Sebastián Arrebola

Shoshanah Jacobs

Antarctica

DISCOVERING THE LAST CONTINENT

Prologue by
Pierre Yves Cousteau

Editorial Utopías

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EDITORIAL UTOPIAS

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PROLOGUE

Antarctica. The last virgin continent on Earth. Having never set foot on this land, I can only imagine the feeling of remoteness and solitude that humans, in their daring efforts to explore the hostile continent, have experienced. I suppose the unique, untamed nature strikes the heart of the visitor with humility, reviving ancient feelings.

In this marvelous book, I have discovered with awe the diversity and beauty of the creatures that populate the white continent, along with tales of audacious explorers who braved the elements to quench their thirst for exploration. My father was one of those men. Fully aware of the value of this pristine land for future generations, he sailed to Antarctica with twelve children from all five continents and raised four million signatures throughout the world to protect Antarctica from human exploitation for fifty years.

Below is an extract of my father's impressions about Antarctica. Today, the Cousteau Society and Cousteau Divers continue his work for the respect and preservation of all life on Earth as do the millions of people he inspired to love and study the Ocean.

Pierre-Yves Cousteau
www.cousteau.org
www.cousteaudivers.org

"It is a vast continent, eternally white, which clings to life on the brink of death. The icy air whisks the lungs, and the eye beholds a transparent magic. The enchanting hour of calm and sunshine is swept away by furious blizzards that forgive intruders only by chance. The great southern land was buried under mountains of snow piled up and frozen during tens of millions of years; fossil remains, important chapters in the history of our planet, sleep in their immaculate shroud. All around circulates a silent carousel of giant icebergs ripped from the shore. Dwarfed lichens dot the coastal ice with their timid coloured spots. A fringe of salty ice advances and then disappears with the season, while on the soft ground the ice melts only for consolidation. The sea sometimes becomes a cloudy red with small shrimp – krill – which the penguins, whales, and – indirectly - the seals gorge themselves upon to survive. All these creatures circulate in the pack, singing strange songs; the fish, "icefish" inject into their blood colourless protein as antifreeze, killer whales with majestic fin mix their breath with the morning mist.

In December 1972, I first landed in Antarctica onboard the Calypso. A serene sun shone upon a dusting of snow that had fallen overnight. Heart pounding, I took my first steps but a squeak made me go back. My footprints were smeared with a little grease that contrasted with the blinding whiteness of everything around me. Naively, I felt a rush of shame for failing to clean my boots.

The ice piled up over millions of years on this continent at the end of the world is for mankind like the sword of Damocles: its release would cause the collapse of most urban centers, Antarctic wildlife clings to life and is at our mercy.'

Jacques-Yves Cousteau

ACKNOWLEDGMENTS

The people in our lives could not have been more supportive during this long period.

First of all we would like to thank our publishers Utopías for trusting us on this project. We would like to thank Stan Goldner and Margaret Jacobs for reading the earliest versions and for suggesting the very first of many changes. Marc Pritchard, our editor and good friend, made sure that we made sense. Viviana Quse, our translator, made sure that we made sense in two languages and she also made very useful comments and suggestions. Lucas Marti ensured that all the information was as accurate and up-to-date as possible. Any errors, however, are entirely ours. Pablo Wainschenker was a fountain of useful information and we are very appreciative of his patience with us. He is our Antarctic Guru!

A big thanks to Jose Arrebola and Julia Di Virgilio who allowed us to use their home as a base for our research in Buenos Aires, for putting up with our computers and papers everywhere, and for making sure that we ate from time to time.

We also want to thank Cornelia Lüdecke for correcting the German expeditions and providing us with some photographs; Monika Schillat for reading the history section; Michael Richardson for reading an early version of the book; Gerardo Scolari and Belen Capdevila for lending us some of their many books; Veronica Mollevi, Marcela Arrebola, Julia Di Virgilio and Yamila Arrebola for reading a draft and for suggesting some changes in the Spanish version; Valeria Otero Faus for her priceless help in correcting the Spanish version; Garv Hoefler, a naturalist extraordinaire, for contributing with an article on nasal parasites in seals. Thanks to Dr. Leonardo Magnoni for his contribution on Antarctic fish and to Drs Richard Lee Jr. and David Denlinger for their contribution on terrestrial animals. Their work was supported by the National Science Foundation.

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ILLUSTRATIONS

All illustrations, maps, and figures were drawn by Shoshanah Jacobs and her trusty mouse. Thanks to Agustin Ullmann, Tara Ryan, and Cornelia Lüdecke for suggesting improvements.

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INTRODUCTION

"To anyone who goes to the Antarctic, there is a tremendous appeal, an unparalleled combination of grandeur, beauty, vastness, loneliness, and malevolence – all of which sound terribly melodramatic – but which truthfully conveys the actual feeling of Antarctica. Where else in the world are all of these descriptors really true?"

Captain T.L.M. Sunter

Antarctica is the last human discovered continent. Throughout history it has seduced the spirits of explorers and entrepreneurs. It has infused those few lucky enough to have been there with a passion beyond the understanding of those who have never seen the "White Continent." Wild and unpredictable, Antarctica is surrounded by fierce seas and has a unique and almost impenetrable geography.

Unlike its polar opposite, the Arctic – an ocean surrounded by continents – Antarctica is a continent surrounded by an ocean: The Southern Ocean. These waters have moulded Antarctica's climate and biology, acting as a thermostat for the planet, regulating the rest of the earth's ocean currents and, consequently, atmospheric conditions. The freezing of the waters around the continent during the austral winter acts as a cleaner for the atmosphere, with sinking water bringing dissolved greenhouse gases to leviathan

Tabular Iceberg in the Southern Ocean. © Kunz depths. The Southern Ocean cuts off Antarctica from atmospheric and oceanic contact with the rest of the planet and has lead to the evolution of some bizarre, though highly effective, methods of surviving in extreme conditions.

Truly a land of records, Antarctica is the highest (and also lowest?), windiest, driest, and coldest continent on earth, with the most dynamic glacier activity. The average annual temperature on the Polar Plateau is -50°C. However, there is a fluctuation of 40°C between summer and winter and average temperatures are significantly higher on the Peninsula. The average altitude is 2250 m above sea level. The desert plateau is at 3500 m above sea level. From there, the katabatic winds begin flowing down the ice surface like a gentle breeze, rushing towards the sea, reaching the coastal area at speeds over 200 km/h.

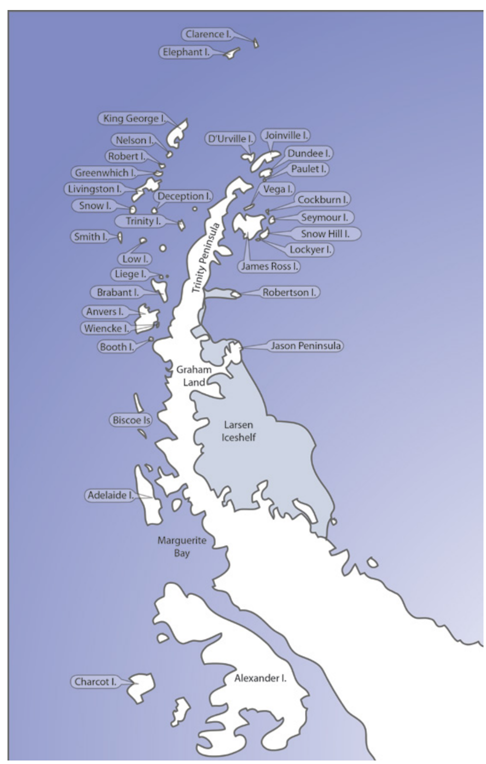
Tales of strange wildlife have been documented within the accounts of scientific and exploration expeditions. Animals, plants, bacteria, and fungi, living in such inhospitable conditions have had to evolve unique and marvellous adaptations in order to survive. Some

Map 1. The Antarctic continent and surrounding islands. © Jacobs.

leave during the frigid winter, others tolerate it, others sleep until the Sun's rays once again touch the extreme south of the planet. Irrespective of the method of coping, all these organisms have fascinated visitors both for their simple beauty and for their scientific marvel. And there is another story worth telling, though it almost ended in tragedy: The extremely cold temperatures that animals must endure require them to have a thick layer of fat or fur. This fat and fur attracted hunters and entrepreneurs from all over the planet. Consequently, some populations of fur and elephant seals were completely destroyed. This destruction has, however, led to the protection of all species in Antarctica that are now recovering – some slowly, some rapidly.

Antarctica also has another side to its human history, rich in heroic and tragic tales that have fascinated readers all over the globe and, in some instances, brought feuding nations together. The patchwork of this history is stitched together with facts from well chronicled expeditions, retold as part of an Antarctic tradition, and with the legends and rumours of lesser known exploits, where many times only artifacts retrieved on the beaches reveal tiny details of history and the ways of life and death in this hostile land. On this continent, dates and names are often secondary to the details of the hardships overcome.

Antarctica is owned by no nation. The Antarctic Treaty, signed by nations representing over 75% of the Earth's human population, was established to protect this natural wonder for the purposes of peace and science. Currently the economic wealth of Antarctica is unavailable; the petroleum, minerals, and freshwater are inaccessible to us now because of the harsh environment and because they are forbidden by the Antarctic Treaty through the Protocol of Environmental Protection. At present, the development of technology to facilitate the exploitation of mineral resources in such an inhospitable environment is too expensive. However, it is our hope that despite whatever technological developments arise in the future, the signatory nations will choose to protect this territory as a natural reserve devoted to peace and science.



Map 2. The Antarctic Peninsula. © Jacobs.

THE PLACE

THE SOUTHERN OCEAN

Tales of the Southern Ocean's merciless fury have been passed down throughout maritime history as a warning to those sailors daring to venture south. The stories that present-day travellers tell generally serve only to strengthen the legend. This relatively young body of water holds the world's record for the highest average waves and wind combination, and surviving tales are ones of bravery in the face of pure natural terror. However, biologically speaking, the Southern Ocean is a cradle of life; not only does it contain a vast array of microscopic phytoplankton and nine species of baleen whales but a surprising number of species are still being discovered.

A Wandering Albatross *Diomedea exulans* is at home soaring over the waters of the Southern Ocean; the windiest ocean on Earth. © Jacobs and Arrebola.

BASIC OCEANOGRAPHIC PRINCIPLES

Earth's oceans are not a homogeneous mass of water, neither collectively nor individually. Though they are all connected, the oceans of the world have very different characteristics dependent upon their geography, the topography of their floor, and the type of water that flows into them. Additionally, all five oceans contain different water masses at various depths in constant motion, flowing in all directions and circulating around the world owing to four key processes:

1) tides
2) wind
3) differences in water density
4) rotation of the earth

Tides are driven by the proximity of the Moon and the Sun to the Earth (Figure 1.1), such that the Moon and Sun's gravitational force upon the Earth pull the oceans' water toward them. Though it is much smaller than the Sun but because it is closer to the Earth, the Moon has a larger influence. The water therefore bulges from the Earth's surface towards the Moon, and bulges only slightly towards the Sun. When the Sun and the Moon are in alignment (either together on one side of the Earth or on opposite sides), the tides are greater in range, with the highest highs and the lowest lows. These are called spring tides. When the Moon and the Sun are adjacent to each other, the tides do not fall or rise as much, and are called neap tides. The cycle of tides observes approximately 12 hour intervals: a high tide occurs about 6 hours after a low tide. Ocean floor topography and the presence of landmasses can influence the range of the tides locally. Depending upon the topography of the sea floor, tidal ranges can be a just few centimetres or over 10 m. This movement of water around the Earth, drawn towards the Moon and Sun, contributes to the movement of surface currents.

When integrated over large distances of coastline, the tidal ranges on the Antarctic Continent are rather small (less than 20 cm). On the Antarctic Peninsula, however, ranges are higher with amplitudes up to 2 m. The tides contain enough energy to push even the thickest of ice shelves up to 5 m. Though this phenomenon is not very well studied, it is now thought that tidal amplitudes may share a significant portion of responsibility for the breakup of some ice shelves.

Friction between the ***wind*** and the sea surface creates a strong horizontal displacement at the crest of the waves and causes the water to flow with the wind. For example, a wind blowing for approximately 10 hours across the surface of the ocean will cause the water to flow at about 2% of that wind's speed. The direction of the water current does not always coincide with the direction of the wind because the influence of the Coriolis effect depends upon the speed at which the matter is travelling. Water travels more slowly and therefore turns more sharply than air.

Water density is a function of the water's temperature and its salinity. Water is most dense at 4 °C. Below and above this temperature, density decreases - for example allowing ice to float in liquid water. Warmer water is less dense than cold water owing to

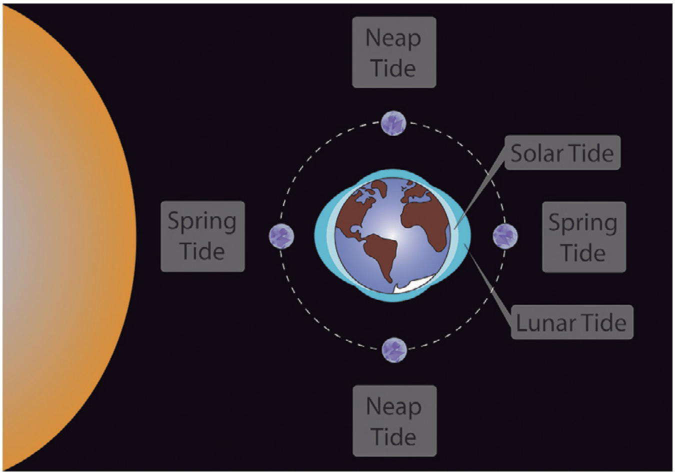


Figure 1.1. The relationship between the height of the tide and the position of the Moon and Sun relative to Earth. When the Sun and Moon are aligned, spring tides occur. When the Sun and Moon are at adjacent angles, neap tides occur. © Jacobs.

a difference in the activity level of the H_2O molecules within the water mass. In warm water the molecules are more energised and vibrate more rapidly, creating larger spaces between each one. Conversely, in colder water the molecules do not move as quickly or as far and there are more molecules per volume of water. Below 4 °C, water becomes less dense and the crystal structures of ice begin to form (between 0 and -2 °C, depending upon the salinity), in which process frozen water molecules eventually push away from each other to create a crystal lattice that is less dense than the liquid form.

Salt water is denser than fresh water. Based upon a similar principle regarding temperature, salt water contains more molecules per volume (but this time, the molecules are those of salt). The circulation of water caused by a difference in density is called thermohaline circulation and the resulting movements of water masses are called sea currents. These currents follow a specific pathway, influenced by the ocean floor topography, and allow the exchange of water among different oceans of the world. Every current, big or small, has an important influence upon the climates and equilibrium of the Earth.

Water masses will move from areas of high density to areas of low density but due to the ***rotation of the Earth***, they will not do so along a straight pathway. The Coriolis effect, or the perceived deflection of a moving object as it is observed from a rotating frame of reference, causes moving water masses to be diverted towards the right in the northern hemisphere and towards the left in the southern hemisphere.

THE SOUTHERN OCEAN: THE YOUNGEST ON EARTH

The Southern Ocean (Figure 1.2) was formed approximately 30 million years ago (though some scientists believe that it could have been about 41 million years ago), with the separation of the Antarctic Continent from South America that connected the

Getting to the Southern Ocean requires sailing across the roaring 40s and the furious 50s until you reach the shrieking 60s. The direction of the surface current is determined, in part, by the strong winds. © Jacobs and Arrebola.

Atlantic and Pacific Oceans through the Drake Passage. The world's fourth largest ocean (20,327,000 square km), it is also its youngest and includes the Ross Sea, Weddell Sea, Bellingshausen Sea, Amundsen Sea, and parts of the Scotia Sea and Drake Passage. Before the year 2000, the Southern Ocean was considered little more than a southern extension of the Atlantic, Pacific, and Indian Oceans. Since then, it has been recognised as a separate body of water by a vote of the members of the International Hydrographic Organisation (IHO, 77 international members in 2006).

Of the 28 respondents to a solicitation for opinions on the matter of this rather distinct body of water, 27 agreed that a fifth ocean should be named. The decision reflected the Southern Ocean's unique oceanographic properties, and with it came political boundaries that coincide with the Antarctic Treaty border of 60° S. For others, the borders of the Southern Ocean extend to the biological boundary that lies at the Polar Front, where the cold Antarctic waters sink beneath the warmer waters from the north, isolating the continent from outside influence.

Owing to the strong upwelling (movement of water towards the surface) of nutrient-rich water, the Southern Ocean is one of the most biologically productive places on Earth. Nutrients provide the key ingredients for photosynthesis and a jump-start to the food web. This explains every austral summer's influx to Antarctic waters of feeding and breeding marine wildlife and birds. Moreover, the Southern Ocean currents have a major impact upon all other ocean currents and therefore upon the planet's various and interconnected climates.

Between 1955 and 1995, the average global ocean temperature increased by 0.1°C in the upper 1000 m of the water column. Though this may seem rather small, this change is significant because of the environment's historical stability. This trend corresponds with a warming of similar magnitude in the oceans of the southern hemisphere alone. There is, however, a dearth of data from latitudes below 30° S because of reduced shipping activity. The data that have been collected show a warming in the Southern Ocean since 1950 of 0.17°C at depths between 700 and 1100 m. Almost double the global average, this change implies that the Southern Ocean, and therefore Antarctica, are becoming less isolated from the rest of the world's ocean systems. If so, this is likely to have a significant impact on both the annual formation of Antarctic sea ice and the global climate.

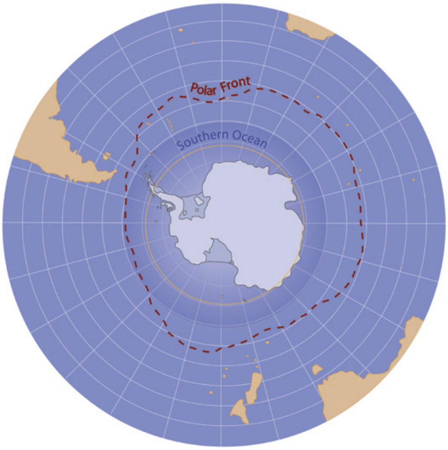


Figure 1.2. Officially named in 2000, the Southern Ocean has a northerly border of 60° S. For many biological scientists, the Polar Front defines the limits of the Southern Ocean because of the dramatic change in biodiversity from one side to the other. © Jacobs.

Currents of the Southern Ocean

Two important currents, each flowing in opposite directions, are the principle isolating factors of the Southern Ocean and Antarctica. The Circumpolar Current flows in a constant direction to the east and is the largest ocean current in the world, transporting about 130 million cubic metres of water per second. The flow is therefore equivalent to approximately 100 times all the freshwater flow on Earth. Because there are no land barriers to the ***Circumpolar Current***, it transmits climatic cues from and to the Atlantic, Pacific, and Indian Oceans, making the Southern Ocean a critical determinant of the global climate. This current is characterised by strongly tilting pycnals, or layers of water in which there are sharp changes in water density. Along the ***isopycnals***, or surfaces of constant water density, there is an increase in mixing and, in the case of the Circumpolar Current, water in the middle of the column is brought to the surface, creating a barrier between this current and others to the north. The action of pycnals therefore serves to further isolate the Southern Ocean and Antarctica. When this current reaches the Drake Passage it intensifies and becomes the strongest and deepest ocean current in the world.

Further south and closer to land, the strong winds coming from the continent generate another current flowing from east to west. This ***Continental Current*** is a comparatively thin band of water that runs close to the continent, at around 65° S, particularly in East Antarctica. The Continental Current is slower and shallower than the Circumpolar Current; both, however, are generally superficial and are separated by the Antarctic Divergence (Figure 1.3).

When the Continental Current arrives at the Weddell Sea it follows the coast, first to the south and then to the west, where the Antarctic Peninsula blocks the flow and deflects it northward to meet the Circumpolar Current, forming a circular current flowing clockwise called the ***Weddell Gyre***. Its influence dissipates at the South Sandwich Islands. The same type of gyre is found in the Ross and Bellingshausen seas.

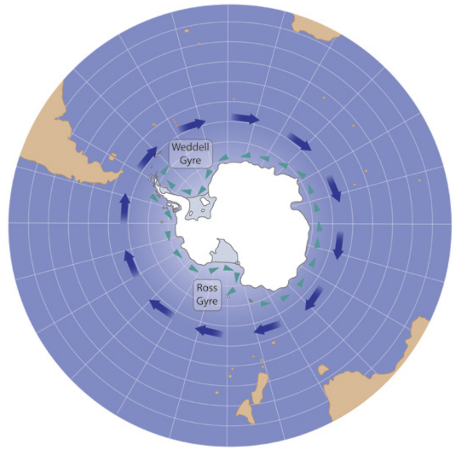


Figure 1.3. The currents of the Southern Ocean. The Circumpolar Current (blue arrows) flows towards the east. The Continental Current (green arrows) flows towards the west, creating the Weddell and Ross Gyres. © Jacobs.

Water masses of the Southern Ocean

Vertically, the Southern Ocean contains three distinct water masses or currents, which differ in temperature, salinity, and direction of flow (Figure 1.4). The superficial and the deepest water masses flow northwards, while the intermediate mass takes its waters south to the continent.

Antarctic Surface Water

This current originates in the Antarctic Divergence and is characterised by low salinity and temperature, qualities owing largely to the melting of ice (which freshens the water) and the cold winds blowing off the continent. The surface water can reach a maximum of 250 m in depth before it sinks below the Sub-Antarctic Surface water at the Polar Front.

In winter, the water temperature remains stable at -1°C because the sea ice insulates it from the colder winds and air temperatures. The onset of summer causes the sea ice to melt and the water can reach temperatures of up to 3 °C at its northern limits. When this current reaches the Polar Front it collides with the Sub-Antarctic Surface Water, which is warmer and saltier. Here the colder and denser Antarctic Surface Water sinks underneath the warmer waters and flows northward as the Sub-Antarctic Intermediate Current, chilling the coasts of the southern hemisphere continents on its way. The properties and movements of this current directly affect Antarctic wildlife because light penetration in the summer and the upwelling of nutrient-rich waters provide the key ingredients for photosynthesis. In the winter, however, the sea ice reduces the sunlight's penetration, thus lowering productivity in the Southern Ocean. This creates great inter-seasonal variability in the life cycle.

Circumpolar Deep Water

Circumpolar Deep Water, originating in the Atlantic, Pacific and Indian Oceans, flows southwards to the continent under the Sub-Antarctic Intermediate Water and the Antarctic Surface Water until it reaches the Antarctic Divergence where it climbs to the surface. Once at the surface, this water cools and decreases in salinity as it changes direction northward, becoming the Antarctic Surface Water. It has the highest temperature and salt content of the three currents.

Antarctic Bottom Water

The Circumpolar Deep Water that does not reach the surface is pushed toward the Continent, where it chills, sinks along the continental shelf, and then flows northward as the deepest layer of water. This current's rate of flow is estimated to be 10 million cubic meters per second, spreading far into the Atlantic and Pacific Oceans beyond the equator, influencing waters of the Northern Hemisphere. This current is characterised by low temperature and high salinity.

Polar Front (Antarctic Convergence)

The Polar Front, also known as the Antarctic Convergence, is a circumpolar belt situated in the middle of the Circumpolar Current. It is approximately 40 km wide and generally located between 58° S and 60° S in the Drake Passage (Figure 1.5). In this belt, the colder and fresher waters of the Southern Ocean sink beneath the warmer and saltier waters of the Atlantic, Pacific and Indian Oceans. The Polar Front is considered the biological boundary of Antarctica, where a steep gradient in the water's temperature (between 3 and 5°C) and composition is located. Some organisms that live south of this boundary are placed within biological isolation, where waters are not only colder but thermally more stable than waters to the north. The isolation of these organisms is the result of adaptation to such extreme cold that many species are no longer able to tolerate warmer or fluctuating temperatures. Some species of fish and other organisms that inhabit one side of the Polar Front are rare or simply not found on the other side.

This belt is not fixed permanently at the same latitude year-round; found between 50 and 60° S, its location varies seasonally and even annually. In the Atlantic Ocean, for instance, the Polar Front is located further north owing to the large volume of cold water flowing from the Weddell Sea that pushes the Front northward. The Polar Front's position can also vary depending upon atmospheric conditions. When the low pressure centers (wind generators) create the westerly winds in the Southern Ocean, the winds push the surface

CONVERGING AND DIVERGING WATERS

CONVERGENCE: The geographically fluctuating boundary where two water masses collide. The denser water mass sinks beneath the other, bringing oxygen and other gases, including carbon dioxide, to greater depth.

DIVERGENCE: The geographically fluctuating boundary where two water masses separate. As a result, the water beneath is brought to the surface, or upwelled. This process is generated by the flow of deep water into islands or submerged mountains, where mineral and nutrient-rich waters rise to the surface.

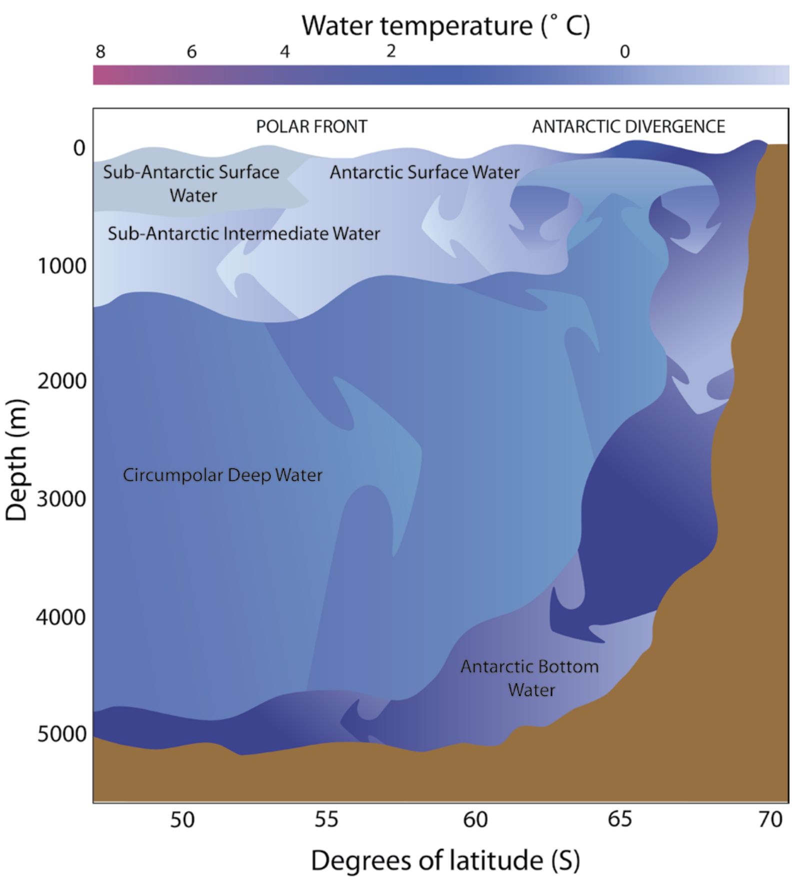


Figure 1.4. Antarctic water masses. Sub-Antarctic surface water and Antarctic Surface Water collide to form the Polar Front. Circumpolar Deep Water rises and divides, some moving north, some moving south, to form the Antarctic Divergence. © Jacobs.

waters in a northeasterly direction, moving the limits of the Polar Front towards the north. Conversely, when the low pressure centers are weak, the limits of the Front move southward.

Antarctic Divergence

The Antarctic Divergence is found where the Circumpolar Deep Water rises almost to the surface (located around 65° S) and heads in opposite directions, separating the Antarctic Circumpolar Current from the Continental Current. As it reaches the surface, bringing mineral and nutrient-rich waters from beneath, the water chills, loses salinity and part of it changes direction to flow northward as the Antarctic Surface Water while the rest flows towards the continent where it sinks to become the Antarctic Bottom Water.

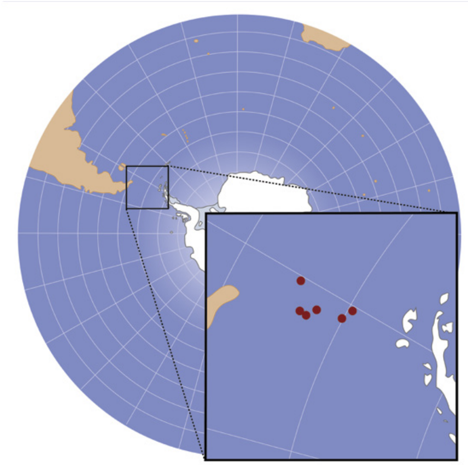


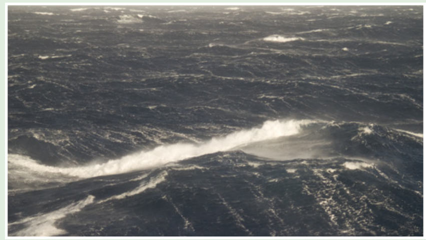
Figure 1.5. The Polar Front does not remain in a fixed position throughout the year. Here, measurements of the position of the Polar Front are plotted (red points) from December 20, 2007, to March 3, 2008, at various intervals. The distance between the furthest two points is 180 nautical miles. Data Collected by Officer E. Kant, M/V Ushuaia. © Jacobs.

This account is an admittedly simplified version of existing scientific literature. Either way, it is difficult to appreciate the Southern Ocean's vastness. Its combination of complexity and uniqueness drives not only its environment but, consequently, its diversity of life. Its isolating nature has created a physical and biological island where a variety of singularly strange and unusual creatures have evolved. Expedition cruises to Antarctica usually aim to navigate these waters with haste, both for the comfort of passengers and to better reach their ultimate destination. And though the Southern Ocean could very well be the destination itself, exploring all its facets would take an individual lifetime.

TRAVEL TO ANTARCTICA MAY GET WINDIER. . .

Dramatic increases in the Southern Hemisphere's air temperatures have caused an increase in the speed of the westerly winds that whip through the narrow Drake Passage. This could mean even rougher crossings for the majority of visitors to Antarctica.

But there are even deeper implications. An increase in wind speed will result in an increase in mixing of warm waters across the Polar Front, which may exacerbate the effects of rising air temperatures.



ANTARCTIC GEOGRAPHY

The name "Antarctica" is generally used in reference to the continent itself, though the definition also includes the territory within the political boundaries designated by the Antarctic Treaty – therefore all emergent landmasses south of 60° S, including the ice shelves. At approximately 14,200,000 km^2, then, Antarctica is the world's fifth largest continent and occupies 9% of its land surface area. Though this is a significant portion of the Earth, only 2% of it can actually be seen; the rest is hidden beneath dense ice, the average thickness of which is 2,600 m with a maximum thickness of 4,700 m. This represents 90% of the Earth's ice cover and 70% of its fresh water – if it melted completely, that is. This volume of water would raise global sea level by 60 m.

The Land of Records

Due to its extreme isolation and geographic position, Antarctica holds several records including the coldest, windiest, driest, highest, and lowest continent (Table 1.1). These records are often set within the continent's interior, where very few people tread. However, an appreciation for a few of them can be gained at some of the more coastal destinations.

Coldest: Parts of Antarctica experience average winter temperatures of -40 °C. At -89.5 °C, the lowest temperature ever registered on the continent (July, 1983) was also the coldest temperature ever recorded on the planet.

Windiest: The strongest wind ever recorded in Antarctica rushed by the

French Dumont D'Urville Station (continental East Antarctica) in July, 1972 at 327 km/h.

Driest: The majority of the continent receives fewer than 10 cm of precipitation, in the form of snow, per year. The interior receives as little as 20 mm per year.

Highest: Owing to the very thick ice sheets that cover it, Antarctica's average elevation is 1,818 m, double that of the second highest continent, Asia.

Lowest: If the thick ice sheets are excluded from the calculation of Antarctica's average elevation, approximately half of the continent is actually below sea level. Under the ice, East Antarctica's mean altitude is at about sea level while West Antarctica's mean altitude is about 800 m below. Though some scientists, accounting for the continental rebound that would occur if there were no ice cap, calculate an average elevation of hundreds of metres, this is still rather low compared to other continents.

Geological History

Of all the continents' geological histories, Antarctica has perhaps the most dynamic, having changed climate, fauna, and flora more often than any other. In fact, most of Antarctica's geological history is associated with the history of the land masses now known as South America, Africa, India, and Oceania.

Approximately 250 million years ago all emergent lands masses were united as one supercontinent called Pangaea (Figure 1.6). At the beginning of the Mesozoic Era (250-65 million years ago) this supercontinent started to drift apart, forming the Tethys Sea, the basin of what today is the Mediterranean Sea. Pangaea was divided into two mega continents: Laurasia to the north, which includes today's North America, Europe and Asia; and Gondwana to the South, including Africa, South America, Australia, New Zealand, India, and Antarctica.

Table 1.1. A comparison of Earth's continents.

	Size (km²)	Average elevation (m)	Population (x 1,000,000)	Population density (/km²)	Highest recorded temoerature (°C)	Lowest recorded temperature (°C)	Highest recorded annual precipitation (mm)	Lowest recorded annual precipitation (mm)
Antarctica	14.200.00	1818	0*	0	15	-89	NA	203
Africa	30.368.609	579	1000	28	58	-24	10.287	2,5
Asia	49.694.700	914	3.800	76	54	-68	11.872	45,7
Australia	7.686.850	304	31	2,7	53	-23	8.636	102,9
Europa	10.180.000	299	731	70	50	-55	4.648	162,6
N. America	24.346.000	609	528	30,5	57	-63	6.502	21
S. America	17.846.954	548	385	0,76	49	-33	13.284	21

*Though there is no permanent population living in Antarctica, approximately 1,000 people overwinter annually and 4,000 people spend the summer.

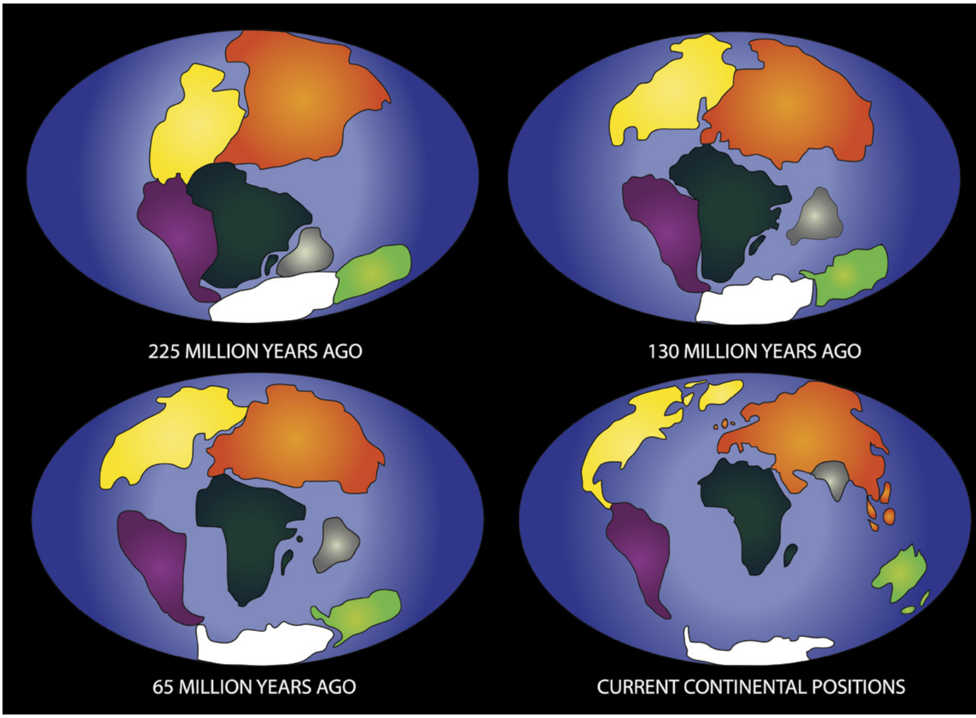


Figure 1.6. Plate tectonics is the mechanism by which the continents move around the planet. Approximately 250 million years ago, the continents were connected to form a super-continent called Pangaea. Millions of years of slow movement has lead to the continental positions of today. © Jacobs

The separation of Gondwana began in the Jurassic period, 180 million years ago. The first land masses to split apart from this big continent were India and Africa, both drifting north – Africa in a direction that would lead it almost to close the Mediterranean Sea; India drifting north of the equator to collide against Central Asia and creating the Himalayan Mountain Range.

Gradually, a very different Antarctica from the one that we know, with dense forest and a more temperate climate, began to move towards its polar position at a slower-than-snail's pace of just a few centimetres per year. Around 50 million years ago, Australia and New Zealand were already separated from Antarctica, while South America still had a land link to the continent. This provided terrestrial animals a land connection to use for migration to and from the South American continent.

With the opening of the Drake Passage, estimated to have occurred between 49 and 17 million years ago, South America was officially separated from Antarctica. It is thought that the separation of the two continents jump-started the Circumpolar Current and prevented warmer waters from penetrating further south. Therefore, with the formation of the Drake Passage, Antarctica became the most isolated continent on the planet.

Progressively, the climate became colder. The most adapted or adaptable organisms prevailed in an environment that grew increasingly hostile. Great modifications to body shape and be-

ANTARCTICA'S CHANGING WILDLIFE PROVES CONTINENTAL DRIFT

Once part of the super-continent, Pangea, Antarctica was not a frigid desert but a warm and moist land with lush vegetation, dinosaurs, and marsupial mammals. Evidence of this can be found in the fossil record of the continent. Fossilised remains of the plant species ***Glossopteris***, which once lived across Gondwana, were first discovered when the fossil collection made by Scott on his final expedition was salvaged from the site of his death on the Ross Ice Shelf. They are the definitive indicator that Antarctica was once a more hospitable place for life. However, this discovery did not prove that all continents were once attached. Scientists at the time, reluctant to fathom the idea of slowly moving continents and widening seas, argued that the spores of these plants simply travelled by strong winds and established themselves on the once warmer southern continent.

The definitive proof of the drifting continent theory came with the discovery of the remains of a short-legged giant amphibian, called ***labyrinthodont*** that lived at the time of ***Glossopteris*** (during the late Paleozoic and Early Mesozoic eras, 350 – 210 million years ago). This animal travelled only short distances through the water and could not have reached Antarctica had it been an isolated land mass.

Paleontologists continue their work in Antarctica, thawing the evidence of a much warmer place.

Fossilised plants found around the Antarctic Peninsula and South Shetland Islands are evidence that the continent was once a much warmer place. © Ullmann.

haviours occurred as land became covered by a growing ice cap and the sea became a more inviting environment. Those species that could not adapt to the conditions became extinct.

Around 48 million years ago, the first ice sheet appeared in East Antarctica; 33 million years later, the same occurred in West Antarctica. Some believe that annual ice existed on the continent even before those periods but there is no unequivocal evidence of this. In the last 5 million years, this continent that once hosted a dense forest on its mountain slopes began to freeze over and has since then remained almost completely covered by a layer of ice up to 4 km thick.

East and West Antarctica

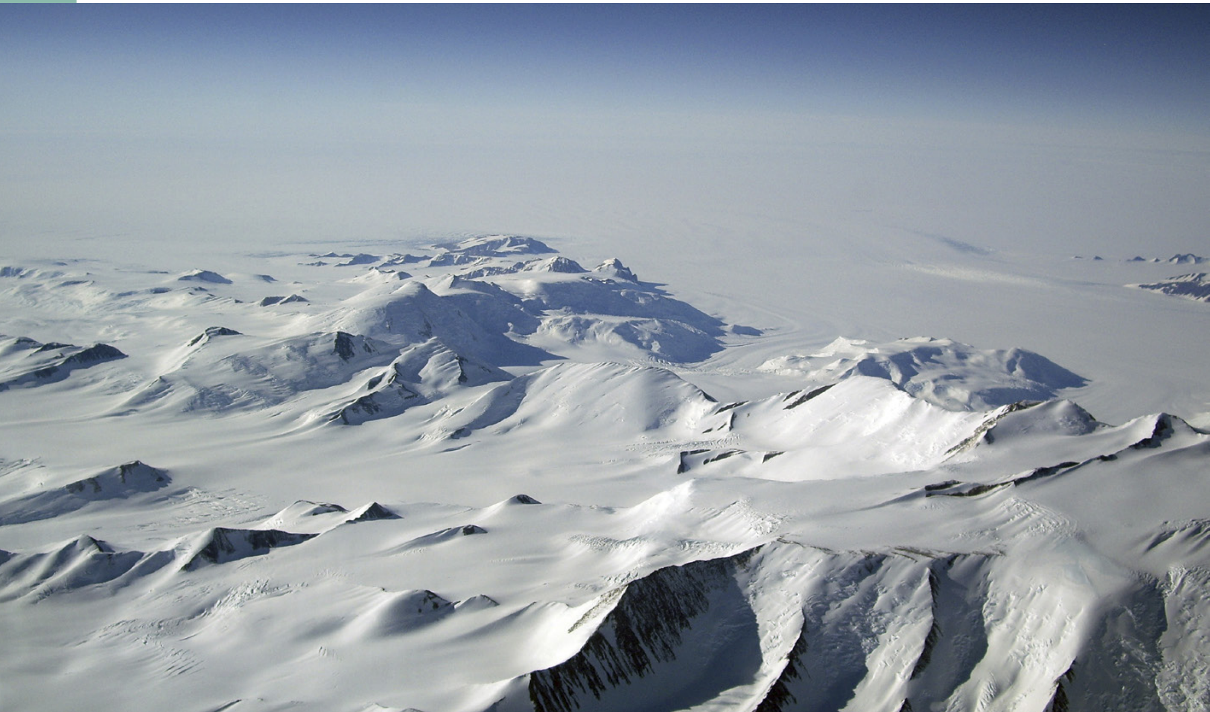
Based on its geology, the Antarctic continent can be divided into two units: a shield and a mobile belt, referred to respectively as East and West Antarctica. These two geological units are united by the Transantarctic Mountains.

East Antarctica (Shield) is composed of rocks formed up to 3.8 billion years ago. The continental base is composed of metamorphic and igneous rocks with younger sandstone, coal, shale, and limestone overtop. These younger layers, laid down during the Devonian (440-400 million years ago) and Jurassic Periods (200-180 million years ago), also form the Transantarctic Mountains. East Antarctica holds 89% of the continental ice where the ice sheet can be up to 4,000 m thick. Also referred to as a dome or cap, this ice sheet flows very slowly towards the coasts, nourishing the ice shelves.

West Antarctica is still in motion, with both seismic and volcanic activity. © Jacobs and Arrebola.

West Antarctica (Mobile Belt) occupies the area of the Ross Sea, Marie Byrd Land, the Antarctic Peninsula, and the Weddell Sea, just one third of the Antarctic continent. This region possesses the remaining 11% of the continental ice, which can be up to 2,000 m thick. Unlike East Antarctica, West Antarctica has experienced recent seismic and volcanic activity. The mountains of the Antarctic Peninsula are Mesozoic and Cenozoic outcrops (between approximately 250 and 2 million years old) related to the Andes Range, which travels underwater across the Drake Passage before resurfacing on the South American continent. Owing to their relative accessibility, significant research has been conducted on

The Transantarctic Mountain Range marks the border between East and West Antarctica. © Embree, National Science Foundation.



Mount Erebus, on Ross Island, is Antarctica's most active volcano.
© Landis, National Science Foundation.

Mount Erebus (the most active volcano of the continent, located in the Ross Sea) and on Deception Island (part of the South Shetland Islands, whose most recent eruptions occurred from 1969-1970). The most common rocks found in West Antarctica are andesite and rhyolite volcanics, formed during the Jurassic Period.

The Andes Mountain Range was formed approximately 40 million years ago and runs through South America on a North-South axis. When the range reaches south Patagonia, it changes direction, running on a West-East axis through Tierra del Fuego, the northern part of the Scotia Arc.

The Scotia Arc is the submerged mountain range between Tierra del Fuego and the Antarctic Peninsula which, pushed by the Pacific Plates, is now moving in an easterly direction. Part of this range emerges above water in various places, forming islands such as the South Georgia, South Sandwich, South Orkneys, and the South Shetland Islands until it reaches the Antarctic Peninsula, along its westward axis. Once above water on the Peninsula, these mountains continue on a North-South axis and disappear under the ice of Ellsworth and Marie Byrd Lands, protruding as isolated nunataks (mountain tops emerging from ice caps) of West Antarctica.

Polar Climates

The way in which the Earth orbits around the Sun is responsible for the days, nights, seasons, and years, in addition to ice ages and periods of

Plunging into the waters of the Drake Passage at the southern tip of South America, the Andes Mountain Range emerges a few times on sub Antarctic islands before emerging at the Antarctic Peninsula. © Jacobs and Arrebola.

warming. Discussion of these variables warrants its own volume so here we present the important factors relating to Antarctica.

The Earth orbits the Sun at an approximate angle of 23.5° relative to the position of the geographic poles. During half an orbit (six months), one pole will receive significantly more light than the other, which accounts for the poles' well-known difference in daylight hours compared to more temperate latitudes. However, the entire Arctic and Antarctic do not have 6 months of complete darkness or light during the year. Rather, the transition between longer days and longer nights is a slow progression as the Earth orbits around the Sun. The Arctic and Antarctic Circles (at the latitudes 66° 33′), experience one day per year where the Sun either does not rise (winter) or does not set (summer). All latitudes above that have an increasing number of dark days during the winter and light nights during the summer. During the austral summer, the Earth's orbit is closer to the Sun than during the boreal summer. Consequently, the Antarctic receives 7% more radiation from the Sun during the summer than the Arctic.

The decrease in average temperature with latitude can also be explained by the Earth's position relative to the Sun and its curvature. The Sun's rays hitting the Earth at more temperate latitudes have the shortest distance to travel through the atmosphere because (1) they do not pass through it at an angle and (2) they are concentrated on a smaller surface area. At the poles, the atmosphere, relative to the distance the Sun's rays must travel, is thicker and the rays are distributed over a larger surface area. These factors decrease the average Sun radiation per unit of surface area, receiving 40% less radiation on the poles (Figure 1.7). The atmosphere above the Antarctic has fewer radiation-absorbing particles and the continent itself, as discussed, is well above sea level. Therefore, the Antarctic receives more radiation than does the Arctic. Combined with the effect of the Earth's closer orbit during the austral summer, this results in Antarctica receiving 16% more sun's energy than the Arctic. However, between 80% and 90% of the incoming radiation is reflected by the white snow and ice surfaces, more accentuated during the winter as this surface is extensively larger in the Southern Ocean. This reflection process is called the ***albedo effect***.

Antarctic Climates

Though Antarctica is cold, dry, and windy, the continent and its adjacent islands can be divided into three climatic regions: Interior, Coastal, and the Peninsula, all of which vary in their environmental variables (Figure 1.8). Having heard that Antarctica is the driest place on Earth, many visitors are surprised to see snow or rain fall when travelling around the Antarctic Peninsula, but it receives precipitation frequently compared with the Interior, which receives almost no precipitation. Integrated over the entire continent, however, Antarctica is still the driest place on Earth.

Interior Climate

This climate is characterised by extreme cold, with winter temperatures varying between -40° and -70 °C. The lowest temperature ever registered (-89.5 °C) was recorded at the Russian Vostok Station (78.5° S, 106.9° E) in 1983 and is the coldest temperature ever recorded on the entire planet. (In 2010, a new lowest record of -93.2 °C was set when the measurement was recorded by the satellite Landsat-8 on the mountain ridge between Dome Argus and Dome Fuji at 3,900 m. This record, however, remains 'unofficial' because it was not confirmed by measurements taken at ground level.) In the Interior, summer temperatures range from -15° to -35 °C.

Despite having the largest store of freshwater on the planet, the Polar Plateau is a desert, with fewer than 100 mm of annual precipitation. This low precipitation is due to extremely cold air temperatures and to the isolation of air masses from contact with ocean water. Though air masses travel over the Southern Ocean, they travel around the continent, not across it. In addition, the sea ice that forms during the austral winter creates a barrier of contact and limits the absorption of moisture into the air. The winds that do on occasion penetrate the continent must rise over the coastal mountains causing precipitation near the coast as the air mass cools. Consequently, they arrive in the Interior with very little moisture, only 10% that of temperate air masses. The continental plateau is therefore generally cloud-free. Temperature inversions are also not uncommon on the Plateau. There, as we move higher above the surface of the ice, the temperature rises. This is a result of the high albedo of the snow surface that reflects nearly all incoming radiation. The air near the ice surface is chilled and dense, but above that layer of air, between 200 and 1,000 m, there is a less-dense air layer containing more moisture that absorbs some of the outgoing long-wave radiation and remains warmer.

