

SCIENCE NORTH  SCIENCE NORD
SUDBURY ONTARIO CANADA

presents

Ends of the Earth: From Polar Bears to Penguins

A Special Exhibition

At the San Diego Natural History Museum
May 14, 2011–April 15, 2012



EDUCATORS GUIDE

ARCTIC

ANTARCTIC



Supporting Sponsor

QUARK
EXPEDITIONS
quarkexpeditions.com

Inside:

- Key concepts to prepare for your visit
- Gallery inquiries and classroom activities for your students
- Useful Web Resources
- California Content Standards

Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

Dear Educator,

Welcome to *Ends of the Earth: From Polar Bears to Penguins*. This guide includes an exhibition overview, web resources, and curriculum to help make your Museum visit an engaging and educational experience.

California State Content Standards are included. Full text of standards is available at <http://www.cde.ca.gov/index.asp>.

If you have questions related to this guide, please call the Museum Education Department at 619.255.0278 or email education@sdnhm.org.

If you would like to book a school group visit, please call 619.255.0210.

Presentation of *Ends of the Earth: From Polar Bears to Penguins* at the San Diego Natural History Museum is made possible with generous funding from:
Bank of America Charitable Foundation; Ellen Browning Scripps Foundation; Sempra Energy Foundation; and the County of San Diego Board of Supervisors, at the recommendation of Supervisor Ron Roberts and Supervisor Pam Slater-Price.

SCIENCE
NORTH  SCIENCE
NORD
SUDBURY ONTARIO CANADA



QUARK
EXPEDITIONS
quarkexpeditions.com



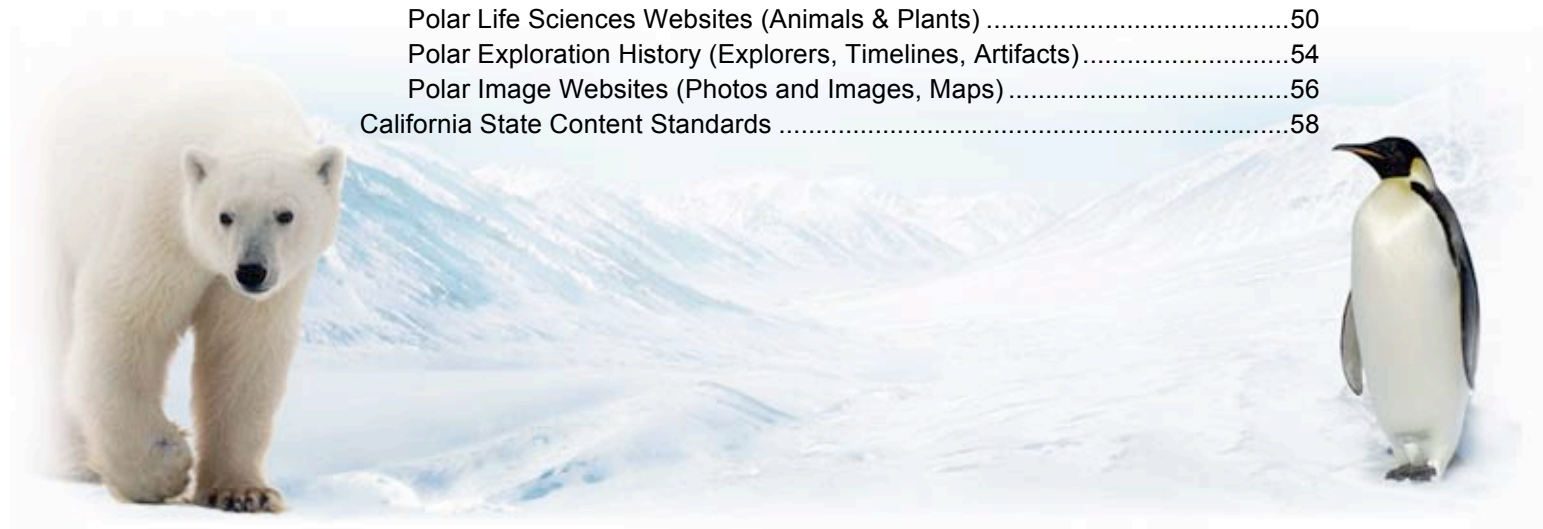
Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

Contents

Introduction	4
Exhibit Overview	5
Polar Geography	6
What is the Arctic?	6
Explore Arctic Geography in these exhibits:	8
What is the Antarctic?	9
Explore Antarctic Geography in these exhibits:	10
Polar Wildlife	11
Arctic Wildlife	11
Explore Arctic Wildlife in these exhibits:	13
Antarctic Wildlife	14
Explore Antarctic Wildlife in these exhibits:	17
People and the Poles	18
Explore People and the Poles in this exhibit:	19
Polar Explorers	20
Explore Polar Explorers in these exhibits:	21
Climate Change and the Poles	22
Explore Climate Change and the Poles in these exhibits:	24
Science Activities	25
Try a Blubber Glove!	25
What's so Different About a Penguin Feather?	28
How Unique is Polar Bear Fur?	30
Why are the Polar Regions in either total darkness or in total light?	31
Tracking Polar Bears	34
Compare Bear Skulls!	36
Compare Bear Claws!	38
Some Useful Web Resources	40
Educational Polar Websites (Lesson Plans, Activities, Worksheets)	40
General Polar Websites (Expeditions, Research, Resources)	42
The Cryosphere (Ice & Snow on Earth)	46
Climate Change and the Polar Regions Websites	47
Polar Peoples Websites	49
Polar Life Sciences Websites (Animals & Plants)	50
Polar Exploration History (Explorers, Timelines, Artifacts)	54
Polar Image Websites (Photos and Images, Maps)	56
California State Content Standards	58



Introduction

This Education Guide to the traveling exhibit *Ends of the Earth: From Polar Bears to Penguins* is a tool for educators to explore the many fascinating aspects of the two Polar Regions - the Arctic and the Antarctic. *Ends of the Earth* explores the key themes of polar geography, polar wildlife and their adaptations, polar exploration, and the impact of climate change on the poles.

This guide provides background information on these themes, descriptions of participatory activities, as well as references and other resources. The guide may be used to prepare the students for a visit to the exhibition, as a follow up to the visit, or to simply stimulate exploration of themes not covered within the exhibition. The suggested activities can be adapted to various grade levels and complement other studies in science, biology, geography, and history.



Exhibit Overview

The Earth's poles may well be the last great wilderness on Earth, and for them to have survived as wilderness this long is stark testament to the challenges they impose on any human interlopers.

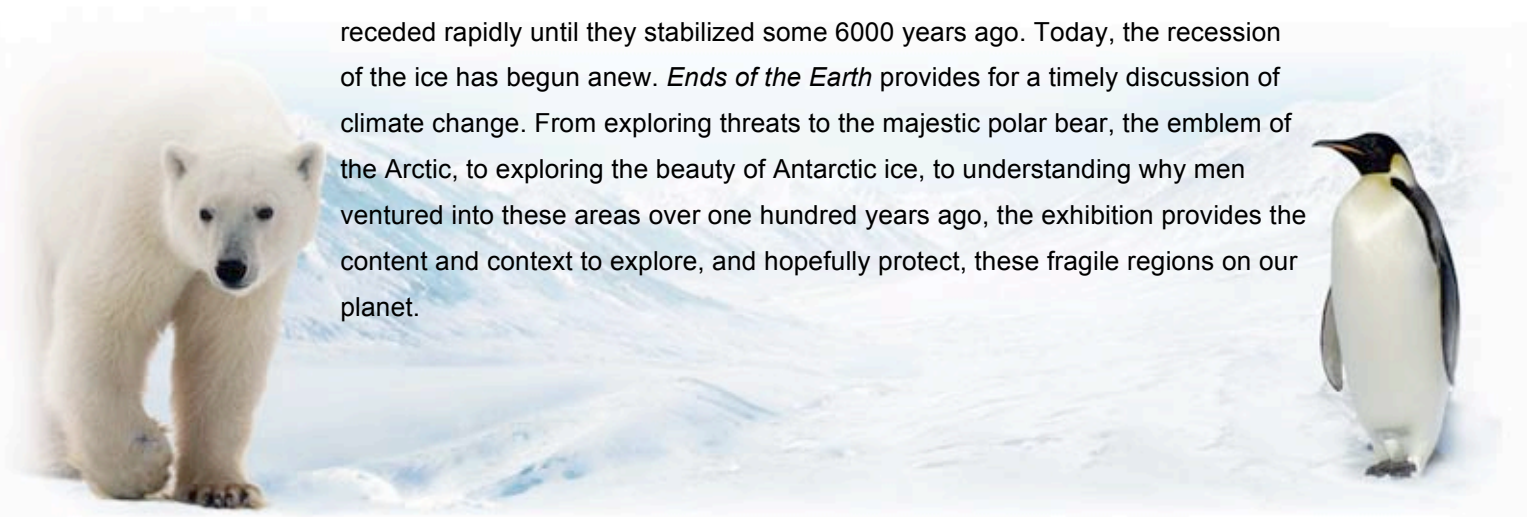
Through the 19th century and the first half of the 20th, much of the attention given to the poles was purely in the realm of exploration. Explorers traveled through lands never before seen and, in many cases, experienced unimaginable hardships. Some never returned to claim their fame, while others returned and lost their glory.

In recent decades, both poles have become very active research areas. *Ends of the Earth* compares and contrasts the two polar environments. The Arctic and the Antarctic, at first glance, have much in common, but they really are polar opposites. The Arctic is an ocean surrounded by continents. The North Pole is situated at sea level and beneath the polar sea ice is the Arctic Ocean. The Antarctic is a continent surrounded by oceans. The South Pole is located 2750 meters (9000 feet) above sea level and is atop a plateau of land, not water.

Both the Arctic and the Antarctic are home to some of the most fascinating creatures ever encountered. The Arctic has both terrestrial and marine ecosystems, which support both land and marine mammals. People have lived in the Arctic for many centuries, and have long mastered the skill of Arctic survival.

Antarctica has proven too forbidding for any human habitation or any land mammal. All life in Antarctica is part of one large, interconnected marine ecosystem; all life requires the sea to survive.

Polar forces sculpted much of the landscape we see around us today. Just 18,000 years ago, the polar glaciers reached their maximum extent. These glaciers receded rapidly until they stabilized some 6000 years ago. Today, the recession of the ice has begun anew. *Ends of the Earth* provides for a timely discussion of climate change. From exploring threats to the majestic polar bear, the emblem of the Arctic, to exploring the beauty of Antarctic ice, to understanding why men ventured into these areas over one hundred years ago, the exhibition provides the content and context to explore, and hopefully protect, these fragile regions on our planet.



Polar Geography

What is the Arctic?

The Arctic can be defined in many different ways—by geography, by climate, and by territory.

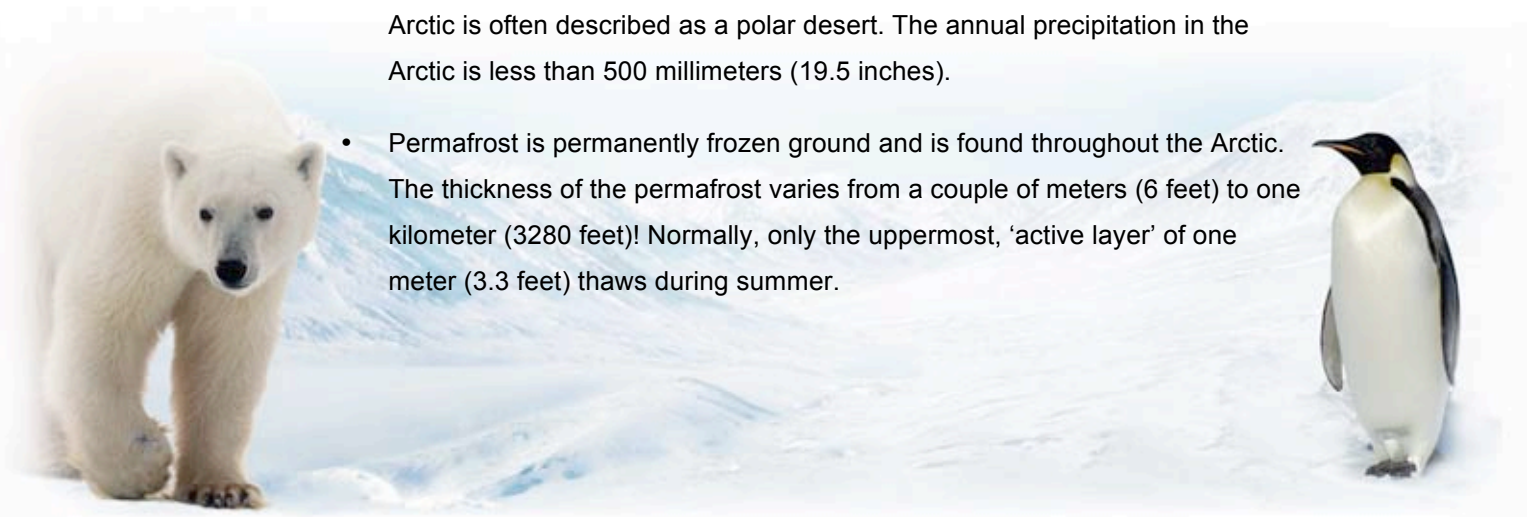
- The Arctic is the region north of the Arctic Circle, at 66 degrees, 32 minutes North (66° 32' N).
- A climate is considered an Arctic climate if the mean temperature of the warmest summer month is below 10⁰ C or 50⁰ F.
- The Arctic is a region that has continuous and discontinuous permafrost, which is permanently frozen soil.

The circumpolar Arctic covers a huge area, almost equal in size to the entire North American continent!

The Arctic is comprised of both land and ocean. It is the northernmost area of the eight countries that border the Arctic Circle - United States (Alaska), Canada, Russia, Finland, Norway, Sweden, Denmark (Greenland), and Iceland.

Key features of the Arctic:

- The Arctic experiences 24 hours of daylight in the summer months (July and August) and 24 hours of darkness in the winter months (November through February). The darkest time of the year at the North Pole is December 21, the Winter Solstice. The sun rises again at the North Pole on March 21, the Spring Equinox. On the Fall Equinox, September 21, the sun sinks below the horizon, leaving the North Pole in twilight and then full darkness.
- The Arctic is a dry region. The further North you go, the drier it is. The high Arctic is often described as a polar desert. The annual precipitation in the Arctic is less than 500 millimeters (19.5 inches).
- Permafrost is permanently frozen ground and is found throughout the Arctic. The thickness of the permafrost varies from a couple of meters (6 feet) to one kilometer (3280 feet)! Normally, only the uppermost, 'active layer' of one meter (3.3 feet) thaws during summer.



