Chapter

Human Beings in Antarctica

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Abstract

Research on Antarctica has been continuing for over a century. While living in Antarctica remains difficult owing to the extreme conditions there, expeditions have progressed greatly in improving accommodations. Expeditioners are exposed to a harsh natural environment such as coldness, dryness, dramatic change in sunshine time, ultraviolet rays, and high altitude. They also live in an extreme condition: closed small groups, absolute isolation, limited equipment and supplies, and no evacuation. As such, expedition members are placed in an extreme physical and mental state. Antarctic doctors are responsible for protecting the health of members who are wintering-over. Statistical analysis of diseases showed that the most common cases were of injuries followed by internal medicine and dental problems. Some diseases were related to environmental factors. Medical operations such as medical screening expedition, remote medical care, and telehealth care contribute to the safety, and better health management systems are themselves subjects of research. Medical researches and operations are advancing and supporting one another. As a simulation of space, the Antarctic experience and the related breakthrough are utilised in space research. Outcomes of research on Antarctica contribute to the better understanding of human society as well.

Keywords: Medical research in Antarctica, Antarctic medicine, extreme medicine, remote medicine, telehealth, isolation

1. Introduction: departure for Antarctica

With a grand send off, the Japanese ice breaker *Shirase* leaves Tokyo's pier bound for Antarctica on a mid-November day. This fourth generation icebreaker is used by the Japanese Antarctic Research Expedition (JARE), a national Antarctic program established 60 years ago.

The ship heads south through the Pacific Ocean, crossing the equator, calls at Fremantle in the southwest of Australia, and loads supplies and the rest of its crews by airlift. Finally, it is time to head to Antarctica (**Figure 1**).

The waves in the Indian Ocean are rough. The ship enters the windstorm zone, tilting 60° to the left and right, making it hard for the crew to hold. More and more expedition members find that they cannot leave their rooms because of seasickness. Severe seasickness is a particular problem because it can exhaust members before arriving at Antarctica, lessening their ability to cope with the challenges ahead. To address this issue, a seasickness survey was conducted on a ship during a Southern Ocean storm in 2012. In the group that did not experience seasickness, there was no excessive decline in exhaled CO_2, which suggested that they were able to breathe slowly and deeply [1].

Figure 1.
Icebreaker Shirase *en route to its destination though the sea ice. (Copy right NIPR).*

The first role of doctors going to Antarctica is to provide practical medical care. However, as this seasickness issue shows, the medical data also highlight the unique influence of the special environment of the Antarctic on the minds and bodies of human beings. The effects of Antarctica on human residing there will be illustrated in this chapter.

After clearing the storm area, the *Shirase*'s crew discovers a calm sea dotted with huge icebergs and covered with ice and snow. The ship makes its way to its destination, slowed by the need to make hundreds of back-and-forth manoeuvres to cut through the thick ice (**Figure 2**). Temperatures here are much lower than those in late autumn in Japan. Nights gradually become shorter, indicating that summer is starting in Antarctica. During the "white night", when the sun does not set, the crew gathers on the bow deck to see with their own eyes the immensity of the polar continent.

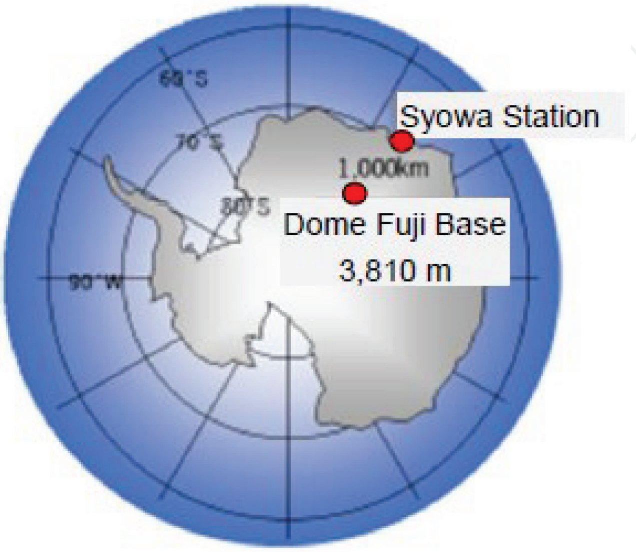

Figure 2.
Syowa Station and Dome Fuji Base. The Japan Antarctic Expedition team built Syowa Station (S 69°00′, E 39°35′) in 1956 and has continuously conducted wintering activities ever since. In 1995, Dome Fuji Base (S 77°19′, E 39°42′), altitude of 3810 m) was built inland about 1000 km away from Syowa Station.

One month after leaving Japan, they arrive at Antarctica 15,000 km away from home. This is not the end of a long journey rather the beginning of a year of surprising mysteries.

2. Antarctic station: entrance to the unknown world

Syowa Station, the Japanese Antarctic station, was built in 1956 on Ongul Island (S 69°0′, E 39°35′) 4 km off the main landmass. One of the key features of the polar region is the dramatic difference in night-time: there is both a polar night period (24 hour of darkness) and a white night period in which the sun shines all day. At Syowa Station, from November 20 to January 20, the sun does not set, and from the end of May to July 10, the sun never rises.

The eastern part of Antarctica, where the station is situated, is known for its inaccessibility. Because Japan started to explore Antarctica later than other developed nations, it had no choice but to build its station on this isolated island (**Figure 3**).

Each summer, the icebreaker carries not only a new wintering participant but also the fuel, food, and observation instruments needed for overwintering. When the short summer is over, the ship must leave the shores of Antarctica for Japan lest it be stranded in the ice, carrying with it the researchers and logistical staff whose annual mission has come to an end.

In winter, members of the station are truly isolated; the ship cannot keep pace with the thick ice mass. To complicate matters further, air routes are closed by stormy weather conditions and extreme darkness. This makes it impossible to deliver additional supplies or expedition members. Antarctica becomes almost lifeless and impenetrable. Even cold-resistant penguins and seals disappear from the landscape. The wintering-over team at the outpost must live in the narrow, enclosed space without means of escape for a long year.

Station members endure harsh conditions caused by both nature and the confinement of their outpost; indeed, the conditions are similar to what might be experienced on a Mars station in the future.

Three factors determine the number of wintering team members (**Figure 4**). One is the amount of goods that can be carried to the station, which has increased as the new generation of ship enters service. The immense thickness of winter ice makes it impossible for even a modern ship to reach the station. However,

Figure 3.
Syowa Station. The station is located on Ongul Island, 4 km off the Antarctic continent. There are no nearby bases, and when a ship departs for Japan, the station is completely isolated for 1 year.

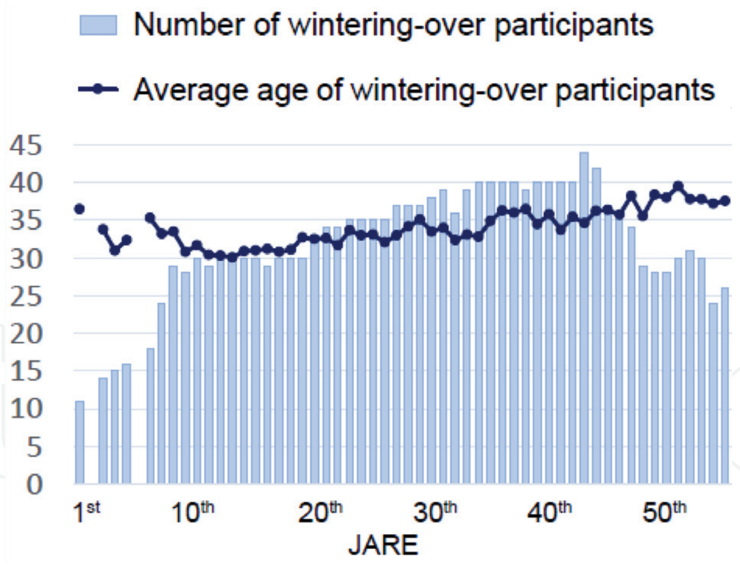

Figure 4.
Trends in number of crew members and their average ages. The first team was composed of 11 members. The number has increased to peak at 44 and then decreased to around 30. The average age has increased gradually. The most recent team's average age is 37 years.

icebreaking capacity has progressed significantly since Japan began sending Antarctic expeditions, and Japan has been forced to abandon overwintering of the second expedition team in 1957 and to reduce the number of wintering-over members for the 55th and-56th expedition in 2013—2014 when only one doctor was available. The second factor affecting wintering team member size is the capacity of the station. The station is expanded every year, and it is scalable to accommodate more than 40 wintering members. The third is the size of the research plan. Due to observation automation and the use of aircraft in the summer, the number of summer parties expanding their activities has increased and the number of wintering members is decreasing. Japan's first team consisted in 11 members; the number increased, peaking with 44 members in 2003. More recently, wintering parties have comprised about 30 people.