Coastal Climate

The climate of the coast is heavily influenced by the ocean. Conditions here are generally milder, with temperatures ranging from -15 °C to -32 °C in winter and between -5 °C and 5 °C in summer. This region also experiences greater precipitation, receiving between 200 and 600 mm annually. It is in the coastal region that the winds are strongest. All the prevailing winds originate upon the Plateau and flow in a downward direction, along lines of altitudinal change. Therefore, the majority of the winds are katabatic. Derived from the Greek katabatikos for 'downward,' these are winds generated by a gravitational pull of cold, dense air down steep declines. On the Plateau, where they originate, the katabatic winds are gentle breezes, but as they travel, they accelerate to astounding speeds as they plummet over the edge of an ice shelf. Average coastal wind speeds reach approximately 54 km/h. These winds are strongest during the austral winter, when the air is coldest, and can travel at speeds up to 300 km/h (Figure 1.9).

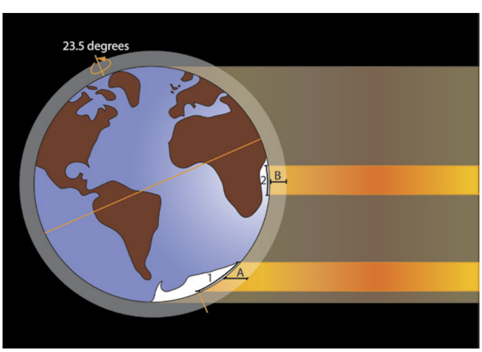


Figure 1.7. The tilt of the Earth's axis causes the dark winters and light summers at the Poles as the planet revolves around the Sun. The Poles are colder because the Sun's rays must travel through relatively more atmosphere (A relative to B), and are distributed along more surface area (1 relative to 2). © Jacobs.

WHY IS IT COLDER AT THE SOUTH POLE THAN AT THE NORTH POLE?

The South Pole is located on land surrounded by water. The strong ocean and air currents circulating around the continent essentially isolate Antarctica from the rest of the planet. In addition, the South Pole is located at approximately 2,835 m above sea level, and this high altitude also contributes to the very low temperatures.
The North Pole is located over water surrounded by land, and is therefore found at sea level. This means that the Arctic Ocean is essentially a basin for relatively warmer temperatures, the water acting as a buffer, with mixing air currents.

Peninsula Climate

Acting as a barrier from the West Winds off the Southern Ocean, the Peninsula has a relatively warm and humid climate. With up to 1000 mm of annual precipitation in the form of winter snow and summer rain, the Peninsula is the only region in Antarctica where precipitation is frequent.

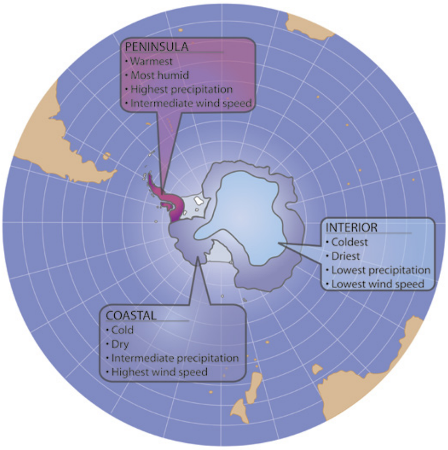


Figure 1.8. Though Antarctica is generally cold, dry, and windy, the continent can be divided into three separate climates. © Jacobs.

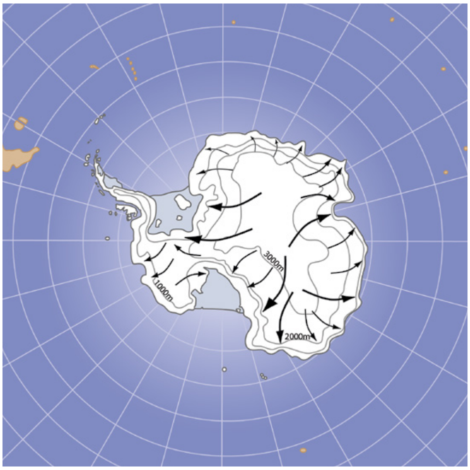


Figure 1.9. The prevailing winds on the continent have a downward direction as they travel along gradients of altitude toward the coasts. The arrows on this map show the directions of the prevailing winds in association with the altitude. © Jacobs.

During the summer, average temperatures fluctuate between 0 °C and 5 °C and between -10 °C and -30 °C in winter. It is here that the majority of ice-free land (less than 2% of the entire continent) is found. In addition, it is in this area where a great amount of Antarctica's wildlife congregates to breed during the short summer season.

The Atmosphere and Ozone Layer

Earth's atmosphere is the key to life. It provides protection by buffering the temperature extremes between day and night, and by absorbing harmful solar radiation. By absorbing heat, nights are not as cold, and by filtering radiation, the days are not as hot. The atmosphere is composed of relatively few gases including nitrogen (78.1%), oxygen (20.9%), argon (0.9%) and carbon dioxide (0.04%), and is kept near Earth's surface by gravity.

Though it is divided into five distinct layers, there are no definite borders between the layers of the atmosphere because they gradually merge and their thicknesses change, especially closer to Earth's surface (Figure 1.10). The Troposphere begins at Earth's surface and reaches up 17 km in altitude at the equator and 7 km at the poles. Due to greater gravitational pull closer to the surface of Earth, most of the atmospheric gases are found within this layer and there is a lot of vertical mixing because surface radiation warms the air, causing it to rise. The Stratosphere lies between 7-17 km and 50 km in altitude and contains the majority of the Earth's ozone. The Mesosphere lies between 50 and 85 km. The Thermosphere is found between 85 and 690 km in altitude and is host to both the auroras and the international space station. The Exosphere lies between 690 km and 10,000 km, beyond which no traces of atmospheric gases are detectable.

The Antarctic Peninsula area is where the majority of ice-free land is found. Consequently, this is also the area where most human and penguin landings are made. © Jacobs and Arrebola.

During the winter months, as temperatures fall at either pole, large cyclones called polar vortices form in the troposphere and stratosphere. The polar vortex over Antarctica is stronger because it is more isolated from other landmasses and atmospheric currents. Stratospheric clouds composed of water and nitric acid crystals form because of the extremely low temperatures (-80 °C) of both the long winter nights and the isolation of strong westerly winds. During the summer months, when the vortex breaks down, air currents from lower latitudes bring pollutants along with the regular composition of air, including ozone. These pollutants are a cocktail of human-made compounds, including chlorofluorocarbons (CFCs), nitrous oxide, methane and other gases. When the vortex forms during the winter, these pollutants are trapped within the clouds and remain above Antarctica. Here they lie dormant without the catalytic effect of light. When sunlight begins to reach the poles, these stable compounds break up into more reactive forms, including chlorine gas.

Ozone (O3), which filters out 90% of the ultra violet (UV) radiation coming from the Sun, is composed of three oxygen atoms bonded together. The greatest concentration of ozone is found within the stratosphere between 15 and 30 km in altitude. Ozone is created when UV radiation of wavelengths between 180 and 242 nanometres (nm) break the bond between the two atoms of an oxygen (O2) molecule. The now free-floating oxygen atoms (O) then bind with another oxygen molecule to form ozone (O + O2 = O3). Ozone is a very unstable gas: it exists for up to 30 minutes when it is hit by UV radiation of wavelengths up to 320 nm before breaking apart into a free-floating oxygen atom and an oxygen molecule (O3 + UV = O2 + O).

Invented in the late 1920s, chlorofluorocarbons are non-toxic, non-flammable coolants and fire retardants used in refrigerators, aerosol sprays, air conditioners, and cleaning solvents. Their ability to trap heat made them ideal for foam insulation. CFCs ($CFCl_3$) are very stable in the lower atmosphere and it was not known when they were first invented that they become very unstable in the stratosphere, interacting with the ozone layer. Their use was widespread until, in the 1970s, it was discovered that they were destroying the ozone layer over the poles.

The recipe for an ozone hole requires specific conditions that can only be found at the poles, more so over Antarctica because of even colder temperatures than over the Arctic. The polar vortex forms a barrier, trapping CFCs and other gases within the stratospheric clouds. When the CFCs break down into more active chlorine gas (Cl_2), the stratospheric clouds prevent them from returning to their stable form because the nitrous oxide needed for this process is locked up in the clouds. When sunlight returns to the poles, the Cl breaks down, releasing single atoms of chlorine (Cl_2 + UV = Cl + Cl). These chlorine atoms break apart ozone into chlorine monoxide and oxygen ($O_3 + Cl = ClO + O_2$). ClO then breaks down and the chlorine atom is released, unchanged, and able to break apart thousands more ozone molecules (Figure 1.11).

The hole over Antarctica is not a hole per se but rather a drastic reduction in the concentration of ozone within that region. Over the Arctic, because temperatures rarely reach the required -80 °C, the hole is more of a dent. When the summer months come to the poles and the vortex loses strength, the CFCs are dispersed to lower latitudes, destroying ozone molecules in other regions. For example, a 10% decrease in ozone levels above New Zealand was detected during the spring months. This could have significant consequences for human health, including increased sunburn, skin disorders and cancers, eye damage, tumours, mutations, immune system damage, and decreased plant productivity, causing crop failures.

Though the production and use of CFCs has been limited since the sovereign nations of the United Nations signed the Montreal Protocol in 1987, these gases have a very long life with-

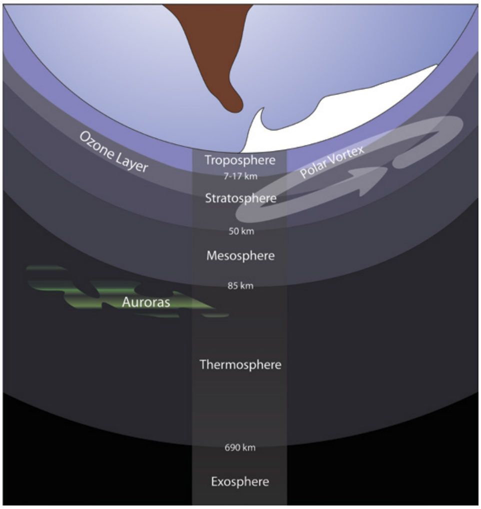


Figure 1.10. The atmosphere is composed of different layers based on their temperature characteristics and their gas composition. © Jacobs.

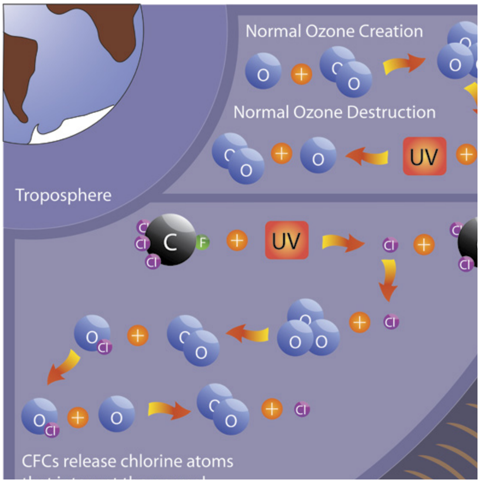


Figure 1.11. Ozone is created when a free-floating oxygen atom binds with an oxygen molecule. This bond is relatively unstable, breaking down and reforming repeatedly. Chlorofluorocarbons release chlorine gas, which is broken down by UV radiation into free-floating chlorine atoms. These chlorine atoms break apart ozone atoms to form chlorine monoxide and oxygen. The chlorine is then released and can continue to break down thousands of ozone molecules.
© Jacobs.

in the atmosphere. CFCs can remain in the stratosphere anywhere from 65 to 130 years, halon gas up to 110 years, nitrous oxide 150 years, and methane 10 years. Therefore, even though we are no longer releasing as much of these gases, it will take a very long time, perhaps another 60 years, before the holes begin to recover. Tropospheric chlorine ions have been decreasing since 1993 and, since the 1998-1999 seasons, the hole has been disappearing earlier in the year. This is good news.

Geographic Curiosities

Aurora Australis. The mystical nature of the southern (and northern) lights remained mysterious until the mid 1960s, when laboratory experiments finally began to reveal the cause. The flow of electrons and protons originating from the Sun (solar wind) collides with the gases of the thermosphere. This collision produces electrical charges that excite oxygen and nitrogen atoms and then that release this energy in the form of photons, or light. These events occur at the magnetic poles because Earth's magnetic field channels the solar winds to these regions. Auroras are highly correlated with the sunspot cycle (approximately every 11 years) and continue with greater frequency for years to follow.

Different light patterns have been observed, including pillars, streaks, wisps, haloes, and curtains. The colours that appear depend not only on which gases are struck, but also on how far they are from the Earth. The red and green colours are associated with oxygen; oxygen at altitudes between 100 and 200 km gives off the familiar yellow-green color, while at higher altitudes (about 200-500 km) it gives the all red auroras. Purple, blue and pink are generally caused by energised nitrogen. White is created by a combina-

Auroras were once considered omens of bad fortune. © Powell, Antarctica NZ Pictorial Collection.

Stastrugi are formed by katabatic winds travelling great distances over the surface of ice domes. © Metcalf, Antarctica NZ Pictorial Collection: K058 06/07

tion of green, red, and purple auroras. The shimmering lights generally last between 15 and 40 minutes and are often repeated 2 or 3 hours later.

Katabatic Winds. Unlike other winds, the katabatic winds are phenomena associated with gravity rather than only atmospheric conditions. These winds are caused by a temperature inversion. In the interior, the lowest layer of air is chilled by the ice and snow surface. This layer is denser than the other air layers above and it flows by the influence of gravity. At first a gentle breeze in the interior, it picks up speed along its 1,600 km journey across the continent and can rush to the coasts travelling at up to 300 km/h (Figure 1.12). If the winds are sufficiently strong they can create ridges in the snow surface known as **Sastrugi**.

Dry Valleys. These areas are free of the snow and ice found on most of the continent. Those dry valleys located in Victoria Land, on the west side of the McMurdo Sound, Ross Sea area have been investigated intensively: Victoria, Wright and Taylor. Victoria and Wright were discovered in 1955 by the American Commonwealth Transantarctic Expedition, and Taylor was discovered in 1903 by The British National Antarctic Expedition. The Three Valleys run through the Transantarctic Mountains towards the Ross Sea, covering 2,500 km^2. A long time ago, they were covered by glaciers that drained ice from the in-

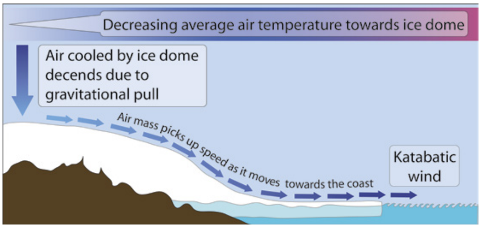


Figure 1.12. Katabatic winds are created by the downward movement of cold air due to gravity along the surface of the ice dome. When they reach the coasts these winds can be travelling as quickly as 300 km/h. © Jacobs.

Dry valleys such as this one in Victoria Land, were created by the sudden uplift of glacier-covered land. Cut off from the rest of the glacier, these valleys 'dried up'. © Barnes, Antarctica NZ Pictorial Collection: K250 06/07

terior toward the Ross Sea. The valleys became dry when suddenly the land rose at a rate faster than the glaciers were able to erode it. Now the lowest part of the valleys is free of ice because there is insufficient precipitation to allow for accumulation. The precipitation that does fall is rapidly evaporated by the katabatic winds, preventing ice formation (Figure 1.13).

Sub-Glacial Lakes. These lakes are formed by the accumulation of water in low-lying areas that have been isolated by ice from atmospheric exchanges for millions of years. The temperatures and pressures in these environments are similar to those in the Earth's deepest oceans. These sub-glacial environments are essentially ecological experiments that have been taking place for more than 35 million years and are therefore unique laboratories found nowhere else on Earth. They could provide insight into the evolution of life and the conditions under which it occurred. There has been a significant debate among Antarctic Treaty members regarding whether these lakes should be explored and, thus, opened to our present atmosphere (Figure 1.14).

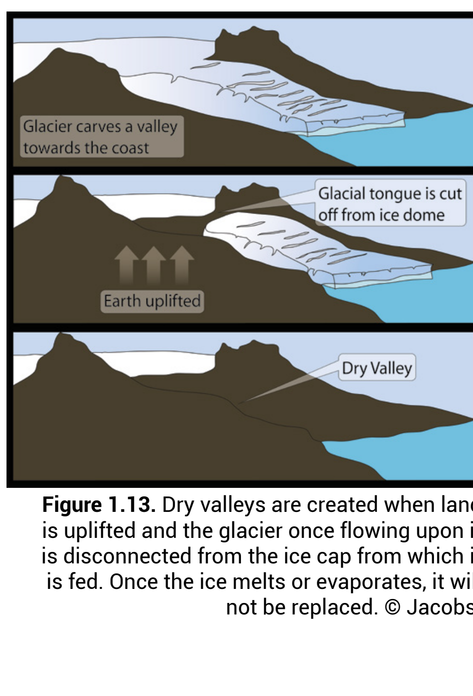


Figure 1.13. Dry valleys are created when land is uplifted and the glacier once flowing upon it is disconnected from the ice cap from which it is fed. Once the ice melts or evaporates, it will not be replaced. © Jacobs.

To date, about 170 sub-glacial lakes have been found beneath the thick ice sheets. Roughly 70% of the known sub-glacial lakes are clustered in the region of East Antarctica. No lakes larger than Lake Vostok, discovered by British and Russian scientists in 1996, have been identified. These lakes are classified into three categories based on the region in which each was formed. The first group includes lakes formed in basins within the ice-sheet interior. This includes Lake Vostok and the majority of other lakes. The second group includes lakes located on the flanks of mountains. The third includes lakes that are formed in areas of enhanced ice flow.

Though it is still unclear how sub-glacial lakes are formed, two proposals dominate the debate. The first states that the lakes formed as part of a relatively stable ice sheet configuration. In this case, the source of the sub-glacial water would have been due to geothermal heating, where run-off water would have travelled into a bedrock trough to

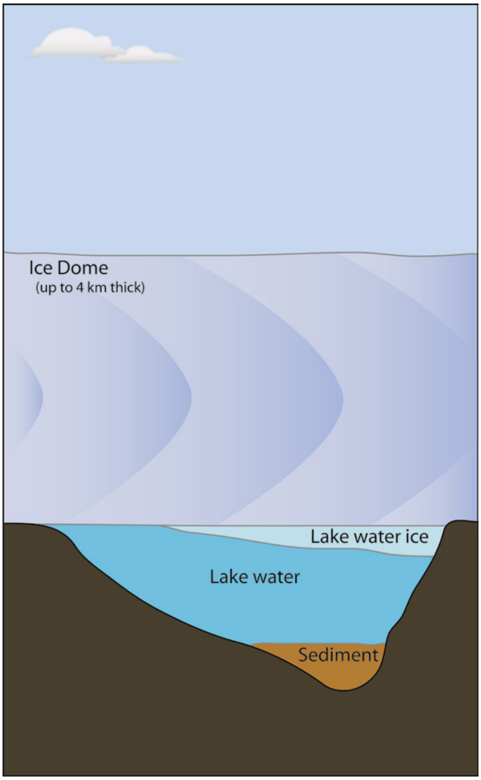
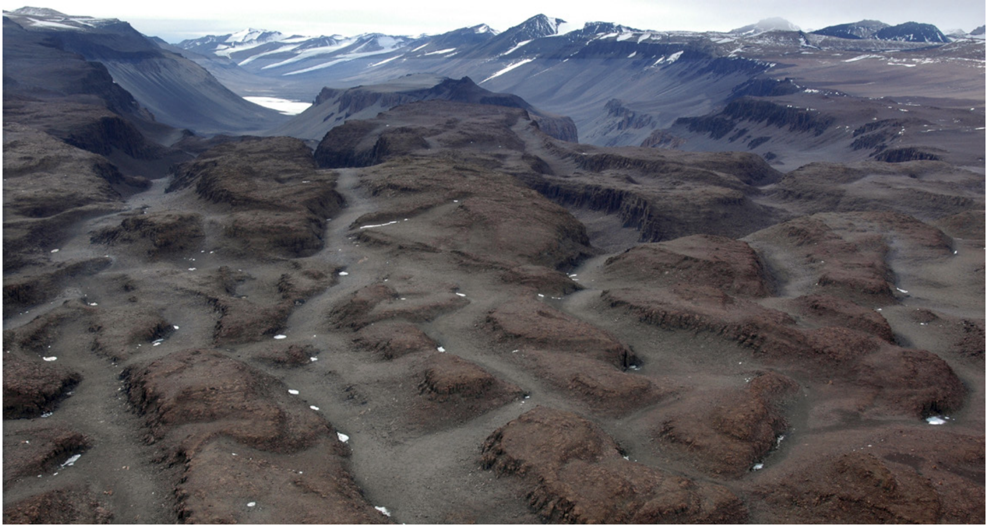


Figure 1.14. Antarctic sub-glacial lakes are covered by thousands of metres of ice, isolating them from our modern-day atmosphere. If penetrated, they may be able to tell us about what the Earth was like hundreds of thousands of years ago. © Jacobs.



Scientists think that these strange labyrinth-like valleys were formed by an ancient flood. © Rejcek, National Science Foundation.

form the lakes. If the water originated from the glacier, this proposal predicts that the lake salinity would be roughly equal to the salinity of the basal ice.

In the second proposal, the lakes pre-date the formation of the glacial ice sheet. As the ice sheet grew, the lakes were covered and isolated from the surface. In this model the salinity of the sub-glacial lakes could be much higher than in the first proposal (fresh water lakes are saltier than glacier waters). A third proposal is supported by recent evidence suggesting these lakes may be interconnected forming a network that is perhaps flushed somewhere on a periodic basis. Not enough is yet known about the sub-glacial lake environments to draw a conclusive picture regarding their formation.

Approximately the size of Lake Ontario (Canada), **Lake Vostok** is by far the largest of the known sub-glacial lakes. Owing to the lake's relatively and conspicuously flat topographic signature from satellite altimetry data, it is unlikely that a comparable lake has been overlooked. The value of this lake for scientific study is potentially very high. Its water is estimated to be approximately 1 million years old and could provide much information about the climate and nature of the pre-historic atmosphere. The thickness of the ice sheet is just over 4 km at the northern end of the lake and decreases towards the south. The water temperature is -3 °C, well below the freezing temperature of fresh water (0 °C), made possible by the high pressure from the large volume of ice covering the lake. The average depth of the water is 344 m but it reaches a maximum depth of 1,000 m.

In 1998, the world's longest ice core was drilled by an international scientific team composed of Russian, French, and American scientists. The ice core was drilled to a depth of 3,623 m, approximately 100 m above the lake surface into ice estimated to be 420,000 years old. The lowest 85 m of this ice core is composed of lake ice accreted to the bottom of the ice sheet.

Specialised annual studies of the sub-glacial Lake Vostok were begun with seismic soundings by the Russian Antarctic Expedition (RAE) in 1995. In 1998, they were supplemented by ground-based radio-echo sounding. In April, 2005, German, Russian, and Japanese scientists discovered that the lake has a tidal cycle with water rising and falling 1-2 cm, in accordance with the movements of the Moon and Sun. In May, 2005, an island was discovered. In early 2012, the remaining ice layer was penetrated by Russian scientists, and in January, 2013, they succeeded in extracting the first samples of frozen water.

Polynyas, derived from the Russian meaning "area of open water within the sea ice". There are two types of polynyas: ***Open Water Polynyas*** are produced by an upwelling of warm subsurface water over an oceanic mountain and/or by wind action. ***Coastal Polynyas*** are those located close to shore and are formed by strong winds blowing offshore. These polynyas need to remain open for only a few days to persist throughout the whole winter, and in some places they remain open year after year. They provide access to open water for wildlife during the winter and are therefore important for their survival (Figure 1.15).

DID YOU KNOW THERE ARE FIVE SOUTH POLES?

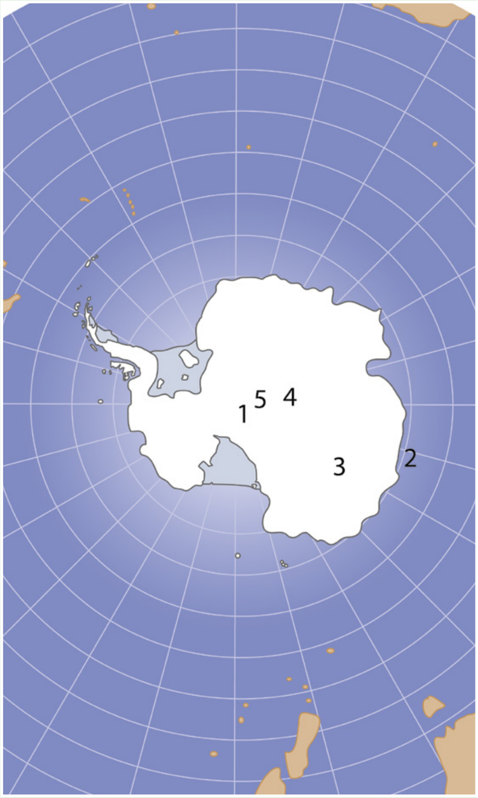
1- The True Geographic South Pole: Also referred to as the Geodetic Pole, the True Geographic South Pole is located at the intersection between the Earth's surface and its axis of rotation where all the lines of longitude intersect. The pole, located at an altitude of 2,835 m, is marked with a stake. However, because the ice sheet above that location is flowing at approximately 10 m/yr along the 60° West meridian, the personnel of Amundsen-Scott Station move it to the correct position every New Year's Day. The True Geographic South Pole is located approximately 2,900 km from the South Magnetic Pole.

2- The South Magnetic Pole: It is here that the planet's magnetic field is directed vertically. This pole drifts and is currently moving North Northwest. Today, it is located off the coast of Wilkes Land, East Antarctica. It is to this pole that your compass will lead you if you do not make the necessary corrections when heading south.

3- The Geomagnetic Pole: Located at the intersection of the surface of the Earth with the extension of the magnetic dipole (assumed to be found at the center of the Earth), the Geomagnetic South Pole does not drift and is found at 78° 30' S, 111° E, near the Russian Vostok Station.

4- The Pole of Inaccessibility: This pole is located at the furthest point from all the coasts on the continent. It is found at 84° S, 64° E.

5- The Ceremonial Pole: Originally marked at the True Geographic South Pole, a red and white striped barbershop marker with a large chromium ball surrounded by the flags of the first signatory countries to the Antarctic Treaty can be found near Amundsen-Scott Station.



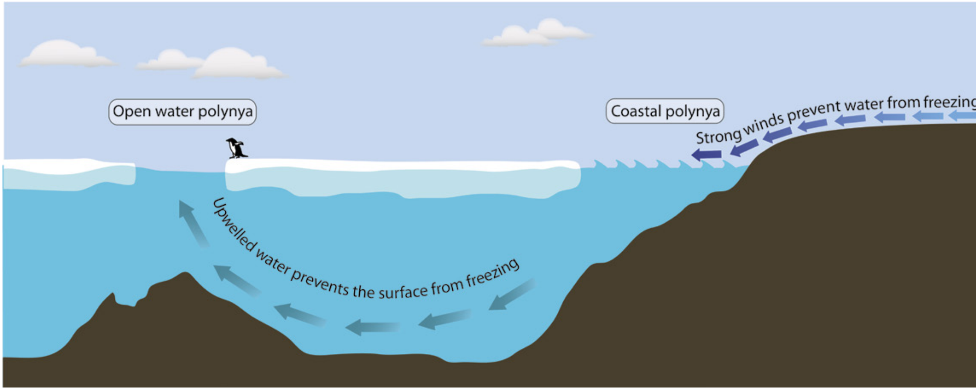
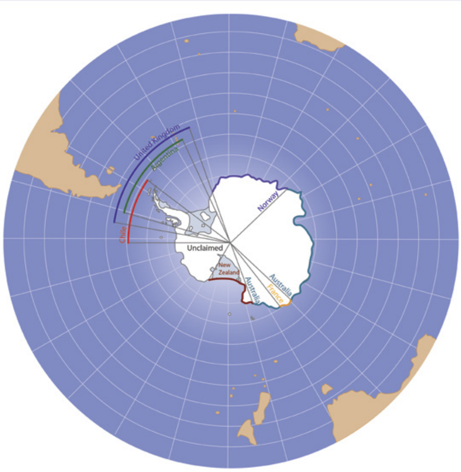


Figure 1.15. Open areas of water provide access for wildlife to the ocean below during winter months. Open water polynyas are formed by upwelled currents that prevent the surface from freezing in the most turbulent areas. Coastal polynyas are formed by strong offshore winds that keep the surface in constant motion. © Jacobs.

The Antarctic Polar Circle is an imaginary line marked on maps at 66° 33′ S. This line sets the northernmost point where the Sun does not set on December 21st during the summer solstice. On this day, the Sun will be at its highest point above the horizon, approximately 23.5°. Before December 21st, the Sun will be rising over its zenith and, afterward, will be descending. Therefore we would have to travel further south to see the Sun above the horizon during a continuous 24 h period.



WHAT TIME IS IT NOW AT THE SOUTH POLE?

In most places on the planet, time is matched to the position of the Sun in the sky (or to the established time zones). This does not work at the South Pole because of the very prolonged periods of time with or without sunlight. There is no particular reason why the South Pole should be at any specific time zone as it is located at all lines of longitude and occupies all time zones. However, the American station Amundsen-Scott, located at the South Pole, keeps New Zealand time for practical use because they conduct all their logistics through the Ross Sea.

Figure 1.16. No nation has sovereignty over Antarctic land. However, seven nations have made land claims, three of which overlap. Though no claim has been made to date, the United States of America and Russia have reserved the right to do so in the future. © Jacobs.

WHO OWNS ANTARCTICA?

Antarctica is not owned by any sovereign nation. However, certain countries have made land claims to various and sometimes overlapping parts of it. The condition of sovereignty requires that claims be undisputed internationally. Only Australia, Norway, France, New Zealand and the United Kingdom do not dispute one another's claims while the claims of Argentina, United Kingdom, and Chile overlap. However, Argentina and Chile recognise each other's rights over the region. In addition, Argentina and the United Kingdom are in disagreement over the sovereignty of the Malvinas Islands, South Georgia Island and South Sandwich Islands (Figure 1.16).

To gain sovereignty over claimed land, proof of discovery is not the only requirement by international law; rather, a specific intention to effectively control that land must be demonstrated. Consequently, sovereignty has not been granted to any nation. Some nations have made claims based on historical rights (exploration or exploitation of resources), proximity, geological affinity, the sector principle (when a coast is explored and the borders of the claim are drawn straight to the pole from the easternmost point to the westernmost point along the discovered coast- line), and symbolic acts (flag planting, the construction of post-offices). For example, both Argentina and Chile have made claims of sovereignty based on (1) geological affinity because of the connection of the Andes Mountain Range to the Antarctic Peninsula under the Drake Passage, (2) permanent occupation, (3) Spanish heritage and (4) the land conceded by the papal bull in 1493 and the Treaty of Tordesillas in 1494. On the other hand, Australia, France, the United Kingdom, Norway, and New Zealand have made claims based on discovery and exploration. In addition to that, the United Kingdom and New Zealand also base their claims in permanent occupation. The Antarctic Treaty, signed in 1959, has effectively frozen all claims. Still, claim enforcement (though perhaps more discreet) continues with the establishment of new or the expansion of current scientific bases. Trapped beneath thousands of metres of ice, Antarctica is a land of curiosities, strange geographical and geological formations, and important scientific features that are difficult to observe. Nevertheless, scientists from around the world gather here to study them, looking for insights into the past to make predictions about the future. Although we have only scratched the surface of discovery, in the near future and as new technological methods for scientific investigation are developed, discoveries will continue to spark our imaginations.

Almost the entire Antarctic continent is covered in ice and snow. The ice does not melt away during the summer months and has accumulated for thousands of years. © Jacobs and Arrebola.

ANTARCTIC ICE

Images of Antarctica invariably feature ice – ice white and glowing with blue lines, hints of green, or spotted and striped with brown. Nowhere else on the planet is so much ice to be found. It is this ice, formed under frigid conditions, that attracts most of the visitors to Antarctica – the scientists, the sailors, the climbers, and the tourists. Almost entirely inhospitable, ice is cold, contains no nutrients, and is not a ready source of water for life.

There are two rather broad categories of ice: ***continental ice***, which is accumulated upon the continent; and ***sea ice***, which is formed every winter upon the surface of the ocean. Within each of these categories are many different forms, all of which have a unique character and history.

The ice blanketing the continent is derived from precipitation and has been accumulating for thousands of years. It flows, under its own weight (ice domes and caps) or with the aid of gravity (temperate glaciers, ice domes, and ice caps) to the sea. When ice domes reach the coast, they continue to grow over the surface of the water. These ice shelves can extend for hundreds of kilometers and when they break – or calve – icebergs are released into the sea that can travel for years before melting.

The formation of sea ice occurs annually as the winter months descend upon the Southern Ocean. The freezing begins with small crystals at the surface of the water and a layer of ice one or two meters thick forms rapidly, isolating the ocean from the air. As the Sun begins to remain longer above the horizon and spring returns, the ice melts and a celebration of life begins from where they once lay dormant.

In very general terms, over 98% of Antarctica is covered by continental ice and is sufficiently massive to force the land in many areas below sea level. Meanwhile, the enormous expanse of sea ice doubles Antarctica's surface area each austral winter. The following sections explore each primary category in detail.

Continental Ice

Continental ice formation is produced by the compression of snow under its own weight. It is a slow process that requires centuries of snow accumulation. Therefore, the snow must survive from one winter to the next, without melting during the summer. Generally, low temperatures are required for the growth of glaciers. However, in some cases, high temperatures can speed up ice formation and ice movement. For example, high temperatures during the day can melt the snow on the surface of the glacier, where it will flow into the crevasses. Ice is accumulated when that water freezes due to lower overnight temperatures. The speed of the glacier may be increased if that melt water reaches the base of it and provides a slippery layer upon which it slides.

The movement of continental ice is due to two processes:

1. Sliding: where a thin layer of water at the base of the ice allows the glacier to slide over it. This results in relatively rapid movement, with high erosion of the ground topography and is most common in temperate glaciers.

2. Internal deformation: where the ice is frozen to the bedrock and layers above it flow due to their weight. There is no melt water and the movement is slower with very little erosion of the ground topography. Movement by internal deformation occurs in ice domes in Antarctica, Greenland and Svalbard (although temperate glaciers can also have some stage of internal deformation).

At approximately 30 million km^3, the Antarctic Ice Sheet is the largest single mass of ice on Earth, containing 84% of its ice and 70% of its freshwater. Though the majority of Antarctica receives no more than 10 cm of precipitation per year, the very cold temperatures have allowed most of this precipitation to accumulate in the form of snow. It falls in fluffy or granular flakes and does not melt. Over time, the weight of the snow increases the pressure on lower layers and compresses it to form ***firn***: denser snow, with bonds between the granules that increase in density towards the bottom of the accumulation. Though there is great variation in the depth of snow at which the formation of firn begins, the average is approximately 10 m. As the firn is covered further with fresh snow, the

The tops of temperate glaciers and ice domes are riddled with crevasses, making travel over their surfaces very dangerous. © Jacobs and Arrebola.

penetrability of air decreases and is released as the snow is compressed. The firn is converted to glacial ice at a depth of approximately 70 m. When a critical weight is reached, the glacial ice begins to flow downhill, scouring the ground and dramatically changing the landscape underneath. This movement is slow (an average minimum of 2 cm per day up to an average maximum of 300 cm per day in temperate glaciers) and packs a lot of energy. Due to its contact with the ground below, the lower layers of the glacier move more slowly than the upper layers, or not at all. This strain creates pressure ridges and crevasses which can make travel upon the surfaces of glaciers very dangerous.

There are two types of glaciers, distinguished by their internal temperature and their consequent movement – temperate glaciers and ice caps. Temperate glaciers are formed at the tops of mountains and flow along the valleys to the sea. They produce relatively small, irregularly shape icebergs. Ice caps are colder and move under their own weight. They give rise to ice shelves as they extend over the surface of the ocean, which produce large tabular icebergs.

Temperate Glaciers

Most of the ice on the Antarctic Peninsula is locked up in temperate glaciers: these are glaciers that flow owing to weight accumulation and sliding. Unlike ice caps, alpine glaciers are modified by the continent's topography as they flow through pre-existing valleys, in turn molded and excavated by the ice to form alpine valleys. The internal temperature of temperate glaciers is higher than that of ice caps and, consequently, they flow much faster. In addition to the movement of the gla-

TERM	ORIGIN	DEFINITION
BERGY BIT	Continental	Small pieces of floating ice 1-5 m in height
BRASH ICE	Mixed	Small pieces of ice (less than 2 m2) broken from continental and/or sea ice
FRAZIL ICE	Sea	Tiny crystals formed at the surface of sea water
GREASE ICE	Sea	A greasy slush at the surface of sea water
GROWLER	Continental	Dense, transparent ice floating at or below sea level
ICEBERG	Continental	Large floating pieces of ice calved from a glacier
ICE CAP	Continental	Small ice sheet formed by the accumulation of snow
ICE DOME	Continental	Large ice sheet formed by the merging of ice caps
ICE SHELF	Continental	Large span of the ice dome that hangs over sea water
OLD ICE	Continental or Sea	Denser ice that is usually more transparent because air bubbles have been released
PANCAKE ICE	Sea	Round, dinner plate shaped ice formed after a thin sheet of sea ice is broken up by wave action
PACK ICE	Sea	A solid sheet of sea ice with very few cracks or open water
TABULAR ICEBERG	Continental	Usually large, flat topped icebergs originating from ice shelves

Table 4.1. Types of Antarctic ice: quick definitions.

As icebergs adjust to their diminishing size they change their position in the water. Here it is possible to see the many water- lines that have formed. © Jacobs and Arrebola.

cier, there is a thin layer of melt water, created by friction between the bottom of the glacier and the land, allowing the glacier to slide down towards the sea (Figure 1.17). Also, on warmer days the ice and snow on the top of the glacier melt and the water runs through the crevasses to the bottom of the glacier, allowing the glacier to slide further.

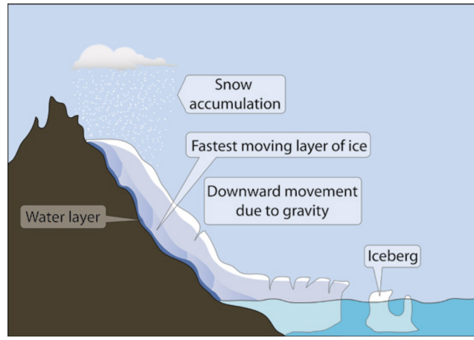


Figure 1.17. Temperate glaciers originate from the tops of mountains and flow in the valleys between the peaks. There is a thin layer of water between the ice and the land and the glacier slides towards the sea due to gravity. When the glacier reaches the sea, icebergs are calved into the water in various shapes and sizes. © Jacobs.

Ice caps

Fixed firmly to the ground are the colder ice caps. They cover the land like a blanket and are not modified by topography. Their downhill flow is due only to the great weight that accumulates upon the upper surface of the glacier, causing internal deformation of the ice crystals (Figure 1.18). Ice domes are formed when several ice caps converge, creating an even larger blanket upon the landscape.

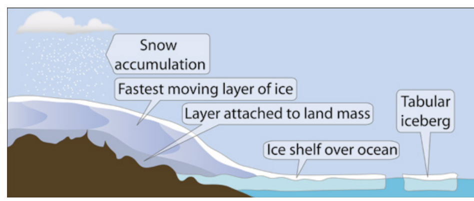


Figure 1.18. Ice cap glaciers are not altered by the underlying topography. The movement towards the sea is the result of internal deformation as it accumulates. The bottom layer is frozen to the land and does not flow. Once the ice reaches the sea it forms an ice shelf that can extend hundreds of kilometers over the surface of the water. When it breaks off, flat-topped tabular icebergs are calved into the ocean. © Jacobs.

The ice dome over Antarctica is called the Polar Plateau and it flows both northward and downhill. It is so thick (more than 4 km) that the underneath topography does not influence its trajectory and the weight has depressed the land in West Antarctica to below sea level. If the ice dome were to melt, the continent would rebound, just like Northern Europe is doing at present.

Ice shelves on the coasts are nourished by the ice coming from the heart of the continent and extending towards the sea for hundreds of kilometers. These attached-but-floating ice sheets occupy 47% of the Antarctic coastline and can be up to 50 m above and 100 to 600 m below sea level. On average, ice shelves are 185 m thick and are thickest near the coastline (up to 1,300 m). The most important ice shelves are the ronne, filchner, and larsen ice shelves in the weddell sea and the ross ice shelf in the ross sea (414,000 km2). The ross ice shelf, ranging in thickness from 150 to 3,000 m and covering a surface area approximately equivalent to that of france, is the biggest ice shelf in the world. The ice dome over antarctica likely began to form during the oligocene epoch (34 to 23 million years ago, at the time of saber-toothed cats) by a series of ice caps which appear to have joined during the pliocene epoch (5.3 To 1.8 Million years ago, with increasing mammalian distribution and widespread global cooling). Determining the ice balance (degree of accumulation and melting) of the continental ice of antarctica, however, is difficult and requires the use of satellite altimeter measurements. Essentially, satellites monitor changes in the elevation of the ice and can therefore determine whether the ice is melting or thickening. Observations are divided into two geographical regions: in east antarctica the trend is towards a general thickening of the ice, while in Western Antarctica (including the Peninsula) there is a general thinning.

Icebergs are created when pieces of ice, either from temperate glaciers or ice shelves, break off into the ocean. Their subsequent trajectory is then determined by the direction of the wind and ocean currents.

No fixed percentage of an iceberg is visible above the water – the ratio is dependent upon the density of the ice within the iceberg – but, on average, about 20% of the iceberg is above sea level. Generally, older ice of a glacier is more compressed by its own weight, and therefore has fewer air bubbles. When it calves, it is denser and less of the iceberg is visible above the surface of the water. Younger ice has more air bubbles and floats higher in the water. As an iceberg melts, both above and below the water, it changes its position, rotating slowly or suddenly. Consequently, different areas of the ice are exposed to the air and new water lines are formed by wave action. The surfaces that were once below the water ap-

Temperate glaciers are modified by the landscape as they flow down valleys into the sea. They, in turn, modify the valleys through which they flow, scraping out deeper gouges. © Jacobs and Arrebola.

A RAINBOW OF COLOURS…

Icebergs are rarely of uniform colour. The colour and the pattern can tell you a lot about the iceberg's history.

Blue: The blue colour is created when the ice is sufficiently dense that air bubbles do not interfere with the trajectory of light. Likely formed when still part of the glacier, denser ice is created either by compression over time or by melting and then refreezing. The melting or compression allows the trapped air bubbles to be released. As light travels through dense ice, the longer wavelengths (reds) are absorbed. Therefore, the denser areas absorb more red and reflect the light with shorter wavelengths that appear blue to the human eye. White ice scatters all the colours of light at the boundaries between ice and air (air bubbles) and therefore appears colourless.

Brown: The brown stripes are created by sediment, or dirt. These sediment deposits are laid down when the ice is still part of the glacier. The wind carries the sediment from eroding mountains, or volcanic eruptions, and it slowly settles upon the ice. Snow falling after the sediment covers the layer and seals it within the glacier.

Green: Green icebergs are not at all common. They are formed only when sea ice is created beneath an ice shelf and contains organic material. This portion of sea ice then becomes attached to the submerged side of the ice shelf and is released when that portion of the ice shelf calves.

Blue stripes are formed when ice melts and refreezes or is compressed, releasing air bubbles, allowing light to penetrate more deeply thereby absorbing more red light and reflecting blue light. © Jacobs and Arrebola.

Green icebergs are very rare. They are full of organic material which gives them their colour. © Jacobs and Arrebola.

Brown stripes are formed by the deposition of airborne sediment. © Jacobs and Arrebola.

Iceberg amidst brash ice. © Jacobs and Arrebola.

pear dimpled and smoother (like a golf ball) while those that have never been immersed are rougher with sharper corners. From these clues, the rotational history of an iceberg can often be approximated (Figure 1.19).

Pieces of ice too small to be icebergs are called ***bergy bits***. These chunks are between 1 and 5 m in height, up to 15 m in length and are usually pieces that have broken off larger icebergs. ***Growlers*** are generally smaller than bergy bits but are different in that they are extremely dense. They are made of old ice that is almost completely free of air bubbles, making them almost transparent. This low floating, transparent ice is very difficult for ships and other vessels to locate either by radar or by sight. Consequently, growlers can be very hazardous. ***Brash ice*** consists of smaller pieces of ice floating like a mat that has broken from continental and/or sea ice.

Tabular icebergs are huge pieces of ice calved from ice shelves. They have never rolled over and are easily identified by their flat top and awe-inspiring enormity. These icebergs can be hundreds of kilometers long and drift for many years before eventually melting. Many of the tabular icebergs calved from ice shelves in the Weddell Sea drift with the continental current – first to the west and then north until they meet up with the circumpolar current where they change direction and drift in an easterly direction towards South Georgia Island. Others pass through the Antarctic Sound, between the Ant-

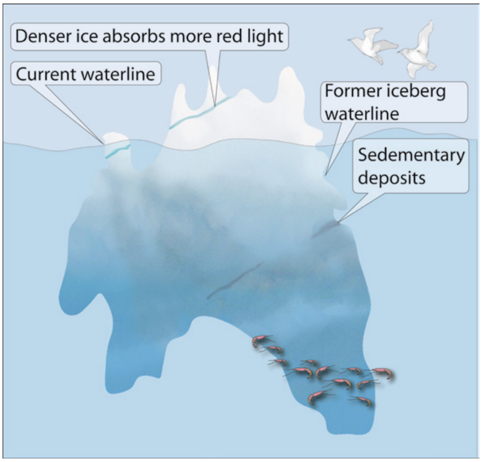


Figure 1.19. The water hides the majority of an iceberg. The amount visible above the surface is dependent upon the density of the ice. Denser ice floats lower and less is visible. © Jacobs.

Water currents and channeled melt water carve beautiful and strange patterns in the icebergs. © Jacobs and Arrebola.

arctic Peninsula and Joinville Island, and can be seen in the Bransfield Strait.

More icebergs still remain within the Weddell Gyre and drift clockwise around the Weddell Sea for several years. During the summer of 2006, a tabular iceberg drifted north through the Atlantic Ocean approaching Brazilian latitudes. It is thought that it originated from an ice shelf in the Weddell Sea.

Tabular icebergs are flat or dome topped with horizontal walls. They can be several to hundreds of kilometers long. © Kunz.

A NATURAL BUFFER: IN THE NEWS...

Though the Southern Ocean is host to very few human settlements, it has begun to show the signs of our activity. With the annual formation of sea ice during the austral winter, the Southern Ocean acts as a great natural buffer – a sponge – to human and naturally produced greenhouse gases (GHGs). When ice crystals are formed, salt is expelled, creating very dense and cold water at the surface, just beneath the ice. When this water sinks, it takes with it dissolved gases from the atmosphere such as carbon dioxide.

Some concern has been expressed regarding the potential effects of global warming on this buffer system. Decreased winter sea ice formation may have a long lasting effect on the global climate.

In June 2007, leading climatologists and oceanographers reported that this sponge system was functioning 30% less efficiently when compared with measurements taken approximately 25 years ago. It also appears that the sponge system is saturated, suggesting that the Southern Ocean has reached its absorption limit. This decline in efficiency may have been indirectly caused by an increase in atmospheric GHGs. With emissions still on the rise, losing this natural sponge could exacerbate the deleterious effects of high emissions.

Penguins rely on sea ice for a place to rest and a platform from which to fish. © Jacobs and Arrebola.

