Week 3: The Southern Ocean

In a Nutshell

Location

- Located south of 60 degrees South latitude, The Southern Ocean is the world's southern most ocean. It connects the Atlantic, Indian and Pacific Oceans and encircles the continent of Antarctica.

Size

- With a size of just over 20 million km^2, it is regarded as the second smallest of the five oceans.
- The size of the Southern Ocean is not fixed as the ocean is believed to be drifting by a few inches each year due to spreading of the sea floor.

Depth

- The majority of the Southern Ocean is made up of deep waters of between 4,000 and 5,000 m. The average depth of the Southern Ocean is around 3,350 meters. The deepest point in the Southern Ocean with a depth of over 7,000 meters, is in the South Sandwich Trench.

Climate of The Southern Ocean

- The Southern Ocean is known for its strong winds, intense storms, dramatic seasonal changes and cold temperatures. Winds can can reach up to 200 kilometers per hour and waves that can reach heights of up to 30 meters. Storms are intense because of the temperature contrast between ice and open ocean.
- The ocean contains some of the coldest bodies of water on earth, ranging between negative (-) 2 degrees and 10 degrees Celsius.

How it was formed

- Geologically the youngest of the oceans, it was formed when Antarctica and South America moved apart, opening the Drake Passage roughly 30 million years ago. The separation of the continents allowed the formation of the Antarctic Circumpolar Current. This current is the unique feature of the Antarctic Ocean due to its ability to flow the waters clockwise around the continent of Antarctica.

Water currents and flows in The Southern Ocean

The Antarctic Convergence

- The Antarctic Convergence occurs where the cold Antarctic waters meet the warmer waters of the sub-Antarctic. The cold, dense Antarctic surface water dives beneath the warmer waters coming from the north creating a natural, biological boundary. In summer, the sea temperature may drop 4°C at the convergence and in winter, it may drop as much as 10 °C.

The Antarctic Circumpolar Current

- The Southern Ocean is dominated by the Antarctic Circumpolar Current. It is this current that makes the waters of the Southern Ocean distinct from the waters of surrounding oceans.
- The current circles from west to east (clockwise) around Antarctica. It is the longest, strongest and deepest-reaching current on earth. At 21,000 km in length, it transports 130 million cubic metres per second of water – 100 times the flow of all the world's rivers - enough to fill Lake Ontario in just a few hours.
- The current helps keep Antarctica cold by keeping warm water from coming close.
- To the south, the current butts up against Antarctica, bringing relatively warm Circumpolar Deep Water into contact with the ice fringing Antarctica, thus cooling the ocean and effecting the climate.

Three distinct layers of water contribute to water flows in The Southern Ocean

- The Antarctic Ocean is made up of three distinct masses of water in different layers which differ in their temperatures, salinities, and directions of flow. The upper and lower layers move northward, carrying cold waters from the Antarctic to the tropics, while the middle layer flows southward, replacing the water lost to the other two currents, and brings nutrients and warmer water from temperate and tropical regions.
- Large-scale upwelling of cold water occurs in The Southern Ocean as the water flows northwards.

The Southern Ocean plays a significant role in the global carbon and oxygen cycles

- It stores large amounts of carbon through oceanic uptake and phytoplankton growth, while also producing oxygen through photosynthesis and gas exchange.
- It is estimated that 40% of the human-produced CO2 in the ocean, worldwide, was originally absorbed from the atmosphere into the Southern Ocean, making it one of the most important carbon sinks on our planet.
- Photosynthesis by the Southern Ocean phytoplankton produces oxygen as a byproduct. The Southern Ocean has a global-scale circulation system that distributes oxygen throughout the world's oceans.

The Southern Ocean plays a crucial important role in regulating the earth's climate and supporting a rich ecosytem

It regulates the climate through its currents, seasonal sea ice and by absorbing heat and carbon dioxide from the atmosphere:

1. It has a cooling effect
    - Through The Antarctic Circumpolar Current, it cools the ocean by bringing relatively warm Circumpolar Deep Water into contact with the ice fringing Antarctica.

2. It slows the pace of climate change by absorbing heat from the atmosphere
    - Over the past 50 years, the world's oceans have absorbed over 90 percent of the excess heat produced by human activity. Despite its relatively small size, the Southern Ocean has absorbed as much as 75 percent of the excess heat absorbed by the ocean as a whole. It is a powerful heat sink as it is much colder than the air above it and has some of the strongest currents on the planet.

3. The seasonal sea ice of The Southern Ocean also plays a vital role in regulating climate
    - It affects the globe's climate by reflecting heat from the sun so it is not absorbed by the ocean.
    - It affects climate by playing a role in global ocean circulation. When the new ice grows, the salt from the freezing sea water gets squeezed out and mixes with the seawater below, creating colder and saltier seawater that sinks to the seafloor and drains northward. This is part of the engine that drives the global ocean conveyor - the mass movement of water that helps regulate energy in the climate system.
    - Sea ice plays a role in absorbing carbon dioxide, the cause of global warming.

Due to climate change, The Southern Ocean is heating up, causing winter sea ice cover to declined dramatically. It is also causing the ice shelves of Antartica to recede and even collapse, reducing their ability to slow the flow of Antartica's ice sheet into the ocean. Melting sea ice and ice sheets can have profoundly detrimental effects:

- Currents interrupted: Changes in ocean temperatures already appear to be affecting ocean circulation in some regions, disrupting the climate and resulting in unpredictable new climate and weather patterns.
- Rising sea levels: Rising sea levels have many impacts on low-lying communities: contaminated freshwater sources, farmland inundated with saltwater and flooded homes.
- Intense storms: Heat from the water at the surface of the ocean provides energy for storms.

The sea ice also plays an essential role in supporting the Antarctic food web and reduced sea ice is having a detrimental effect:

- Less sea ice means less sea algae grows on the underside of the ice through the winter, providing less food for krill, which in turn, provides less food for whales, seals, penguins and other birds which feed on the krill. Thus, the entire food chain is detrimentally affected. A warming ocean also means that fewer krill eggs will hatch.
- Many of Antarctica's animals and birds are adapted to living with sea ice, using it for resting, molting, breeding and feeding. Less sea ice reduces their numbers.

The Southern Ocean ecosystem

- The Southern Ocean is one of the most productive and unique ecosystems on earth. It is home to more than 9,000 known marine species. Many species of marine life are found only in its waters, such as emperor penguins, southern elephant seals, and the Antarctic krill.
- Virtually all the wildlife we associate with Antarctica, from tiny krill to the massive Antarctic blue whale, rely on the ocean and ice for their survival.
- The marine mammals found in the Southern Ocean include whales, dolphins and seals.
- The ocean is also home to a variety of birds including 5 penguin species. The rocky shores of mainland Antarctica and its offshore islands provide nesting space for over 100 million birds every spring including albatrosses, petrels, skuas, gulls and terns.
- There are relatively few fish species in few families in the Southern Ocean. Some fish species no longer produce red blood cells but instead produce antifreeze proteins in their blood to help them survive in the subzero waters.
- Antarctic invertebrates make up more than 90% of the species in the Southern Ocean. More than 50% are unique to this ocean. These invertebrates are often much larger than their relatives in more northern, warmer waters, a phenomenon is know as "polar gigantism" The largest invertebrate in the Southern Ocean is the colossal squid which can grow up to 15 metres.
- Five species of krill (small free-swimming crustaceans), have been found in the Southern Ocean. The Antarctic krill is one of the most abundant animal species on earth, with a biomass of around 500 million tonnes.