Ends of the Earth:

From Polar Bears to Penguins

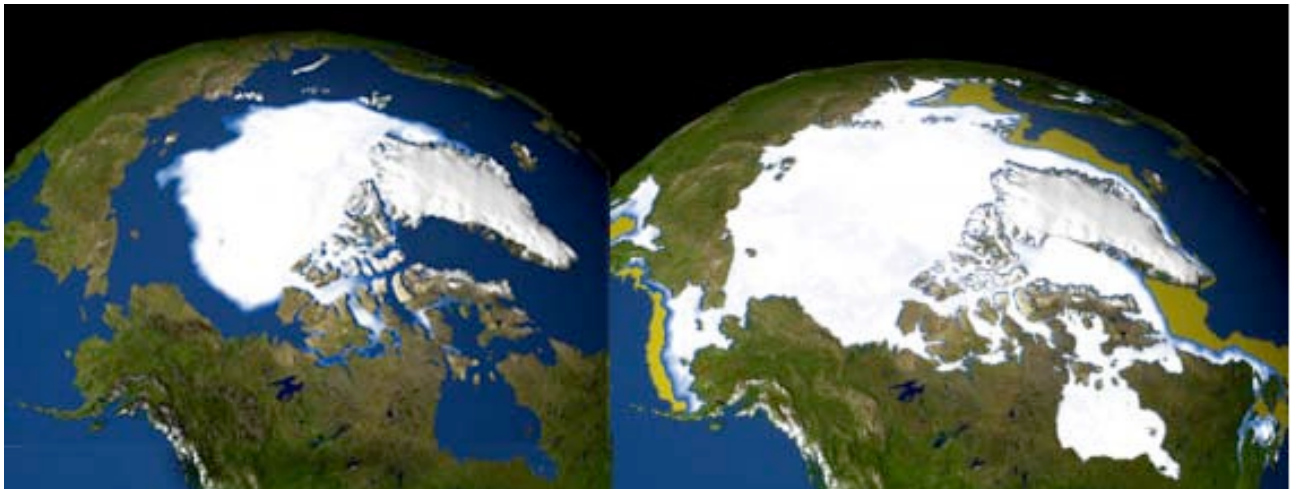
A Special Exhibition

7

- The Arctic Ocean is the smallest of the world's five oceans. It features an enormous permanent ice pack of eight million square kilometers (3 million square miles). During the summer, open seas surround the permanent ice pack around the North Pole. In winter, this frozen area nearly doubles in size and stretches to the surrounding continents. The ice in the Arctic Ocean is dynamic, meaning it moves, breaks up, and changes form.

sea ice minimum, summer 2005

sea ice maximum, winter 2006



- Arctic life is dependent on either of two ecosystems: (1) the terrestrial ecosystem of which caribou, musk ox, fox, lemmings, and wolves are a part, and (2) the marine ecosystem of which polar bears, whales, krill and seabirds are a part.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

8

Explore Arctic Geography in these exhibits:

Arctic Polar Projection Map

Visitors measure the distance from cities around the world to the North Pole.

Physical Map of the Arctic

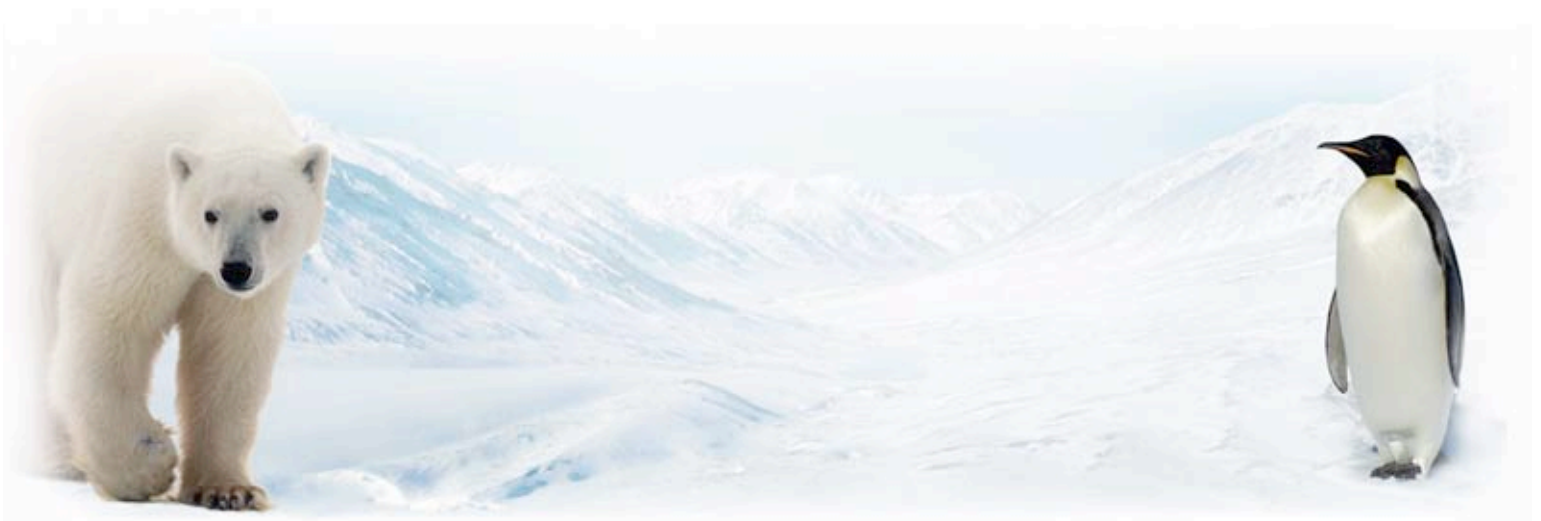
This is a large map of the circumpolar Arctic. Graphics cue visitors to find places of prominence in the Arctic, for example, the northernmost capital city of Iceland, which is Reykjavik, or the highest mountain in North America, which is Mount McKinley, Alaska.

Physical Profiles of the Arctic

Visitors use stereo viewers to look at stereo photographs of fabulous Arctic geography. The stereo photos depict beautiful three-dimensional landscapes that have been carved out by glaciers.

Take a Garden Tour of the Arctic

The Arctic comes alive in the summer months and blooms with many species of hardy Arctic plants. This exhibit features a diorama of selected Arctic plants and a video presentation of their unique adaptations.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

9

What is the Antarctic?

Antarctica is the world's fifth largest continent. It is slightly larger than the continental United States, covering an area of 14 million square kilometers (5.4 million square miles). The continent is 98% covered by ice, which can reach well over 4 kilometers (2.5 miles) thick. This ice contains about 90% of the Earth's fresh water.

Key features of the Antarctic:

- Antarctica is divided the longest mountain range in the world, the Transantarctic Mountains, which are 4800 kilometers (3000 miles) in length.
- The western portion of the continent consists of the Antarctic Peninsula, which points towards South America and is a geological continuation of the Andes Mountains. It is the only part of the continent that is above the Antarctic Circle. The remaining western portion is covered by an ice sheet that is, on average, 2 kilometers (1.2 miles) thick.
- Eastern Antarctica is the larger portion of the continent and contains the South Pole. The ice sheet here is also on average 2 kilometers (1.2 miles) thick.
- Life is found only along the coastline of the Antarctic. All life is dependent on one ecosystem, the marine ecosystem. There are no land mammals in Antarctica. A tiny insect called a 'midge' is the continent's largest land animal.
- No life exists in the interior, which is a massive ice plateau rising to the South Pole at an elevation of 2835 meters (9300 feet). This interior plateau is the world's largest, driest and coldest desert, receiving less than 5 centimeters (2 inches) of water (measured as snow melt) per year!
- Antarctica boasts the coldest temperature ever recorded on Earth, which was -89.4°C (-129°F) at the Russian Research Station, Vostok.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

10

Explore Antarctic Geography in these exhibits:

Antarctic Polar Projection Map

Visitors measure the distance from cities around the world to the South Pole.

Physical Map of Antarctica

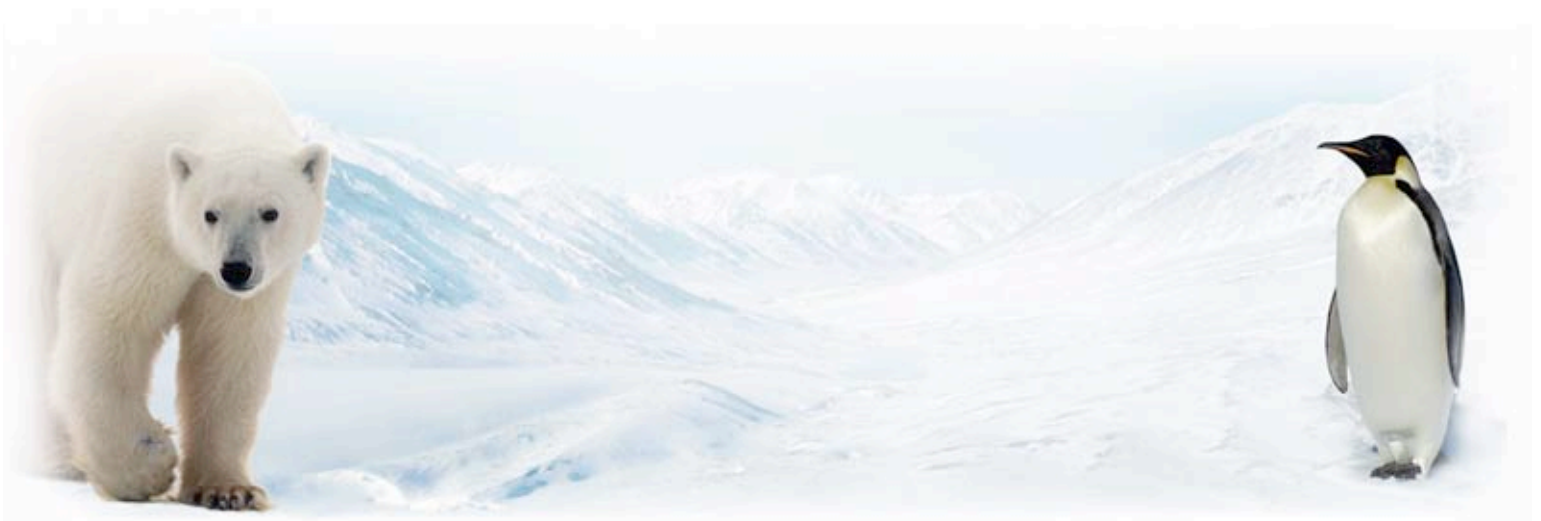
This is a large map of the Antarctic continent. Graphics cue visitors to find places of prominence in the Antarctic, for example, Mount Erebus, an active volcano in the Ross Sea, or Vostok Station, where the coldest temperature ever on Earth was recorded.

Physical Profiles of the Antarctic

Visitors use stereo viewers to look at stereo photographs of fabulous Antarctic geography. The stereo photos contrast the extreme landscapes of this continent, from the world's southernmost active volcano, Mt. Erebus, to the highest mountain, Vinson Massif, to the McMurdo Base, a research station that is a seasonal home to 1000 people!

Meet the Antarctic Animals

In a video kiosk, visitors are introduced to some of the predatory animals found in Antarctica—the leopard seal, the skua, and the Antarctic killer whale.



Polar Wildlife

Polar animals have evolved unique adaptations to survive the most extreme conditions on the face of the Earth.

Arctic Wildlife

Arctic wildlife is a part of one of two major ecosystems—terrestrial and marine. The animals that live on land such as musk ox, caribou, fox, wolves, and lemmings depend solely on a terrestrial ecosystem. Contrary to popular belief, few animals hibernate through the long Arctic winter. In the high Arctic, there is very little snow to insulate or protect a hibernating animal. To survive the Arctic winter, the animals have developed unique adaptations, such as changing fur color and sophisticated heat exchange systems. The collared lemming is fed upon by foxes, wolves and many predatory birds. These small rodents change from their drab brown summer coats to a winter 'morph' that looks like a totally different animal. The lemming's coat turns white in winter, it develops a hump over its front shoulders, and its front claws develop two hooks for each of its three toes. These adaptive claws are used for digging through frozen ground in order to feed on plants.



Winter morph lemming and lemming claws



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

12

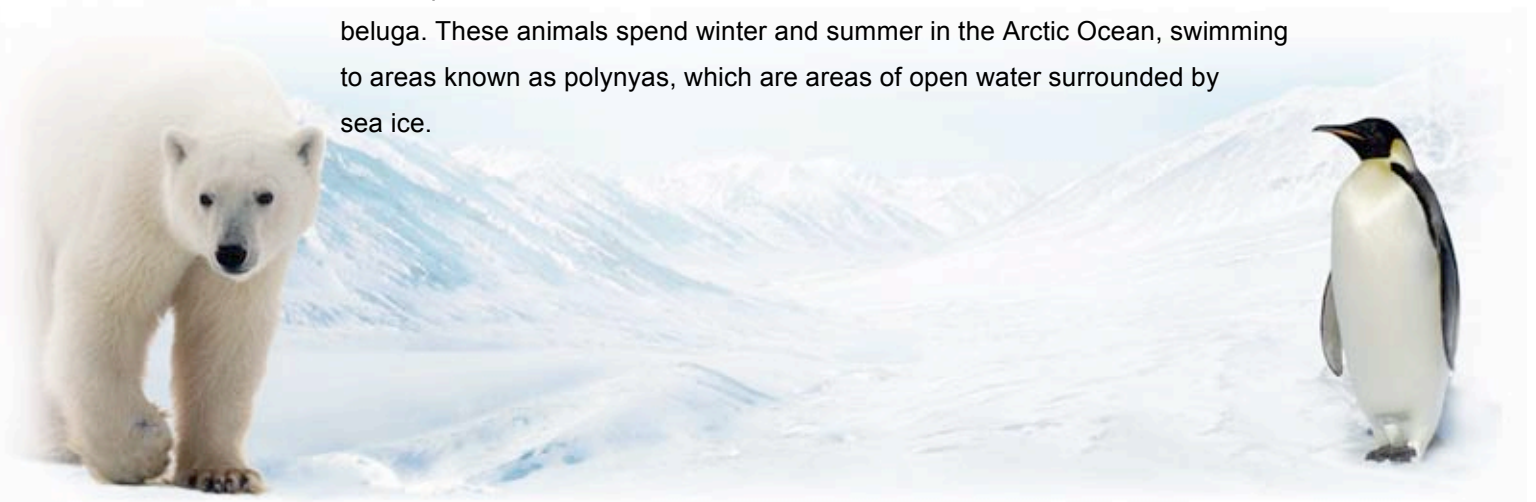
Marine animals, such as polar bears and whales, depend solely on the marine ecosystem. Polar bears travel thousands of kilometers each year on the sea ice in search of their favorite meal, ringed seals. Their white fur camouflages them and keeps them warm, as does the 10 centimeter (4 inch) layer of blubber under their skin.



Steve Amstrup (Alaska Image Library)

Walrus, like polar bears, are only found in the cold waters of the Northern Hemisphere. The male walrus is the largest, weighing up to 1900 kilograms (4100 pounds). Walrus feed primarily on mollusks diving to depths of 90 meters (300 feet), sometimes staying under water for as long as 30 minutes.

Many species of whales are found in Arctic waters. In the winter, most of these whales migrate further south, away from the encroaching sea ice. There are three whale species that are true Arctic whales – the bowhead, the narwhal, and the beluga. These animals spend winter and summer in the Arctic Ocean, swimming to areas known as polynyas, which are areas of open water surrounded by sea ice.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

13

Explore Arctic Wildlife in these exhibits:

Polar Bear Anatomy and Adaptations

A mounted polar bear specimen is the icon for this exhibit. Visitors handle polar bear, grizzly bear, and black bear skulls (replicas) to compare the skull size and tooth structure of each bear. They look at polar bear hair under a stereoscope, count the 'age' layers in a polar bear tooth section, and compare the claws of each of the three bears.

Polar Bear Den

The annual cycle of a polar bear is presented with a large graphic panel and a video. Visitors learn how polar bears hunt, how they raise their cubs, and what they do in the Arctic summer. Young visitors can even crawl in to a mock-up of a polar bear den!

Polar Bear Research

Visitors learn how researchers study polar bears in the field and what topics are currently being studied. Visitors can compare their weight to that of a polar bear and understand that polar bears are the largest land predator in the world.

Meet the Arctic Animals

Visitors play a multi-player computer quiz to learn about Arctic animal adaptations. Real specimens, such as bowhead whale baleen, a narwhal tusk, and musk ox hair are used as props and cues for the quiz.

Whales of the Arctic

Large graphic panels, scale models, and a video kiosk portray the three true Arctic whales—the beluga, the bowhead, and the narwhal—and their specific adaptations to living in the Arctic year-round.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

14

Antarctic Wildlife

All Antarctic wildlife is part of one large, interconnected marine ecosystem. There are no land mammals on this continent. The only land animal is a tiny insect, a 'midge' measuring just a few millimeters in length.

