbial 'purity' of the continent meant that scientists claimed it as a perfect 'natural laboratory' for studies on human infection, the action of microbes, and the potential of cold to both protect and harm our natural defences against disease.

This article begins to rebalance our historiography by bringing cold climates back into the story of environmental medicine and germ theory. It suggests three periods of Antarctic (human) microbial research, as well as exploring underlying ideas about 'purity' and infection, about the realities and pitfalls of fieldwork and the use of model experiments in biomedicine, and reveals Antarctica not as an isolated space but as a deeply complex, international, well-networked node in global science ranging from the first international consensus on pandemic-naming through to space flight. In the initial 'heroic age of sampling' the assumption persisted that Antarctica was a microbially clean environment, actively healthy for the human body in terms of infection. Even as the samples taken on the first expeditions to the continent demonstrated bacteria and fungi in the ice and water of Antarctica (and in its animal life) these were framed as *imported*, rather than autochthonous life. Uniquely, without an indigenous population to blame as a store of microbial life or a risk to the invading European bodies, it was the bodies of white explorers which became the site of threatening infection, as the healthy environment of the Antarctic hut could be disrupted by the arrival of a relief ship, or even a bundle of clothing, causing an imported disease to rage through the isolated community. As a medical officer to the Falkland Islands Dependencies Survey (FIDS) wrote as late as 1960 '[a] popular myth states that sepsis does not occur in the Antarctic. It may not occur while living or journeying in the open, but it certainly does occur in base huts, *where man is accompanied by his own bacterial flora* [my emphasis]'.[6]

As the initial anecdotal accounts of disease in the far south, and limited microbial sampling of skin, noses, and faeces were unable to fully explain phenomena such as the 'burn out' of diseases in isolation, or the 'bounce back' infections experienced by healthy returning explorers, a second phase of systematic studies was established. A larger population in the Antarctic from the 1950s facilitated substantial microbial studies, and scientists repeatedly referred to the continent as a 'natural laboratory' for understanding the normal behaviour of infections, as well as aspects of the human immune response, facilitated by a tightly observable and controllable human population. The stories in this paper will give the lie to this claim, as it became very clear that Antarctica was not a controlled or controllable space. As well as failures of experiments, hut fires, lost samples, and the apparently impossible task of successfully identifying viruses collected in the far south, Antarctica also emerged as an incredibly complex field space – not of a single human experience but dozens of subtly different patterns of stress, infection, cold exposure and symptoms. Luckily for Antarctic researchers, as the continent became perhaps less representative of the normal world, it became more representative of another one: outer space. Consequently, through the third period of Antarctic microbial research, the National Space and Aeronautic Administration (NASA) became a significant supporter of ongoing infection research.

Through the three phases of Antarctic work – heroic sampling, natural laboratory, and experimental space analogue – it is evident that Antarctica was not an isolated or peripheral place, but an explicitly

[4]Christoph Gradmann *Laboratory Disease: Robert Koch's Medical Bacteriology* (Baltimore, MD: Johns Hopkins University Press, 2009); Christopher Hamlin, 'Bacteriology as a Cultural System: Analysis and Its Discontents', *History of Science*, 49, 3 (2011), 269–98; Thomas Schlich, 'Linking Cause and Disease in the Laboratory: Robert Koch's Method of Superimposing Visual and Functional Representations of Bacteria', *History and Philosophy of the Life Sciences*, 22 (2000): 43–58.

[5]Cf. the lack of cold climates in this special issue: Guillaume Linte and Paul-Arthur Tortosa '"The Most Unhealthy Spots in the World": Thinking, Dwelling In, and Shaping Pathogenic Environments', *Centaurus* 65, 1 (2023): 9–30.

[6]John Nelson Norman 'Man in the Antarctic' (unpublished PhD thesis: University of Glasgow, 1960).

https://doi.org/10.1017/mdh.2024.39 Published online by Cambridge University Press

international, interdisciplinary space for science, whose workers learned from and contributed to the cutting edge of biomedical research. It also emphasises the role of Australian researchers in particular – whose contributions to microbiological history are not well considered in the traditional stories of penicillin, etc.[7] Antarctica is revealed as an excellent case study to understand global science and as a space to consider the *agency* of environments. Antarctica itself intervened directly in the processes of experimentation, as scientists over the course of a century experienced resistance and frustration as reagents froze, blood samples were lost at sea, and human and animal subjects rebelled against experimental protocols. All these themes will be explored in the paper below, which will proceed chronologically through the three periods of Antarctic human microbiology, as well as considering a surprising absence – studies and fears about antimicrobial resistance.

Heroic sampling

The start of the 'Heroic Age' of Antarctic exploration at the very end of the nineteenth century overlaps with the end of what is sometimes termed the 'Golden Age' of microbiology.[8] Although there were suspicions of a southern continent and some exceptional journeys were made into the Antarctic Ocean in the early modern period, it was not the focus of sustained scientific and exploratory interest until the later nineteenth century. Likewise, although there was at least one sighting of a bacterium in the seventeenth century, it was not until the nineteenth that these organisms gained the name 'bacteria' or that microscopical technology became reliable – and inexpensive enough – for the routine investigation of life invisible to the naked eye.[9] In the very last years of the nineteenth century, the 'Heroic Age' in the far south was inaugurated by the first overwintering teams, which coincided with the discovery of viruses in the 1890s. By the time sustained land-based exploration was taking place on the Antarctic continent in the first decades of the twentieth century, both bacteria and viruses were confirmed as causative agents of disease in specific ways.[10] Likewise, the principle had been established that vaccines could be human-made to protect against infectious diseases, and the first human-designed drugs specifically targeting disease-causing microorganisms were being created in laboratories.[11] This 'heroic' age of microbiology also included dramatic technological innovations making it feasible to collect, visualise, and culture microbes even in the unpromising conditions of a ship berth or Antarctic hut.[12]

Many authors have pointed to the role of science in colonial projects of exploration, and this paper is not the appropriate place to rehash arguments about whether these were covers for imperial aims, sources of national pride, or a genuine desire for knowledge; the reality is that sampling for micro-organisms formed part of the official activity of Antarctic expeditions from the start of the Heroic Age, and almost every expedition made some attempt at microbiological work.[13] While ocean-bound expeditions sometimes carried a zoologist or botanist who included the sampling of micro- as well as macroorganisms in their remit, it was more common for such work to be conducted by a medical doctor, either the official medical officer or a 'spare' medically trained expedition member. As Guly points out in his extensive survey of this early Antarctic bacteriology, such medically trained explorers, at least in the

[7]Robert Bud, *Penicillin: Triumph and Tragedy* (Oxford: Oxford University Press, 2008).

[8]C. Gradmann, 'Medical Bacteriology: Microbes and Disease, 1870-2000' in M. Jackson (ed), *The Routledge History of Disease* (Boston: Routledge, 2017), 378–401.

[9]Steere-Williams, Jacob, 'Seeing Germs, Selling Ferms: Translating Anglo-American Bacteriology', *Interdisciplinary Science Reviews*, 48, 2 (2023) 181–201.

[10]K, Codell Carter, 'Koch's Postulates in Relation to the Work of Jacob Henle and Edwin Klebs', *Medical History* 29, 4 (1985): 353–74.

[11]John E. Lesch, *The First Miracle Drugs: How the Sulfa Drugs Transformed Medicine* (Oxford: Oxford University Press, 2007).

[12]Hamlin 'Bacteriology as a Cultural System', *op. cit.* (note 4). For science and imperialism at the poles, see Sollie Finn, 'Polar Politics: Old Games in New Territories, or New Patterns in Political Development?', *International Journal* 49 (1984): 695–720.

[13]H.R. Guly, 'Bacteriology during the Expeditions of the Heroic Age of Antarctic Exploration', *Polar Record* 49, 4 (2013): 321–7.

https://doi.org/10.1017/mdh.2024.39 Published online by Cambridge University Press

early years of the twentieth century, 'would have all been taught bacteriological techniques as students and may have been taught the bacteriological examination of water and soil'.[14] Prior to the formation of microbiology as a specialism with its own career path, the sampling and testing of substances would have been seen by a doctor as 'an extension to their medical role and not as a separate branch of science'.[15]

Although much scientific work in the Antarctic has been conducted by non-specialists, this should never be read as indicative of amateur or non-expert work. The early part-time microbiologists often had guidance and training from Europe's leading scholars and 'heroes' of bacteriology. When Dr Jean-Baptiste-Étienne-August Charcot led his first Antarctic expedition in 1903–05 his bacteriological surveys were designed on the instruction of Emil Roux, the director of the Pasteur Institute and a key figure in the development of vaccination and immunology.[16] Charcot's studies of oceanic bacteria are particularly interesting because much of the microbial visualisation and analysis was done by a woman, Mlle Tsiklinsky, Pasteur Institute-trained, and Russia's first female professor.[17] (Women remain otherwise largely invisible in Antarctic microbiology due to their deliberate exclusion from the continent).[18] These studies were part of a practice of sampling and identification of environmental bacteria which was already well established by 1903 as a public health practice as well as in natural history, and Charcot's studies had five earlier Antarctic precedents, the first being on the Belgian expedition of 1897–99.[19] Sampling of environmental bacteria continued through the twentieth century, looking at Antarctic air, water and fauna.[20] In this paper, I am more interested in the bacteria that live on human bodies and sometimes cause human disease, and the first person to consider this category of microbial work was Dr Reginald Koettlitz, the doctor and botanist on Robert Falcon Scott's *Discovery* expedition of 1901–4. According to Guly, Koettlitz intended to take samples from the explorers as well as the more typical environmental samples, but did not publish any findings; as Armston-Sheret has pointed out he was quite busy with other aspects of disease prevention, including concentrating on germ theory informed hygienic activities and proposing bacteria as the cause of scurvy, and his study of the blood colour and weights of the expedition members made it to his notebooks and a passing reference in Scott's *Voyage of the Discovery* but not into the scientific press.[21]

The first study to seriously consider human microbes in the Antarctic was conducted by Dr Archibald McLean, the doctor on Douglas Mawson's Australasian Antarctic Expedition of 1911–14. Unlike Koettlitz he published his results, first as an MD thesis for the University of Sydney (1917), then as an article in *Nature* (1918) and finally as a volume of the Australasian Antarctic Expedition reports (1919).[22] His work remained 'the most extensive work in studying microorganisms of the Antarctic'

[14]Guly 'Bacteriology' *op. cit.* (note 13), 321

[15]Guly 'Bacteriology' *op. cit.* (note 13), 321.

[16]Guly 'Bacteriology' *op. cit.* (note 13), 323.

[17]Sara Maroske and Tom W. May, 'Naming names: The First Women Taxonomists in Mycology', *Studies in Mycology*, 89 (2018), 63–84, 80.

[18]Morgan Seag, 'Women Need Not Apply: Gendered Institutional Change in Antarctica and Outer Space', *The Polar Journal* 7, 2 (2017): 319–35; Daniella McCahey, '"The Last Refuge of Male Chauvinism": Print Culture, Masculinity, and the British Antarctic Survey (1960-1996)', *Gender, Place & Culture* 29, 6 (2022): 751–71.