The wintering-over member's average age has been trending upward year and year. In 2015, the average age of wintering team was 37 years old.

Women have been participating in Japanese Antarctic wintering-over team since 1998. They totalled 5% of participants from 2002 to 2015.

The composition of the wintering-over party is decided a year prior to departure. Candidates are subjected to a rigorous health check including head CT, gastroscopy, abdominal ultrasonic examination, and electroencephalogram. The examination also includes a psychological assessment. Researchers and some logistics staff are selected by recommendation. Other staff members, such as medical doctors and cooks, are recruited through public offering.

Each new group meets when they begin to prepare for the trip. The selected candidates participate in two training camps in winter and summer. After completing the camp trainings, they start gathering supplies at the expedition centre 5 months before departure. They also complete a 24-hour shared life experience on the outbound ship. Through this training, mutual understanding and relationships gradually develop. In such isolated conditions as those in Antarctica, cooperation within the team is indispensable not only for research but also for the safety of the station and wintering-over members. Despite their extensive training, some members might have difficulty adapting to their new environment. Cases of severe depression and suicide have been reported at other international stations. Methods for screening for unsuitability at the time of selection have been studied, though this remains a significant challenge, as many people who manifest psychological and social problems during overwintering are known to have led a normal life before setting foot in Antarctica. The behavioural gap makes it difficult to identify individuals who may be unfit for the mission during the selection process. A screening method that can be universally recommended has not yet been found.

Meanwhile, the importance of leadership in the Antarctic context is of growing interest. Spending a long time in isolation is always challenging. Managing individual personalities for the benefit of the team is critical to the success of the mission and the wellbeing of all members.

3. At the bottom of the dancing aurora

White nights end around mid-January. Towards the end of February, nights begin to become darker still, and during nice weather, the aurora dazzles onlookers in against a sky full of stars. The length of the day decreases by 5 hours per month up to the polar night. The speed of change is fast enough for observers to notice the difference in brightness within 2 days. The weather deteriorates and the temperature drops rapidly.

At the outpost, work progresses smoothly. The medical office has adequate space in the narrow station. One of the two station doctors is a surgeon. Most stations in Antarctica have only one doctor, which is risky, as he or she may also require medical attention. To avoid this hazard, stations such as JARE make the presence of two doctors mandatory. There are no other medical staff such as nurses.

The total number of injuries and diseases during JARE's first 43 wintering-over periods is 4931 cases (from 1956 to 2002) [2]. The percentage of occurrences sorted by specialty is shown in **Figure 5** above. The most common cases comprise injuries, followed by internal medicine issues and dental problems, respectively. Dental problems are known to be prevalent at every Antarctic station. Because all kinds of medical troubles including dental problems occur among Antarctic overwintering participants, doctors universally act as generalists.

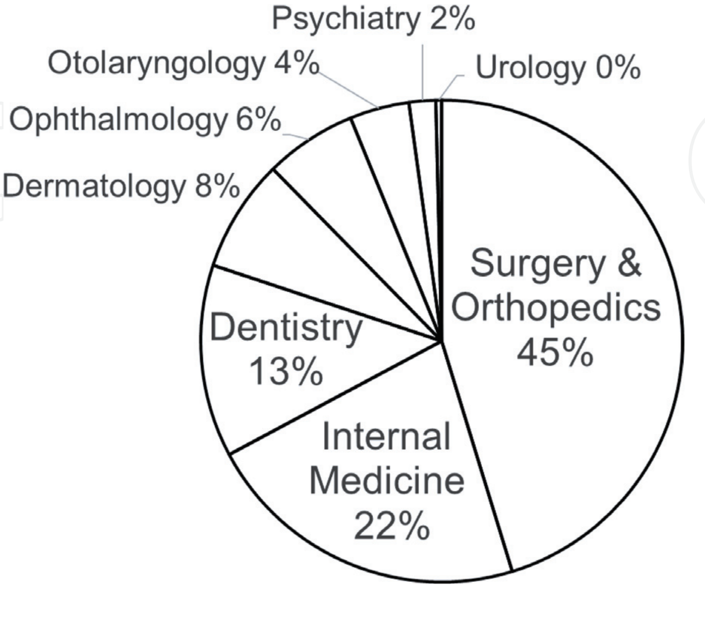

Figure 5.
Medical consultations of wintering crew members. The total number of medical consultations at Syowa Station cases from 1956 to 2003 was 4931. Among them, 4633 cases with known onset month were analysed. The most common cases were surgery and orthopaedics, followed by internal medicine and dental problems, respectively. The diseases covered every field.

The sole death at Syowa Station was caused by distress in a blizzard. The majority of the recorded 76 deaths at Antarctic stations were caused by accidents (e.g., aircraft accidents, falls, distress, and carbon monoxide poisoning). However, acute cardiac insufficiency, such as a myocardial infarction, has also claimed wintering-over persons [3, 4].

The medical post in Syowa Station is equipped much like a small hospital in Japan: it has the capacity to conduct X-ray fluoroscopy, electrocardiograms, blood tests, and abdominal ultrasounds in addition to general examinations [3, 4]. Although the equipment is rarely used, it is always maintained as well as in Japan so as to handle any emergency; the station is prepared to treat severe cases, all anticipated diseases expected to occur, and even rare but serious infectious diseases such as tuberculosis.

Syowa Station has an operating room with enough equipment to conduct surgical operations under general anaesthesia. To date, two appendectomies have been conducted at the station. Other stations have reported operations relating to appendicitis, subdural hematoma, and fractures. Surgical operations are extremely difficult to perform in Antarctic conditions for a variety of reasons, such as difficulty maintaining anaesthesia, applying blood transfusion via “walking blood bank”, preparing an aseptic operation space and working without assistants such as nurses. In a case at a Russian station in 1961 illustrating the risks of relying on a single physician, the station’s sole doctor was forced to perform surgery on himself when he suffered from appendicitis [5].

Given capacity limitations, there are cases when evacuation to Japan becomes necessary. At Syowa Station, four medical evacuations have been undertaken for patients who suffered pelvic and femoral fractures, acute renal failure, and arrhythmia. Three cases required sea evacuations that lasted 25 to 120 days. The other case was air lifted to Japan. This patient was carried by a small regional plane to Norway’s Antarctic station 1200 km away, and this is one of the few stations equipped with a runway that an intercontinental airplane can use. The patient was then transported to Japan via South Africa over a period of 6 days. Although the use of an aircraft drastically shortened the evacuation duration, it cannot be said that the procedure is fast enough to suffice in case of a severe emergency. It was fortunate that all evacuations happened in summer, when it was still possible to transport patients off the continent [3, 4].

Every country operating in the Antarctic, including Japan, pursues the possibility of an evacuation route, especially in winter. Though a few intercontinental air operations have been conducted in winter as unusual events at certain stations under extremely favorable conditions, it is nearly impossible for any evacuation or rescue team to operate either by sea or air during winter because of limited visibility and bad weather.

Medical collaboration occurs between various nations in areas where stations are adjacent. There are nine stations of representing eight countries on King George Island at the northern tip of the Antarctic Peninsula. In these areas, mutual medical cooperation is advancing through consultation on specialised fields, shared use of inspection equipment, and so on. However, most of the stations on the continent, including Syowa Station, are isolated and do not have any nearby stations with which to cooperate.

In such situations, telemedicine plays a vital role; it has been successfully operationalised in Antarctica. Nonetheless, it is notably restricted by the technology available. In 2004, a satellite television connection was installed, linking Syowa Station and domestic hospitals in Japan (**Figure 6**). Telemedicine using this system is highly effective for both diagnosis and treatment in orthopaedic medicine (e.g., fractures, arthritis, and ligament injuries), rehabilitation, and dentistry, among

Figure 6.
Telemedicine Scene. The patient has a knee ligament injury. To evaluate the joint motion and pain, the therapist in Japan (left side in foreground) demonstrates the procedure on the simulated patient (right side). Then, Antarctic doctors (on the screen) perform as instructed by the therapist in Japan, who diagnoses the case and recommends a therapy plan.

other fields. However, in certain areas as audiology and dermatology, the technology shows some limitations because of the difficulty in taking images or ensuring a high enough resolution [6]. In summary, consultations with colleagues in Japan have advantages for both patients and Antarctic doctors who deal with patients issues outside their own specialty and within the restrictions of the limited local facilities.