Sea Ice

Every year, after the summer daylight begins to fade, leaving behind long winter nights, the waters of the Southern Ocean begin to freeze. During the summer months, the sea ice occupies approximately 2.5 million km^2. Eventually covering approximately 20 million km2 during the winter months, a surface even bigger than the continent itself, it is one of the true wonders of the natural world. During the winter months, the sea ice reaches as far north as 56° S in the Atlantic and 64° S on the Pacific side.

With the arrival of winter, freezing begins during the night in the calm sheltered waters of small bays and channels of the continent and adjacent islands. Though you might expect the sea ice then to grow from south to north in a consistent manner, the initial freezing occurs in patches and is unevenly distributed. Ice crystals begin to appear on the surface as the water reaches freezing temperature – between -1.8 and -2.8 °C, depending upon the level of salinity. The more saline the water, the lower the temperature must be for it to freeze. In calm conditions, these ice crystals start to join together becoming ***frazil ice.***

As the winter continues, this young ice formed during the nights and melted during the shortening day will eventually build up enough thickness to remain frozen, becoming a greasy slush at the surface of sea water called ***grease*** ice. With the influence of tides and waves, this thin ice sheet breaks up into smaller pieces that collide among themselves rounding their edges to form ***pancake ice.***

As long as the temperature remains low, the pancake ice will freeze together. Pancake ice, thickening in the ever cold winter and combined with a load of snow over the surface forms pack ice. With the sea freezing underneath and the snow accumulating over it, thin pack ice will thicken to approximately one meter. Multi-year pack ice, ice which survives through at least one summer melt, can eventually reach more than 5 m thick. Sea ice melts rapidly from November to January and the flux of heat from the atmosphere and the upwelling of relatively warm Circumpolar Deep Water share equally in the responsibility for the annual melt-

Dense ice reflects blue light.
© Kunz.

ICE ISLANDS AND GLOBAL WARMING…

With rising air and sea temperatures in the Southern Ocean, there has been an increase in the calving activity on ice shelves and temperate glaciers. This means that there are more icebergs drifting around the continent. Researchers have found that these icebergs contain nutrients from the continent, which, when released into the water, kickstart the food web and create a halo of life with a radius of up to 3 km from the iceberg. Using underwater remote video cameras and above water observations, scientists have found an abundance of phytoplankton, krill, fish, and seabirds. Though it is not yet possible to determine whether there will be a significant impact on the ecosystem of the Southern Ocean, it is thought that the melting icebergs may increase global sea level.

Icebergs attract an abundance of sea life. Phytoplankton, crustaceans, and small fish swarm the waters below and seabirds soar above looking for a meal. © Jacobs and Arrebola.

ing. Relatively little data are available regarding the change in sea ice extent over the years. Satellite trends goes back only as far as 1973 (Department of Environment and Water Resources, Australia), and information from before this have been estimated from measurements of methanesulphuric acid (produced by phytoplankton and correlated with sea ice extent).

This aside, the general trend shows that between 1850 and 1950, there was very little change in the range of sea ice extent. However, after this period the data show a dramatic decline in sea ice extent (approximately 20%).

Growlers are very dense and transparent pieces of ice that can be hazardous to navigation. © Jacobs and Arrebola.

THE INHABITANTS

Terrestrial wildlife

British naturalist James Hooker first inventoried Antarctic terrestrial plant life in 1841. A member of the James Clark Ross Expedition from 1839-1843, Hooker described a total of 18 species. Though this list now includes hundreds of species, it remains short in comparison to other ecosystems at more temperate latitudes.

A number of factors contribute to the Antarctic terrestrial ecosystem's essential simplicity, not the least of which is the limited availability of ice-free land. Though the continent is 14 million km^2, only 2% of it is ice-free in the austral summer – Antarctica is the only biome in the world where knee pads are required to appreciate the terrestrial wildlife. Comprised entirely of lower organisms, the charismatic species (such as penguins and seals) are intimately tied to the sea and spend only a small proportion of their life on land.

Limited by the same factors as in other ecosystems (i.e. fresh water, soil, and temperature), those species that have managed to survive in Antarctic extremes are true wonders of nature. They have evolved unique and complicated methods for surviving in harsh conditions. Unlike most species in Antarctica (that is, uniquely adapted to cold temperatures and unable to withstand a dramatic, or even slight, change in temperature), the species that cling to the surface of the exposed rock must endure temperatures ranging from -10 ° to +30 °C during the summer months when the rock surfaces absorb the Sun's radiation. They must resist dehydration in the face of howling winds, block out harmful UV radiation, tolerate both fresh water (melting ice and snow) and salt water (ocean spray), as well as over-exposure to penguin guano. For plants and lichens, liquid water (a necessity for growth) is available for only a few weeks per year. Yet these harsh environmental conditions explain the paucity of species found in Antarctica only in part. Isolation is another important factor. Spores and seeds transported by the wind or by other animals very rarely make it as far as Antarctica. A growing human presence will likely contribute to an increase in the number of species if we are not careful.

Antarctic vegetation is limited to 380 lichens, 200 bryophytes (mosses and liverworts), an unknown number of species of algae, and 2 species of flowering plants found only on the Peninsula.

Free-living terrestrial animal life compiles an even shorter list. The majority of the terrestrial animals found in Antarctica make their living as parasites of warm-blooded species. Limited to invertebrates that seek refuge within the vegetation, the largest terrestrial animal is up to 6 mm long.

Algae

Modern algae are the descendants of the most ancient form of life on Earth – blue-green cyanobacteria have been found in rocks dated over 3 billion years. These species grow within the protection of the limited available soil, or beneath and even within rocks.

Up to 700 species have been recorded; due, however, to the limited number of scientists studying these organisms and the propensity for a single species to be named twice, the total number of species is unknown. But these algae play a vital role in providing nutrients to Antarctica's limited soil.

Guano from penguin colonies provides a concentrated source of nutrients, principally nitrogen. The winds locally distribute this nitrogen to be used by the algae and other plant life living around the colony, creating a localised centre of biodiversity. Thick undulating green mats of algae (i.e. ***Prasiola crispa***) are common in these areas.

Algae have also found a home on and within surface layers of snow. Ice and snow are generally inhospitable to life because they are a source neither of water nor nutrients. However, snow algae are able to acquire water by using their pigments to absorb the Sun's heat, melting the snow and ice around them. This process stops when the Sun drops below the horizon, at which time the algae must survive without a source of water until the Sun reappears.

Up to 250 species of snow algae are known to paint the snow in de-

Mats of algae are often found near penguin colonies. © Jacobs and Arrebola.

Snow algae have adapted to living on the surface or within the first few centimetres of snow accumulations. The red colour is generally caused by the reproductive spores of green algae, though there are some species that are uniquely red.

lightful colours. The so-called ´red snow´ is actually an accumulation of spores from the green algae during its reproductive cycle, though some species also contain red pigments in their vegetative stage. Depending upon the species, algae are responsible for the colours green, brown, grey, and yellow. These special pigments provide extra protection from the higher UV radiation found in Polar Regions. Snow algae produce a special adhesive that allows them to bind to snow and to each other and that may assist in protection from UV radiation, though there is a limit to the protection provided. Increases in UV radiation exposure have shown to decrease photosynthesis by up to 85% in snow algae.

Lichens

Lichens are a conspicuous and hardy life form on the Antarctic continent. Often considered a plant, they are in fact a symbiotic relationship between a photosynthetic partner and a fungus, neither of which is capable of living independently.

Lichens are special for a number of reasons, not the least of which is that they may consist of organisms from three different life streams (Kingdoms Fungi, Prototista and Monera). Generally arranged in the form of a sandwich, the mycobiont (a fungus) provides shelter for its partner and collects moisture and nutrients. The photobiont is a photosynthetic partner that is either an algae (green algae) or cyanobacterium (blue-green algae). All lichens contain a mycobiont and a photobiont but some contain both alga and cyanobacterium. The partnership among lichens is so strong that the fungus cannot survive on its own except as a spore.

Lichens are able to colonise extremely harsh ecosystems and are usually the first to appear in regions that have been devastated by natural disaster such as volcanic eruptions and landslides or that have experienced glacial retreat. Approximately 380 of the known 19,000 species of lichens distributed worldwide are found in Antarctica. Often found near bird colonies, they adhere to rock faces in shades of orange, grey, and green and can be found on the most southerly nunataks. Lichens produce an acid which slowly breaks down the rock substrate into soil, allowing other less hardy species to move in.

Surviving in the most severe of climates, lichens have developed a number of adaptations. Many develop darker colouration in response to high UV levels. Some grow into the surface of porous, translucent rock (cryptoendolith), while others are able to "hibernate" during periods of dark, cold or moisture stress. Some species are able to photosynthesise in temperatures as low as -17 °C.

Three primary growth forms of lichens can be found in Antarctica: Crustose lichens form a thin crust on the substrate to which they have adhered, have only one distinct surface (the top) and are often inconspicuous as they can be microscopic in size. Foliose lichens form tiny leaf-like structures, which have two distinct surfaces – an upper and a lower. Fruticose lichens look like tiny shrubs with no distinction between upper and lower surfaces. In Antarctica, lichens are found on exposed rock as far south as 86° 21′ S and at altitudes of 2,450 m.

Identifying lichen species is very difficult and generally requires microscopic examination and a lot of experience. Identifying specifically Antarctic species is even more challenging because environmental processes, such as ice blasting, can make the lichen grow in bizarre shapes that are not typical of the species.

What's more, the distribution of lichens across the continent is uneven. The Peninsula is host to the largest concentration and diversity while some areas of East Antarctica are almost completely devoid of lichens altogether. The fastest growing lichens on Earth grow at a snail's pace of 30 mm per year; in Antarctica, the fastest grower holds the record at 10 mm per 100 years. The black lichen ***Buellia frigida*** may grow as slowly as 10 mm in 1,000 years in the dry valley area of McMurdo. Though slow-growing, lichens can live an exceedingly long time – the record is over 4,500 years. Consequently, scientists are able to use lichen growth as an indicator of changes in landscape, such as glacial growth and retreat.

Crustose lichens often cover rock surfaces and camouflage the rock's colour. © Jacobs and Arrebola.

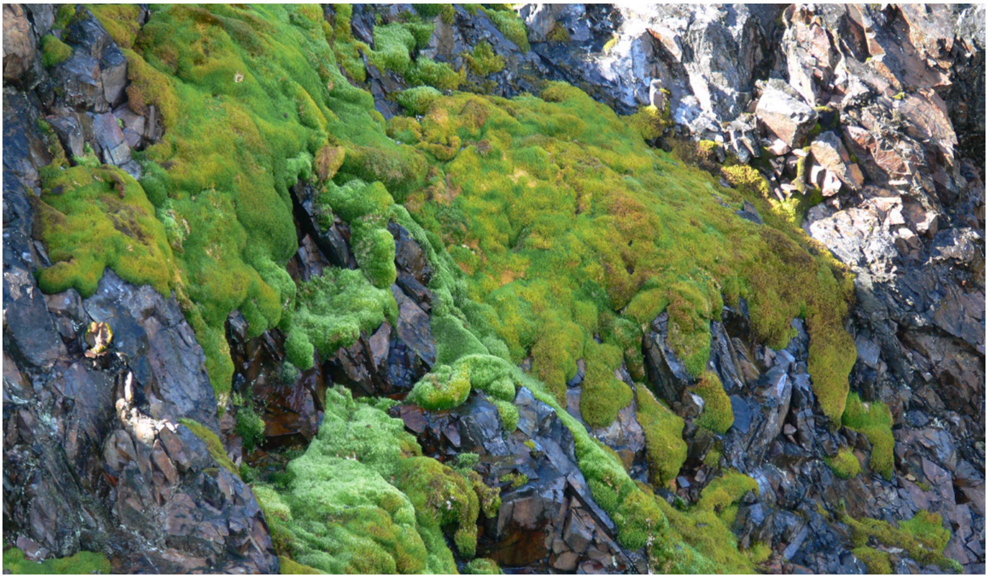
Lichens. © Richardson.

Lichens decorate the rocks in many colours. © Richardson.

Mosses

Approximately 200 of the world's 22,000 species of mosses can be found on the Antarctic continent. They are distributed as far south as 84° S, though the majority are restricted to the Peninsula. Generally forming flat velvet-like beds upon slopes surrounding penguin colonies, these plants represent one of the first branches of the evolutionary tree, likely evolved from green algae. At least a small layer of sandy soil is required in order for mosses to establish themselves. This soil, in many cases, is produced by the breakdown activity of lichens that have already colonised the area. Antarctic species have developed several adaptations to facilitate their survival. These species, compared with more temperate ones, are particularly tightly packed to minimise water loss and to create warmer microclimates within their primitive leaves. However, because they are not as hardy as the lichens, their distribution is even more limited. Antarctic mosses also often contain an orange pigment that may protect them against a higher intensity of UV radiation. During the coldest months, mosses become freeze-dried where they wait in a state of hiberna-

Fructicose lichens. © Jacobs and Arrebola.



Mosses grow very slowly in Antarctica. © Jacobs and Arrebola.

tion for the return of summer. Mosses grow between 1 and 5 mm per year depending upon the availability of water during the growing season.

Vascular plants

There are only two species of flowering plants that survive south of 60° (though there have been observations of at least two other species in very small patches on the Peninsula). Antarctic hairgrass ***Deschampsia antarctica***, the more common of the two, and Antarctic pearlwort ***Colobanthos quitensis*** are both found on the South Shetland Islands and the west coast of the Peninsula reaching as far south as

68° S. Indeed, the dramatic warming of the Peninsula has lead to a population explosion of vascular plants. It is estimated that there has been a 25- and 5-fold increase in seed germination of hairgrass and pearlwort respectively, and both species are found further south than they have been in recent history.

These plants seek protection in moss beds and use the soil produced by lichens and mosses. They often get their nutrients from the guano expelled at penguin colonies. Antarctic pearlwort in particular is moss-like in appearance because it tends to grow in small dense patches, reaching a height of approximately 5 cm.

Antarctic pearlwort is a tiny plant, sometimes confused for a moss. © Jacobs and Arrebola.

Antarctic hairgrass nestles in around the moss for protection. © Jacobs and Arrebola.

Antarctic pearlwort. © Richardson.

Animals

Terrestrial animal life is of very low diversity in Antarctica. The majority of Antarctic insects are parasitic, relying upon the warmth of their warm-blooded hosts for survival. In fact, 45 of the 67 recorded insect species in Antarctica and the majority of the 528 species of mites are parasites. Parasitic ticks, members of the ***Arachnidae*** (spiders), mainly parasitise seabirds. They can tolerate an astounding range of temperatures because they must survive off their host as well as remain attached to it, which they do for only one month of the year.

For the remaining 11 months, they clump together to prevent dehydration.

The springtails (8 species) are the only non-parasitic, free-living insect-like animals on the continent and average about 1 mm in length. They are found most commonly in cool and moist areas, usually under rocks, packed together in a dense mat to prevent desiccation. During the winter months, they can supercool to temperatures well below 0 °C, but they will not freeze. Springtails live up to 3 years and play a dominant role in the Antarctic terrestrial ecosystem.

The wingless midge ***Belgica antarctica*** is the largest terrestrial animal in Antarctica. Though they are a true fly, they have no wings. This is an adaptation to remaining upon land and not being blown out to sea.

These insects have two distinct life stages: larval and adult. The larvae live for two years to accumulate enough reserves for reproduction. During the winter months they freeze solid and resume metabolism when the summer arrives. Like the springtails, the larvae are often found grouped together under rocks but they can also tolerate a loss of 65% of their body mass due to dehydration. In summer, the larva metamorphoses and becomes the reproductive adult, only to live for 10 days before dying. It is distributed in association with moss beds and can be seen walking across them on warmer summer days.

Because these species remain upon the continent throughout the winter

A pair of Belgica Antarctica mating.© Lee.

months, preventing the formation of ice crystals within the body is of primary importance. They have developed a special system, similar to that of some marine fish for surviving in cold temperatures. Springtails, midges, and mites have antifreeze compounds within their bodies that allow them to supercool to temperatures as low as -35 °C without freezing. These anti-freeze compounds include glycerol, alcohol derivatives of sugar, and some sugars, all of which are produced by the body. Food particles within the gut are particularly susceptible to ice crystal formation. Springtails therefore undergo cycles of feeding and fasting in relation to environmental conditions.

Belgica Antarctica larvae. © Lee.

TERRESTRIAL ARTHROPODS ON THE ANTARCTIC PENINSULA: THE DOMINANT LAND ANIMALS

Dr. Richard E. Lee, jr., Miami University, Oxford, U.S.A.
and Dr. David L. Denlinger, Ohio State University, Columbus, U.S.A.


Raft of the collembolan Cryptopygus antarcticus on a small pool of water. © Lee.

Although only a few free-living species of insects and related arthropods survive on the Antarctic Peninsula, as is true elsewhere in the world, these groups comprise the dominant land animals. Unlike fair-weather summer tourists - the penguins and whales - these species remain on the land and must be able to survive the full rigors of winter. These animals are associated with moss beds, terrestrial macroalga (especially ***Prasiola crispa***), and outwash and detrital habitats associated with seal wallows and seabird rookeries.

A few species of ***Collembola***, commonly called springtails or snow fleas, are commonly found in alpine and polar regions. Springtails are tiny, usually less than 1-2 mm in length, and are often associated with moist microhabitats, where they feed on lichens, algae and fungus. ***Cryptopygus antarcticus*** is a common species on the Peninsula that sometimes forms rafts on small pools of water. A recent study found that springtails may be picked up by the wind and dispersed hundreds of meters - and possibly several kilometres - which may be an important means for their dispersal to new habitats.

Small mites (0.5 to 2 mm) are also commonly observed in moist areas beneath rocks and near vegetation. But not all species are restricted to moist environments. Colonies of the ubiquitous mite ***Alaskozetes antarcticus*** are frequently found in dry microhabitats such as the surface of protruding rocks. Most mites are scavengers on dead organic material or feed on algae, including the common macroalga ***Prasiola crispa***, but some solitary species prey on other mites and springtails. Low temperature and short summers limit the growth and development of mites and springtails, which often require more than one year to complete their life cycle. However, these microarthropods appear to feed opportunistically in response to favourable temperatures and environmental conditions throughout the year.

The tick ***Ixodes uriae*** parasitises more than 50 species of colony-nesting seabirds including various penguins, albatrosses, and petrels. The tick is notable because it exhibits a circumpolar distribution in both the northern and southern hemispheres. Its geographic distribution is likely owing to the legendary transpolar migrations of some of its hosts. This ectoparasite typically takes only one blood meal per year when its host is nesting, and consequently requires four years to complete its life cycle. After feeding it forms (sometimes massive), aggregations beneath rocks near the rookeries where it moults and remains quiescent for the remaining 11 months each year. Due to global warming during the past 30 years, the Adelie penguin populations near Palmer Station on Anvers Island have decreased dramatically to the point where no breeding colonies are expected to remain in a few years; unsurprisingly, adjacent tick populations have decreased concomitantly.

Only a few true insects are found in the maritime Antarctic. Of these, the wingless fly ***Belgica antarctica***, occurs further south than any other insect. Typical of many insects living in windswept alpine and oceanic habitats, the adults are wingless; in short, high-flyers are blown out to sea and do not leave offspring. This midge species has the distinction of being the largest, free-living land animal on the Peninsula; some of these giants reach 6 mm as mature larvae, while the adults are smaller (2-4 mm). This species has no known predators or parasites. Larvae feed on moss, terrestrial algae (particularly ***Prasiola crispa***), plant and animal detritus, and microorganisms, and require two years to reach adulthood. In contrast, the non- feeding adults live for fewer than two weeks; enough time to mate and lay eggs.

Compared to continental Antarctica, environmental conditions on the maritime Peninsula are less severe. However, even during the austral summer microarthropods may experience subzero temperatures at any time. Springtails, mites, and ticks must avoid freezing and do so by lowering their supercooling point (the temperature at which ice forms spontaneously within their bodies) to temperatures of -20 or -30 °C. The depression of their super-cooling point is promoted by the accumulation of glycerol and related polyhydric alcohols and sugars and the removal of potential ice nucleators from the gut.

In contrast, midge larvae can survive freezing of their body water year-round. Their capacity to survive freezing is associated with the production of sorbitol and other cryoprotective compounds. Our research team also discovered that midge larvae can rapidly increase their cold tolerance in response to cooling. Summer larvae that were exposed to freezing at -5 °C for only one hour were able to survive -20 °C for 24 hours, whereas all larvae directly exposed to -20 °C died. Additionally, our research suggests that instead of freezing, larvae may undergo an extensive cryoprotective dehydration whereby they avoid freezing during the winter.

Colony of the mite Alaskozetes antarcticus on a rock. © Lee.

Close-up of the adults, nymphs and eggs of the mite Alaskozetes antarcticus. © Lee.

The sea floor of coastal Antarctica is covered with a vibrant community of invertebrates and algae.

MARINE WILDLIFE

The abrupt cooling of the Southern Ocean some 15-5 million years ago led to a widespread extinction of organisms living within its depths, but surviving species have since evolved unique adaptations to thrive, often in incredible numbers, within the near-freezing waters. With comparatively few species living in the Southern Ocean, this ecosystem is considered a simple one. This, however, should not suggest that Antarctica in general and the Southern

Ocean in particular are empty of life, but rather that diversity in these regions is lower than it is in ecosystems at lower latitudes. Few species are capable of surviving under such pressures (cold temperatures, for example) (Figure 2.1). In spite of the Southern Ocean's simplicity, new research has revealed that its biodiversity is a lot higher than previously thought; it has just been a matter of looking. Recent samples collected deep below the surface have revealed a suite of new species. In 2007, a team of European researchers raised samples of water and sediment from depths of 6,200 m and discovered that of the 674 species of isopods (tiny invertebrates) found in the samples, 585 had never been seen before.

With respect to biomass (the mass of life), some of the largest congregations of animals can be found among the penguin colonies and the swarms of Antarctic krill. During the austral summer, the Southern Ocean is the most productive on Earth (actually, it is about four times more productive than the other oceans combined). This astounding productivity is due to a combination of upwelling areas and low water temperatures. Upwelling brings nutrients from the sea floor towards the surface for photosynthesising algae. Cold water carries more dissolved oxygen than warmer water, making it easier for animals to access it. Those few species adapted to living so far south are, therefore, extremely successful within their environment. Though many species can be found along the coasts of Antarctica during the summer months, most marine species are migratory and seek more temperate climates during the extremely harsh winter. Very few species are truly endemic to Antarctica. The list of endemics does include the famous Emperor Penguin, of course, but also the less celebrated terrestrial arthropods. Irrespective, all the plants and animals that endure even the warmest of summer conditions are specially adapted for survival in such a climate. In Antarctica, fat, feathers, and fur are the rule for marine animal survival. Certainly, there are still too many species living in the Southern Ocean to provide even a brief description of them all here. Instead, we will focus upon the species encountered most frequently by visitors – those found near or on the Antarctic continent and adjacent Islands of the Peninsula.

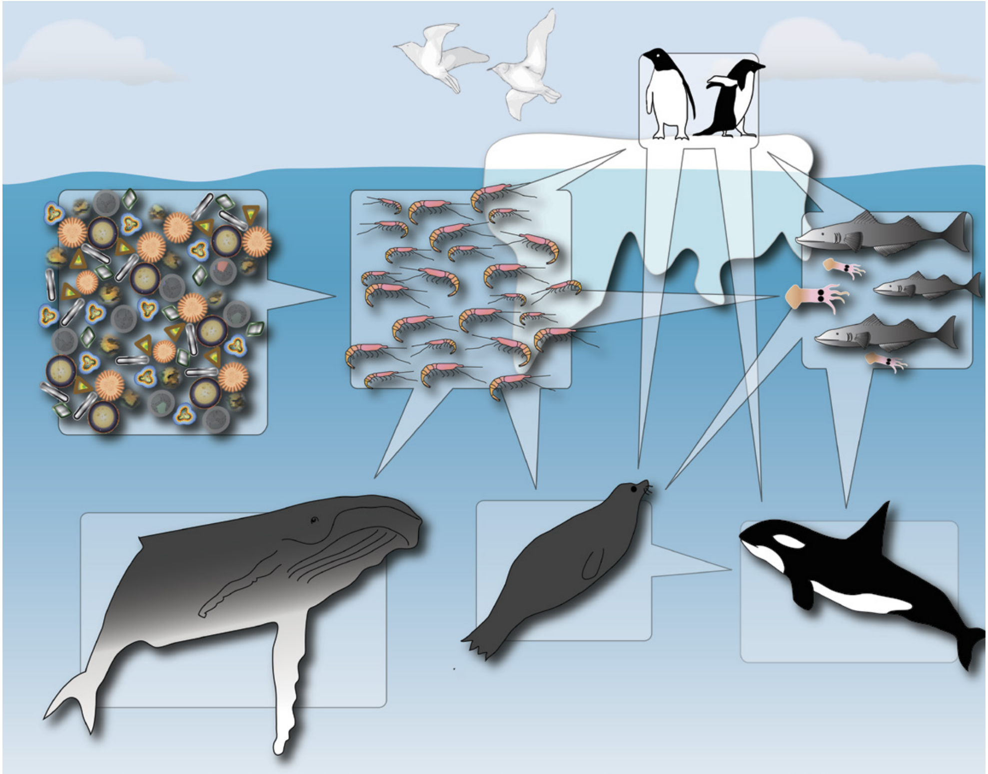


Figure 2.1. Antarctic food web. Phytoplankton, the food web's photosynthetic kick-start, are consumed by zooplankton, a category dominated by krill. Though it may appear complex, the Antarctic food web is relatively simple compared to ecosystems at more temperate latitudes. © Jacobs.

Many species of whales, including the humpback whales *Megaptera novaeangliae*, make their way to the Southern Ocean during the summer to feed on rich concentrations of krill. © Morgenthaler.

Plants and invertebrates

During the austral summer, the long daylight hours promote photosynthesis of microscopic algae – mainly unicellular diatoms – which bloom explosively to provide the base of the Antarctic food web. This explosion is followed by an increase in the numbers of krill, copepods, and amphipods that feed directly upon phytoplankton. In turn, these grazers of phytoplankton attract birds, whales, and other sea mammals – all voracious eaters of krill.

Black rockcod Notothenia coriiceps. Antarctic fish have anti-freeze proteins running through their veins and arteries to ensure that ice crystals do not form in their bodies. © Jacobs and Arrebola.

Productivity reaches a minimum during the winter months when the Sun is hidden below the horizon for the better part of each day. The sea freezes, dimming the underwater light, and diminishing photosynthetic processes. Most of these unicellular algae will remain trapped in a latent state inside and beneath their prison of ice waiting to be released the next summer and reinitiate their explosive celebration of life. Even though productivity is low, the presence of phytoplankton is essential

The Southern Ocean is host to a colourful and diverse array of life. A jellyfish floats in the water column just offshore of McMurdo Station, Antarctica. © Clabuesh, National Science Foundation.

for the survival of krill, which find shelter and food under the surface of the sea ice during the long winter months. As a consequence of this close association between the marine ecosystem and ice coverage during the winter months, it is thought that the declining annual winter sea ice cover may cause the krill population to decline in future years.

Algae and phytoplankton

Algae are a very diverse group of both marine and freshwater plant-like organisms. They range in size from microscopic free-floating single cells to individuals metres long that live in dense forests on the sea floor. Within this range, the very small phytoplankton are the most important within the Antarctic marine ecosystem. They form the base of the food web upon which all life depends.

Phytoplankton are tiny, single-celled organisms that use the Sun's energy in combination with chlorophyll to make sugars, or food. Their movements are determined by the winds, tides, and currents because they are too weak to move against these great forces on their own. Diatoms, single-celled organisms with cell walls made of silica (glass), are the most abundant phytoplankton with approximately 8,000 species (more than 350 of which can be found in the Southern Ocean). They can be distinguished from each other by their unique shapes and grooved patterns in their silica walls. Another important group of phytoplankton is the dinoflagellates. A few of these species are responsible for red tides; a dramatic increase in the population of dinoflagellates that can turn the water red. A biproduct of this bloom is the release of a toxin that can accumulate in the tissues of shellfish. Human consumption of these shellfish can lead to serious illness or death. The Sun's hiatus during the winter months has created an important seasonal cycle in the phytoplankton populations of the Southern Ocean. When there is no sunlight, the phytoplankton cannot photosynthesise and the rest of the food web must either reduce their consumption or migrate to more productive waters. At the other extreme, during the summer months, the Southern Ocean is home to one of Earth's greatest concentrations of phytoplankton. ***Macro***

Macro algae are washed up on the beaches of the Antarctic Peninsula. © Jacobs and Arrebola.

Algae come in many shapes, sizes and colours, from single celled, to broad leafed. © Jacobs and Arrebola.

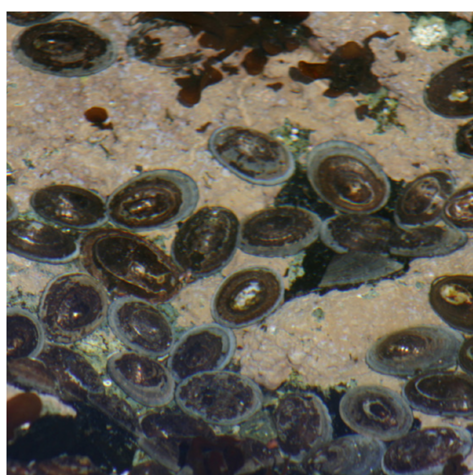
algae form dense beds along the shallow ocean floor (up to 80% coverage in some areas) where there is sufficient light for photosynthesis. Not a lot of research is currently being conducted on these populations because they are not harvested for human consumption, nor do they appear to play a significant role in the food chain of the marine ecosystem. Macro algae are not grazed upon by marine herbivores because they contain a chemical toxin that deters herbivory. Upon their death, however, they are a source of nutrients for the ecosystem.

DID YOU KNOW THAT PHYTOPLANKTON CAN CONTROL CLIMATE?

1) A significant proportion of the atmosphere's carbon dioxide is absorbed by phytoplankton for the production of sugars by photosynthesis. When the phytoplankton dies, it brings with it that stored carbon dioxide as it gently sinks to the ocean depths. This helps to reduce the atmospheric concentration of carbon dioxide, a greenhouse gas.
2) During photosynthesis, some phytoplankton release sulphuric compounds that facilitate cloud formation. Clouds increase the reflection of the Sun's light back into space and thus influence the local climatic conditions.

Seafloor invertebrates

The majority of the habitat on the Antarctic Continental Shelf is found within the soft sediment that occupies over 90% of the area. These benthic (living on the sea floor) communities

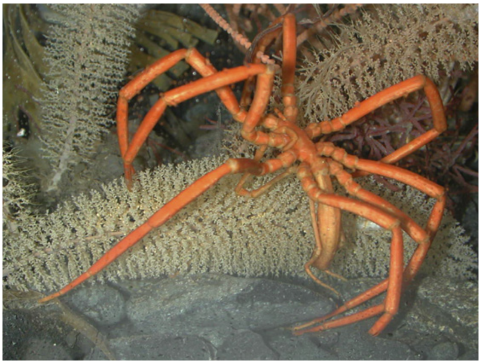


Limpets line the shallow sea floor, or the intertidal zone. They are an important source of prey for Kelp Gulls. © Jacobs and Arrebola.

of animals are composed of worms, crustaceans, echinoderms (starfish and urchins), shellfish, and many other groups of animals with which we are less familiar. Though cold water often gives an impression of drab and sparse life, this is not the case. The benthic communities of the Antarctic Continental Shelf exist in full colour and densities, sometimes with over 150,000 animals per square meter!

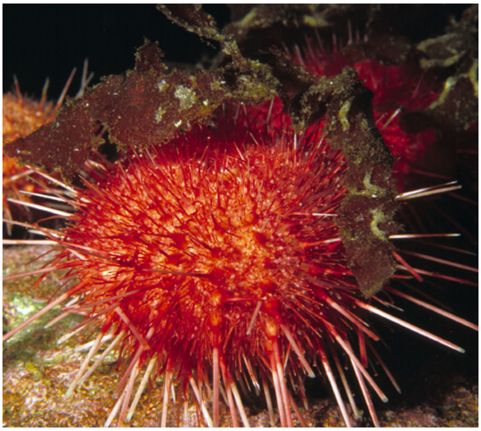
Several interesting adaptations among the seafloor invertebrates have evolved to sustain life in this frigid environment. Gigantism is likely the result of the high concentrations of oxygen and limited predators within the cold waters. Some isopods can reach up to 20 cm in length and weigh up to 70 g. This is enormous compared with more temperate species, which are only a few centimetres long and weigh only a few grams. Giant underwater spider-like creatures (class ***Pycnogonida***) can be as large as 70 cm across.

They are completely harmless to humans and feed on corals and sponges. Some species also live longer than their relatives living in more temperate environments. This adaptation allows individuals to wait out harsh conditions for a more favourable period in which to reproduce. A particularly harsh breeding season for an organism that lives only one or two seasons could be devastating to the population. A longer lifespan also explains in part why the invertebrates of the Southern Ocean tend to be larger than their more northerly counterparts.

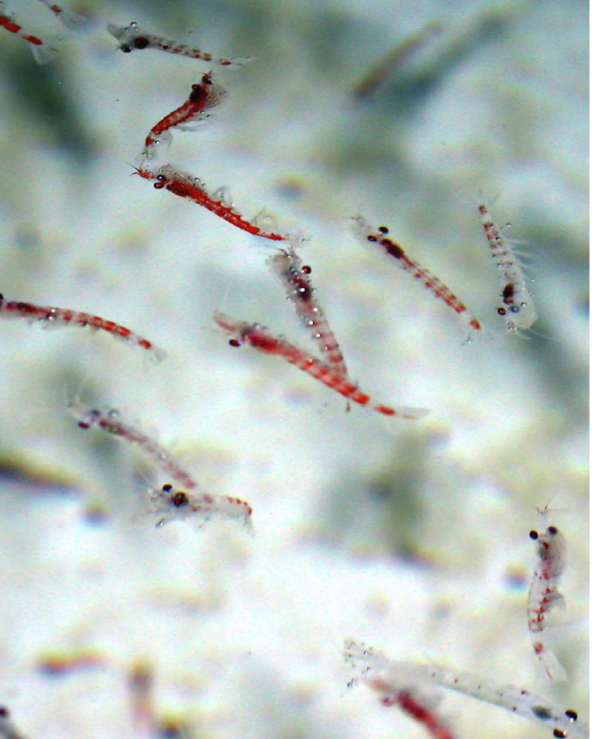


Sea spiders are strange creatures that live on the bottom of the ocean. They are particularly large in the Southern Ocean, though completely harmless to everything except corals and sponges. © Magnoni.

An echinoderm (starfish) collected by scientists at Palmer Station, Antarctica. ©Wainschenker.



Warm colours in cold waters. A sea urchin Sterechinus neumayeri camouflaged with red seaweed Phyllophora antarctica, under the ice near Cape Evans in Antarctica. © Budd, NIWA: K081 01/02.



Krill can range in size from 1 – 6 cm and are a key component of the Southern Ocean food web. © Magnoni.

Krill

Krill are the primary source of food for baleen whales, some seals, penguins, and other birds that visit the Antarctic waters every summer to feed and reproduce. They are extremely abundant and successful, with a wide geographic distribution. Of the 86 species of krill known worldwide, seven live in the Southern Ocean. Of those seven species, six belong to the genus ***Euphausia*** while the other belongs to the genus ***Thysanoessa*** (***T. macrura***). In addition to being the largest of these species, the Antarctic krill ***Euphausia superba*** is the most abundant, with an estimated biomass of approximately 500 million tons. It lives at depths between 0 and 100 m and is found at latitudes above 55° S.

Like other crustaceans, krill grow by moulting their shells to increase in

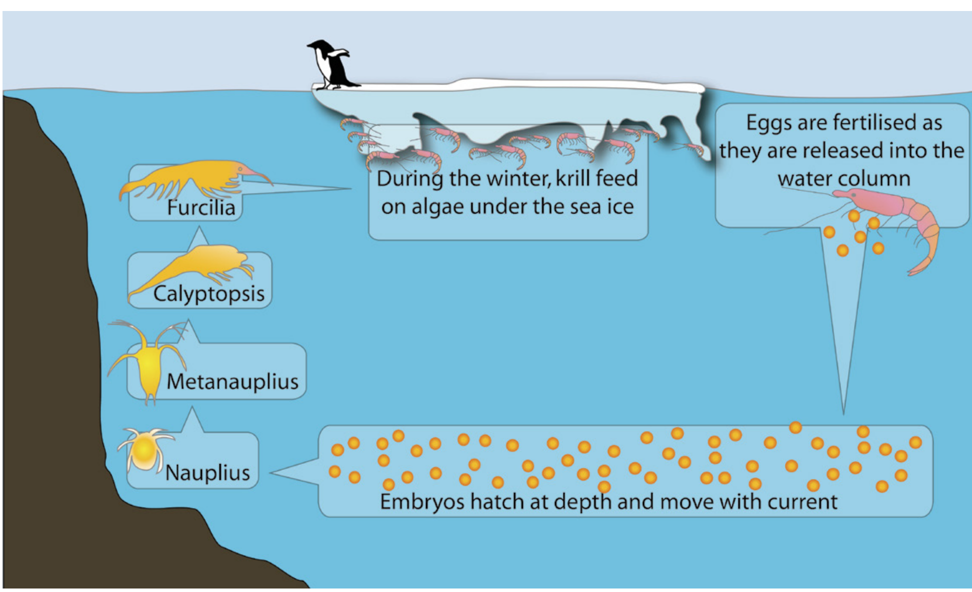


Figure 2.2. Krill eggs sink to depths of 1,000 m, joining the Circumpolar Deep Water as protection from predators. After the eggs hatch, krill undergo a series of body changes as they feed upon their yolk sac. When they have reached the surface, they have well developed mouth parts and begin to feed on phytoplankton. © Jacobs.

Almost translucent, it is possible to see inside the stomachs of these krill. They are full of phytoplankton. © Macfarlane, Antarctica NZ Pictorial Collection: AnMK7.

size. Females, which are slightly larger than males, can reach up to 6 cm in length. In periods of limited food an adult krill can actually reduce its size to survive, obtaining nourishment from the proteins stored within its body. Determining the age of an individual cannot, therefore, be done simply by measuring its size. It has been estimated that these cold water species can live up to seven years, although some evidence suggests that life spans differ between the sexes. Each reproductive female can release up to 10,000 eggs at a time and does so several times during the summer months. The males deposit a sperm sac within the genital opening of the female and the eggs are fertilised as they are released into the water column. As the embryos develop, they sink at a rate of approximately 150 m per day to a final depth of up to 1,000 m, entering the Circumpolar Deep Water. Here the embryos escape surface predators looking for a fatty meal. Once at depth, the eggs hatch and the larvae begin an ascending migration, feeding upon their yolk sac, growing and changing shape several times before they reach the surface (Figure 2.2). Concurrently with the ascending movements of the krill itself, the Circumpolar Deep Water will transport them southward towards the continent to the Antarctic Surface Water at the Antarctic Divergence. This area is high in phytoplankton productivity. Upon their arrival the larvae, having exhausted their supply of energy-rich yolk, will have fully developed mouths and digestive systems for feeding. During the summer months, adults feed upon the rich concentration of phytoplankton within the water column. However, when the Sun retreats and the ice begins to form, much of the phytoplankton dies and is no longer available for grazing organisms. Krill find shelter under the sea ice and shift their diet to algae that adhere to the under surface of the ice. Even

Penguins regurgitate stomach linings saturated in fluorine to prevent its toxic effect. © Jacobs and Arrebola.

with low light, these algae not only are able to photosynthesise – they are responsible for the survival of krill during these cold and dark months. Krill graze upon these algae in two ways in accordance with the freezing and melting cycle of sea ice. When the ice has formed and the algae are thriving upon the surface, krill scrape the surface clean to remove their food. When the ice begins to melt and releases the algae into the surrounding water, krill filter the melt water to gather food. It is clear that the annual formation of sea ice is a requirement for the survival of krill. It has even been shown that the larger the annual extent of sea ice, the more successful the population of krill the following summer. As a defence mechanism against smaller predators that hunt individual prey items, krill are gregarious and can concentrate in swarms extending for many kilometres and reaching depths of 200 m. These congregations also increase their chances of finding food. However, the strategy of swarming possesses some important disadvantages: individuals are completely exposed to their primary predators, the baleen whales, which feed upon krill in enormous numbers, filtering large volumes of water through their baleen plates. A secondary disadvantage of gregarious krill behaviour is exposure to commercial capture. The commercial fishing of krill began in the 1970s, mainly by Russian and Japanese fleets. The Russians made use of krill products for feeding farm animals while the Japanese utilised the products for human consumption in staples such as soup mix, cheese, and some beverages. The health of the krill population in the Southern Ocean has been identified as an essential parameter required for ecosystem management under the Convention on the Conservation of Antarctic Marine Living Resources (CCAMLR) regime. In 1993, with the high catch of krill for commercial use, the members of CCAMLR limited future commercial krill fishing to ensure that the Southern Ocean population is not depleted. In the same year, Russia abandoned its fishing operations, thus dramatically reducing the catch. Currently, Japan, South Korea, Ukraine, and Poland are the most important krill fishing nations. Krill meat is high in protein but it is also very toxic to humans due to high concentrations of fluorine. The krill absorbs fluorine from the seawater, which is deposited in the body's chitinous exoskeleton (the outer shell.) When the krill dies, decomposition causes the fluorine to pass through the exoskeleton into the soft part of the body. The enzymes that

Trematomus bernacchii is one of the 200 known species of fish living in the Southern Ocean. © Davison, Antarctica NZ Pictorial Collection: K057 06/07.

cause the fluorine to be released from the exoskeleton and leach into other parts of the body are denaturalised at temperatures higher than 30 °C. So, in order to be suitable for human consumption, the krill must be processed quickly after capture to avoid contamination. Seabirds and marine mammals can denature the enzymes by their body heat and store the fluorine in their bones for a while. In penguins, the majority of the fluorine is excreted with the non-digested shell, while the rest is stored in the bones and eliminated by the kidneys. Penguins also have a stomach lining, which has recently been discovered to absorb fluorine. This lining is regurgitated and replaced once it becomes saturated.

Fish and squid

Squid and fish are located in the middle of the food web, feeding upon plankton while being fed upon by birds and marine mammals, including large toothed whales.

Though relatively little is known about squid inhabiting the waters of the Southern Ocean, it is estimated that animals higher in the food web consume approximately 34 million tons of squid, or 33% of the stock, annually. Up to 72 species have been identified south of the Polar Front, most of them pelagic. Squid range in size from the 15 cm ***Brachioteuthis*** to the 4 m long ***Mesonychoteuthis*** with large hooks on its fins. It is thought that many species continue to live in the Southern Ocean unknown to humans. Of the 200 species of fish found in the Southern Ocean, 75% of the species and 90% of the individuals belong to the same suborder, the ***Notothenioidei*** (a group commonly referred to as Antarctic cod, though this is a misnomer because they are not related to true cod). Furthermore, 80% of the species within this suborder are endemic to Antarctica.

A benthic fish collected by scientists at Palmer Station, Antarctica. © Wainschenker.

Though the strategies for living in such cold environments evolved separately, they are similar to those previously described for mosses, terrestrial insects, and marine invertebrates. Fish living in the Southern Ocean have a lower metabolism, anti-freeze compounds, and can grow very large. Antarctic Cod ***Notothenia coriiceps*** can reach lengths of 1.5 m and weights of 25 kg. Curiously, the ice fish (named for its pale colour; ***Chaenocephalus aceratus***), a member of the group ***Channichyidae***, is the only vertebrate that does not have red blood cells (and therefore, no haemoglobin) and is currently the focus of several research projects in Antarctica. It has been suggested that these adaptations reduce the blood's viscosity and therefore the amount of energy required to circulate oxygen throughout the body. Along with the ability to survive the lowest temperatures of any cold-blooded animal, these adaptations have rendered these cold water species intolerant to any changes in temperature, making them the holders of the narrowest thermal tolerance ranges. This means that while they would thrive at the kinds of low temperatures that would kill every other fish in the world, a small change in temperature could lead to their death. There are two species of toothfish in the Southern Ocean: the Antarctic toothfish ***Dissostichus mawsoni***, which inhabits the deep waters closer to Antarctica, and the Patagonian toothfish ***Dissostichus eleginoides***, which inhabits deep waters further north. Though both species are sought by the commercial fishery, the Patagonian toothfish is most popular because the Antarctic toothfish is often inaccessible under the sea ice. Individuals caught in the Southern Ocean have been greater than 2 m in length. The fishing of toothfish is currently regulated by CCAMLR (Convention for the Conservation of Antarctic Marine Living Resources), though illegal fishing is estimated to be triple that of the officially reported catch. As it happens, toothfish fishing regulations for the Southern Ocean do not apply north of the Polar Front. But there is reason for concern with overfishing: toothfish are long-lived and reproduce at low rates; individuals do not begin breeding until they have reached 8-10 years old. This is hardly an ideal condition for a commercial fishery that is most sustainable when targeting species that breed frequently and yield high numbers of offspring. Regarding the remaining fish species, very little is known about their biology. This is because of their small size, their inaccessibility, and their consequent lack of economic value. Most of them grow no longer than 40 cm and live at great depths, including the rattail fish ***Coryphaenoides filicauda*** and the rakery beaconlamp ***Lampanyctus macdonaldi***. Some, such as ***Oneirodes notius***, have not been given common names.

COLD-BLOODED AND BIG-HEARTED: ANTARCTIC FISH

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The waters of the Southern Ocean range from the freezing point of seawater (-1.9 °C) to +2 °C throughout the year. Isolated by bitterly cold circumpolar currents and the deep ocean trenches that surround Antarctica, fish fauna have been evolving for some 14 million years. Their inaccessible and pristine habitat has formed the backdrop for the development of unique physiological and biochemical traits. Perhaps the most well-known adaptation of Antarctic fish is the production of antifreeze compounds, or glycoproteins, that have the same function as winter windshield wiper fluid. Antifreeze compounds have very regular geometrical structures, which help prevent the growth of small ice crystals by excluding new water molecules from the ice structure. The blood of these fish contains high concentrations of these compounds, which is why body fluids removed from Antarctic fish do not freeze unless immersed in temperatures below -2 °C. This allows these extraordinary fish to live in ice cold waters without freezing their tissues. Antarctic fish are so well adapted to life in the cold that they cannot survive exposure to water temperatures above 5 °C. The presence of antifreeze compounds in the fluids of Antarctic fish alone is not the only reason that these animals are able to survive in such frigid waters. Other structural and functional characteristics enable Antarctic fish to flourish in temperatures human beings could not endure for more than a few seconds. In very cold temperatures, metabolic processes are slower, resulting in diminished response times from hormonal release to muscle contractions. To combat this, Antarctic fishes have modified enzymes and cell walls, similar to the skeletons of cells, which allow their metabolisms to keep churning. In addition, these fish have high numbers of mitochondria (the furnaces of cells that burn fuel to obtain energy for the organism). Because there are more of these 'little burners' within each cell, the number of enzymes per cell increases proportionally, allowing the fish to convert food into energy at a faster rate. In seawater, the colder the water is, the higher the concentration of oxygen, making the Antarctic seas an exceptionally well oxygenated aquatic habitat. This may help to explain why some mutations that probably would have been disastrous in other warmer environments were passed on in the icefish family of Antarctic fishes (***Channichthyidae***). This group of Antarctic fishes has lost the capability to produce hemoglobin, a compound found in red blood cells used to deliver oxygen to the rest of the body and that is ever-present throughout the animal world. Instead of using hemoglobin, icefish transport gases dissolved directly in the blood. Scientists are not sure whether this is an adaptation to a cold environment. Some researchers believe that the increased blood thickness that occurs at low temperatures is linked to the loss of hemoglobin, and could explain some of the icefish's unusual anatomic characteristics such as its super-sized heart, enormous capillaries and elevated blood volume.

Blackfin icefish Chaenocephalus aceratus (top), humped rockcod Gobionotothen gibberifrons (middle), and ocellated icefish Chionodraco rastrospinosus (bottom). © Magnoni.