One tiny marine creature, the Antarctic krill, is the keystone species of the Antarctic food chain. Krill provide a primary essential food source for whales, seals, squid, penguins, and many species of birds. Since Antarctic krill feed on the algae found on the undersurface of the sea ice, reduced amounts of sea ice have adversely affected the quantity of krill in the Southern Ocean, over the past few decades.

Of the 17 species of penguins, only five breed in Antarctica: king, emperor, Gentoo, chinstrap, and Adelie. Emperor and Adelie penguins nest further south and under harsher conditions than any other penguin. The hardest are emperor penguins that nest during the heart of the Antarctic winter. The male incubates the emperor pair's sole egg while the female returns to the open ocean to feed.

Gentoo penguin



© Christian Elliott, Science North

Adelie penguins



© Lloyd Davis, Adelie Productions



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

15

Penguins spend most of their life in the water swimming and hunting for food. Their body shape, flippers, and feathers are specially adapted for this aquatic lifestyle. Penguin feathers are curved, very stiff, densely packed and overlapping. Some penguins have almost 30 feathers per centimeter of body surface area (or 70 feathers per inch)! These feathers help to keep the penguin warm and dry by trapping a layer of insulating air near the penguin's skin. This layer acts like a diver's dry suit, and provides about 80% of a penguin's insulation, while blubber provides the rest.

Emperor penguin



© Guillaume Dargaud 1992-2006

Emperor penguin feather



Kirsti Kivinen-Newman, Science North



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

16

Antarctic seals are a signature species of the Southern Ocean. There are six species of Antarctic seals—Weddell, Ross, crabeater, leopard, southern elephant, and fur seal. The Antarctic supports a much larger seal population than does the Arctic, due to the highly productive feeding areas in the Southern Ocean, and the lack of predators, such as polar bears. Four of the seals are considered true Antarctic species—the Weddell, the Ross, the crabeater and the leopard seals. The southern elephant seal and the fur seal do occasionally venture on to the continent, but prefer the more northerly islands of the warmer subantarctic seas. Though most of their time is spent in the water, all Antarctic seals must return to land to breed. Breeding sites are found primarily on fast shelf ice and pack ice surrounding the Antarctic continent or on coastal shores of the more northerly islands.

Crabeater Seal



Jennifer Pink, Science North



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

17

Explore Antarctic Wildlife in these exhibits:

Walk and Slide Like a Penguin

Visitors put on penguin costumes and walk and slide like a penguin in a custom-made environment. The Penguin Walk has Adelie and emperor penguin-size footprints side by side. The Penguin Slide is set up for 'tobogganing' or sliding on your belly!

Meet the Penguins

Each of the 17 species of penguins is represented as a life size photo cut-out. The penguins are grouped according to geographic distribution. Visitors learn that not all penguins live in Antarctica and that all 17 species of penguins look very different!

Feed the Chick

This is a video game that challenges players to be an adult penguin who goes to sea to gather food for its chick. Visitors can play in pairs or in groups and interact with a large game board that represents the Southern Ocean. The object of the game is to find krill and fish on the game board in time to feed the chick at the nest. Video plays throughout the game to confirm the player's actions.

Penguin Behavior

This is a computer interactive that involves visitors with specific behaviors of Adelie penguins. Visitors choose from 3 video quizzes—Penguin Chatter, Penguin Huddle, and Feed the Chick.

Meet the Antarctic Animals

In a video kiosk, visitors are introduced to some of the predatory animals found in Antarctica—the leopard seal, the skua, and the Antarctic killer whale.



Ends of the Earth: From Polar Bears to Penguins

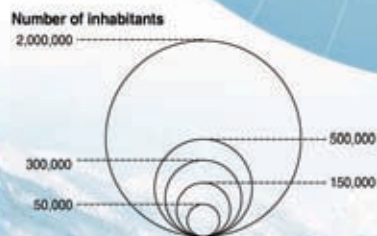
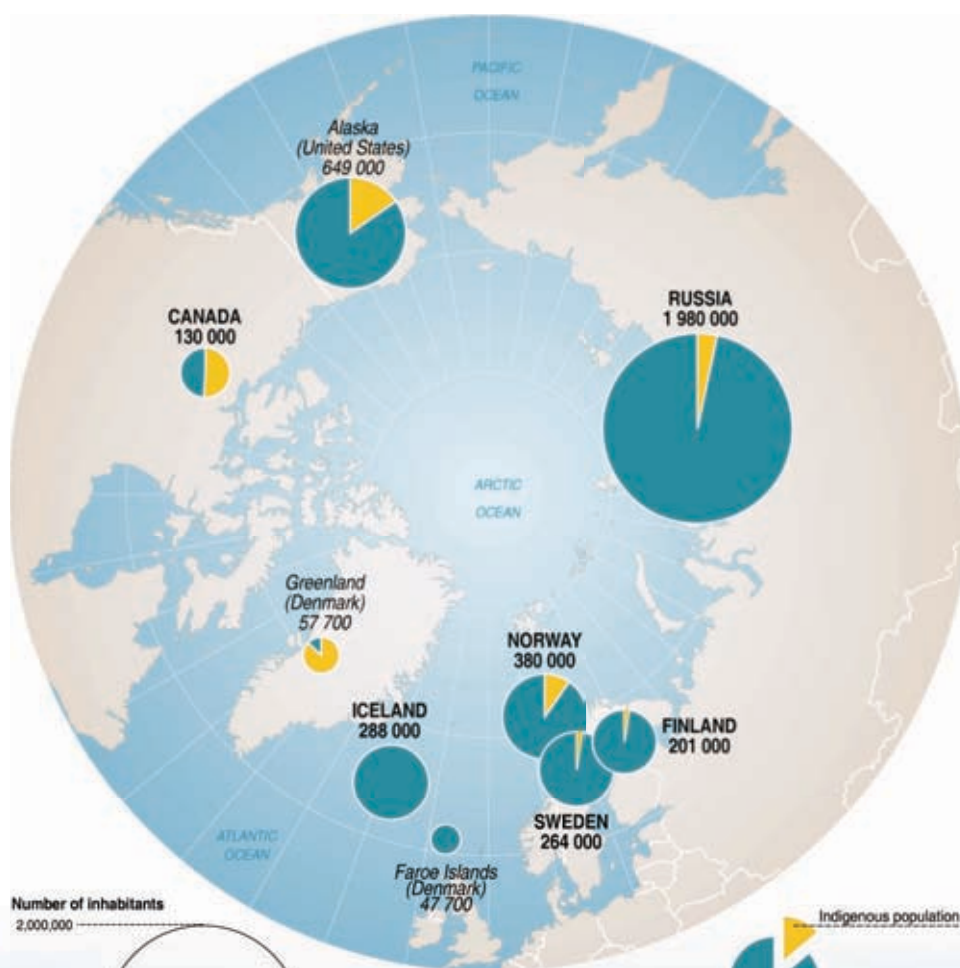
A Special Exhibition

18

People and the Poles

People have lived in the circumpolar Arctic for thousands of years. Indigenous people have lived in the North American Arctic for at least 4000 years.

Over centuries these people have lived and flourished under some of the harshest conditions on Earth. Today, more than four million people live in the circumpolar Arctic, with the indigenous population ranging from 80 percent in Greenland to 15 percent in Arctic Norway, and as little as 3% in Arctic Russia.



Non-indigenous population

NB: Figures show the number of inhabitants in the Arctic area, as defined in the Arctic Human Development report, of each country.

Sources : United States: US Census Bureau, 2002 and United States department of commerce 1993; Canada: Statistics Canada, 1995 and 2002; Greenland: Statistics Greenland, 1994 and 2002; Faroe Islands: Faroe Islands Statistics, 2002; Iceland: Statistics Iceland, 2002; Norway: Statistics Norway, 2002; Sweden: Statistics Sweden, 2002; Finland: Statistics Finland, 2002; Russia: State Committee for Statistics, 2003; Republican information and publication center, 1992; State committee of the Russian Federation for statistics 1992; AMAP, 1998; AMAP Assessment Report; Arctic Pollution Issues; AMAP, 1997; Arctic Pollution Issues: A State of the Arctic Environment Report; Stefansson Arctic Institute, 2004; Arctic Human Development Report.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

19

Arctic people include the Inuit in Canada, Greenland, Alaska, and Russia, the Na'Dene in Canada and Alaska, the Aleuts and Athabaskans in Alaska, the Saami in Scandinavia, and the Chukchi, Nenets, and many more in Russia.

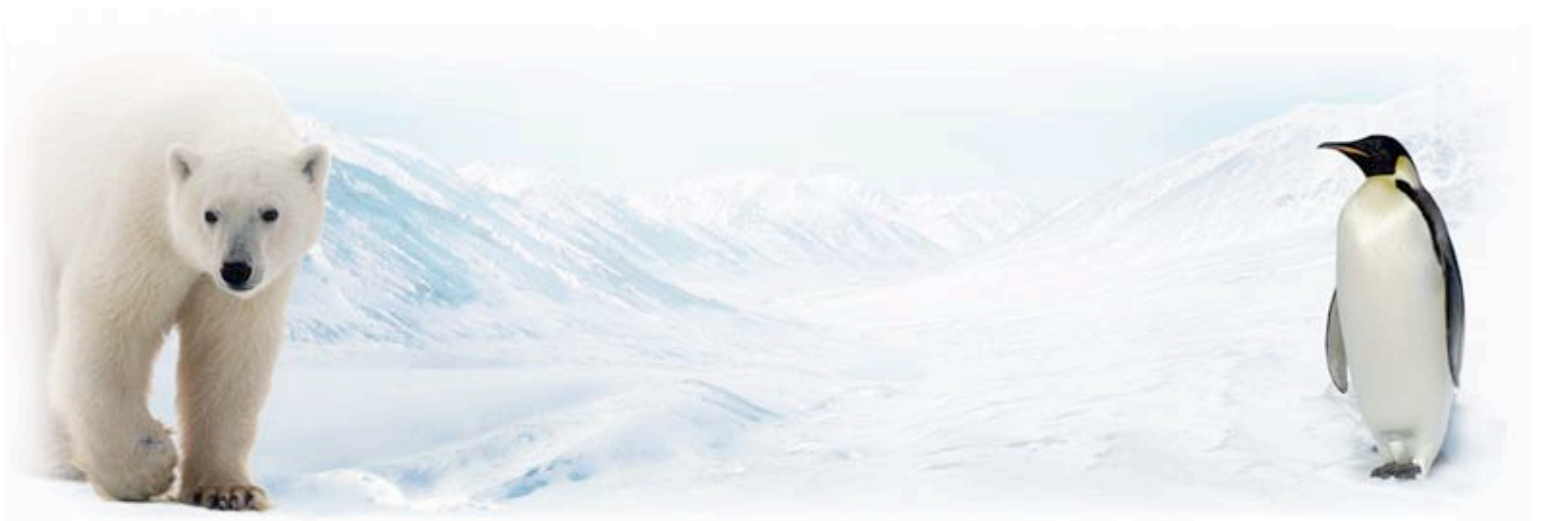
Current issues such as natural resource development and climate change are altering the way of life of Arctic peoples and are certain to have an impact on the environment and their future. Despite tremendous pressures, many Arctic communities are still closely linked to the native wildlife and local resources.

There are no native human populations living in the Antarctic. The first human explorers set foot on Antarctica in the 1820s. Today only a small number of people stay year round in Antarctica, and they are all scientists who reside at research stations.

Explore People and the Poles in this exhibit:

Living in the Arctic

Visitors learn about clothing, tools, and other objects important to Inuit people. Real objects are on display and their stories are told through video.



Polar Explorers

The poles have been the quest for many nations' adventurers for centuries. Many have risked great pain, suffering and even their lives in trying to reach the Earth's most remote regions.

The Golden Age of Polar Exploration came to a climax at the turn of the 20th century. In the far north, a race to the North Pole ensued between Americans Frederick Cooke and Robert E. Peary. Both claimed to have reached the North Pole in 1909. Cooke's claim was proven false and support was thrown behind Peary, but controversy still remains regarding Peary's polar success. In the south, in 1911, a race between the British naval captain, Robert Falcon Scott, and the Norwegian, Roald Amundsen, succeeded in the return of only one party.

Their harrowing and courageous stories have raised the bar for heroism. Polar exploration did not begin or end with these men. The successes and failures of expeditions such as John Franklin's search for the Northwest Passage, Fridtjof Nansen's quest for the North Pole, and Ernest Shackleton's harrowing expedition to cross Antarctica paved the way for continued exploration of the Polar Regions.

- Richard Byrd flies over the North and South Pole in 1926 and 1929 respectively.
- In 1958, Vivian Fuchs of Great Britain makes the first successful land crossing of Antarctica via the South Pole.
- In 1995, Richard Weber (Canada) and Mikhail Malakhov (Russia) ski unsupported to the North Pole and back, the only time that feat has ever been accomplished.



Ends of the Earth: From Polar Bears to Penguins

A Special Exhibition

21

Explore Polar Explorers in these exhibits:

The Explorers Theater

Journey to the North and South Poles and along the Northwest Passage through the eyes of the polar explorers—Roald Amundsen, Captain Robert Scott, Admiral Robert Peary and Frederick Cook. The Explorers Theater tells their compelling stories of challenge and survival through photographs, objects, video vignettes, and journal excerpts.

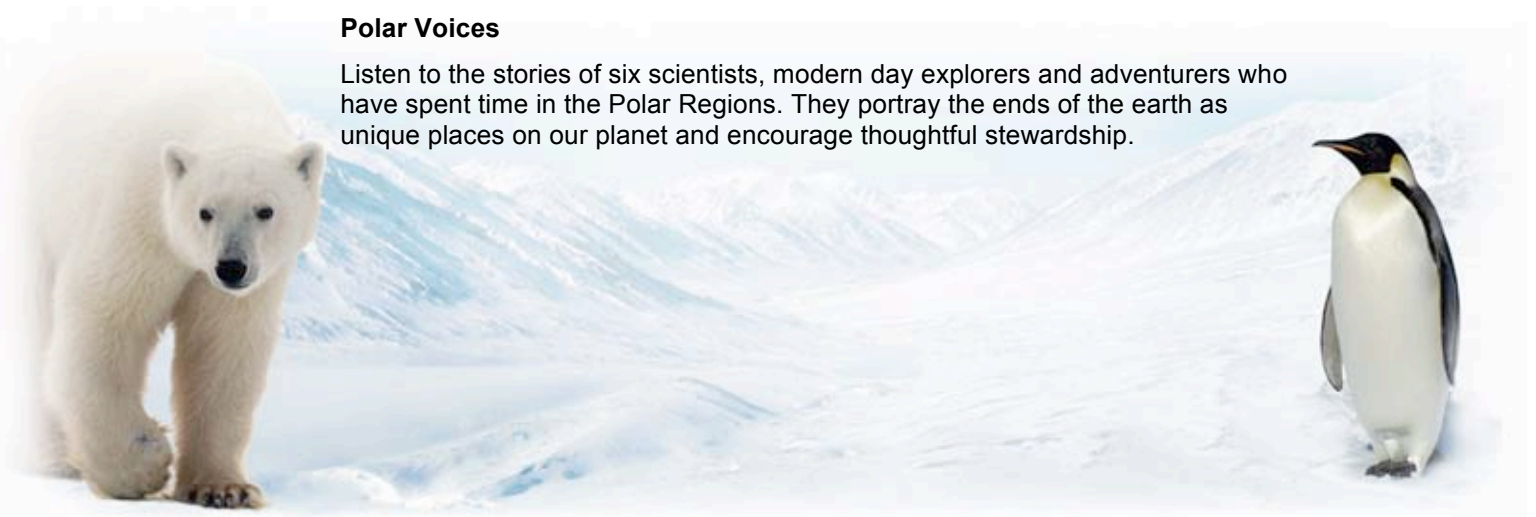


The Explorers Timeline

This exhibit presents chronological timelines of both Arctic and Antarctic exploration from before the 1500s to modern day. Representative historical maps accompany the timelines.