[19]Guly 'Bacteriology' *op. cit.* (note 13). For earlier arctic work see J.N. Sieberth, 'Microbiology of Antarctica', in J. Van Mieghem, P. Van Oye, and J. Schnell (eds), *Biogeography and Ecology in Antarctica* (The Hague: Dr W Junk Publishers, 1965): 267–95.

[20]Environmental bacteria turned the 1902–4 Swedish expedition's baking rather sour: Erik Ekelof, 'Medical Aspects of the Swedish Antarctic Expedition, October 1901—January 1904', *Epidemiology and Infection* 4, 4 (1904), 511–40, 530.

[21]Edward Armston-Sheret, 'Tainted Bodies: Scurvy, Bad Food and the Reputation of the British National Antarctic Expedition, 1901–1904', *Journal of Historical Geography* 65 (2019): 19–28. Edward Armston-Sheret, 'Nourishing Food, Clean Air and Exercise: Medical Debates over Environment and Polar Hygiene on Robert Falcon Scott's British National Antarctic Expedition, 1901–1904', *Medical History* (2024): 1–17. Guly 'Bacteriology' *op. cit.* (note 13); Henry Guly, 'Dr Reginald Koettlitz (1860–1916): Arctic and Antarctic Explorer', *Journal of Medical Biography*, 20, 4 (2012): 141–7; R.F. Scott, The Voyage of the Discovery (Hertfordshire: Wordsworth Editions, 2009; originally published 1905), 164.

[22]AL McLean 'Bacteriological and Other Researches in Antarctica'(unpublished MD thesis: University of Sydney, 1917); A.L. McLean, 'Bacteria of Ice and Snow in Antarctica', *Nature* (1918): 35–9; A.L. McLean, 'Bacteriological and Other

through to the 1940s, and was repeatedly cited even to the end of the twentieth century.[23] This 'extensive' work included the well-established environmental survey, which makes up the bulk of the *Nature* article, in which McLean crucially demonstrates that Antarctica is not 'pure' and does have microbial life, but makes the claim – in quite lyrical terms – that these bacteria are not autochthonous but are invaders from more temperate climates. Arriving as hitchhikers on 'aqueous vapour, or clinging to small foreign bodies', they originate elsewhere and are driven 'under the impetus of… equatorial air into the atmosphere' eventually becoming part of snowflakes that fall on the Antarctic continent and then 'sparse or in numbers, the[se] frozen organisms, extruded with the dust-mote they accompanied to the periphery of the nuclear snow-crystal, commence a new life-history'.[24]

The other way in which bacteria colonised Antarctica was on the bodies of birds and animals, particularly the new species – humans – who began to cluster at camps on the fringes of the continent. Here McLean also shaped future microbial research by focusing on how human-microbe interactions might be affected by extreme cold exposure. Prompted by two observations, firstly that Antarctic explorers often succumbed to infections when they returned home despite being 'healthy' while in the far south, and secondly the devastating impact of infectious disease on Indigenous populations in the Arctic brought by European settlers, McLean theorised that cold climates reduced natural immunity to infection. His method for measuring this was to study the newly discovered phenomenon of *opsonins.* These had been named a few years earlier, in 1904, by Almoth E. Wright and Stewart R. Douglas, both working at St Mary's Hospital in London on vaccines and anti-bacterial medicines (notably, Wright's trainee, Alexander Fleming, was continuing threads of this work when he first published on the anti-bacterial action of *Penicillium*).[25] Opsonins are chemical substances that enable white blood cells to absorb and destroy bacteria through a process known as phagocytosis; measuring opsonins in the blood – creating an opsonic index – rapidly became a proxy measure indicating an immune response, and could be fairly easily elicited by exposing a sample of blood sera to bacterial cultures, a method that is still used today.[26]

McLean exposed the Australian explorer's blood to two bacteria, *Staphylococcus albus*, a common bacterium on human skin, and *Mycobacterium tuberculosis*, the causative agent of tuberculosis (TB). The hope was to compare reactions to a commonly experienced bacterium and to an unfamiliar one (medical screening should have excluded any explorers with a history of TB). Unfortunately for McLean, the opsonin studies were, in his words, 'disappointing' – he was unable to get control values in Australia, and believed that he had taken the samples too early in the expedition for the full impact of cold to be seen; this was due to the pressure of more important work, and because of 'technical difficulties which are increased under the rough conditions of an Antarctic hut'.[27] Likewise, his meticulous swabs of the mouths, noses, throats and skin of the explorers also fell victim to the challenges of Antarctic life – culture media became contaminated and tubes cracked, and he was only able to grow samples from the first nine months of the multi-year expedition, up to the first overwinter in August 1912.[28] This foreshortened study did seem to show 'a certain tendency of the bacteria [in and on human bodies] to fall off', further backed up by the fact that wounds 'did not become infected readily even though neglected'; therefore the observation that three men suffered from whitlows – a herpes-mediated infection of the finger – indicated a reduced immune response to their own skin bacteria rather than a new toxin from the atmosphere.[29]

Researches', Scientific Reports - Series C Zoology and Botany. Australasian Antarctic Expedition 1911-14. Sydney, Australia, 1919. NB that the scientific report is almost identical to his thesis, and as the former was the first publication I read, I will use this throughout the rest of this paper rather than the later official report.

[23]Chester A. Darling and Paul A. Siple, 'Bacteria of Antarctica', *Journal of* Bacteriology 42, 1 (1941): 83–98, 95.

[24]McLean, 'Bacteria of Ice and Snow', *op. cit.* (note 22), 38.

[25]Donald R. Forsdyke, 'Almroth Wright, Opsonins, Innate Immunity and the Lectin Pathway of Complement Activation: A Historical Perspective', *Microbes and Infection* 18, 7–8 (2016): 450–9.

[26]Forsdyke, 'Almroth Wright', *op. cit.* (note 25).

[27]McLean, 'Bacteriological and other Researches', *op. cit.* (note 22), 219.

[28]McLean, 'Bacteriological and other Researches', *op. cit.* (note 22), 5.

[29]McLean, 'Bacteriological and other Researches', *op. cit.* (note 22), 232.

https://doi.org/10.1017/mdh.2024.39 Published online by Cambridge University Press

Despite all McLean's setbacks and his distant location it is clear he was striving to contribute to international cutting-edge research with his opsonin studies, and was part of a network in the southern hemisphere where ideas, samples, and technologies flowed between countries; the culture tubes used to grow up whitlow pus samples were shipped out to McLean in the Antarctic by a colleague at the Bureau of Microbiology in Sydney.[30] Indeed pus samples proved to be a regular feature in microbiological research in the Antarctic and moved around the globe, linking the continent to science being done elsewhere – in one case providing a direct connection to Arctic microbiology. The pus that draws in the Arctic belonged to Paul Siple, better known as the 'father of windchill'. Siple experienced a particularly nasty finger wound infection on the Second Byrd expedition of 1933–5. As McLean had established, wound infection was a relatively rare medical phenomenon, which is why Siple commented on it. Most likely this infection was due to handling seal blubber, resulting in *spekkfinger* ('blubber finger'), also known as seal rot or seal finger, a disease long recognised by sealers, whalers, and fishing boat crews before it was formally recognised as a microbial disease by Western scientists in 1907.[31] Already established as an *Arctic* disease, seal finger gained new interest in the 1950s as it turned out to be naturally resistant to the earliest antibiotics (penicillin and aureomycin); the causative organism, *Mycoplasma phocacerebrale* was finally identified only in 1998.[32] Siple's infection was in the pre-antibiotic era, and luckily he avoided the only previous treatment – amputation – as his infection cleared up by itself; still, it was a reminder that the continent was not bacteria-free, as his samples of snow, ice, mud, and plant debris demonstrated. However, McLean's origin story for bacteria remained in place: anecdotes about *harmful* bacteria, whether in Siple's finger or discovered in the rotting remains of a previous expedition's fur clothing and food, emphasised the role of human and animal occupation of the land, rather than being strictly indigenous to the continent.[33]

Two decades on from McLean's ambitious research, Siple's 1930s studies were firmly in the 'collect, grow, identify' tradition that had dominated Antarctic microbial work since the 1880s. Part of the reason for the lack of progress was straightforwardly the challenge of the natural and human-made environment in Antarctica. Laboratory space, if available, was crowded, and the equipment was not always sufficient – some of Siple's samples were collected in repurposed glass fruit jars sterilised using a pressure cooker.[34] Like McLean, Siple experienced the 'pressure of other work', as he was also engaging in physiological research.[35] Siple's work also demonstrates the persistent interdisciplinary nature of science in the Antarctic, as although he took most of the bacterial samples, he also roped in colleagues James M Sterrett (a biologist and dog driver) and Quin A. Blackburn (a geologist).[36] All these researchers knew that their work fell short of the controlled ideal of the laboratory, but were able to be self-reflexive about potential contaminants and weaknesses of the method. They often highlighted their ingenuity in solving research problems 'live' in the field (such as using food jars), and all demonstrated a strong global network of colleagues in laboratories and clinics elsewhere, where samples, photos, drawings, and sometimes telegrams asking for advice were sent.[37]

[30]McLean, 'Bacteriological and other Researches', *op. cit.* (note 22), 36.

[31]Colin P. White and David D. Jewer, 'Seal Finger: A Case Report and Review of the Literature', *Canadian Journal of Plastic Surgery*, 17. 4 (2009), citing: J.H. Bidenknap, 'Spackflegmonen', *Norsh Magazin for Legevidenskaben* (1907): 68:515–23; White and Jewer, p. 144; K. Panagis, P. Apps, and M.H. Knight 'Seal Finger: Occurrence in Antarctica', *South African Journal of Antarctic Research*, 12 (1982): 49; Kåre Rodahl, 'Notes on the Prevention and Treatment of 'Spekk Finger'', *Polar Record* 4, 25 (1943): 17–8; Kaare Rodahl, '"Spekk-Finger" or Sealer's Finger', *Arctic* 5, 4 (1952): 235–40.

[32]Ann Sullivan Baker, Kathryn L. Ruoff, and Sarabelle Madoff, 'Isolation of Mycoplasma Species from a Patient with Seal Finger', *Clinical Infectious Diseases*, 27,5 (1998): 1168–70.

[33]Darling and Siple, 'Bacteria of Antarctic', *op. cit.* (note 23), 83.

[34]Darling and Siple, 'Bacteria of Antarctic', *op. cit.* (note 23), 83–4.

[35]For a range of interdisciplinary studies conducted during these years at the American bases see Russell G. Frazier, 'Acclimatization and the Effects of Cold on the Human Body as Observed at Little America III, on the United States Antarctic Service Expedition 1939-1941', *Proceedings of the American Philosophical Society* 89, 1 (1945): 249–55.

[36]Note that Sterret is mistyped as Sterrit in Siple, 'Bacteria of Antarctic', *op. cit.* (note 23), 84.

[37]Siple noted *B. megatherium* [sic] from his finger infection but did not propose it as the infectious agent due to the likelihood of contamination. Darling and Siple, 'Bacteria of Antarctic', *op. cit.* (note 23), 90. B. megatherium is likely a mispelling of B. megatarium – known since 2020 as Priestia megaterium.