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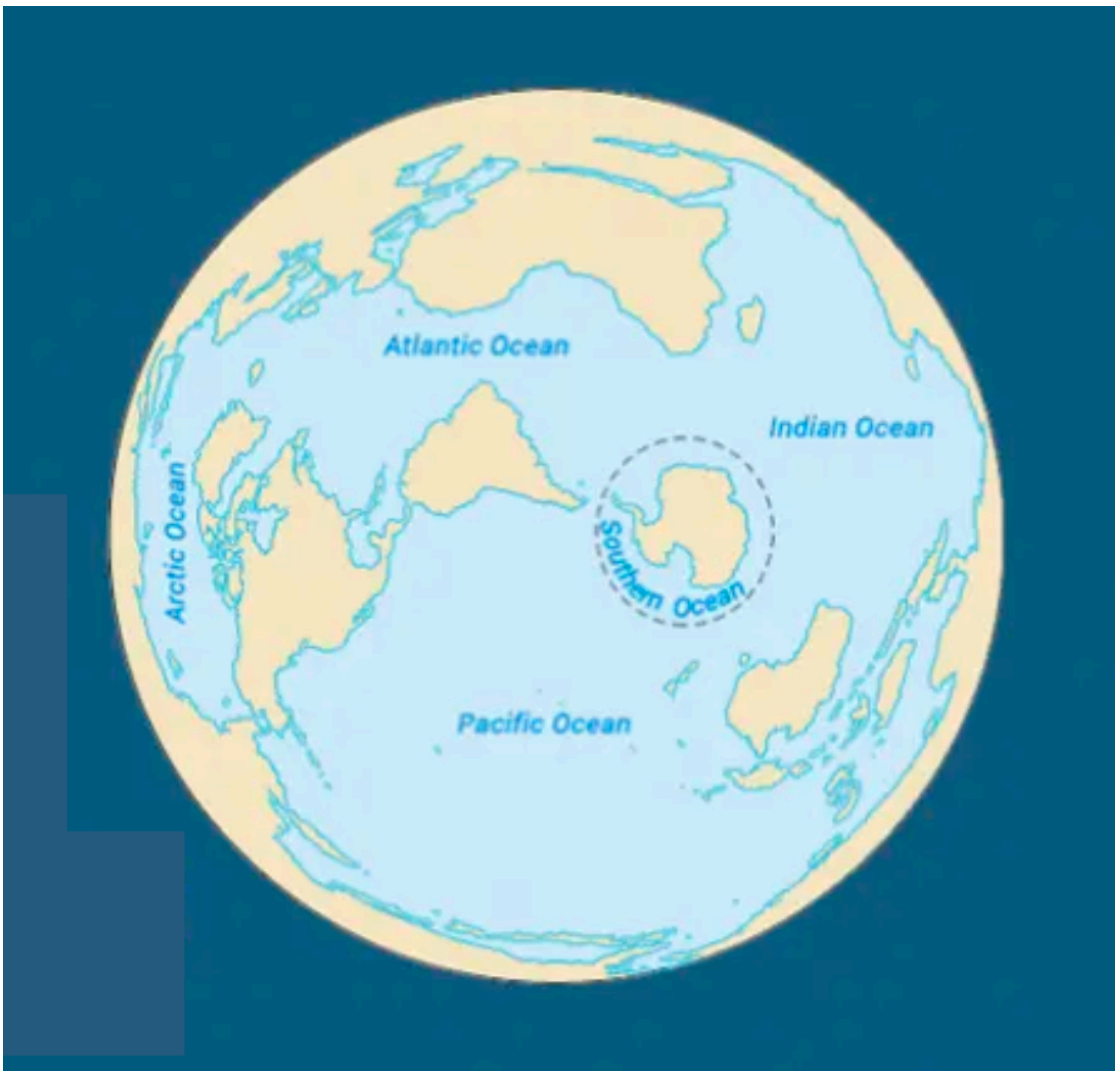
Introduction to The Southern Ocean

Where is The Southern Ocean located?

- The Southern Ocean is located in the southern hemisphere, south of 60 degrees South latitude.
- It is the southern most ocean and connects the Atlantic, Indian and Pacific Oceans.
- The Southern Ocean occupies the entire South Pole and encircles the continent of Antarctica.



The size of The Southern Ocean

- With a size of 20,327,000 km^2, it is regarded as the second smallest of the five oceans: smaller than the Pacific, Atlantic, and Indian oceans but larger than the Arctic Ocean. About twice the size of the USA, it covers 6% of the earth's surface.
- The size of the Southern Ocean is not fixed as the ocean is believed to be drifting by a few inches each year. Scientists believe this drifting is caused by the spreading of the sea floor.

The depth of The Southern Ocean

- The majority of the Southern Ocean is made up of deep waters with few areas having shallow waters. It has typical depths of between 4,000 and 5,000 m over most of its extent with only limited areas of shallow water. The average depth of the Southern Ocean is around 3,350 meters.

- The deepest point in the Southern Ocean with a depth of over 7,000 meters, is in the South Sandwich Trench. This is located west of the Mid-Atlantic Ridge, between South America and Antarctica.

How was The Southern Ocean formed?

- Geologically the youngest of the oceans, it was formed when Antarctica and South America moved apart, opening the Drake Passage roughly 30 million years ago. The separation of the continents allowed the formation of the Antarctic Circumpolar Current. This current is the unique feature of the Antarctic Ocean due to its ability to flow the waters clockwise around the continent of Antarctica.

The Southern Ocean plays a crucial important role in regulating the earth's climate

- The Southern Ocean contains the coldest and densest water on earth and is notable for its high biological productivity.
- As the primary mixing zone between the world's major oceans, the Southern Ocean plays an important role in the circulation of water around the globe.
- It plays a key role in regulating the earth's climate through its currents, seasonal sea ice and by absorbing heat and carbon dioxide from the atmosphere.
- The Antarctic Circumpolar Current, The Southern Ocean's major current, butts up against Antarctica. Here the ocean plays a crucial role in the global climate system by bringing relatively warm Circumpolar Deep Water into contact with the ice fringing Antarctica.

The Southern Ocean: Is it actually an ocean?

- Since the late 18th century, the Southern Ocean has been a subject of contention to cartographers and geographers with some accepting the existence of the Southern Ocean but some believing that the ocean is just but a southern extension of the Pacific, Atlantic, and Indian Oceans.
- The waters of the Southern Ocean are distinct from the waters from surrounding oceans due to the presence of the Antarctic Circumpolar Current which causes the waters of the Southern Ocean to circulate rapidly around Antarctica, a fact used by International Hydrographic Bureau in their argument for the recognition of the Southern Ocean.

Climate of The Southern Ocean

- The Southern Ocean is known for its strong winds, intense storms, dramatic seasonal changes and cold temperatures.

Ocean temperatures

- The Southern Ocean's proximity to the south pole causes it to experience one of the most extreme weather conditions with the sea temperatures coming just above freezing point, ranging between negative (-) 2 degrees and 10 degrees Celsius.
- In winter the ocean freezes outward to 65 degrees south latitude in the Pacific sector and 55 degrees south latitude in the Atlantic sector, lowering surface temperatures well below 0 degrees Celsius.

Winds and storms

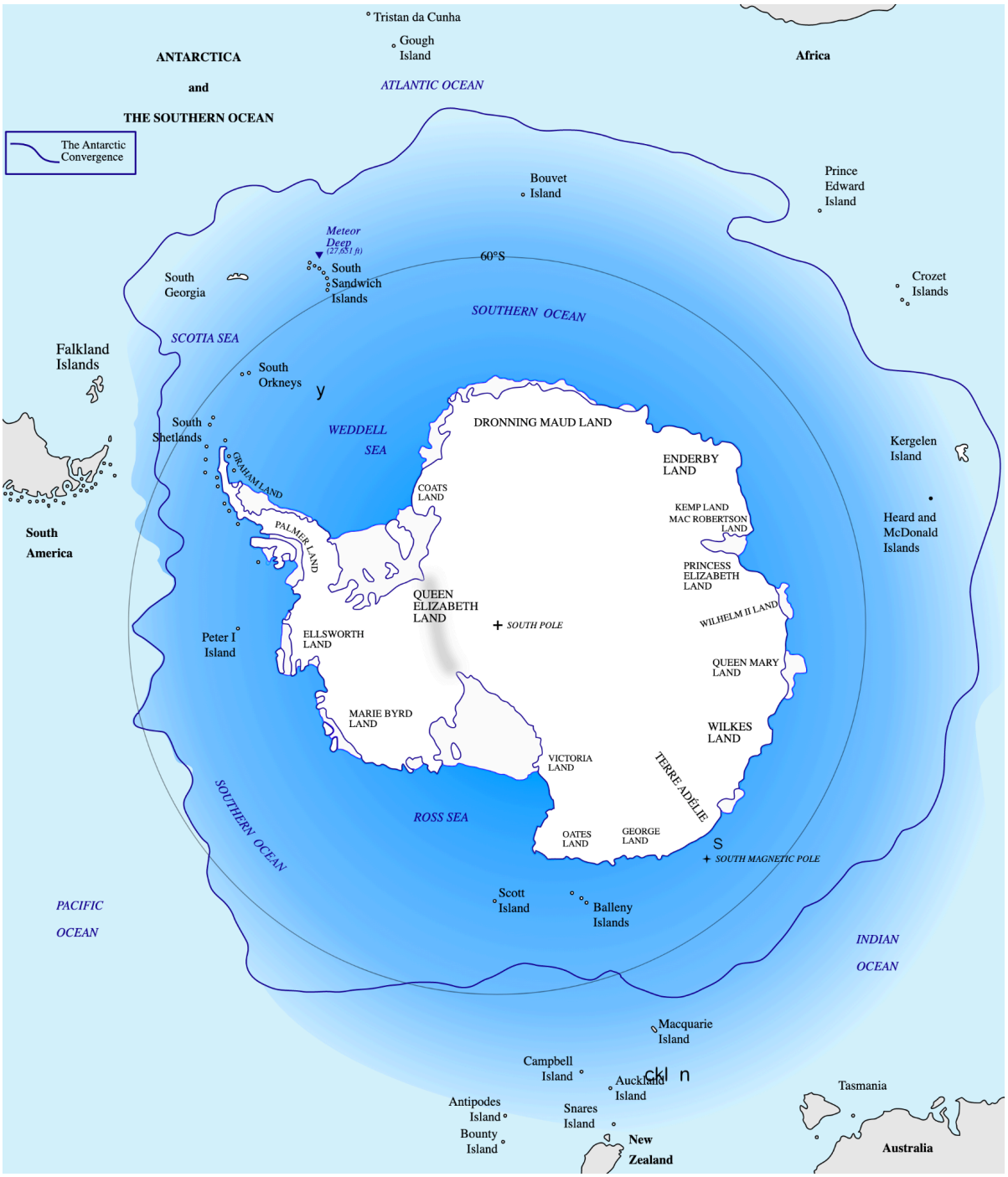
- The Southern Ocean is known for its wild and unpredictable weather, with winds that can reach up to 200 kilometers per hour and waves that can reach heights of up to 30 meters.
- Cyclonic storms travel eastward around the continent and frequently become intense because of the temperature contrast between ice and open ocean.
- The Roaring Forties, Furious Fifties and Screaming Sixties are all popular names for the strong westerly winds that blow, nearly uninterrupted, across the Southern Ocean, creating equally impressive waves. This ocean-area (latitude 40 - 60 south) has the strongest average winds found anywhere on Earth. This results in a massively energetic ocean surface.