An Antarctic doctor lives with several constant stresses, including the tension between the knowledge that their services may not be required—healthy young participants rarely need doctors' aid—but , once they are needed, that need may be extraordinary, and they may not be able to save the lives of those suffering from severe issues.

4. Careless frostbite and unpreventable frostbite

It is the first experience for almost all doctors to visit Antarctica. They are confused by the difference of medicine between Antarctic environment and the daily site. However, if it is possible to predict the diseases which may occur and the time of onset, doctors can prepare themselves and take preventive measures.

For that purpose, an analysis was done on the medical consultations of participants at Syowa Station during the first to 43rd wintering over (from 1956 to 2003). The total number of wintering-over participants was 1278; 4931 medical cases occurred during this period. Among them, 4633 cases in which the month of onset was clear were used to analyse rates of incidence by month.

In the analysis of each year, there are limitations in seeing the original tendency because the number of cases is small, and circumstances unique to each year may exert influence. Aggregation over 40 years eliminates these problems.

Figure 7 shows numbers of monthly consultations. The cases increase at the start of overwintering and sharply drop during the polar night. Thereafter, the rate shows a gradual decreasing trend with no particularly notable changes.

Frostbite increases and peaks in May (**Figure 8**). This coincides with late autumn which is not the coldest season of Antarctica, experiencing temperatures of −15 to −20°C (rarely experienced in Japan) that drop rapidly. Such an increase in frostbite incidence may be due to carelessness and unpreparedness.

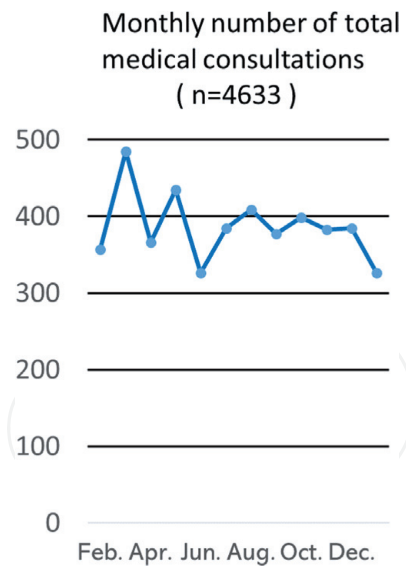

Figure 7.
Monthly evolution of all 4633 cases recorded from 1956 to 2003. The total number of medical consultations at Syowa Station was 4931 cases from 1956 to 2003. Among them, 4633 cases of with known onset month were analysed. There is no particular seasonal variation, but the cases frequently occur at the start of overwintering, and there is a gradual decreasing trend thereafter.

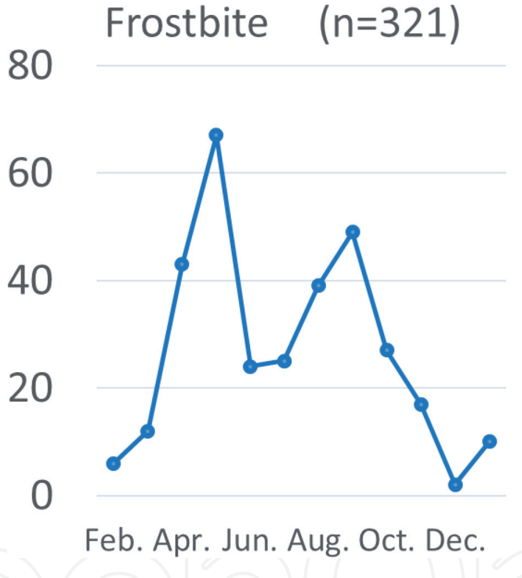

Figure 8.
Monthly occurrences of frostbite. A total of 321 cases of frostbite occurred from 1956 to 1999. In the aggregate, incidence peaks twice: the highest in May and the second in September, during the coldest season.

Subsequently, in the polar night season, frostbite cases decrease because outdoor work is restricted.

August and September are the coldest months with temperatures of nearly −40°C. In addition, outdoor activities come into full swing. Frostbite case increases again, reaching a second lower peak that does not exceed the first. Frostbite is considered unpreventable because these cases still occur despite awareness policies and preventive measures.

5. Viruses in closed populations always require the next new population to survive

According to the same aggregate data, respiratory diseases totalled 218 cases, including instances of the common cold and upper respiratory inflammation

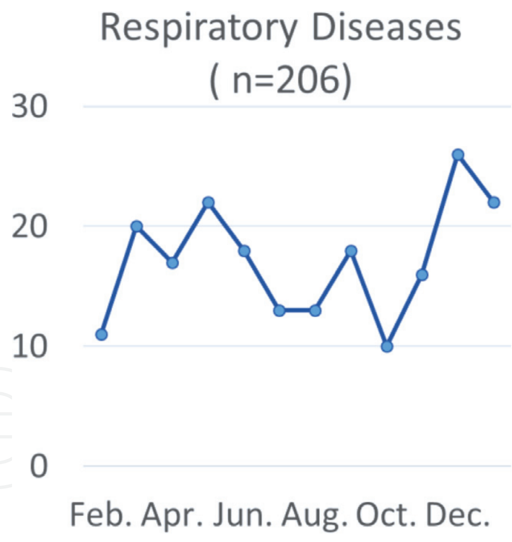

Figure 9.
Monthly occurrence of respiratory diseases. There were 218 cases of respiratory diseases from 1956 to 1999. They tend to occur at the beginning of overwintering and then decrease gradually before soaring in December.

(**Figure 9**). Environmental factors such as coldness and dryness contribute to these diseases, and the viruses that are the biggest causes of these illnesses in Japan may also be the culprits here. However, there are no viruses which naturally occur in the harsh environment of Antarctica, and it is hard for viruses brought in by humans to survive among the small isolated group of station occupants once the people

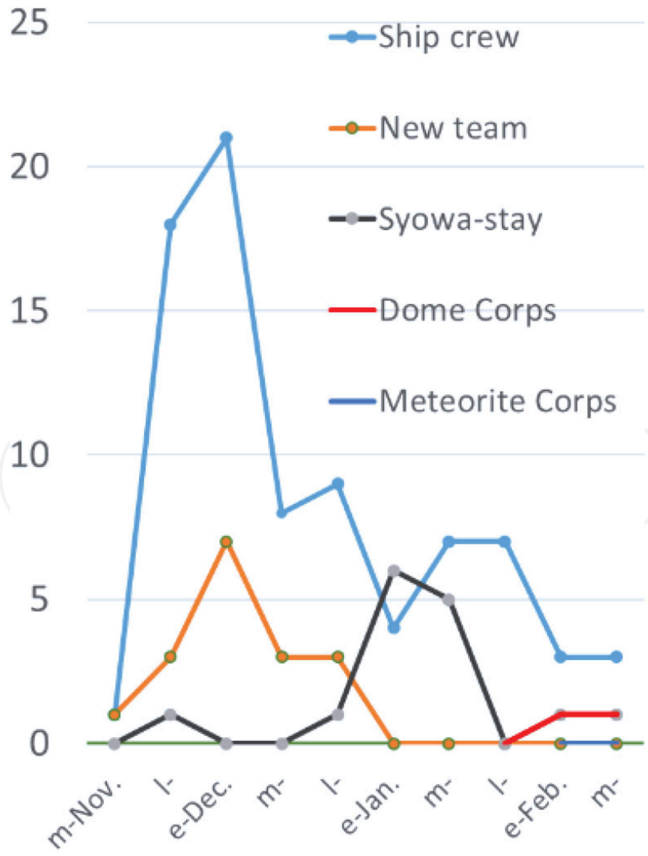

Figure 10.
A cold outbreak on the Icebreaker ship and at Syowa Station after the ship's arrival. The number of newly cold-affected people is shown by period: early (e-), middle (m-), and late (l-) in each month. Groups include "ship crews" and "JARE 40", who were new expedition members arriving from Japan on the ship as part of the 40th expedition. Members of the JARE 39th expedition were divided into three groups when the ship arrived at the station: 25 members were at the station; 6 members were at Dome Fuji base, returning to the station back in January; and 8 members were absent on meteorite survey inland and came back in February.

infected have acquired immunity. Looking at the disease occurrences by month, it is shown that respiratory ailments are frequent at the beginning of overwintering and then decrease gradually until soaring in prevalence in December. It is commonly known among Antarctic excursion members that a cold outbreak will present as soon as a ship has come for the first time in a year.