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So whatever the weaknesses of this work, it epitomised certain characteristics (interdisciplinarity, ingenuity, internationalism) and established several principles that undergirded research for the rest of the century. Antarctica was not a pure continent, free of microbes, and these microbes were concentrated in the water and wildlife and were much sparser in the ice and soil. Furthermore, the bacterial content was often thought of as an *import* not *indigenous* – moved by air currents, leached into the snow from rutting-season wounds on male seals, or brought in by human beings and their dogs. As a consequence, human microbial infections were relatively rare, but contact with other – 'outsider' – humans could cause mini-outbreaks, either when expedition groups or relief teams met, or on the return home. In rarer cases, this infectious contact could be via material goods rather than human-to-human, for example during the 1907–9 Nimrod Expedition where Ernest Shackleton described an outbreak of coryza (cold-like symptoms) which he blamed on opening a bale of blankets, or when the Australian team at Wilkes credited an outbreak of influenza in 1959–61 on 'the unpacking of a kitbag with clothing from home'.[38] What remained a pressing mystery was the specific effect of the Antarctic environment on these processes, e.g. was McLean right that the cold suppressed the immune system? Or was it the case that human immune systems deregulated in the absence of microbes regardless of temperature? Or was some other physiological or epidemiological factor at play? In the late 1950s, the US Navy decided to try to find out.

Systematic 'snuffle' studies

The man chosen to lead the US Navy's first major microbe hunt has become better known for his work in animal behaviour and conservation. Professor William 'Bill' Sladen (1920–2017) was born in Wales, trained in medicine at the University of London, and sailed out with the FIDS in 1947 to act as a medical officer, which changed the course of his career entirely. Here he did microbe and bird studies, leading eventually to a PhD on the biology of penguins at the University of Oxford in 1954, which he published as a book in 1958 marking the start of a long and distinguished career in researching and trying to protect the ecology of Antarctica and beyond.[39] But for an intervening period, from about 1947 to 1959, Sladen was also an Antarctic microbiologist.[40] It is a testament to his commitment to the Antarctic that he ever got beyond that 1947–9 season and into the major US Navy-funded project. As he began both penguin and microbe survey work he faced a devastating trauma: four days after he and colleagues Oliver 'Dicky' Bird and Mike Green had been left alone at Hope Bay while a sledding party conducted work elsewhere, Sladen returned from a penguin rookery to find the base on fire. 'I tried to force my way through the … window but was compelled to come out as the fumes were so hot and suffocating', he wrote

> There was no answer to frantic shouts made between breaths inside the window…[t]he sinister silence; the dark smoke torrenting down to the sea, pressed low by the gale and drift; the feeling of complete and utter helplessness; worse still, the thought of Dick and Mike with no one to save them was the most terrifying thing I have ever experienced.[41]

[38]McLean, 'Bacteriological and other Researches', *op. cit.* (note 22), 217; National Archives of Australia, Hobart, Australian Antarctic Division [hence: Hobart/AAD], B1387, 1996/818 *Medical – general Part 3 1954–1959.* Medical Physiology Programme 1959-62, Bacteriological program Wilkes 1961 – no author.

[39]David G. Ainlye, 'In Memoriam: William JL Sladen', *Marine Ornithology* 45 (2017): 237-8; Anonymous, 'Ecologist William Sladen, Whose Work Helped Convince EPA to Ban Pesticide DDT, Dies at 96', https://hub.jhu.edu/2017/06/21/ecologist-william-sladen-dies-at-96/ [accessed 3 Feb. 2024] – archived at: https://web.archive.org/web/20230928232454/https://hub.jhu.edu/2017/06/21/ecologist-william-sladen-dies-at-96/; WJ Sladen 'The Biology of the Pygoscelid Penguin' (unpublished PhD thesis: University of Oxford, 1954).

[40]David G. Ainley, 'William J.L. Sladen 1921–2017', *Marine Ornithology*, 45 (2017), 237–8.

[41]Vivian Fuchs, *Of Ice and Men: The Story of the British Antarctic Survey, 1943-73* (Oswestry, Shropshire: A. Nelson, 1982), 112–13.

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Sladen went on to survive for sixteen days alone in a tent, continuing his penguin work as a way to distract himself from what had happened. His later scientific publications make only a passing reference to this event ('all throat cultures…were lost in a fire'), and in his thesis, he simply states '[t]he total loss of the hut with all its equipment and results of a hard year's work was insignificant in comparison with the tragic loss of two of our best companions.'[42]

Despite this dramatic and devastating experience of the realities of scientific work in Antarctica, by 1953 Sladen was confident that better microbiological work could be done – 'times have changed' he writes, suggesting that the major stumbling blocks (contamination due to poor conditions and the 'pressure of other work') could be overcome.[43] In the late 1950s he was given the opportunity to prove this; having moved to the USA to take up a position at Johns Hopkins, Sladen was recruited by the US Navy to lead an Antarctic bacteriology project as part of a broader epidemiological study supported by over a dozen organisations including the National Science Foundation (NSF), the Arctic Institute of North America, and the US Public Health Services. This was part of a growing interest on the part of the US military in funding basic research into 'extreme environments' given that basic biomedical questions about survival in both hot and cold climates remained unanswered, particularly inspired by the experiences of troops during World War II and the Cold War era recognition that conflict could now take place anywhere on the globe, including the Arctic and Antarctic.[44] Taking advantage of Operation Deep Freeze IV – one of a series of US Naval expeditions to Antarctica – the icebreaker ship USS Staten Island was to host a microbial research project that aimed to study the distribution and correlation between infections and microbes in the bodies of healthy adult men on board and at Antarctic bases, hoping to ascertain which bacteria caused disease, and how they were spread in closed communities. The project was given the rather charming title of Operation Snuffles.[45]

Snuffles was a vast undertaking compared with previous Antarctic microbiology: everyone on board the USS Staten Island donated a blood sample before and after they sailed, and a further fifty-six volunteers had roughly monthly samples taken, as well as nasal swabs. Blood and swabs were also collected from staff at two Antarctic stations, the 'semi-isolated' Hallet base and 'completely isolated' Wilkes. Equipment was left at the naval base at McMurdo in the hope that medical officers at other stations could collect additional specimens from the overwintering parties.[46] Nearly 900 blood sera samples were returned to the USA, alongside around 4000 cultures (1300 viral, either 2550 or 2660 bacterial).[47] Despite so much data, and so much institutional backing, Snuffles suffered similar personnel, logistical, and environmental challenges as Sladen and others had experienced in the first half of the century. These were not limited to Antarctica – in December 1959 the director of the Walter and Elisa Hall Institute of Medical Research (IMR) in Melbourne had to rather hastily ask that either the (Australian) Antarctic Division or the American-funded research immediately provide £150 for a new deep freezer, as the IMR had not anticipated the sheer volume of frozen sera (3 cubic feet) returning from Wilkes base.[48]

[42]W.J.L. Sladen, 'Staphylococci in Noses and Streptococci in Throats of Isolated and Semi-Isolated Antarctic Communities', *Journal of Hygiene* 63, 1 (1965): 105–16, 112; WJ Sladen 'Bacteriological Work in the Antarctic: Medical Organization of the Falkland Islands Dependencies Survey 1947-1951' (unpublished MD thesis: University of London, 1953).

[43]Sladen, 'Bacteriological Work', *op. cit.* (note 22), 2.

[44]Vanessa Heggie, 'Blood, Race and Indigenous Peoples in Twentieth Century Extreme Physiology', *History and Philosophy of the Life Sciences*, 41, 2 (2019).

[45]William J.L. Sladen and Victor R. Goldsmith, 'Biological and Medical Research Based on USS Staten Island, Antarctic, 1958-59', *Polar Record* 10, 65 (1960): 146–8.

[46]Sladen and Goldsmith, *op. cit.* (note 45).

[47]Sladen and Goldsmith, *op. cit.* (note 45), 147; Sladen claims the higher number of 2660 bacterial cultures in: W.J.L. Sladen, 'Upper Respiratory Staphylococci and Streptococci in Antarctic Communities', in C.R. Holdgate and J. Prevost (eds), *Biologie Antarctique: Proceedings of the 1st SCAR Symposium on Antarctic Biology* (Paris: Hermann, 1964), 101–14.

[48][Hobart/AAD] B1387, 1996/818 *Medical - general Part 3 1954 – 1959*, letter FM Burnet to PG Law, 2 Dec. 1959.

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There are also personal tragedies at the heart of this work, albeit, like Sladen's story, well hidden from the official records. Sladen relied on base staff for samples, which at Wilkes base was Hungarian-born Australian National Antarctic Research Expedition (ANARE) Medical Officer Dr John Boda. While reporting that the blood samples from the 1959 winter season were being sent for safe keeping to the IMR, Boda added that 'no throat or nasal swabs have been collected from Wilkes members due to accidental destruction of the various agar-agar solutions early in the year'.[49] Sladen did not ask further questions, instead getting absorbed in queries about undersized freezers and lost blood sera. But buried in an oral history interview with John 'Snow' Williams, an ANARE mechanic who also overwintered in 1959 is the claim that 'Henry' 'saw all these cultures going on in the doctor's surgery and he smashed them all. And that was the end of Operation Snuffles.'[50] There is only one staff member with the first name mentioned in this account in the 1959 ANARE winter team at Wilkes, and this was a mechanic who apparently, after the tragic death of the senior mechanic Harley Ricketts Robinson in a tractor accident, began to exhibit erratic and paranoid behaviour. He was confined to an improvised padded cell before being airlifted from the base in December 1959 by an American aircrew.[51]

I emphasise the everyday logistical problems and the deeply personal stories not just to demonstrate how the realities of scientific work are elided in official publications, but also to underline Antarctica's status as an *international* 'natural laboratory'. There is, rightly, a tendency to look at large collaborative scientific projects in Antarctica (such as the International Geophysical Year [IGY]) with some scepticism when it comes to claims of friendly cooperation and national disinterest.[52] But it is also clear that on a day-to-day basis, scientists and other Antarctic base staff worked in a multinational space, collaborating, engaging, supporting, and cross-funding each other's efforts, creating a network of people, shared experiences, ideas, and even samples of blood and nasal mucus that cobwebbed across the world. Unfortunately, in the case of Operation Snuffles, the result of this cooperative, international science involving hundreds of human volunteers and thousands of samples was surprisingly little. Almost no publications appeared – one summary of the work was published in *Polar Record* in 1960 and a longer account in the *Journal of Hygiene* in 1963 but little else. Sladen went on to study the bacteria of wildlife, particularly penguins, rather than people.

Consequently, by the 1960s, the understanding of infectious disease in the far south mostly confirmed the findings of Sladen and earlier researchers: certain bacteria (mostly *Staphylococcus* [staph] strains) could survive in the bodies of explorers for extended periods, even in Antarctic conditions, but there was as yet no evidence that these bacteria were the cause of outbreaks of illness, nor that they were passed on to other members of boat or expedition crews. Somewhere between one in six to one in eight men remained 'persistent carriers' of staph strains, but there was no obvious correlation between the presence of culturable bacteria and symptoms.[53] This negative finding can obscure the fact that mid-century studies were pioneering a new approach to epidemiology, using cutting-edge science. What was novel about these studies was a powerful new tool that could (relatively) easily identify individual bacterial species – without which it was impossible to state with confidence who had infected whom in a base or on

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[49][Hobart/AAD] B1387, 1996/818, *Medical - general Part 4 1959 – 1963*, Letter John Boda to Dr William JL Sladen, 17 Mar. 1960.