The Antarctic Convergence: Where the cold Antarctic waters meet the warmer waters of the sub-Antarctic

- Around the northern limit of the Southern Ocean, there is a natural, biological boundary called the Antarctic Convergence, or Polar Front. The Antarctic Convergence is a natural boundary between the relatively warm subantarctic surface water and the cold Antarctic surface water. Here cold, dense Antarctic surface water dives beneath the warmer waters coming from the north without much mixing.
- North of the convergence, the water temperature near the surface sits at around 5.6 °C, ideal for marine species adapted to the subantarctic climate. South of the convergence, the water temperature drops dramatically to below 2 °C, creating the perfect conditions for uniquely Antarctic wildlife to flourish.
- A ship sailing south to Antarctica over the Antarctic Convergence will encounter a sharp drop in temperature between 49° and 55°S latitude. At that point one can usually detect subtle changes in both the ocean and the atmosphere. During the

southern summer, the sea temperature may drop from 7°C to 3°C at the convergence. During winter months the difference in sea temperatures may be as great as 10°C.

The Antarctic Covergence



Sub-divisions of The Southern Ocean

- Sub-divisions of oceans are geographical features such as seas, straits, bays, channels, and gulfs.
- The Southern Ocean is made up of 17 subdivisions. These subdivisions are all geographical features and include the Bransfield Strait, the Drake Passage, the Bellingshausen Sea, the Amundsen Sea, the McMurdo Sound, the Ross Sea, the Somov Sea, the Dumont D'Urville Sea, the Mawson Sea, the Tryoshnikova Gulf, the Davis Sea, the Cooperation Sea, the Cosmonauts Sea, the Riiser-Larsen Sea, the Lazarev Sea, and the Weddell Sea.

Water currents and flows in The Southern Ocean

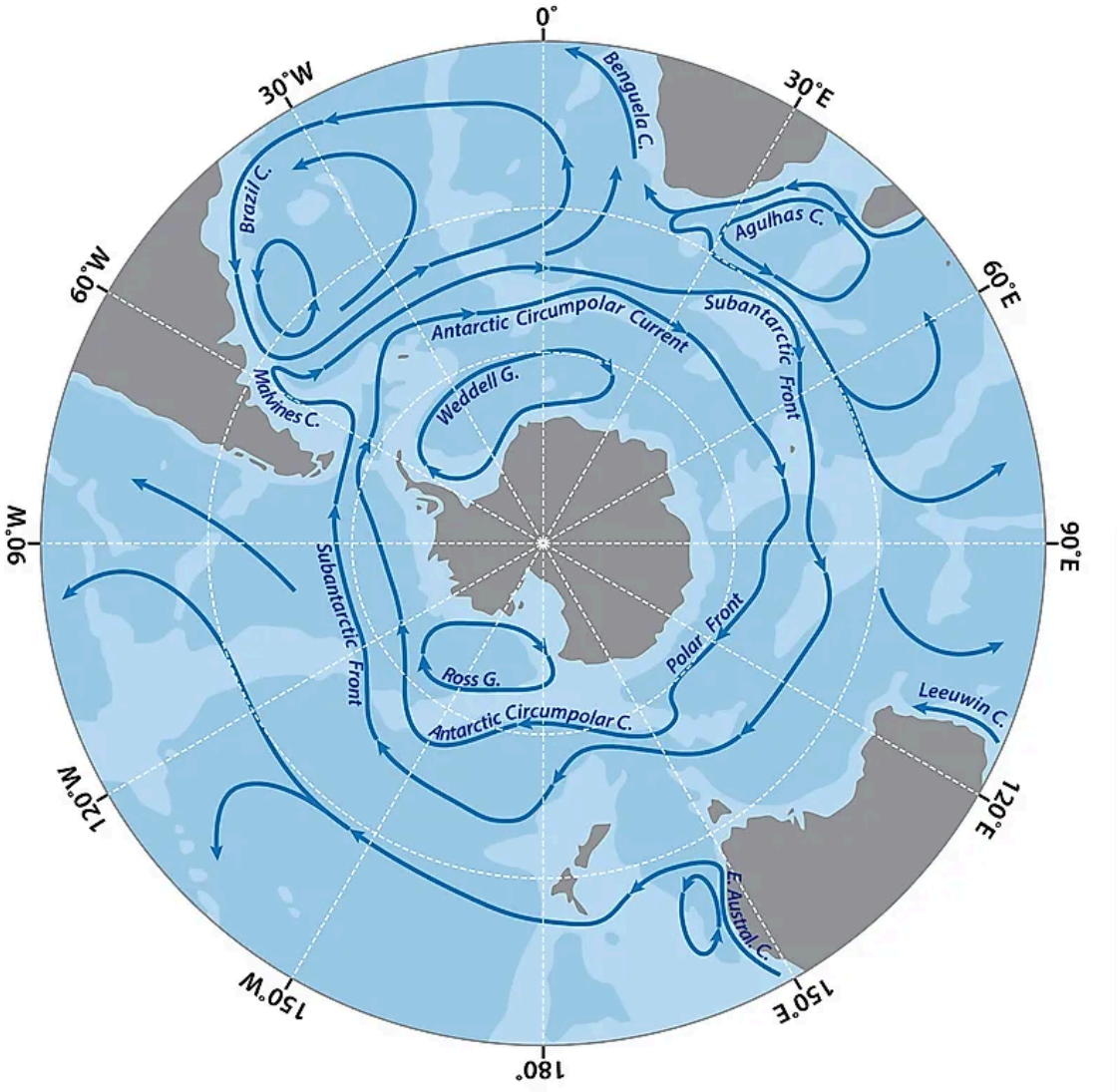
The Antarctic Circumpolar Current

- The Southern Ocean is dominated by the Antarctic Circumpolar Current (ACC) which is the longest, strongest and deepest-reaching current on earth.
- At 21,000 km in length, the ACC transports 130 million cubic metres per second of water – 100 times the flow of all the world's rivers. It transports enough water to fill Lake Ontario in just a few hours.
- The ACC circles from west to east (clockwise) around Antarctica. Ships use this current to move faster when going in the same direction. If going in the opposite direction though, the current slows ships down significantly.
- To the south, the ACC butts up against Antarctica. Here the ocean plays a crucial role in the global climate system by bringing relatively warm Circumpolar Deep Water into contact with the ice fringing Antarctica.
- The ACC helps keep Antarctica cold by keeping warm water from coming close. The ACC brings up cold water from the deep ocean and prevents warmer water from