Polar Voices

Listen to the stories of six scientists, modern day explorers and adventurers who have spent time in the Polar Regions. They portray the ends of the earth as unique places on our planet and encourage thoughtful stewardship.



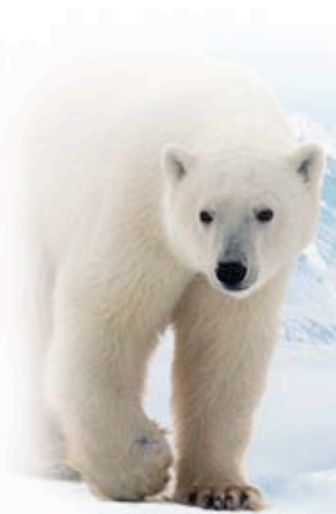
Climate Change and the Poles

The poles are the barometers of climate change for the planet. They are the first places to experience the impacts of climate change. Scientists have documented that glaciers at the poles are melting at a faster rate than they were just decades ago. Sea ice over the polar oceans is becoming thinner from year to year.

The impacts of thinning sea ice and disappearing sea ice are emerging in numerous ways. For example, polar bears in the Arctic who normally spend nine months of the year traveling on sea ice in search of seals, are being forced to spend three to four weeks less time hunting. The polar bear's sea ice hunting platform is melting earlier in the spring and forming later in the fall. As a result, the bears have a longer fasting period in the Arctic summer. Research is showing that adult bears are smaller than they were 20 years ago, and that females are having fewer cubs.



Susanne Miller (Alaska Image Library)



Ends of the Earth:

From Polar Bears to Penguins

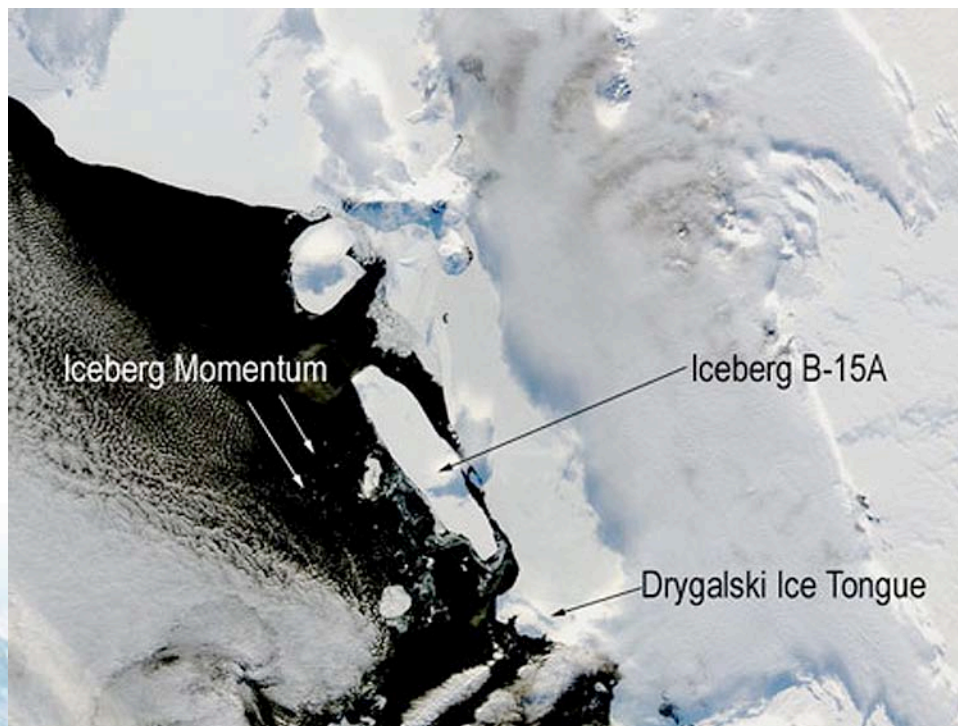
A Special Exhibition

23

In the Antarctic, emperor penguins, who nest on fast ice (sea ice attached to land) at the beginning of the Antarctic winter, are finding less ice to nest on.

Humans are also feeling the effects of rapid change. In the Arctic, Inuit people who hunt for seals on sea ice are finding the sea ice less predictable and more dangerous to travel on during certain times of year. Traveling on ice roads in the Arctic is a popular method of moving vast amounts of goods during winter, and a much cheaper method of transportation than having to bring products in by air. However, a warming climate is making certain ice roads very dangerous due to thin ice conditions. Melting permafrost is also destabilizing the ground beneath buildings and roads.

In Antarctica glaciers are melting faster, which is resulting in larger and more numerous icebergs. The largest known iceberg, B-15, roughly the size of Jamaica, broke away from the Ross Ice Shelf in March 2000. In 2005, the largest remaining chunk, B-15A, caused a major ice jam and for a period of time separated Adelie penguins, nesting on Ross Island, from their food in the open ocean.



© NASA



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

24

References:

- IUCN/SSC Polar Bear Specialist Group, <http://www.pbsg.npolar.no/>
- Impacts of a Warming Arctic, Arctic Climate Impact Assessment, 2004, Cambridge University Press
- National Snow and Ice Data Center, University of Colorado, Boulder, Colorado, <http://www.nsidc.org>
- Marine Ecosystem Sensitivity to Climate Change, BioScience, Vol. 49, No. 5, May 1999
- Tracking Antarctic Icebergs With RADARSAT-1 Imagery, Canadian Space Agency, 2005, http://www.space.gc.ca/asc/eng/apogee/2005/05_icebergs.asp

Explore Climate Change and the Poles in these exhibits:

Polar Bear Threats

Visitors choose from six questions, such as 'Climate Change and Polar Bears', 'Polar Bears and Pollutants', or 'Polar Bear Future'. The questions are answered, on camera, by Canadian research scientists, Dr. Nick Lunn and Dr. Andrew Derocher, in a documentary style that highlights the plight of the polar bear.

What's Happening to the Ice?

This is a computer interactive where visitors explore four global examples of changes in ice over time – the Larsen Ice Shelf in Antarctica, Antarctic Sea Ice, the Jakobshavn Glacier in Greenland, 2005 Arctic Ice and Snow Cover.

How big are Icebergs?

Visitors illuminate a scale model of an iceberg to reveal how much of an iceberg sits below the water. Graphics depict images of the formation and classification of icebergs.

Meet the Antarctic Scientists

In a video kiosk, Dr. Lloyd Davis, a biologist who studies Adelie penguins on Ross Island and Dr. Kathy Conlan, a marine biologist who has done research under the Antarctic ice, speak about their work and their thoughts on climate change and the poles.



Science Activities

In the classroom: Try a Blubber Glove!

How do polar creatures survive and thrive in temperatures that are -50 degrees or more? Learn about one of the key adaptations that makes survival possible: blubber!

Objective:

Learn how blubber is effective against the cold and why it is important for many polar animals.

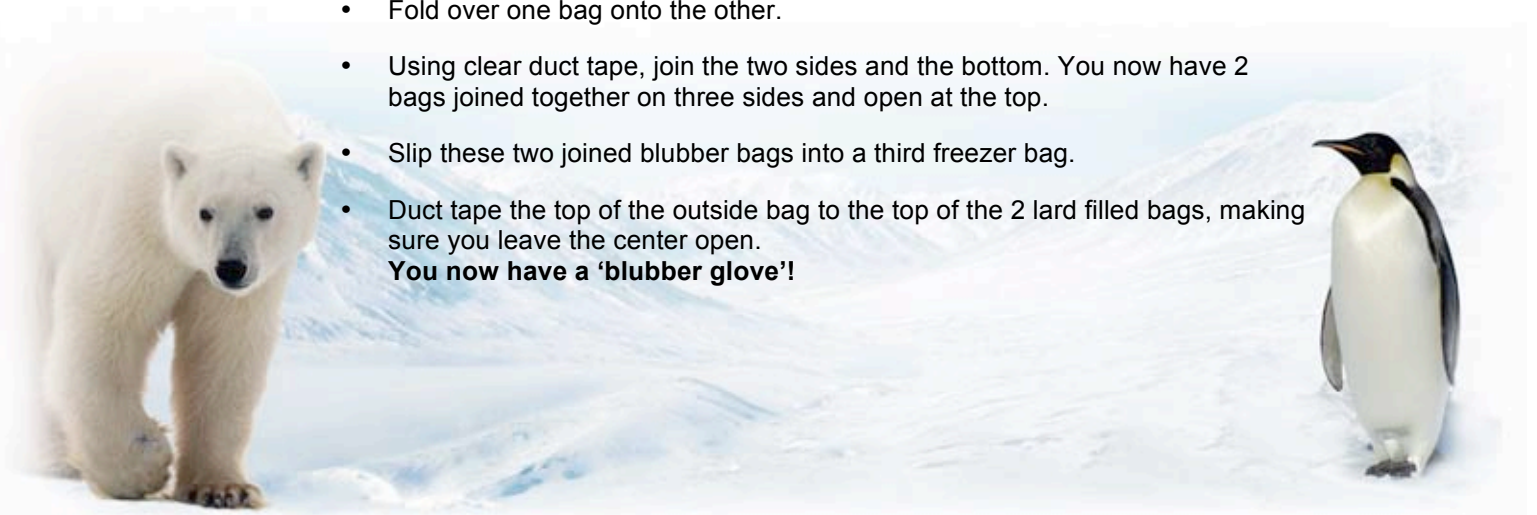
What you need:

- Freezer lock bags (3 bags per blubber glove), size 9 inches x 7 inches
- 1 pound of lard or © Crisco per bag
- Duct tape and clear duct tape
- Plastic tub for water
- Ice cubes
- A thermometer for measuring water temperature.

Making the Blubber Glove:

We recommend making the gloves prior to this activity. Students working in small groups can make 1 glove per group.

- Lay two freezer bags side by side, with the sides touching.
- Using clear duct tape, join the two touching sides.
- Fill each bag with a ½ pound of lard and spread evenly through the bags. Seal the tops.
- Fold over one bag onto the other.
- Using clear duct tape, join the two sides and the bottom. You now have 2 bags joined together on three sides and open at the top.
- Slip these two joined blubber bags into a third freezer bag.
- Duct tape the top of the outside bag to the top of the 2 lard filled bags, making sure you leave the center open.
You now have a 'blubber glove'!



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

26

What you do:

Many marine animals depend on blubber to keep warm; for example, a walrus's blubber can be up to 10 centimeters (4 inches) thick!

Let's see how effective blubber can be.

- Fill a plastic, tabletop tub with 5 inches of water and several trays of ice cubes. Put the thermometer into the water. After a few minutes the water should be quite cold. Record the water temperature.
- Take out your 'blubber glove' and place one hand inside it. With the other hand hold the edge of the glove so it does not slip off your hand and into the water.
- Dip the glove with your hand inside into the water, making sure the water level does not go above the glove.
- Ask students to wiggle their fingers inside the glove. Ask if their fingers feel the cold.
- After 10 seconds, ask students to take the hand that was inside the glove out of the glove and immediately place it in the water.
- Ask for their reaction!

Discussion:

Do you feel the difference?

Absolutely, the water will feel very cold against the skin.

Why do you think the blubber helps your hand stay warm?

It insulates your hand from the cold.

Why is it difficult to feel the cold water through the 'blubber' in the glove?

The blubber is a barrier and keeps the heat in.

What is the thickness of blubber among different polar animals?

Compare bowhead whale to walrus, polar bears to penguins.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

27

References:

'Why whales need blubber'

<http://whale.wheelock.edu/archives/ask03/0098.html>

Blubber as an insulator

<http://database.portal.modwest.com/start.php>

<http://www.seaworld.org/infobooks/PolarBears/pbadaptations.html>

<http://www.seaworld.org/animal-info/info-books/polar-bear/adaptations.htm>

Bear blubber

<http://www.polarbearsinternational.org/galleries/churchill-videos/2759> (*video*)

<http://www.polarbearsinternational.org/faq/#q6>

<http://www.polarbearsinternational.org/polar-bears-in-depth/physiology/>

Seal and Walrus blubber

http://www.scienceandthesea.org/index.php?option=com_content&task=view&id=269&Itemid=10 (*includes audio*)

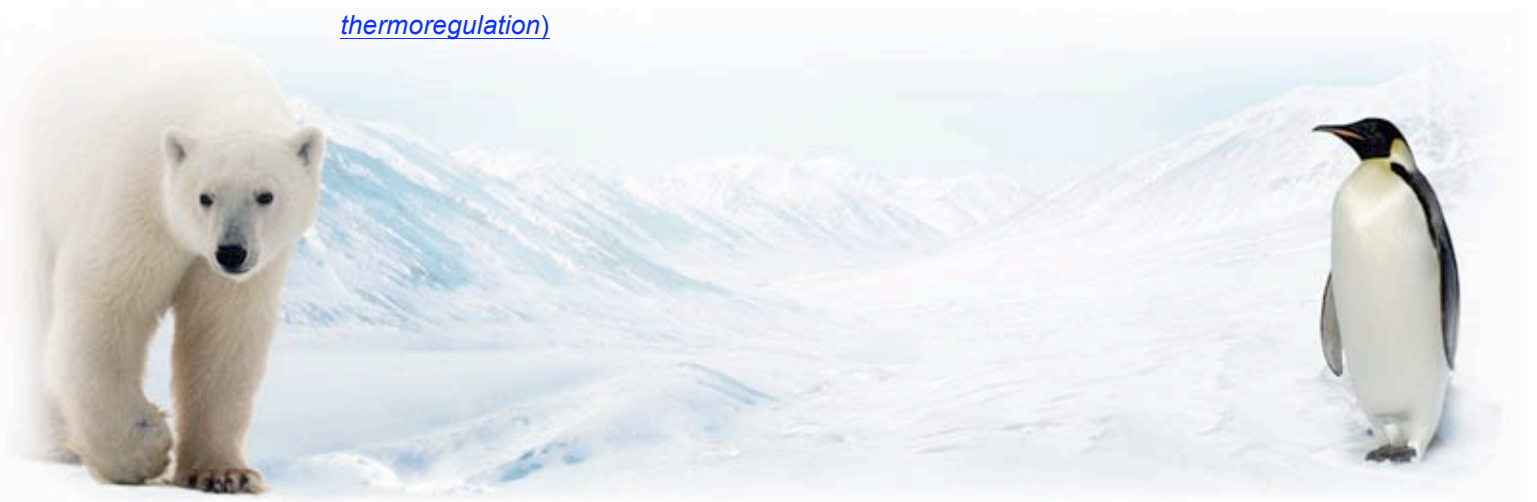
http://www.polarcruises.com/antarctica/articles/wildlife_4/seal-adaptations_11.htm

Penguins and blubber

<http://www.kidzone.ws/animals/penguins/facts3.htm>

<http://www.kidzone.ws/animals/penguins/index.htm>

<http://www.penguinworld.com/features/thermoregulation.html> (*penguin thermoregulation*)



In the exhibition:

What's so Different About a Penguin Feather?

This activity explores another form of insulation, feathers. Penguins live on the opposite side of the globe from polar bears, and have feathers instead of fur.

Objective:

Discover why the feathers of a penguin are different in structure than the feathers of other birds.