During the breeding season, the accessible coasts of Antarctica are covered with parents and chicks, mostly penguins. © Jacobs and Arrebola.

BIRDS

Of the 35 species of birds found within the boundaries of the Southern Ocean in either their winter or summer range, 16 are known to breed on the Antarctic continent. Two more species breed only on offshore islands, and a very small number of Macaroni Penguins ***Eudyptes chrysolophus*** have been recently observed breeding on the South Shetland Islands (Table 2.1). What Antarctica lacks in species diversity, it more than makes up for in numbers; over 200 million individuals are thought to breed or visit Antarctica during the summer months, 65% of which are penguins.

Here we present those breeding in the Southern Ocean and a few more commonly seen gliding over its waters.

Though the waters of the Southern Ocean reach peak productivity during the summer, making it an ideal source of nutrition for breeding birds and their offspring, this abundance of food does not last long. Because the Antarctic summer lasts only a few months, all reproductive activities must be rushed. Even a small mistake during the season can be fatal. For example, late arrival at the breeding colony could make finding a suitable nest site impossible, or reduce the quality of the site that the couple is able to obtain. For the ***Pygoscelis*** penguins, the loss of an irreplaceable egg, for whatever reason, will reduce potential breeding success by half (only Gentoo Penguins ***P. papua*** are sometimes capable of laying a replacement clutch if their first attempt is lost). Breeding in such harsh conditions requires a lot of teamwork. In Antarctica, long lasting, monogamous relationships are essential.

Among those birds that challenge the unpredictable Antarctic weather, we find one group that has become

ORDER	FAMILY	SPECIES	BREEDING LOCATION IN ANTARCTICA
Sphenisciformes	*Spheniscidae*	Emperor Penguin	Peninsula, Coastal Antarctica
		Adelie Penguin	Offshore Islands, Peninsula, Coastal Antarctica
		Gentoo Penguin	Offshore Islands, Peninsula
		Chinstrap Penguin	Offshore Islands, Peninsula
		Macaroni Penguin	Offshore Islands, Peninsula (very few pairs)
Procellariiformes	*Procellariidae*	Southern Giant Petrel	Offshore Islands, Peninsula, Coastal Antarctica
		Cape Petrel	Offshore Islands, Peninsula, Coastal Antarctica
		Snow Petrel	Offshore Islands, Peninsula, Coastal Antarctica
		Antarctic Petrel	Offshore Islands, Peninsula, Coastal Antarctica
		Petrel plateado	Offshore Islands, Peninsula, Coastal Antarctica
		Southern Fulmar	Offshore Islands, Peninsula, Coastal Antarctica
	Hydrobatidae	Antarctic Prion	Offshore Islands
		Wilson's Storm Petrel	Offshore Islands, Peninsula, Coastal Antarctica
		Black-bellied Storm Petrel	Offshore Islands
Pelicaniformes	*Phalacrocoracidae*	Antarctic Cormorant	Offshore Islands, Peninsula
Charadriiformes	*Chionidae*	Snowy Sheathbill	Offshore Islands, Peninsula
	Stercorariidae	South Polar Skua	Offshore Islands, Peninsula, Coastal Antarctica
		Brown Skua	Offshore Islands, Peninsula
	Laridae	Kelp Gull	Offshore Islands, Peninsula
	Sternidae	Antarctic Tern	Offshore Islands, Peninsula

Table 2.1: Species list of birds breeding in Antarctica.

the true symbol of a continent with no natural land predators and a wealth of marine food. Specially adapted for swimming and diving, and totally incapable of flight but nonetheless a bird, penguins are synonymous with the White Continent.

Penguins

The order ***Sphenisciformes*** has only one family. Within the family ***Spheniscidae*** are six genera and 17-20 species, depending upon the definition. Species from two genera, the Emperor Penguin ***Aptenodytes forsteri*** and the Adelie penguin ***Pygoscelis adeliae***, breed only within the limits of the Southern Ocean, making them 'True Antarctic Penguins'.

All contemporary penguin species live exclusively in the Southern Hemisphere but, contrary to popular belief,

Flightless and awkward above the sea surface, penguins have evolved to prosper in the freezing waters surrounding Antarctica. © Jacobs and Arrebola.

penguins do not require cold air temperatures for survival, only cold water. Owing to the higher concentration of dissolved oxygen, cold water can support more food than warm water. The warm waters at the Equator have prevented penguins from dispersing further north; they are only found at lower latitudes if there is a cold-water current. The Galapagos Penguin ***Spheniscus mendiculus***, for example, can nest on those islands thanks to the cold Humboldt Current that flows northward from the southern tip of Chile to the Galapagos Islands as it turns westward into the Pacific. The majority of Earth's penguins nest along a wide band north and south of the Polar Front.

With the exception of moulting and breeding activities, penguins spend most of their life cycle in the ocean and are highly adapted to water. Their fusiform, hydrodynamic body allows them to move quickly and efficiently in the denser water medium. Their bones, unlike other birds (which are flexible and hollow), are rigid and solid, increasing their mass for ease of diving.

Their wings have evolved to flippers, allowing them to drive themselves into the water. They use their strong tail and feet as rudders. Their feathers are short, stiff, packed densely together, and kept impermeable by preening with oil obtained from the uropygial gland located above their tail. Preening involves using the bill to spread the oil over their bodies and is a frequent behaviour. The oil, a thin layer of air beneath the feathers, and a thick layer of fat under their skin provide the penguins with the necessary insulation for survival in the cold sea. Their feet have sharp claws for moving across the ice and snow, though slipping still occurs frequently, generally to the delight of human observers.

Penguins, known for their uncoordinated, comical movements on land, are otherwise graceful swimmers and utilise specific techniques that are thought potentially to enhance the conservation of energy while maximising speed in order to avoid predators. Porpoising, or repeatedly leaping out of the water, allows penguins to breathe while swimming at high speed. Movement through the air has less resistance than through water, so porpoising may also decrease the overall cost of swimming. Similarly, out of water penguins often fall to their bellies and move along the snow in a swimming-like motion. This also utilises less energy than walking upright and allows them to move faster over ice and snow.

Penguins are very attentive parents, and males and females share the work equally. Those species that build nests use small stones, feathers, and other small objects to make a pile in the middle of which is a depression where the eggs are laid. Building materials, most frequently stones, are often stolen from neighbours. The stealing and retrieval of stones will continue throughout the season and can outlast chick fledging. In the smaller penguins, males and females take turns incubating the egg and feeding the young while the other is feeding at sea. The couple performs an elaborate nest-relief ceremony that serves in mate and nest recognition and in facilitating nest relief by the mate. Four types of display ceremonies have been described: 1) the loud mutual display, in which both members of the pair stand facing each other, bills pointed upwards, making loud calls while waving their heads back and forth; 2) the quiet mutual display, in which both members stand facing each other, bills pointed upwards, making gentle calls with bills closed; 3) circling, in which one member of the pair walks around the nest while bowing its head; and 4) the bow-gape-hiss, in which the two members of the pair face each other, bow their heads, and softly hiss. The ceremonies are repeated several times and the combination of displays is species specific. Adelie and Chinstrap penguins, for example, do not exhibit the bow-gape- hiss display.

In the small penguins, when the chick reaches a few weeks old, it joins a nursery, or crèche, allowing both parents to forage at sea for themselves and their young. The crèche is guarded by a few adults that protect the chicks from predators such as skuas ***Catharacta antarctica*** and ***Catharacta macormicki***; Kelp gulls ***Larus dominicanus***; and Southern Giant Petrel ***Macronectes giganteus***, among others. When parents return from sea with food, they announce their return with a call that no chick has difficulty recognising. In fact, every penguin has a unique voice with which to make themselves known. The chicks come running down the beach, chasing their parent in search of a meal. Parents feed their chicks by regurgitation directly into their offspring's mouth. When plenty of food is available penguins with two chicks feed them equally. However, in some species, a shortage of food leads to the reduction of feeding in the smaller of the two chicks.

After the chicks have grown their adult plumage and are no longer under the care of their parents, the adults moult upon the beaches of the breeding colonies. Because they are replacing their feathers of the previous year, they are not waterproof during this time and are forced to spend up to two weeks without going to the sea for food. This is a stressful time for them and they seek shelter in rock outcroppings to avoid the cold winds.

The fossil record shows that ap-

Penguins have robust, compact bodies, short, dense feathers, fused wing bones, and legs that have shifted position to allow them to walk upright. ©Jacobs and Arrebola.

The uropygial gland is located at the base of the tail and produces the oil needed to keep feathers waterproof. Preening ensures that a light coating is spread around the entire body. © Jacobs and Arrebola.

Moulting is stressful for penguins because it compromises their waterproofing. © Jacobs and Arrebola.

proximately 40 different species of penguins have lived on Earth. Though it has been suggested that penguins share a common ancestry with grebes (***Podicipedidae***) and herons (***Ardeidae***), DNA (desoxyribonucleic acid) evidence does not support this. It is more likely that the ancestor was similar to modern day albatrosses and petrels, which were also strong divers. Of the six modern genera of penguins, two are found breeding in Antarctica: ***Aptenodytes*** (Emperor Penguins) and Pygoscelis (Adelie, Chinstrap, and Gentoo penguins). Research has shown that the ***Aptenodytes*** are likely the oldest of modern penguins and that speciation into the different types occurred between 20-15 million years ago.

Recent findings are turning previous theories upside down. Skeletal remains of a penguin just over 1.5 m tall found on the Peruvian coast suggest that penguins reached low latitudes 30 million years prior to previous estimates, when the Earth was experiencing one of its warmest periods in over 65 million years. Penguins may not have evolved to thrive in cold water after all.

Most birds nest in Antarctica during the Antarctic summer, building their

Many penguin species porpoise while swimming. This behaviour allows them to breathe without stopping and may reduce drag through the water. © Morgenthaler.

nests in colonies in the few places free of ice. When days begin to shorten and the ice starts to cover the summer nesting sites, most species of penguins embark upon their winter dispersal, remaining near the ice edges or polynyas (areas of open water) to feed. However, not all of them leave the continent. When the winter arrives the Emperor Penguins are only beginning their rather astonishing breeding cycle.

The penguin sitting on the nest is distracted by the two penguins stealing pebbles from its nest (right). Another penguin is closing in from behind (left). Pebble stealing behaviour goes on all season. © Jacobs and Arrebola.

#Emperor Penguin

Aptenodytes forsteri

Population status and distribution:

The 270-350,000 Emperor penguins are confined to coastal Antarctica during the breeding season. They are otherwise spread throughout the Southern Ocean and are (rarely) observed as far north as New Zealand.

Size and appearance:

The largest among the penguins, with an average height of 1.15 m and weighing up to 45 kg. Its back is grey-blue and its head is black with yellow and orange neck patches. The under parts are white turning to pale yellow on the upper breast.

Diet and hunting strategy:

The Emperor Penguins are terrific divers, with a maximum performance of 18 min, reaching 450 m (average depth of 50 m). They feed on fish (mainly Antarctic silverfish), crustaceans, and squid by pursuit diving (catching prey by actively swimming after them).

Natural history:

Unlike other penguins, Emperor Penguins breed on the pack ice during the austral winter. At the end of March or the beginning of April, males and females gather together at the edge of the continent, where the recently formed ice will not melt until the beginning of the next summer. Females, who outnumber males (approximately 60% females to 40% males), arrive first to the breeding grounds. When the males arrive, the females monopolise the males and the pair bond is formed within 24 h. Between the end of May and the beginning of June, the female lays only one egg. The female entrusts

Emperor Penguins are serially monogamous, changing partners almost every breeding season. © Gonsior, Antarctica NZ Pictorial Collection: K068 07/08

the egg to her partner who incubates it for more than two of the harsh Antarctic winter months, taking the brunt of the most extreme weather conditions. Males protect the eggs on the tops of their feet, covering them with a fold of skin that exposes them to the brood patch, a featherless area on their abdomen that transmits body heat to the egg. This is absolutely necessary to protect the egg against the cold. The males huddle together, creating a compact group, to reduce the effects of the inclement weather conditions.

During this period, females return to sea to feed and recover energy until the eggs have hatched. Having fasted for more than three months and having lost 45% of their body weight, the males provide the first meal of fat and proteins preserved inside their own

Marching to the ice edge can be done standing up on lying down. © Riedel, Antarctica NZ Pictorial Collection: K084 07/08.

bodies to their newly hatched chick. When the females return to the colony, males make their way towards the sea to feed. After several days, they return to the rookery and join the females in feeding the chick.

The chicks join the crèche at three weeks old. This increases their chances of survival from both predators and exposure. When they are five months old their down feathers change to juvenile plumage and, before they are ready to head out to sea, they are abandoned by their parents. At the beginning of the new summer season, the melting ice forces them to venture to the sea. Four years later, the chicks will return as breeding adults to the colony.

Juveniles do not have the bright orange and yellow neck patches. © Jacobs and Arrebola.

DIVORCE IN PENGUINS...

The majority of seabird species exhibit some degree of mate fidelity. This behaviour is a special adaptation to increasing reproductive success when breeding requires a high level of cooperation between partners and the execution of highly technical behaviours. Success comes with practice. The smaller penguins, such as those belonging to the genus *Pygoscelis* – the Gentoo, Adelie, and Chinstrap penguins – show a high degree of monogamy, consistent with the adaptation to increasing reproductive success. However, the penguins from the genus *Aptenodytes*, the Emperor and King penguins, tend to divorce quite frequently (15% and 19-29% mate retention from one breeding season to another). Two reasons exist for this difference:

1) Emperor and King Penguins do not build nests. When adults return to the colony to breed, monogamous species must have a mechanism to find their mates. Occupying a specific nesting site increases the chances of mate reunion because individuals have a specific geographic location to which they can return. Finding a mate among thousands can be difficult if there is no set meeting place.

2) The Antarctic breeding season is very short. Spending time waiting for a mate to return to the colony and then finding that specific mate takes a lot of time and may cost valuable energy stores. In Emperor and King penguins, reproduction begins almost immediately, with coupling occurring within 24 hours of arrival at the colony. The chance of both mates arriving at the same time is quite low, so individuals form new bonds for the season.

Penguins that do not form nests show higher rates of divorce. © Jacobs and Arrebola.

Reproduction requires a complicated series of behaviours. Practice makes perfect. © Jacobs and Arrebola.

#Gentoo Penguin

Pygoscelis papua

Population status and distribution:

Approximately 520,000 individuals. Their distribution is generally restricted to regions of the Scotian Sea. However, some are known to be in the area of Tasmania, and New Zealand. The overall population appears to be in decline and is classified as near-threatened.

Size and appearance:

Gentoo Penguins are distinguished from other Pygoscelis penguins by a bright red bill and a white bonnet over their head. They are the third largest species of penguin with an average height of 80 cm, an average weight of 6 kg and a maximum weight of 8.5 kg. Those individuals breeding further south are fatter, have longer feathers, and shorter bills than those living at more northern latitudes.

Diet and hunting strategy:

The species' feeding habits vary with the availability of prey in the water surrounding the breeding colony. In Antarctic waters, 85% of their diet is composed of krill, while further north, on sub-Antarctic islands, they feed mostly on fish. Prey is caught by pursuit diving in waters generally close to shore and at depths less than 100 m, with an average of 10 m.

Natural history:

Between October and November, adults arrive at the rookeries and rebuild the nests from previous years using small pebbles, bones and even the moulted feathers of their tails. Nesting sites are found up to 8 km inland along exposed coastlines, though the majority of colonies are located next to the shore. Two eggs are laid within the central depression of the nest and both males and females take turns during the incubation period ranging between 30 and 39 days. Chicks are fed by both parents and at four to five weeks old they join crèches, fledging in mid-February. Gentoo Penguins are the only species that feed their chicks after they have fledged. They are also the last species to leave the breeding sites, staying as late as the end of March.

Gentoo Penguin. © Jacobs and Arrebola.

Calm and less nervous than other penguin species, Gentoo Penguins are visited by tourists frequently. © Jacobs and Arrebola.

#Adelie Penguin

Pygoscelis adeliae

Population status and distribution:

Though the Adelie population appears to be in decline, the current estimate is approximately 4-5,200,000 individuals. The species occupies coastal Antarctica and some of the more southerly islands in the Southern Ocean.

Size and appearance:

The smallest of Antarctic penguins, they are 70 cm in height and weigh an average of 5 kg with a maximum of 8 kg. The head and back are completely black with white under parts, pink feet, and a white eye ring. The bill is orange-pink with a black tip.

Diet and hunting strategy:

Adelie Penguins feed mostly on crustaceans and squid but will also take small fish by pursuit diving at shallow depths.

Adelie Penguin. © Jacobs and Arrebola.

Adelie Penguins gather along the beach before plunging into the water all together. This is a behaviour performed to minimise predation by leopard seals Hydrurga leptonyx waiting in the shallows.
© Jacobs and Arrebola.

Natural history:

Adelie Penguins are true "Antarctic Penguins" and nest on the continent farther south than any other species, including Emperor penguins. They are the first of any bird to return back to Antarctica when the winter pack ice begins to melt. Males precede females to the breeding grounds at the end of September or the beginning of October, crossing over large extensions of sea ice to reach the rookery, sometimes up to 50 km from the ice edge. Females arrive a few days later to begin their short breeding cycle. Two eggs are laid in November and they hatch after about 35 days of incubation. Two weeks after the chicks hatch, they join a crèche, allowing their parents to feed simultaneously. At approximately eight weeks old, the chicks fledge. Adults and chicks are the first to leave the breeding colonies at the end of the season, with nearly all of the penguins having left by mid-March.

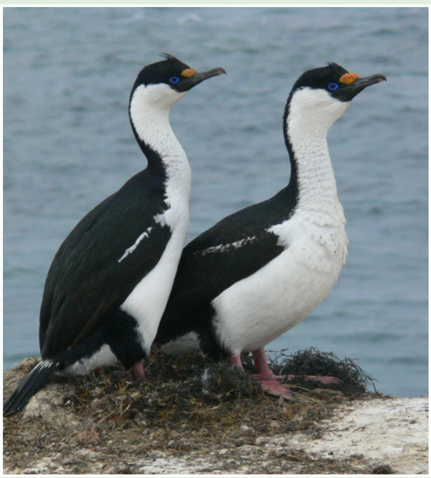
Adelie Penguins on an iceberg.
© Jacobs and Arrebola.

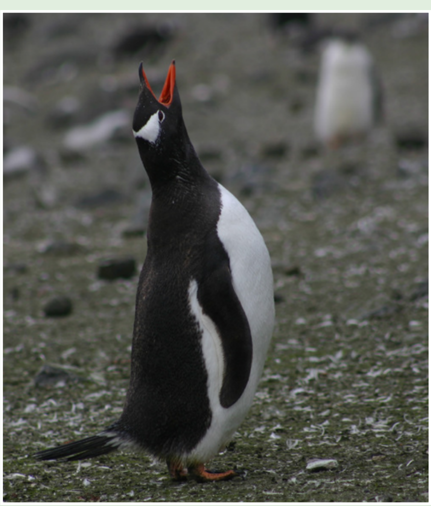
WHY DO SOME BIRDS WEAR TUXEDOS?

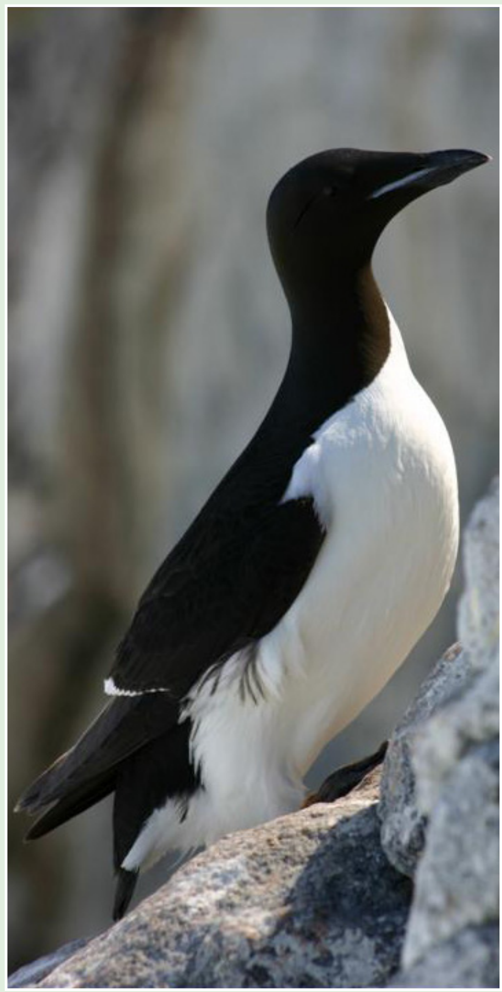
'PENGUINS WEAR TUXEDOS TO BE PROPERLY DRESSED FOR DINNER.' CAIRNS (1986).

The black and white tuxedo feathers of penguins are not restricted to this family. In fact, many species of pursuit divers, those that catch prey by diving after them, wear tuxedos including cormorants and alcids (Northern Hemisphere seabirds).

The reason for their rather formal attire is related to camouflage while hunting. A prey underneath its hunter, looking up, would see the white belly of the hunter against a bright background (the sky through the water column). A prey above its hunter, looking down, would see the dark back of the hunter against a dark background (the sea floor). The same goes for when the hunter becomes the hunted: it is camouflaged and has a greater chance of escape.







Several pursuit divers wear tuxedos, including cormorants, alcids, and penguins.
© Jacobs and Arrebola.

#Chinstrap Penguin

Pygoscelis antarctica

Chinstrap Penguin. © Jacobs and Arrebola.

Population status and distribution:

The population estimate is in the range of 8,000,000 individuals, with approximately half of it breeding on the South Sandwich Islands. Chinstrap Penguins are found in regions between the true Antarctic species and those of the islands of the Southern Ocean.

Size and appearance:

Adults reach up to 77 cm in height and weigh up to 5 kg. They are most easily distinguished by the conspicuous black stripe extending below each eye and joining under the chin. The top of the head and back are black, with white under parts. The face and neck are white.

Diet and hunting strategy:

Chinstrap Penguins take crustaceans and some fish by pursuit diving at very shallow depths with a maximum of 102 m.

Natural history:

Chinstraps are the last of the ***Pygoscelis*** species to arrive at their breeding colonies (between the end of October and beginning of November).

With strong claws and a tail used as a walking stick, they can be seen nesting on slopes up to 100 m high, where there is good drainage of water and snow to keep nests and chicks dry. The eggs are laid between November and December but dates can vary depending upon the colony's latitude. The incubation periods vary from 31 to 39 days. Once hatched, chicks are fed by both parents until they fledge. The chicks join a crèche at three weeks old and fledge at seven weeks.

Of all the species of small penguins breeding in Antarctica, Chinstrap Penguins are by far the noisiest. © Jacobs and Arrebola.

Albatrosses

The family ***Diomedeidae*** is part of the order ***Procellariiformes***, an order that includes albatrosses, petrels, storm-petrels, and diving-petrels, divided into 4 families. Within ***Diomedeidae***, there are 4 genera and between 13 and 24 species (depending upon taxonomic classification), but a total of 21 species is the most widely accepted number.

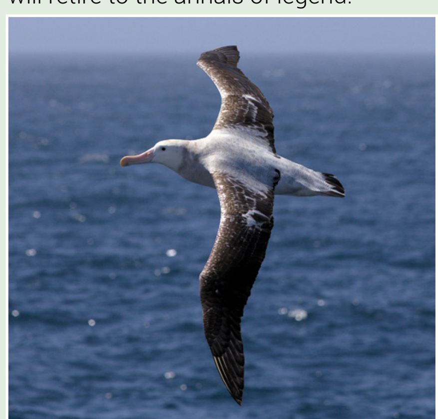
An albatross at flight is easily identified by its long and slender wings, its short tail and its unsurpassed gliding abilities. It takes advantage of the strong winds of the Southern Ocean and remains in the air with minimum effort. Careful observation reveals a flight pattern: albatrosses glide downwind towards the trough between two waves, almost touching the water with the tips of their wings, and then gain altitude just over the crest of the waves while turning towards the wind. In strong winds, albatrosses can reach speeds of 80 km/h. But flapping is too expensive for birds as large as these (wingspans of over 3 m and weighing over 10 kg). Consequently, on days with little wind, they generally remain on the surface of the water, waiting for a breeze. In fact, it is thought that albatross distribution into lower latitudes and the Northern Hemisphere is restricted by the low winds of the Doldrums (region around the equator).

Black-browed albatross. © Jacobs and Arrebola.

MYTHIC BIRDS

Superstition and ghost stories have been carried out to sea for as long as men have been sailing. Owing to their graceful flight in even the harshest of winds, the albatross has been the stuff of legend, perhaps most famously in Samuel Taylor Coleridge's epic poem "The Rime of the Ancient Mariner." Sailors once believed that the souls of seamen lost at sea were reincarnated into these great flying wanderers and that killing such a majestic bird would bring bad fortune, or worse. Thus the albatrosses were protected and very rarely harmed.

Nowadays we tell a different story. In recent years, the protection of albatrosses seems to have ended. With increasing commercial fishing and pollution the albatrosses are drowning on long lines (used in large scale fishing) and in fishing nets, and choking on plastic bags. Protection efforts are currently underway to raise awareness and to alter fishing practices. In time, these efforts may prove worthwhile. However, if not widely implemented, the Wandering Albatrosses will retire to the annals of legend.



Albatross used to enjoy protection on the high seas. In recent years, that protection is no more. © Kunz.

#Wandering Albatross

Diomedea exulans

Population status and distribution:

Estimated at just over 50,000 mature individuals. The breeding colonies are located on islands within the Southern Ocean, generally north of the Polar Front, including South Georgia, Prince Edward, and Kerguelen Islands. Ocean distribution extends as far north as 22° S.

Size and appearance:

The largest flying birds on Earth, Wandering Albatrosses have wingspans of up to 3.5 m and weigh up to 11 kg. Adults have a solid white back with black wings and outer tail feathers. Their bills are pale pink. A peach-coloured patch can often be seen behind the ear, more commonly in males. Juveniles have darker plumage along the entire body. Differentiation from a distance between adult Wandering and Southern Royal Albatrosses can be difficult, if not impossible.

Diet and hunting strategy:

Mainly squid caught at the surface but they will occasionally dive very shallowly (up to 1 m) to catch prey.

Natural history:

Adult Wandering Albatrosses arrive at the breeding site in the Sub-Antarctic islands in November and commence rebuilding their nests of mud and grass. Both parents incubate a single egg for just under three months. For the first few weeks, the chick is fed daily by both parents who alternate between short foraging trips and brooding, but as the chick matures and its energy demands increase, both parents will forage, leaving the chick unattended. By this time, the chick is large enough to keep itself warm. The chick fledges one year after the parents' arrival at the breeding site, leaving the nest but remaining with its parents before it goes to sea. Individuals form lifelong pairs, though those pairs exist only for breeding purposes: they do not otherwise socialise and successful parents usually skip a breeding year.

Some adults have a peach coloured patch behind the ear. © Jacobs and Arrebola.

Adult Wandering Albatrosses have a solid white back with black wings and outer tail feathers. © Suter.

#Southern Royal Albatross

Diomedea (epomophora) epomophora

Population status and distribution:

Approximately 29,000 individuals. The breeding colonies are limited to islands off the southern coast of New Zealand. Ocean distribution is more restricted than Wandering Albatrosses to between 36° and 63° S, though in the eastern South Pacific Ocean, this range increases northwards to approximately 18° S.

Size and appearance:

Like Wandering Albatrosses, Southern Royal Albatrosses have wingspans of up to 3.5 m. Maximum weights are 10 kg. Adults have a solid white back with black wings, but an all white tail tip. Unlike the Wandering Albatross, the juveniles are similar to the adults and are much whiter than the juvenile Wandering Albatross. A black line is also present on the upper mandible and there is never a peach coloured patch behind the ear.

Diet and hunting strategy:

Mainly squid caught at the surface but they will occasionally plunge to catch prey.

Natural history:

The adults return to the breeding colonies in late November and December. The female lays one whitish egg that is incubated for 80 days.

After hatching, the chick is cared for equally by the female and the male until it is approximately 250 days old. Due to such a long breeding period, successful adults breed every second year so that they can recover their body condition before the next attempt.

Southern Royal Albatross. © Sutherland.

#Black-browed Albatross

Thalassarche melanophrys

Black-browed Albatross. © Petracci.

Population status and distribution:

The most abundant and widely distributed albatross, it is estimated that there are 1.2 million individuals. However, a recent dramatic decline in certain populations may put this species at risk. The breeding colonies are found on islands of southern Chile and of the Southern Ocean including the Malvinas, South Georgia, Kerguelen, Heard, and Macquarie Islands. Individuals disperse during non-breeding winter months as far north as 20° S.

Size and appearance:

The Black-browed Albatross attains a wingspan of 2.5 m and weighs up to 5 kg. Easily distinguished from the Wandering Albatross (not only by size), they have prominent black markings around their eyes and the black of the upper wings extends across the back. Their bill is orange with a dark pink tip and they have light grey legs and feet.

Diet and hunting strategy:

This species feeds mainly on fish

Black-browed Albatrosses nest in dense colonies on gently sloping cliffs. © Jacobs and Arrebola.

and krill caught at the surface. They will occasionally plunge and dive to shallow depths to catch prey.

Natural history:

Due to a much shorter breeding cycle, Black-browed Albatrosses are annual breeders. They reach the colonies sometime between late September and mid-November, where they form column-like nests made of grass, mud and roots. The females lay one egg with reddish spots that is incubated for approximately 70 days. The chick fledges approximately 120 days after hatching and is brooded by both the female and male equally. The pair bond likely lasts a lifetime.

Black-browed Albatross chick in the nest. © Jacobs Arrebola.] Jacobs y Arrebola328

Black-browed Albatrosses form lifetime pair bonds with their mates. © Jacobs and Arrebola.

#Grey-headed Albatross

Thalassarche chrysostoma

Population status and distribution:

It is estimated that there are 250,000 individuals in the Southern Ocean with an ocean distribution ranging from approximately 58° to 25° S.

Size and appearance:

The wingspan of the Grey-headed Albatross extends to 2.2 m; individuals can weigh up to 3.75 kg. They are easily identified by their solid grey-coloured head and bright yellow stripes along the center of the top and bottom mandibles.

Diet and hunting strategy:

Mainly fish and squid caught at the surface but they will occasionally plunge and perform shallow dives to catch prey.

Natural history:

The Grey-headed Albatross breeds every second year beginning in late September. They construct nests of soil, grass, and roots, lay a single egg within the central depression. The egg is incubated for approximately 75 days and the chick is then reared for 140 days by both the female and the male. Grey-headed Albatrosses likely form lifelong relationships with their partners.

Grey-headed Albatross. © Sutherland.

Juvenile Grey-headed Albatrosses are considerably lighter in colour on the back and head. © Jacobs and Arrebola.

Petrels

The family ***Procellariidae*** resides within the order ***Procellariformes***, along with the albatrosses. Within ***Procellariidae*** are 14 genera and more than 80 species (although the precise number of species is currently under debate). The distinctive tube on the top of a petrel's bill identifies it easily.

A petrel will spend most of its life – except the breeding season – at sea, where it feeds on zooplankton, squid, fish, and crustaceans. Most petrels are gregarious, living in colonies and building diverse types of nests; some species nest in holes, on cliffs, or in the crevices created by boulders and scree. Others build their nests with pebbles, feathers, grass and even bones. All of them lay only one egg and the chick is fed by regurgitation from both parents. Generally, fish is stored in their stomachs, preserved by a special oil that can also be used as defence when projectile vomited at an intruder.

A FACE ONLY A MOTHER COULD LOVE…

Erroneously believed to be used for the excretion of excess salt, tubenoses have been shown both to possess an excellent sense of smell and to help an individual so adorned to determine the direction from which a smell is coming. This allows individuals to hone in not only on their nesting site but also on their prey. By studying petrels in captivity, it has been demonstrated that individuals can differentiate between the odour of their mate and another individual, or between their chick and another's. This powerful sense of smell is essential for species that forage over a large range but that must also return to a single point where their hungry chick awaits a meal.

Petrel gigante del sur © Jacobs y Arrebola.

In open waters different species of petrels are frequently seen flying together. In this photo: Antarctic Petrel, Southern Fulmar, and Cape Petrel. © Petracci.

#Southern Giant Petrel

Macronectes giganteus

Population status and distribution:

Population size is estimated at just over 100,000 mature individuals. The range in the distribution of breeding colonies is quite broad – from the southern tip of South America to the South Shetland Islands. The Southern Giant Petrel's ocean distribution extends as far north as 2° S.

Size and appearance:

The largest of the petrels, the Southern Giant Petrel has a wingspan extending as far as 2.1 m and can weigh up to 5 kg. Their colour ranges from almost completely black to white with a few black feathers. They have a very prominent bill with a large tube, the end of which is slightly greenish.

Chick and parent sitting at the nesting site. Both parents share the work of raising the young. © Jacobs and Arrebola.

Southern Giant Petrels on the breeding colony. © Petracci.

Diet and hunting strategy:

Often referred to as the 'vultures of the Antarctic,' Southern Giant Petrels are scavengers and predators. They feed on the carcasses of seals, whales, and other birds (including penguins); take eggs and chicks from nesting birds; hunt penguins, and also hunt from the surface of the water for fish and squid.

Southern Giant Petrel (white morph). © Jacobs and Arrebola.

Natural history:

Usually associated with penguins and seal colonies, Giant Petrels tend to establish their nest sites in high and exposed places where they can easily take to the air. Their breeding activity begins in October with the return to the colony and the building of nests. The single egg is laid in November and hatches two months later. The chick is carefully brooded by the parents during the first three weeks, after which the parents go out to sea, returning to the colony only to feed the chick. The chick fledges at the beginning of May.

Petrel gigante del sur © Jacobs y Arrebola.

#Cape Petrel

Daption capense

Population status and distribution:

Population estimates lie between 250,000 and 600,000 individuals. The Cape Petrel ranges widely at sea, reaching as far north as the Galapagos Islands. Breeding colonies are located on islands of the Southern Ocean.

Size and appearance:

Among petrels, Cape Petrels are small, coloured black and white, have a wingspan of approximately 85 cm, and weigh no more than 450 g. The top of the wings have a checkerboard appearance when fully extended.

Diet and hunting strategy:

Mainly squid, fish, and krill caught at the surface. They are also found at carrion sites, scavenging off carcasses with other petrels.

Natural history:

Adults return to breeding areas (forming only loose colonies, in small groups) in November and December. The females lay one egg in a depression formed by scraping together loose pebbles and stones. The egg is incubated for approximately 45 days and the chick fledges another 50 days after being reared by both parents. Cape Petrels form long-lasting, monogamous relationships.

Cape Petrel. © Jacobs and Arrebola.

The top of the wings of Cape Petrels have a checkerboard appearance. © Jacobs and Arrebola.

#Southern Fulmar

Fulmarus glacialoides

Population status and distribution:

Population estimates average 2 million individuals. This species is widely distributed in the Southern Ocean and off the coasts of South America. Breeding colonies are found in East Antarctica and on the islands of the Southern Ocean between South America and Africa.

Size and appearance:

Wingspans are as long as 120 cm and adults weigh no more than 1 kg. Fulmars have a very flat forehead with a pink bill and prominent tube on the maxila (upper mandible). The feathers are pale grey and the wings have black and white primary feathers (feathers on the tip of the wing).

Diet and hunting strategy:

Southern Fulmars hunt krill, fish, and squid from the surface of the water.

Natural history:

Adults begin breeding activities in December at large colonies that may include other petrel species. The nests are usually built on exposed outcroppings of sea cliffs. A single egg is laid and incubated for up to 50 days. Chicks are reared for 56 days and are cared for by both the male and the female. Pairs form long lasting, monogamous relationships.

Southern Fulmars. © Petracci.

Southern Fulmars fly with a very stiff wing beat, barely bending their wings as they flap. © Petracci.

#Antarctic Petrel

Thalassoica antarctica

Population status and distribution:

Very little is known about the size of the population. Estimates range between 500,000 and 20 million individuals. Antarctic Petrels are found in regions of pack ice and icebergs around coastal Antarctica. In winter months they disperse as far north as 48° S.

Size and appearance:

A medium-sized petrel, Antarctic Petrels have a wingspan extending to 110 cm and weigh approximately 675 g. The plumage is white on the underparts with some dark brown on the leading edge of the wing. The upper body is dark brown and the tail is white with brown ends, as are the trailing edges of the wings.

The Antarctic Petrel's plumage is white on the underparts with some dark brown on the leading edge of the wing. © Petracci.

Antarctic Petrel. © Petracci.

Diet and hunting strategy:
Antarctic Petrels feed on squid, krill, and fish by surface feeding.

Natural history:
Adults begin breeding at colonies in November. Nest depressions are built from small stones on steep cliffs. A single egg is laid and incubated for about 45 days. The chick fledges approximately 45 days later. Both sexes likely share equally in raising the chick and form long lasting, monogamous relationships.


Antarctic Petrel. © Richardson.

#Snow Petrel

Pagodroma nivea

Population status and distribution:
The population size is unknown. Breeding colonies are found in coastal and inland regions of Antarctica as well as islands of the Southern Ocean. Ocean distribution itself is generally restricted to waters south of 60° S.

Size and appearance:
A medium-sized petrel with a wingspan of up to 96 cm and weighing approximately 550 g. Snow Petrels are completely white with no variation. They have a solid black bill and black legs.

Diet and hunting strategy:
Mainly squid, fish, and krill caught at the surface but surface plunging and diving have been observed. They are often observed feeding among ice flows in association with other petrels.

Natural history:
Adults arrive at the colony between October and November to begin breeding. Nesting sites are generally located on steep cliffs at high altitudes and no nest is built. A single white egg is laid and incubated for 45 days. The chick is reared by both parents for 50 days. Snow Petrels form long-lasting pair bonds.


Snow Petrel. © Jacobs and Arrebola.

Prions

Very small, with cryptic colours, prions are easily camouflaged as they swoop over the surface of the sea. There are six species living exclusively over the waters of the Southern Ocean; they are, however, notoriously difficult to identify down to species when observed in flight.

Prions, as a group, are easily recognisable. They have white under parts, including their chins, and also white brows above the eyes. The upper parts are a bluish grey with a diagnostic M-shaped black line extending from one wing tip to the other. The tail tip is black. As part of an anti-predation strategy, they have a fast and spiralling flight. In addition, departures and arrivals at the breeding colony generally occur under the protection of darkness.

The Broad-billed Prion ***Pachyptila vittata*** breeds in waters off New Zealand but also on islands in the South Atlantic Ocean. The Antarctic Prion ***P. desolata*** breeds on islands of the Scotia Arc, including South Georgia and the South Shetland Islands, and coastal Antarctica. The Slender-billed Petrel ***P. belcheri*** breeds on islands of the southwest Atlantic and on islands in the South Indian Ocean, including Kerguelen Island. The Fairy Prion ***P. turtur*** breeds off the coast of South America, on South Georgia Island, on islands in the South Indian Ocean and South Australia, and New Zealand. The Fulmar Prion ***P. crassirostris*** breeds around New Zealand and on Heard Island in the South Indian Ocean. The Saint Paul Prion ***P. macgillivrayi*** breeds only on Saint Paul Island in the South Indian Ocean.

Breeding couples gather at large colonies where they form nests in burrows. Females lay a single egg that is incubated for up to 50 days. The chicks are brooded and fed by parents for up to 58 days.

Prion. © Richardson.

Prion in flight. © Jacobs and Arrebola.

Storm-Petrels

The order P*rocellariiformes* includes the family ***Hydrobatidae***, or the storm-petrels. These are the smallest of all seabirds and are divided into 7 genera with 22 species.

The Wilson's Storm-petrel is the best known and most abundant of storm-petrels and breeds in Antarctica. They are dark brown to black, with a white rump and dark wings with a narrow grey band in the upper part. The Black-bellied Storm-Petrels have a distinctive black line running through a white belly from breast to tail. Though they do not breed on the continent, breeding sites can be found as far south as the South Shetland Islands.

Three more species of storm-petrels can be found flying over the Southern Ocean but they do not breed within its limits: the White-bellied Storm-petrel, with a white belly and white underparts; the Grey-backed Storm-petrel with a completely white belly and grey back extending across some of the upper wings; and the White-faced Storm-petrel with a white belly and white face with black cap and black eye patches.

All members of each species are tiny, weighing no more than 60 g with wingspans reaching a maximum of 46 cm. They are easily recognised as a group by a sharply hooked bill and long spindly legs that frequently hang perpendicularly to their bodies while in flight.

Unlike the larger petrels, storm-petrels fly somewhat erratically, dipping their feet in the water and flapping their wings vigorously. They dance like butterflies flitting across the water as they hunt for tiny krill, fish, and squid. They are commonly seen either in the open and choppy waters of the ocean or in the protected waters of coastal areas.

The breeding colonies of Wilson's Storm-Petrels are distributed all around the continent and on sub-Antarctic Islands, nesting in cliffs and boulder screes above the beaches. Adults return to nest at the age of four or five years. Females lay a single white egg that is incubated for 50 days. The chick is reared by both parents and fledges at 60 days. Activity around the breeding area is generally nocturnal, thereby avoiding predation. The pair forms a long-lasting relationship.

Although skuas are the main predator of storm-petrels, the introduction of animals like rats and cats to sub-Antarctic islands has significantly reduced populations of this family.

Wilson's Storm-petrel. ©Jacobs and Arrebola.

Storm-petrels nest in crevices between rocks and their activity around the colonies is generally limited to night time hours to avoid predation. © Jacobs and Arrebola.

Cormorants

Sorting out the different species of southern cormorants is a difficult task that is still controversial. The confusion is because very similar forms, with almost no difference in physical appearance, are separated geographically. Are these different species, or just different populations?

The family ***Phalacrocoracidae*** falls within the order ***Pelecaniformes***, which includes gannets and frigatebirds divided into seven or eight families (the classification is currently under debate). There is only one genus of cormorants (***Phalacrocorax***), with between 35 and 43 species.

The name cormorant originates from the Latin ***corvus marinus*** or "sea raven." Cormorants are medium-sized coastal or freshwater birds and are distributed globally except in the central Pacific Islands. They have long, thin, hooked bills and range in plumage from completely black to black and white. Several species have areas of exposed coloured skin on the face (a fleshy growth like the comb of a rooster

Cormorants lay more eggs when prey is abundant. © Jacobs and Arrebola.

Antarctic Cormorant. © Jacobs and Arrebola.

called a nasal caruncle), which brightens during the breeding season, and all have long, S-shaped necks. Most species do not have waterproof feathers and are frequently observed on rocks with their wings spread to dry. Southern Ocean species in particular do have waterproof feathers – an adaptation to extreme conditions.

Cormorants are related to pelicans, gannets and boobies. This group is highly adapted to an aquatic life and individuals are able to dive relatively deeply to pursue prey such as fish. They have broad, webbed feet capable of propelling them through the water while tucking in their short wings to minimise drag. Thick necks give them speed and flexibility to reach out for prey.

Within the Southern Ocean, and compared with other seabirds, cormorants are fairly unique in that they lay more than 2 eggs. If they lose the first clutch, this species is capable of laying a replacement. Breeding adults are monogamous but they change partners every year. The male gathers the materials for nesting and awaits the arrival of the female, who builds it to her specifications.

#Antarctic Cormorant

(A.K.A. Blue-Eyed Shag)
Phalacrocorax atriceps bransfiliensis

Population status and distribution:

Population estimated at approximately 22,000 individuals. Confusion with other species of cormorants is not possible as it is the only one to breed on the Antarctic Peninsula, and South Shetland Islands. Their at sea distribution is limited to this area as well.

Size and appearance:

This species wears a tuxedo of black and white and can be confused for a penguin at distance, until they take flight. They are approximately 75 cm tall and weigh up to 3 kg. Males are significantly larger than females. They have a blue eye ring, a bright orange nasal caruncle, and pink legs and feet.

Diet and hunting strategy:

Feed on mainly fish and squid, though they will hunt crustaceans and benthic invertebrates caught by pursuit diving up to 70 m in depth.

Natural history:

During breeding, adults develop a white patch on their back and a bright orange nasal caruncle at the base of the bill. They arrive at the breeding colony in October and lay two or three greenish eggs in a column-shaped nest made of seaweed, guano, moss, and feathers. The eggs are incubated for 30 days. The chicks grow quickly and fledge in March at 40 or 45 days old. They are reared by both parents who form a monogamous relationship each year.

Antarctic Cormorant. © Jacobs and Arrebola.

Males and females share equally in the responsibility of reproduction. © Jacobs and Arrebola.

Sheathbills

The order ***Charadrii-formes*** is very large, with about 20 families and more than 350 species and includes oystercatchers, plovers, snipes, gulls, and terns. The family ***Chionidae***, however, is very small, with only one genus and two species.

Technically related to skuas and gulls, sheathbills are so unique in appearance and habit that they have been placed in their own taxonomic family; it is, in fact, still unclear where exactly they fit into bird classification. (They may be a link between gulls and shorebirds.) Within this family are two species: the Snowy Sheathbill ***Chionis alba*** and the Black-faced Sheathbill ***C. minor***, easily distinguished because the latter has a completely black face. They resemble pigeons and even walk with that characteristic head wobble. Their bills have a special horn-like sheath growing from the base and extending towards the tip.

Snowy Sheathbills bob their heads up and down during courting. © Jacobs and Arrebola.

A Snowy Sheathbill feeds a penguin stomach lining to its single chick. © Jacobs and Arrebola.

#Snowy Sheathbill

Chionis Alba

Population status and distribution:

Population estimated at approximately 20,000 individuals. This species is found breeding in the South Shetland Islands, Antarctic Peninsula and South Georgia. At sea distributions extend from 65° S to northern Brazil.

Size and appearance:

Pigeon-like bird with a wingspan of 84 cm and weighing up to 780 g. The body is completely white, the eye is surrounded by pinkish exposed skin, and the feet are not webbed. A horny sheath extends from the base of the bill towards the tip.

Diet and hunting strategy:

Scavengers at other bird colonies including those of penguins and cormorants. Sheathbills feed on regurgitated food, guano, and stomach linings, in addition to trying to perforate penguin eggs, which are then rejected from the penguin's nest. Sheathbills will also scavenge on carcasses.

Natural history:

Adults begin nesting in September, building nests of feathers and bones. The females lay 2-3 brownish eggs and incubation lasts approximately 30 days. Generally, not all the chicks survive to fledging (at approximately 55 days after hatching).

Skuas

The family ***Stercorariidae*** lies within the order ***Charadriiformes***, which includes the gulls, terns, sandpipers, and other shorebirds. Within ***Stercorariidae*** are two genera and seven or eight species, depending upon the classification.

Though skuas are related to gulls and terns, they are easily recognised by their dark colour and white patches at the base of the primary feathers. Additionally, unlike gulls, adult female skuas are slightly larger than males. The females lay two eggs in nests built on the ground and breeding pairs generally mate for life. Though the taxonomy of skuas is controversial, there are likely two species breeding in Antarctica, though hybrids between them are known.

Skuas are highly aggressive and territorial birds, not only at their breeding site, but also within their feeding grounds, such as penguin colonies. Parents will dive bomb human intruders until they hit them on the back of the head with their feet. This can be a disorienting experience and it is recommended that visitors avoid it.

These birds are the most frequent of all seen inland and are highly opportunistic, making Antarctic research stations their homes as successfully as their more natural habitat. Rumours have been circulating among Antarctic scientists of a couple of individual skuas have been known to steal a drink or two and then behave badly around the station!

Though penguins are very attentive parents, skuas are quite successful at taking the occasional chick for a meal. © Richardson.

Skuas are powerful predators and scavengers in addition to being very protective parents. © Jacobs and Arrebola.

#South Polar Skua

Catharacta maccormicki

Population status and distribution:

Population estimated at between 10,000 and 16,000 mature individuals. This species breeds only on the coast of Antarctica as far north as the South Shetland Islands. However, in the winter months, ocean distribution extends as far north as Alaska.

Size and appearance:

The South Polar Skua has a wingspan of 130 to 160 cm and weighs up to 1.7 kg. There are three plumage morphs ranging from very light to very dark, making it difficult to distinguish the South Polar from the Brown Skua.