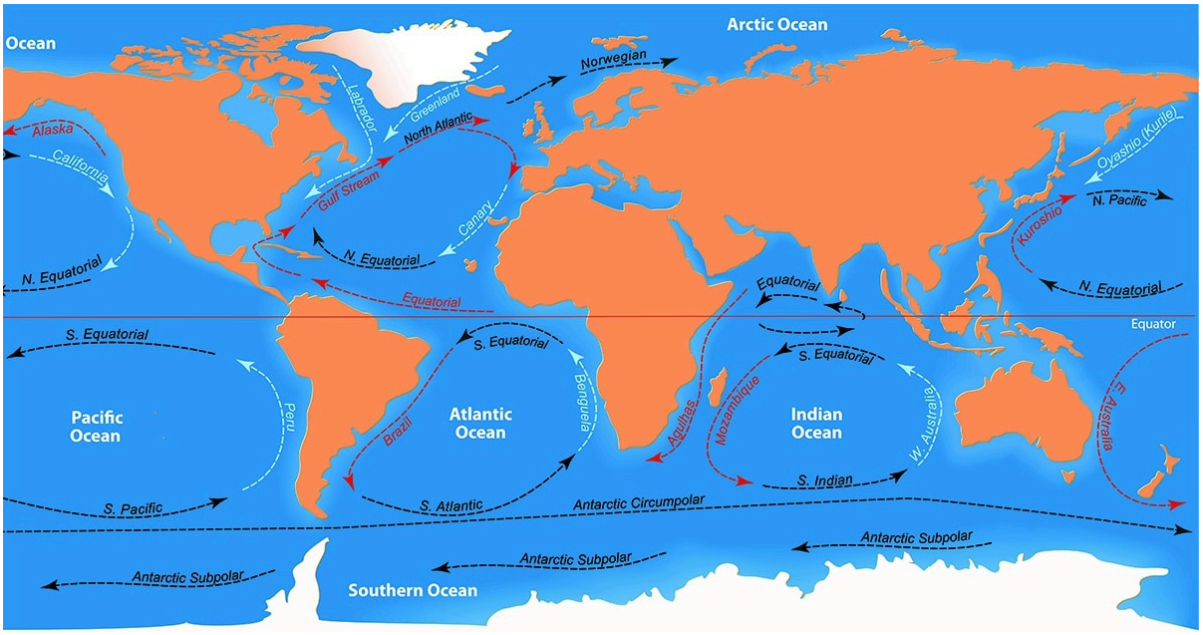
reaching the continent. In contrast, the Arctic Ocean receives warm water from the Atlantic Ocean through the Gulf Stream, which helps to moderate its temperatures.

- The ACC helps nourish the continent's rich marine life with its convection currents. Warm water rises and cold water sinks, bringing nutrients with it across the levels of the water.

The Antarctic Circumpolar Current flowing clockwise around Antarctica



The Antarctic Circumpolar Current relative to other currents in the world's oceans



The East Wind Drift

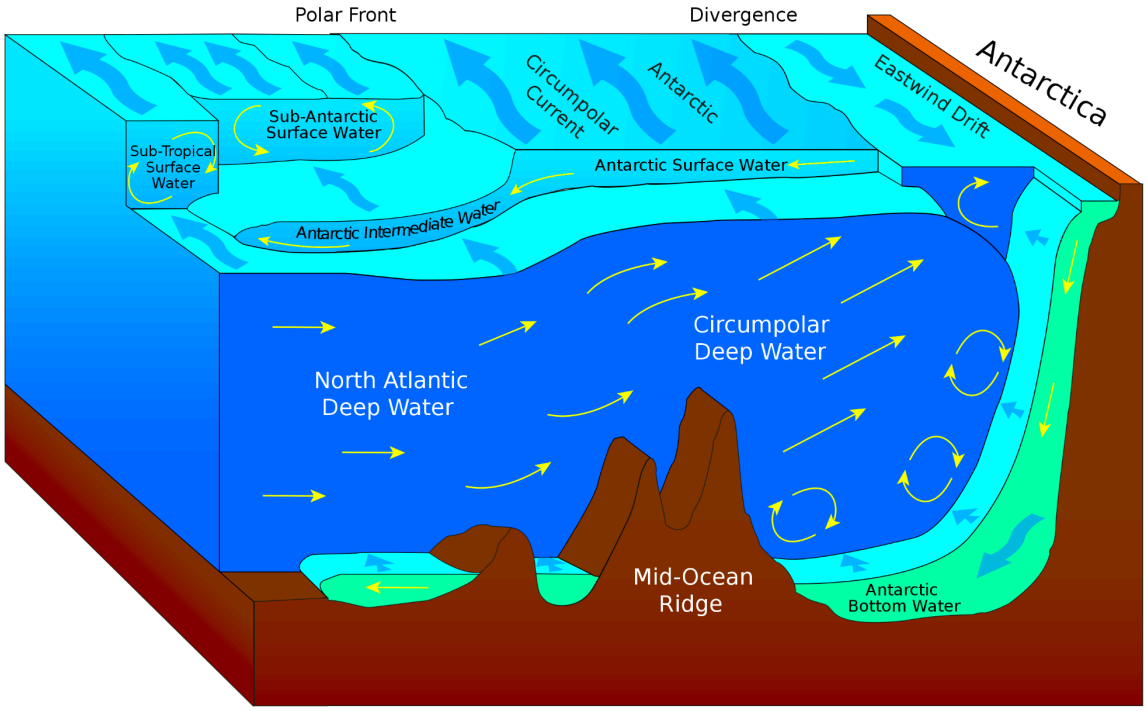
- Farther south, close along the coast of the continent, easterly winds cause a westward-flowing current called the East Wind Drift. Along much of the coast, particularly East Antarctica, this is a relatively narrow band, but where it is deflected by deep embayments, such as the Weddell, Bellingshausen, and Ross Seas, it forms clockwise gyres that become important in how ice travels through the system.

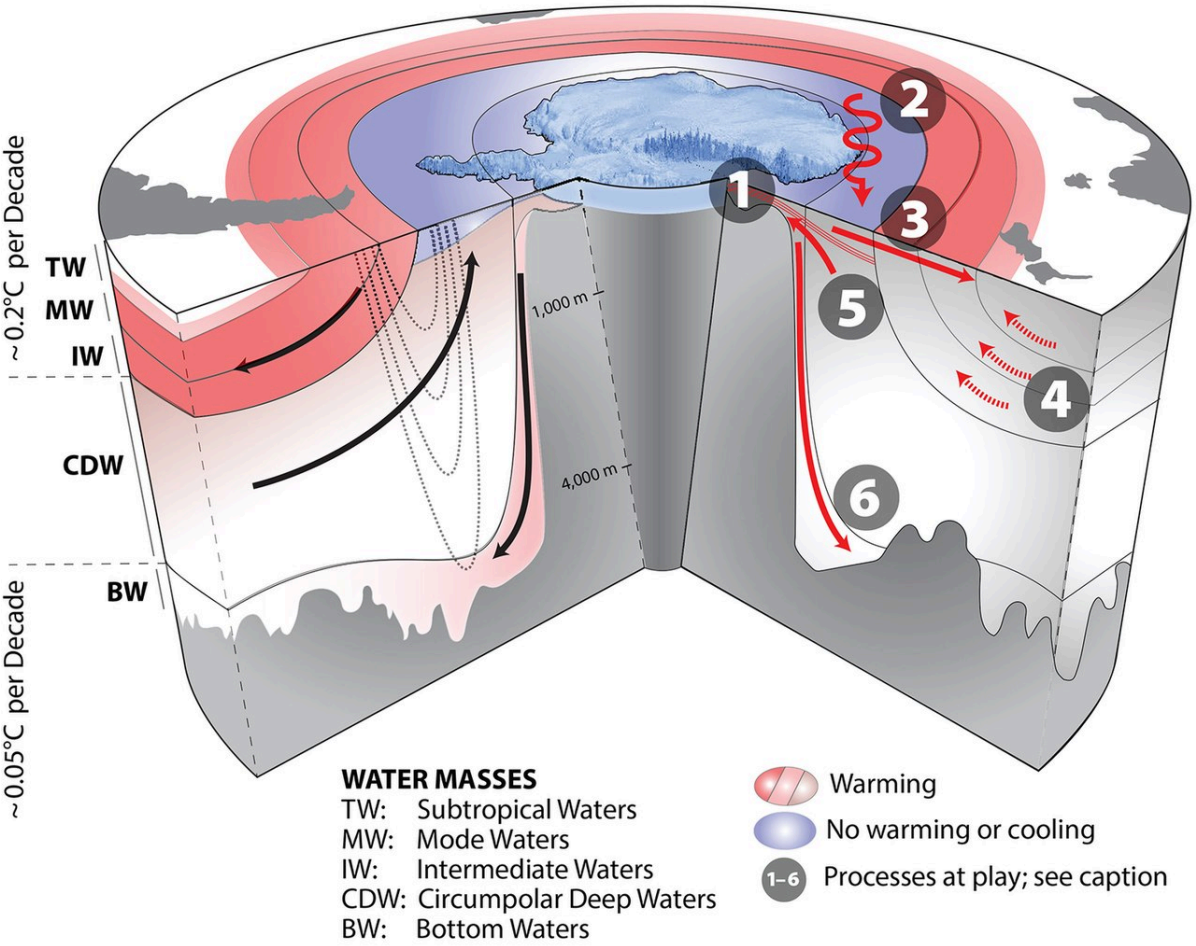
Upwelling and mixing of different masses of water

- The Antarctic Ocean is made up of three distinct masses of water in different layers which differ in their temperatures, salinities,
  and directions of flow.
  The three sandwiched layers are driven by westerly winds in constant, eastward-flowing spirals around Antarctica. The upper and lower layers also move gradually northward, carrying cold waters from the Antarctic to the tropics, while the middle layer flows southward, replacing the water lost to the other two currents, and brings nutrients and warmer water from temperate and tropical regions.
- These three distinct masses of water mix both horizontally and vertically in eddies. Relatively warm subtropical water is mixed with the waters down south while deep cool water from the North Atlantic rises back up toward the surface and colder polar water masses mix northward and sink back down. This complex interplay is guided by the wind and by the shape of the seafloor.
- Large-scale upwelling of cold water occurs in The Southern Ocean. Strong westerly winds blow around Antarctica, driving a significant flow of water northwards. This is actually a type of coastal upwelling. Since there are no continents in a band of open latitudes between South America and the tip of the Antarctic Peninsula, some of this

water is drawn up from great depths. The Southern Ocean upwelling represents the primary means by which deep dense water is brought to the surface.