What you need:

- Penguin feathers and 'regular' feathers (included with the *Ends of the Earth* exhibition)
- Magnifying glasses
- Photo of penguin feather
- Photo of a patch of penguin feathers
- Photo of a regular feather

Note: Penguin feathers are included with the *Ends of the Earth* exhibition; photos are downloadable from the Educators Guide section of the Science North *Ends of the Earth* website: <http://sciencenorth.ca/media/m01eote/educators/index.html> (click on the "Penguin Feather Photo Archive" to download a folder of photos)

What you do:

- Use the magnifying glass to look at penguin feathers and those of a flying bird.
- Notice the difference in thickness and stiffness of the shaft (or rachis), between the penguin feathers and the flying bird feathers.
- Notice the curved part of the shaft at the base of the penguin feather (called the calamus or quill).
- Look at a flying bird's feathers. What is the shape of the shaft?



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

29

Discussion:

Why do you think the penguin feathers are so stiff and curved?

Look at the curved shaft at the base of the feather. The curve of the shaft allows the penguin to raise or lower the feather against the body. In doing this, it increases or decreases the air space against its body; the greater the air space, the greater the insulative value. Penguins have more feathers than any other bird, up to 70 feathers per square inch of body surface area. Penguin feathers provide 80% of the bird's insulation while their blubber provides only 20%.

If you've ever looked at a plucked dinner turkey or chicken, you might have noticed that the skin bumps (where the feathers would have been attached) are arranged in lines or 'tracts'. Penguins are very different; their feathers grow out of their body all over in a random pattern. This creates an overlapping pattern of feathers, like the shingles on a roof. The arrangement of overlapping feathers helps to hold the insulating layer of air in and keeps the water out!

References:

<http://www.penguin.net.nz/faq/faq.html> (from New Zealand Penguins)

<http://www.penguinscience.com/education/adaptations.php> - go to 'Feathers'

<http://www.extra.rdg.ac.uk/eng/BIONIS/pdf%20files/Penguin%20Down%20Feathers.pdf> (from University of Reading, UK)

Feather anatomy (in general):

<http://fsc.fernbank.edu/birding/feathers.htm> (from Fernbank Science Centre)

<http://www.peteducation.com/article.cfm?cls=15&cat=1829&articleid=2776>
(PetEducation.com)



In the exhibition:

How Unique is Polar Bear Fur?

Polar bears are active throughout the year, experiencing some of the harshest weather on the planet. Their fur is a key adaptive feature for their survival.

Objective:

Learn why polar bear fur is special and why it is generally white.

What you need:

- Strong magnifying lenses
- Polar bear hair samples
- Polar bear hide sample
- Petri dishes (for hair)
- Thermographic image of polar bear

Note: Polar bear hair and hide sample are included with the *Ends of the Earth* exhibition; photos are downloadable from the Educators Guide section of the Science North *Ends of the Earth* website: <http://sciencenorth.ca/media/m01eote/educators/index.html> (click on the "Polar Bear Hair Images" to view the PDF)

What you do:

- Pick up a fiber of polar bear hair. Hold the hair up to the light.
- Place a strong magnifying glass in front of it and observe. Notice that the polar bear hair is transparent (clear).
- It appears to be hollow. Why?
- Now look at the patch of polar bear fur. Is there more than one type of polar bear hair?
- Look at the photo of the polar bear taken by thermal or infrared imagery. What are you seeing?
- Take a look at the thermographic polar bear photos. Where do you think the most heat loss occurs on a bear's body?

Discussion:

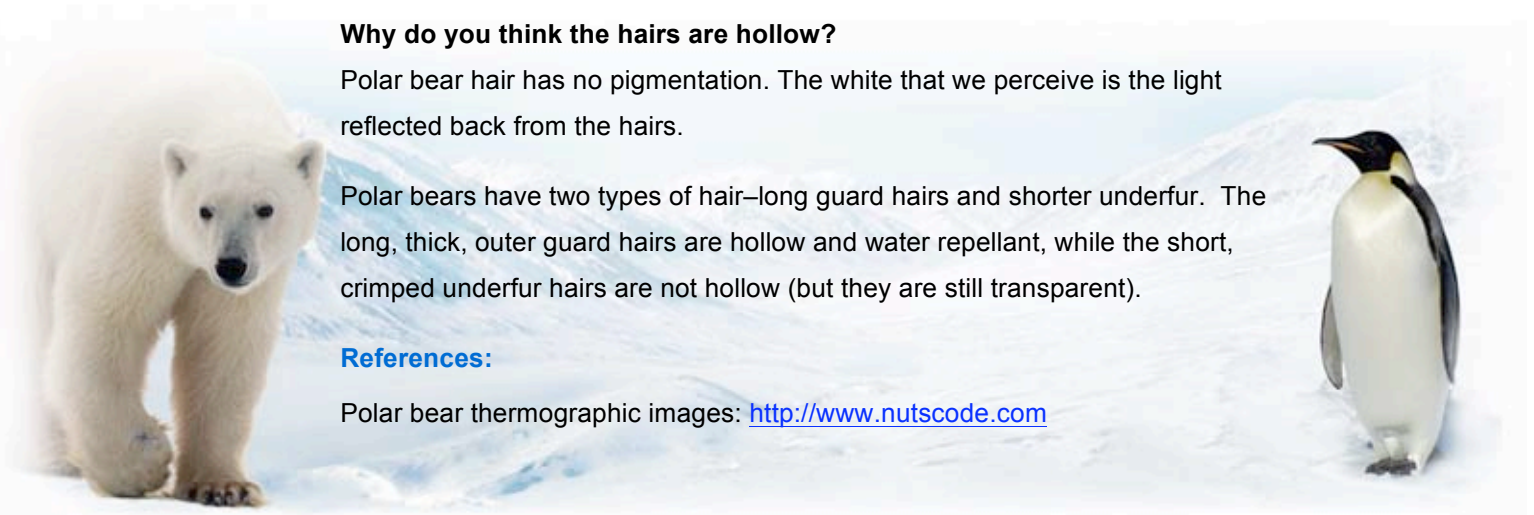
Why do you think the hairs are hollow?

Polar bear hair has no pigmentation. The white that we perceive is the light reflected back from the hairs.

Polar bears have two types of hair—long guard hairs and shorter underfur. The long, thick, outer guard hairs are hollow and water repellant, while the short, crimped underfur hairs are not hollow (but they are still transparent).

References:

Polar bear thermographic images: <http://www.nutscore.com>



Myth of fiber optic polar bear hair: <http://it.stlawu.edu/~koon/polar.html>

In the classroom: How can the Polar Regions be in total darkness or in total light?

Why do the Polar Regions experience 24 hours of daylight in the middle of the summer and 24 hours of darkness in the dead of winter? Seasons and length of daylight are determined by the Earth's rotational axis and its orbital location around the Sun.

Objective:

Understand why the Earth's Polar Regions have 24 hours of total darkness in winter and 24 hours of light in summer.

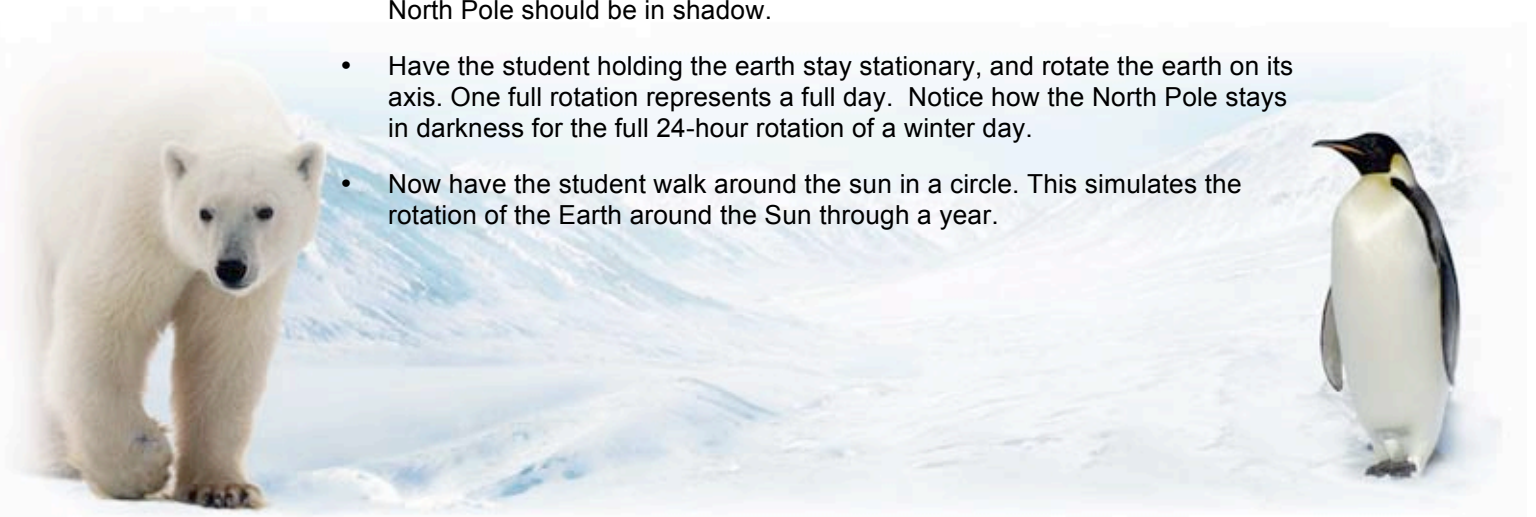
What you need:

- Inflatable Earth globe
- Flashlight

What you do:

You will be demonstrating the passage of the Earth around the Sun, so you will require a reasonable amount of floor space.

- Have a student stand in the center of a large space. They will be the sun and will be holding a flashlight ('sunlight').
- Have a student hold the inflatable Earth globe and face the 'sun'. The globe should be held with the North Pole axis tipped towards the student holding the globe (about 23.5°). The position that they are in now is winter in the Northern Hemisphere.
- Dim the room lights, so that the light from the flashlight can be seen. Turn on the flashlight.
- Look at the earth and see where the shadow from the flashlight falls. The North Pole should be in shadow.
- Have the student holding the earth stay stationary, and rotate the earth on its axis. One full rotation represents a full day. Notice how the North Pole stays in darkness for the full 24-hour rotation of a winter day.
- Now have the student walk around the sun in a circle. This simulates the rotation of the Earth around the Sun through a year.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

32

Discussion:

The Earth is always tilted to one side. The Earth spins on its axis and does one complete rotation every 24 hours. We have day and night because the Sun only shines on the side of the Earth that is facing the Sun as the Earth rotates.

The Earth also goes around the Sun, and one complete circle around the Sun takes one year. Look closely as I move the Earth around the Sun. Look at the axis and its relationship to the Sun (*use the light to throw a shadow*). Notice that during our summer the Earth's axis in the Northern Hemisphere is always facing the Sun. This allows for 24 hours of daylight starting from the Arctic Circle, here (*point to the Arctic Circle*). Note, however, that the South Pole and the Earth's axis in the Southern Hemisphere is pointing away from the Sun, so it is in total darkness. The darkness occurs from the Antarctic Circle and below (*indicate location on globe*).

If the Earth rotates around the Sun to represent six months later, then the opposite is now true. The South Pole now has 24 hours of light while the Northern Hemisphere is experiencing winter and the far north has 24 hours of darkness. The North Pole and the South Pole can never experience light nor darkness at the same time, because when the North Pole is facing the Sun, the South Pole is facing away. When there are 24 hours of daylight in either region, it is the summertime, and when there are 24 hours of darkness, it is the wintertime. When it is summer in the Arctic, it is winter in the Antarctic, and vice versa.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

33

Arctic Tern

The Arctic tern is the only creature (other than research scientists) that flies from one pole to the other within the same year. This is a phenomenal roundtrip of about 19,000 miles (30,000 kilometers) per year. Arctic terns only experience darkness when they near the Equator. Near the Equator, there is always about 12 hours of light and 12 hours of darkness year round.

References:

Earth's rotation around the Sun

Daylight, Darkness and Changing of the Seasons at the North Pole:

http://www.arctic.noaa.gov/gallery_np_seasons.html

'Why is it cold at the poles?' animation:

http://www.educapoles.org/multimedia/animation_detail/why_is_it_cold_at_the_poles/ (from Educapoles)

Polar Nights' animation:

http://www.educapoles.org/multimedia/animation_detail/polar_nights/ (from Educapoles)

Arctic tern migration:

<http://www.arctictern.info/> (The Arctic Tern Migration Project)



In the classroom: Tracking Polar Bears!

Polar Bears spend an average of nine months of the year hunting for food on the sea ice. This raises several questions: Where do they travel? How far do they travel? Do they come back to land at the end of their hunting season?

Objective:

Learn what satellite tracking has revealed about polar bears traveling on ice. Students will translate polar bear movements from maps created with real data and determine distances traveled over time.

What you need:

- Three polar bear atlas maps

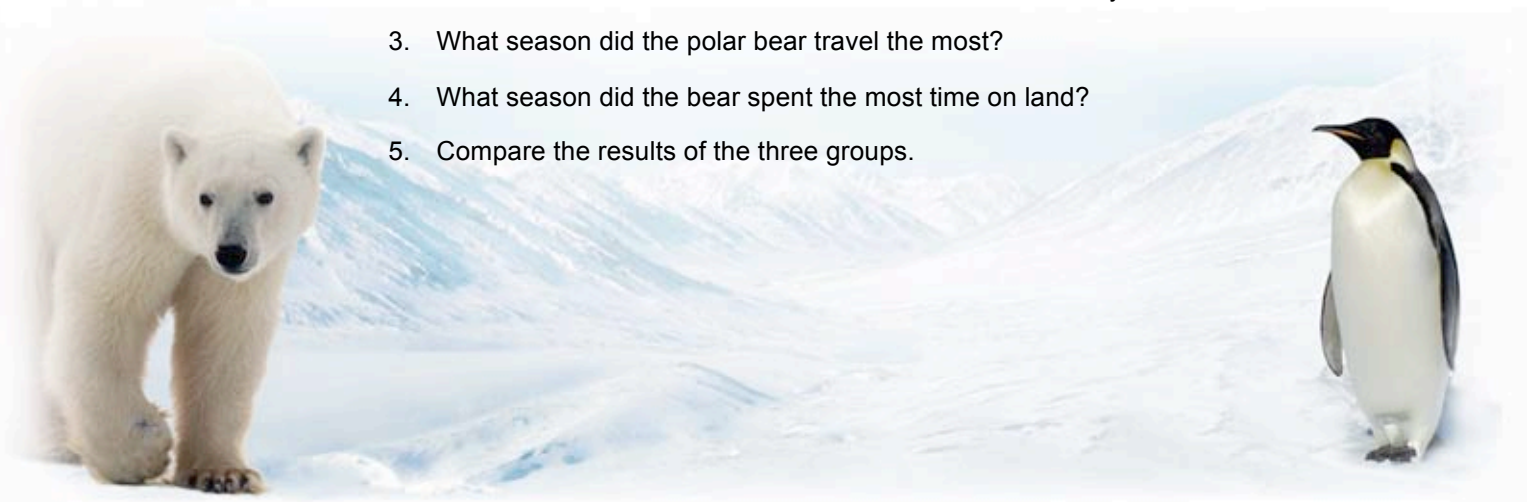
Note: The maps show polar bear movements as done by satellite tracking from a part of Hudson Bay, Canada. Movements of a bear appear in four different coloured lines. See the legend for what time of the year the colors represent.

- String, ruler

Note: Polar Bear Atlas is downloadable from the Educators Guide section of the Science North website: <http://sciencenorth.ca/media/m01eote/pdf/Educator-Polar.pdf>

What you do:

- Have students break into three groups. Each group is given a tracking map representing a different polar bear, a string and a ruler.
- Select a colored line, which represents a season. Lay the string along the line chosen. Record how long the line is.
- Use the scale on the map and the ruler to determine how far the bear traveled in your chosen season.
- Make notes on the following questions that the data reveals.
 1. What is the distance traveled in each of the four seasons?
 2. What distance was traveled over the course of the entire year?
 3. What season did the polar bear travel the most?
 4. What season did the bear spent the most time on land?
 5. Compare the results of the three groups.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

35

Discussion:

The satellite data collected from different polar bears reveals that these animals spend much of their year traveling on sea ice. We know that their time on the ice is spent searching for their favorite food, ringed seals. When the sea ice melts, the bears retreat to land. During the warm weather, they fast and enter what scientists call a 'walking hibernation'.