Diet and hunting strategy:

Skuas feed primarily on fish but will also scavenge other bird colonies, including penguins. They will take eggs and chicks, often hunting cooperatively with each other.

Natural history:

Adults return to colonies to breed in late October, usually nesting on rocky screes near penguin colonies and establishing predation territories among other skuas. Females lay one or two eggs in a nest formed by scraping away dirt or pebbles on the ground. The egg is incubated for 30 days and the young leave the nest to wander the moss beds or cliffs nearby after one or two days. Siblicide, the killing of a sibling, is common as the chicks compete for their parents' offering of food. The chicks fledge after approximately 40 days.

South Polar Skua. © Jacobs and Arrebola.

A skua kills an older Chinstrap Penguin chick. © Jacobs and Arrebola.

#Brown Skua (Sub-Antarctic)

Catharacta Antarctica

Population status and distribution:

This species breeds on the islands of the Southern Ocean, generally located near the Polar Front, but also on the Antarctic Peninsula to 65° S.

Size and appearance:

Like the South Polar Skua, the Brown Skua has a wingspan of up to 160 cm but is much heavier, weighing up to 2.5 kg. This species is generally darker and more uniform in body colour. The bill and neck are thicker than the South Polar Skua.

Diet and hunting strategy:

Predate burrow-nesting bird colonies and penguin colonies, often working cooperatively to feed on eggs and chicks. They will also scavenge carrion such as dead seals and whales.

Natural history:

Similar to the South Polar Skua. Adults arrive at breeding areas between October and November. Females lay one or two eggs in an ill-defined nest scraped out of the soil or pebbles. The eggs are incubated for 30 days and young are reared out of the nest for about 45 days before fledging.

Skuas fighting a Southern Giant Petrel for a prized meal of penguin. © Richardson.

Brown Skua. © Jacobs and Arrebola.

Gulls and Terns

Charadriiformes, a large and diverse order with over 350 species, contains the family ***Laridae*** (11 genera and approximately 56 species) and ***Sternidae*** (12 genera, 45 species). Some taxonomists, however, include the terns within ***Laridae***, while others recognise two distinct families.

Of the approximately 56 gull species (the name "seagull" is a misnomer), only one is found in Antarctica, making identification simple. Gulls are medium-to-large birds and are generally grey or white with black markings. They are ground-nesting carnivores who scavenge opportunistically. Due to its Antarctic distribution, the Kelp Gull ***Larus dominicanus*** cannot fall within the stereotypes of scavenging human garbage sites and is therefore an excellent fisher and hunter, though it will frequent human settlements within Antarctica and will certainly not ignore a free meal.

Also commonly known as Sea Swallows, terns are closely related to gulls but are smaller and more delicately built. They are distributed from pole to pole, though most species make their homes in the tropics. There are two species found in Antarctica, the Arctic ***Sterna paradisaea*** and the Antarctic ***S. vittata*** tern. These two are almost indistinguishable from each other in their breeding plumage. Luckily, one species breeds in the north and the other in the south. When they are together in the same range, one is breeding and the other is on winter holiday. An additional species, the Kerguelen Tern ***S. virgata*** breeds on islands of the South Indian Ocean.

The female Antarctic Tern calls out loudly for a meal. Finally, the male comes to feed her on an iceberg. © Jacobs and Arrebola.

#Kelp Gull

Larus dominicanus

Population status and distribution:

Population estimated at over one million individuals. This species is widely distributed over the Southern Ocean and northwards along coastal areas.

Size and appearance:

The Kelp Gull has a wingspan of up to 142 cm and weighs approximately

1.3 kg. Unmistakable in Antarctica, the Kelp Gull is the only species of gull whose range extends that far south. This gull has a white body with black or slate-grey upper wings and white wing tips. The bill and legs are yellow and there is a red spot on the lower part of the bill.

Diet and hunting strategy:

Gulls are opportunistic and will take advantage of any feeding occasion. They will prey upon penguin eggs and chicks in addition to feeding on carrion such as dead seal or whale. Fishing for krill is also not uncommon; their main food source, however, is limpets obtained from submerged rocks along coastal areas.

Natural history:

Breeding begins usually in December when two or three eggs are laid and incubated in a nest made of moss and seaweeds. The eggs are incubated for up to 30 days and chicks are reared for 50 days before fledging.

Juvenile Kelp Gulls are darker and mottled compared with adults. © Jacobs and Arrebola.

Kelp gull. © Jacobs and Arrebola.

#Antarctic Tern

Sterna vittata

Population status and distribution:

Population estimated at over 100,000 individuals. The breeding colonies are distributed on islands in the Southern Ocean between South America and Africa and south of Australia, also extending into the Southern Atlantic and Indian Ocean. Ocean distribution includes waters off South America and South Africa and as far north as the South East Atlantic.

Size and appearance:

The Antarctic Tern has a wingspan of up to 80 cm and weighs just over 200 g. The body is grey with a white line between the body and a black cap. The bill and feet are bright red.

Diet and hunting strategy:

Terns feed mostly on small fish but will also feed on limpets and krill by plunge diving, typically hovering over prey before dipping into the water to capture it.

Natural history:

Antarctic Terns begin breeding in October in loose colonies located in rocky outcroppings or even ship wrecks. They are well advertised: any approach by potential predators results in a swarm of adults calling loudly. Terns are known to dive bomb as well. The females lay one or two eggs in slight depressions scraped out of the substrate. They are incubated for up to 25 days and the chicks fledge about 30 days later.

Antarctic Tern. © Jacobs and Arrebola.

Terns take turns incubating the egg so that one adult may forage for prey while the other is guarding the nest. They are very protective and will dive bomb any intruders. © Jacobs and Arrebola.

#Arctic Tern

Sterna paradisaea

Population status and distribution:

Population estimated at over one million individuals. This species breeds exclusively in the Arctic, in colonies with a circumpolar distribution. They are a distant migrant, and spend the winter off the coasts of southern South America, Africa, and Antarctica.

Size and appearance:

Arctic Terns have a wingspan of up to 85 cm and weigh up to 130 g. Their breeding plumage is almost identical to that of the Antarctic Tern. Winter plumage is similar to that of the juvenile Antarctic Tern: the forehead is white and only a thin black ring remains around the head. The bill is also generally darker and may have a black tip.

Diet and hunting strategy:

Arctic Terns feed mostly on small fish but will also feed on krill by plunge diving, typically hovering over prey before dipping into the water to capture it.

Natural history:

After the completion of the breeding season in the north, Arctic Terns undergo the longest winged migration of any animal, covering over 35,000 km annually. They arrive to the Southern Ocean in the summer months to feed and then return to the Arctic to breed.

Arctic Tern in breeding plumage.
© Jacobs and Arrebola.

Arctic Tern in non-breeding plumage. © Suter.

Occasional visitors to Antarctica

Two species of birds are rarely seen on the Antarctic Peninsula, the coastal areas, or the adjacent islands – the King Penguin and the Macaroni Penguin. However, and of the infrequent visitors, these two are likely the most frequent!

#King Penguin

Aptenodytes patagonicus

Population status and distribution:
more than 4.000.000 individuals. The species generally remains in the vicinity of breeding colonies, located on islands around the latitudes of the Polar Front.

Size and appearance:
King Penguins are the second largest penguin, reaching up to 95 cm and weighing an average of 13 kg. They are silvery-grey to black on the back. Their head is black and has bright orange neck patches spreading to the upper breast, which becomes white at the front. The bill is black with orange along the sides and it is more slender and longer than that of the Emperor Penguin.

King Penguin chicks join a crèche at five weeks old so that they can be fed by both parents. © Jacobs and Arrebola.

Diet and hunting strategy:
King Penguins feed on fish and squid, catching their prey by pursuit diving up to 240 m in depth, though generally they dive to 25 m for up to 10 minutes.

Natural history:
Unlike other penguins, the King Penguin's breeding cycle is quite long, taking over a year; consequently, they are unable to breed annually. In general, they reproduce twice every three years, although on some colonies the average is once every two years. The first eggs are laid in November. The first two week incubation shift is taken by the male, followed by the female for an additional two weeks, after which the parents change-over every three to four days until the egg hatches; approximately 55 days after that. At five

King Penguins. © Jacobs and Arrebola.

weeks old, the chick joins a crèche and spends the winter fasting on land. By the time spring returns, the chicks have undergone considerable weight loss, occasionally leading to starvation and death. During the following November and December, the chicks fledge and go to sea. At this point, the parents may start breeding again, even though these eggs will not be laid until some time between January and March. Eggs laid during this period will likely fail during the winter. Due to these long breeding periods, King Penguin rookeries are always occupied by one-year old chicks sharing space with newly hatched chicks.

#Macaroni Penguin

Eudyptes chrysolophus

Population status and distribution:

Over 11 million pairs breed as far north as islands off the southern coasts of Australia, South Africa, and South America. Breeding colonies are generally found in the Sub-Antarctic Islands close to the Polar Front. This species is periodically seen breeding as far south as the South Shetland Islands, though there is no established breeding colony.

Macaroni Penguins breed on sub-Antarctic Islands such as South Georgia and South Sandwich Islands. However, a few pairs have been observed breeding further south, on Antarctic islands. © Suter.

Size and appearance:

Adults reach up to 71 cm in height and weigh up to 6.5 kg. They have yellowish-orange crest feathers and large reddish bills with a pink skin patch at the base. Their underparts are white and the back and face are black.

Diet and hunting strategy:

Hunt krill, some fish, and a few squid by pursuit diving offshore at shallow depths, though occasionally exceeding 100 m.

Natural history:

Males arrive at the rookery in October and start rebuilding the nest while waiting for the females to arrive. Females lay two eggs of different size in November. The first egg is 15% to 40% smaller than the second egg and not likely to hatch. After 35 days of incubation, the second egg hatches.

During the first 25 days of brooding, the chick is attended to by the male, but it is fed by the female, usually daily. Just after three weeks, the chicks join a crèche and are fed by both parents. Towards the end of February, chicks fledge and leave the colony for their winter dispersal.

The yellow crest feathers give the Macaroni Penguin a comical appearance. © Suter.

A leopard seal rests on the sea ice.
© Morgenthaler

Seals and Fur Seals

Pinnipeds are aquatic mammals that must give birth and moult on either ice or land. The 36 species are separated into three families (***Phocidae***, ***Otariidae*** and ***Odobenidae***), two of which are represented in Antarctica. Species of the family ***Phocidae*** are commonly referred to as True Seals.

Five species are distributed throughout the waters surrounding Antarctica.

The family ***Otariidae*** includes fur seals and sea lions, but only one endemic species – the Antarctic fur seal ***Arctocephalus gazella***, which lives in the Southern Ocean around Antarctica. A number of other fur seals and sea lions breed on islands just south of 50° S; none of them cross the Polar Front, however. True seals and fur seals likely evolved more than 20 million years ago from a single ancestor. It is thought that fur seals were the first to branch out and that later the true seals and walrus ***Odobenus rosmarus*** evolved.

Fur seals have external earflaps and are capable of supporting their body weight upon their hind flippers and can therefore walk on land. Males are also much larger than females. True seals do not have external ear flaps and cannot support their weight on their hind flippers. True seals must move across land by undulating their blubbery bodies, much like a slug in fast-forward. There is relatively little difference in size between true seal males and females except in elephant seals ***Mirounga leonina***, where males can weigh five to six times more than females. Due to the close proximity of the ventral surface of a true seal with the land, the testicles are protected within the body; fur seals, meanwhile, exhibit the more common mammalian trait of testicles outside the body.

Seals give birth to a single pup that is nursed for a short period of time on land or ice. The milk is very high in fat, ensuring that the pup gains as much weight in the shortest time possible. Gaining weight puts on a thick layer of blubber under the skin and keeps the pup warm. Elephant seals and fur seals form harems that are guarded by a single bull (male). Although the bull mates with all the females of the harem, occasionally a sneaky, weaker male catches the beach master off guard and mates with one of his females. The remaining seal species do not form harems – though males may mate with several females, depending on the species and opportunity. Some species, like the Weddell Seal ***Leptonychotes weddelli*** aggressively guard their breathing holes in the sea ice and attract females to breed.

Sea lions have an external ear. © Jacobs y Arrebola.

Young male elephant seals need a lot of practice if they are going to defend a harem. © Petracci.

#Southern Elephant Seal

Mirounga leonina

Population status and distribution:

There are between 500,000 and 650,000 elephant seals. This population is recovering from a relentless 200-year hunt beginning in the late 1700s. Breeding colonies are widely distributed in the Southern Ocean as far south as 78° S and extending as far north as 35° S along the coasts of South America.

Size and appearance:

There is extreme sexual dimorphism between males and females. Males can be up to 6.5 m in length and weigh up to 3,700 kg, while females are about 3.0 m long and weigh no more than 800 kg. These seals have particularly large eyes, with coats varying from a yellowish tan to dark brown. Colour patterns and other markings on the coat are also common. Fully mature males have a large proboscis that generally hangs limp. During competitions with other males, this proboscis is inflated and used to make deep resonating sounds. Males often have many scars from fighting with other males. Moulting occurs at various times for the sexes and age groups but generally from January to February.

Diet and hunting strategy:

Elephant seals feedmainly on squid and fish, diving to depths over 1000 m to catch them by pursuit diving. Most dives are an average of 500 m deep and 25 minutes long.

Natural history:

Elephant seals spend most of their

A colony of elephant seals is a cacophony of belches, barks, and growls. © Jacobs and Arrebola.

time at sea, coming to land only to breed and moult in the austral summer. Males, pulling their large mass out of the water in September, are the first to arrive to the beaches of the breeding colonies. However, not all of them will mate. Males defend territories on the beach but the real fighting does not begin until the females arrive. The largest bulls form harems of up to 100 females (the average is 32) and only the strongest will procreate. Gestation lasts about 50 weeks: females arrive to the breeding beaches in October and give birth three to seven days later to the previous year's efforts. The females feed their pups for about 23 days. Mother's milk is rich in fat and the pups put on 5 kg per day until they are weaned at three weeks old. During lactation, females fast and lose up to 135 kg of their body mass. Just before weaning their pups, females are ready to copulate with whichever male controls their part of the beach. The male fighting, meanwhile, continues throughout the breeding season and can be very aggressive; pups can even be smashed or trampled by the fighting adults.

Elephant Seal. © Jacobs and Arrebola.

HOW CAN ELEPHANT SEALS DIVE SO DEEPLY?

Deep diving requires specific adaptations to prevent crushing from the pressure forced upon the body, to carry enough oxygen to feed the muscles, and to see in almost complete darkness. Humans overcome these challenges by using submersible vehicles with walls half a meter thick, carrying tanks of air, and using artificial sources of light. Elephant seals, however, do not have these technological options. Their anatomy does the job instead.

1) Large concentrations of haemoglobin in the blood allows them to store a great amount of oxygen in the arteries and use it while diving. High concentrations of myoglobin in the skeletal muscles of all deep (greater than 100 m) diving animals has also been found and suggests that it is an important adaptation.

2) The veins and arteries are not crushed because elephant seals have a high concentration of cholesterol within the walls of these tubes. Cholesterol increases the rigidity of the walls and keeps them open even under enormous pressure.

3) Elephant seals slow down their heart rate to around 1 beat per minute to reduce oxygen consumption. They reduce the blood flow to periphery organs and give priority to the brain and heart.

4) The eyes can capture more light at depth because they are very large. This allows them to hunt squid and fish by pursuit diving.

Elephant seals have big eyes in order to capture the bioluminescence of some animals that live deep in the ocean. © Jacobs and Arrebola.

#Crabeater Seal

Lobodon carcinophaga

Population status and distribution:

Probably the most numerous seal on Earth, population estimates (between 1958 and 1971) range between 2 and 75 million individuals. A more recent estimate (1991) puts the population size at approximately 12 million. Crabeater seals spend their entire lives around the pack ice of Antarctica and are rarely seen north of the Sub-Antarctic Islands.

Size and appearance:

Crabeater seals grow to approximately 2.5 m and weigh up to 400 kg. Females are slightly larger than males. The fur is a silvery grey and is usually free of markings, though a great number of adults have scars from predation attempts. Adults with coloured patches are often confused for Weddell seals. Older adults have whitish fur.

An old adult crabeater seal. The fur becomes paler as the individual ages. © Jacobs and Arrebola.

Crabeater seal. © Jacobs and Arrebola.

Diet and hunting strategy:

Despite their name, crabeater seals feed almost exclusively on krill by diving at night when large aggregations of krill are near the surface. They swim through these aggregations with their mouths open like a sieve and dive at depths between 20 and 30 m. Crabeater seals are likely the largest single consumer of krill on Earth.

Natural history:

The females have a nine month gestation period and give birth on the ice. The pups are born between September and October and are 1.10 m long and weigh approximately 30 kg. During this time, the male patrols a large aquatic territory around the female and her pup. He is waiting for her to wean the pup so that he can mate with her. The pup is nursed by their mother for two to five weeks during which time it increases in size by up to four times. A couple of weeks after weaning, adult males and females copulate and start feeding.

#Weddell Seal

Leptonychotes weddelli

Population status and distribution:

This most southerly breeding seal (up to 78° S) has a circumpolar distribution, remaining near fast ice for protection from predators.

The range in population estimates is broad: current research suggests that there are 500,000 to 1 million individuals. Winter movements follow the freezing of sea ice.

Size and appearance:

Adults are usually no longer than 3 m and weigh no more than 600 kg. The fur is silvery grey often with darker or lighter patches. The head is small relative to the body; the face has a short snout that is more cat-like than crabeater seals, with large eyes.

Diet and hunting strategy:

Weddell seals feed on fish, squid, and krill. They can dive over 700 m and remain underwater for more than an hour. Hunting mostly under the ice, these seals can maintain their own breathing hole by chewing the ice along the sides of the hole to keep it from freezing over. This causes damage to the teeth, however, which may limit their lifespan.

Natural history:

Pups are born on the ice between September and October. Their size can vary from 1.20 to 1.40 m and they weigh up to 30 kg. They are weaned at eight weeks. Males defend underwater territories around breathing holes and copulate underwater with those females that swim within the boundaries. They communicate with other males and females by very loud, high pitched vocalisations.

Weddell seal. © Jacobs and Arrebola.

Weddell seal pup. © Jacobs and Arrebola.

#Leopard Seal

Hydrurga leptonyx

Population status and distribution:

Population size is not known, but estimates range between 100,000 and 450,000. These seals have a wide distribution as far south as 78° S.

Size and appearance:

Individuals average about 3 m in length and up to 500 kg. Females are generally larger than males. They get their name from the diagnostic spots on their fur; there is, however, considerable variation among individuals. The shape of the head is an easy give away: the snout is long, broad and along the same plane as the forehead. The mouth extends until the eyes, as if grinning, and the body has a rather serpentine shape.

Diet and hunting strategy:

Famous for the dramatic way in which they hunt and eat penguins, the largest portion of their diet consists of krill, fish, and squid. However, penguins are frequently taken, especially during the fledging period for chicks that have no experience with marine predators. Captured penguins are often caught in a game of cat-and-mouse and played with until the final blow. Leopard seals also predate young seals, especially crabeater seals.

Natural history:

Little is known about specific breeding behaviours and it is rare to see the pups, born sometime between September and January. There is insufficient information regarding courting and mating. At birth the pups are 1 m long and weigh 30 kg. The lactation period can last between four and six

Leopard seal. © Jacobs and Arrebola.

Leopard seals are curious and without fear of humans and their small rubber boats. This can be quite dangerous. © Velazquez.

Leopard seals are very agile and fast under water. © Velazquez.

weeks and the pups are suckled on the ice. Mating takes place in the water after pups are weaned.

#Ross Seal

Ommatophoca rossi

Population status and distribution:

This seal is the least known of all seals. Vague population estimates suggest that there are approximately 130,000 individuals.

Little is known about it because it appears to remain within heavy pack ice around the Antarctic continent up to 78° S, though it has been recorded as far north as Southern Australia.

Size and appearance:

Ross seals are approximately 2 m long and weigh up to 225 kg. They are the smallest of Antarctic seals and appear to have no neck. The snout and mouth do not extend out of the face, giving them a blunt front end. The fur colour is highly variable among individuals but ranges from a buff colour to dark grey.

Diet and hunting strategy:

Very few data are available. Ross seals likely take squid, fish, and krill by pursuit diving at night. They dive to an average depth of 100 m for durations of approximately 6 min.

Natural history:

Very few data are available. Pups are born between November and December. The female nurses her pup for approximately 25 days. Females reach sexual maturity at three to four years old, while males begin to reproduce at three to seven years old.

The Ross seal is very rarely seen due to their preference for thick pack ice. © Franeker.

#Antarctic Fur Seal

Arctocephalus gazella

Population status and distribution:

Breeding colonies are located on the islands of the Southern Ocean around the Polar Front to the South Shetland Islands. At present 90% of the births occur at colonies on South Georgia. Within Antarctica, there are two breeding areas: on the South Orkney Islands and at Cape Shirreff, on Livingston island. Populations were nearly hunted to extinction but are now making a remarkable recovery: estimates number them at just over six million individuals.

Size and appearance:

These are small animals compared to the true seals of Antarctica. Males are approximately 2 m long and weigh less than 200 kg. Females are just over a meter long and weigh no more than 50 kg. Fur seals rely on a thick layer of fur to keep them warm and have relatively little fat. They are able to walk across the beach by supporting their weight on their hind flippers as well as their long fore flippers. The coat colour can vary among individuals but generally it is a dark brown.

Pups weigh only 5 kg when they are born. Irrespective, they are feisty little creatures and a safe distance should be maintained. © Jacobs and Arrebola.

Diet and hunting strategy:

Fur seals feed mainly on krill around the breeding ground but shift to fish by pursuit diving when they leave after the breeding season towards more southern latitudes, including the South Shetland Islands, and the Antarctic Peninsula.

Natural history:

Males arrive first to the breeding colonies at the end of October when the first territorial disputes begin and males establish tightly guarded harems. From that moment on, the adult males will fast until the end of the copulation period. Females arrive at the end of November and give birth a few days after their arrival. At birth, pups are dark, 60 to 70 cm long and can weigh between 5 and 6 kg. Copulation will take place the week following the birth. The mother will attend to her pup for about a week, after which time she begins to make feeding trips to sea. The harems split up in mid-January and males, after fasting for almost three months, go to the sea to replenish their energy stores.

A small percentage of the fur seal population exhibit a honey-blond colour morph. © Jacobs and Arrebola.

THOSE UNWANTED GUESTS: PARASITES IN SEALS

GARV HOEFLER, M.A.

Most of us have experienced either a series or a single incident of uncontrollable sneezing. Sneezing is often attributed to spring pollens, allergies, or the simple common cold. Consider for a moment what it might be like to experience these sneezing events almost continuously, while simultaneously lacking hands with which to use a tissue or perhaps a nasal spray.

Such is the case with many species of seals, sea lions, and walruses. Their bouts of sneezing, however, are not a response to any of the irritations mentioned above but is a reaction to a very tiny parasite whose larval form moves around in the nasal passages.

The adult of this little antagonist is barely longer than 1 mm (the larvae are considerably smaller). These little creatures are mites belonging to a class of animals called *Arachnida*, more commonly known as spiders and to the order *Acarina*: the mites and ticks. Mites are typically oval in shape and the adults have four pairs of legs, while the newly hatched larvae have only three. Most species of mites are terrestrial; however, a few are adapted to life in water, whether fresh or marine. Those living in marine environments belong to a suborder called *Prostigmata*. Over the years, scientists have isolated many of these sea dwelling mites from various marine mammals and even from penguins. With careful observations of comparative anatomies and life cycles, many of the mites have been found to be very particular – that is, each species of mite makes only one species of host its home. For example, the mites found in walruses are of a different species than those found on true seals.

Halarachne spp. are the types of mites found on true seals. Each species of seal plays host to a different species of mite. One mite occurs on the harbour seal *Phoca vitulina* in the Eastern Pacific Ocean; another on the northern elephant seal *Mirounga angustirostris* off the west coast of California and Mexico; and, thousands of miles away in the Southern Ocean, the southern elephant seal *Mirounga leonina* serves as host to one named *Halachne erratica*.

Adult mites occupy much of the respiratory pathways of their hosts, including the lungs. Larval forms are more often found in the nasal passages and can be cultivated for study from sputum or discharge. Sneezing or any mucus discharge is thought to be the mechanism by which they move from one animal to another. In some marine mammal species, lesions can develop in the tissue around the area where the mite is imbedded. Infections can then occur and develop into emphysema and/or pneumonia. It seems that young adults are more prone to getting these mites than the very young or much older animals because young adults interact with a greater number of individuals as they establish their place within the social hierarchy, thus increasing the probability of contact with a sneezing or coughing animal.

So, next time you have a sneezing fit, relax in the realisation that it will pass and that there is no little parasite traipsing around your airways or burrowing into your nasal passages.

Southern elephant seal Mirounga leonina:
Does anyone have a tissue?
© Jacobs and Arrebola.

Humpback whales have the longest pectoral fins of all whales. © Ullmann.

WHALES

There are 88 species of whales and dolphins in the Earth's seas and rivers. Of these, approximately 37 frequent the Southern Ocean. Not all of these species will be described here as many of them are rarely seen. We will instead describe the nine most commonly observed species, five of which can be seen regularly on crossings of the Drake Passage and visits to the Antarctic continental coastline. The dense concentration of food within the Southern Ocean during the summer months attracts over half of the world's cetaceans. Eleven species of dolphins (family ***Delphinidae***) are also found in the waters of the Southern Ocean, though very few are seen near the Antarctic Continent. The long-finned pilot whale ***Globicephala melas*** is seen on occasion within the narrow channels of the Peninsula, and the killer whale ***Orcinus orca*** is frequently seen by visitors, hunting in large or small pods with adult males, females, and juveniles.

Whales are separated into two types depending upon their dentition. The toothless ***Mysticetes***, and the ***Odontocytes***. The ***Mysticetes*** are whales that have evolved complex structures inside their mouths called "baleen" to capture food. Made of the protein keratin (also found in fingernails and hair), baleen grow in long plates from the gums of the upper jaws towards the tongue. They range in length from 0.6 to 3.6 m depending upon the species and the age of the individual and grow continuously throughout the lifetime of a whale. The inside edge of each plate is frayed, like a fringe, through which enormous quantities of water are filtered by pushing on the baleen with the tongue, trapping small organisms such as krill and copepods. The tongue sweeps along the baleen and empties the fringe and the captured prey are swallowed whole. Earth's densest schools of krill can be found in waters between the Antarctic Peninsula and South Georgia, attracting baleen whales with their calves.

The ***Odontocytes*** have teeth like most mammals, with layers of pulp, cementum, dentine, and enamel. The difference with these animals is that each tooth is of the same shape (no incisors, canines, or molars) and more or less of the same size. This suborder includes the sperm whale, beaked whales, dolphins, and porpoises.

Cetaceans made their appearance in the fossil record between 55 and 60 million years ago. It was previously thought that the baleen and toothed whales had separate ancestry but it is now generally accepted that they have a common terrestrial ancestor that went extinct over 30 million years ago. The closest relative to cetaceans living today is the hippopotamus.

To keep warm, whales and dolphins have a thick layer of oil-rich blubber that insulates them from the cold sea. This blubber layer can be up to 30 cm thick and was highly sought as a source of energy before the invention of electricity. Like pinnipeds, cetaceans give birth to only one calf and the lactation period varies by species. Cetacean milk is extremely rich in fat content – approximately 40% – and contains five times more calories per unit of volume than human milk. It is very thick, like toothpaste, and is actively pumped out of the nipple to prevent it from being diluted by sea water. This function allows the calf to avoid swallowing excess water when nursing, encouraging rapid growth.

Humpback whales are frequent visitors to Antarctic waters. © Jacobs and Arrebola.

Evolving over 55 million years, whales have a completely aquatic life. © Suter.

#Humpback Whale

Megaptera novaeangliae

Population status and distribution:

The current population estimate is 38,000 individuals with between 20,000 and 30,000 in the Southern Hemisphere; numbers that would undoubtedly be greater had they not been hunted for their oil in the 1800s and 1900s. Pre-hunting population size estimates average 100,000 individuals. The intensive hunting was owed to the whale's coastal distribution, its high oil yield, and its relatively slow swimming pace. It is thought that up to 2,500 individuals currently frequent the Southern Ocean and they are commonly seen by visitors to Antarctica during the austral summer. Otherwise, humpback whales are world wanderers, though Northern Hemisphere populations do not cross the equator and vice versa. They are likely the longest migrators of all the mammals, covering more than 8,000 km.

Size and appearance:

Mature individuals are up to 19 m long and weigh up to 36 tonnes. Males are usually slightly smaller than females. Humpback whales have a stocky body with many barnacles and tubercles (thickened patches of skin forming bumps along the body) on the head and on the lower surface of the ridges of the pectoral fins and highly variable skin colour and patterns. The pectoral fins are particularly long, extending up to 5 m from each side and are on occasion lifted out of the water. The dorsal fin is small and wedge shaped, while the tail fins (flukes), which have markings on their undersides unique to each individual, are often lifted out of the water when the whale performs a deep dive. The blow can be seen at a distance – tall, bushy (V-shaped) and reaching heights of up to 3 m from the water's surface. Indeed, the humpback whale is the most surface active of all whale species. Spyhopping, pectoral

WHALE TALES

The shapes and colour markings of the flukes of each humpback whale are as unique as human fingerprints. By comparing them, scientists can recognise individuals and work out their migration patterns, sexual maturity, population size, and social behaviour. Although, nowadays, there are some other modern techniques that allow scientists to obtain more information – DNA samples collected by skin biopsy, for example – these require a more invasive approach than simply taking a photo for comparison.

Photos © Jacobs and Arrebola.

A humpback whale calf checks out the camera. At birth, calves are approximately 4.5 m long and weigh up to 2 tonnes. © Sutherland.

fin slapping, fluking, and breaching are all common behaviours.

Diet and hunting strategy:

Humpback whales are baleen whales that feed on krill and small schooling fish. Prey are captured by gulping, skimming, and creating a bubble net (air bubbles used to form a wall around prey to restrict their movements) beneath schools. Bubble netting techniques in the Southern Ocean are not as developed as in the Northern Hemisphere, particularly off the coast of Alaska.

Natural history:

Adults reach sexual maturity between four and seven years old. Males attract females in underwater territories by singing long and complex songs that have fascinated scientists for decades. After a period of 11 to 12 months, and generally in August, females give birth to a single calf in warm tropical waters. The calves are weaned by one year. Though some females remain in warmer waters with their calves, others travel south to Antarctica. Females give birth every two or three years. Humpbacks generally remain in small pods of a few individuals, but these can be as large as 15 individuals. It is not uncommon, however, to see only a mother and calf travelling together.

The shapes and colour markings of the flukes of each humpback whale are as unique as human fingerprints. By comparing them, scientists can recognise individuals and work out their migration patterns, sexual maturity, population size, and social behaviour. Although, nowadays, there are some other modern techniques that allow scientists to obtain more information – DNA samples collected by skin biopsy, for example – these require a more invasive approach than simply taking a photo for comparison.

#Minke Whale

Balaenoptera bonaerensis

Population status and distribution:

Perhaps the most numerous of all the whales, Minke whale population estimates currently range between 300,000 and 400,000 individuals. They are frequently seen in the waters of the Antarctic Peninsula and other areas off the continent during the austral sum mer. Due to their relatively small size, Minke whales were hunted in great numbers by small fishers and coastal hunters after the depletion of the populations of larger whales. Currently, over 400 individuals are taken annually by Japanese whalers for "scientific" purposes. Minke whales have a circumpolar distribution generally remaining within 20° S and 65° S; however, sightings have been made in the Ross Sea as far south as 78° S. During the winter months, Minke whales migrate to between 5 and 35° S.

Size and appearance:

One of the smallest of this genus, individuals range between seven and 10 m long and weigh up to nine tonnes. Minke whales are slim and sleek, and can swim quickly. Females are approximately 1 m longer than males. The grey back appears completely black when surfacing. The snout forms a point, which is frequently lifted from the water before the blow. The blow is weak, reaching up to 3 m above the surface but often not seen at all. The dorsal fin is curved and pointed and the flukes are rarely seen above the water.

Diet and hunting strategy:

Minke whales are baleen whales and eat krill skimmed from near the surface of the water.

Natural history:

Adults begin breeding at about seven years old; mating itself can occur anytime between June and September. The gestation period lasts 10 months and calves are born in warm waters in May or June. Weaning usually occurs at the most southern point of their distribution. Minke whales are often seen in small groups of up to four individuals, though it is currently thought that there is no social bond between them.

Minke whales frequently lift their snouts above the surface of the water when breathing. © Jacobs and Arrebola.

Minke whale. © Kunz.

#Sei Whale

Balaenoptera borealis

Population status and distribution:

These whales are less known because they rarely visit coasts and generally inhabit deeper waters. Estimates of the population that frequents the Southern Ocean are between 10,000 and 70,000, though these have not been recently updated. With a global distribution, this southern population may spend a short period of time closer to Antarctica, as far south as the ice edge.

Size and appearance:

Adults reach up to 20 m long and weigh up to 30 tonnes. Females are generally larger than males. A long, sleek, dark grey coloured whale with a pointed head, the sei whale is easily confused for the fin (see below) or Minke whale, though it is generally smaller than the former and larger than the latter. The blow is narrow and tall, up to 3 m from the surface of the water and slanted backwards. The fluke is never lifted from the water; however, the splashguard (in front of the blowhole) and the dorsal fin (which is larger than that of a fin whale) can both be seen above the water (unlike the fin whale but similar to the Minke whale).

Diet and hunting strategy:

Sei whales capture krill, squid, and small fish by skimming the surface with their baleen. Their ability to swim very quickly may assist them in capturing more fish than other baleen whales.

Natural history:

The males and females begin breeding when they are 10 years old, but peak reproductive activity does not occur until they are around 25 years old. Calving generally occurs in June. No information about mating is available but gestation is known to last approximately 11 months and calves are weaned at seven months in colder waters where there is an abundance of food. Sei whales likely breed every two or three years. Though small pods of up to five individuals are often seen, these groups are unstable.

Sei whales are often confused with fin, Minke, and even female killer whales due to their similarly shaped dorsal fin. © Vasconcelos de Oliveira.

Sei whales catch krill and small fish by skimming the surface of the water with their baleen. © Vasconcelos de Oliveira.

#Fin Whale

Balaenoptera physalus

Population status and distribution:

Current population estimates are between 85,000 and 120,000individuals. Prior to the development of the explosive harpoon and the consequent increase in hunting efficiency, the population estimate for fin whales was 400,000 to 500,000. The most widely distributed of all whales, fin whales have a global distribution with important migration patterns. Small pods in the Southern Hemisphere move northward during the austral autumn. Before this migration, individuals can be seen as far south as the ice edge, though most do not go further than 60° S.

Size and appearance:

Adults reach up to 25 m in length and weigh up to 70 tonnes. The females can be considerably larger than males. The grey body is long and sleek, with a small and curved dorsal fin that is larger and more hooked than that of the blue whale, but less so than that of the sei whale. The dorsal fin appears above the surface of the water shortly after the blow. The blow is tall (up to 6 m) and narrow and the snout is often raised above the surface prior to breathing. Flukes are not lifted above the surface of the water, except on occasion when feeding at the surface. This species is generally seen in small groups of approximately three individuals.

Fin whales can remain below the surface of the water for over 30 minutes and dive to depths of over 200 m. © Fernandes.

Fin whales are commonly observed in small pods of two or three individuals. © de Albuquerque Martins.

Diet and hunting strategy:

Feeds on krill and small fish by gulping. Fin whales sometimes feed at the surface.

Natural history:

The adults begin breeding at between six and 12 years old. Mating occurs in about July with an 11-month gestation period. Calves are born in warmer waters during the austral winter and are weaned at about seven months. Adults and juveniles then migrate towards the poles for feeding. Females give birth every two or three years.

The fin whale has an asymmetric colour pattern on the lower jaw: the right side is white, the left is dark. © Whooley.

#Blue Whale

Balaenoptera musculus

Population status and distribution:

Overall population estimates are very low (approximately 10,000), with perhaps 700-1,200 individuals found in the Southern Ocean. Prior to the development of the explosive harpoon (which allowed whalers to hunt the faster whales), it is thought that the population was approximately 220,000. The Southern Ocean population migrates northwards as far as Ecuador and Brazil during the austral winter and can be found as far south as the ice edge during the summer months.

Size and appearance:

The blue whale is likely the largest animal ever to have lived on Earth. Mature adults can be as long as 33 m (the average is 25 m) and weigh up to 150 tonnes (though the record is 190 tonnes). Females are slightly larger than males. The body is greyish-blue with small lighter spots. While breathing, more of the shoulders and blowhole are raised above the surface of the water than other similar species. The blow is very tall (up to 12 m), thin, and dense. The dorsal fin is relatively small and rarely appears above the surface of the water. Flukes can be seen when the whale is diving (though rarely in colder waters), and the body appears to bend in half. Lone individuals are not uncommon and, if they are in groups, they are generally not associated.

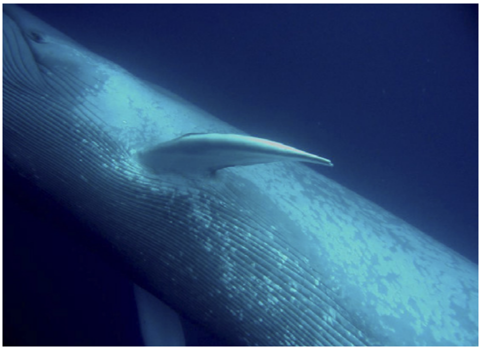
Diet and hunting strategy:

Blue whales eat only larger zooplankton by gulp feeding.

In accordance with their size, the blow of the blue whale can reach over 8 m in height.
© van Franeker, Wageningen - IMARES.

Natural history:

Both the males and females mature by about 10 years old. Mating begins in the late austral summer. The gestation period lasts approximately 11 months. Calves are born in warmer waters and are weaned at about seven months. Females breed every two or three years.



Reaching lengths of over 30 m, blue whales are the largest living organism on the planet. © Fernandes.

Blue whales are easily identified by their huge size and tiny dorsal fins. © Bott.

While not common, occasionally blue whales show their flukes on the water's surface. © Augliere

#Southern Right Whale

Eubalaena australis

Population status and distribution:

There are approximately 5,000 southern right whales. Prior to intensive hunting activity in the 1800s and extending into the 1970s, it is estimated that the population was once 100,000. Southern right whales have a circumpolar distribution within the southern regions of the Atlantic, Pacific, and Indian Oceans and are not found further north than the waters off of southern Brazil. During the austral summer, individuals move southwards to feed in waters around the Polar Front, and off the Antarctic continental shelf. They are also seen on occasion around the Antarctic Peninsula.

Size and appearance:

Right whales reach up to 17 m in length and weigh up to 45 tonnes. The females are generally slightly larger than males. The body is very round and stocky, with a head measuring up to one third of the total body length. The skin is black with white patches on the under parts. The blow is deeply V-shaped and there is no dorsal fin. Callosities on the head (along lower jaw, on snout, around blowhole) can be seen when the whale surfaces and individuals can be identified based upon the pattern of these callous-like areas of skin. The flukes are lifted out of the water when diving and have a straight trailing edge with little curve near the lateral tips.

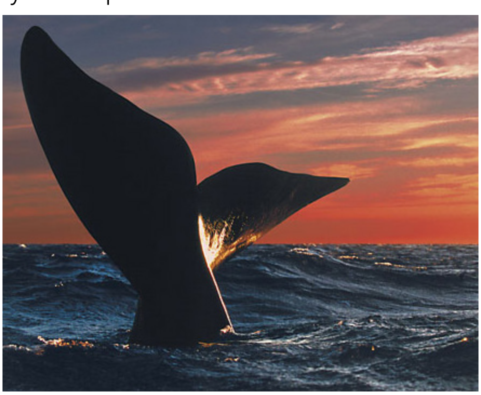
Diet and hunting strategy:

A baleen whale, southern right whales take krill and copepods by skimming the surface.

Natural history:

Females become sexually mature between seven and 15 years old. Mating off the coast of Argentina occurs around the month of September and females will mate with several males.

After a gestation period of about 12 months, the calves are born off various coasts, including those of the islands of the Southern Ocean and further north, to Buenos Aires during the austral winter. The calves are weaned after six to 12 months, although they may remain with their mothers for longer periods. This extended breeding cycle permits females to breed only every three or four years.



Southern right whales frequently lift their tails above the water, especially when they begin a deep dive. © Suter.

Southern right whale calves can be up to 6 m long at birth and weigh 10 tonnes. © Suter.

#Sperm Whale

Physeter macrocephalus

Population status and distribution:

An estimate of population size made over 40 years ago is just under 2 million. However, new models recently published suggest that these numbers are greatly inflated and that the population size today may be only a fraction of what is thought. Approximately 30,000 males are thought to enter the Southern Ocean during the austral summer while the females remain in warmer waters throughout the year. Sperm whales are more likely found off shore in deep water or at the edges of the continental shelf where the water depth increases dramatically.

Size and appearance:

The largest of all the toothed (emerging only on the lower jaw) whales, sperm whales reach up to 19 m in length and weigh up to 60 tonnes. Males are generally much larger than females. They have a distinctive square head with a single blowhole on the left side. The blow is generally up to 2 m high (though it can be higher) and leans forward and to the left. The dorsal fin, which is visible above the surface of the water, is not hooked, but rather hump shaped. Between the dorsal fin and the flukes, a series of bumpy ridges can be clearly seen. The flukes are frequently raised out of the water when diving.

Diet and hunting strategy:

Sperm whales are toothed and catch prey by pursuit diving. They feed primarily on squid and fish but will also hunt sharks. Females hunt and feed in small groups while males usually hunt alone.

Natural history:

Sperm whales are both gregarious and polygamous. The pods consist of a number of females with their young and, during the mating season, a single reproductive male. Adults do not reach sexual maturity until they are over 20 years old. Mating occurs throughout the year, with peak mating occurring in October and November. The calves are born in warmer waters after a gestation period of over 14 months. The calf is weaned after up to three and a half years. Due to the long reproductive cycle, females do not reproduce more than once every four to five years.

Sperm whale. © Sutherland.

The blowhole of the sperm whale is located on the left side of its body. © Morgenthaler.

#Long-Finned Pilot Whale

Globicephala melas

Population status and distribution:

The population is thought to be about 200,000 individuals living in the south of the Atlantic, Pacific, and Indian Oceans. Generally, long-finned pilot whales do not move south of 60° S; however, some have been observed as far as 68° S during the austral summer.

Size and appearance:

Adults reach up to 7 m in length and weigh up to three tonnes. Females are considerably smaller than males. With small, slender bodies and blunt heads, pilot whales are often seen in groups of up to 40 individuals. The dorsal fin is rounded with a broad-base and a slight hook in females and pronounced hook in males. The blow is bushy and reaches up to 1 m in height, although it is often not visible. The pectoral fins are long; about 20% of their body length.

Diet and hunting strategy:

Long-finned pilot whales feed on fish and squid by pursuit diving.

Natural history:

Males likely mate with several females. The gestation period lasts up to 16 months and females likely breed every five or six years. The calves are weaned at 18-36 months.

A long-finned pilot whale surfaces for a look around. © Wall.

Long-finned pilot whales are gregarious, forming large pods that travel together. © Wall.

#Killer Whale (Orca)

Orcinus orca

Population status and distribution:

The Southern Ocean population is estimated at 80,000 individuals. Killer whales were never a direct target during periods of intensive hunting; some were taken, however – upwards of 5,000 individuals – during the mid-1900s. Killer whales are actually the largest members of the family of dolphins and are found all over the world. They are found in groups comprising males, females, and juveniles and it is thought that there is an Antarctic resident population.

Size and appearance:

Males can reach up to 9 m in length and weigh over 8 tonnes. Slightly smaller than males, females reach up to 8 m in length. A mature male has a distinctive dorsal fin, measuring up to 2 m in height. Females and juveniles have easily recognisable dorsal fins that are slightly hooked and larger than those of whales. They have black or dark grey bodies with white or yellowish eye patches and white chin and under parts. Also, a greyish saddle can be found on the back, posterior to the dorsal fin.

Diet and hunting strategy:

Killer whales take a suite of prey including fish, squid, penguins, petrels, seals and will even form large pods to hunt Minke and humpback whales.

Natural history:

Killer whales travel in small pods comprised of usually one adult male, several females, and juveniles. These pods range in size from a few to over 25 individuals. Calves are likely born during the austral winter after up to a 15-18 month gestation period. Females may breed only every five years.

A killer whale takes a look around.
© Ramos, National Science Foundation.

Orcas. © Jacobs y Arrebola.

Orcas are actually the largest member of the family Delphinidae. © Jacobs y Arrebola.

ECHOLOCATION: SEEING BY HEARING

LUCIANA MOTTA – DIRECCIÓN NACIONAL DEL ANTÁRTICO, ARGENTINA

Due to the eyes' position at the sides of their heads, whales and dolphins have only lateral vision, they cannot see straight ahead. Luckily, sounds travel faster and longer distances in water than in air and several species profit from this in the marine environment.

The *Odontoceti* have developed a sensorial system that takes advantage of the water's physical particularity, using sound in a process called sonar or echolocation.

These toothed whales and dolphins can guide themselves by sound. They send out a sound wave that travels through the water; when this wave collides against an object – like, a fish, schools of krill, land, rocks, other whales, or a ship – the sound bounces and is received back by the animal. The time it takes to receive the rebounded signal, combined with the direction from which it is coming, paints a sonic image in the brain that informs the individual of its surroundings.

Orcas. © Suter.

ANTARCTIC VISITORS

History of a human footprint

Antarctica is the only continent on Earth never to have supported permanent human settlements. Isolated and without sufficient resources for the development of a native population, it remained unknown to us until relatively recently. The discovery of the Antarctica was gradual and by the result of commercial pursuit accidentally redirected by furious storms that deviated explorers towards latitudes further south. Some of the most exciting and tragic adventures in history have been set upon the Southern Ocean and the White Continent. Though modern technology has made exploration both more accessible and safer, those lucky enough to explore Antarctica usually return home with an even greater appreciation of the perils faced when the region was first explored.

Early Discovery

The ancient Greeks first imagined ***Terra Australis Incognita*** (Unknown Southern Land) according to the concept of symmetry. It was the foundation of their ancient philosophy: If on the Northern Hemisphere there was a big continent, so it was reasoned, there should be another one in the south to compensate. Claudio Ptolemy – a second-century Greek astronomer, mathematician, and geographer – referred to it as a fantastical territory south of the Indian Ocean. By the 15th century, Portuguese fleets had already crossed the equatorial line to the south in search of new commercial routes toward the East Indies. In February, 1488, Bartholomeu Diaz was caught in a fierce storm that pushed him as far south as Cape of Storms (later renamed Cape of Good Hope by King John II), on the southwestern coast of South Africa. Diaz had reached 40° S and confirmed the existence of a route to the Indies around the cape. In 1497, Portuguese Captain Vasco da Gamma became the first person to navigate from Europe to India by sailing around South Africa, proving that Africa was not attached to ***Terra Australis Incognita***.

In 1502, the Italian Amerigo Vespucci was exploring the Brazilian coast when a raging storm drove him south to sub-Antarctic latitudes, where he claimed to have sighted land. Eighteen years later, Ferdinand Magellan followed the coast of South America (named after Amerigo Vespucci) to Patagonia, searching for a passage between the Pacific and Atlantic oceans that would take him to the East Indies. In October, 1520, Magellan reached a headland he called Cabo Virgenes, and entered into a wide strait opening towards the west. At night the sailors could see giant bonfires on the southern coast of the strait; Magellan named that land Tierra de los Fuegos (Land of the Fires). Could it be the ***Terra Australis Incognita***? That question would not be answered for another sixty years.

Magellan sailed west and was greeted by the vast southern Pacific Ocean which he continued exploring until he was murdered in the Philippines by the natives. From the original crew of 265, only 18 returned to Spain under the command of Sebastian Elcano. These were the first men to circumnavigate the globe.