Mixing and upwelling of different water masses in The Southern Ocean





The Southern Ocean is important as a driver of the entire world's ocean systems

- During the seasonal cycle, Antarctica nearly doubles in size as a massive area of sea around the continent freezes in the winter. As that sea ice forms, much of the salt in the sea water is excluded from the growing ice crystals resulting in the water just below the forming ice becoming much more saline. This salty and cold water is heavier than the surrounding water and huge amounts sink around the continental slope and become the Antarctic bottom water current. When that hypersaline cold water sinks from the surface, mid-level water is pulled up at the coast as upwellings to replace it and a current spreads outward from the coast. As it travels north, it eventually encounters the warmer subantarctic water to form the Antarctic Convergence.
- Some scientists think that the Southern Ocean circulation will slow down as Earth warms. This will most likely increase the rate of climate change.

The Southern Ocean plays a significant role in the global carbon and oxygen cycles

- The Southern Ocean plays a crucial role in regulating the Earth's carbon and oxygen cycles. It stores large amounts of carbon through oceanic uptake and phytoplankton growth, while also producing oxygen through photosynthesis and gas exchange.

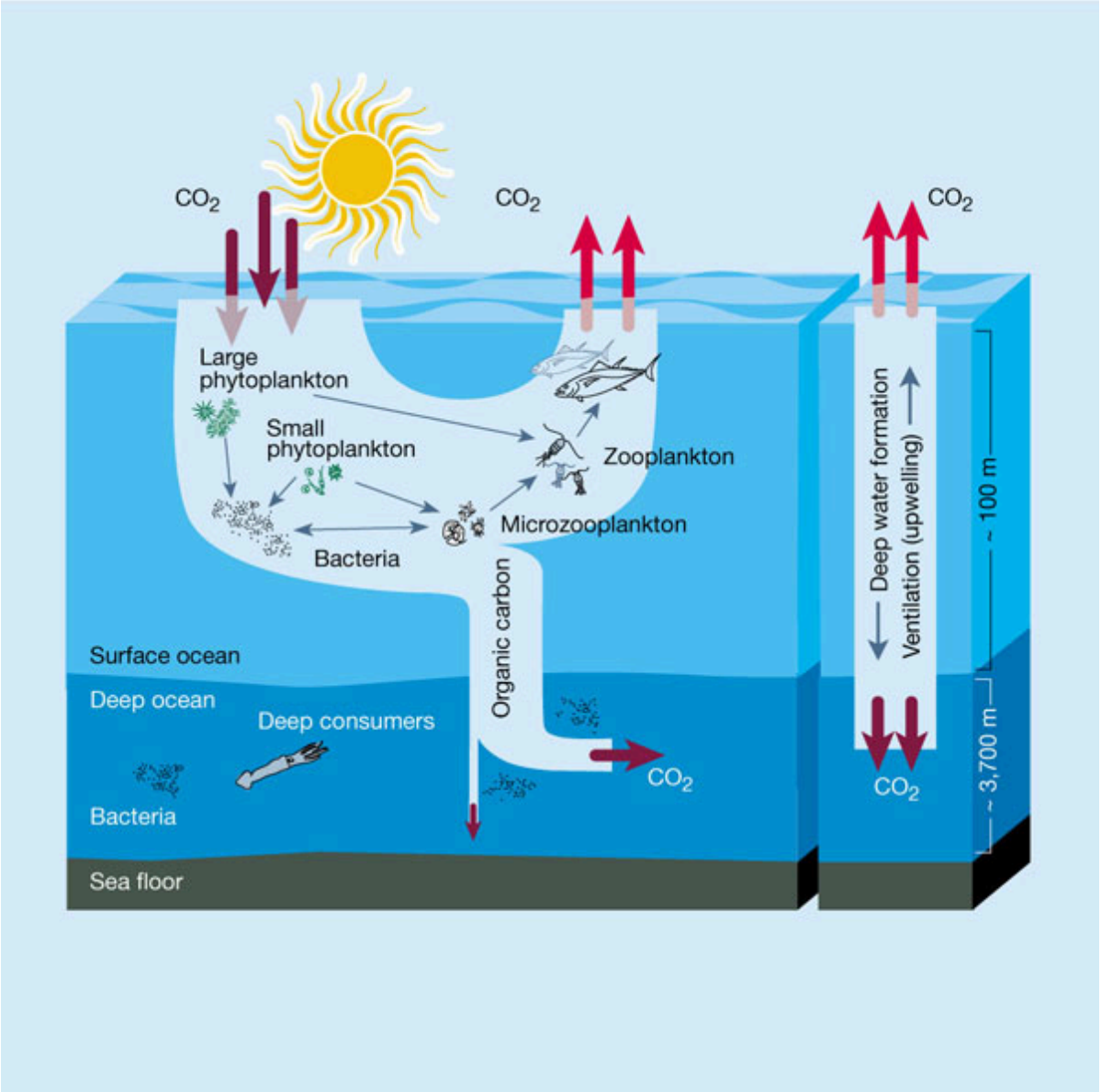
The Southern Ocean is a major sink for carbon dioxide

- The Southern Ocean absorbs much more carbon from the atmosphere than it releases and is thus an important shield against some of the effects of human-caused greenhouse gas emissions.
- Measurements of CO2 and other ocean properties suggest that 40% of the human-produced CO2 in the ocean, worldwide, was originally absorbed from the atmosphere into the Southern Ocean, making it one of the most important carbon sinks on our planet.

How The Southern Ocean absorbs carbon

- The Southern Ocean is home to a large number of phytoplankton, which are tiny plants that photosynthesize and absorb CO2 from the water. When these phytoplankton die, they sink to the ocean floor, taking the absorbed CO2 with them, thus removing carbon from the surface ocean layer.
- The Southern Ocean absorbs large amounts of CO2 from the atmosphere through a process called "oceanic uptake." Cold water from the deep ocean rises to the surface through a process called upwelling. Once at the surface, that colder water absorbs CO2 in the atmosphere – often with the help of photosynthesizing organisms called phytoplankton – before sinking again.

The carbon cycle



How The Southern Ocean produces oxygen

- Photosynthesis by the Southern Ocean phytoplankton also produces oxygen as a byproduct. Oxygen is released into the atmosphere through the process of gas exchange, where the oxygen-rich surface waters mix with the atmosphere.
- Moreover, the Southern Ocean is also the site of the "oceanic conveyor belt," which is a global-scale circulation system that distributes oxygen throughout the world's oceans. The conveyor belt transports oxygen-rich water from the Southern Ocean to the other ocean basins, which supports marine life and helps regulate the Earth's climate.

The Southern Ocean slows the pace of climate change by absorbing heat

The Southern Ocean absorbs far more heat than any other ocean

- The planet is heating up due to carbon dioxide emissions. Over the past 50 years, the world's oceans have absorbed over 90 percent of the excess heat produced by human activity.
- Although it is the second smallest of the five ocean basins, the Southern Ocean has absorbed as much as 75 percent of the excess heat absorbed by the ocean as a whole. Without this valuable 'ecosystem service', temperatures on earth would be much warmer today.
- The Southern Ocean is a particularly powerful heat sink as it is much colder than the air above it, and has some of the strongest currents on the planet.

How The Southern Ocean absorbs heat

- In the Southern Ocean, a unique network of currents connecting surface waters with the deep ocean draw heated surface water down into deeper layers of the ocean, where it will stay for centuries, allowing cooler water to take its place and absorb more heat.
- Antarctica is surrounded by strong westerly winds. These winds blow over what is effectively an infinite distance, cycling uninterrupted at southern latitudes, which continuously draws cold water masses to the surface. The waters are pushed northward, readily absorbing vast quantities of heat from the atmosphere, before sinking into the ocean's interior at around 45°S, north of the eastward flowing Antarctic Circumpolar Current.
- The ocean has a higher heat capacity than air, which means it can absorb heat without its temperature increasing at the same rate. However, this process will become less efficient as the ocean heats up, and there is evidence it is already beginning to slow down.