Ask your students what happens when sea ice decreases and the bears are forced to spend more time on land? What do the bears do on land? What is the cause of sea ice decreasing? If the trend of declining sea ice continues, what will happen to the polar bears? How is other marine life affected?

References:

Polar Bears: Proceedings of the 15th Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 29 June – 3 July 2009, Copenhagen, Denmark,
<http://data.iucn.org/dbtw-wpd/edocs/SSC-OP-043.pdf>

What has been happening to polar bears in recent decades?

http://www.arctic.noaa.gov/essay_schliebe.html

Polar Bears International: Polar Bear FAQ:

<http://www.polarbearsinternational.org/faq/>

Polar Bear Tracker (WWF & Norwegian Polar Institute):

http://www.panda.org/about_wwf/where_we_work/europe/what_we_do/arctic/polar_bear/index.cfm, or <http://www.ngo.grida.no/wwfap/polarbears/>



In the exhibition: Compare Bear Skulls!

The three North American bear species, the black bear, grizzly and polar bear are uniquely adapted to their environments. Comparisons of their skulls give clues to their size and adaptations.

Objective:

Learn about the size and shape of the three skulls of the three North American bears. You will compare and contrast similarities and differences of the three species.

What you need:

- 1) Black bear skull
- 2) Grizzly bear skull
- 3) Polar bear skull
- Magnifying glass (optional)

Note: Skull specimens are included with *Ends of the Earth* exhibition.

What you do:

- Compare the 3 bear skulls 1), 2), and 3).
- Look at the size of each skull.
- Examine the teeth.

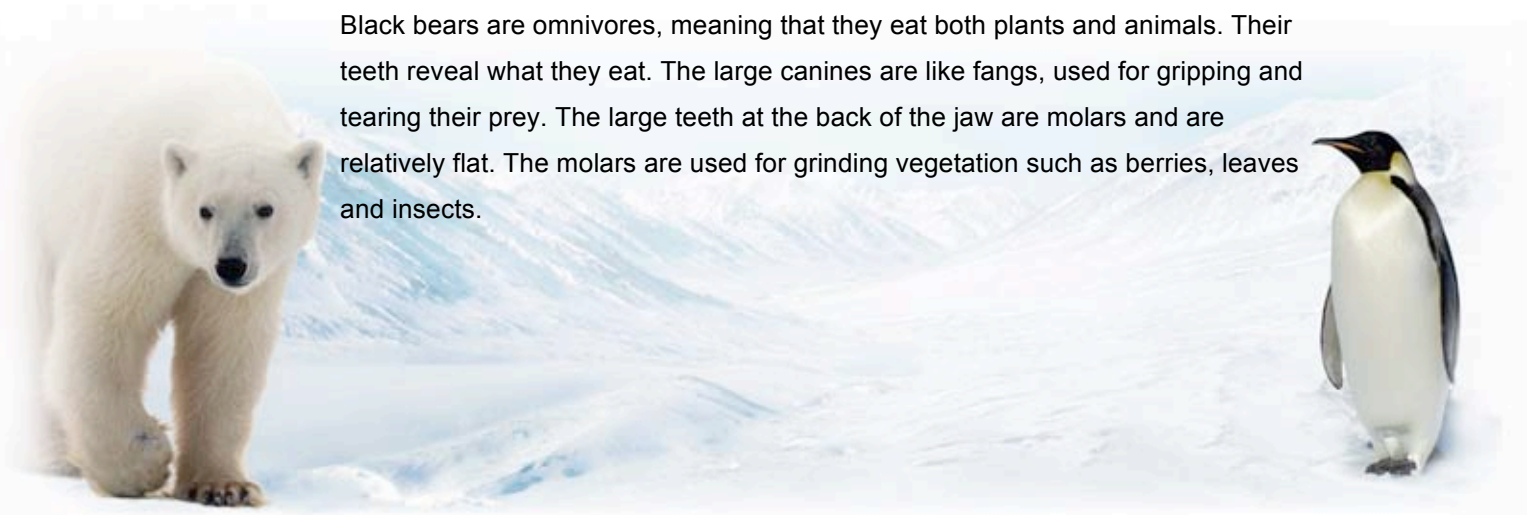
While you are looking at the skulls try to answer the following questions.

- What do you think the bears eat?
- How is the shape of the teeth related to the diet of the bears?

Discussion:

Skull 1 is a black bear skull.

Black bears are omnivores, meaning that they eat both plants and animals. Their teeth reveal what they eat. The large canines are like fangs, used for gripping and tearing their prey. The large teeth at the back of the jaw are molars and are relatively flat. The molars are used for grinding vegetation such as berries, leaves and insects.



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

37

Skull 2 is a grizzly bear skull.

This skull is much larger than the black bear skull. The teeth are virtually identical to a black bear's, except that they are larger. This means that grizzly bears are also omnivores. Grizzlies eat a wide variety of vegetation from roots to berries to leaves. Due to their large size they are also able to take down large prey or scavenge on dead animals from other predators such as wolves; however, they eat mostly plant material.

Skull 3 is a polar bear skull.

The canines are very similar to the other two bear species. However, the molars on a polar bear are sharper than those of a grizzly or black bear. The sharp molars are used mainly for cutting up meat rather than grinding vegetation. This tells us that polar bears are mainly carnivorous.

Explore the status of the three bear species.

- Are any of the North American bears threatened? By what?
- Are there any indications of any of these bears adapting to a changing environment?
- What can be done to safeguard these species' survival?

References:

<http://www.hww.ca/hww.asp?id=8&pid=1> (from Hinterland Who's Who)

<http://www.bearbiology.com/> (from International Association for Bear Research & Management; IUCN/SSC Bear Specialist Group)



In the exhibition: Compare Bear Claws!

North America is home to three magnificent bear species: the black bear, the grizzly bear and the polar bear. Each is uniquely adapted to its environment, and each has similarities and differences. Claws are a physical feature they all share. What are the similarities and differences between the claws of the three bears and how are the claws used?

Objective:

Learn about the size, shape, and use of the claws of the three species of North American bears.

What you need:

- Three sets of claws (provided): 1) black bear, 2) grizzly bear and 3) polar bear
- Ruler
- Magnifying glass (optional)

What you do:

- Compare the 3 bear claws (polar, grizzly, black bear). Pick them up and look at them closely. Note that these are life size replicas. Look at the size and shape of the claws.
- Measure the length of each of the three different claws.

While you are looking at the claws try to answer the following questions.

- Which claw belongs to which bear?
- How are the shapes of the claws related to the diets of the bears?



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

39

Discussion:

Claw 1 belongs to a black bear.

It is the smallest of the claws and is from the smallest bear species. Black bear claws are short and strong and are used for tearing (e.g. searching for ants in a log); digging (e.g. a den); and climbing a tree to escape from danger.

Claw 2 belongs to a grizzly bear.

It is the longest claw. Grizzly bear claws, although long, are not as curved as the claws of the other two species. Adult grizzlies cannot climb trees as well as black bears; however, young grizzlies have more curved claws for exactly that purpose. As grizzlies grow older and bigger, they do not resort to climbing trees since they are large enough to protect themselves on the ground. Grizzly bear claws are used for digging and reflect grizzlies' preferred diet of plant roots and small mammals. Grizzlies are omnivores; they feed on a wide variety of plants and only occasionally eat meat.

Claw 3 belongs to the polar bear.

The polar bear claw is similar to the black bear claw, but is shorter and more curved than the grizzly claw. Polar bears need strong, sharp claws because they spend their lives walking on slippery ice, and they need to grasp and hold on to large prey such as seals.



Useful Web Resources

Educational Polar Websites - Lesson Plans, Activities

IPY-International Polar Year

Features: Educational links and resources, activities, news, events, blogs, discussion groups

Educators' Portal: <http://www.ipy.org/index.php?/ipy/audience/C27/>

IGLO-International Action on GLObal Warming

(ASTC –Association of Science-Technology Centers)

Features: Resources, hands-on and online activities, demonstrations

Quote: "This collection of educational tools and resources is offered to help IGLO participants work together to raise public awareness and understanding of Earth's polar regions and the myriad connections that exist between the Poles and the places where we all live."

<http://www.astc.org/iglo/>

Educapoles (IPF–International Polar Foundation)

Features: Educational animations, images and games, teaching dossiers related to the educational content on the site

Notes: This website is intended mainly for elementary students, but much of the content is very appropriate for older students. The animations are fantastic.

<http://www.educapoles.org/>

Arctic Alive! (ARCUS–Arctic Research Consortium of the US)

Features: Virtual field trips, discussion boards, live audio conference calls, educational materials, activities and more

Quote: "Arctic Alive! is a distance-learning environment for learners to be transported virtually to unique and remote locations within the arctic region. Arctic Alive! is not an information Internet site but an interactive, real-time, and unique web-based education program."

<http://www.arcus.org/arcticalive/>

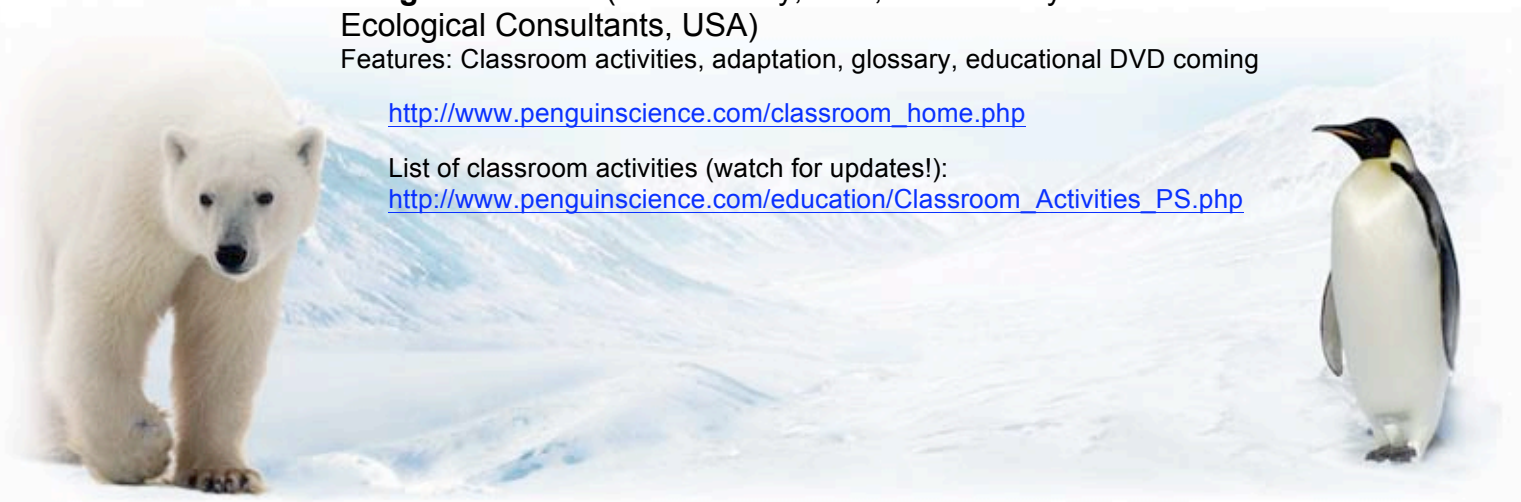
Penguin Science (David Ainley, PhD, H.T. Harvey & Associates–Ecological Consultants, USA)

Features: Classroom activities, adaptation, glossary, educational DVD coming

http://www.penguinscience.com/classroom_home.php

List of classroom activities (watch for updates!):

http://www.penguinscience.com/education/Classroom_Activities_PS.php



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

41

Penguin Activities at Kidzone (© DLTK's Sites)

Features: Printable worksheets, online activities, links

Notes: Great worksheets and printable activities for younger kids.

<http://www.kidzone.ws/animals/penguins/activities.htm>

Antarctic Weddell Seal Activity Site (Dr. Terrie M. Williams, University of California Santa Cruz)

Features: Classroom introductions and activities, postcards and posters and more

<http://bio.research.ucsc.edu/people/williams/teachers/>

Classroom Antarctica (Australian Antarctic Division, Australia)

Features: Classroom activities, lesson plans, resources and printable PDFs

Notes: The information and activities are divided by topic into units of study.

<http://classroomantarctica.aad.gov.au/>

Antarctic School Zone (BAS–British Antarctic Survey, UK)

Features: Teacher and classroom resources, fact sheets, online activities, glossary, images, FAQs, audio clips, activities and games, links

Quote: "A definitive source of Antarctic information and activities for the classroom... These are relevant for teaching current affairs and science as well as geography."

http://www.antarctica.ac.uk/about_antarctica/teacher_resources/index.php

Explore the **Discovering Antarctica** page. "Each of the site's ten sections is divided into: 'Icebreaker' learning activities to introduce the topic, 'Go with the floe' main learning activities, and 'Meltdown' follow-up learning activities..."

<http://www.discoveringantarctica.org.uk/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

42

General Polar Websites - Expeditions, Research, Resources

IPY—International Polar Year

Features: Educational resources, news, resources, launch events, blogs, links, everything polar!

Notes: "International Polar Year is program of coordinated, interdisciplinary scientific research and observations in the Earth's polar regions. The purpose of an IPY is to advance humanity's understanding of the Arctic and Antarctic regions. Past IPYs have led to significant advances in meteorology, magnetism, radio science and the launch of the first satellites."

<http://www.ipy.org/>

NOAA Arctic Theme Page (National Oceanic and Atmospheric Administration, USA)

Features: Everything!

<http://www.arctic.noaa.gov/>

NSIDC Arctic Climatology and Meteorology PRIMER (National Snow and Ice Data Centre, USA)

Features: Meteorology and climate resources, map, glossary, images

Quote: "A collection of interesting and informative meteorology and climate facts with particular emphasis on Arctic phenomena. You can learn general information about the basics of Arctic weather, the factors that determine weather and climate, and some of the weather patterns in the Arctic. Brief sections also explore the Arctic's role in the global climate system and concerns about climate change."

<http://nsidc.org/arcticmet/>

SCAR-Scientific Committee on Antarctic Research (ICSU—International Council for Science)

Features/Topics: Antarctic resources, Antarctic Treaty, news, publications, educational resources

Quote: "SCAR is charged with the initiating, developing and coordinating high quality international scientific research in the Antarctic region, and on the role of the Antarctic region in the Earth system."

<http://www.scar.org/>

AAD-Australian Government Antarctic Division

Features: Resources and Fact Files, research, maps, photos & images, webcams, educational materials, publications and more!

Notes: Check out the "Experience Antarctica" section for general information on the Antarctic continent.

<http://www.aad.gov.au/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

43

USAP—United States Antarctic Program (NSF-National Science Foundation's Office of Polar Programs)

Features: Science research, images and video, maps, Antarctic Treaty and more

<http://usap.gov/>

AINA—Arctic Institute of North America (U of Calgary, Canada)

Features: News, research and education, publications, links and more

Quote: "Created by an Act of Parliament in 1945, the AINA is a non-profit membership organization and a multi-disciplinary research institute of the University of Calgary." "The institute's mandate is to advance the study of the North American and circumpolar Arctic through the natural and social sciences, the arts and humanities and to acquire, preserve and disseminate information on physical, environmental and social conditions in the North."