[50]State Library of New South Wales, Oral history interviews with Australian National Antarctic Research Expeditions (ANARE) members, conducted by Ingrid McGaughey, 10 January 2011-19 November 2012: John (Snow) Williams interview by Ingrid McGaughey, 25 June 2011 -Part II 57m 18 sec https://collection.sl.nsw.gov.au/record/1bGWpDkY/3gZZjKNo8QKrN [accessed August 2023]; see also the user generated transcript https://amplify.gov.au/transcripts/statelibrarynsw/antarctic_expeditions/Antarctic_JohnWilliams_Part2 [accessed May 2024]

[51]H.J.G. Dartnall, 'Bob Dingle – Pathfnder at War and in the Antarctic', *Papers and Proceedings of the Royal Society of Tasmania* 152 (2019), 53–9. 58.

[52]Klaus Dodds, 'The Great Game in Antarctica: Britain and the 1959 Antarctic Treaty', *Contemporary British History*, 22, 1 (2008): 43–66; Adiran Howkins, *Frozen Empires: An Environmental History of the Antarctic Peninsula* (New York: Oxford University Press, 2017).

[53]W.J.L. Sladen, 'Staphylococci in Noses and Streptococci in Throats of Isolated and Semi-Isolated Antarctic Communities', *Journal of Hygiene* 63, 1 (1965): 105–16, 110.

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a ship. This method was the bacteriophage, a group of viruses that infect bacteria and whose preference for certain strains as hosts can be used to identify particular (sub)species of microorganisms. Sladen had been using phages to type the staph he found in the noses of FIDS volunteers in the 1940s, and by the early 1950s methods for phage-type identification had been internationally standardised, and national libraries of phage/bacteria pairings were developing for the most common subtypes of bacteria.[54] This global standardisation proved crucial for two world problems: pandemics and the emerging challenge of antimicrobial resistance, and the bacteria that dominated Operation Snuffles, *S. aureus*, was the 'poster bacterium' for this new technology and its importance.

Staphylococcus aureus is commonly present in and on human bodies without causing disease, but it can sometimes also kill, particularly in hospital settings amongst vulnerable patient groups such as the very old or young. In addition, it is also one of the first bacterial strains to have gained resistance to common antibiotics (in contrast to the species that had a pre-existing resistance, such as the bacterium that causes *spekkfinger*). This was an evolution that Sladen himself observed happening in real-time. FIDS team member WS was a persistent carrier of *S. aureus* in the late 1940s; when retested in the 1950s for Operation Snuffles his staph was now penicillin resistant.[55] Perhaps one of the unique aspects of Antarctica is that although there was easier access to the continent through the twentieth century, there was still a relatively large core of repeat visitors, meaning men could become regular guinea pigs allowing longer-term comparisons to be made.[56] Rather optimistically Sladen claimed '[m]ore will be written about [WS's] nose, which has been studied for 15 years' (in fact, Operation Snuffles was the last study of WS's nose on record).[57]

Given the prominence of Australian researchers in this narrative it is worth pointing out that, as Hillier has explained, it was a team of women working in Australian healthcare settings who made the case for phage typing as the key to understanding, containing, and tracing bacterial epidemics – a method that could also work on ships or in Antarctic bases.[58] From the observation of penicillin-resistant staph lesions in five newborns at a Sydney hospital, *S. aureus* phage-type 80/81 became a global pandemic of resistant *Staphylococcus* infections, and one member of the Australian team (Dr Phyllis Rountree) became a founding member of the International Subcommittee for Phage Typing of Staphylococci in September 1953.

Staphylococcus aureus 80/81 would be identified in Antarctica in the 1960s (see below), but overall the studies of the 1950s and 1960s maintained the continent as a comparatively sterile space, and one relatively free of antibiotic resistance, while one in four of the USS Staten island volunteers hosted bacteria with penicillin resistance, at the Antarctic bases this dropped to as few as one in twenty-five.[59] Even if the men arriving in the far south were crawling with bacteria there was little evidence that these microorganisms caused disease, or that they were passed between 'polarmen' even in the very close contact of crowded living quarters or tents. So, despite the assertions that the Antarctic was an ideal natural laboratory, the work of the mid-century showed that in many ways it was unrepresentative of the microbial world and its threats elsewhere and that the results of experiments here were inconsistent. Often it was the environment that was blamed for this inconsistency. Ironically, making the Antarctic habitable for man had reduced its ability to function as a controlled natural laboratory, as the fact that Antarctic residents had very different levels of cold exposure meant they had very different microbial

[54]Sladen, 'Staphylococci in Noses', *op. cit.* (note 53); Dmitriy Myelnikov, 'An Alternative Cure: The Adoption and Survival of Bacteriophage Therapy in the USSR, 1922–1955', *Journal of the History of Medicine and Allied Sciences*, 73 4 (2018): 385–411; Kathryn Hillier, 'Babies and Bacteria: Phage Typing, Bacteriologists, and the Birth of Infection Control', *Bulletin of the History of Medicine*, 80, 4 (2006): 733–61.

[55]Sladen, 'Staphylococci in Noses', *op. cit.* (note 53).

[56]I have already made the point about the small clique of researchers but the argument extends to human subjects too: Vanessa Heggie, *Higher and Colder: A History of Extreme Physiology and Exploration* (Chicago and London: The University of Chicago Press, 2019). See, in particular, Chapter 2, 'Frozen Fields'.

[57]Sladen, 'Staphylococci in Noses', *op. cit.* (note 53), 111.

[58]Hillier, 'Babies and Bacteria', *op. cit.* (note 54).

[59]Sladen, 'Staphylococci in Noses', *op. cit.* (note 53, Table 3).

experiences. In 1957, at the same time as Operation Snuffles, the US Naval Military Laboratory also sampled the non-pathogenic *Lactobacilus acidophilus* in the saliva and faeces of 37 men at Little America.[60] One striking result emerged: over time oral bacteria declined, while intestinal bacteria remained the same. The reason for the difference was simple: mouth breathing. Oral bacteria experience the cold of the Antarctic and died off; internal bacteria did not and survived.[61]

Antarctica fractured into multiple 'natural laboratories' – hundreds of heterogenous case studies where your vocation, the style of the hut you lived in, and the season you spent there all substantially impacted your microbial load. Some of these effects were counter-intuitive, as studies repeatedly showed *less* cold exposure in winter teams, as many workers never went outside during the worst of the blizzard season, so cold exposure (and oral/skin microbe death) was higher in the summer. For the *Lactobacillus* study, it was February through May that saw the decline of oral microbe loads as '[i]t was in these months…that the majority of the experimental group worked outside'.[62] Perhaps as a consequence the large-scale, but discipline-narrow, epidemiological studies never truly dominated (or contradicted) the more detailed, interdisciplinary, localised microbial studies.

The most influential examples of this style of study in the second half of the twentieth century were those by another Australian, Alexander Scott Cameron. His work at Mawson base between December 1965 and June 1966 was the basis for his 1968 Doctor of Medicine (MD) thesis at the University of Adelaide and included physiological, meteorological, and sociological observations as well as his substantial bacteriology programme and epidemiological work. Twenty-seven men at the isolated Mawson base had skin, nose, and throat swabs taken every three to four weeks from January 1965 to March 1966, and air samples and samples from the dogs were also taken. Full medical histories were drawn up, ranging from December 1964 to June 1966, with worksheets and medical logs recording symptoms and sickness, and a follow-up questionnaire was sent in May 1966 to pick up any infections the team suffered from on arriving back home. Overall, Cameron's findings supported the received wisdom about bacteria and infectious disease in Antarctica: infections did 'burn out' in isolated populations; some men were persistent or intermittent carriers of bacteria with no ill-effects; and bacteria levels were significantly impacted by cold exposure – long sledging expeditions could almost eliminate bacteria on exposed skin and in the mouth.[63]

What is novel about Cameron's findings is how he demonstrated that the unique conditions of Antarctica might affect the results of his, and previous, studies. For example, he was explicit about the fact that cold weather could exacerbate respiratory symptoms, making it very difficult to track the 'true' duration of a respiratory illness via a symptom card, and perhaps explaining why so many apparent respiratory infections did not produce a successful bacterial or viral culture. He also highlighted an apparently trivial issue which could have significant impacts on the interpretation of earlier findings: coagulase-negative staph populations survived much better in the cold than coagulase-positive staph, which was often eliminated from the skin entirely and only survived in nasal populations. Taken alongside earlier findings that coagulase-negative staph could outcompete coagulase-positive populations in petri dishes Cameron speculated that maintaining a healthy coagulase-negative population in the nose could prevent invasion, and therefore infection, by the usually more pathogenic coagulase-positive staph variants (competition in petri dish cultures could also have led to inaccurate estimates of total Antarctic bacterial loads).[64]

[60]Robert J. Adams and William R. Stanmeyer, 'Effects of Prolonged Antarctic Isolation on Oral and Intestinal Bacteria', *Oral Surgery, Oral Medicine, Oral Pathology*, 13, 1 (1960): 117–20, 119.

[61]See also the differences between skin and respiratory tract microflora in Russian explorers: R. Yu Tashpulatov and V.V. Petrosov, 'Study of the Quantitative Changes in Human Microflora during the 12th and 13th Soviet Antarctic Expeditions' in A.L. Matusov (ed.), *Medical Research on Arctic and Antarctic Expeditions* (Chichester: John Wiley, 1974), 190–5. (Translated by A Ferber. Israel Program for Scientific Translations, 1973.)

[62]Adams and Stanmeyer, 'Effects of Prolonged', *op. cit.* (note 60), 119.

[63]Alexander Scott Cameron 'Staphylococcal and Viral Epidemiology in an Isolated Community in Antarctica' (unpublished MD thesis: University of Adelaide, 1968).

[64]Cameron, 'Staphylococcal and Viral Epidemiology', op. cit (note 63). also see R.A. Williams, 'Bacteriological Survey in Antarctica', *British Antarctic Survey Bulletin* 19 (1969): 97–8.

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Just like his predecessors, Cameron was unable to culture or identify any viral infections in the far south (and lost some samples at sea in a storm), and so his work belongs to this middle period of Antarctic microbiology, as the final stage of work in the far south included a specific focus on overcoming the difficulty of viral research. Before we move to this last phase, however, it is necessary to address a glaring absence in this story so far: the danger of antimicrobial resistance (AMR), which despite all the interest in bacteria is rarely discussed. This is not because Antarctica was immune to AMR – *spekkfinger* had already been revealed as a resistant infection; Sladen tested both the FIDS and Operation Snuffles cultures for penicillin sensitivity; and Cameron not only identified many bacteria in his studies as penicillin-resistant but also discovered erythromycin and tetracycline resistance, which in one case he put down to previous treatment with the antibiotics in Australia.[65] Cameron even showed that Antarctica was not safe from pandemic organisms, as one of his twenty-seven subjects tested positive for the penicillin-resistant *S. aureus* phage-type 80/81, the strain responsible for the 1950s pandemic. Yet these discoveries did not seem to lead to systematic interest in AMR.