In one example, when the ship arrived at the station where the participants of the 39th season were finishing their 1-year term, 25 members stayed on at Syowa Station. Six members of Dome F corps and eight members of the meteorite corps were absent when the ship arrived.

A cold epidemic occurred among the outbound ship crews and new expeditioners on the ship (**Figure 10**). The outbreak was dying down when the ship arrived at Syowa Station. Immediately after the ship's arrival, an outbreak of colds occurred among the station members. When the Dome F team came back to the station, the outbreak had almost faded but two of six members caught a cold. Eight members of the meteorite corps came back to the station, 1 month after the arrival of the ship, and no cold case was recorded. This is an extremely interesting demonstration of virus behaviour in a closed group.

6. Diseases and daily living factors

There were 199 documented injuries and diseases in 1 year among the 39th team, which had 39 participants. The causes of all cases were investigated.

Diseases and injuries that occurred during overwintering are classified into three categories: health problems attributable to the natural environment (63 cases), cases related to indoor and outdoor work (55 cases), and cases related to daily life other than tasks (34 cases). The monthly number of these three categories is shown in **Figure 11**.

Natural environment-related diseases are frequent in the coldest season. Work-related diseases are high at the beginning of overwintering and from spring to summer, when outdoor activities are resumed. Lifestyle-related issues occurred throughout the year, with a tendency to increase at the beginning and end of overwintering.

Human factors may also be at play. Looking at the number of medical cases per capita among the team, there was no difference between researchers and logistical members. However, a clear difference was shown among generations; the morbidity rate is lowest in the 40s and higher among members in their 20s and 50s (**Figure 12**) [7]. This suggests that life experience might be involved in the

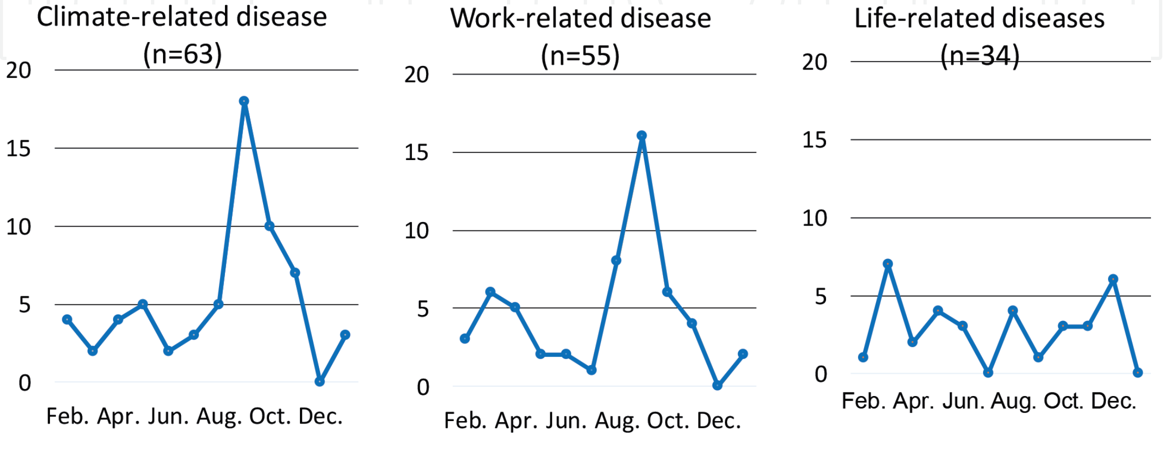

Figure 11.
Monthly change in number of diseases attributed to natural environment, work and ordinary life. Among 199 cases that occurred during one year at Syowa Station from February 1998 to January 1999, 63 cases were due to natural environment, 55 cases to work, and 34 cases to daily life. There was a seasonal change in occurrence in each disease category.

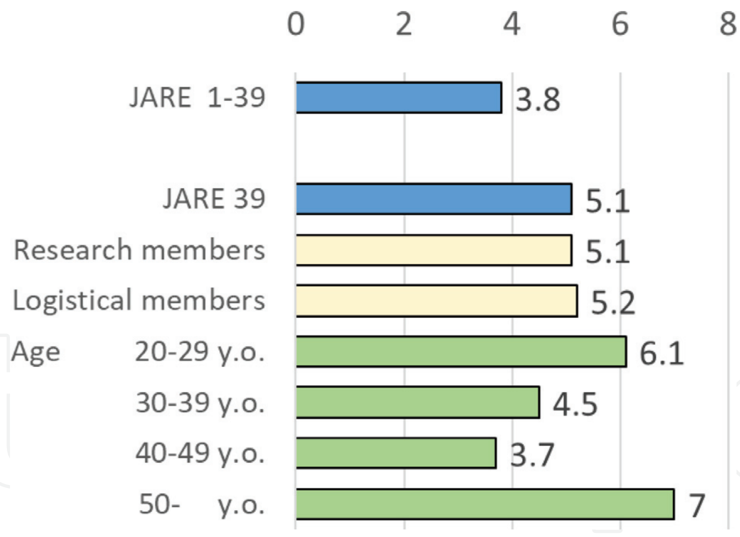

Figure 12.
The number of medical cases per capita on the 39th wintering-over team. The wintering team of JARE 39th was composed of 39 participants and had 199 medical consultations. Frequency of injury and disease was compared between research and logistical members, between generations. (Quoted from reference [7] and partially modified.)

occurrence of injuries and diseases in addition to pointing out the relevance of physical age in extreme environments.

7. Bond strengthening at Antarctic stations

At Syowa Station, there are up to 10 activity teams for entertainment, farming, sports, movies, drinking, and more. Members are responsible for several tasks beyond their official work. These activities are thought to create an atmosphere promoting strong and smooth relationships at the station to prevent loneliness.

The sports team organises monthly events such as baseball, golf, and dodge-ball matches. Golfing in the snow has resulted in many lost balls. A beautiful game of football was once played on sea ice with diamond dust sparkling in the sky. However, few members are familiar with playing sports on the snow and ice; as a result, sports activities cause 10% of medical consultations during overwintering. Despite the potential for injuries, sports are believed to contribute to the prevention of severe medical cases by allowing members to experience and enjoy the Antarctic environment.

The entertainment team plans season-based events in monotonous Antarctica. For instance, in July, *Tanabata*, a Japanese traditional star festival, is celebrated. Everyone hangs two wish cards on a bamboo-like branch. Wishes recorded on the cards were as follows: 29% of participants wished for “Safety & Health”, 26% for “Something not in Antarctica”, 21% for “Family”, 16% each for “Work”, “Lover”, and “Weight loss”. The wishes are considered to be different expressions of experienced stressors. This result is similar to finding from a study on single Japanese individuals living overseas.

8. Losing the sun

Entering the overwintering period, the day, ever shortening, finally disappears. Losing sunshine for a complete day is characterised by the experience of darkness, coldness, and a sense of the solar loss. People feel sleepy at noon and have difficulty sleeping at night. Confusion abounds; when a person wakes up and sees the clock showing 1 o’clock in the dark, he or she cannot judge quickly whether it is daytime or the middle of the night.