<http://www.arctic.ucalgary.ca/>

National Geographic Antarctica Hub

Features: Resources, and interactive map, games, links and much more

Interactive map: <http://ngm.nationalgeographic.com/ngm/antarctica/>

Taiga.net (UNEP-United Nations Environment Programme/GRID-Arendal)

Features: Reports, educational materials, wildlife, links and more

Quote: "Taiga Net is a co-operative environmental and community web network facilitated by UNEP/GRID-Arendal. Each site on this network owns and manages its own content."

<http://www.taiga.net/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

44

ANDRILL-ANTarctic geological DRILLing Project

Features: Educational resources, news, animations, photos, Antarctic historical timeline, Podcasts, links and more

<http://www.andrill.org/>

Educational resources: <http://www.andrill.org/education/index.html>

Antarctic organizations: <http://www.andrill.org/about/index.html>

United States Polar Rock Repository (National facility at the Byrd Polar Research Center, The Ohio State University, USA)

Features: FAQ, Kids Space and the Rock Sample Database

Quote: "The repository houses rock sample collections from Antarctica and the Arctic, along with field notes, photos, maps, paleomagnetic cores, rock and mineral residues, thin sections, and microfossil mounts, microslides and residues."

<http://www-bprc.mps.ohio-state.edu/emuwebusprrr/pages/usprrr/Query.php>

Cool Antarctica

Features: News, wildlife, history, shopping, photos, links and more!

Notes: Run by Paul Ward, a teacher who spent two years in Antarctica with British Antarctic Survey as a marine biologist. He developed this site after his return.

<http://coolantarctica.com/>

Amundsen-Scott South Pole Station (USA)

Features: News, history, photos, webcams, links

<http://www.southpolestation.com/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

45

WHOI Expeditions (Woods Hole Oceanographic Institution, USA)

Features: Expedition outlines (see below), polar resources, images, fact sheets, video, blogs and journals, interviews, live teleconferences, games and more

Topics: Oceanography, polar comparisons, temperature and climate, biology, sea ice, optical effects, Arctic exploration history

Edge of the Arctic Shelf 2004:

<http://www.whoi.edu/science/PO/arcticedge/index.html>

Polar Discovery: <http://polardiscovery.whoi.edu/>

NOAA Ocean Explorer Explorations

(National Oceanic and Atmospheric Administration, USA)

Features: Expedition outlines (see below) and mission summaries for each expedition, classroom lesson plans, slideshows, explorer/researcher biographies, research data, animations, publications, images and much more

Notes: Updates are constantly being added. Only a few polar related explorations are outlined (see below), explore the site to find more

<http://oceanexplorer.noaa.gov/explorations/explorations.html>

Tracking Narwhals in Greenland 2006–2007:

<http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html>

Sounds of the Southern Ocean 2006:

<http://www.oceanexplorer.noaa.gov/explorations/06sounds/welcome.html>

The Hidden Ocean Arctic 2005:

<http://oceanexplorer.noaa.gov/explorations/05arctic/>

Gulf of Alaska: Exploring Alaska's Seamounts 2004:

<http://oceanexplorer.noaa.gov/explorations/04alaska/welcome.html>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

46

Cryosphere Websites - Ice & Snow on Earth

The Cryosphere (NSIDC-National Snow and Ice Data Centre, USA)

Features: Resources, publications, datasets, images, glacier photo comparisons over time, news, links, glossary and much more

Topics: Snow and ice (glaciers, sea ice, etc.)

<http://nsidc.org/cryosphere/>

The Cryosphere Today (Run by William Chapman; Some snow and ice data provided by the NCEP/NOAA)

Features: archived datasets, sea ice animations over time (very cool!), daily sea ice images since 1978 (Check your birthday!)

<http://arctic.atmos.uiuc.edu/cryosphere/>

Canadian Ice Service (Environment Canada)

Features: Latest ice conditions, news, datasheets (look for the PDFs under 'Ice Codes'), image of the month, ice terminology and more

<http://ice-glaces.ec.gc.ca/>

SnowCrystals.com (California Institute of Technology, USA)

Features: Photo galleries and crystal classification, educational activities, video of growing snowflake crystals, news

Quote: "Your online guide to snowflakes, snow crystals, and other ice phenomena."

<http://www.its.caltech.edu/~atomic/snowcrystals/>

SVS-Scientific Visualization Studio: A Tour of the Cryosphere (NASA Goddard Space Flight Center, USA)

Features: Computer animated Cryosphere videos, resources, links and more

Notes: There are various ways to search the visualizations. It's a site worth exploring!

<http://svs.gsfc.nasa.gov/vis/a000000/a003100/a003181/index.html>



Climate Change and the Polar Regions Websites

WHOI Ocean Climate Change Institute (Woods Hole Oceanographic Institution, USA)

Features: Publications, related topics, expedition outlines, educational materials, interviews, researcher biographies and much more!

Notes: Join their mailing list, and follow along on their Antarctic expedition.

<http://www.whoi.edu/institutes/occi/index.htm>

Dive and Discover educational site: <http://www.divediscover.whoi.edu/>

Arctic Change: A Near-Realtime Arctic change Indicator (National Oceanic and Atmospheric Administration, USA)

Features: Datasets, links, maps, resources, everything!

Quote: "The objective of this website is to present recent indicators that describe the present state of the Arctic climate and ecosystem in an accessible, understandable, and credible historical context."

<http://www.arctic.noaa.gov/detect/>

Report: NOAA State of the Arctic report (NOAA, 2006):

<http://www.arctic.noaa.gov/soa2006/>

AMAP—Arctic Monitoring and Assessment Programme (one of 5 Working Groups of the Arctic Council)

Features: Publications, maps and graphics, video clips and animations.

Quote: "The primary function of AMAP is to advise the governments of the eight Arctic countries; on matters relating to threats to the Arctic region from pollution, and associated issues."

Quote: "The report (see below) is an "international project of the Arctic Council (www.arctic-council.org) and the IASC-International Arctic Science Committee (<http://iasc.arcticportal.org/>), to evaluate and synthesize knowledge on climate variability, climate change, and increased ultraviolet radiation and their consequences. The results of the assessment were released at the ACIA International Scientific Symposium held in Reykjavik, Iceland in November 2004."

<http://www.amap.no/>

Report: ACIA-Arctic Climate Impact Assessment: <http://www.acia.uaf.edu/> or <http://www.amap.no/acia/>

WCRP—The World Climate Research Programme

Features: Audiovisual materials, publications and newsletters, news and links

Quote: "The World Climate Research Programme (WCRP) was established in 1980 with two major objectives: to determine the extent to which climate can be predicted, and to determine the extent of human influence on climate."

<http://wcrp.wmo.int/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

48

NCP-Northern Contaminants Program (Indian and Northern Affairs, Canada)

Quote: "The Northern Contaminants Program (NCP) was established in 1991 in response to concerns about human exposure to elevated levels of contaminants in wildlife species that are important to the traditional diets of northern Aboriginal peoples." "The Program's key objective is: to work towards reducing and, where possible, eliminating contaminants in traditional/country foods, while providing information that assists individuals and communities in making informed decisions about their food use."

http://www.ainc-inac.gc.ca/ncp/index_e.html

Publications: <http://www.ainc-inac.gc.ca/nth/ct/ncp/pub-eng.asp#ncp>

IcebergFinder.com (Hospitality Newfoundland & Labrador, Canada)

Features: Iceberg guide, live satellite iceberg map, tracking technology, links

Quote: "IcebergFinder.com is the place to find information on viewing icebergs in Newfoundland and Labrador, Canada."

<http://www.icebergfinder.com/>



Polar Peoples Websites

Arctic Council

Features: Outlines of the scientific work, links to the Arctic Council Scientific Working Groups and Arctic indigenous representatives within the Arctic Council.

Quote: "A high-level, intergovernmental forum for cooperation, coordination and interaction between Arctic states, indigenous communities and other Arctic residents." "The scientific work of the Arctic Council is carried out in five expert working groups focusing on such issues as monitoring, assessing and preventing pollution in the Arctic, climate change, biodiversity conservation and sustainable use, emergency preparedness and prevention in addition to the living conditions of the Arctic residents."

<http://www.arctic-council.org/>

ICC-Inuit Circumpolar Council

Features: News and archives, links, publications

Quote: "...the Inuit Circumpolar Council (ICC) has flourished and grown into a major international non-government organization representing approximately 150,000 Inuit of Alaska, Canada, Greenland, and Chukotka (Russia). The organization holds Consultative Status II at the United Nations."

<http://www.inuitcircumpolar.com/index.php?Lang=En&ID=1>

IPS-Arctic Council Indigenous Peoples' Secretariat (Indigenous Peoples at the Arctic Council)

Features: News and articles, newsletter, backgrounders, calendar of events

Quote: "The Arctic Council Indigenous Peoples' Secretariat is a support secretariat for the International Indigenous Peoples' Organizations that are Permanent Participants to the Arctic Council."

<http://www.arcticpeoples.org/>

Arctic Studies Centre (Smithsonian Institution)

Features: publications, exhibitions, research and resources and more

Quote: "The Arctic Studies Center invites you to explore the history of northern peoples, cultures, and environments and the issues that matter to northern residents today. Join us as we excavate arctic sites; support indigenous efforts to preserve cultural heritage; and work with communities and scholars to share the treasures preserved in museum collections and archives."

<http://www.mnh.si.edu/arctic/index.html>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

50

Maps of Circumpolar Peoples:

Map: Population distribution in the circumpolar Arctic (UNEP/GRID-Arendal Maps and Graphics library):

http://maps.grida.no/go/graphic/population_distribution_in_the_circumpolar_arctic

Map: People of the Arctic (from ACIA Report Graphics):

<http://www.arctic.noaa.gov/detect/human-socio-economic.shtml>

Polar Life Sciences Websites - Animals & Plants

POLAR BEARS:

Polar Bears International (USA)

Features: educational materials and resources, video, satellite tracking maps, polar bear webcam, links and much more!

<http://www.polarbearsinternational.org/>

Polar Bear Specialist Group (IUCN Species Survival Commission)

Features: Links, resources and polar bear FAQ, publications and meeting reports, maps and more

<http://pbsg.npolar.no/>

Proceedings of the 15th Working Meeting (2009):

<http://data.iucn.org/dbtw-wpd/edocs/SSC-OP-043.pdf>

Polar Bear Tracker (WWF & Norwegian Polar Institute)

Features: Range maps with satellite signals from individual bears, general polar bear resources, threats to polar bears and more

http://www.panda.org/about_wwf/where_we_work/europe/what_we_do/arctic/polar_bear/index.cfm

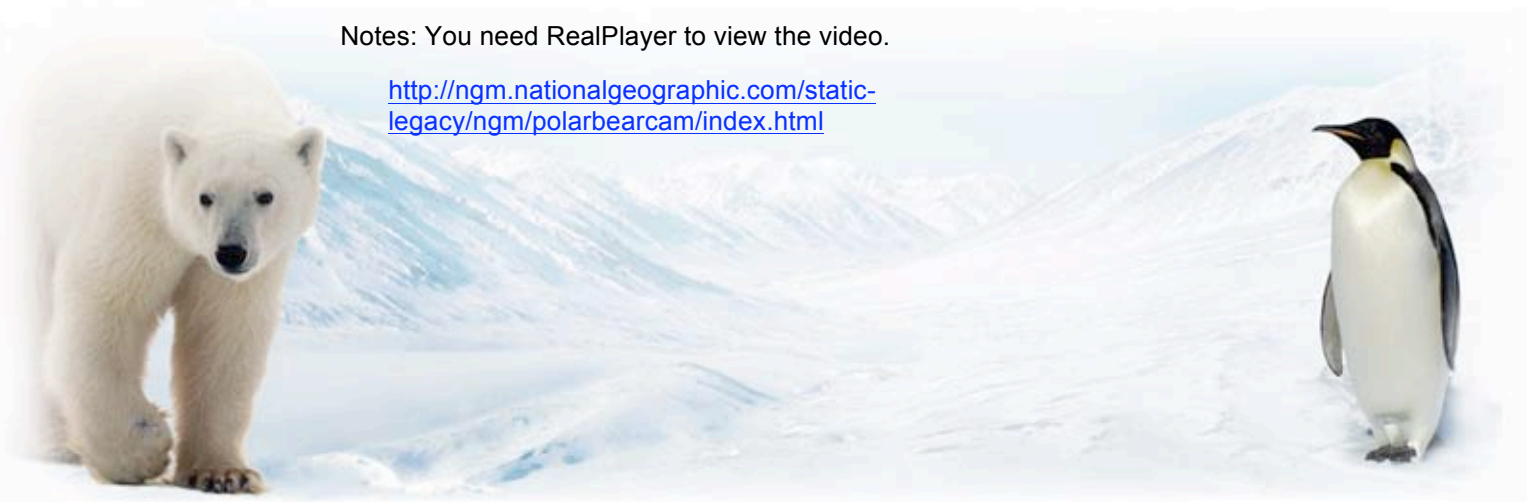
<http://www.ngo.grida.no/wwfap/polarbears/>

Polar Bear Cam (National Geographic)

Features: video highlights from past years, photos and wallpapers, forum, maps and general polar bear information

Notes: You need RealPlayer to view the video.

<http://ngm.nationalgeographic.com/static-legacy/ngm/polarbearcam/index.html>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

51

PENGUINS:

Penguin World (Dr. Lloyd Davis, University of Otago, New Zealand)

Features: Species information and distribution maps, Ask Dr. Penguin, books, Penguin Reference Database, news

Notes: This is the website of Ends of the Earth's penguin advisor, Dr. Lloyd Davis (<http://www.otago.ac.nz/Zoology/staff/otago008920.html>)

<http://www.penguinworld.com/index.php>

Penguin Science (David Ainley, PhD, H.T. Harvey & Associates—Ecological Consultants, USA)

Features/Topics: Penguin Cam, climate change, research data and reports, video, educational DVD coming soon, educational materials and resources, glossary and much more!

<http://www.penguinscience.com/index.php>

New Zealand Penguins (Dr. Dave Houston, Department of Conservation in Wellington, New Zealand)

Features: species information, threats and conservation, research, webcams, FAQ, games, links and more

Notes: Check out the **Penguin FAQ** (<http://www.penguin.net.nz/faq/faq.html>) and the colony of penguins that Houston advises to (**Oamaru Blue Penguin Colony**: <http://www.penguins.co.nz/>)

<http://www.penguin.net.nz/>

Adélie Penguin Research (Manaaki Whenua—Landcare Research, New Zealand)

Features: resources, research, satellite imagery, behavior, photos, Antarctic information and more

Notes: This site is very good at describing how the penguin research is conducted.

<http://www.landcareresearch.co.nz/research/biodiversity/penguins/index.asp>



Yellow-eyed Penguin Trust

Features: Yellow-eyed penguin resources and information, educational material, threats and conservation work

Quote: "In 1987 Dunedin conservationists formed the Yellow-eyed Penguin Trust with the aim of saving the penguin by restoring coastal forest and controlling predators. The penguin is the focus but the Trust's efforts also benefit other native species of plant and animal."

<http://www.yellow-eyedpenguin.org.nz/>

IPCWG-International Penguin Conservation Working Group

Features: Species, threats, map, links and much more!

Quote: "The IPCWG was formed in September 2000, following the 4th International Penguin Conference, in order to address mounting threats to penguin populations world-wide. It is made up of penguin biologists, research institutes, zoos and aquaria, and other international organizations working in the field of penguin conservation, research and education."

<http://www.penguins.cl/index.htm>

WHALES:

Arctic Whale Information (American Cetacean Society, USA)

Features: physical descriptions, distribution and range maps, feeding and reproduction, status, references, photos, PDF fact sheets

Notes: the map on the narwhal page is wrong; narwhal is pronounced "Nar-whale"

Bowheads: <http://www.acsonline.org/factpack/bowhead.htm>

Belugas: <http://www.acsonline.org/factpack/BelugaWhale.htm>

Narwhals: <http://www.acsonline.org/factpack/Narwhal.htm>

Tracking Narwhals in Greenland 2006–2007 (NOAA-National Oceanic and Atmospheric Administration, Ocean Explorer, USA)

Features: Photos (tags, narwhals), satellite tracking maps, educational material, narwhal biology, researcher biographies and more

<http://oceanexplorer.noaa.gov/explorations/06arctic/welcome.html>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

53

OTHER ANIMALS:

Notes: Many of the general polar sites listed above have very good wildlife resources on their sites.