Through the many years of research I have only been able to identify two studies of AMR, which took place in the 1970s and do not appear to have ever been published; they are evidenced only in traces within the ANARE archives, via a project proposal and some enigmatic telegrams. In 1974 Dr Steven ('Steve') Karay was recruited to the position of Medical Officer at Casey Station for the following season, apparently on condition that he was able to organise a study on antibiotic resistance in the Antarctic, which he hoped to use as a basis for an MD thesis at the University of Adelaide. Karay aimed '[t]o survey bacteriological flora of people of diverse geographical origins; to detect changes in bacterial populations due to effects of the cold environment and to the close proximity of community living'[66] and drew up an ambitious programme which 'involved considerable cost and a large part of the resources of the medical section'.[67] Swabs were taken of noses and throats, blood was drawn, and samples of faeces were collected – from penguins as well as humans. Serological and biochemical studies joined phage typing to identify species of microorganisms and their resistance profiles, and Karay hoped not only to study a much larger range of bacteria but also fungi.[68] Some samples were studied at Casey, but many were supposed to be freeze-dried and returned to Australia. This study was plagued by all the challenges Antarctica usually posed and more: samples were spoilt, essential chemicals spilt and lost, growth medium ran out, and due to a problem with the vacuum pumps 'very few specimens…survived freeze drying.'[69] On return to Australia funding suddenly became problematic, with the Deputy Director of ANARE, Dr DJ ('Des') Lugg struggling to secure space for Karay's work in Melbourne, or to find funding for him to travel to Adelaide to complete the studies.[70] The correspondence ended in April 1976, and there is no evidence that Karay submitted a thesis to the University of Adelaide.[71] There is a single telegram in 1979 from Casey Station reporting the results of a project that tested *Escherichia coli* samples against twelve antibiotics and found no persistent resistance; this telegram is signed 'Manning', and the only Manning

[65] Sladen, 'Upper Respiratory Staph', *op. cit.* (note 47), 102; Cameron, 'Staph and Viral Epidemiology' *op. cit.* (note 63), 80.

[66] Melbourne/AAD, B1387, 80/463, *Medical Services, Support & Research, Medical Research 1978-1980*, Casey 1975 – Stability and Transfer of Antibiotic Resistance of Bacteria in a closed Antarctic Community by Dr S. Karay.

[67] Melbourne/AAD B1387, 80/463, *Medical Services, Support & Research, Medical Research 1978-1980*, DJ Lugg, Senior Medical Officer to Director, 17 Feb. 1976 Dr S. Karay's Medical Research Project.

[68] The bacteria would include Staphs, Streps, Penumococci, Neisseria, a range of enteric organisms, diphtheroid and listeria Melbourne/AAD, B1387, 80/463, *Medical Services, Support & Research, Medical Research 1978-1980*, Casey 1975 – Stability and Transfer of Antibiotic Resistance of Bacteria in a closed Antarctic Community by Dr S. Karay

[69] Melbourne/AAD, B1387, 80/463, *Medical Services, Support & Research, Medical Research 1978-1980*, Casey 1975 – Stability and Transfer of Antibiotic Resistance of Bacteria in a closed Antarctic Community by Dr S. Karay.

[70] Melbourne/AAD, B1387, 80/463, *Medical Services, Support & Research, Medical Research 1978-1980*, DJ Lugg, Senior Medical Officer to Director, 27 Feb. 1976; RI Garrod Director to Acting Executive Officer and cc. Lugg, 2 March 1976; From DJ Lugg, Acting Deputy Director to Acting Director/Executive Officer 12 March 1976; From DF Styles a/director to Dr Lugg A/deputy director 19 Mar. 1976; Letter DJ Lugg a/Deputy Director to A/Director, 22 mar 1976; NOTE FOR FILE: Signed GH Nichol, A/executive officer, 26 March 1976; Note DJ Lugg Acting dep dir to Director, 2 April 1976; Note DF Styles, Acting Director, to Acting Deputy Director [Lugg], 2 April 1976.

[71] Personal correspondence, Maria Long (Senior Archives Officer, University of Adelaide), 15 October 2023.

https://doi.org/10.1017/mdh.2024.39 Published online by Cambridge University Press

at Casey in this season was a tractor operator, not a doctor. This, and Karay's study, appears to be the first and possibly last, twentieth-century studies of AMR in the far south.

Viruses, artificial infections, and artificial environments

One reason for the lack of interest in AMR is likely the fact that, in general, infectious disease was not a significant problem at Antarctic bases (and more on this below). Medical screening produced an unrepresentative healthy population on the continent, and the relative sterility of the atmosphere led to an incredibly low rate of wound infections – this even though serious wounds and surgical procedures were experienced, including the removal of appendixes, eyeballs, fingers, and toes. Even when medical care was provided by amateurs bacterial infection was rare – as in the case of Dr Andrews who sustained a serious head wound in 1946 and had to give instructions on wound care and stitching to the meteorologist O'Sullivan 'between periodical relapses into unconsciousness'.[72] A question remained, however, about the presence and significance of *viruses* in this ecosystem.

No evidence was found of viral infection during Operation Snuffles; no viral cultures were successfully grown, and the blood samples sent (via Australia) to Dr Robert Chanock at the National Institutes of Health (NIH) showed no evidence of antibodies for 'influenza … parainfluenza… respiratory syncytial virus [or] the adenovirus group.'[73] The 1961–2 South African National Antarctic Expedition (SANAE) also reported negative findings from their own viral/immunology work. Notably, neither of these negative findings are available in the published records of the studies – neither Chanock nor the SANAE scientists published even a note about their absence of findings – instead, these were communicated to Cameron by letter.[74] This not only emphasises the role of 'grey literature' even in cutting-edge laboratory-based science, but also, as I have shown previously for physiology, that science in Antarctica was built on informal communications that circulated within a small community of researchers.[75] Furthermore, it demonstrates that viral studies, due to the difficulty of culturing viruses, often used immune responses/antibody production as a proxy for viral presence – harking back to MacLean's work with opsonins at the start of this story in the 1910s.[76] Proxy studies were always uncertain because all the proxies that were used were susceptible to the force of the Antarctic environment. This section will return to the question of Antarctica's impact on immune responses below, but more frequently it was symptoms that were used as a proxy for untraceable viral infection. Yet symptoms were also problematic.

The increasing population of Antarctica meant that larger-scale epidemiological studies could be undertaken, such as the analysis of medical records of the US Navy during Operation Deep Freeze where from 1955 to 1958 complete statistics of the medical 'incidents' were analysed by Captain EE Hedblom of the US Navy.[77] This study revealed the high risk of accidental death and the relatively low risk of respiratory infection. However, Hedblom highlights weaknesses in the study as the self-reporting of symptoms was deeply subjective. He complains that naval men used the word 'influenza' to refer to a 'bad cold', exaggerating the seriousness of viral diseases; worse, it was always possible that symptoms such as running noses and headaches were caused by the environment or lifestyle as well as the cold and the wind, as '[f]atigue, irregular hours, overindulgence and lack of supplementary vitamins' might be to blame rather than viruses.[78]

[72]Fuchs, 'Of Ice and Men', *op. cit.* (note 41), 70.

[73]Notably, they were not tested for rhinovirus antibodies. Cameron, 'Staph and Viral Epidemiology', *op. cit.* (note 63), 29.

[74]Cameron, 'Staph and Viral Epidemiology', *op. cit.* (note 63), 24.

[75]Heggie, *Higher and Colder*, *op. cit.* (note 56). See Chapter 2 'Frozen Fields' in particular.

[76]The first successful viral cultures were not grown until the mid-1970s. H.G. Muchmore, A.J. Parkinson, E.N. Scott, and L.V. Scott, 'Respiratory Virus Infection Late in Isolation at the South Pole', *Antarctic Journal of the United States*, 13, 4–5 (1978): 171–2.

[77]E.E. Hedblom, 'The Medical Problems Encountered in Antarctica', *Military Medicine*, 126, 11 (1961): 818–24.

[78]Hedblom, 'The Medical Problems', *op. cit.* (note 77), 822.

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One way to regain control of viral studies was to deliberately inoculate human subjects with known viruses and observe the results. In 1968 men at a British Antarctic Survey (BAS) base on Stonington Island were deliberately infected with both coxsackievirus A21 and influenza A2, and in 1970 they were given rhinovirus type 2; in 1969 the BAS staff at Adelaide Island were also enrolled in a planned study of 'easily traced viruses'.[79] All three studies were organised by researchers at the Salisbury Common Cold Unit in the UK, with cooperation from the British Medical Research Council, and the Antarctic teams were 'paired' with control groups in isolation in the UK in the hope that more robust conclusions could be drawn about the differing impact of isolation and environment on respiratory infections. The BAS medical officer who ran the trials, Dr MJ Holmes, confidently claimed that the 'unique conditions [in Antarctica] make it feasible to study the effects of a single infection and the roles of the various protective mechanisms…where elsewhere their effects are obscured', but the reality of their experimental work demonstrated once again that Antarctica was not a model for other spaces, but a complicated environment with its own challenges and outcomes.[80] In the 1968 trial, the infected men in Antarctica experienced atypical symptoms (at least in comparison with temperate climate studies), reporting 'usually high instance[s] of gastro-intestinal [GI] symptoms'; this result has a significant impact not just on this study, but on the entire extant body of epidemiological work in Antarctica (and possibly the Arctic), as it raised the spectre that reports of GI disturbance at polar stations in the past may not have been a dietary issue or food poisoning but actually part of a respiratory viral outbreak. Once again, this emphasises the weaknesses of using symptoms as a proxy for infection. More problematically, although in 1968 the men in Antarctica experienced much milder (albeit different) symptoms than the UK volunteers, in 1970 the situation was reversed, with the men in Antarctica experiencing a longer duration of symptoms, and much more significant disease burdens, including fever, inflamed tracheas, and chest pains.[81] It is possible the severity of these symptoms, given the lack of medical infrastructure in Antarctica, led to the end of the programme.

Notably, too, the planned 1969 study at Adelaide Island had to be abandoned entirely, not because of the consequences of artificial infection, but because infection happened 'naturally' *after* burnout was supposed to have been completed. To the surprise of the researchers, after seventeen weeks of total isolation, a respiratory disease appeared at the base, eventually affecting half the men working there and putting an end to the planned study. Blood sera were sent back to Salisbury to find a cause, and the samples were tested for antibodies to coronaviruses as well as the usual suite of coxsackie, influenza and streptococci; nothing was found in the blood, and attempts to grow viral samples or visualise viruses with electron microscopy all failed to find a cause for the outbreak.[82] Even an extraordinary attempt at deliberate infection failed – the researchers pooled the nasal secretions from the sick men and 'inoculated' this mucus into the ten asymptomatic men, resulting in one 'doubtful cold' alone, quite different to the infection patterns achieved previously in 1968, or subsequently in 1970. Allergies were ruled out, and zoonotic infection from the Husky dogs was ruled out. All the researchers were left with were two speculative ideas: firstly that cold viruses had survived on material objects, in this case reused clothing which had been unpacked from boxes in midwinter.[83] (As we have seen before, fabrics had been blamed as far back as 1908 by Shackleton for a disease outbreak, and 'a kitbag with clothes from home' had recently been cited as the cause of a respiratory illness at Wilkes base in 1960.)[84] The second

[79]M.J. Holmes *et al.*, 'Studies of Experimental Rhinovirus Type 2 Infections in Polar Isolation and in England', *Journal of Hygiene*, 76, 3 (1976): 379–93; T.R. Allen *et al.*, 'An Outbreak of Common Colds at an Antarctic Base after Seventeen Weeks of Complete Isolation', *Epidemiology and Infection*, 71, 4 (1973): 657–67.