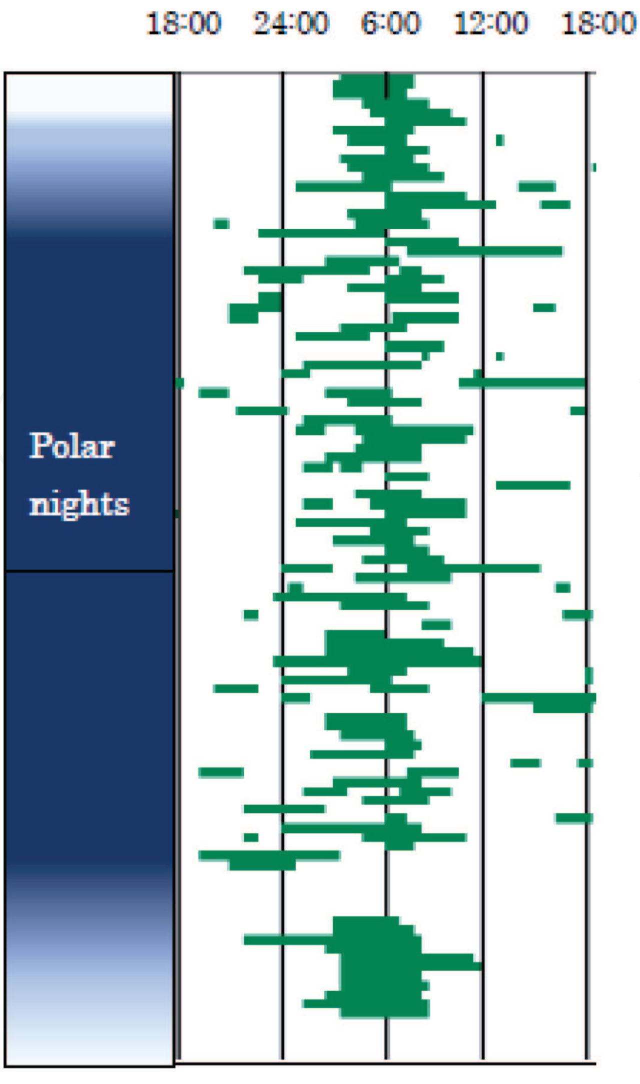

Figure 13.
Trend of sleeping hours of one crew member. The vertical axis shows the period from May to July, while the horizontal axis depicts the time of day; the green belt is the sleeping time. The person is a male mechanical member in his twenties. He originally had a habit of staying up late. Regularity of sleeping hours disappears during the polar night period. After the polar night is over, his work-load increases, which improves sleeping patterns.

The human biorhythm is said to consist of a 25-hour cycle, which is 1 hour longer than a normal day. This cycle is reset by the brightness of morning sunshine.

During polar nights, the sun never appears during the day. The human biorhythm will not be reset and will fall into its 25-hour cycle. As social life is another trigger to reset this rhythm apart from light, the regimented timetable of station life ensures that the rhythm sustains the typical 24-hour cycle.

However, during this period, outdoor activities cannot be carried out because of the darkness, a measure to prevent accidents. Monotonous days become the norm and are less effective in resetting the circadian rhythm (**Figure 13**).

In addition to sleep disturbances, the darkness, cold, and confined nature of station life also make people feel depressed or uneasy.

9. Midwinter

Surviving this dark period safely is one of the biggest goals of station management. Various innovative activities have been initiated to address the issue. One of them is the midwinter festival.

The summer solstice of the northern hemisphere in late June coincides with the midwinter day, which is celebrated grandly in Antarctica.

The festival consists of certain special events and a grand dinner. Anticipation of this celebration, and preparation for the events and dinner, gives the station a bright atmosphere for several days.

This festival has been held since the time of Amundsen and Scott, competitive pioneers who each sought to be the first to reach the South Pole. Even now, the midwinter festival is held at most Antarctic stations, which send congratulatory messages to one another.

After the festival, the participants plod through the other half of the polar night season, and the blurred line between reality and dreams stretches on.

In mid-July, people gather at a small hill behind the station. At noon, the sun shines over the side of an iceberg for a moment before sinking behind another one. The polar night season is over. Although the end of darkness is only a short moment, when the sun peeks all too briefly out to turn the blue world to an orange shine, each member of the crew witnesses the scene and feels the moment intensely.

Despite the sun's gradual return, the cold becomes increasingly severe, yet outdoor operations increase with the daylight. Each person has clear tasks. During this period, sleep quality and rhythm improve.

10. Physiological changes in the Antarctic inland

Antarctica is covered by ice that averages 2000 m in thickness. Therefore, the Antarctic inland is an extremely cold place, and the air is rarefied. Dome Fuji Base (Dome F), an inland Antarctic research base operated by Japan, is located at S77°19′, E39°42′. It is 3810 m above sea level and separated from Syowa Station by about 1000 km (**Figure 14**). The annual mean temperature at Dome F is −54.3°C; the lowest temperature (−79.7°C) was recorded in 1996.

In general, an inland JARE party typically comprising around 10 members leaves Syowa Station with several large snow vehicles on a 4-week drives to Dome F. Extreme environmental conditions in the Antarctic inland may cause hypoxia, mountain sickness, frostbite, depression, and so on. To better protect the safety of excursion members during Antarctic inland expeditions, we are collecting physiological data from members of inland parties.

Figure 14.
Dome Fuji Base. It is located at S 77°, E 39°, 3810 m above sea level and separated from Syowa Station by about 1000 km, where the snow field extends as far as the eye can see. Most of the base facilities are under the snow.

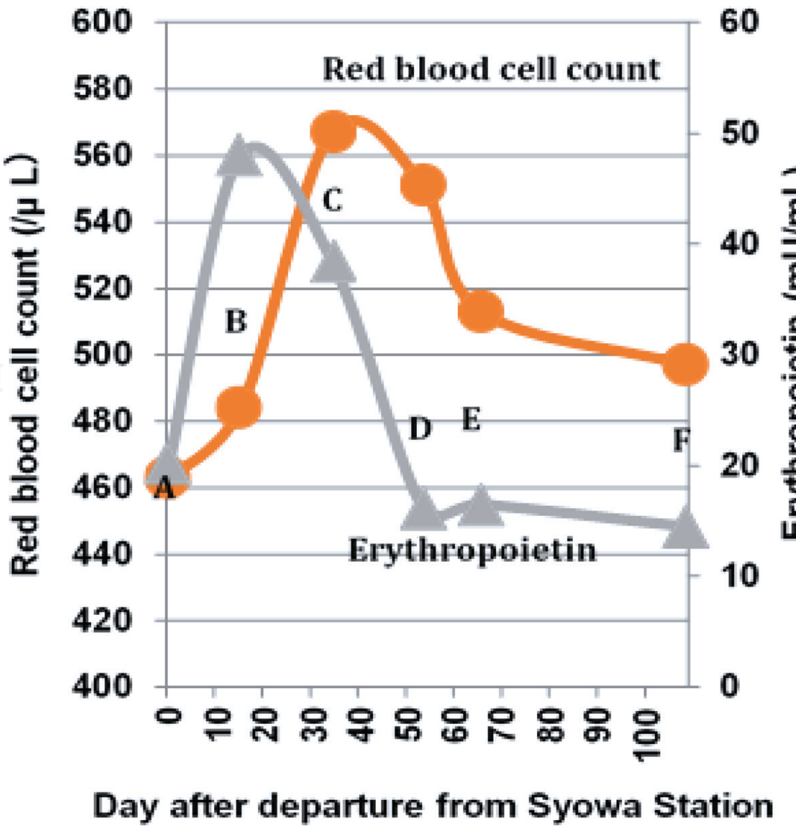

Figure 15.
Trends in the serum concentration of erythropoietin and red blood cell count. Sampling point: A, Syowa Station (29 m); B, 3032 m; C, Dome F; D, 2960 m; E 2077 m; F, Syowa Station.

Among party members, the serum concentration of erythropoietin quickly increased, subsequently leading to increased red blood cell count in a seven-member party which sets out during the austral summer of 1999–2000 (**Figure 15**). Haematological adaptation to a high altitude was completed in several weeks [8]. Percutaneous arterial blood oxygen saturation (SpO_2) levels from four parties (totalling 33 members) had a significant negative correlation with higher elevation above sea levels. However, after arriving at Dome F, party members` SpO_2 levels showed a positive correlation in the duration of their stay. This may be explained by effective high-altitude adaptation [9] (**Figure 16**).