The seasonal sea ice of The Southern Ocean plays a vital role in regulating climate and supporting ecosystems

The sea surface of The Southern Ocean around Antarctica freezes each winter

- The surface waters freeze to form a layer of ice 1–3 meters thick and extending 100–200 kilometers offshore, and may extend about 800 kilometers from the coast in some areas. This enormous seasonal process effectively doubles the area of the Antarctic ice blanket.
- The annual cycle of sea ice growing and melting around Antarctica is one of the defining rhythms of our planet and an important facet of the Southern Ocean.

The sea ice affects climate by reflecting heat from the sun

- The sea ice has a major effect on world climate by increasing the amount of reflection of incoming radiant energy from the sun, and reducing its penetration into the sea.

The sea ice affects climate by playing a role in global ocean circulation

- When the new ice grows, the salt from the freezing sea water gets squeezed out and mixes with the seawater below, creating colder and saltier seawater that sinks to the seafloor and drains northward. This global transport system sees water sinking at the poles, flowing north to be mixed upwards in a cycle lasting close to 1,000 years. This is part of the engine that drives the global ocean conveyor - the mass movement of water that helps regulate energy in the climate system.

The sea ice plays an essential role in the Antarctic food web

- The underside of sea ice is a substrate where algae grows through the winter and that algae is extremely important as food for Antarctic krill through the winter. Krill are small crustaceans that are a critical part of Southern Ocean food webs. They provide an essential food source for whales, seals, penguins and other birds.

Most animals of Antarctica are adapted to living with sea ice

- Crabeater seals, Ross seals and leopard seals all give birth on floating pack ice. Weddell seals use fast ice through the winter and mostly give birth to their pups on fast ice if it is present.
- Emperor penguins breed on sea ice in the winter, and form colonies as soon as the ice is strong enough (in April). The other penguins all breed on land, during the summer, but they live on the edge of the pack ice for the rest of the year. It greatly extends their feeding ranges.

Sea ice plays a role in absorbing carbon dioxide

- The underside of sea ice provides an important habitat and shelter for Antarctic life including microscopic algae and krill, which participate in the climate system by

absorbing carbon into the food web, where it is eventually stored in the ocean for centuries or longer.

Due to climate change, The Southern Ocean is heating up

- Some parts of the Southern Ocean are heating up more quickly than others, with marked temperature increases noted across the Antarctic Peninsula, the Weddell Sea, and under some ice shelves in both East and West Antarctica.
- On the west Antarctic Peninsula, summer sea surface temperatures have increased by over 1°C since 1955. This is roughly three times the global average. To the east of the Peninsula in the Weddell Sea, deep layers of the ocean are warming five times faster than the rest of the ocean at the same depth. Further south, warm currents have been detected under parts of the West Antarctic and East Antarctic ice sheet, melting their floating ice shelves from below.

Sea ice cover is declining due to climate change

- The Southern Ocean is one of the regions in which rapid climate change is the most visibly taking place. In this region, small perturbations in temperature lead to major environmental perturbation.
- Winter sea ice cover has declined dramatically. In 2019, winter sea ice cover lasted for 90 days less than in 1979. Sea ice helps regulate the global climate, and any decrease in its extent or duration has widespread impacts across the climate system. Sea ice reflects more heat than it absorbs, (between 50 and 90 percent, more when covered with fresh snow) helping to keep the climate cool. It also insulates the ocean from the cold air above it.

Climate change is aso causing the ice shelves of Antartica to recede and even collapse

- Not only is Antarctic ice melting more quickly than new snow can replace it, but the rate of loss due to melting and calving is increasing. Each year, the ice sheet is shrinking more rapidly. By the year 2020, the speed of ice loss in Antarctica had multiplied sixfold over thirty years.
- Around the Antarctic coastline, the ice sheet flows out into floating plates of ice called ice shelves. Ice shelves help stabilize the ice sheet and slow their flow, but warming ocean temperatures are causing them to melt from below.

Melting sea ice and ice sheets can have profound effects

- It can cause an enormous impact around the globe including disturbances to the Southern Ocean food web, the melting of Antarctic ice shelves and changes in the conveyor belt of ocean currents.

Currents interrupted

- There are important ocean currents that help regulate the climate, which begin in the polar regions. Changes in ocean temperatures already appear to be affecting ocean circulation in some regions, disrupting the climate and resulting in unpredictable new climate and weather patterns into the future.

Rising sea levels

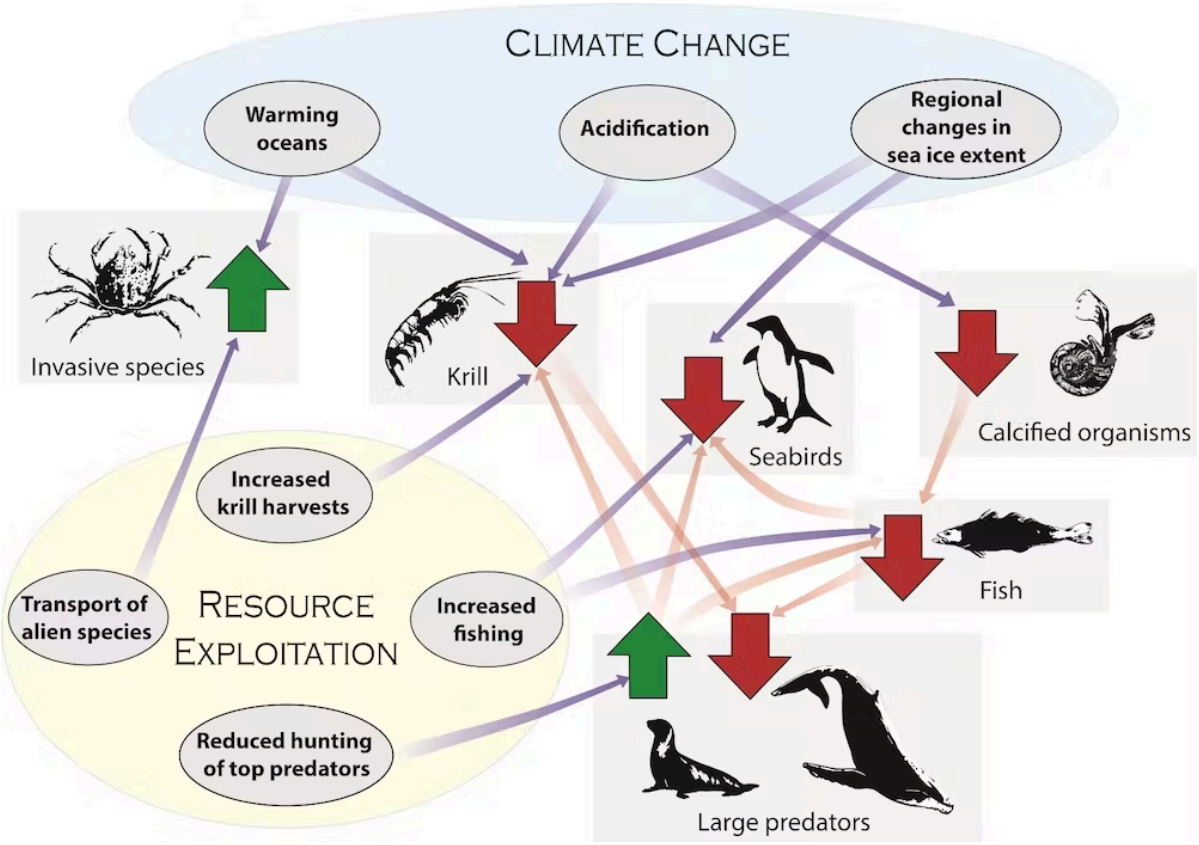
- Warm water takes up more space than cold water due to thermal expansion. As the ocean warms up it is expanding, contributing to rising sea levels. Rising sea levels have many impacts on low-lying communities: contaminated freshwater sources, farmland inundated with saltwater and flooded homes.
- If Antarctica's ice sheets melted, the world's ocean would rise by over 61 meters.

Intense storms

- Heat from the water at the surface of the ocean provides energy for storms. Warmer oceans and increased air temperatures together result in more evaporation, higher rainfall and more powerful storms.

Antarctic ecosystems under threat

- Antarctic krill (Euphausia superba) are at the heart of the Antarctic food web, providing a vital food source for many Antarctic species, including penguins, seals and whales. But research has shown that a warming ocean and reduced sea ice means that fewer krill eggs will hatch, and fewer will develop successfully from larvae to juveniles. This will have a particular impact on species like crabeater seals and Adélie penguins, which rely heavily on krill as a food source. There is already evidence of Adélie penguin colonies vanishing from the northern Antarctic Peninsula. Their disappearing colonies have been linked to warmer oceans, reduced sea ice cover and declining krill populations.