[80]M.J. Holmes, 'Respiratory Virus Disease in the Antarctic: Immunological Studies' in O.G. Edholm, E.K. Eric Gunderson, International Council of Scientific Unions, International Union of Physiological Sciences, and International Union of Biological Sciences (eds), *Polar Human Biology: The Proceedings of the SCAR/IUPS/IUBS Symposium on Human Biology and Medicine in the Antarctic* (London: Heinemann Medical, 1973), 125–34, 134.

[81]Holmes *et al.*, 'Studies of Experimental', *op. cit.* (note 79), 393.

[82]Allen *et al.*, 'An Outbreak of Common Colds', *op. cit.* (note 79).

[83]Allen *et al.*, 'An Outbreak of Common Colds', *op. cit.* (note 79), 666.

[84][Hobart/AAD] B1387, 1996/1093, *Medical Physiology Programme* 1959-1962, Letter Z Soucek (MO Wilkes) to Director, Antarctic Division, no date; Mclean, 'Bacteriological and other Researches', *op. cit.* (note 22); Hedblom, 'The Medical Problems', *op. cit.* (note 77), 821–2.

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explanation the researchers offered was the entirely speculative idea that while bacteria were killed off by cold, perhaps some common cold viruses were somehow 'reactivated' by low temperatures, as the outbreak had occurred just after a sustained fall in the outside air temperature.

Through all this research there remained anxiety about the immune systems of the men who spent prolonged time in Antarctica. As we saw above, this was one of McLean's concerns at the start of the century, and his hypothesis that the human immune system was somehow 'downregulated' by a period in Antarctic isolation had been reinvestigated multiple times through the century. At first, these studies had largely been anecdotal and observational, citing the phenomenon of the 'otherwise healthy' returning explorer suddenly experiencing disease on the arrival of a relief ship or the return home. Later studies looked at ways to provoke or measure immune response, from McLean's attempts with opsonin, leucocyte, and red blood cell measurements (including work by Cameron), and a range of techniques to measure antibody and antigen levels in blood and tissue samples. All of these gave at best ambiguous, and at worst contradictory results. For example, in the late 1960s, Cameron found no change in the leucocytes of his twenty-seven subjects over an Antarctic season or on the return home, remaining confident that the disease experienced in and after Antarctica was usually mild.[85] Yet at the same time, in the late 1960s, Russian studies of blood serum to measure antibodies suggested a significant decline in 'polarmen' over a single wintering-over period, which correlated with reports of 'sharp respiratory and dyspeptical [sic] illnesses on their way back home'.[86]

To summarise, in the closing decades of the twentieth-century folk wisdom, 'common sense' and empirical evidence still dominated writing about infection in Antarctica, which usually framed the experience in the established manner: burnout of disease, prolonged periods of 'good health', and then the rapid reinfection of a body on encountering new people, material objects such as old clothes, or on return home. But the claim of Antarctica as a 'natural laboratory' seemed increasingly untenable as the continent was revealed as a challenging and complex research space, offering a bewildering mix of heterogenous case studies and microbial ecosystems, and almost entirely populated by a very unrepresentative demographic of healthy young and middle-aged adult men, most of European descent. Luckily for researchers, then, this complex environment with its strange population suddenly began to appeal to a brand new funder in the second half of the twentieth century, as Antarctica moved away from being a microbial model for the 'real world', and instead became a model for spaces beyond our planet, as NASA began to take an interest in the question of disease within small, isolated, all-male populations.

This is my last phase of Antarctic microbiology, which persisted through the end of the twentieth century into the twenty-first. As was the case for 'heroic sampling', the space-oriented interest in microbiology included environmental microbes as well as those in and on the bodies of explorers. Indeed, by the mid-1960s the valleys of Antarctica were already the site of disputes over the possibility of life on Mars – with researchers arguing that Antarctica functioned as a simulacrum of the Martian surface both to prove the possibility (or impossibility) of Martian 'life', and as a space to test technologies and sampling methods. Antarctica-as-Mars proved as deadly as other forms of Antarctica, with the death in 1973 of the American microbiologist Wolf V. Vishniac, on an NSF expedition to try to prove that microbes could multiply in Antarctica's barren soil, part of an ongoing dispute with NASA scientists about the potential for life on Mars; he fell to his death in the Asgard mountains trying to retrieve sampling equipment.[87] Just three years later the NSF and NASA would collaborate to fund the largest study of respiratory diseases in Antarctica since Operation Snuffles: WinFly.

[85]Cameron, 'Staph and Viral Epidemiology', *op. cit.* (note 63), 98; A.S. Cameron and B.W. Moore, 'The Epidemiology of Respiratory Infection in an Isolated Antarctic Community', *Journal of Hygiene*, 66, 3 (1968): 427–37.

[86]I.F. Ryabinin, 'The Research of Immunological Reactivity of Polarmen in Antarctica', *Acta Socio-Medica Scandinavia*, Supp. 6, Proceedings of the Second International Symposium on Circumpolar Health, Oulu, Finland June 21-24 1971 (1972): 254–8, 257.

[87]Robert Zubrin, *Mars on Earth: The Adventures of Space Pioneers in the High Arctic* (New York: Jeremy P. Tarcher/Penguin, 2004), 21.

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The Winter-Fly In study (WinFly) ran from 1976 to 1980 and focused on the overwintering personnel at McMurdo Base, which included both military and civilian members drawn from multiple nations. Initially a single-season study, WinFly 1976 included seventy-seven human volunteers and its results immediately challenged the received wisdom of Antarctic disease: respiratory diseases did not 'die out' in the winter, and the blood samples taken from twenty-eight of the volunteers showed no change in white blood cell counts, suggesting no decline in immune response.[88] Building on these novel results the study continued through each winter season until 1980. Results were trickled out in publications in the 1980s and 1990s and were directly presented to NASA audiences in reports and at conferences.[89] Confidence in the results was high, despite the fact they contradicted the established 'myths' of disease in the far south; part of the reason for this was a substantial change in how such work could be done in Antarctica. By the late 1970s bases such as McMurdo were well-established, well-funded scientific outposts, with laboratories and significant facilities for basic microbiology.[90] In addition, the funding model now meant that the epidemiologists were just epidemiologists – not juggling roles as medical officers or contributing to geological or meteorological research, engaging in gruelling sledging expeditions, or collecting bird's eggs. The WinFly researchers were, therefore, able to collect and analyse far more data than had ever been previously feasible, including daily symptom interviews with nearly 200 residents when the base was at maximum capacity, and one-on-one follow-up interviews to trace infection chains. Blood samples were taken at the start and end of each man's time in McMurdo and anyone experiencing respiratory symptoms was asked for a nasal wash or swab, while samples were packed in dry ice and shipped to the University of Wisconsin for analysis.

Over the years of the study, WinFly contradicted every long-held assumption about disease in the far south: there was no burn out, there was no evidence new arrivals caused outbreaks, nor that the Antarctic overwintering population were made more vulnerable to infections – in fact, colds spread less easily than compared with baseline statistics from outbreaks anywhere else in the world.[91] This was, of course, extremely important news for NASA, which was very concerned that astronauts exposed to a sterile environment for a prolonged period might become extremely sick on return to Earth. But as important was the WinFly finding that disease could be relatively easily *prevented* in the sort of spaces that interested NASA: enclosed, overcrowded, artificial environments. The careful contact tracing evidenced that it was not the extreme natural environment of Antarctica itself but the human-created one that enabled transmission; rather obviously to readers in the age of COVID-19, transmission of respiratory viruses was tightly associated with overcrowding and poor ventilation. But even more exciting was the finding that even in buildings with high transmission rates, infection could be completely prevented by using an extremely simple, cheap technology: the Killer Kleenex.[92]

[88] E.C. Dick *et al.*, 'Respiratory virus transmission at McMurdo Station: isolation of rhinoviruses from common colds during the winter fly-in period, 1976', *Antarctic Journal*, 12, 4 (1977): 2–3; E.C. Dick, 'Lack of Increased Susceptibility to Colds in the McMurdo Winter Parties of 1975 and 1976', *Antarctic Journal*, 12, 4, (1977): 3–5; T.C. Flynn, L.W. Fusch, and E.C. Dick, 'Colds and Immunity in the 77 Winter Personnel at McMurdo', *Antarctic Journal*, 12, 4 (1977): 5–6; P.A. Shult, F. Polyack, and E.C Dick, 'A Mild Outbreak of Adenovirus Type-21-Caused Respiratory Illness at McMurdo Station in 1977', *Antarctic Journal* (1985), 261–2.

[89] Anonymous, 'Epidemiologic Research in Antarctica', in *Biomedical Polar Research Workshop Minutes* (Washington DC: NASA, 1990). https://ntrs.nasa.gov/citations/19930007611; E.C. Dick, 'Rhinovirus Infections in an Isolated Antarctic Station: Transmission of the Viruses', *Antarctic Journal* (1984): 183–5; Peter A. Shult *et al.*, 'Adenovirus 21 Infection in an Isolated Antarctic Station: Transmission of the Virus and Susceptibility of the Population', *American Journal of Epidemiology*, 133, 6 (1991): 599–607.

[90] Georgina A. Davis, 'A History of McMurdo Station through Its Architecture', *Polar Record*, 53, 2 (2017): 167–85.

[91] David M. Warshauer *et al.*, 'Rhinovirus Infections in an Isolated Antarctic Station. Transmission of the Viruses and Susceptibility of the Population', *American Journal of Epidemiology*, 129, 2 (1989): 319–40.

[92] E.C. Dick *et al.*, 'Interruption of Transmission of Rhinovirus Colds Among Human Volunteers Using Virucidal Paper Handkerchiefs', *Journal of Infectious Diseases*, 153, 2 (1986): 352–6.