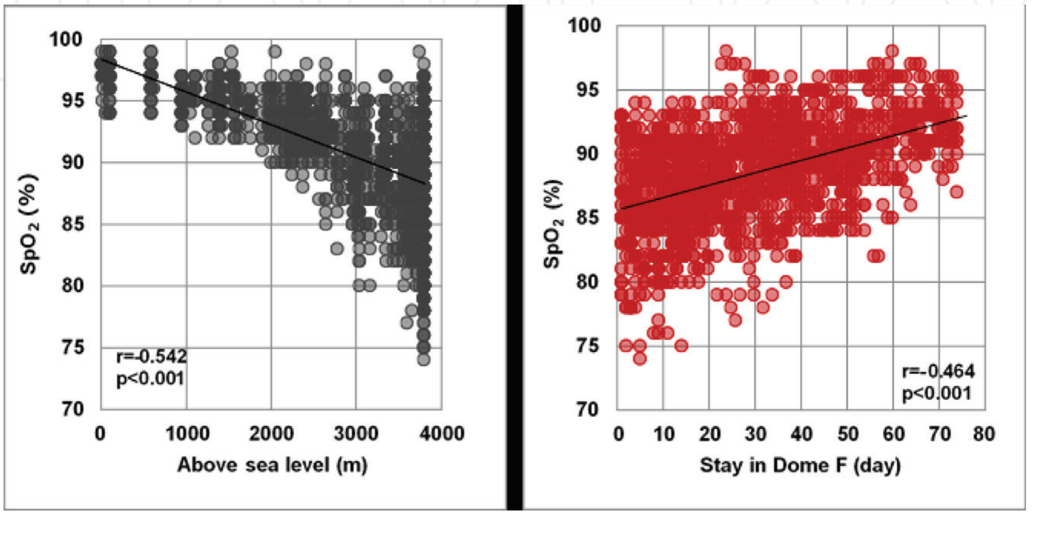

Figure 16.
Correlation between percutaneous arterial blood oxygen saturation (SpO2) levels and altitude above sea level (left), and duration of stay (days) at Dome F (right).

None of the participants suffered from severe mountain sicknesses like pulmonary or brain oedema, although some experienced headache, fatigue, sleep disturbance, or elevated blood pressure because of the slow increase in altitude. Most of party members remained in relatively good health during their Dome F stay. This demonstrates that humans can successfully survive in and acclimate to the extreme environmental conditions in the Antarctic inland.

11. Human being as an indicator of Ozone hole

After the polar night, daytime becomes longer by 5 hours a month, leading into the white night season. There are four clear seasons with noticeable light changes in Antarctica.

In October, the sun reflects on brand-new, pure white snow and ice, creating a world of light. During this time, the ozone hole is emphasised.

The ozone hole was first observed in 1980, and it continues to expand.

Ultraviolet rays from space are pouring through the hole in the ozone layer, which normally blocks them.

We have compared the ultraviolet rays in Antarctica in October with those at the equator (**Figure 17**) [10].

The results show that ultraviolet rays emanating from the sun's precise direction are as strong as those at the equator, and that the ultraviolet rays irradiating a person's face are stronger in Antarctica because of the low sun and reflection by the snow and ice (**Figure 18**).

Diseases caused by ultraviolet rays include dermatitis, conjunctivitis, and facial dermatitis. The incidence of these issues is low in winter and tends to increase in summer, which shows a correlation with the quantity of ultraviolet rays encountered. The highest incidence spans from October to December. Looking at the number of occurrences at this time in terms of annual change, a trend of gradual

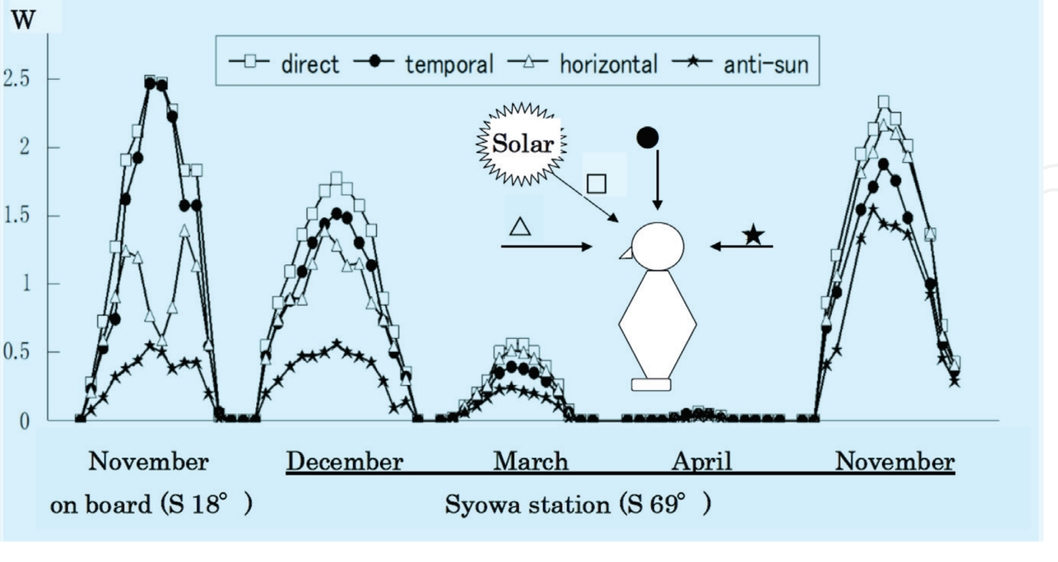

Figure 17.
Change in UVB radiation dose by latitude, season, direction, and time of day. Measurement of the ultraviolet ray radiation doses was conducted at S 18°on November 25, when the sun is directly overhead, and at Syowa Station in December (during the white nights), March, April, and November (under the ozone hole). The measurement was made every hour from 7:00 to 19:00 in four directions (zenith, direct sunlight direction, horizontal direction of the sun's direction, and horizontal direction opposite to the sun). Ultraviolet rays in Antarctica in November were as strong as those at the equator. Ultraviolet rays irradiating the face of a person were stronger in Antarctica because of the low sun and the reflection by the snow and ice. (Quoted from reference [9] and partially modified.)

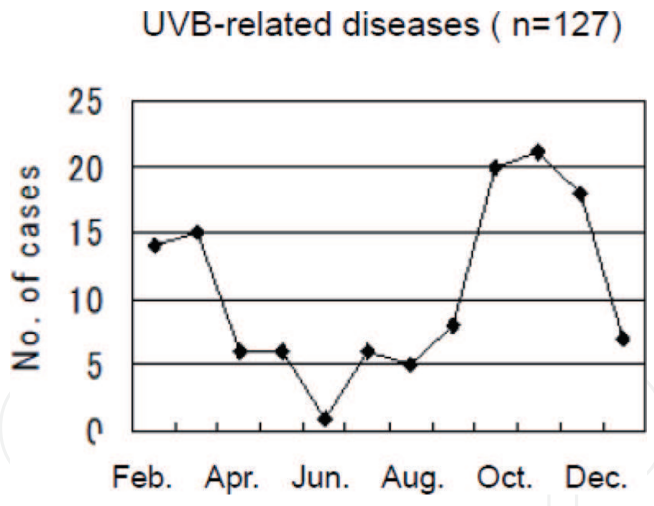

Figure 18.
Monthly occurrence of UVB-related diseases. A total of 127 cases of UVB-related diseases were recorded from 1956 to 1999. Here, dermatitis, conjunctivitis, and facial dermatitis are compiled as UV-related diseases. Not all of these are exclusively caused by ultraviolet rays; for example, they may be affected by the amount of outdoor work. The incidence is low in winter and tends to increase in summer, which shows correlation with the amount of ultraviolet rays. The highest peak is recorded from October to December, when the ozone hole appears. (Quoted from reference [9] and partially modified.)

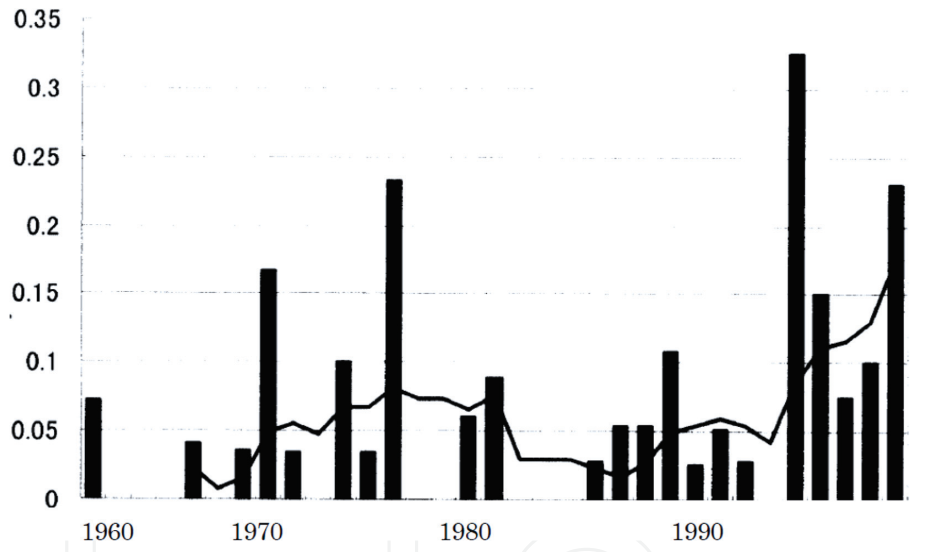

Figure 19.
Annual change in incidence of UV-related cases in the ozone hole season. Time series of total number of UV-related cases per person from August to December and moving average from 1956 to 1999. The ozone hole first appeared in the 1980′ and continues to expand. Both annual incidence and moving average have been increasing since the late 1980s (Quoted from reference [9] and partially modified.).

increases can be observed from around 1980, consistent with the appearance and expansion of the ozone hole (**Figure 19**).