Walrus Research Projects (Alaska Science Center, U.S. Geological Survey)

Features: Satellite tracking animations, research data, PDFs, walrus information and links

<http://alaska.usgs.gov/science/biology/walrus/index.html>

Walrus (US Fish and Wildlife Service, Alaska)

Features: Reports, biology information, links

<http://alaska.fws.gov/fisheries/mmm/walrus/nhistory.htm>

Ringed Seals: Beaufort Sea Seals Research and Monitoring

Features: photos, satellite tracking, maps and distribution, research data, threats and conservation, links

<http://www.beaufortseals.com/>

NMML—National Marine Mammal Laboratory (Alaska Fisheries Science Center, NOAA-National Oceanic and Atmospheric Administration, National Marine Fisheries Service, USA)

Notes: Look up Arctic marine species (<http://nmml.afsc.noaa.gov/education/>, <http://nmml.afsc.noaa.gov/species/species.htm>)

<http://www.afsc.noaa.gov/NMML/>

***Tiktaalik roseae* Discovery Site** (University of Chicago)

Features: Video animations, photos, researcher biographies, history, fossil information, links and more

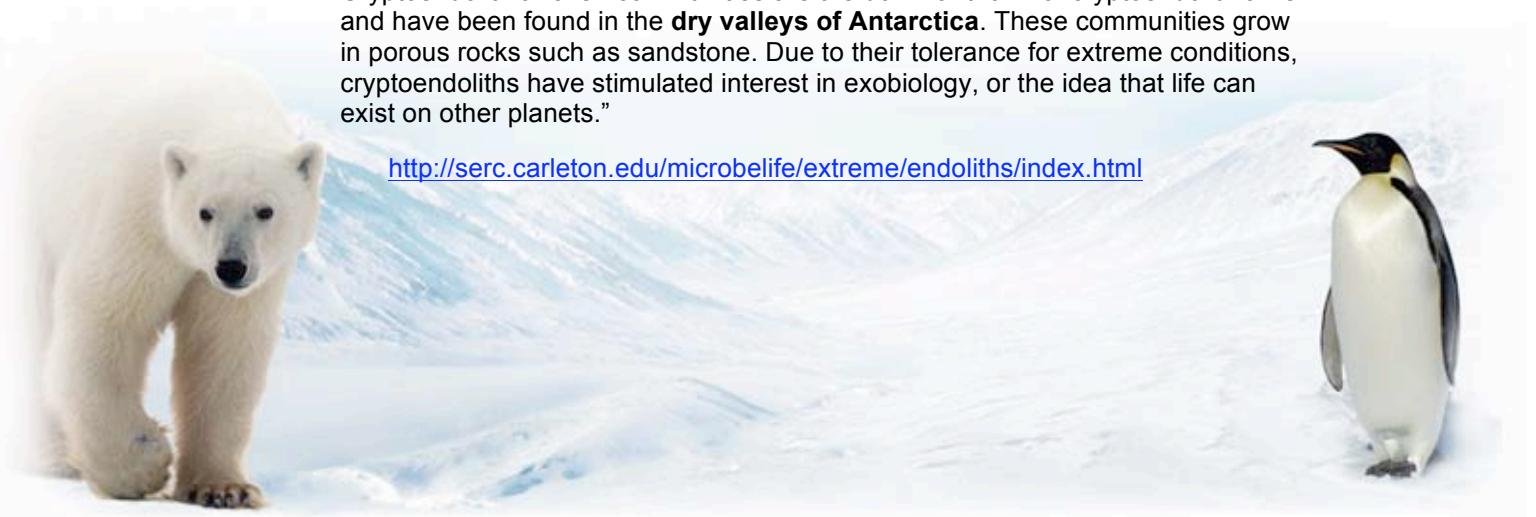
Notes: *Tiktaalik* is a fossil discovered in Nunavut, Canada. It represents an animal that was part way between a fish and a tetrapod (four-legged animal).

<http://tiktaalik.uchicago.edu/>

Endoliths: Microbes Living within Rocks (Carleton College, USA)

Quote: “**Cryptoendoliths** are endoliths that live in rock on the Earth's surface. Cryptoendolithic lichen communities are the dominant form of cryptoendolithic life and have been found in the **dry valleys of Antarctica**. These communities grow in porous rocks such as sandstone. Due to their tolerance for extreme conditions, cryptoendoliths have stimulated interest in exobiology, or the idea that life can exist on other planets.”

<http://serc.carleton.edu/microbelife/extreme/endoliths/index.html>



Ends of the Earth: From Polar Bears to Penguins A Special Exhibition

54

Polar Exploration History - Explorers, Timelines, Artifacts

South-pole.com (US Antarctic Program, USA)

Features: Stamps, images and photos, Arctic and Antarctic timelines, history, explorers and more

Quote: "This site is dedicated to the heroic explorers of our polar regions and the surrounding islands. The tales of these brave souls were often related in expedition mail sent home to anxious loved ones and beneficiaries. As you browse through this site, you will witness an extensive mix of reference material that will be useful to philatelists and students of polar history alike."

<http://www.south-pole.com/homepage.html>

Of Maps and Men: In Pursuit of a Northwest Passage (Princeton University Library)

Features: map chronology, explorers and expeditions, books, artwork and photos

http://libweb5.princeton.edu/visual_materials/maps/websites/northwest-passage/contents.htm

The Fabled Northwest Passage (Library and Archives of Canada, Collections Canada)

Features: explorer biographies, expeditions, maps, historical documents

<http://epe.lac-bac.gc.ca/100/206/301/lac-bac/explorers/www.collectionscanada.gc.ca/explorers/index-e.html>

Breaking the Ice: Canada and the Northwest Passage (CBC-Canadian Broadcast Corporation Archives, Canada)

Features: Educational activities, TV and radio broadcasts, links to news articles

http://archives.cbc.ca/IDD-1-73-2349/politics_economy/northwest_passage/

Antarctic—Extreme Wilderness (Unlocking the Archives, Royal Geographical Society and the Institute of British Geographers, UK)

Features: Resources and PDFs, Teacher's Area and educational materials

Topics: Discover the story of the race to the Pole. What were their views of Antarctica? What is the climate and landscape like? How has Antarctica been used for science? How has Antarctica been used for commercial profit? Which countries have signed up to the Antarctic Treaty system?

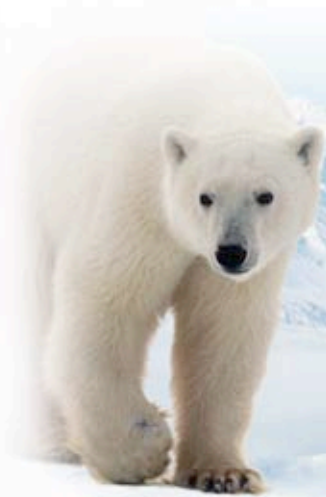
<http://www.unlockingthearchives.rgs.org/themes/antarctica/default.aspx?id=350&idrepresents=page>

Polar Scientists & Explorers: Past & Present (PRISM-Polar Radar for Ice Sheet Measurements)

Features: Resources, educational materials, news archives

Notes: Check out the archived newspaper articles from the late 1800s (<http://ku-prism.org/polarscientist/1800sAntarctic/1800index.html>)

<http://ku-prism.org/polarscientist/polarscientists.html>



EXPLORERS:

In the Footsteps of Sir Douglas Mawson

(South Australian Museum)

Quote: "Douglas Mawson was a scientist, an explorer and an adventurer." "Upon entering the site, you view a reconstruction of Mawson's hut...Here you can click on one of three notebooks. One gives an abbreviated life history of Sir Douglas...The other notebooks give information about the places where Mawson pursued his major scientific interests..."

<http://www.mawson.sa.gov.au/ie.htm>

Scott: Secrets of the Dead - Tragedy at the Pole (PBS)

Features: Resources, wallpapers, links

http://www.pbs.org/wnet/secrets/previous_seasons/case_southpole/index.html

Shackleton: 'Voyage of Endurance' (NOVA)

Features: timeline, educational materials and teachers' guide, Shackleton biography, diary of a survivor, NOVA Expedition 1999-2000

<http://www.pbs.org/wgbh/nova/shackleton/>

Virtual Shackleton (Scott Polar Research Institute, U of Cambridge, UK)

Features: Historical documents, expedition outlines

Quote: "...aims to provide a scholarly resource as well as an introduction to the Institute's wealth of historical documents and artifacts."

<http://www.spri.cam.ac.uk/library/archives/shackleton/>

Frederick A. Cook Society

Quote: "...a nonprofit, educational organization which holds an annual meeting, publishes a membership newsletter three times a year, and an annual journal...maintains the Frederick A. Cook Collection...and assists writers, scholars, and individuals seeking information on the life and work of Frederick Albert Cook..."

<http://www.cookpolar.org/>

Peary & Henson Foundation (a free public service provided by Bradley Robinson)

Features/Topics: gift store, images, links, Peary/Cook controversy

<http://pearyhenson.org/index.htm>

Fridtjof Nansen: Scientist and Humanitarian (Nobel Prize)

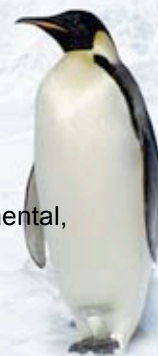
Features: biography and resources

http://nobelprize.org/nobel_prizes/peace/laureates/1922/nansen-article.html

FNI-Fridtjof Nansen Institute (Norway)

Quote: "...independent foundation engaged in research on international environmental, energy and resource management politics."

<http://www.fni.no/>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

56

Polar Image Websites – Images, Photos, Maps

IPY-International Polar Year Photo Gallery

<http://www.ipy.org/index.php?/ipy/gallery/>

USAP Photo Library (US Antarctic Program, USA)

Features: Photos of people, stations, scenery, scientific research, historical photos

Notes: A great place to start. Photos are easy to search and download, and credit information is provided.

<http://photolib.usap.gov/>

National Digital Library (US Fish and Wildlife Service, USA)

Features: Public domain images, publications, video & audio

Notes: Photos are easy to search and download, and credit information is provided.

<http://digitalmedia.fws.gov/>

NASA Earth Observatory

Features: Data, images, satellite photos, printable news and research articles and PDFs, resources, links and more

Notes: Use the search function, and look for articles.

<http://earthobservatory.nasa.gov/>

ANDRILL-ANTarctic geological DRILLing Project

Notes: Photos are public domain, but credit goes to the photographer and to the National Science Foundation.

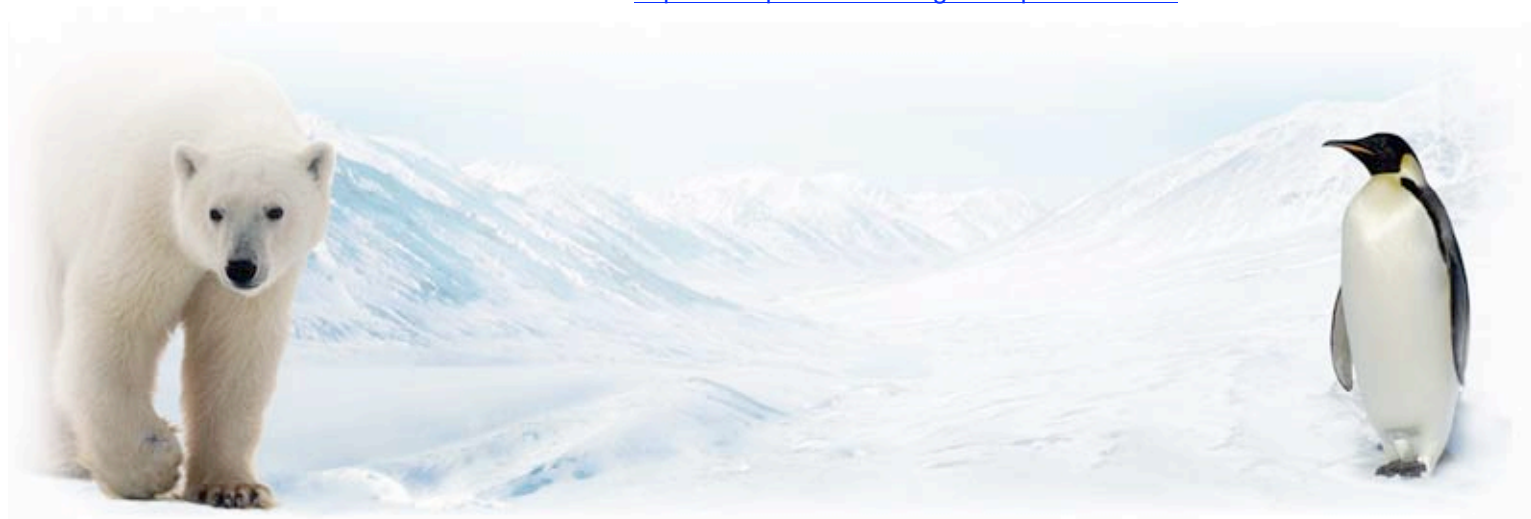
<http://www.andrill.org/album/Site/ALBUMS.html>

NOAA Image Libraries (NOAA-National Oceanic and Atmospheric Administration, USA)

Features: live camera images, scientists, wildlife, scenery and historical images

Gallery of Arctic images: <http://www.arctic.noaa.gov/gallery.html>

Ends of the Earth: <http://www.photolib.noaa.gov/corps/index.html>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

57

RGS–Royal Geographical Society Picture Library

<http://images.rgs.org/index.aspx>

Glasgow Digital Library (Royal Scottish Geographical Society)

<http://gdl.cdlr.strath.ac.uk/scotia/gooant/index.html>

The Polar Circle (polar photography)

Quote: "The Polar Circle is a group of polar photographers and specialist collections on polar regions offering a one stop source for Polar imagery. We have come together on this website to offer the best in specialised polar imagery, History, technology, industry, science, wildlife, landscape and the people."

Notes: See also: **Bryan & Cherry Alexander Photography** (Stock photography of the polar regions): <http://www.arcticphoto.co.uk/>

<http://www.thepolarcircle.com/index.htm>

Thomas D. Mangelsen (professional photographer)

Notes: His book of polar bear photographs, "Polar Dance: Born of the North Wind", was recipient of the American Booksellers Association's 1998 Best of Small Press Award, and a "Holiday Pick" on Good Morning America.

<http://www.mangelsen.com/>

Guillaume Dargaud (photographer)

Features: Wallpapers, royalty-free image CDs.

<http://www.gdargaud.net/Photo/index.html>

Antarctic and Subantarctic Maps (Australian Government Antarctic Division)

<http://www.antarctica.gov.au/about-antarctica/fact-files/geography/maps>



Ends of the Earth:

From Polar Bears to Penguins

A Special Exhibition

58

California State Content Standards

Grade K

Life Sciences 2a, c

Earth Sciences 3a, b

Investigation and Experimentation 4a–e

Grade 1

Life Sciences 2a, c, d

Investigation and Experimentation 4a, b, e

Grade 2

Life Sciences 2a, c

Investigation and Experimentation 4a

Grade 3

Life Sciences 3a–d

Grade 4

Life Sciences 2b, 3a, b

Earth Sciences 5a

Investigation and Experimentation 6a–c

Grade 5

Earth Sciences 3a, d, 4a, b

Grade 6

Ecology 5c, e

Grade 7

Evolution 3e

Grade 9–12

Ecology 6a, b

Energy in the Earth System 4c, 6a–d