The Southern Ocean ecosystem

The Southern Ocean is one of the most productive and unique ecosystems on earth

- Powerful currents, cold temperatures and nutrient and oxygen-rich waters make the Southern Ocean one of the most productive marine ecosystems on Earth. Virtually all the wildlife we associate with Antarctica, from tiny krill to the massive Antarctic blue whale, rely on the ocean and ice for their survival.
- In summer billions of microscopic algae (phytoplankton) proliferate, spreading into blooms large enough to be seen from space. These single-celled marine plants provide nourishment for small invertebrates, shellfish, and Antarctic krill (Euphausia superba).
- South of the Antarctic convergence there is a zone of wind-driven upwelling, where water rises from the depths bringing nutrients to the surface. These nutrients act as a fertilizer for the ocean, and when they’re combined with sunlight, marine life flourishes.

- The Southern Ocean has a unique ecosystem, with many species of marine life found only in its waters, such as emperor penguins, southern elephant seals, and the Antarctic krill, which is a key component of the ocean's food chain.
- The cold Southern Ocean is also home to hot hydrothermal vent systems. These communities, which include huge densities of crustaceans and echinoderms, get their energy from chemicals that seep out of Earth’s crust, rather than from the Sun..

The Southern Ocean is home to many marine animals and birds

- Despite the cold temperatures, the Southern Ocean is teeming with marine animals and has one of the most diverse habitats of marine animals anywhere in the world. The Southern Ocean is home to more than 9,000 known marine species — and expeditions and studies keep revealing more.

Mammals

- The marine mammals found in the Southern Ocean include the largest animals in the history of the world; the blue whale which is found in significant numbers around the ocean due to the abundance of Antarctic krill on which the blue whale feeds. Other marine mammals of the Southern Ocean are orcas, the Antarctic fur seals, Weddell seals and leopard seals. The biggest of the seals are the elephant seals which weigh up to 4,000kg.

Birds

- The ocean is home to a variety of birds including the usual Antarctic resident, the penguin which has several species living in the Southern Ocean such as the emperor penguin, the rockhopper penguin and the king penguin. Other birds found in the Southern Ocean are albatross, terns, petrels, and gulls.
- The rocky shores of mainland Antarctica and its offshore islands provide nesting space for over 100 million birds every spring. These nesters include species of albatrosses, petrels, skuas, gulls and terns.

Fish

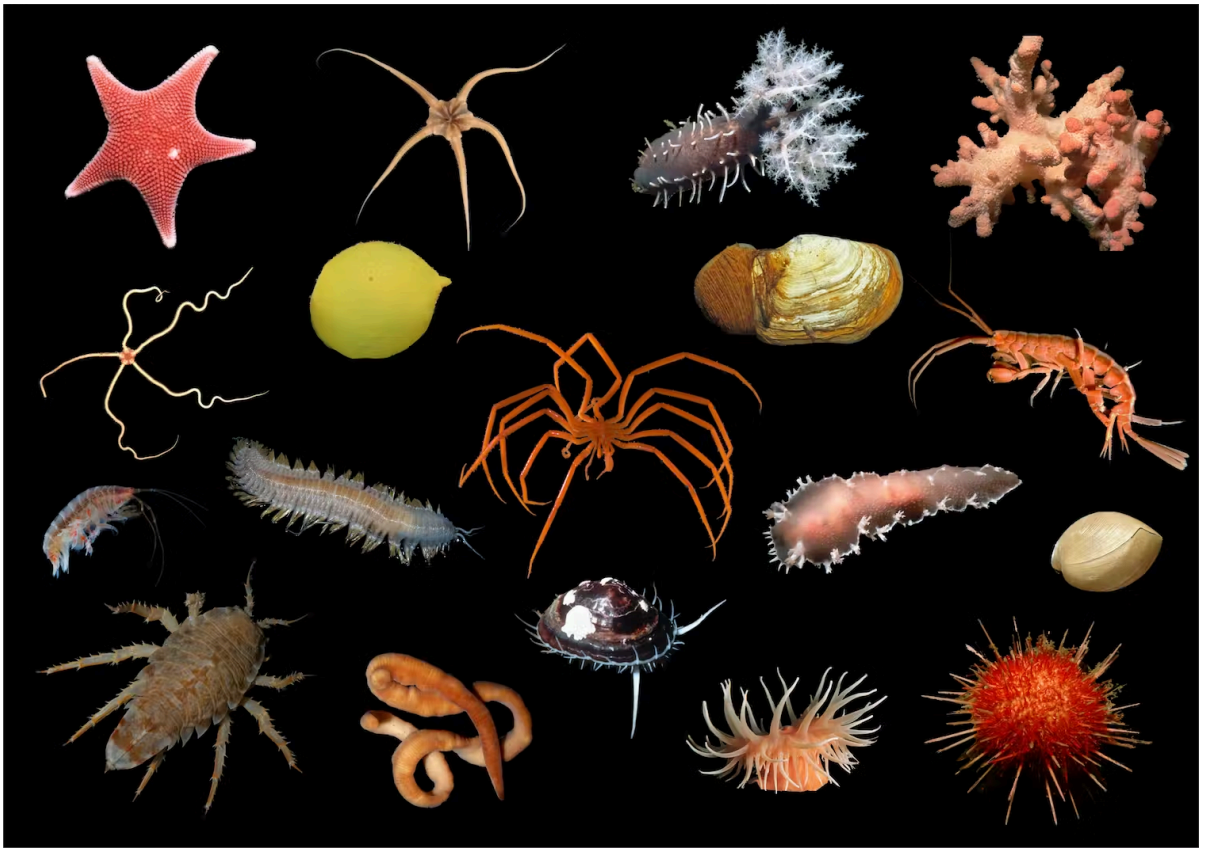
- There are relatively few fish species in few families in the Southern Ocean. The most species-rich family are the snailfish, followed by the cod icefish and eelpout.
- Some fish species are so well adapted to the oxygen-rich cold waters that they no longer produce red blood cells but instead produce antifreeze proteins in their blood to help them survive in the subzero waters.

Invertebrates

- Antarctic invertebrates make up more than 90% of the species in the Southern Ocean. More than 50% are unique to this ocean.

- These invertebrates are often much larger than their relatives in more northern, warmer waters. This phenomenon is know as “polar gigantism” and is found across many groups, with giant sea spiders, huge sponges and scale worms the size of a forearm. Nobody is quite sure why Antarctic invertebrates grow so large, but it may be related to high oxygen levels, slow growth rates or the absence of key predatory groups such as sharks and brachyuran crabs.
- There are around 70 cephalopod species in the Southern Ocean, the largest of which is the colossal squid, which at up to 15 metres, is among the largest invertebrate in the world.
- Five species of krill (small free-swimming crustaceans), have been found in the Southern Ocean. The Antarctic krill is one of the most abundant animal species on earth, with a biomass of around 500 million tonnes. Each individual is 6 centimetres long and weighs over 1 gram. The swarms that form can stretch for kilometres, with up to 30,000 individuals per 1 cubic metre, turning the water red. These small, shrimp-like crustaceans form the basis of many Antarctic marine animals’ diets, including penguins, seals and whales.

Invertebrates of The Southern Ocean



Human exploitation of The Southern Ocean ecosystem

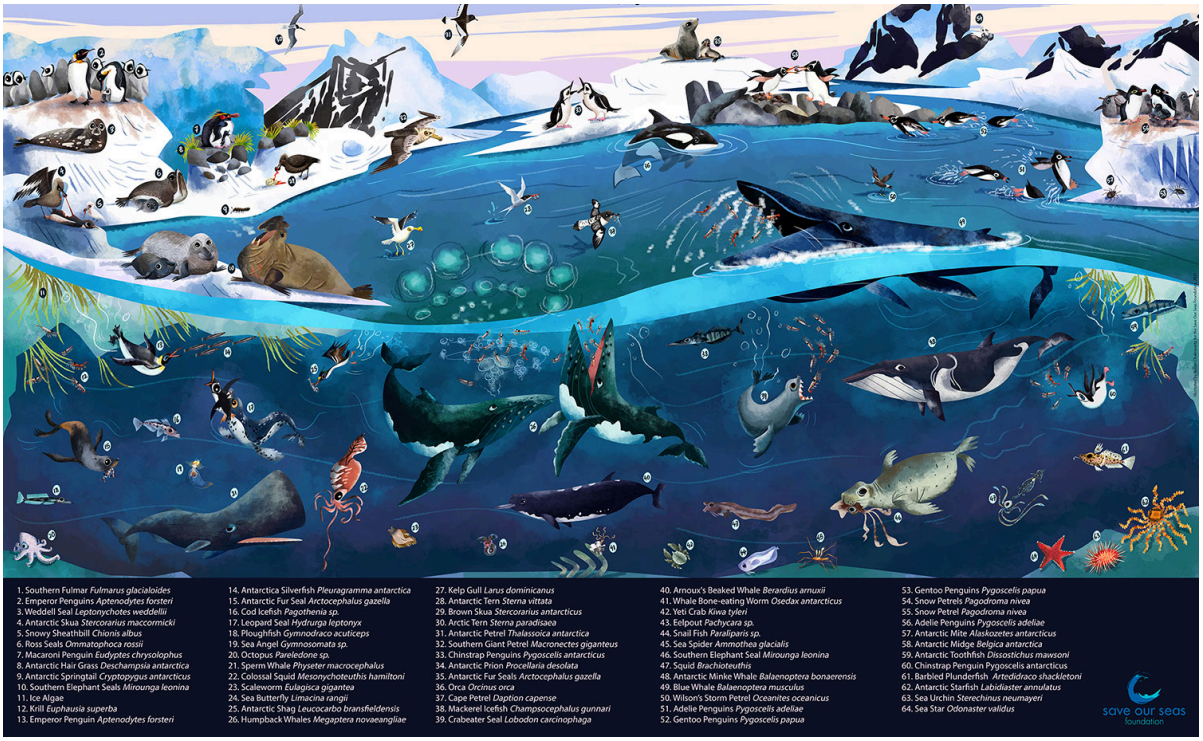
- The most voracious predators in the Southern Ocean are humans. Antarctica might be remote, but in the 200 or so years since its discovery, the seas around Antarctica