Statistical analysis of these diseases has revealed the effect of the ozone hole on human health in this context.

12. Third-quarter syndrome

For many team members, wintering-over is a year in which they will endure stresses that they never previously experienced.

Diseases attributed to stress include insomnia, headaches, urticaria, hypertension, and digestive troubles. The annual occurrence of such diseases shows a

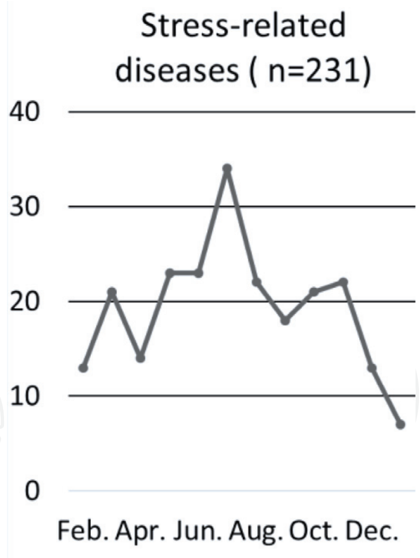

Figure 20.
Monthly change in number of diseases attributed to stress. A total of 231 stress- related diseases were recorded from 1956 to 1999. A small peak is observed at the beginning of the wintering-over period, increasing continuously until the polar night period, when it makes the highest peak. Subsequently, it decreases gradually. In early summer, incidence increases again until reaching a second lower peak.

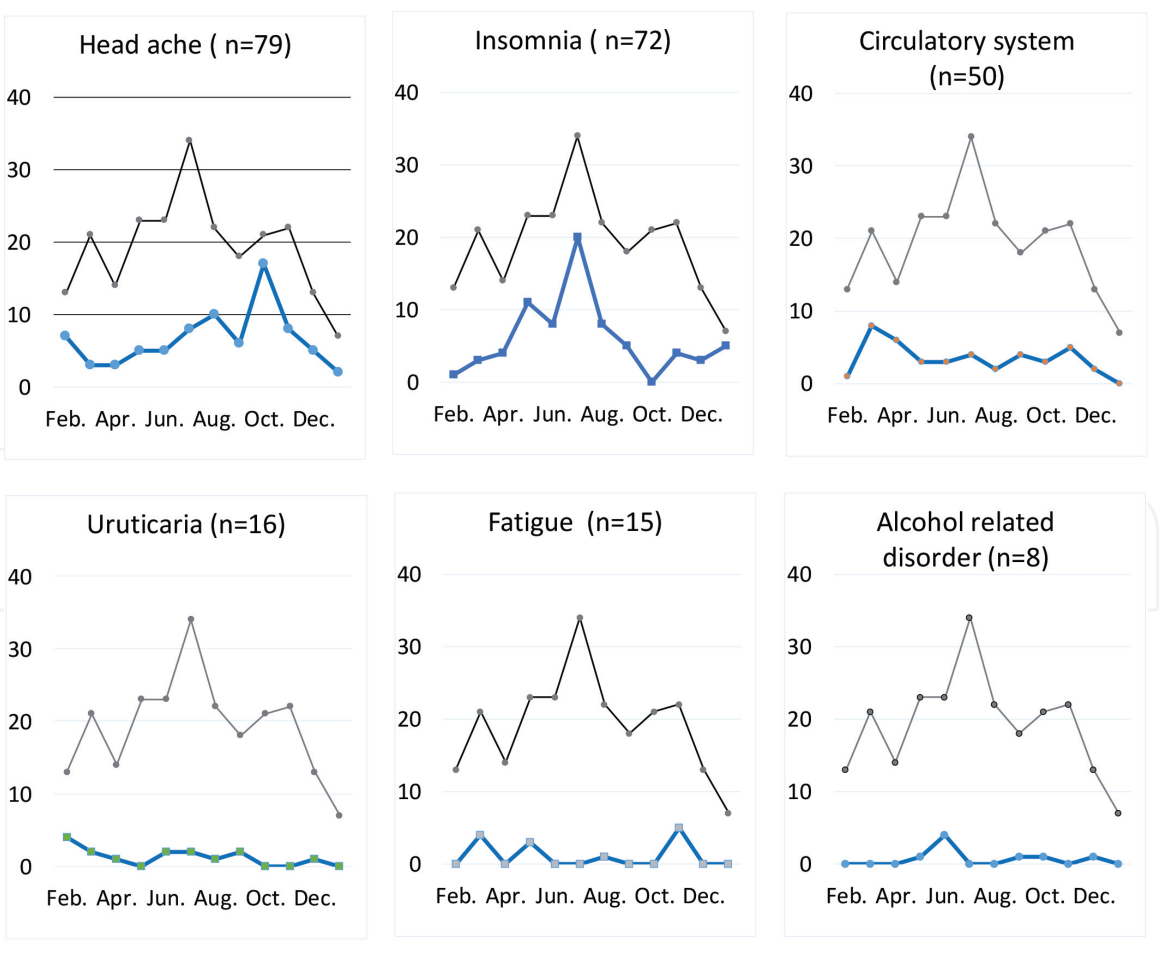

Figure 21.
Changes in numbers of major diseases attributed to stress. Several diseases caused by stress, including headaches, insomnia, circulatory system issues, urticaria, fatigue, and alcohol-related disorders were indicated in 228 cases at Syowa Station from 1956 to 1999. The blue line shows each disease, and the black line in each graph shows the total number of stress-related diseases. Each disease showed a characteristic distribution. The peak of all stress-related diseases is the sum of these various diseases, that is, various stresses.

three-peak pattern, highest at the beginning of overwintering, during polar nights and in late spring (**Figure 20**). The last peak coincides with the so-called third-quarter syndrome. It is hypothesised that the third quarter of the mission is when psychological crises tend to arise, such as a drop in morale and a rise in negative emotions.

In a psychological study of 10 consecutive years from 2003 to 2013, such a phenomenon was recognised in seven parties. Various fluctuations were found in the number of injuries and diseases experienced by these parties. However, in other parties, the number of medical consultations decreased during this time. These facts may suggest that while the harsh nature of Antarctica is similar every year, the cause of stresses experienced by team members differs each year, perhaps in accordance with human group formation changes every year.

Looking at the number of occurrences by month of each stress-related disease individually, we observe seasonal variations peculiar to each (**Figure 21**). But these changes have no relation to a seasonal change in the total number of all stress-related diseases and there is no similarity between diseases.

This suggests that the third-quarter syndrome exists, but it is not inevitable or consistent in its emergence. Second, we may infer that stress in the Antarctic is, in fact, a complex of a wide variety of stresses. Moreover, the stress that causes stress-related diseases can differ from disease to disease.