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Instead of the standard WinFly in 1979 the team instead experimented with a virucide-impregnated facial tissue in cooperation with a pharmaceutical company, SC Johnson of Wisconsin (the final product was made in the Auckland factory of SC Johnson for easier transport to the Antarctic).[93] A series of staff briefings explained the purpose of the tissues, and two weeks into the season a box of tissues was handed out daily to McMurdo residents as they waited in the 'chow line' at the mess hall; larger packs were placed as 'strategic places over the base'.[94] These packs were renewed every day as the group 'loaded the bed of a truck with large tissue packets' for distribution on what they called 'a very cold "paper route"'.[95] This effort was rewarded, as after an initial rise in infections at the start of the season, both the incidence and prevalence of infection plummeted, sustaining a statistically significant lowered rate of infection for the whole of the 1979 winter season. But even this successful experiment, and its follow-ups, demonstrated the specificity of the Antarctic environment as an experimental space; the Killer Kleenex researchers acknowledged an 'atypically' high compliance level from the approximately 200 base personnel, which they credited to the fact that influenza was identified on the base early in the season, making the Antarcticians more wary of infection. In a subsequent study in 1980, no flu outbreak occurred and less dramatic (though still significant) declines in infection were observed – in part due to less compliance (the team were unable to give their pre-experiment briefing on the tissues), and in part due to an atypical respiratory disease outbreak just before the experiment, blamed on a visiting band whose leader may have spread his own infection by singing to crowded audiences.[96] The variability, and expense, of Antarctica, perhaps proved too much for the researchers who continued to pursue their tissue studies in a simpler laboratory setting, using isolation chambers back in the USA, with human guinea pigs asked to play poker, sometimes for as long as 12 hours, all of which emphasised the role of ventilation (and not touching one's face too much) in prevention as much as the value of the tissues themselves.[97]

This slippage between Antarctica as a natural 'controlled' laboratory, and a complex and unique environment echoes my argument that in these spaces researchers moved – almost seamlessly – between field and lab, simulation and model, 'natural' and 'artificial' laboratory through the twentieth century.[98] This slippage is particularly visible in the scholarship on NASA's biomedical and biological research, where, for example, medical puzzles such as the impact of weightlessness on the human body were studied using 'vomit comets', subaquatic studies, and investigations into the consequences of bed rest.[99] Antarctica was folded into these varied studies as a possible model, simulation, and laboratory, particularly focusing on the isolation of its populations in relation to psychological and pandemic puzzles. Most notable in terms of tying Antarctica to space research was the appointment in 1991 of Dr Desmond Lugg as Chief of the NASA committee on the Medicine of Extreme Environments; we have previously met Dr Lugg briefly, trying to get funding for an antibiotic resistance study, and when he took up the NASA post he had already put in three decades of leadership of the medical program of the Australian Antarctic Division – again emphasising the role of Australian research in a global, and now extra-global, scientific realm.

It is not my intention here to provide a detailed list of the NASA-funded work in Antarctica through to the end of the twentieth century. The relationship between Antarctica and space travel is too much to be considered in depth in this article; artificial simulation in the Arctic has been considered by Zubrin, and Bimm has offered our first serious consideration of the physiology of astronauts – including simulations – so there is a strong platform on which to build a better understanding of the role of the

[93]Elliot C. Dick *et al.*, 'Possible Modification of the Normal Winter-Fly-in Respiratory Disease Outbreak at McMurdo Station', *Antarctic Journal of the United States*, 14, 6 (Review 1980), 173–4.

[94]Anonymous, 'Epidemiologic Research in Antarctica', *op. cit.* (note 89), 7.

[95]Anonymous, 'Epidemiologic Research in Antarctica', *op. cit.* (note 89), 7.

[96]Anonymous, 'Epidemiologic Research in Antarctica', *op. cit.* (note 89).

[97]Dick et al., 'Interruption of Transmission', *op. cit.* (note 92).

[98]Heggie, *Higher and Colder*, *op. cit.* (note 56).

[99]Priyavarshini Ramesh, '"Floating in a Most Peculiar Way": A History of Space Medicine and the Knowledge of Human Physiology in Weightlessness during the Space Race (1955-1975)' (Unpublished BMedSc Dissertation: University of Birmingham, 2021).

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Antarctic in space exploration.[100] I will generalise here though and say that the research tended to move away from the microbial and into the psychological (as indicated by the late 1980s emphasis on behavioural research), and where the microbial remained of interest the focus was on the immune systems of isolated populations.[101] When it came to immunity, NASA was particularly interested in the question of whether it was the cold or the isolation that suppressed immune systems – and indeed if they were suppressed at all, as the consequences for astronauts on arrival in new, unsterile environments, or on return to the germy earth could be deadly.[102] It will probably come as no surprise to readers to find that Antarctica provided no simple answers to this puzzle, and into the early twenty-first century the apparently simple question 'does lack of exposure to microbes cause a (risky) decline in human immune response' did not have a conclusive answer.[103]

Conclusion: Three phases and three lessons from Antarctic germ theory

The three-phase chronology of Antarctic microbiology proposed here maps to funding justifications and practices. Initially, expedition organisers were able to appeal to novelty; this was an unexplored region, its microbial life was entirely unknown, and even the most basic samples – in the 'collect, grow, identify' tradition of the 'heroic age' – could provide discoveries, further scientific knowledge, and by extension add to national prestige as well as boosting claims to possession and exploitation of the new continent.[104] As human presence in Antarctica increased and brought more permanent laboratory structures, the justification and need for more focused *human* microbial studies separated from those of environmental microbial life; this is the point where researchers began to appeal to the trope of the continent as a 'natural laboratory', moving us into the more systematic studies of the late 1940s and onwards. Antarctica was viewed as a simplified population laboratory, providing an isolated, easily surveilled, and highly compliant series of human populations, allegedly functional as models for a wider, more complex, society. This imagining of Antarctica was not limited to microbial work but was deployed for studies including psychosocial interactions, dietary studies, and circadian rhythm research, and this 'natural laboratory' concept was widely applied to justify the risk and the expense of research in many forms of extreme environment.[105] This intense study led to its decline as the results of epidemiological studies and artificial infections alike upset the notion of a 'natural laboratory' and Antarctica as a model for 'the real world'. Results were challenging, ambiguous and contradictory, established beliefs such as 'burn out' or 'reduced immunity' were repeatedly overturned and then restored, and it became very obvious that Antarctica was not a pure, simplified, experimental space but a series of heterogenous environmental

[100]Zubrin, *Mars on Earth*, *op. cit.* (note 87); Jordan Bimm and Patrick Kilian, 'The Well Tempered Astronaut', in *Nach Feierabend: Der Kalte Krieg* (Zurich: Diaphanes, 2017), 85–107; Jordan Bimm, 'Andean Man & the Astronaut', *Historical Studies in the Natural Sciences*, 51, 3 (2021): 285–329.

[101]Albert A. Harrison, Yvonne A. Clearwater, and Christopher P. McKay, 'The Human Experience in Antarctica: Applications to Life in Space', *Behavioural Science*, 34, 4 (1989): 253–71.

[102]See the link between Antarctic immune studies and 'interstallar travel' here: Harold G. Muchmore *et al.*, 'Neutropenia in Healthy Men at the South Polar Plateau', *Archives of Internal Medicine*, 125 (1970): 646–8. For a later summary of work, see D. Lugg and M. Shepanek, 'Space Analogue Studies in Antarctica', *Acta Astronautica*, 44 (1999): 7–12, 693–99, which suggests any reduced immune response might even be psychological. Cf. the findings of Gerald R. Taylor, 'Immune Changes During Short-Duration Missions', *Journal of Leukocyte Biology*, 54, 3 (1993): 202–8.

[103]Roy J. Shephard and Pang N. Shek, 'Cold Exposure and Immune Function', *Canadian Journal of Physiology and Pharmacology*, 76 (1998): 828–36. For a summary of Antarctic work see also D.L. Lugg, 'Antarctica as a Space Laboratory', in G. Hempel (ed), *Antarctic Science: Global Concerns* (Berlin Heidelberg Paris [etc.]: Springer-Verlag, 1994), 229–49, particularly 236–8.

[104]Dodds, 'The Great Game', *op. cit.* (note 52); Klaus J. Dodds, 'Post-Colonial Antarctica: An Emerging Engagement', *Polar Record* 42, 1 (2006): 59–70; Shirley V. Scott, 'Ingenious and Innocuous? Article IV of the Antarctic Treaty as Imperialism', *The Polar Journal* 1, 1 (2011): 51–62.

[105]Heggie, *Higher and Colder*, *op. cit.* (note 53). For a late use of the argument that Antarctica provides a '"simpler" environment' for microbial studies, see M.D.M. Hadley, 'Nasal Carriage of Staphylococci in an Antarctic Community', in G. Smith and A. Macdonald (eds), *The Staphylococci: Proceedings of the Alexander Ogston Centennial Conference* (Aberdeen [Grampian]: Aberdeen University Press, 1981), 239–51, 251.

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experiences full of variable human factors.[106] Hence the third, complex stage of Antarctica as multiple 'laboratories' where it was allowed to model *itself*, or – more profitably in terms of funding – the unusual and high-stakes challenges of space travel.

There are surprising absences in this story. Although it became clear that microbes behaved differently, and created different infection patterns and symptoms in Antarctica, no systematic form of polar microbiology appeared as a specialism in the twentieth century. AMR, gaining increasing significance globally through the second half of the twentieth century, is barely represented in Antarctic research. Perhaps most surprisingly of all, the issue of *quarantine* is almost entirely absent in the work on Antarctic infections.[107] Even as late as 1980 a band member with a known respiratory infection was allowed into a crowded Antarctic base where a microbial study was taking place. While the logistics of the barely staffed bases of the early century might have made quarantine an impossibility, by the end of the century one might have expected some form of biocontrol for explorers with infections, or at least for the arriving ships given the belief that they posed a particular threat to the reduced immunity of base residents. I have found not even a hypothetical discussion of this possibility. This is in stark contrast to the use of biocontrol for other incoming organisms.[108] Although casual attitudes to invasive species were present in the 1940s, as evidenced by the fact the 1944 BAS team brought soil and plants for 'experimental planting', by the time the BAS director, Vivian Fuchs, wrote his account of the work in 1980, he acknowledged that this should have been considered a biohazard ('fortunately none [of the plants] survived to confuse the natural order').[109] As early as 1961, with the Antarctic Treaty, provisions were put in place to preserve and protect indigenous Antarctic biota, and between 1989 and 1991 debates on the Madrid Protocol developed what is now celebrated as the most vigorous biological border control on the planet, as part of a comprehensive set of commitments to preserving the Antarctic ecosystem (including its more recent human archaeology).[110] For many 1994 marks a significant turning point in Antarctic exploration because this was the year the last Husky was removed from the continent, creating a significant break from a nearly century-old tradition of mobility.[111]

Instead of finding fears of infection and desires for quarantine in the biomedical archives, they are more often encountered in fictional representations, as demonstrated by Leane, Lavery, and Nash.[112] Although early twentieth-century texts, sometimes jokingly, represented the Antarctic as pure and therefore healthful, rapidly a more sinister trope emerged of frozen danger – from aliens in the Lovecraftian mode in the 1930s (visualised most famously in 1982 by Carpenter in *The Thing* remake) through to extremely contemporary anxieties about frozen bacteria and plagues emerging from the ice as the planet warms.[113] Elsewhere we know that fears of infection and quarantine often become highly

[106]On the complications and ambiguities of even sophisticated and well-funded biomedical expeditions see: Jean Rivolier (ed.), *Man in the Antarctic: The Scientific Work of the International Biomedical Expedition to the Antarctic (IBEA)* (London and New York: Taylor & Francis, 1988).