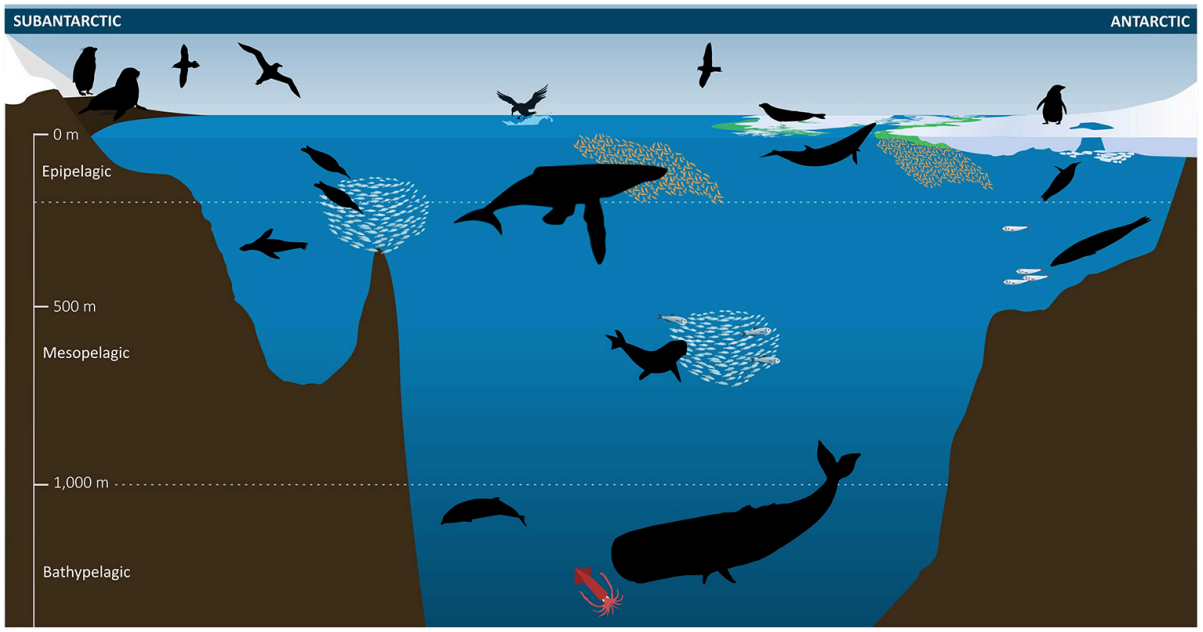
have been heavily exploited by people. First came the sealers, then the whalers, driving species to the brink of extinction. Even penguins were harvested for their oil.

- More recently, fish and krill (which is fished for food or dietary supplements) have been the main targets, and populations of some species have declined sharply as a consequence.

Protection of The Southern Ocean's ecosystem

- Over the several decades since the Antarctic Treaty came into force, we've seen that nations can work together to help resolve challenges facing the Antarctic. One example is the establishment of Antarctic Marine Protected Areas.
- Fishing in the Southern Ocean can be hard to regulate because these waters do not belong to any one nation. To help manage the impact of fisheries, quotas that limit catches are now managed by the Commission for the Conservation of Antarctic Marine Living Resources.
- The Southern Ocean is recognized as a unique and fragile ecosystem, and efforts are being made to protect it from threats such as overfishing, pollution, and climate change.




SUBANTARCTIC
ANTARCTIC
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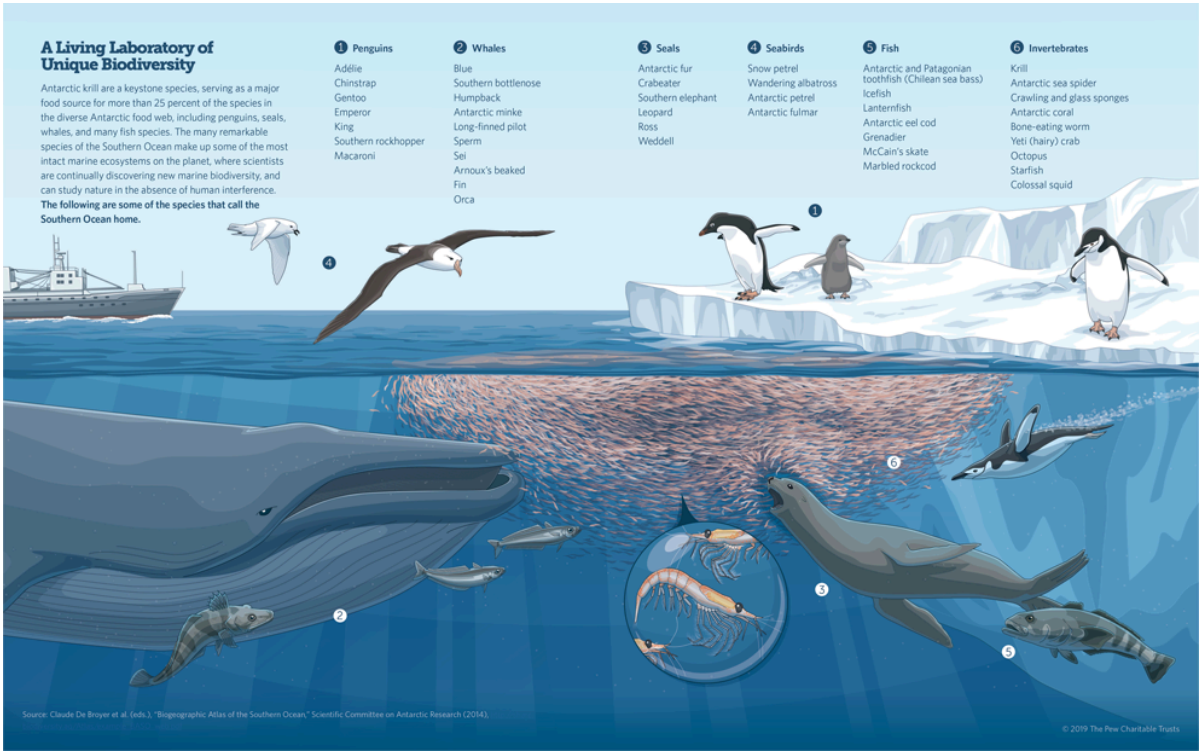
A Living Laboratory of Unique Biodiversity
Antarctic krill are a keystone species, serving as a major food source for more than 25 percent of the species in the diverse Antarctic food web, including penguins, seals, whales, and many fish species. The many remarkable species of the Southern Ocean make up some of the most intact marine ecosystems on the planet, where scientists are continually discovering new marine biodiversity, and can study nature in the absence of human interference.
The following are some of the species that call the Southern Ocean home.
1 Penguins
Adélie
Chinstrap
Gentoo
Emperor
King
Southern rockhopper
Macaroni
2 Whales
Blue
Southern bottlenose
Humpback
Antarctic minke
Long-finned pilot
Sperm
Sei
Arnoux's beaked
Fin
Orca
3 Seals
Antarctic fur
Crabeater
Southern elephant
Leopard
Ross
Weddell
4 Seabirds
Snow petrel
Wandering albatross
Antarctic petrel
Antarctic fulmar
5 Fish
Antarctic and Patagonian toothfish (Chilean sea bass)
Icefish
Lanternfish
Antarctic eel cod
Grenadier
McCain's skate
Marbled rockcod
6 Invertebrates
Krill
Antarctic sea spider
Crawling and glass sponges
Antarctic coral
Bone-eating worm
Yeti (hairy) crab
Octopus
Starfish
Colossal squid
Source: Claude De Broyer et al. (eds.), "Biogeographic Atlas of the Southern Ocean," Scientific Committee on Antarctic Research (2014).
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