In 1578, on board the ***Golden Hind***, Sir Francis Drake followed in Magellan's footsteps and navigated his southern strait. Upon his arrival to the Pacific Ocean, strong winds pushed him south towards the southernmost tip of South America. Drake continued sailing southwards to 57° S, but he found no land and turned back. The open sea south of Cape Horn was later named the Drake Passage.

Francis Drake, an English privateer who navigated the passage that now bears his name. © Archivo Fotográfico del Museo del Fin del Mundo.

Ferdinand Magellan of Portugal explored for the Spanish crown in search of a passage to India. © Archivo Fotográfico del Museo del Fin del Mundo.

In 1598, Dirck Gherritz, a Dutch merchant in charge of the ***Blidje Bootschap*** and part of the expedition led by Jacobo Mahú, was pushed south by a furious storm. Some historians suggest that Gherritz may have sighted the South Shetland Islands, whose most northerly point lies at 61°S (Elephant Island). Others award the discovery to Gabriel de Castilla who, in 1603, while sailing from Peru to strengthen the Spanish claim over the Magellan Strait, was caught in a storm and blown far off course. According to the statement of the Dutch sailor Laurenz Claesz, who navigated with de Castilla, they reached 64° S and saw snow. De Castilla made no such report.

Records show that Laurenz Claesz also sailed with Jacobo Mahú. It is therefore unclear whether land at these southern latitudes was sighted on the 1598 or the 1603 expedition.

Thirty eight years after Francis Drake was blown towards the passage that bears his name, Willem Schouten and Jacob Le Maire, of Holland, confirmed that Tierra del Fuego was an island when they discovered Cape Horn, naming it after their home town. In order to confirm Schouten and Le Maire's discovery, King Felipe III of Spain sent the Nodal Brothers to explore Tierra del Fuego. They circumnavigated the Fuegian Archipelago for the first time and discovered Diego Ramirez Island – the southernmost island of South America. The discoveries made by Schouten and the Nodal brothers confirmed that ***Terra Australis Incognita*** was attached neither to South America nor to Tierra del Fuego.

◊ James Cook (1728 - 1779)

Voyage of the** Resolution **and** Adventure **(1772-1775)

James Cook. © Archivo Fotográfico Museo del Fin del Mundo.

James Cook was born in Marton, North Yorkshire, England. In 1755, he volunteered to join the Royal Navy where he started as able seaman onboard the ***HMS Eagle***. He participated in the siege of Quebec in 1759, developing his cartographic and topographic skills. Cook's first important voyage was onboard the ***Endeavour*** to observe the transit of Venus in the South Pacific. He also mapped the coasts of New Zealand and Australia, proving that New Zealand was not part of a continental landmass. For this great contribution Cook was promoted from Lieutenant to Master and Commander, and sent on his second expedition.

With instructions to explore the far south in search of the Southern Continent, Cook departed England on July 13, 1772. He sailed with two ships – the ***Resolution***, under his command, and the ***Adventure***, commanded by Captain Furneaux. During the expedition, Cook circumnavigated Antarctica and made four incursions south in search of land. The first incursion was made from Cape Town at the end of November,

1772. The ships crossed the Antarctic Circle on January 17, 1773 and a few hours later their progress was halted by ice at 67° 15′ S. In late February, 1773, he reached 61° 52′ S, 095° 02′ E. Due to stormy weather and an impressively dense distribution of icebergs, he retreated to the north. Cook arrived in New Zealand at the beginning of November, 1773 and after three weeks he departed on his third incursion south, crossing the Antarctic Circle and reaching 67° 31′ S, 142° 54′ W on December 22, 1773. He was again stopped by ice and had to retreat to the north.

During his last attempt at reaching the White Continent, Cook crossed the Antarctic Circle on January 26,

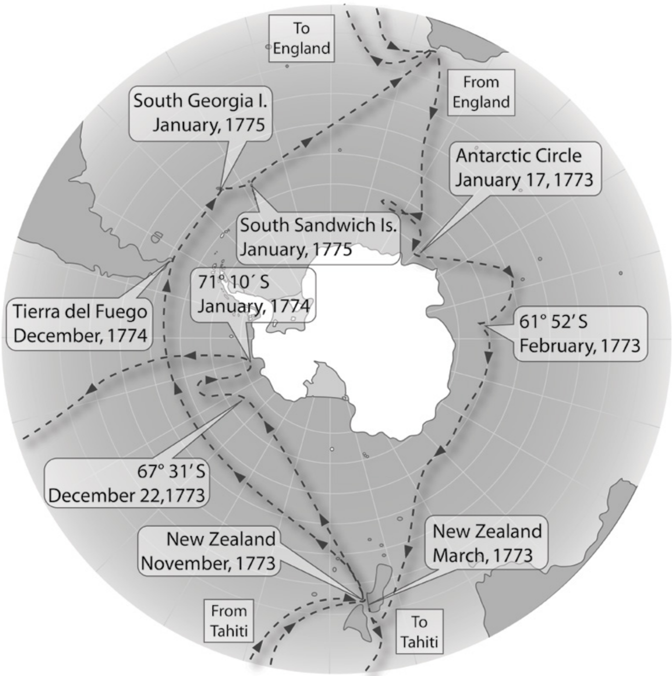


Figure 3.1. Though Captain Cook made four incursions into Antarctic waters, circumnavigating the entire continent, he never saw it. © Jacobs.

1774 and reached 71° 10′ S on January 30 (between the Bellingshausen and Amundsen Sea) before he was stopped by ice. Though Cook never sighted land, he had sailed further south than anyone had before.

After a year in the South pacific, Cook sailed towards Cape Horn. He arrived in Tierra del Fuego by the end of 1774. In January, the ***Resolution*** began its search for the island described by the English navigator De la Roche one hundred years earlier and by the Spaniard Gregorio Jerez in 1756 aboard the ship ***Leon***. When they were found, Cook named the island George, after George III (it is now known as South Georgia Island). When Cook discovered that the island was not part of the White Continent, he continued sailing southeast where he discovered the South Sandwich Islands at the end of January, 1775, naming them after Lord Sandwich of the British Admiralty. Afterward, he sailed towards Cape Town, thus completing the first circumnavigation of the Continent (Figure 3.1).

Captain Cook never saw a continent but he did prove that no known land was attached to Antarctica and that, should the great Southern Continent exist, it would necessarily be located beyond 60° S.

Upon his return to England, Cook began preparations for a new expedition to find the Northwest Passage in the Canadian Arctic. He spent a full calendar year searching for the elusive passage along the west coast of Canada and Alaska but was unsuccessful. Accepting his misfortune, he returned to the Hawaiian Islands where he was killed by the natives in February, 1779.

Cook's report of great colonies of fur seals and other marine mammals in the Southern Ocean did not go unnoticed by profit-driven whalers and sealers in search of new hunting grounds. A few years later, the seal colonies in Patagonia had nearly become extinct. Nevertheless, ships, their holds full of seal skins, were still mooring in the ports of Buenos Aires and Montevideo, suggesting that they had found alternative sources in areas south of Cape Horn.

In fewer than thirty years following Cook's discoveries, the fur seal populations of South Georgia Island, Kerguelen Island, and Heard Island were hunted nearly to extinction.

Though a great number of sub-Antarctic and Antarctic islands were discovered by sealers, it was an English merchant captain who first sighted Antarctic land – or who, at least, first reported the discovery.

◊ William Smith (? – 1840)

Voyage of the** Williams **(1819 – 1821)

Not much is known about this merchant captain before his journey on board the ***Williams***. In 1819, while travelling from Buenos Aires to Valparaiso via Cape Horn, he was forced by raging winds to veer south. That deviation took Smith in sight of the South Shetland Islands on February 19, 1819 for the first time ever confirmed.

Back in Valparaiso, Smith reported the discovery to Captain William Shirreff, a British senior naval officer on the Pacific coast who would not award Smith credit and ridiculed him instead. Word of William Smith's "islands to the south" travelled so quickly that, by the time Smith reached Rio de la Plata from Valparaiso, the news of the discovery had beaten him there.

Though the Northern Hemisphere was almost entirely devoid of seals, the demand for oil to illuminate the growing cities was increasing. Smith was frequently harassed by American sealers to share the position of these newly discovered islands but he swore that he would divulge the coordinates only to a fellow Brit. In October, 1819, Smith sailed south once again and made his first landing on King George Island in the South Shetland Islands and returned to Valparaiso with proof of his success.

On December 20, 1819, Smith returned for the third time to the South Shetland Islands, but, this time, as the pilot of a British Admiralty Expedition under the command of Edward Bransfield on board the ***Williams*** on a mission to officially confirm the presence of Smith's islands. They landed on King George Island and sighted Deception Island, to the southwest. It was a clear day on January 30, 1820, and they could see the mountains of the Antarctic Peninsula, though they had no idea that they had sighted the mysterious and long-hidden White Continent.

The following season, Smith returned south on a sealing voyage. This time he found that he was no longer alone: more than forty British and American sealing vessels were in the area, all of them attracted by the abundance of seals. Smith and the ***Williams*** returned to England in September, 1821, their holds full of seal skins, only to find Smith's partners bankrupted. The ship and cargo were seized. Years later, he requested of the British Admiralty that they compensate him for his Antarctic discovery but this request was promptly denied after the British Admiralty consulted Captain Shirreff, the same man who had ridiculed him in Valparaiso in 1819. William Smith died in poverty.

◊ Fabian Gottlieb von Bellingshausen (1778 - 1852)

Voyage of the* Vostok *and* Mirnyi *(1819-1821)

Fabian von Bellingshausen was born in Estonia (at that time part of the Russian Empire). He joined the Imperial Russian Navy in 1797. In 1819, Bellingshausen was selected to lead the Russian expedition to the southern seas and was entrusted to circumnavigate the world at the most southern latitude possible to expand on the discoveries made by Captain Cook.

In July, 1819, Bellingshausen departed Kronstadt with two ships: the ***Vostok***, under his own command; and the ***Mirnyi***, under the command of Mikhail Lazarev. After a provisioning detour in Buenos Aires, the expedition began with a

Fabian Gottlieb von Bellingshausen. © Archivo del Museo Maritimo de Ushuaia.

stop in South Georgia Island where they mapped the geographical features of the southeast coast. They also discovered three new islands of the South Sandwich Group. Further east, Bellingshausen navigated south once again, where he sighted the Antarctic Continent on January 27, 1820 (three days before Edward Bransfield) at 69° 21' S, 002° 14 'W, close to the Queen Maud Coast. He tried to penetrate further south but was stopped by thick ice three days later.

He then sailed northwards to Sydney and spent four months in the South Pacific, visiting Macquarie Island before turning south again. On his next incursion Bellingshausen was stopped by ice north of the Ross Sea and was forced to sail east along the ice edge. He reached his most southerly point on January 21, 1821, at 69° 53′ S, 092° 19′ W, where he sighted unknown land and named it Peter I Coast. A few days later, he discovered another landmass, which he called the Alexander Coast. These islands are known today as Peter I Island and Alexander Island, both located in what is today called the Bellingshausen Sea.

In February, 1821, Bellingshausen sailed to the South Shetland Islands where he met a young American sealer called Nathaniel Palmer, the third person to sight the continent that year, on board the ***Hero***. The Russian captain continued his journey towards South Georgia Island, and was thus given credit for having made the second circumnavigation of the Antarctic continent (Figure 3.2).

Figure 3.2. Bellingshausen led the second expedition to circumnavigate Antarctica, this time having sighted land. © Jacobs.

The expedition arrived at Kronstadt on August 4, 1821 with a great quantity of biological specimens and scientific data. The accounts of his voyage were published in 1831, the same year he was promoted to the rank of admiral. In 1839, Bellingshausen was named governor of the port of Kronstadt, where he later died in 1852.

◊ Nathaniel Palmer (1799 - 1877)
Voyage of the** Hero **and** James Monroe **(1820 – 1821)

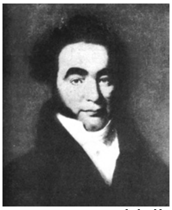
Nathaniel Palmer was born in Connecticut, United States of America. He first sailed to Antarctica as second mate on board the ***Hersilia***, under the command of James Sheffield. He was left in the Malvinas Islands to gather provisions while the ***Hersilia*** navigated the region in search of the long sought-after Aurora Islands. While he was waiting for the ***Hersilia***, the ***Spiritu Santo***, a sealing vessel arrived. The captain of ***Spiritu Santo*** told him they were heading towards islands recently discovered and full of seals. The captain refused to disclose the position of the islands. Somehow Palmer managed to work out the bearing of the ***Spiritu Santo*** as it left port and he informed Captain Sheffield of his conversation and calculations when ***Hersilia*** returned. A few days later, in January 1820, the ***Hersilia*** was hunting seals in what are now called the South Shetland Islands.

The second time that Palmer sailed the Southern Ocean was as captain of the ship ***Hero*** and part of a sealing expedition led by Benjamin Pendleton. Entrusted to find a safe harbour for the expedition's five ships, Palmer discovered the volcanic caldera located inside Deception Island. The ***Hero*** continued north to Greenwich Island where he found a protected bay with an anchorage for the fleet. The complete fleet moved there on November 23, 1820. The site was later named Yankee Harbor.


Nathaniel Palmer.
© Museo Marítimo de Ushuaia.

Palmer sighted the continent for the first time on November 17, 1820, ten months after Bellingshausen and Bransfield. One year later, due to the lack of seals on the South Shetland Islands, Palmer, this time on board the ***James Monroe***, sailed to Elephant Island where he met British Captain George Powell. Powell was experiencing the same difficulties finding seals. Agreeing to work together, the two captains left Elephant Island heading east. A couple of days later, on December 6, 1821, they discovered a group of islands that they called the Powell Group. Six days later, the British captains James Weddell on board the ***Jane*** and Michael McLeod on the ***Beaufoy*** arrived to the same islands and named them the South Orkney Islands, which still holds.

◊ James Weddell (1787 - 1834)
Voyages of the** Jane **(1819-1823)


James Weddell.
© Archivo Fotográfico Museo del Fin del Mundo.

James Weddell was born in London and he joined the Royal Navy as a young boy but left six months later to work in the merchant navy. In 1812, he was promoted to captain of the ***Hope***. A year later, Weddell captured the American privateering vessel ***True Blooded Yankee*** and was then transferred to several ships for short periods of time. In February, 1816, at the end of the Napoleonic Wars and forced to take leave with half-pay, he returned to the merchant navy in the West Indies. There, Weddell was introduced to James Strachan, a shipbuilder from Leith, Scotland, who (along with James Mitchell, a London insurance broker) owned the 160-ton brig ***Jane*** refitted for sealing. Weddell's primary interest was to rediscover the mythical Aurora Islands. The islands had been reported in 1762 by the crew of the Spanish ship ***Aurora*** while sailing from Lima to Cádiz, and then again in 1794 by the corvette ***Atrevida***, sent in search of them. The details of Weddell's first voyage are fragmented. After over-wintering in the Malvinas Islands, Weddell visited Staten Island, searching without success for the Aurora Islands. With the hold full of seal skins, he returned to England.

Weddell's first voyage produced a handsome profit for Strachan and Mitchell. The sale of the cargo allowed them to purchase a second smaller vessel, the 65-ton ***Beaufoy***, and to prepare a second expedition. In September, 1821, the ***Jane***, once again commanded by Weddell, and the ***Beaufoy***, commanded by Michael McCleod, left England. Upon their arrival at the Malvinas Islands they met Charles H. Barnard, commander and owner of the brig Charity. The three ships sailed toward the South Shetland Islands where they encountered 45 American and British sealing ships already in the area. The three vessels split up to find new sealing grounds. On December 12, 1821, the ***Beaufoy*** sighted the South Orkney Islands, discovered by George Powell and Nathaniel Palmer six days earlier. In February, 1822, Weddell, on board the Jane, sailed for the South Orkneys where some seals were taken and where he surveyed the islands. The ***Beaufoy*** sailed directly to South Georgia, where she was joined later by the ***Jane***. At the end of March, the two vessels sailed to England and arrived in July, 1822.

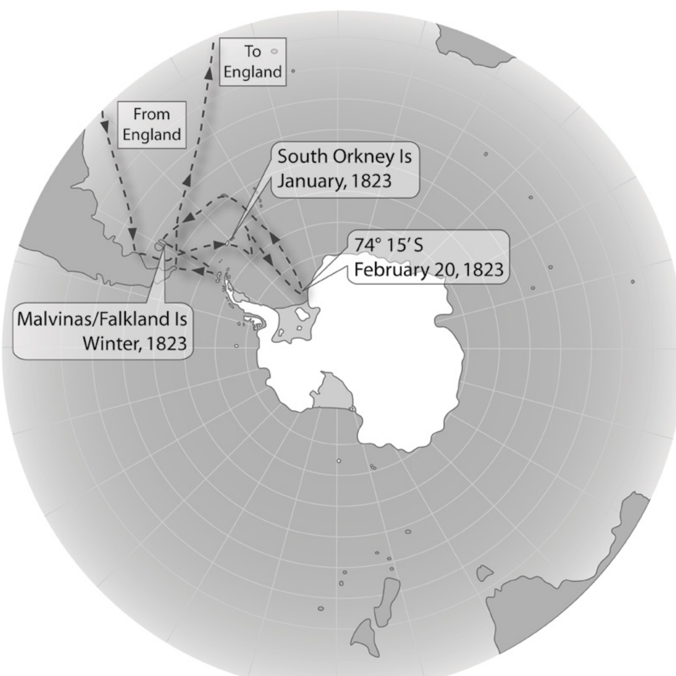
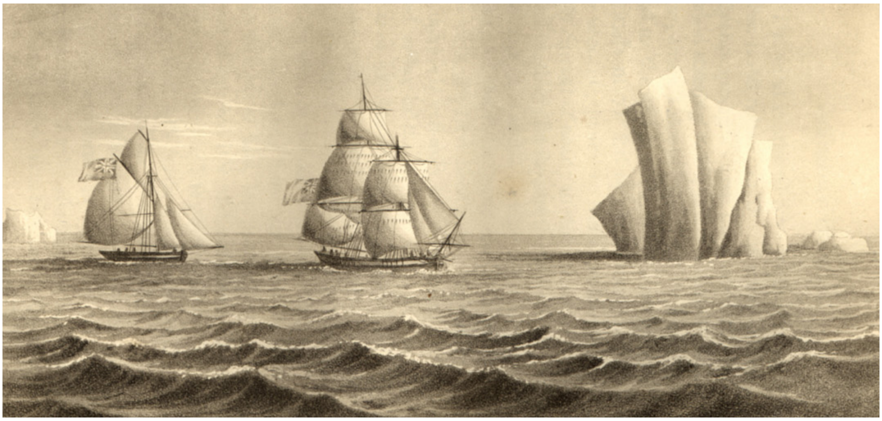


Figure 3.3. Weddell broke Cook's record for most southern latitude in February, 1823. © Jacobs.



The Jane and Beaufoy reaching their southernmost point in the Weddell Sea. Drawing by A. Mafson from a sketch by Captain Weddell. © Archivo Fotográfico Museo del Fin del Mundo.

After his second voyage in 1822, Weddell persuaded the owners of the ***Jane*** to sponsor another sealing expedition. If seals were not found, Weddell would explore new waters. The ships were very well equipped with the latest instruments. He commanded the Jane while Matthew Brisbane captained the Beaufoy. They arrived to the South Orkney Islands at the end of January, 1823. The men landed on Saddle Island and discovered a new species of seal, today known as the Weddell seal Leptonychotes weddelli. Weddell did not find fur seals on the beaches of the South Orkney Islands so he decided to explore further south in search of new land. On February 20, 1823, after easy navigation through what Weddell named the King George IV Sea, now called the Weddell Sea, the ships reached 74° 15' S, about 340 kilometres further south than Cook's record (71° 10' S) fifty years prior. Another two days of sailing would have brought them to discover Coats Land but his discovery would be made by the Scottish Expedition led by William Bruce on March 9, 1904 (Figure 3.3).

After a failed attempt to reach the South Shetland Islands due to heavy pack ice, Weddell sailed to Cape Horn where he remained for a brief period before returning to England. The account of his encounter with the native Yamanas was fully documented and published in 1825. He died in England in September, 1834 at the age of forty-seven.

◊ John Biscoe (1794 - 1843)

The Enderby Voyages on the *Tula* ***(1830-1833)***

John Biscoe was born in Enfield, England. He joined the Royal Navy in 1811 and served during the war against the United States between 1812 and 1815. In 1830, he was hired by the Enderby Brothers to serve as captain of the brig ***Tula*** and led a sealing expedition to the Southern Ocean. Biscoe left London on July 14, 1830, sailing towards the Malvinas Islands

Figure 3.4. John Biscoe made many significant discoveries along the Antarctic coast, and led the third expedition to circumnavigate the continent. © Jacobs.

accompanied by the cutter ***Lively***, under the command of George Avery. After an unsuccessful search for the Aurora Islands, the expedition went south via the South Sandwich Islands (end of December, 1830) and crossed the Antarctic Circle on January 21, 1831, north of what is today known as Dronning Maud Land. On February 24, 1831, after several weeks of fighting harsh weather conditions, Biscoe sighted an ice-covered land with a towering mountain range. He named it Enderby Land, after his sponsors. A few days later they spotted a headland at 66° 25′ S, 049° 18′ E, which Biscoe called Cape Ann. But just when an approach to Cape Ann seemed feasible, a hurricane-force wind pushed them offshore and the ships were separated. By March 16, 1831, Biscoe regained Cape Ann but the ***Tula*** became trapped in the ice and the crew decided to retreat, arriving in Hobart in May, 1831. The expedition departed Hobart on October 10, 1831, sailing southeast. On February 15, 1832, Biscoe sighted Adelaide Island, which he named after the Queen and he sighted Biscoe Archipelago a few days later.

Biscoe landed on what is today known as Anvers Island and claimed to have sighted the mainland of Antarctica. Biscoe named it Graham Land after Sir James Graham, first Lord of the Admiralty. The expedition sailed north toward the South Shetland Islands in search of seals. They returned to London at the beginning of 1833 (Figure 3.4).

John Biscoe's expedition also became the third expedition to circumnavigate the continent. The Royal Geographical Society and the Paris Geographical Society awarded Biscoe gold medals for his achievements.

◊ John Balleny (? - 1843)

The Enderby Voyages on the Eliza Scott (1839)

Also sponsored by the Enderby Brothers, Captain John Balleny's sealing expedition on board the ***Eliza Scott*** along with Captain Freeman on board the ***Sabrina*** left New Zealand in January, 1839. After a few days on Campbell Island, they sailed south until they were stopped by ice. On February 9, 1839, they spotted what are now called the Balleny Islands. Then the expedition sailed west, becoming the first expedition to attempt sailing against the prevailing winds. In March, 1839, Balleny made an important discovery: he sighted the Antarctic continent at what Dumont d'Urville would later name the Claire Coast, though Balleny named it ***Sabrina*** Land. In late March, the two ships were caught in a severe storm, the weakened ***Sabrina***, with no means to continue by her own, turned the emergency lights on, and with the ***Eliza Scott*** crew as witnesses, the ship and her entire crew disappeared in the darkness and were never seen again. Balleny struggled against the storm and finally headed towards England. The expedition was a commercial failure for the Enderby Brothers but it made important discoveries recognised by the Royal Geographical Society. The navigational information was used by James Ross to make an incursion south on his voyage on board ***Erebus*** and ***Terror*** in the Ross Sea.

◊ Dumont d'Urville (1790 - 1843)

Voyage of the Astrolabe and the Zélée (1837-1840)

Dumont d'Urville. © Archivo del Museo Maritimo de Ushuaia.

Dumont d'Urville was born in Normandy, France. At 17 years old, he joined the French Navy and received the highest academic honours. In 1822, the corvette ***Coquille*** sailed to the Pacific with d'Urville as first lieutenant and in charge of natural history. He returned to France with the hold full of impressive collections of flora and fauna from Argentina, Chile, Peru, Australia, New Zealand, and New Guinea. D'Urville organized another expedition to the South Pacific to complete their work in the area. He left Toulon in April, 1826 on board the ***Coquille*** (renamed ***Astrolabe***) and returned to France in March, 1829 with another impressive collection of specimens and nautical charts. D'Urville's logs and papers were so detailed that the South Pacific could now be divided into three geographical regions: Melanesia, Polynesia, and Micronesia. While reviewing the notes and logs of the ***Astrolabe***, he noticed a gap in the exploration of the South Pacific and quickly prepared a proposal for another voyage. He was sent to reach the South Magnetic Pole or, failing that, the southernmost latitude that would best Weddell's record (74° 15' S). This expedition would now thrust France into the race for international recognition in Antarctic exploration. D'Urville upon the ***Astrolabe*** was accompanied by Charles Jacquinot in charge of the ***Zélée***, and the two ships sailed out of Toulon in September, 1837. In January, 1838, they sailed along the coast of Tierra del Fuego and then turned south. For some time d'Urville tried to reach more southern latitudes than James Weddell's record, but they were stopped by ice and the two ships had to retreat to the South Orkney Islands. The second attempt south was stopped two days later by another belt of pack ice in which the ships became trapped. On February 9, 1838, a favourable wind picked up and the ships again reached open water. They returned to the South Orkney Islands and landed on Weddell Island. On February 22, 1838, the ships sailed west towards the South Shetland Islands and a coastline to the south was sighted. (figure 3.5).

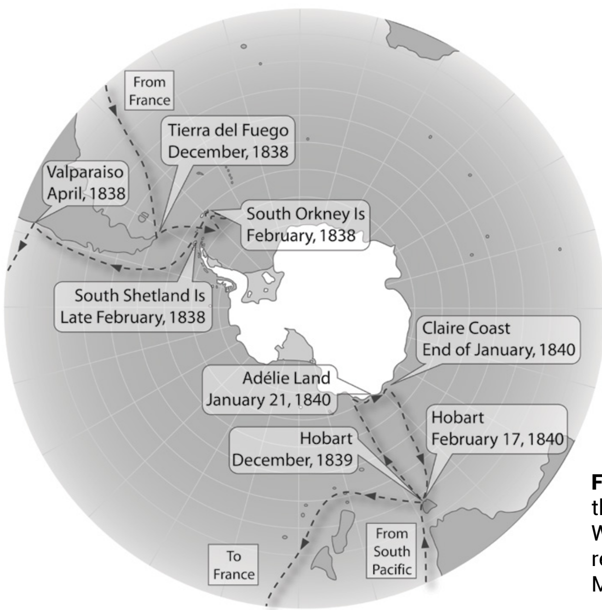
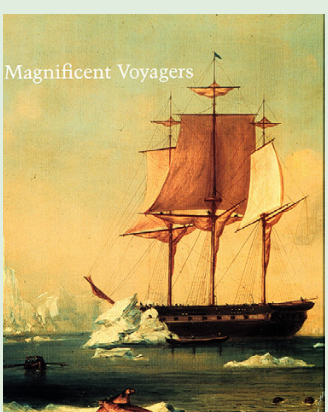


Figure 3.5. D'Urville made three attempts to beat Weddell's southernmost record and reach the South Magnetic Pole. © Jacobs.



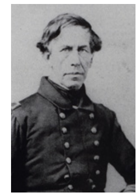
With the added burden of discovery placed upon sealing vessels, many of them were wrecked during the strong gales or forced to retreat to home ports with empty holds. Consequently, American companies funding these expensive exploits lobbied for their government to sponsor expeditions to chart the treacherous Antarctic waters.

In 1836, the U.S. Congress approved the budget for an expedition to the Pacific Ocean and southern seas with the purpose of aiding in commerce and navigation and conducting scientific and geographical research. Charles Wilkes was chosen to lead that expedition.

◊ Charles Wilkes (1798 – 1877)

United States Exploring Expedition on the** Vincennes, **the** Peacock, **the** Porpoise, **the** Sea Gull, **the** Flying Fish, **and the** Relief **(1838 – 1842)

Born in New York, Charles Wilkes joined the United States Navy at the age of twenty, becoming a lieutenant at the age of twenty-eight. In the 1830s, he was responsible for the Navy's Department of Charts and Instruments. For this expedition, Wilkes would be entrusted with six ships – the ***Vincennes***, the ***Peacock***, the ***Porpoise***, the ***Sea Gull***, the ***Flying Fish***, and the ***Relief*** – along with more than four hundred men, including officers, naturalists, scientists, artists, and sailors. None of the ships were ice-strengthened and the equipment and supplies were insufficient for such a lofty venture. Wilkes knew that it was hardly an appropriate fleet for an important expedition to inhospitable climes. The expedition departed Norfolk, Virginia in August, 1838 and sailed to Rio de Janeiro. There they remained for several months in order to make repairs. They arrived in Tierra del Fuego on February 17, 1839. Wilkes divided the expedition into three.



Charles Wilkes © National Oceanic and Atmospheric Administration Department of Commerce.

On board the ***Porpoise*** and with the ***Sea Gull***, Wilkes would try to reach latitudes further south than Weddell had in 1823. Close to the Antarctic Peninsula a storm forced them to return to the South Shetland Islands. Meanwhile, instructed to penetrate Bellingshausen Sea further than Cook had, the ***Peacock*** and the ***Flying Fish*** became separated in a fierce storm and were not reunited until March 25, 1839. Three days earlier, the ***Flying Fish*** had reached 70° 04' S, one degree short of Cook's record. The***Vincennes*** and ***Re-***

Figure 3.6. Wilkes, having sailed over 1,500 km along a frozen coast, suggested that it was part of a great continent, rather than an island. © Jacobs.

lief would stay in the fuegian archipelago.

After several hardships, including the sinking of the ***Sea Gull*** and the loss of the entire crew, the expedition (reunited once again) spent the winter in the South Pacific where they decided to send the damaged Relief back to the United States.

What remained of the expedition set out on December 26, 1839 for another attempt at a southern record. This time Wilkes was in command of the ***Vincennes***. Again the four ships were separated by high winds and fog. On January 16, 1840 they saw land that was finally confirmed three days later after periods of heavy fog.

The ***Porpoise***, ***Peacock*** and the ***Flying Fish***, in need of repair, sailed back to New Zealand and Australia. Meanwhile, Wilkes, on board the ***Vincennes***, continued west and made additional sightings of land along the way. On February 21, 1840, they reached an ice shelf that Wilkes would name Termination Land (today known as the Shackleton Ice Shelf). Having followed the Antarctic coast line for more than 1,500 km, and with over 30 men sick and suffering from scurvy and other ailments, Wilkes decided to return to Sydney and he arrived on March 11, 1840. The narratives of his voyage were published in 1845. He died in 1877, in Washington D.C (Figure 3.6).

◊ James Clark Ross (1800 – 1862)
Voyage of the** Erebus **and** Terror **(1839 – 1843)

James Clark Ross. © Archivo Fotográfico Museo del Fin del Mundo.

James Clark Ross was born in London, England in 1800 and joined the Royal Navy when he was eleven years old. At the age of eighteen he joined his uncle, Sir John Ross, on a voyage in search of the Northwest Passage and then sailed with William E. Parry on four expeditions to the Arctic. Between 1839 and 1843, Ross led this important scientific expedition to Antarctica, which included the study of the Earth's magnetism, gravitational pendulum studies, tidal and sea temperature measurements, botany, and zoology. This expedition also made the first collection of South Polar Skuas ***Catharacta maccormicki*** in Victoria Land, though the species was not properly described until 50 years later.

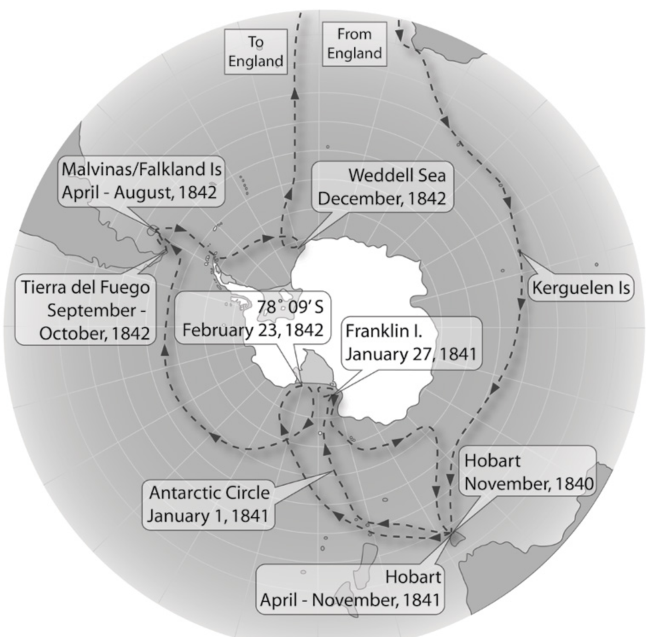
The expedition left England with two sturdy and reinforced ships in September, 1839. Ross was in command of the ***Erebus*** and Francis Crozier of the ***Terror***. Knowing that the South Magnetic Pole was inland, Ross thought it unwise to retrace Wilkes' path and he knew that crossing such a long distance on land would be impossible. He remembered from Balleny's notes that open water had been sighted to the south of the islands that now bear his name. Ross decided to sail there and see if it was possible to attain latitudes even further south in search of the Magnetic Pole.

On New Year's Day, 1841, the ***Erebus*** and ***Terror*** crossed the Antarctic Circle and sailed into heavy pack ice. The ships pushed their way through until the pack gave way. On January 9, 1841, they entered the open sea into what is now called the Ross Sea. They were the first expedition to successfully sail through pack ice. The sailors observed penguins on the floes and a new species of seal was described and named after Ross – ***Ommatophoca rossi***. With no ice to further impede him, Ross headed in the direction of the South Magnetic Pole but was, to his disappointment, stopped by land two days later. Ross went on a naming spree and mapped the mountains and geographic features in the area including Cape Adare, which 59 years later became the backdrop for the first continental over-wintering party led by the Norwegian Carsten Borchgrevink. Ross landed on the Possession Islands and the land was claimed for England as Victoria Land, named after the queen.

On January 27, 1841, Ross and Crozier landed on Franklin Island, named after Ross's good friend, and were the next day surprised to sight an active volcano with a smaller extinct volcano to the east. Ross named them Mount Erebus and Mount Terror respectively. The ice barrier in the Ross Sea was also observed and later called the Ross Ice Shelf. Ross sailed his namesake sea to the east, reaching 78° 04′ S, on February 2, 1841 where he decided to turn back. A few days later he discovered and named McMurdo Sound. This site became the popular starting point for the British expeditions that would attempt to reach the South Pole at the beginning of the 1900s. The expedition arrived in Hobart on April 5, 1841, where they made repairs to the ships.

On November 23, 1841, the expedition left Hobart once again. By February the ice finally cleared up and Ross was able to sail south, reaching his furthest point (78° 09′ S) on February 23, 1842. Afterwards, they set a course for Cape Horn and Malvinas Islands, where they remained for the winter. September to October,

1842 was spent in Tierra del Fuego observing the native people. Ross headed



[Figure 3.7. Ross discovered the Ross Sea and Ice Shelf, Mounts Erebus and Terror, achieved the furthest south record, and explored the northern tip of the Antarctic Peninsula. © Jacobs.

towards the Weddell Sea in December, 1842, mapping Joinville Island, naming the Erebus and Terror Gulf, and discovering Paulet, Cockburn, and Snow Hill Islands (the latter of which would be of great importance for the Nordenskjöld expedition sixty years later). He navigated into the Weddell Sea but did not match the record Weddell set in 1823. Ross finally arrived in England in September, 1843 (Figure 3.7). Upon his arrival, he was knighted and presented with the Gold Medal from the Royal Geographical Society of Paris.

Mount Erebus and Mount Terror, on Ross Island, were discovered on January 28, 1841. © Archivo Fotográfico Museo del Fin del Mundo.

THE HEROIC ERA

Though several expeditions had shown that there was land to be found below 60°S, the nature of that land was still unknown. Was Antarctica a giant atoll connected by ice or a giant continent hidden beneath a glacier? Thus it was that, in 1895, a new chapter in Antarctic history began. The Sixth International Geographical Congress proposed to the world's scientific societies that exploration of the Antarctic continent begin before the end of the century. Belgium was the first country to answer the call and likewise the first to make its mark. By the end of this era, Antarctica was extensively explored both by sea and by land. The Magnetic and Geographic South Poles had been conquered at last.

◊ Adrien de Gerlache (1866 – 1934)

Voyage of the* Belgica *(1897-1899)

Adrien de Gerlache.
© Archivo del Museo Maritimo de Ushuaia.

Adrien de Gerlache was born in Hasselt, Belgium. He abandoned university to enlist on a liner from Antwerp to New York. In 1890, he became a lieutenant in the Belgian navy and worked for four years on hydrographical ships. In 1894, de Gerlache presented his proposal for an Antarctic expedition to the Royal Geographical Society of Brussels and obtained 60,000 francs from the Belgian parliament. He used a significant portion of those funds to travel to Greenland and Norway to learn about polar survival.

The ***Belgica*** set sail on August 24, 1897. Among the selected officers and crew was the Norwegian Roald Amundsen, who would later be the first man to reach the South Pole, and the American Frederick A. Cook, who had previous Arctic experience and would later claim to have been the first to reach the North Pole.

In January, 1898, the ship arrived at the Antarctic Peninsula. After crossing the Drake Passage, the expedition crossed the Bransfield Strait and they discovered what today is called the Gerlache Strait, though de Gerlache named it ***Belgica*** Strait after the ship. They landed on several beaches, made the first Antarctic sledge journey and named the Palmer Archipelago, the western boundary of the Gerlache Strait. Besides Wiencke Island, named after the young sailor who died during the crossing of the Drake Passage, they named Brabant, Anvers,

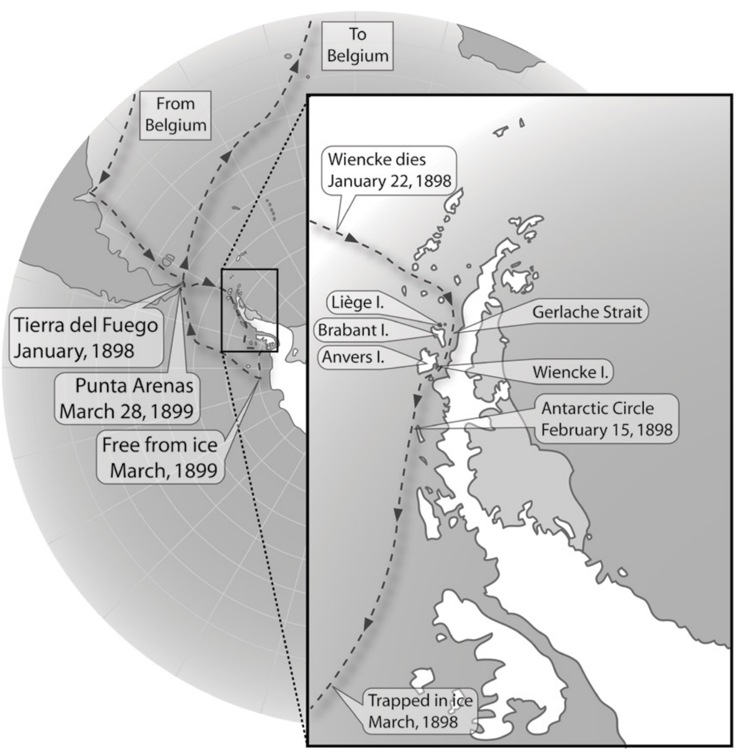
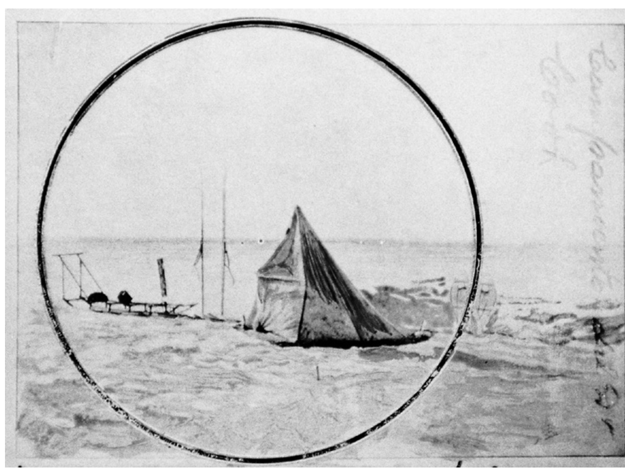


Figure 3.8. In 1898, intentionally or not, de Gerlache and his crew became the first men to over-winter south of the Antarctic Circle. © Jacobs.

and Liège islands. De Gerlache and his crew made over 20 landings on these and other islands and Frederick Cook took the first Antarctic photographs.

On February 15, 1898, they crossed the Antarctic Circle and, despite the fact that the season was well advanced, de Gerlache continued towards the Bellingshausen Sea. When they reached 71° 30' S at the beginning of March, 1898, the sea ice closed around the ship and trapped them for the entire winter. Unintentionally, De Gerlache and his crew became the first party to over-winter south of the Antarctic Circle. On May 19, 1898 the crew became the first witnesses of the long Antarctic night. A lack of sunlight and inadequate food supplies caused a rapid decline in the health of all onboard. The magnetisian Emile Danco died in June due to heart problems. Cook – the physician – took responsibility for their morale, organising entertainment, ensuring clean and dry sleeping quarters, and increasing their physical strength by replacing the meals of canned food with fresh penguin meat. Finally, the health and spirit of the crew started to come back. In March, 1899, after 12 months of Antarctic confinement, the ice gave up and the Belgica could sail again, arriving in Punta Arenas, Chile, on March 28, 1899 (Figure 3.8).

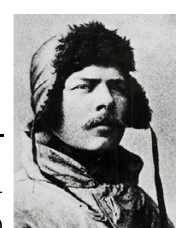
The expedition had made important contributions to science, including gathering support for the geological link between the Andes Range and the Antarctic Peninsula, the winter's meteorological data, and the first Antarctic photographs. Afterward, de Gerlache received gold medals from different geographical societies and institutions in Belgium.



Camping site from the de Gerlache expedition.
© Archivo General de la Nación, Dto. Doc. Fotográficos, Argentina.

◊ Carsten Borchgrevink (1864 – 1934)

Voyage of the* Southern Cross *(1898-1900)



Carsten Borchgrevink.
© Courtesy of Antarctic New Zealand Pictorial Collection.

The son of a Norwegian father and an English mother, Carsten Borchgrevink was born in Norway. At the age of twenty-five, he applied for the position of scientist on Bull's whaling expedition. However, he did not have adequate experience as a scientist and was taken as a seaman with some special privileges. After Bull's expedition on board the ***Antarctic***, Borchgrevink was convinced that it was possible to overwinter on Cape Adare and tried to raise funds to finance a second expedition. For that reason, Borchgrevink travelled to England where he secured £40 000 from publisher Sir George Newnes on condition that Borchgrevink sail on behalf of England.

They left London on August 23, 1898 on an old Norwegian whaler renamed ***Southern Cross***, reaching the Balleny Islands in January, 1899. On February 17, 1899, they arrived at Cape Adare. Landing operations began the following day, consisting of transporting prefabricated huts for ten men (one Belgian, two British, two Finns, and five Norwegians) and seventy-five dogs. This was the first time that dogs had been brought to the Continent.

The crew of the ship was very close to perish by a severe storm, and the men stranded on land were able to survive by bringing the dogs inside the tent.

Before the winter, the party surveyed Robertson Bay and collected wildlife specimens. During the long polar night they experienced several difficulties and hardships, among those, a fire that almost left them without a hut. Hanson, the zoologist, got sick during the winter and died on 14 October 1899. At the end of January, 1900, the ***Southern Cross*** returned to Cape Adare, ending the isolation of the wintering party.

A few days later, the ***Southern Cross*** headed south towards the Ross Ice Shelf. They landed on Possession, Coulman, Franklin, and Ross Islands. The ***Southern Cross*** followed the ice barrier and, on February 11, 1900, surpassed James Ross's furthest south of 78° 34' S, noting that the ice shelf had receded 30 miles since the last record. On February 16, a landing was made on the ice shelf at a place called Borchgrevink's Inlet (today known as The Bay of Whales). There, Borchgrevink, Collbeck, and Savio walked across the ice reaching 78° 50' S, the furthest south ever reached (Figure 3.9).

The expedition

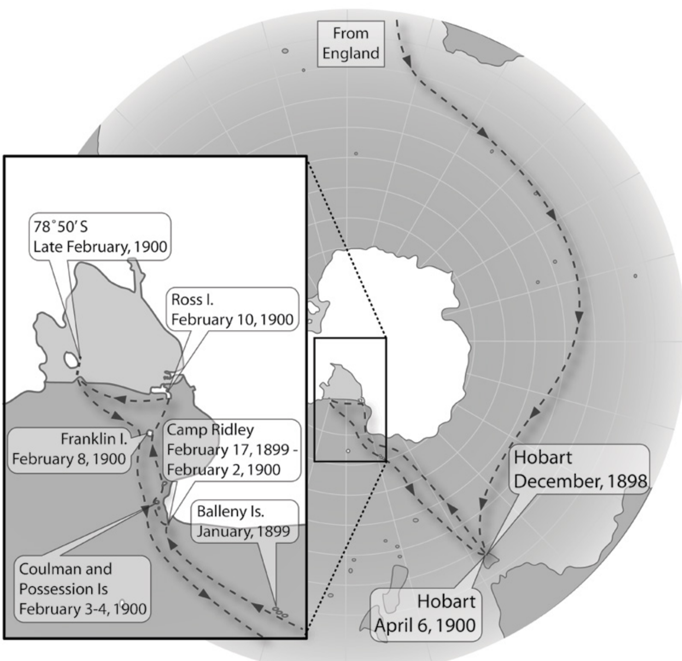


Figure 3.9. Borchgrevink realised his dream of over-wintering on the Antarctic continent, pushed the furthest south record both on sea and on land, and made significant contributions to science. © Jacobs.

Borchgrevink's hut at Cape Adare.
© Brown, Antarctica NZ Pictorial Collection: K002 05/06

arrived in Hobart on April 6, 1900, having made significant contributions to science and exploration. However, the news of their accomplishments in England was received without enthusiasm because all eyes were focused on Scott's expedition set to begin in 1901. In Norway, Borchgrevink was received as a hero and knighted, although his achievements would not be recognised until 1930, when the Royal Geographical Society awarded him the Patron's Medal for his efforts.

◊ Robert Falcon Scott (1868 - 1912)

Voyage of the** Discovery **(1901 – 1904)

Robert Falcon Scott. Courtesy of Antarctica New Zealand Pictorial Collection.

Scott was born in Devonport, England to a family of naval tradition. In 1881, he joined the Royal British Navy as a cadet and, two years later, he boarded the HMS Boadicea as midshipman. In June, 1899, he met Sir Clements Markham and learned about his plans for an Antarctic Expedition. Almost immediately Scott submitted his application for leader.

The British Antarctic Expedition set sail in August, 1901, on board the ***Discovery***. Though the vessel was the first in Britain to be built for exploration, she would later prove to be less than ideal for navigating open waters. Scott was sailing toward the Ross Sea with the intention of walking to the South Pole. After a brief stop at Macquarie Island, the ship called at Lyttelton, New Zealand at the end of December, 1901. A few days later, the ***Discovery*** was pushing through the ice of the Ross Sea and out into open water. On January 9, 1902, the party landed at Cape Adare; two weeks later, they made the first ever landing at Cape Crozier, where the ice shelf meets the easternmost point of Ross Island.

Scott continued to sail east along the ice shelf until the crew spotted land on January 30, 1902 – what would be named Edward VII Peninsula. They had sailed further east than Ross and sighted the eastern limit of the Ross Ice Shelf. They anchored the ship at Borchgrevink's inlet (now Bay of Whales) where Scott ascended in a hydrogen balloon – the first to be launched in Antarctica. Returning west for the winter, Scott sailed to McMurdo Sound and established a winter camp at Hut Point, on Ross Island. Owing to the general lack of experience, their winter exploration was marked by great difficulties and many accidents. There were fractures, losing of people, almost drownings, and during a windy day at Cape Crozier, a young member fell over a cliff and died. The next spring they made their first attempt to reach the South Pole. On October 12, 1902, on a short expedition to Cape Crozier, the first Emperor Penguin ***Aptenodytes forsteri*** breeding colony was discovered.