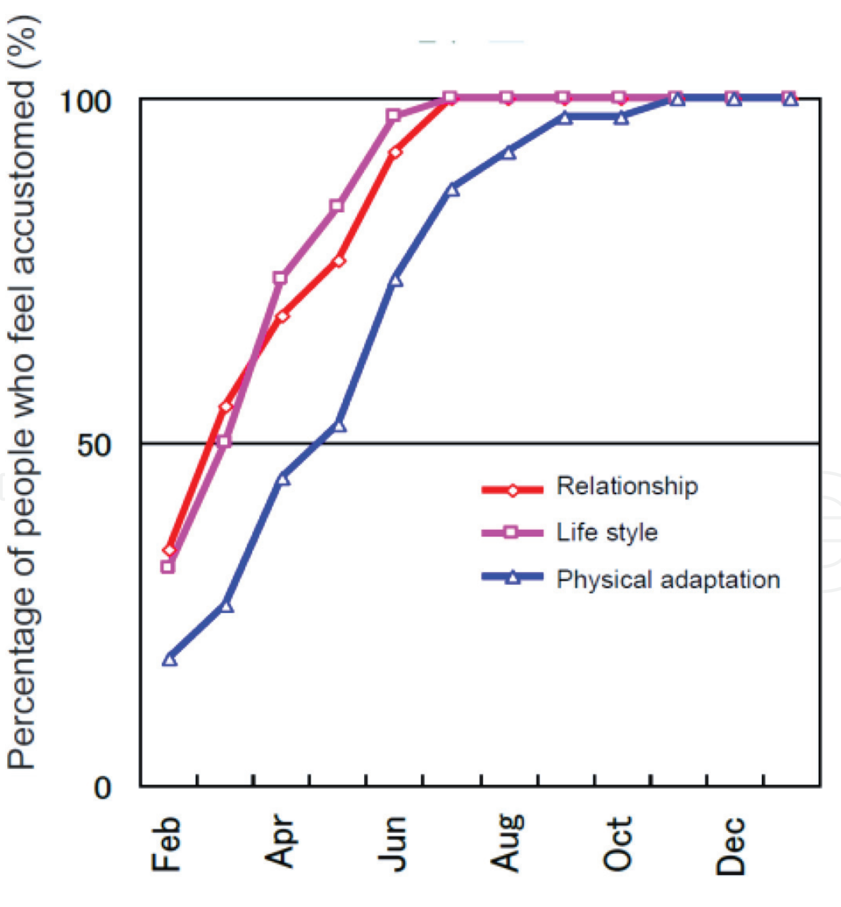

Figure 22.
Percentage of people who feel accustomed to Antarctica. The data source is a questionnaire survey on when each member felt he or she became accustomed to Antarctic relationships (orange line), lifestyle (pink) and physical condition (blue) during their overwintering year. Many persons indicated feeling that they had gotten used to Antarctic life gradually. Regarding human relations and lifestyle, all members answered that they got accustomed by July, when the polar night is over. Meanwhile, physical adaptation appears to take until November. Dramatic changes in the environment that participants had never previously experienced appear one after another. Therefore, adaptation is a continuous process that lasts until the final overwintering period.

Thus, various stresses that cause changes in each disease and the sum of those stresses are causing a yearly change such as the third-quarter syndrome.

Numerous psychological investigations have been conducted at Syowa Station [11]. Further investigation is necessary to elucidate these problems.

13. The fifth-quarter? Difficulty in acclimatising

Each December, the icebreaker arrives at Syowa Station for the first time in a year. The ship brings the next wintering-over participants wearing brand-new cold-weather gear and bearing fresh vegetables, fruits, and consigned items from the families of wintering-over members.

After finishing the handover to the new participants, the previous participants withdraw sequentially.

The helicopter circles the station before heading to the ship. The departing members recognise later that they had just taken their very last step in Antarctica.

How do wintering-over members adapt to the environment and life in Antarctica on their first visit? One-fourth of participants reported that they were able to live without feeling discomfort from the beginning. Although they are embarrassed at their lack of experience, they soon adapt. Many members have indicated that they get used to Antarctic life gradually (**Figure 22**). Regarding human relations and lifestyle, all surveyed participants answered that they got acclimatised by July when the polar night ends.

Meanwhile, full physical adaptation takes time, usually not occurring until November. Dramatic changes in this wholly novel environment appear one after another. Therefore, adaptation is a continuous process that lasts until the end of the overwintering experience.

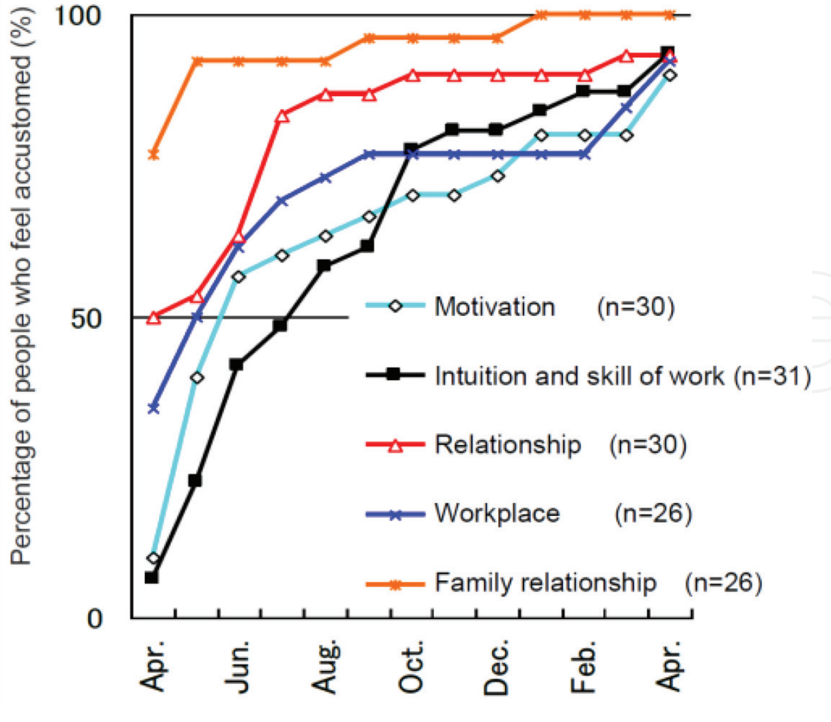

Figure 23.
Reintegration after living in Antarctica for a year. This graph shows the percentage of crew members who feel accustomed to Japan after returning home. Family relationships (orange) recover as if there was no absence. Half of participants perceive difficulties at work (blue) and with social relationships (red) upon returning. Many members recover in about 3 months, whereas some members need more than 1 year to reintegrate. Most people face difficulty at the beginning, and it takes 1 year to regain their intuition and skill at work (black). It takes time for many members to regain motivation (light blue).

Reintegration after living in Antarctica for a year is also a process of interest? Data show that family relationships recover as if there was no absence (**Figure 23**). However, half of participants reported perceiving difficulties in the workplace and with social relationships back home. Many members recover in about 3 months; those who do not recover by that point tend to remain in that tenuous state for a year. It seems to take much more time to adapt to workplace changes after returning home, being absent for a year means re-entering a workplace that may have changed procedures or staff. Most people face difficulty in the beginning, and it takes around 1 year to regain one's contextual intuition and catch up technologically. In addition, it takes time for many members to regain their motivation.

Interestingly, it seems that the strongest group—those who most easily became accustomed to the harsh Antarctic life—struggles the most to return to their lives in Japan. Human society may be harder to adapt to than the Antarctic.

14. Conclusion: departure from Antarctica

Research on Antarctica has been continuing for more than a century. The first expedition started as a challenge to survive in an unknown area. Then, the context of excursions changed to an investigation of Antarctica. At present, the purpose of research is to gain a better understanding of both earth and space.

It is still difficult to live in the extreme Antarctic climate, although expeditions have made great progress in improving the available accommodations. Expeditioners are exposed to a harsh natural environment and live in extreme conditions. The role of doctors going to Antarctica is to ensure the safe return of all overwintering members.

To this end, the effects of this dramatically different environment on the human body and mind need to be understood. Medical treatment itself in Antarctica is a subject of research, as in the case of extreme remote medicine.

Elucidation of these mechanisms and techniques is indispensable for providing medical care that protects local health regardless of environmental conditions. Furthermore, this area of medical research offers a treasure trove of interesting and varied themes for further exploration.

Antarctica has come to be studied as a simulation of space. The Antarctic environment is said to be similar to that of Mars, and an Antarctic station may be compared to a Mars station or a spaceship. Antarctic medicine is also being connected to space medicine. Thus, the value of continuing research in this environment cannot be understated.

Phenomena in Antarctica are extraordinary. What happening on human being may be emphasized and becoming noticeable, and they share commonalities with those in Japan. Experiences and breakthroughs in Antarctica will hopefully help provide both a platform for expanding the human experience in to space and further more a better understanding of our daily living conditions.

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