[107]As late as 2012 experts wrote of the potential danger of pandemics, but without suggesting a quarantine system: see Desmond Lugg and Jeff Ayton, 'A Century of Australian Antarctic Medicine', *Australian Science* (2012): 26–8, 28.

[108]All of the references I find to quarantine within the AAD archives are to do with botanical or biological samples, not human bodies. See, for example, [Hobart/AAD] B1387, 96/898, *Medical Administration – General – 1968-1972*, letter G.M. Budd to Des [Lugg], 23 Jul. 1971 Letter G.M. Budd to Des [Lugg], 23 Jul. 1971 re. Dr Calder's botanical specimens causing 'difficulties over quarantine procedures', and for human blood samples see National Archives of Australia, Hobart, Australian Antarctic Division B1387, 1996/701, *Medical Research – Programmes – Planning and Execution, 1972-1975*, Medical Research Programmes ANARE 1972, Letter DJ Lugg to Prof. DH Curnow, 22 Feb. 1972.

[109]Fuchs, 'Of Ice and Men', *op. cit.* (note 41), 38.

[110]Alessandro Antonello, 'Nature Conservation and Antarctic Diplomacy, 1959–1964', *The Polar Journal*, 4, 2 (2014): 335–53.

[111]Sandra Potter, 'The Quarantine Management of Australia's Antarctic Program', *Australasian Journal of Environmental Management*, 13, 3 (2006): 185–95.

[112]Elizabeth Leane, Charne Lavery, and Meredith Nash, '"The Only Almost Germ-Free Continent Left"', *Environmental Humanities*, 15, 1 (2023): 109–27.

[113]Elena Glasberg, 'Who Goes There? Science, Fiction, and Belonging in Antarctica', *Journal of Historical Geography*, 34, 4 (2008): 639–57.

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racialised, and with the overwhelmingly white population of Antarctica, we might expect more anxiety about international encounters. These are in fact rare and very sporadic: during the first German Expedition to Antarctica (1901–3) a small team left on the sub-Antarctic Desolation Islands suffered from what was eventually diagnosed (in Australia) as beriberi, which they believed to be infectious and blamed on the Chinese crew of the steamer Tanglin which had transported the expedition and its goods.[114] Much later, a mysterious polio-like illness that affected one member of the Royal Australian Air Force resident at an ANARE base in 1959–60 was tentatively blamed on a 'symptomless carrier on board *Ob*', a Russian icebreaker that had extensive contact with Japanese Antarctic teams.[115] In terms of racialised vulnerability, the only reference I have found is to the death, apparently from a respiratory infection, of a US Naval staff member at Byrd Station in the 1930s. He was 'whisked out of the Antarctic and rushed right up to the Arctic. He died a few days later' according to Paul Siple, who goes on to note that '[h]e was the only Negro we had in the scientific group' – Siple suggests his death may have been due to the virulence of that year's 'Asian' influenza, rather than making any explicit connection to the man's own race.[116] Although rare, these occasional moments of nationalised or racialised understandings of health and infection in the far south deserve further investigation.

One explanation for these three absences – specialism, resistance, quarantine – may be the straightforward reality that Antarctica *is* a relatively healthy environment when it comes to infectious diseases, which seemed much less prevalent in the far south, with a comparatively high degree of harm caused instead by accidents.[117] Some of this 'healthiness' has to do with the low environmental microbial load, as Stefansson wrote in 1940, while the explorer of the tropics discovered that 'every scratch festers, even small wounds are dangerous, and that antiseptics must be the central part of your emergency medical equipment. In the polar regions, you have the opposite extreme.'[118] This contrast between the poles and the tropics is significant – as other historians have shown, one of the things that made tropical medicine such a powerful specialism was the acceptance of the inherent danger of hot and humid countries, that these were environments that were literally germ-creating, whether they created miasmas or mosquitos or bacterial colonies.[119] This principle explained and endorsed colonial and settler policies, upheld the supremacy of the white body, and justified segregationist racial policies, including quarantine. This storyline is harder to find in the Antarctic, where the environment was figured as pure and non-pathogenic, and infection was something brought in from outside – usually on the bodies of explorers, the majority of whom were white and/or of European descent. The medical implications of Antarctica as a cold, clean and white space, and the intersections of those metaphors await its own paper, although literary scholars have begun this work.[120] But of

[114]H.R. Guly, '"Polar Anaemia": Cardiac Failure During the Heroic Age of Antarctic Exploration', *Polar Record*, 48, 2 (2012): 157–64, 160.

[115]G.M. Budd, 'A Polio Like Illness in Antarctica', *Medical Journal of Australia*, 1, 13 (1962): 482–6, 435.

[116]Paul Siple, 'Living on the South Polar Ice Cap', in S.M. Horvarth (ed.), *Cold Injury: Transactions of the Sixth Conferences July 6,7,8,9, and 10 1958 US Army Medical Research Laboratory, Fort Knox, KY* (Vermont: Capital City Press, 1960), 89–115, 96.

[117]Hedblom, 'The Medical Problems', *op. cit.* (note 77); D.J. Lugg 'Antarctic Medicine, 1775–1975. II', *Medical Journal of Australia*, 2, 9 (1975): 335–7; D.J. Lugg, 'Antarctic Epidemiology: A Survey of ANARE Stations 1947-72', in n O.G. Edholm and E.K.E. Gunderson (eds.), *Polar Human Biology: The Proceedings of the SCAR/IUPS/IUBS Symposium on Human Biology and Medicine in the Antarctic* (London: Heinemann Medical, 1973), 93–104; Cécile Tissot, Manon Lecordier, and Martin Hitier, 'Surgical Epidemiology of Antarctic Stations from 1904 to 2022: A Scoping Review', *International Journal of Circumpolar Health*, 82, 1 (2023).

[118]Vilhjalmur Stefansson and US War Department, *Arctic Manual* (Washington DC: Government Printing Office, 1940), 303.

[119]However, cf. the possibility that the tropics could be made safe if the indigenous populations and the pathogens were removed: W. Anderson, 'Geography, Race and Nation: Remapping 'Tropical' Australia, 1890-1930', *Medical History Supplement*, 20, S (2000): 146–59; Warwick Anderson, 'Coolie Therapeutics: Labor, Race, and Medical Science in Tropical Australia', *International Labor and Working-Class History*, 91 (2017): 46–58.

[120]Leane *et al.*, 'The Only Almost', *op. cit.* (note 112).

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course, there is a polar environment which has multiple Indigenous populations and it is indicative of how often, and in what ways, the peoples still referred to at this point as 'Eskimos' are discussed in relation to Antarctic microbial work. For many researchers, including McLean, the important lesson is the tragic impact of infectious diseases on a population with an apparently reduced immune system, and even into the early twentieth century they were framed as part of the inevitable extinction of 'primitive' peoples on contact with 'civilization'.[121]

While there remains work to do, as well as lining up a clear chronology this paper offers three conclusions of relevance to work in various historical fields, and in Science and Technology Studies (STS). Firstly, the complexity and blurred boundaries of 'laboratory' and 'field' are well articulated in Antarctica; the work discussed in this paper includes all three of the field spaces I have outlined in an earlier typology – the 'field laboratory', the 'field station', and the 'field site' (and of course the regular laboratory 'back home').[122] Clearly these spaces morph into or impinge on one another – here the 'field station' had direct impacts on the 'field site', actively modifying the ways in which human subjects experienced symptoms, even adjusting their microbial load. The cliched repetition of the phrase 'natural laboratory' to refer in confused ways to both 'natural' Antarctica and its human habitations belied the fact that every study revealed greater complexities.

Secondly, and importantly, the 'messy' nature of research in Antarctica should not be read to imply that it was amateur, backwards, or disconnected from global intellectual movements, or that this messiness was purely a result of 'field' work. The scale and nature of research accidents and failures were often obscured, as mental breakdowns, fires, and personal tragedies were excluded from formal publications. But such problems were not limited to the fieldwork, as they extended into the traditional laboratory spaces in the USA, UK, and Australia where finances were withheld, freezers were not capacious enough, and viruses refused to grow. This form of Antarctic science – despite all its challenges – is revealed as a node in a global network of ideas and researchers. From opsonins to phage typing researchers brought, and developed, the latest ideas in microbiology in the far south; they also returned them – often changed – to the global scientific community. Despite the gloss of national rivalry in Antarctica, the reality of scientific work demonstrates a deeply international community – a genuine community – of explorers, military personnel, scientists, and visitors who collaborated both intellectually and practically (and often emotionally), donating time, labour, and even bodily fluids to scientific work.

Thirdly, and finally, amongst all this international work one nation stands out – Australian researchers and Australian bases are disproportionately featured, at least in the English-language research. In part, this is of course because of logistics, with Freemantle in Western Australia and particularly Hobart in Tasmania as key departure harbours for many nations' Antarctic expeditions. But it has also to do with the men who went south – from McLean's work on Mawson's expedition in the 1910s to Lugg at NASA in the 1990s, Australian doctors and medical officers have contributed in a sustained way over generations to microbiological studies; Australian bases such as Mawson, Davis, and Casey repeatedly feature as sites of experiments and study.

Antarctica has maintained its pure, white, and clean reputation into the twenty-first century, despite increasing concerns about human pollution and litter; in terms of infection, it has recently been the 'last stand' against an epidemic, as the final continent to report a case of COVID-19 in December 2020, a year into the global pandemic.[123] As ever, Antarctica is networked, and yet unique; both a bellwether for danger and a last safe refuge.

[121]Russel McGregor, *Imagined Destinies* (Melbourne: Melbourne University Publishing, 2015). See also this discussion of 'isolation' and vulnerability: John R. Paul, John T. Riordan, and Lisbeth M. Kraft, 'Serological Epidemiology: Antibody Patterns in North Alaskan Eskimos', *The Journal of Immunology*, 66, 6 (1951): 695–713.

[122]Vanessa Heggie, 'Higher and Colder: The Success and Failure of Boundaries in High Altitude and Antarctic Research Stations', *Social Studies of Science*, 46, 6 (2016): 809–32.

[123]SBS News, 'Antarctica has recorded cases of coronavirus for the first time' 23 Dec. 2020 https://web.archive.org/web/20220901222220/https://www.sbs.com.au/news/article/antarctica-has-recorded-cases-of-coronavirus-for-the-first-time/9a7oz658p [accessed March 2024].

Supplementary material. The supplementary material for this article can be found at http://doi.org/10.1017/mdh.2024.39.

Acknowledgments. I want to extend my particular thanks to the various archivists at the National Archives of Australia who facilitated rapid work whilst the world was closing down in March 2020, and to the Interlibrary Loan team at the University of Birmingham Library, without whose support this work would have been impossible. Some of this work was presented at the History of Science & Technology Seminar, University of Oxford, at the History of Science Symposium, University of California, Los Angeles, and to the Antimicrobial Research group at the Institute for Global Innovation, University of Birmingham. I thank these audiences for their questions, which helped shape this final paper.

Funding. This research was made possible by a BA/Leverhulme Small Research Grant (SRG1819\190898).

Cite this article: Heggie V (2025). Germs, infections, and the erratic 'natural laboratory' of Antarctica: from Operation Snuffles to the Killer Kleenex. *Medical History* 1–22, https://doi.org/10.1017/mdh.2024.39