On October 30, 1902 the expedition made their first attempt to reach the South Pole. A support party of twelve men left depots along the way to White Island. The Polar Party, which consisted of Scott, Wilson, and Shackleton continued alone from there. With great difficulties, they managed to cross the 80th parallel and reached 82° 16′ S before turning back on December 30, 1902. The return north was miserable.

The three men got sick very rapidly and Shackleton was suffering different stages of scurvy. The Polar Party met two of their fellow crew members as they approached Observation Hill on February 3, 1903, thus ending their 960-mile trek. This was the furthest penetration into the continent achieved up until that time. There, they learned that the relief ship ***Morning*** had arrived. During this time, a separate party had reached Ferrar Glacier, making them the first to tread upon the interior of Victoria Land. Assessing the condition of the ***Discovery***, which was still frozen in McMurdo Sound, Scott realised that they would have to over-winter there another year and decided to send eight people back home. Against his will, Ernest Shackleton was one of them.

During the winter, the party completed journeys to a variety of locations, including Ferrar Glacier, White Island, and Cape Crozier; Scott also led a long expedition to Victoria Land. The crew made biological, geological, and meteorological observations while also mapping the region. The ***Morning*** returned the next summer with the ***Terra Nova*** and orders to evacuate the entire party and abandon the ***Discovery*** if necessary. After weeks of cutting ice and deploying explosives, the ***Discovery*** was freed. Scott sailed west and sighted the Balleny Islands, making it as far as 154° E before meeting up with the ***Morning*** and the ***Terra Nova*** in the

Figure 3.10. Scott spent two winters at the furthest south campsite, broke the furthest south record, and mapped an impressive area of the Ross Ice Shelf and Victoria Land. © Jacobs.

Auckland Islands. The three ships arrived in Lyttelton, New Zealand on April 1, 1904 (Figure 3.10). Upon their return, Scott received a number of awards, most notably being made Commander of the Victorian Order and officer of the French Legion of Honour.

Covered in soot from the heating, everything remains as it was when Scott left. © Mitchell, Antarctica NZ Pictorial Collection: K310 03/04

FRESH FOOD CAN SAVE YOUR DAY... AND YOUR LIFE!

Most reported cases of scurvy were in association with sailing the seas. It was originally believed to be a sailor's sickness because, during the 18th century, scurvy was responsible for the deaths of more men at sea than storms, shipwrecks, and wars combined.

Although, it was strongly related to sailing, scurvy also appeared in northern countries during the long months of winter, when cities were under siege, in prisons, during years of failing crops, or generally, when people had limited access to fresh food and suffered dietary deficiencies. Scurvy is caused by a severe lack of vitamin C.

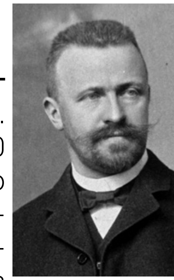
The symptoms are: swollen and bleeding gums, spots on the skin, prostration, degeneration of the ligaments, loose teeth, rotten breath, physical weakness, and opening of previously healed broken bones.

Captain James Cook was one of the very first to actively try to prevent scurvy from afflicting his sailors. When he left England in July, 1772 to circumnavigate the world at the highest possible southern latitude, Cook brought with him: 100 lbs of sauerkraut, 25 lbs of cabbage, 15 lbs of portable soup, and 31 half barrels of malt and wort per person on board. By the end of the trip, Cook had lost only four men (only one to illness); a record for that time.

Scott's hut at Hut Point.
© M Mitchell, Antarctica NZ Pictorial Collection: K310 03/04

◊ Erich von Drygalski (1865 – 1949)

German South Polar Expedition on the* Gauss *(1901 – 1903)



Eric von Drygalski. © Gazert, Garmisch-Partenkirchen with permission of Thomas Mörder.

Born in Köningsberg, East Prussia, Erich von Drygalski became a professor of geography at Berlin University, leading expeditions to Greenland in 1891 and 1892-1893.

Funded by the German government, a crew of 32 men left Germany on board the ***Gauss*** on August 11, 1901. As they navigated south, the ice became denser and their final approach to the continent was difficult. A new land was seen on February 21, 1902 and named Kaiser Wilhelm II Land (now Wilhelm II Coast). In March, the expedition made an eight-day sledge journey to the interior where they discovered a low volcanic cone (now extinct) that they named Gaussberg, after the ship. On March 29, 1902, Drygalski made his first ascent in a hydrogen balloon. He remained at over 500 m for more than two hours, taking many photographs, and observing that Gaussberg was the only ice-free land in sight.

Two more journeys were made to Gaussberg where they obtained great views from the summit, took geological samples of the volcanic rock, and made geodetic surveys, allowing the production of a detailed map of this strange land protruding from the glacier. In September, Drygalski led a one-month sledging expedition. He took one party back to Gaussberg to study the inland ice while another party went to study compressed blue ice.

With the arrival of summer, the men struggled to free the ship. Drygalski had learned from de Gerlache's expedition on board the ***Belgica*** that dark objects absorb the sun's radiation and melt the ice. He ordered that ash and garbage be placed in a line upon the ice towards open water. Soon, pools and cracks along the ice were observed and, by the end of January, 1903, the ***Gauss*** began to drift. Not until mid-March were they totally freed.

The crew made an unsuccessful attempt at exploration to the southwest

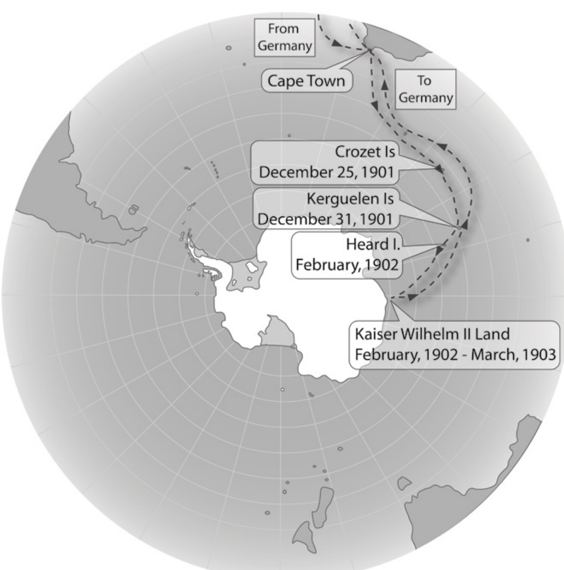
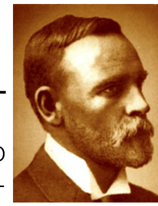


Figure 3.11. Drygalski over-wintered in King Wilhelm II Land, making many scientific collections and mapping over 600 miles of coastline. This expedition provided the strongest evidence for the existence of the Polar Front, the boundary where the temperate sub- Antarctic and the cold Antarctic waters meet. © Jacobs.

of the over-wintering camp and the decision to return north was made on April 8, 1903. In June Drygalski arrived in South Africa, whereupon he asked for permission to spend another winter in Antarctica. He was denied and the *Gauss* arrived in Kiel on November 24, 1903 (Figure 3.11). After the expedition, Drygalski was awarded the first chair of geography at Munich University.

◊ Nils Otto Gustaf Nordenskjöld (1869 – 1928)

Swedish Antarctic Expedition on the* Antarctic *(1901 – 1903)



Nordenskjöld would unintentionally spend a second winter on Snow Hill Island. © Archivo Fotográfico del Museo del Fin del Mundo.

Nils Otto Gustaf Nordenskjöld was born in Sjogelo, Sweden. He was a student of geology at Uppsala University, where later he became a professor. Between 1895 and 1897, Nordenskjöld led a scientific expedition to Tierra del Fuego and Chile. The following year he was in Alaska and, in 1900, led an expedition to Greenland. That same year, Nordenskjöld was selected to lead the Swedish Antarctic Expedition. The ship chosen was the ***Antarctic***, Bull's old ship, to be captained by Carl Anton Larsen, who had previously travelled to Antarctica and had commanded the ***Jason*** during the Antarctic Whaling Expedition between 1892 and 1893. They relied entirely upon private contributions and were, therefore, not as well prepared as some of the other national expeditions. Their plan was to penetrate as far south into the Weddell Sea as possible, where they would leave a wintering party until the following summer.

The expedition left Sweden on October 16, 1901. The Argentine government requested that one of their naval officers be accepted on the expedition. Nordenskjöld, interested in promoting South American participation in Antarctic exploration, and after meeting the young man, agreed to the proposal, accepting him also as a member of the wintering party.

The ***Antarctic*** left Buenos Aires in December, 1901, and called in Port Stanley (Puerto Argentino), to replace

The Antarctic in Sweden. © Archivo Fotográfico del Museo Naval de La Nación, Buenos Aires.

Nordenskjöld and his men endured severe weather in this tiny hut on Snow Hill Island. © Archivo Fotográfico del Museo del Fin del Mundo.

the dogs that had died in the heat on the way to Buenos Aires. Then they called on New Year's Island in the Staten Island archipelago to calibrate their instruments at the Argentine observatory. Nordenskjöld and his crew arrived in the South Shetland Islands on January 11, 1902. After exploring for a while, the party departed towards the Orléans Strait, on the west side of the Antarctic Peninsula, where they confirmed that Trinity Peninsula and Danco Land were connected, and that the Orléans Strait was connected to the Gerlache Strait. As Nordenskjöld himself would note, this would be their major geographical discovery.

Nordenskjöld chose Snow Hill Island to over- winter. A magnetic observatory was built first for shelter while they erected the main hut. After a farewell among the crew, the six members of the over-wintering party were left on Snow Hill Island. While the Snow Hill party explored the area – with trips to James Ross Island and Seymour Island – and made journeys by sledge and small boat to the east side of the Antarctic Peninsula, the ***Antarctic*** spent the winter working on South Georgia Island and in Tierra del Fuego.

The winter came and the men on Snow Hill Island passed the time with biological and oceanographic studies, taking advantage of every break in the weather to go on walks. The next spring, Nordenskjöld, Sobral and Jonassen made a 400-mile sledge journey over 33 days and proved that the Trinity Peninsula and Oscar II Coast were connected. During the early summer, Nordenskjöld made some important fossil discoveries on Seymour Island, but his mind was focused on the ice not breaking up and the ship not yet being visible upon the horizon. By the end of the summer, the six men understood that the ship would not relieve them and they began to prepare for another winter on Snow Hill Island.

The ***Antarctic*** left the Malvinas Islands on November 5, 1902, to relieve the crew on Snow Hill Island. But the ice prevented them from making progress south. On December 29, 1902, three men disembarked

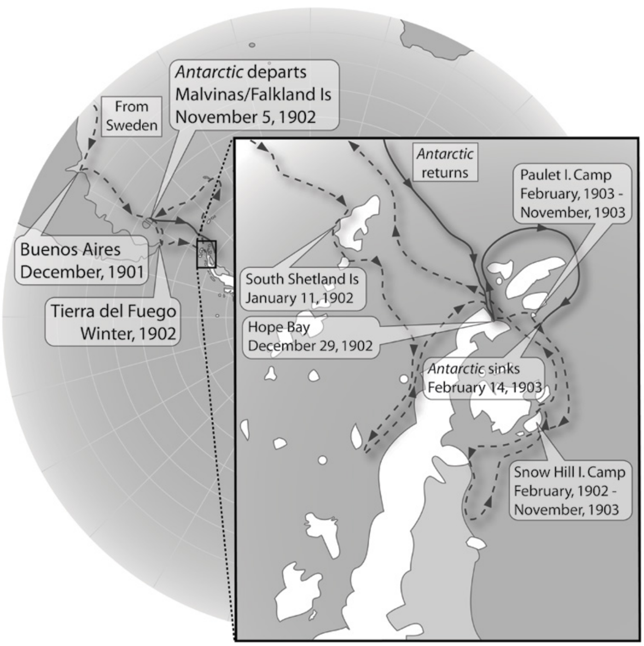


Figure 3.12. Nordenskjöld and his crew would realise one of the greatest Antarctic adventures ever lived. Separated into three parties, ship sunk, with little hope of rescue, they reunited within 24 hours of each other and were all, except one, returned home. The first voyage of the Antarctic is in dotted line, the second, where she sank off Paulet Island, is in solid line. © Jacobs.

at Hope Bay to reach Snow Hill on foot over the frozen Weddell Sea and bring the party back to the Peninsula. They were stopped on the east side of the Antarctic Peninsula by an open sea, forcing them to turn back, where they built a small stone hut, hoping that the ***Antarctic*** had had better luck and that they, too, would soon be rescued. What they did not know was that, southeast of Dundee Island, the ship had become trapped in the ice pack and sank 25 miles off Paulet Island. The crew of the ***Antarctic*** made a fourteen-day journey toward Paulet Island, arriving there on February 28, 1903. They built a tiny hut of rocks surrounded by a huge colony of penguins. The expedition was divided into three parties: Snow Hill Island (six men), Hope Bay (three men), and Paulet Island (22 men), each of them unaware of the fate of their other fellows.

In October, 1903, Nordenskjöld and Jonassen set out for another sledge journey; they discovered Prince Gustav Channel and continued through to James Ross and Vega Islands to check for any possible access to Paulet Island. There they saw three distant spots upon the ice. At first they thought these were penguins but, when they approached, they realised that they were Andersson, Duse and Toralf – the Hope Bay Party! The place was named Cape Well-Met. The group of five returned to Snow Hill Island with the understanding that something terribly wrong had happened to the ***Antarctic***.

Meanwhile, the pack ice had opened up around Paulet Island. Larsen and five crew members departed towards Hope Bay in a whaleboat in search of the three men left there eleven months before. There, they found a map with the route they had taken to Snow Hill Island. Larsen set out in that direction and, within fifteen miles of the hut, the boat was stopped by sea ice. They were forced to walk the remaining distance.

The young naval officer Sobral would accompany the expedition as an Argentine representative. © Archivo Fotográfico del Museo del Fin del Mundo.

Meanwhile, great concern had grown in Argentina and Sweden regarding the fate of the expedition, and the Argentine government began preparations for the rescue expedition lead by Julian Irizar on board the ***Uruguay***. On November 8, 1903, coincidence and good luck once again marked the fate of the expedition. The Snow Hill Island party saw four people approaching the hut. Two of them were Bodman and Åkerlund, sent to Seymour Island, but the other two were Captain Irizar and Lieutenant Yalour of the ***Uruguay***. All hope was lost for the remaining members of the Antarctic expedition. But a few hours later the dogs barked, alerting the men to another six people approaching the hut: Captain Larsen and five crew members from the Paulet Island party (Figure 3.12).

The Snow Hill party, now composed of the Hope Bay party and members of the Paulet Island Party, left Snow Hill Island toward Paulet Island and the rest of the expedition was rescued. Back in Buenos Aires, all members of the expedition were received as heroes.

◊ William Bruce (1867 – 1921)

Scottish Antarctic Expedition on the* Scotia *(1902– 1904)

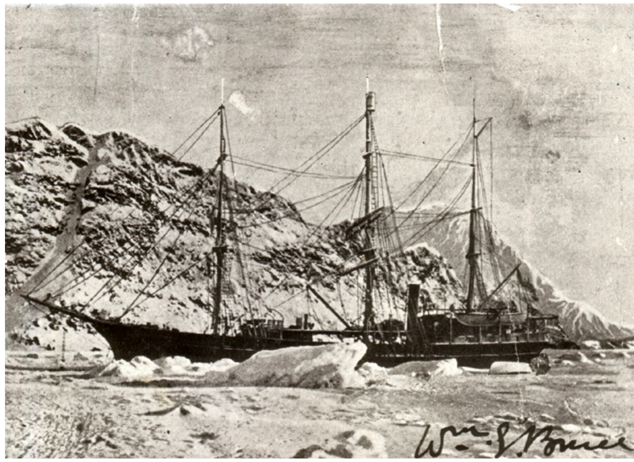
Born in London, William Bruce studied medicine in Edinburgh, took some courses in the natural sciences and became fascinated with oceanography. In 1892-93, he joined the Dundee Whaling Antarctic Expedition as a surgeon and naturalist. Afterward, Bruce declined Scott's offer to sail as naturalist on board the ***Discovery*** because he was already engaged in the planning of his own Antarctic expedition. He focused on oceanographic and biological questions because so few had been answered. As he could not convince the Royal Geographical Society of England to finance his project, he managed to get the necessary funds from private sponsors. On November 2, 1902 the expedition left on board the ***Scotia***.

After a stopover in Malvinas, the South Orkney Islands were first seen in February, 1903, and a landing was made on Saddle Island. Bruce would then navigate toward the Weddell Sea until he was stopped by ice at 70° 25' S on February 25, 1903. He then returned to South Orkney Islands and established a winter camp on Laurie Island, called Omond House; an observation station that later would be managed by the Argentine government. Bruce's surveys proved that the South Orkney Islands were part of the Andes Mountain Range. In late October, 1903, Bruce made the first video recording in Antarctica, starring Adelie Penguins.

[Figure 3.13. Bruce over-wintered in the South Orkney Islands, where he built Omond House. He made two incursions into the Weddell Sea, sighting Coats Land for the first time. © Jacobs.

The following summer, Bruce sailed to the Malvinas Islands and then to Buenos Aires where he negotiated with the Argentine government to take over the meteorological studies on Laurie Island and was joined by three Argentines. On February 22, 1904, the Argentines were left at the station and the expedition made a second attempt at the Weddell Sea. The party remaining on Laurie Island was relieved the following season by the Argentine vessel ***Uruguay***.

Pushing south again, Bruce was able to reach 74° 01' S on March 9, 1904. He would go on to discover a new land on the eastern side of the Weddell Sea, calling it Coats Land after his sponsors. By the end of the season, Bruce decided to put an end to his polar expedition and set sail towards Cape Town. Bruce returned to Ireland in July, 1904 (Figure 3.13). He was awarded a gold medal from the Royal Scottish Geographical Society.



The Scotia at South Orkney Islands. © Archivo Departamento de Estudios Históricos Navales, Armada Argentina.

◊ Jean Baptiste Charcot (1867-1936)

French Antarctic Expedition on the* Français *(1903-1905)

Jean Baptiste Charcot was born in Neuilly-sur- Seine, France. Following in his father's steps, Charcot studied medicine even though he was not excited about a career in that field. After his father's death, and the inheritance of a considerable fortune, he began the construction of an exploration vessel designed specifically for the Arctic – the ***Français***. In the midst of his preparations for an Arctic expedition, Charcot learned that Otto Nordenskjöld and the Swedish Antarctic Expedition was missing in Antarctica. He changed his plans and set sail south from Le Havre on August 27, 1903 in search of professor Nordenskjöld and his men.

In Buenos Aires, Charcot learned that the Nordenskjöld Expedition had been rescued by Captain Irizar on the ***Uruguay***. He decided to continue south and if possible fill in the gaps left by de Gerlache's expedition.

On February 19, 1904 Charcot discovered Port Lockroy, a natural harbour later used by whalers as a mooring place. By the end of February, the men established winter quarters, including a magnetic hut in a bay called Port Charcot named after his father, on Booth Island. In November, 1904, Charcot and four other men set out in a small boat for an eleven-day journey to the

Jean Baptiste Charcot. © Archivo Caras y Caretas, 1905. Museo Histórico Sarmiento.

Graham Land coast. Their landing on Cape Tuxen, represented the first confirmed landing on the west coast of the Antarctic Peninsula.

On December 25, 1904, the expedition left their winter quarters and headed south. By mid-January, 1905 they could see a glimpse of Alexander Island but were unable to approach due to densely packed ice.

Two days after turning north, the ***Français*** hit a rock near Adelaide Island. The crew was forced to return to Port Lockroy to make repairs, whereupon they abandoned all plans for further exploration (Figure 3.14). Charcot's party arrived in Buenos Aires in March, 1905, and the Argentine government offered to buy the ***Français***, renaming it ***Austral***. In France, Charcot was received as a hero. He had managed to map more than 600 miles of Antarctic coastline. Many of the places along the Peninsula still retain the name that Charcot designated.

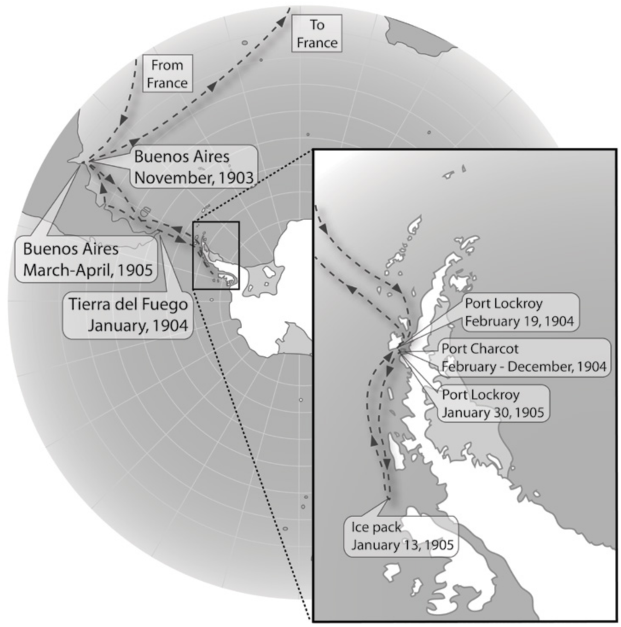


Figure 3.14. Charcot originally planned his expedition to the Arctic. He changed his destination to rescue Otto Nordenskjöld. Charcot was forced to end the expedition when his ship struck a rock near Adelaide Island. © Jacobs.

◊ Ernest Shackleton (1874 – 1922)

British Antarctic Expedition on the** Nimrod **(1907-1909)

Ernest Shackleton. © Courtesy of Antarctica New Zealand Pictorial Collection.

Ernest Shackleton was born in Kilkea, Ireland, though his family returned to their country of origin, England, when he was ten years old. At sixteen years old he left college and spent the next years sailing. In 1898, he was certified as Master. In 1901, Shackleton joined the British National Antarctic Expedition led by Robert F. Scott. During the southern sledge journey, he became ill and was sent home by Scott.

Never giving up, and with a strong and charismatic personality, Shackleton resolved that he would one day return to Antarctica.

In 1907, he began to organise an expedition to the South Pole – one that would prove to be very important for future expeditions. With the majority of the funds coming from private contributors, the preparations for the expedition were made quickly. On August 7, 1907, the ***Nimrod*** left England sailing towards New Zealand.

Before leaving England, Scott wrote to Shackleton to inform him that he was planning to make another expedition himself and asked him to establish winter quarters anywhere but McMurdo Sound. Shackleton agreed and headed towards the Bay of Whales (where the Discovery expedition had launched the hydrogen balloon) but the ice shelf had since calved, making it impossible to set up camp. He therefore sailed east towards the Edward VII Peninsula but was stopped by ice. Shackleton decided to set up his winter station at McMurdo Sound, in spite of Scott's request and they landed on Cape Royds in February, 1908. Shackleton wanted to set out towards the south to establish food depots but the sea beyond Cape Royds was not open and so, in the true spirit of exploration, they organized and executed the first ascent of Mount Erebus.

During the winter the expedition team wrote the first book to be published in Antarctica: ***Aurora Australis***. By mid-September, the team began laying depots using Scott's hut to store supplies. The Polar Party, including Shackleton, Adams, Marshall, and Wild, set out for the Pole via the Beardmore Glacier. Ten more accompanied the party for ten days. They took ponies instead of dogs. On November 26, 1908, they broke the furthest-south record at 82°16'S. The ponies were shot and eaten. The ascent up Beardmore Glacier was the most difficult leg of the journey. By January 1, 1909, the team had reached the highest latitude ever achieved by a human, at 87° 54' S, 162° E. Starving and suffering from frostbite and dysentery, their dream of realising the pole would not be achieved and they turned back on January 9, 1909 from 88° 23' S, only 180 km from their goal.

While the South Pole Party was away, the Northern Party, composed of Da-

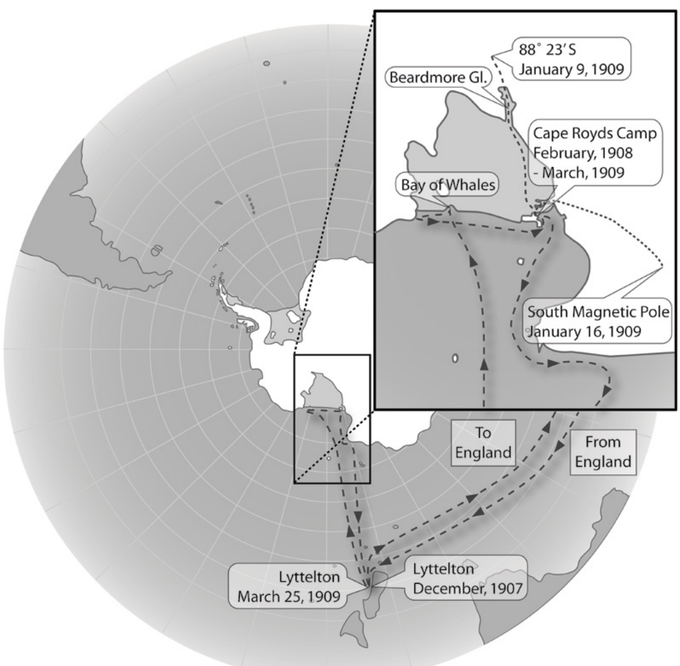


Figure 3.15. Ernest Shackleton's first attempt to reach the Geographic South Pole was unsuccessful, though he did break the furthest south record and some of his team reached the Magnetic South Pole. © Jacobs.

vid, Mawson, and Mackay, made a long journey towards the South Magnetic Pole, reaching it on January 16, 1909. The expedition was picked up by the ***Nimrod*** on March 4, 1909 and arrived at Lyttelton, New Zealand on March 25, 1909 after reaching the furthest west ever sailed (166° 14' E) along the coast of Antarctica from the Ross Sea. Shackleton did not reach the South Pole, but he had opened the route to it via the Beardmore Glacier (Figure 3.15).

Inside the hut at Cape Royds. © E Barnes, Antarctica NZ Pictorial Collection: K400 07/08.

◊ Jean Baptiste Charcot's Second Expedition

Second French Antarctic Expedition on the Pourquoi-Pas? (1908-1910)

Encouraged by the results of his first expedition, Charcot submitted a plan to the Academy of Science for a new endeavour. He received the support of the French government, private sources, and different academic institutions. In September, 1907, Charcot began the construction of a new ship to be named Pourquoi- Pas? (Why not?) after a toy boat he had as a child.

The Second French Antarctic Expedition left Le Havre on August 15, 1908. On board the Pourquoi- Pas? Charcot crossed the Drake Passage and reached the South Shetland Islands in late December, 1908. He sailed to Deception Island and, to his surprise, he learned that the whalers were using his charts of the Graham Land Peninsula to navigate these dangerous waters. The ship left Deception Island and, on January 1, 1909, Charcot discovered a well-protected harbour on Petermann Island, south of the Lemaire Channel. He named it Port Circumcision to honour the date of the discovery.

From there, Charcot, Gourdon, and Godfrey set out in a small boat to look for a route to the south. On their way back they discovered that the channel leading to the ship was no longer open and ice was blocking the way. It was snowing and soon the three men were soaked; in addition, they only had small rations for one day. Three days went by before they were rescued by the ***Pourquoi-Pas***?

The day after Charcot was rescued, the Pourquoi- Pas? realised the same fate as the Français four years earlier by hitting a rock and running aground. Luckily the pumps were able to handle the leak so Charcot decided to carry on with his exploration before the winter. The crew charted Adelaide Island and discovered a large bay to the south, which Charcot named Marguerite Bay, after his wife. At the end of January, the ***Pourquoi-Pas***? returned to Port Circumcision for the winter. They built a small hut that was supplied of electricity from the ship. Men enjoyed winter by reading and outside activities. They created the first Antarctic Sports Club and made ski and sledge races on the low hill of the island. On November, 27 1909, they arrived to Deception Island to resupply their stock of coal. In Whalers Bay the Norwegian divers inspected the ship and discovered that part of the keel was torn away. They recommended Charcot not to continue but he disregarded the advice. They went to Hope Bay to pick up geological specimens left by Nordenskjöld, but the ice in the Antarctic Sound blocked their way and Charcot decided to turn south again. A few days later, they sighted Alexander Island and, on January 11, 1910 they discovered a new land at 70° S, 076° W, which Charcot named Charcot Land (now Island) after his father. On February 11, 1910, the ship entered the port of Punta Arenas.

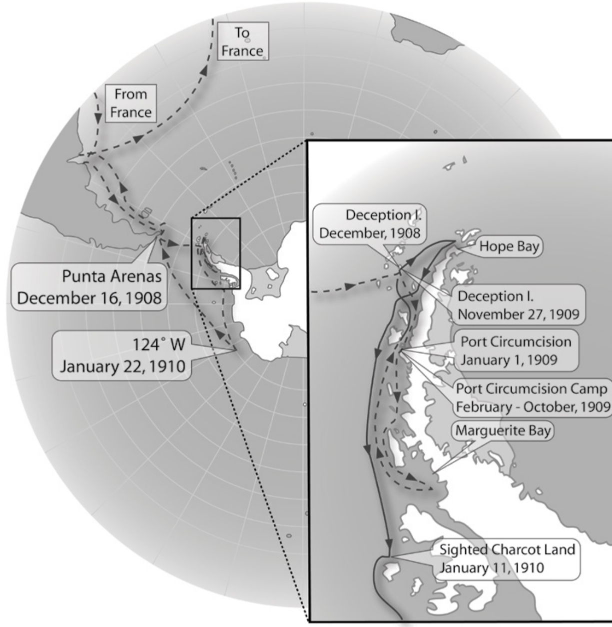


Figure 3.16. Charcot's second expedition earned him his reputation as one of Antarctica's greatest explorers. He and his crew mapped 1,250 miles of coastline and discovered Charcot Land (now Island). Within the Peninsula map, the second season is marked with a solid line. © Jacobs.

The Pourquoi Pas? was named after Charcot's childhood toy. © Archivo General de la Nación, Dto. Doc. Fotográficos, Argentina.

In addition to the collection of important scientific data, the expedition mapped 1,250 miles of Antarctic Coastline. Their maps would be used by whalers for more than twenty-five years (Figure 3.16).

THE RACE TO THE SOUTH POLE

◊ Roald Amundsen (1872 – 1928)

Norwegian Antarctic Expedition on the* Fram *(1910-1912)

Roald Amundsen was born in 1872, near Oslo, Norway, to a family immersed in the sailing tradition. Between 1897 and 1899, Amundsen sailed with Adrien de Gerlache on board the ***Belgica*** to the Antarctic Peninsula and, in 1903, he led the first expedition to successfully sail across the Northwest Passage, in the Canadian Arctic. As a child, Amundsen dreamed of being the first man to arrive at the North Pole; by 1909, while beginning to prepare for a major expedition to the Arctic, he received the worst possible news: the North Pole had already been conquered. Robert Peary and Frederick Cook, both Americans, claimed to have reached the Pole. It was then that Amundsen decided to pull one of the greatest and best kept secrets in Antarctic history – he would sail south and capture the Pole there. His crew and supporters would not know of this plan until it was too late to back out.

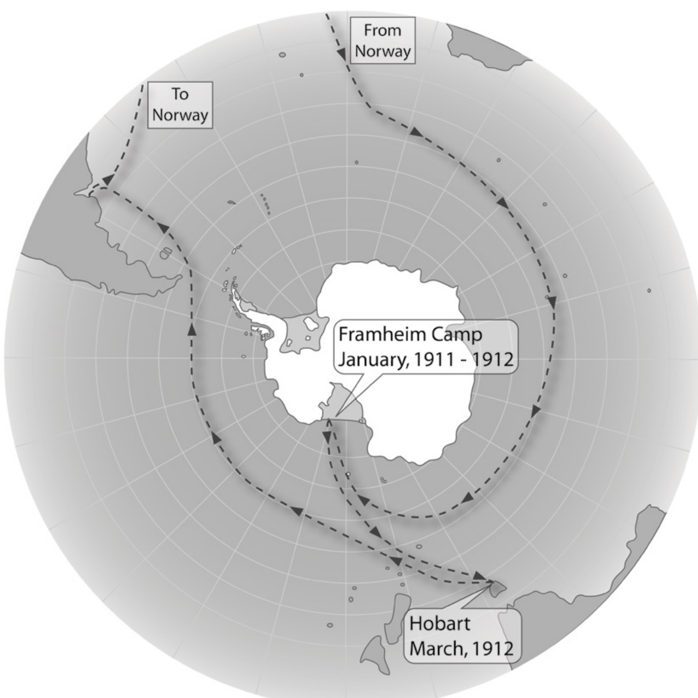


Figure 3.17. Amundsen's original plan was to take the North Pole. Having heard the claims of Peary and Cook, he changed his plan and sailed to take the South Pole. © Jacobs.

The expedition left Norway in August, 1910, on board the ***Fram***. One month later, during their stop in Madeira, Amundsen informed the expedition members about the change of destination. The news shocked the crew but each member pledged their loyalty to their leader. Amundsen sent a terse telegram to Scott, who was also on his way to the South Pole, informing him of his intention to take The expedition arrived to the Bay of Whales on January 14, 1911, where they established the winter quarters, calling it Framheim (Figure 3.17). The camp was sixty miles closer to the Pole than the place previously chosen by Shackleton and now by Scott. However, they would have to break a new route, while Scott would have the benefit of following Shackleton's footsteps over the Beardmore Glacier.


Amundsen (left) on board the Fram in Buenos Aires. © Archivo Departamento de Estudios Históricos Navales. Armada Argentina.

The crew spent the first summer laying depots at 80 and 82° S with supplies for eight men and their dogs. Though it was common opinion that ponies were superior to dogs, Amundsen disagreed and, in the end, those dogs would make all the difference. The first attempt failed due to poor weather conditions and the team was forced to return to Framheim. The expedition members were divided in two groups – one to the pole (5 men) and another one to explore the Edward VII peninsula. If they did not succeed in taking the Pole, perhaps the Peninsula Party would achieve another record and now the depots to the south would be ample for a reduced team. The Polar Party made their second attempt for the South Pole on October 19, 1911. They arrived at the edge of the Polar the Bay of Whales towards Australia on January 30, 1912. The ***Fram*** stopped in Buenos Aires on their return home,

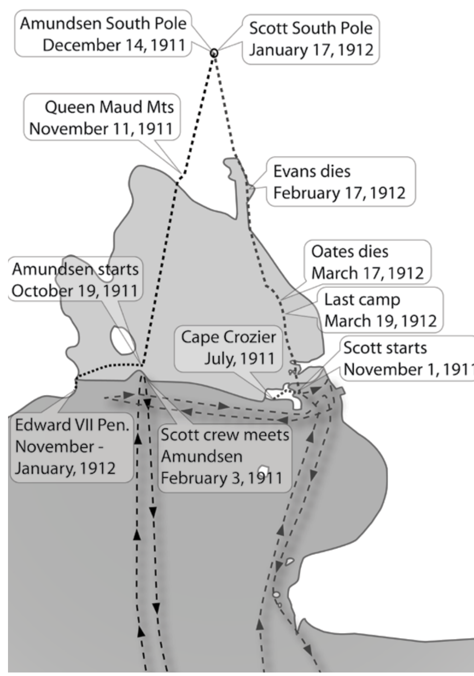


Figure 3.18. Amundsen and Scott had very different approaches to taking the South Pole. Amundsen wanted only the record while Scott conducted important scientific research along the way. In the end, Amundsen's approach and equipment would serve him in his goal while Scott would pay the ultimate price. © Jacobs.

where they were welcomed by the Argentine government.

In 1926, Amundsen, the American Lincoln Ellsworth, and the Italian Umberto Nobile made the first passage of the North Polar Ocean by air on the dirigible ***Norge***. In 1928, in an attempt to rescue Nobile, who was in distress north of Spitsbergen, Amundsen disappeared. Nobile, however, would be rescued.

◊ Robert Falcon Scott's second expedition

Voyage of the *Terra Nova* ***(1910-1913)***

After the Discovery expedition and his failed attempt to reach the South Pole, in September 1909, Scott made known his plans for a second expedition to reach the South Pole. With little funding, Scott was forced to settle for the ***Terra Nova***, an old whaling ship. The ship left in June, 1910, but Scott joined the ***Terra Nova*** in Cape Town and sailed to Melbourne.

Upon his arrival, in October 1910, he learned of Amundsen's intentions to take the South Pole. Scott met up again with the ***Terra Nova*** in Lyttelton, New Zealand, where they were drydocked to repair a leak that had been of concern since leaving England. On November 29, 1910, the ship set out for the Antarctic. The ice blocked their way into McMurdo Sound, so Scott had to settle the winter quarters north of Cape Hut at Cape Evans where construction and transportation of all the equipment onto shore was completed by January 17, 1911. On January 24, the men began to lay depots. The explorers quickly realised the disadvantages of using ponies: the dogs could better

Figure 3.19. Scott, low on funds at the beginning of the expedition, met up with the ship in Cape Town and then disembarked in Melbourne to do some more fundraising. The expedition left from Lyttelton, New Zealand and headed towards McMurdo Sound. © Jacobs.

handle blizzards and did not need to be covered with blankets or protected behind snow walls. Meanwhile, the ***Terra Nova*** set out to the west and dropped off a team of four men across McMurdo Sound on January 27, 1911. Then the ship sailed to the east following the ice barrier towards Edward VII Peninsula with the intention of exploring the coast and collecting scientific data. On February 3, 1911, they met Amundsen's Fram and were informed by the Norwegians of their intentions to take the Pole. Demoralised, the crew returned to Cape Evans with the news and then dropped off a crew at Cape Adare before taking the ship further north for the winter (Figure 3.19).

Unlike Amundsen, who had arrived to make a dash to the Pole and nothing more, Scott's expedition included long and tedious scientific work. During the middle of the winter (June and July, 1911), three of the crew, Wilson, Cherry-Garrard, and

Bowers – made an incredibly difficult journey to an Emperor Penguin ***Aptenodytes forsteri*** colony. The journey lasted 35 days and they were able to collect only a few eggs. Scott departed from Cape Evans on November 1, 1911, accompanied by 15 men and the remaining ponies and dogs. Along the way, they set more depots, each approximately 65 miles apart to ensure that the Polar Party would make a safe return. A terrible blizzard weakened the now-starving ponies and they were shot. The party broke up and the dogs were sent back, leaving 12 men to haul their own sledges. On December 20, 1911, the party broke up further, and four men returned to Cape Evans from Mount Darwin where another depot was laid. The remaining men continued and, having abandoned their skis to increase their progress, they laid another depot at 87° 20` S on December 31, 1911. When Scott sent three men back to Cape Evans from 87° 32′ S on January 3, 1912, he had effectively selected his Polar Party: Edward Wilson, Edgar Evans, Lawrence Oates, and Henry Bowers, who was added last minute. This later proved to be a mistake as food, tent space, and equipment were planned for a four-man party.

On January 9, 1912, the Polar Party passed Shackleton's furthest-south record, making it to 88° 25′ S. They

Scott's hut at Cape Evans. © N. Cox, Antarctica NZ Pictorial Collection: K401 07/08.

reached the South Pole on January 17, 1912 – thirty-four days later than Amundsen, whose flag and tent they found. The tent contained two letters: one for Scott, and one for Scott to deliver to King Haakon VII of Norway. This could not have been a more devastating blow to the expedition. The way back was a race against cold and starvation, on a desperate attempt to reach one depot after another. With two of five men sick and cold, the Party reached the Mount Darwin Depot on February 7, 1912.

On February 17, Evans died. The other four men managed to reach the ice shelf but with great and increasing difficulty. On March 17, Oates opened the tent flap, and said to his companions "I'm just going outside and may be some time." He was never seen again.

Two days later, the three remaining members made a camp. A blizzard kept them inside, only eleven miles from the next depot. Scott's diary entries are recorded until March 29, 1912 (Figure 3.18). The three bodies were found inside the tent the following November by a rescue party that had over-wintered at Cape Evans. The remaining crew and expedition team returned to Oamaru, New Zealand on February 10, 1913. The scientific research conducted on Scott's expedition proved to be of the highest quality and included important geographic discoveries such as Oates Land and the exploration of the dry valleys.

◊ Nobu Shirase (1861– 1946)

Japanese Antarctic Expedition on the** Kainan Maru **(1910-1912)

Nobu Shirase was a lieutenant in the Japanese Army when he began to organise the first Japanese Antarctic Expedition. The expedition left Tokyo on December 1,

1910, on board the ***Kainan Maru***. After a short stop in Wellington, New Zealand on February 7, 1911, the ship reached Victoria Land in March, 1911. Unable to reach land or ice shelf due to inclement weather, they returned to Sydney on May 1, 1911, where they were greeted with hostility. Most of the party spent the winter camping in the garden of a wealthy philanthropist. They had almost no money or food, prompting Captain Nomura and a few of the other members of the expedition to return to Japan for fresh supplies.

Nobu Shirase. © National Institute of Polar Research, Japan.

The following season the expedition left Sydney on November 19, 1911, returning to the Ross Sea. They arrived to the Edward VII Peninsula on January 16, 1912, but deep and hidden crevasses made exploration very dangerous. Instead, they sailed west where they met Amundsen's ship at the Bay of Whales. A party of five men was put ashore and the ***Kainan Maru*** returned east toward the Edward VII Peninsula for another attempt.

Shirase led a sledge journey from the Bay of Whales reaching 80° 05' S on January 28, 1912. The Edward VII Peninsula Party managed to reach the base of the Alexandra Mountains. Until that moment they had never been seen at close range. Unable to climb the mountains due to a deep crevasse, the team planted a flag and returned to meet the ***Kainan Maru***. They returned to Bay of Whales to pick up Shirase and his men, but not until February 2, 1912, due to bad weather. The expedition returned to Yokohama on June 20, 1912, where they were received as heroes (Figure 3.20). Nobu Shirase died in 1946.

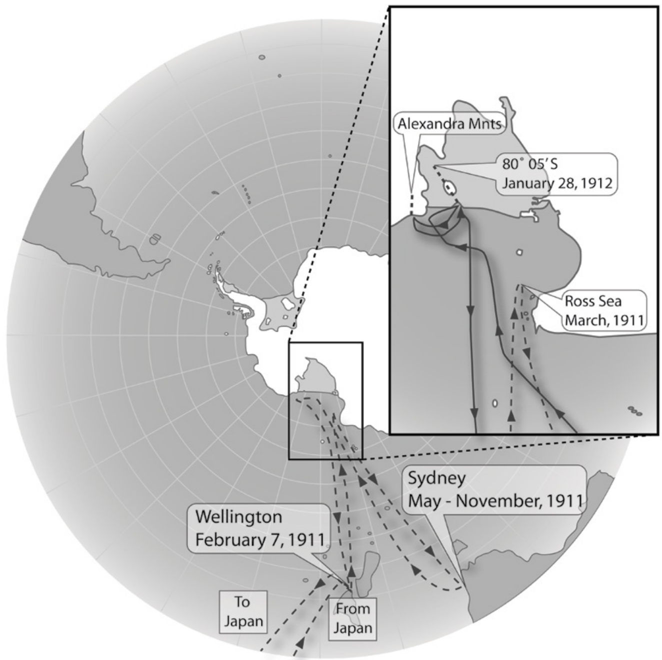


Figure 3.20. Shirase's plans to reach the South Pole were thwarted by bad weather. Instead, he divided his expedition in two the following season, leading a journey south and reaching the base of the Alexandra Mountains. Within the Ross Sea map, Shirase's second season is marked with a solid line. © Jacobs.

◊ Wilhelm Filchner (1877 – 1957)

Second German Antarctic Expedition on the *Deutschland* ***(1911-1912)***

German born, Wilhelm Filchner was an experienced explorer and by the time he set his sights on Antarctica, he had already been in expeditions to the Pamir Mountains and Tibet. In 1910, he developed a proposal for a privately funded Antarctic Expedition to determine whether West and East Antarctic were connected by land or ice. Before receiving the funding, he led a small training expedition with four scientists and one mountaineer to Spitsbergen (the Arctic). The expedition left on board the ***Deutschland***, a Norwegian ship built in 1905. She was specially equipped and modified for exploration in the ice. Filchner remained in Germany to make the final arrangements. In Buenos Aires the crew of the ***Deutschland*** met the crew of Amundsen's Fram. Once reunited, the complete Filchner expedition set sail and arrived in South Georgia in late October, 1911, where they were received by Carl Larsen, who was in charge of the whaling station.

On December 11, 1911, they headed On January 30, 1912, at 76° 40' S, the crew sighted land and they determined that this coast (known as Leopold Coast) was indeed the continuation of Coats Land and the Filchner Ice Shelf.

The crew of the Deutschland in Buenos Aires.
© Archivo General de la Nación, Dto. Doc. Fotográficos, Argentina.

Finally, the expedition settled the winter base on the ice shelf in Vashel Bay at 77° 44' S, 034° 38' W (the southernmost point reachable by ship in the Weddell Sea) on February 9, 1912, but the plans were aborted when the ice shelf broke off nine days later.

On March 7, 1912, the frozen sea trapped the ***Deutschland*** before it could escape to the north, and it remained frozen-in, drifting with the current of the Weddell Gyre for nine months. Vahsel's health deteriorated over time and he died of heart complications on August 8, 1912. The first officer, Wilhelm Lorenzen, became the captain and the relations between Filchner and the crew (supportive of Vahsel) deteriorated further. The ship broke free from the ice on November 26, 1912 and they sailed back to South Georgia. Arranging for the mutinous crew to return to Buenos Aires (with the help of Larsen at Grytviken whaling station), Filchner returned to Germany by himself (Figure 3.21).

From the logs and records of the expedition, it appears as though Captain Vashel was purposely trying to sabotage the success of the expedition. Consequently, Filchner's attempts to establish a winter camp were inhibited.

Figure 3.21. Filchner had great plans for his expedition to Antarctica but conflicts with the Captain of the Deutschland made achieving his goals difficult. © Jacobs.

Their most important scientific discovery was the description of four distinct water masses in the Southern Ocean. Filchner died in Zurich in 1957 at the age of eighty.

◊ Douglas Mawson (1882 – 1958)

Australasian Antarctic Expedition on the* Aurora *(1911-1914)

Douglas Mawson was born in Yorkshire, England, and moved to Australia when he was still a boy. He studied geology at the University of Sydney and became a highly respected petroleum and mining engineer. He joined Shackleton's ***Nimrod*** expedition in 1907, and was one of the three men to reach the Magnetic South Pole on January 16, 1909.

After his return to Australia, Mawson began to dream about an expedition to explore the region south of their continent, between Cape Adare and Gaussberg, which remained unexplored. The Australian government financed over fifty percent of the expedition's cost; other funds came from different governments and geographical societies.

The expedition left Hobart on December 2, 1901, on board the ***Aurora***, an old sealing vessel built in Dundee in 1876, with Captain Davis as second in command. The original plan was to establish a station on Macquarie Island and three stations in Antarctica, but the difficult ice conditions and the advanced season made for a reduction in the number of Antarctic stations to two. The ship arrived at Macquarie Island on December 11, 1911 and, after a brief stop that included the construction of a small hut for five men, they continued south.

Main Base was set up at Cape Denison, Commonwealth Bay at the beginning of January, 1912. A crew of eighteen men was left there. Arriving to unusually calm weather, the crew would soon realise that the place chosen was one of the windiest places on Earth. The ***Aurora*** then sailed west along the coast of Wilkes Land, Queen Mary Coast and Western Base was established on the Shackleton Ice Shelf, about 175 nautical miles east of Gaussberg, the volcano discovered by Drygalski.

Douglas Mawson.
© Mitchell Library State - Library of New South Wales.

At Main Base, the winds were by far the most important factor in determining the quality of life. With regular gusts up to 80 miles per hour, and breaking records of over 200 miles per hour, men were lifted off their feet and transported several meters before falling to the ice. Some were lost for hours though they were only 60 m away from camp, and they were constantly losing and retrieving gear.

Divided into two bases, the expedition explored new territory and carried out comprehensive and extensive work. On August 20, 1912, a team from Western Base embarked on a three week journey to the east to lay depots and they discovered many places inland of the Shackleton Ice Shelf. A second depot journey was to head to the west but they were discovered fewer than 10 miles away after the date of their return had passed. Intense blizzards had halted their progress and they remained in their tents for more than two weeks awaiting a change in the weather.

After the depots were laid, the men from Western Base began their primary expeditions. One team headed west and the other east. Encountering deep impassable crevasses, the Eastern Team made it as far as the Denman Glacier and then headed south, climbing Mount Barr Smith on December 19, 1912 and returning to the base on January 6, 1913. Meanwhile, the Western Team sighted Drygalski Island and camped on Hanswell Island among the penguin colonies and hauled-out seals. On December 22, 1912, the team arrived at Gaussberg and the end of their journey west. They reached Western Base on January 20, 1913. The entire team was picked up by the ***Aurora*** on February 23, 1913.

The men at Main Base also explored their surroundings and reached 70° 36′ S, 148° 10′ E, almost the Magnetic South Pole, on December 21, 1912. After a journey of over 600 miles, they returned to the base on January 11, 1913. A team of men arrived at Cape Robert on December 25, 1912 where they discovered a meteorite and endured blinding storms and extreme cold to return their prized find safely to the base. Another team headed east to examine the Mertz Glacier and as far past it as possible. They arrived to 68° 18′ S, 150° 12′ E on December 18, 1912 before heading back with precious samples of fossilised plants. However, in spite of all these achievements and tales, this expedition is mostly remembered for the ordeal that Mawson endured on a terrible sledge journey. Accompanied by Belgrave Ninnis and Xavier Mertz, Mawson left Cape Denison on November 10, 1912 to explore the eastern region. In addition to the trying winds and harsh cold, they endured many challenges. They encountered many crevasses and their progress was slowed as the dogs, dangling from their harnesses over the dark blue abyss, had to be retrieved. On December 14, 1912, about five hundred kilometres from the base, Ninnis disappeared down a crevasse with his sledge, dogs, and most of the indispensable supplies (tent, food, and spare clothing). Mertz and Mawson were left with only ten days' rations and nothing

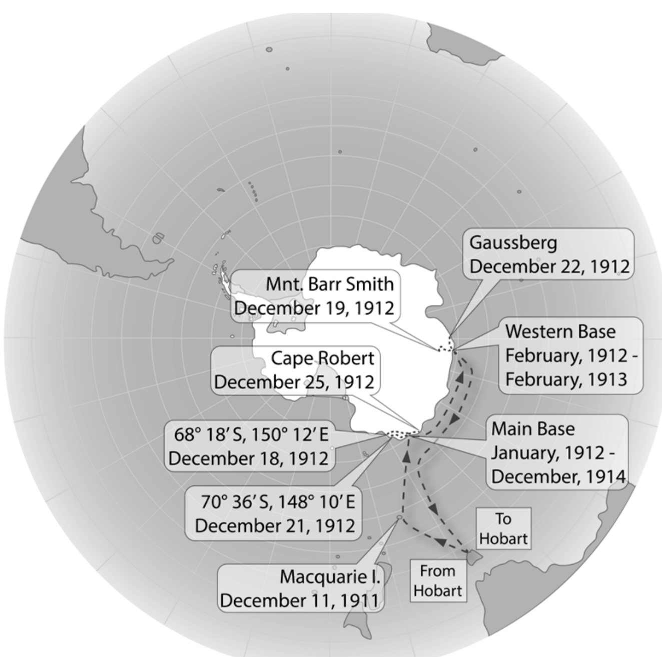


Figure 3.22. Mawson was the first to explore the coastline of Wilkes Land. On a journey east from Main Base, both of Mawson's companions died and he was forced to make his way back alone. Subsequently, he missed the ship and had to over-winter a second time before rescue. © Jacobs.

for the dogs. Thus began one of the most incredible stories of survival on other dogs and men until there were no dogs left. The men were suffering from vitamin-A poisoning (the result of eating too much dog liver) and Mertz became so weak that Mawson had to haul him on the sledge. Mertz died on January 7, 1913, after which Mawson sawed the sledge in half with a pocket knife to lighten his load and continued alone.

On January 17, 1913, he fell into a crevasse. Exhausted, he struggled to get out only to fall back in for a second time. Somehow he managed to save himself and reach the base at Cape Denison on February 6, 1913, but he had returned a few hours too late and saw his ship leaving on the horizon to relieve the men at Western Base. The men at Western Base arrived in Australia on March 14, 1913 while those that had remained behind to search for Mawson, and Mawson himself, remained for a second winter.

The ***Aurora*** returned to pick up the men at Main Base on December 12, 1913. Still in the mood for exploration, the ship surveyed the coast from Mertz Glacier to Gaussberg (Figure 3.22). Mawson arrived back to Australia on February 26, 1914. He was knighted and appointed Professor of Geology at the University of Adelaide. In 1929-31, he returned to Antarctica as leader of the British Australian New Zealand Antarctic Research Expedition. He died in 1958 as the last remaining leader from the Heroic Era.

◊ Ernest Shackleton's Second Expedition

Imperial Transantarctic Expedition on the *Endurance* ***(1914-1917)***

In 1911, after Amundsen and Scott conquered the South Pole, Shackleton was planning a more ambitious expedition. He was going to walk from the Weddell Sea to the Ross Sea via the South Pole. This time the expedition would need two parties – the Weddell Sea Party, which would walk across the continent; and the Ross Sea Party, which would set up the supply depots from Beardmore Glacier to the Ross Sea. Funding sources were largely Shackleton's personal friends, though some funding came from the Royal Geographical Society and the government. Applicants responded in droves to that now famous (although not confirmed) notice placed in a newspaper:

MEN WANTED FOR HAZARDOUS JOURNEY, SMALL WAGES, BITTER COLD, LONG MONTHS OF COMPLETE DARKNESS, CONSTANT DANGER, SAFE RETURN DOUBTFUL. HONOUR AND RECOGNITION IN CASE OF SUCCESS.

Although thousands applied, only twenty eight men per party were chosen.

Shackleton bought two ships – the ***Endurance*** (formerly the ***Polaris***) from Adrien de Gerlache, a whaling vessel constructed in Norway, that would sail to the Weddell Sea; and the ***Aurora***, from Douglas Mawson, that would sail

Ernest Shackleton's grave at Grytviken.
© Jacobs and Arrebola.

Shackleton´s coffin inside the church of the whalers in Grytviken, South Georgia.
© Archivo Departamento de Estudios Históricos Navales. Armada Argentina. Dept.

to the Ross Sea. It was becoming clear that a great war would break out in Europe and Shackleton offered his ships and crew to join the war effort. Instead, however, he was given the order to proceed with his expedition and it departed from England on August 5, 1914.

Weddell Sea Party

After calling at Madeira and Buenos Aires, the ***Endurance*** arrived in South Georgia in December, 1914. There, Shackleton was advised by the whalers at Grytviken to enter the Weddell Sea from the east, where they could find open water. On January 19, 1915 the crew reached 76° 34′ S and soon became trapped in a sub-zero prison of pack ice from which they would never be freed. On February 22, 1915, the ship reached her most southern latitude of 77° 00′ S at 035° 00′ W. After ten months of drifting and constant ice pressure, the ship was abandoned on October 26, 1915 at 69° 11′ S, 051° 05′ W. She sank a month later. The crew was now forced to camp on the sea ice, where they remained for five months drifting northwards with the Weddell Gyre.

By February, 1916, they were about eighty miles from Paulet Island. Shackleton was aware of Nordenskjöld supplies left on the north shore. But the drifting ice pushed them so far to the east that Shackleton turned his attentions to Elephant Island.

In April, 1916, close to the northeast side of the Antarctic Peninsula, they launched the three lifeboats, reaching Elephant Island after six days of misery and suffering. Elephant Island was hardly a hospitable place but touching land for the first time in over 16 months renewed the crew's spirit. Aware that nobody would search for them on that island, Shackleton undertook a 16-day journey to South Georgia on board one of their small lifeboats. For this 800-mile crossing, Shackleton selected Worsley, Crean, McCarthy, Vincent, and McNeish to accompany him.

Figure 3.23. Shackleton's plan was to cross the Antarctic continent. For this, he would need two ships and two expedition parties. The Endurance became trapped in the ice in the Weddell Sea, sinking 9 months later. They never reached the continent. © Jacobs.

On May 10, 1916, after a difficult trip with intense waves and winds, they arrived at South Georgia, but the boat's condition, lack of fresh water and McNeish and Vincent's failing health did not allow them to sail around the island where the whaling stations were located. Shackleton, Worsley and Crean – exhausted, ill-equipped, and poorly fed – crossed the unmapped island's interior on a thirty-six-hour non-stop journey to a Norwegian whaling station on the other side. Four months and three unsuccessful attempts later, on August 30, 1916, Shackleton rescued the men on Elephant Island from Port Stanley (Puerto Argentino) on board the Chilean vessel Yelcho and sailed to Punta Arenas (Figure 3.23). He then went directly to New Zealand, arriving in December, 1916, to assist in the rescue of the Ross Sea Party.

The Ross Sea Party

The Ross Sea Party sailed from Hobart on December 24, 1914. They entered the McMurdo Sound on January 16, 1915 and began to offload supplies. Their instructions were to lay depots from the Beardmore Glacier to support the Transantarctic expedition coming from the Weddell Sea. The dogs were in poor condition and many of them

Figure 3.24. The Ross Sea Party accomplished their objective of laying depots for the Transantarctic crossing. It was all for naught: Shackleton and the crew of the Endurance were stuck in the ice in the Weddell Sea. © Jacobs.

died. The temperatures were relatively warm and at times made sledging impossible. After great difficulties and the loss of three members of the expedition, the party managed to set the supply depots up to the Beardmore Glacier (83° 30′ S) by January, 1916. After leaving the men on land, their ship became trapped in the sea ice and drifted for nine months; however, the ***Aurora*** finally returned to New Zealand where she was repaired. In December, 1916, the ship left Dunedin, New Zealand and returned to McMurdo Sound with Shackleton to relieve the Ross Sea Party in January, 1917. Their tale has largely been ignored in the shadow of what was happening on the Weddell Sea (Figure 3.24).

Shackleton did not achieve his goal of crossing the continent via the South Pole. However, he realised one of the greatest survival feats in the history of human expedition. Some years later, he returned to Antarctica in charge of a new, but poorly planned, expedition on board the ***Quest***. Eight members of the Transantarctic expedition were again loyally under his command.

The expedition arrived at Grytviken on January 4, 1922, and the next morning the members of the crew woke up to terrible news: Shackleton was dead from a heart attack. His body was taken to Montevideo where the crew advised his wife by telegraph of the sad news. She decided to have him buried on South Georgia. On March 5, 1922, Shackleton was buried in the tiny cemetery at Grytviken.

◊ John Cope (1893-1947)
British Imperial Expedition (1920–1922)

Contrary to the high-brow name, The British Imperial Expedition was a low-budget endeavour with only four members and no ship. The expedition had almost no funding and each member had to make their own way to Antarctica. Expedition leader John Lachlan Cope (a former team member of Shackleton's Ross Party) intended to make the first flight over the South Pole. However, funds were insufficient and he had to reduce his plans for exploring the west coast of the Weddell Sea.

The other three members of the expedition were Maxime Charles Lester, Hubert Wilkins (who later served Shackleton in his last expedition and became a famous Antarctic aviator) and a young geologist, Thomas Wyatt Bagshaw. The four men rendezvoused at Deception Island in December, 1920, with a plan to over-winter on Snow Hill Island where Nordenskjöld had over-wintered between 1902 and 1904.

They arranged to be taken by the whaling factory ship ***Svend Foyn*** but heavy pack ice blocked their way through the Antarctic Sound. They decided to go to the west of the Antarctic Peninsula and the Norwegian whalers left the four members in Paradise Bay on a tiny spot of land where the Norwegian factory ship ***Neko*** had left a water supply boat eight years earlier.

Now the plan was to cross the Peninsula on foot and explore the eastern side but they very quickly came to realise that this would be a fatal journey given their equipment and lack of experience: the mountains rose to over one thousand meters and in their valleys were oceans of crevasses. Considering the situation, and that none of their plans were achievable, Cope decided to travel to Montevideo, find a ship, and return the following year for Bagshaw and Lester (who, despite the advice of the whalers, decided to stay for the winter) where he would then reattempt to reach Snow Hill Island. Cope and Wilkins left the two men on February 26, 1921 and in a lifeboat headed to Port Lockroy, where they were taken by the whalers back to Montevideo on the factory ship ***Solstreif***.

Lester and Bagshaw made a primitive hut with the Norwegian water boat, some cases, and wood left from the whaling vessel. They called the place Waterboat Point. The two men were left with a group of dogs that required daily maintenance and, despite their very primitive materials and equipment, managed throughout the winter to carry out some important scientific data collection ranging from natural history to meteorology.

Cope did not find a vessel and never returned for them. The whalers, who had promised Bagshaw and Lester that they would pick them up, were so convinced that the two were dead that they sent the recovery ship with a prayer book to perform a memorial service. To their surprise, the two young men were still alive. In December all the dogs were rescued, and Lester and Bagshaw left Antarctica in January, 1922.

Shackleton's death in 1922 marked the end of a golden age of exploration, where men pushed their wills to extreme limits in pursuit of their frigid goals. It was an almost poetic period in Antarctic history, with accounts of incredible strength and courage. From this point on, the future of Antarctic research and exploration would be accomplished by the power of tractors, caterpillars, and planes, which brings us to the "Mechanical Era."

WHALING IN THE SOUTHERN OCEAN

The history of the whaling industry can be divided into two rather distinct eras. The first, Early Whaling, was widespread and existed for the acquisition of oil for illumination, heating, and cooking. The second era, Post Petroleum Whaling, describes a significantly reduced hunt for very specific industries, including lubricants and infantry.

With the discovery of petroleum and its uses in 1859, the Early Whaling industry experienced a precipitous decline. Petroleum was a much more desirable product for illumination and heating: it was more readily available in more predictable quantities. Kerosene, a product of petroleum, was more efficient, cleaner, and safer than whale oil. Electricity (Thomas Edison invented the incandescent lamp in 1879) caught on very quickly and spread within the large cities of America and Europe. The prices of whale oil dropped and hunting became unprofitable for most companies. However, a few companies and whaling grounds remained open. The baleens were still used for the manufacture of strong and flexible products until the mid 20th century and the oil was still the best available as lubricant for industrial machinery. The invention of the exploding harpoon by ***Svend Foyn*** in the 1860s, followed by the development of steam-powered whale catchers, allowed whalers to turn their attentions to the fast-swimming rorqual whales.

Although so far away from their country of origin, whaling companies revitalised the dying hunt and turned their attention to the Southern Ocean for several important reasons:

1) The number of whales in the Northern Hemisphere had declined dramatically.
2) The human population in Europe was booming and there was a growing demand for some products that could be replaced by whale products, especially fat for the production of artificial lard, soups, and food for farm animals.
3) A ban was placed by the Norwegian government on shore-based whaling, forcing Norwegian whalers to find other whaling grounds.
4) A dramatic fall in the availability of linseed oil in Europe.
5) The discovery and development of hydrogenation (making it possible to reduce the strong smell and taste of whale oil, allowing the manufacture of margarine).
6) With the start of the First World War, whale oil was used for the manufacture of glycerine, used for making bombs.

Captain C. Larsen, during the Swedish Antarctic Expedition, recognised the commercial opportunity of whaling in the waters off South Georgia Island. After his rescue by the Argentine vessel Uruguay, Larsen found financial support in Buenos Aires to establish a whaling Station at Grytviken, the company was named Compañia Argentina de Pesca. The commercial success of the first season (1904-05) caused Norwegian and British companies to further establish whaling stations in the Southern Ocean and to operate with floating factory ships in the protected harbours of South Georgia, Malvinas Islands, South Shetland Islands and the Antarctic Peninsula.

The factory ships could not provide their own fresh water and the steam engines could operate either the engine or the boilers, but not both at the same time. For that reason these ships, converted from old merchant or passenger liners, were dependent upon safe harbours in order to operate. The large factory ships could support a crew of between 50 and 60 men. The smaller and faster catchers that hunted the whales with a harpoon gun placed at the bow, were operated by about 10 men. Whaling was dirty and dangerous work and living conditions were harsh. The living area below deck would be a space shared with not only the rest of the crew but all of their tools and gear. Above deck, it was filthy and slippery with whale blubber. Infections of the hand were common as the men worked all day with whale blubber and meat and were exposed to all sorts of bacteria.

Unlike the sealers or the whalers of earlier times, whalers in the Southern Ocean received salaries. However, they also received a bonus per whale captured, the size of the bonus depending upon the species. The majority of the bonus was allotted to the gunner (the harpooner) for their precision hunting. The gunner usually signed up for a summer hunting season, but in land- based whaling there were men who remained during the winter for repairs. It was common practice (maybe an old tradition) for the captains and managers of the waling companies to be accompanied by their wives, and those women were likely the first seen in Antarctica.

The whaling companies had licenses and leases issued by the British and the Malvinas Islands governments to operate whaling stations. Those licenses created formal disputes between Argentina, Chile, Norway, and the United Kingdom. By 1916, many of the companies turned to using land-based stations instead of factory ships as they provided safer working environments, more efficient use of technology, and allowed them to process the entire whale carcass.

In the 1920s, added pressure placed on the whaling companies by the British government to process the entire whale for oil, and allusions to the withdrawal of their licenses, forced Norwegian companies to find another solution to maintain their business. The threat of potential economic loss, combined with the development of ships with water distilling facilities and slipways, jump-started pelagic whaling. Once again, it was Captain Larsen who pioneered the activity; he was on board Sir James Clark Ross I as manager of the factory ship when they performed the first pelagic whaling season on the Ross Sea in 1923-24.

During the 1930-31 season, a massive over-production plus worldwide recession caused the whaling market to collapse and many companies began to abandon the stations and whaling grounds. A few companies remained in South Georgia Island during World War II. Between 1904 and 1931, more than 200,000 whales were caught in Malvinas, South Georgia, South Sandwich, South Orkney, South Shetland Islands, and the Antarctic Peninsula.

The International Whaling Commission (IWC) was created in 1946, not for conservation purposes but to maintain a sustainable population of whales for an industry that was still running. The Russian and Japanese fleets that carried out whaling in the Southern Ocean during the 1970s without regard for conservation led the IWC to limit the catches of whales in 1975. In 1982, with whale populations highly endangered, the IWC decided to stop all commercial whaling from 1985-86, except for scientific and traditional whaling, thus ending a long commercial tradition of approximately 1,000 years. Today, whaling activity is highly controversial. Some countries are opposed and some others like Japan, Faroe Islands and Norway continue to hunt.

Whalers as Explorers

- Between 1820 and 1823 most places

of the South Shetland and South Orkney Islands were discovered by men in close association with sealing and whaling activity.
• The German Dallman Expedition between 1871 and 1874 on board the Grönland was supported by the hunting of seals and whales.
• Bull's Expedition on board the Antarctic was sponsored by ***Svend Foyn***, a prominent whaler.
• During the Second French Antarctic Expeditions, Jean Baptiste Charcot received coal, stores, and repairs from the whalers in Deception Island.
• Wilhelm Filchner received support from the whaling stations on South Georgia, to the point of Larsen helping Filchner to stop the mutinous activity on board his ship, the ***Deutschland***.
• Shackleton received support (among other contributions) from Compañia Argentina de Pesca, both for the ***Endurance*** Expedition and the ***Quest*** Expedition. Shackleton also sought the help of whalers to rescue his men from Elephant Island.

Catcher Undine towing whales. © Archivo Departamento de Estudios Históricos Navales, Armada Argentina.

• The four members of John Cope's British Imperial Expedition rendezvoused in Deception Island and were transported by whaling vessels to and from the Antarctic Peninsula.
• The first flight over Antarctica was also supported by a whaling company. The whaling vessel ***Hektoria*** transported Wilkins and his two planes from Montevideo, Uruguay to Deception Island.
• Nine crewmembers of the Ellsworth Expedition on board the ***Wyatt Earp*** had previous Antarctic experience, having worked on Norwegian whaling vessels.

THE MECHANICAL ERA

Advancements in technology allowed men to live year round in Antarctica to undertake further exploration under safer conditions. In the interest of new geographical discoveries and the establishment of sovereignty over the territory, governments continued to support these expeditions, which could now be executed rapidly with the aid of machines. Certain individuals and expeditions stand out.

◊ Hubert Wilkins (1888 – 1958)
Wilkins-Hearst Antarctic Expeditions (1928-1930)

Hubert Wilkins. © Mitchell Library State - Library of New South Whales.

Wilkins was born in Hallett, Australia. As a young man he studied engineering though his passion was for photography and cinematography. He was a naturalist, a stow- away, an aviator, a war hero, a geographer and a polar explorer. In

1913, he made his start in polar exploration as second in command of Stefansson's Expedition to the Canadian Arctic. He learned to fly and entered the Australian Flying Corps in 1917. In 1920, he joined (but only very briefly) Cope's low budget expedition to the Antarctic Peninsula and, in 1922, Shackleton's ***Quest*** expedition. In April, 1928, Wilkins and pilot Carl Ben Eielson flew from Alaska to Spitsbergen in a 20-hour flight.

With the objective of becoming the first men to fly over Antarctica, Wilkins organised a new expedition to the White Continent. He and partner Carl Ben Eielsen, along with backup pilot Joe Crosson, sailed from New York in September, 1928 and arrived in Montevideo in October. From there they sailed to Deception Island on board the whaling vessel Hektoria, arriving at the beginning of November, 1928. They had with them two Lockheed Vega monoplanes – the ***San Francisco*** and the ***Los Angeles***. That month they made a 20-minute flight from Deception Island in the ***Los Angeles*** before the weather closed in on them.

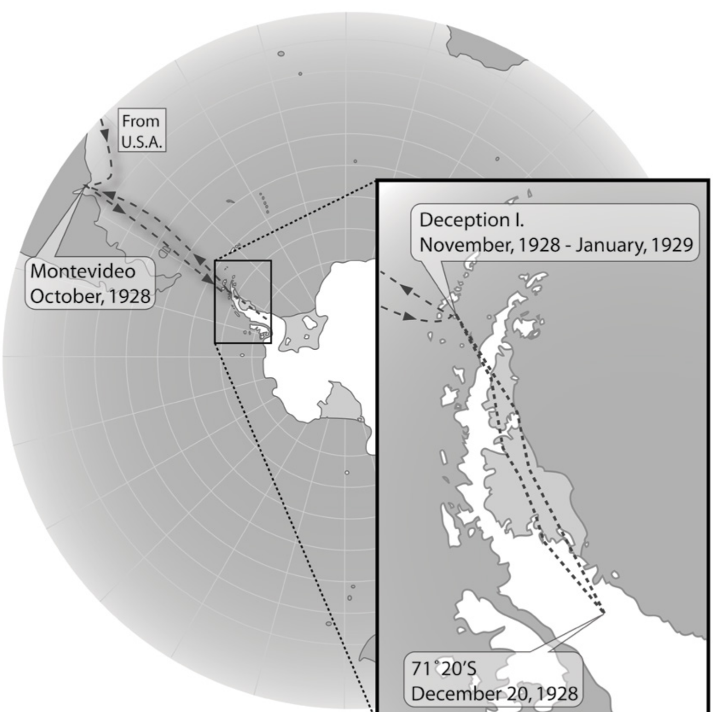


Figure 3.25. Wilkins explored the Antarctic Peninsula by plane, introducing a new platform from which to explore Antarctica. © Jacobs.

The next month, after several short flights and the sinking and subsequent recovery of the ***Los Angeles***, they were ready for a second attempt. On December

20, 1928, Wilkins and Eielsen covered approximately 2,100 km along the Antarctic Peninsula in the ***San Francisco***, reaching 71° 20' S. Wilkins discovered and named Hearst Island after his sponsor, William Hearst. Crosson remained with the ***Los Angeles*** in case a rescue was needed. This flight marked the beginning of a new era of exploration: Wilkins and Eielsen cut down the time it takes to map a coastline from several months to several minutes. After another flight on January 10, 1929, Wilkins flew 460 km to confirm his previous sightings. The team returned to Montevideo on the British warship ***HMS Flerus*** (Figure 3.25).

During the second Wilkins-Hearst season, Wilkins returned to Deception Island on board the ***Melville*** and a number of successful flights were completed between December, 1929 and January, 1930, during which he flew over new territory and discovered a new island, naming it for King George V.

In 1931, Wilkins attempted to reach the North Pole underneath the ice with a submarine that he named ***Nautilus***, but he failed because the submarine broke down.

◊ Richard Byrd (1888 - 1957)

Voyage on the** Floyd Bennett **(1928-1930)


Richard Byrd. © Archivo General de la Nación, Dto. Doc. Fotográficos, Argentina.

Richard Byrd was born in Virginia, United States of America in 1888. At the age of twenty, he enlisted in the U.S. navy and learned to fly during World War I. Byrd had established a solid reputation as a pilot and was responsible for the first transatlantic flight from Newfoundland to the Azores, accomplished in May, 1919. In 1926, together with ***Floyd Bennett***, Byrd flew over the North Pole.

Two years later, Byrd decided to take the South Pole. Heavily supported by corporate America, including the Rockerfeller family, Byrd brought three planes: a Ford tri-motor monoplane named ***Floyd Bennett*** after his friend who died in 1928; a Fokker universal named ***Stars and Stripes***; and ***The Virginian***, a Fairchild monoplane.

Not only would the Pole be taken, but the flights were to include extensive land surveying. Well prepared, Byrd orchestrated the most strategically complicated plan to date. It had the support of four ships, three planes, 94 dogs, more than 60 men and 1,400 tons of supplies.

The expedition reached the Bay of Whales on December 28, 1928, and they established a base camp – Little America – at the beginning of January, 1929. Byrd flew for the first time over Antarctica on January 27, 1929, ten weeks after Sir Hubert Wilkins. During a five hour flight, he discovered a new mountain range which he named Rockefeller Mountains. On March 13, 1929, three members of the expedition returned to the Rockefeller Mountains to make more detailed surveys and collect geological samples. They spent a few days working and then a terrific wind lifted their plane off the ice and launched it a kilometre away, destroying it completely. When they failed to respond to scheduled checks, Byrd rescued them in the ***Virginian***.

Forty-two men spent the winter at Little America. The men occupied themselves with preparations of equipment, magnetic and meteorological observations, radio communications with the outside world, and setting up several depots on the ice shelf for the following season.

On November 28, Byrd, Bernt Balchen, Harold June, and Ashley McKinley took off from the Bay of Whales in the ***Floyd Bennett***, their Ford tri-motor monoplane, heading south towards the Pole. The plane reached the South Pole shortly after midnight on November 29, 1929, and returned to Little America within eighteen hours and forty-one minutes of take off. After several more flights, and the completion of the Geological Party's expedition, the men returned to Dunedin on the ***Eleanor Bolling*** and ***City of New York*** on March 10, 1930, and then to New York in June, 1930 (Figure 3.26).

Byrd returned to Antarctica four more times; he undertook his second expedition between 1933 and1935. There he spent five months alone operating a meteorological station where he almost died of carbon monoxide poisoning.

Byrd returned to Antarctica again in 1939 on his first expedition officially supported by the United States government. But the expedition was cut short when Nazis seized his ships near Queen Maud Land in March, 1940. Byrd's fourth expedition and the climax of his career was Operation Highjump, in 1946 and 1947. It was the largest Antarctic expedition to date and involved more than four thousand people, fifteen U.S Navy support ships, six helicopters, six flying boats, and two seaplanes. This would give the U.S forces the appropriate training in Polar Regions in the case of a cold war with the Soviet Union. The expedition explored the region between 0° and 150° E, making aerial surveys and discovering new mountain ranges. In February 1947, the en-

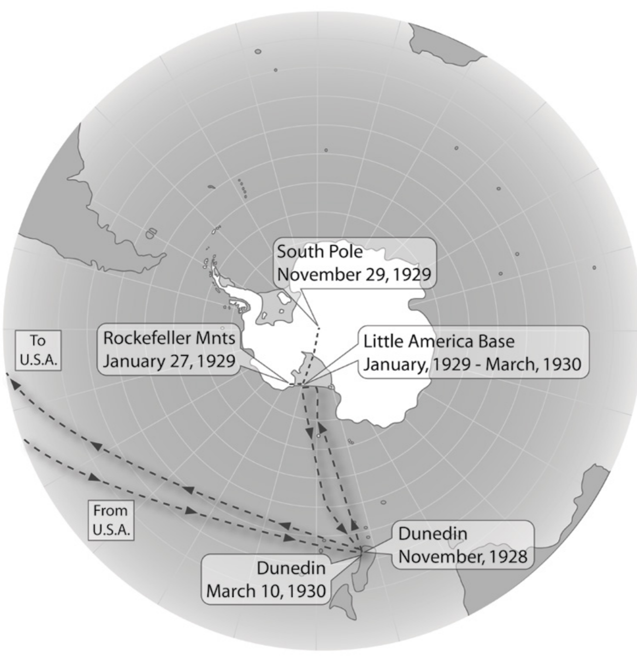


Figure 3.26. Byrd embarked on several Antarctic expeditions with the motivation of claiming parts of it for the United States. He flew over the South Pole on November 29, 1929 on a flight that lasted 18 h and 41 min. © Jacobs.

tire expedition returned to the United States.

Byrd's last expedition was in 1955-56 during Operation Deepfreeze, when McMurdo and Amundsen- Scott stations were established. He died on March 12, 1957, in his house in Boston.

◊ Lincoln Ellsworth (1880 – 1951)

Voyage on the Wyatt Earp and Polar Star (1933-1939)

Lincoln Ellsworth was born in Chicago, United States of America. His first polar expedition was in 1925 when he, Roald Amundsen, and four other men tried to fly over the North Pole. They were unsuccessful and almost lost their lives when their planes went down. After struggling for several days, the six members finally managed to take off in one plane and arrived at Spitsbergen with the fuel tanks almost empty. The following year, Amundsen, Ellsworth, and Umberto Nobile finally accomplished the first traverse of the North Polar Ocean on the dirigible ***Norge***.

In 1931, with the support and advice of Hubert Wilkins, Ellsworth began the preparations for a new and even more difficult challenge: cross the Antarctic continent by plane. To accomplish this goal, Ellsworth made four expeditions to Antarctica between 1934 and 1939. He purchased a small Norwegian fishing ship that he reinforced, renaming it the ***Wyatt Earp***, after his hero.

In 1934, in the Bay of Whales, his plane (a Northrop Gamma monoplane) called the ***Polar Star*** was severely damaged when the Ross Ice Shelf calved enormous pieces

of ice into the sea. Ellsworth moved his attempt to the Antarctic Peninsula and arrived at Deception Island, the new starting point, in 1934.

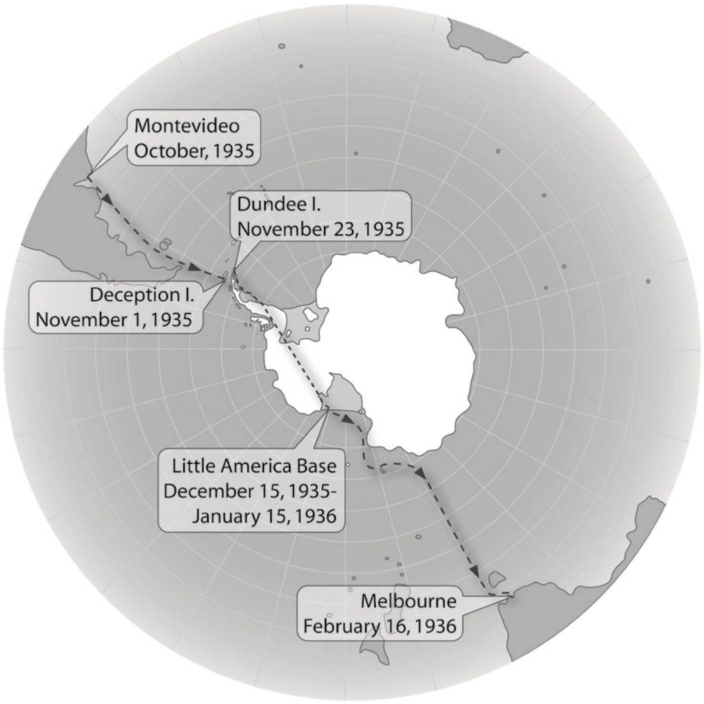


Figure 3.27. Ellsworth made the first trans-Antarctic voyage, from the Antarctic Peninsula, to Byrd's Little America Base. © Jacobs.

However, the ***Polar Star*** had suffered some damage once again, and the ***Wyatt Earp*** was sent to South America to recover the needed part for the repair. On January 3,

1935, Ellsworth and pilot Bernt Balchen (Byrd's South Pole co-pilot) made their third attempt, but they had to turn back because of poor weather conditions.

Ellsworth returned to the United States in search of a new pilot. He boarded a ship and met up with his crew and plane in Montevideo in October, 1935. They sailed to the Strait of Magellan, Chile to provision the ship, and arrived at Deception Island on November 1,

1935. On November 23, 1935, Ellsworth and new pilot Herbert Hollick-Kenyion made the first Transantarctic flight in history, discovering along the way the mountains that today bear Ellsworth's name. They flew from Dundee Island to the Ross Ice Shelf, a 4,800 km flight with an anticipated twenty hours flying time. The flight, however, took 14 days. The weather conditions were poor and they had to land several times to wait for an improvement. They finally landed 30 km from Little America and, after much difficulty with land-based navigation, the two found the well-stocked hut on December 15, 1935. The RRS Discovery II, an Australian vessel was first to the rescue on January 15, 1936. The ***Wyatt Earp*** joined them a few days later. Ellsworth returned to Melbourne with the Discovery, arriving on February 16, 1936, and Hollick-Kenyion stayed with the ***Wyatt Earp*** to recover the ***Polar Star***.

Ellsworth and Hollick-Kenyion had covered over 4,800 km and sighted new territory, claiming the land between 80° and 120° E for the United States and naming it James W. Ellsworth Land in honour of Ellsworth's father (Figure 3.27).

Ellsworth made his last Antarctic Expedition accompanied by his friend Wilkins as operations manager in 1938. They flew over the continent along the 79th meridian and made it to 400 km inland before having to turn back for lack of fuel.

◊ Alfred Ritscher (1879 - 1963)

German Antarctic Expedition of 1938–1939

Alfred Ritscher.
© Wissenschaftliche und fliegerische Ergebnisse der Deutschen Antarktischen Expedition 1938/39, Hrsg. in Auftrag der Deutschen Forschungsgemeinschaft, Amelang & Koehler, Leipzig, Bd.

The German Antarctic Expedition (December 1938 to April 1939) has been virtually omitted from most history books. It was led by Captain Alfred Ritscher, experienced ship captain and an accomplished aircraft pilot. He had previous Arctic experience, working as ship's captain during the German Schroeder-Stranz expedition to Spitsbergen in 1912. Eight people lost their lives and Ritscher performed a remarkable hike through the winter night to get help.

During the first part of the 20th century, whaling was still an important industrial activity and supplied oil, lubricants, glycerine (for nitroglycerine used in explosives), margarine, soap, and other essential products. In the 1930s Germany was the second largest purchaser of Norwegian whale oil. However, Germany no longer wanted to be dependant upon foreign sources, especially in light of an approaching war. Consequently, they established a large and modern whaling fleet and invested considerably in the industry. In addition, the government was not keen on paying the United Kingdom whaling concessions and operating under their restrictions.

A series of secret expeditions were planned to claim a piece of Antarctica for Germany to develop their own whaling industry, free of foreign influence. The first expedition, conducted in 1938–1939, was given the objective of mapping the region by air for the purposes of discovery and exploration.

The vessel used in the expedition was the ***Schwabenland*** and belonged to the German airline Lufthansa. It was an 8000-tonne aircraft carrier, equipped to catapult hydroplanes into the air and to lift them out of the water upon their return. The crew included a complement of scientists and a whaler who had worked in this region before, Otto Kraul, hired as the ice pilot.

The expedition left Germany on December 17, 1938 and arrived to the Dronning Maud Land coast on January 19, 1939. While ***Schwabenland*** steamed along the coast taking soundings and collecting ocean samples, its two Tenton Dornier-Wal hydroplanes, ***Boreas*** and ***Passat***, conducted the first systematic aerial photographic survey of Dronning Maud Land (69° S and 74° S, and longitudes 005° W and 018° E). The photographs revealed the true nature of the coast. It was an ice shelf extending over the ocean, ending in precipitous cliffs of several mountain ranges. However, a small oasis of ice-free land was also discovered north of the Wohlthat

Figure 3.28. The German Antarctic Expedition, lead by Alfred Ritscher, was to be conducted in two phases. The onset of World War II allowed only for the first phase to be executed.

Massif and named Schirmacher Oasis, after the pilot who discovered it.

German flags were raised along the coast and flags bearing the swastika were dropped from aircraft to provide a basis for a claim to what Germany referred to as Neuschwabenland. The ***Schwabenland*** sailed toward home on February 15, 1939.

Upon the return of the ***Schwabenland*** to Germany, discussions took place about the possibility of a second expedition to survey the coast between 80° W and 130° W, where no claims were currently made. The expedition could not be carried out because of the outbreak of World War II. Another expedition was planned, though not executed, for 1940–1941, to establish a base in Neuschwabenland.

By 1940, Antarctica had become less of a geographical mystery as explorers filled in the pieces. Flags had been planted, capsules had fallen from airplanes, and political disputes had been played out between sovereign nations who felt that they had some claim over the continent. The rich resources of Antarctica were apparent and governments asserted pressures on their explorers to secure them for future exploitation.

World War II provided a new rationale for staking claims. Chile and Argentina both declared their sovereignty over the Peninsula and the adjacent sub-Antarctic islands. Great Britain organised Operation Tabarin to monitor the movements of German warships and prevent them from using the safe harbours of the South Shetland Islands to launch attacks on allied ships transporting supplies for the war effort. Argentina and Britain volleyed back and forth, planting stakes only to have them painted over or removed by the other nation. During this time, the United States did not participate in the squabbles. However, when World War II ended and tensions rose with the U.S.S.R., military training exercises in Polar Regions were deemed essential. Operation Highjump, led by Byrd in 1946, brought 4,700 men to Antarctica for training, though the government stressed that this was a scientific expedition.

In 1950, the eight countries that have been engaged in acts of sovereignty over Antarctic territory met to resolve their differences. Argentina, Australia, Chile, France, Great Britain, New Zealand, Norway, and the United States decided to exclude Russia from the discussion because they had yet to make a claim and the other nations were still suspicious as a result of the Cold War. Russia responded by refusing to recognise any claims and to carry out their Antarctic activities irrespectively. This stance would later be adopted by the United States as well.

THE ANTARCTIC TREATY SYSTEM

The Protocol on Environmental Protection to the Antarctic Treaty designates Antarctica as a nature reserve devoted to peace and science. Sovereignty claims over these large areas are limited by access and this is limited by technology. However, individuals and nations with sufficient access to the required technology have been exploring and, in some cases, exploiting these resources with little interference. No nation has internationally recognised sovereignty over any part of the continent of Antarctica or the islands within the geographic boundary of the Antarctic Treaty, 60° S. The most southern landmass with internationally recognised sovereignty is Cook Island (59° 29' S, 027° 11' W), part of the South Sandwich Islands, which is over 1,400 km from the Antarctic continent. The United Kingdom's claim, however, is currently disputed by Argentina.

The territorial claims made during the early half of the twentieth century caused friction at best and, at worst, vigorous disputes among nations with interests in the Antarctic continent and islands of the Southern Ocean. The governments of the United States and Soviet Union were reluctant to make and recognise any sovereignty claims over the continent. However, there were other governments with a highly active presence in the area. Most of the Norwegian whaling companies were actively hunting whales in the region and Great Britain was busy controlling and charging royalties for those hunted whales in the area of the Antarctic Peninsula, Malvinas, South Georgia, South Orkney, and South Shetland Islands.

Between 1906 and 1908, Argentina and Chile began their discussions regarding the borders and the territories claimed by the two countries, which also included Antarctica.

In 1908, Great Britain, interested in maintaining control over the prosperous whaling industry, made its first official claim over the Antarctic region. Curiously, its claim included parts of South America, and the mistake was finally corrected in 1917, when it was revised.

In 1924, France claimed the area previously explored by the French navigator Dumont D'Urville, known as Adelie Land. The same year, Great Britain claimed all the land of the Ross Sea area and placed it under the protection of New Zealand. In 1931, Norway, mainly concerned with protecting its whaling grounds, claimed sovereignty over Peter I Island.

In 1933, Australia claimed the region between 45° and 160° E, excluding the region previously claimed by France. Six years later, with the threat of World War II at its doorstep, Norway hurried to claim the region of Queen Maud Land before the Germans. They did so on January 14, 1939, although the claim did not include northern and southern limits. Between January 19 and February 15, 1939, Germany claimed several sector of the Queen Maud Area; however, after the war the claim was not ratified. In 1940, Chile made its official claim and Argentina claimed the Antarctic Peninsula in 1942.

Other countries involved in Antarctic exploration did not immediately make any territorial claims, however, they asserted their right to do so in the future. This is the case for both the United States and Russia. Russia maintains its right to claim any land discovered by Russian explorers. Peru and South Africa have also reserved this right over the continent and Brasil has designated it an area of interest.

In 1950, a large group of scientists lobbied the International Council of Scientific Unions to advance the date of the next International Geophysical year to 1957-1958 in light of the new technologies available for research. In preparation, the USSR, United States, South Africa, Norway, New Zealand, Japan, Great Britain, France, Chile, Belgium, Australia, and Argentina all established or refurbished scientific bases, totalling more than 50 points from which research would be conducted.

The IGY brought many nations together to discuss important scientific information and, perhaps more importantly, the knowledge that was still missing. Putting all political differences aside, nations worked together to make important atmospheric discoveries to science and humanity, including detection of the ozone hole. The success of this collaboration, combined with the recognition of the importance of Antarctica as a natural laboratory, lead to the creation of the Antarctic Treaty.

The Antarctic Treaty was originally signed by the same 12 nations on December 1, 1959, in Washington, ratified by the signatory governments in June 1961 (Table 3.1) and applies to all the landmasses and ice shelves south of

COMMITTING A CRIME AT THE SOUTH POLE…..

Without an official citizenship or government, any legal matters would be rather difficult to solve within the political boundary of Antarctica. Any disputes among countries are settled either by the parties concerned or by the International Court of Justice. However, crimes against individuals are not addressed within the Antarctic Treaty. Consequently, Treaty Nations with scientific bases have devised their own legislation.

Argentina: Crimes committed within the territory claimed by Argentina fall under the jurisdiction of Tierra del Fuego, the most southern province of Argentina, and will be tried in Ushuaia, its capital.

Australia: The Australian Antarctic Territory falls under the laws that apply to the Australian Continental Territory.

Chile: If the crime is committed within the territory claimed by Chile, the accused can choose to be judged in a Chilean court.

United States: The U.S. bases now have special U.S. Marshals to ensure law enforcement at the stations. Some of the laws apply specifically to Antarctica and generally follow the recommended guidelines for visitors to the continent. They include prohibiting the introduction of non-native species and waste management legislation. A person found guilty of these crimes could be fined up to $10,000 and spend up to one year in prison (the good news is that you get to spend it in warmer climes!).

60° S. The Treaty promotes scientific research and the dissemination of any findings throughout the world. It forbids any military activity, use and disposal of nuclear weapons, or the disposal of radioactive waste, and any further territorial claims. Originally established to prevent any secret military conduct, treaty members are granted the right to perform inspections. Nowadays, these inspections focus upon environmental protection, waste and energy management, and control of environmental impact. Not only scientific stations are subject to inspection; aircraft and ships can also be boarded.

The text of the Antarctic Treaty also states that nothing within it revokes the specific territorial claims of sovereignty made by certain nations, or the rights of nations to make claims in the future. In addition, it states that no act of sovereignty carried out during the enforcement of the Treaty will be recognised. It places all the claims and territorial disputes in a latent (or frozen) state. The Treaty remains in force indefinitely and can be changed or amended with unanimous consent.

In order to create an effective system, the treaty parties agreed to meet periodically. The first meetings occurred biannually but from 1991 this was changed to an annual schedule.

In addition to the Treaty, subsequent conventions were drafted at meetings and signed by Treaty Nations. The most well known have been signed by most, though not all, of the Treaty Parties. The Convention for the Conservation of Antarctic Seals (CCAS, London, 1972) and the Convention for the Conservation of Antarctic Marine Living Resources (CCAMLR, Canberra, 1980) were designed to preserve the ecosystem of the Southern Ocean. Currently, only 16 nations have signed the CCAS, while 30 have signed the CCAMLR. The Agreed Measures for the Conservation of Antarctic Fauna and Flora was drafted in 1964 (Belgium) but did not take effect until 1982. The Convention for the Regulation of Antarctic Mineral Resource Activities (CRAMRA), drafted in 1988 (Wellington), has been rejected and is not in force.

Due to the potential threat of mineral and petroleum extraction upon wildlife, the Antarctic Treaty members adopted the Protocol of Environmental Protection. Drafted in 1991 (Madrid), it took effect in 1998. This document bans mineral resource mining except for scientific purposes. Five of the six amendments are currently under force in areas related to marine pollution, flora and fauna protection, environmental impact assessments, waste management, recognition of historic sites, and Antarctic Special Protected Areas (ASPAs). A sixth amendment, regarding environmental emergencies, drafted in 2005, is still waiting to take force.

The Antarctic Treaty System Consultative Meetings are held in cities all around the world. It is a mechanism by which changes related to the Treaty can be made without the creation of an international organisation. Consequently, representatives of Consultative Nations exchange information and make recommendations to their governments to further support the principles of the Treaty.

Since 1959, 39 countries have entered into the Treaty and are either full Consultative members or Non-consultative members. Those nations that maintain regular research programs and international recognition have been granted Consultative status and are able to participate in decision-making processes. Those nations that have subsequently been granted Consultative status must maintain their interests or risk losing the privilege of full participation. Curiously, the 12 original signatory nations remain Consultative Nations irrespective of their present interest in Antarctic science. All nations within the Antarctic Treaty System comprise over 75% of the global population.

During the first 30 years, the Antarctic Treaty System worked with a non-permanent secretariat. The permanent Antarctic Treaty Secretariat was established in Buenos Aires, Argentina by the Treaty members, following an Antarctic Treaty Consultative Meeting in September, 2004. Its purpose is to support the annual Consultative Meetings, provide a mechanism for information dissemination among Treaty Nations, archive Treaty documents, and draft Treaty documents, and other activities.

CONSULTATIVE PARTY	DATE RATIFIED	NON-CONSULTATIVE PARTY	DATE
Argentina	June 23, 1961	Austria	August 25, 1987
Australia	June 23, 1961	Belarus	December 27, 2006
Belgium	June 23, 1961	Canada	May 04, 1988
Chile	June 23, 1961	Colombia	January 31, 1989
France	June 23, 1961	Cuba	August 16, 1984
Japan	June 23, 1961	Denmark	May 20, 1965
New Zealand	June 23, 1961	Estonia	May 17, 2001
Norway	June 23, 1961	Greece	January 08, 1987
South Africa	June 23, 1961	Guatemala	July 31, 1991
USSR	June 23, 1961	Hungary	January 27, 1984
United Kingdom	June 23, 1961	Korea	January 21, 1987
United States	June 23, 1961	Papua New Guinea	September 16, 1975
Brazil	May 16, 1975	Romania	September 15, 1971
Bulgaria	September 11, 1978	Slovak Republic	January 01, 1993
China	June 08, 1983	Switzerland	November 15, 1990
Ecuador	September 15,1987	Turkey	January 24, 1996
Finland	May 15, 1984	Venezuela	March 24, 1999
Germany	November 19, 1974	Monaco	May 30, 2008
India	November 19, 1974	Portugal	January 29, 2010
Italy	March 18, 1981	Pakistan	March 01, 2012
Czech Republic	September 01, 1993	Malaysia	October 31, 2011
Korea	November 28, 1986	Kazajstán	27 Ene 2015
Netherlands	March 30, 1967		
Peru	April 10, 1981		
Poland	June 23, 1961		
Spain	March 31, 1982		
Sweden	April 24, 1984		
Ukraine	October 28, 1992		
Uruguay	January 11, 1980		

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