

KNOWLEDGE ORGANISER

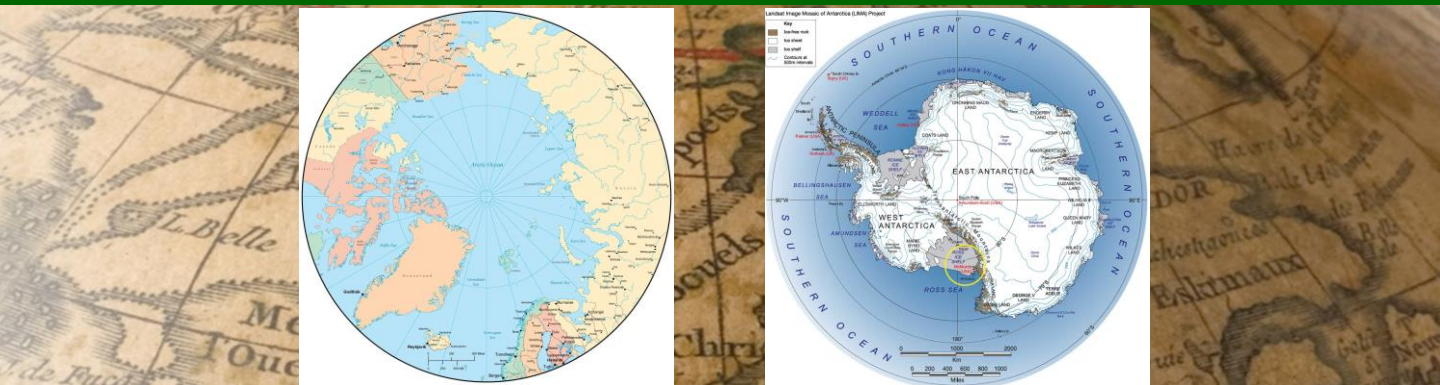
WORLD STUDIES

Year 9 Geography

Polar Regions Part 2

Name:

Class Teacher:



HOMework












Big Question	Task	Due Date
2	Revise page 4 and 6 and complete recall quiz on page 7	
5	Revise pages 9 – 13 and complete recall quiz on page 14	
8	Revise pages 16 – 18 and complete recall quiz on page 19	
10	Revise for the End of Unit test	

Key terms found in the glossary on pages 4 and 5 will be tested throughout the unit


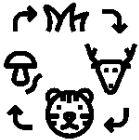






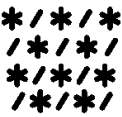


ENQUIRY QUESTIONS

1. Where is the Arctic and who lives there?
2. What is the Cryosphere and what processes are taking place?
3. What are the periglacial processes affecting the Arctic?
4. Why is the Arctic such a sensitive environment?
5. What are the impacts of climate change in the Arctic?
6. Why is the Northwest passage important?
7. What are the Northern lights?
8. What impact is the demand for energy having on the polar regions?

GLOSSARY

Key term	Icon	Definition
Ablation		the loss of ice or snow from a glacier or iceberg, or the loss of rock or similar material, caused by a process such as melting or erosion
Abrasion		Blocks of rock in the base and sides of the glacier are scraped over the rock surface, just like sandpaper.
Biodiversity		The number and types of plants and animals that exist in a particular area or in the world generally
Biome		Large area characterised by its vegetation, soil, climate and wildlife.
Climate		The weather conditions in an area over a long period of time.
Climate change		changes in the world's weather, in particular the fact that it is believed to be getting warmer as a result of human activity increasing the level of carbon dioxide in the atmosphere
Condensation		Vapour being converted to a liquid
Crevasse		a very deep crack in the thick ice of a glacier (= moving mass of ice)
Deposition		The geological process in which sediments, soil and rocks are added to a landform or land mass
Erosion		The wearing away and transport of materials
Evaporation		Liquid being converted to water vapour

GLOSSARY

Key term	Icon	Definition
Extinction		a situation in which something no longer exists
Food chain		a series of living things that are connected because each group of things eats the group below it in the chain
Fossil fuels		fuels, such as gas, coal, and oil, that were formed underground from plant and animal remains millions of years ago
Geology		The science which deals with the physical structure and substance of the earth, their history, and the processes which act on them.
Greenhouse effect		an increase in the amount of carbon dioxide and other gases in the atmosphere (= mixture of gases around the earth), that is believed to be the cause of a gradual warming of the surface of the earth
Greenhouse gases		a gas that causes the greenhouse effect, especially carbon dioxide
Infiltration		(of water) to flow slowly down into the earth from the earth's surface, for example, through cracks in rocks
Pangea		the name given the one large area of land that began to break apart about 200 million years ago to create the present continents
Permafrost		an area of land that is permanently frozen below the surface
Plankton		very small plants and animals that float on the surface of the sea and on which other sea animals feed
Precipitation		Moisture that falls from the sky in the form of rain, hail, sleet and snow

BQ1 & BQ2. WHERE IS THE ARCTIC AND WHO LIVES THERE?

How can the Arctic be defined?

- ☐ The Arctic Circle is the latitude at which the sun does not set at the summer solstice, 66° 33' N
- ☐ The Arctic is the area above the tree line
- ☐ The boundary of the Arctic is the line at which the average temperature of the warmest month is 10C (summer isotherm)
- ☐ The Arctic is where the warm salty water of the Atlantic and Pacific meet the colder less salty waters of the Arctic Ocean
- ☐ The Arctic is north of latitude 60°



Who lives in the Arctic?

There are over 40 indigenous ethnic groups, with a total indigenous population of approximately 650,000. Though around 4 million people live in the Arctic in total.

The Inuit live in northern Canada, Greenland and Alaska. The Lapps (or Sami) herd reindeer in northern Scandinavia in an area nicknamed Lapland.

POLAR HOMEWORK 1: ANSWER ALL QUESTIONS

Define the term greenhouse gases (1)	
When was the Mercator map drawn? (1)	
Outline two ways to define the Arctic (2)	
What country is the world's coldest town located in? How cold? (2)	
How many time zones does the Arctic cover? (1)	
Name three countries found within the Arctic (3)	
Describe the site and situation of Resolute (3)	
Explain one reason why Antarctica is so dry (2)	
Between which lines of latitude do we find tropical rainforests? (1)	
State two rules in place to prevent tourists from damaging Antarctica (2)	
Explain one reason why Antarctica is so cold (2)	
Total out of 20:	

POLAR HOMEWORK 1: CHECK YOUR ANSWERS

Define the term greenhouse gases (1)	A gas that causes the greenhouse effect, especially carbon dioxide
When was the Mercator map drawn? (1)	1595
Outline two ways to define the Arctic (2)	The Arctic Circle is the latitude at which the sun does not set at the summer solstice, 66° 33' N/ The Arctic is the area above the tree line/ The boundary of the Arctic is the line at which the average temperature of the warmest month is 10C (summer isotherm)/ The Arctic is where the warm salty water of the Atlantic and Pacific meet the colder less salty waters of the Arctic Ocean/ The Arctic is north of latitude 60°
What country is the world's coldest town located in? How cold? (2)	<input type="checkbox"/> Russia <input type="checkbox"/> -71.2
How many time zones does the Arctic cover? (1)	24
Name three countries found within the Arctic (3)	Canada/ Russia/ Norway/ Finland/ Sweden/ Iceland/ Greenland (Denmark)/ Alaska (USA)
Describe the site and situation of Resolute (3)	Resolute is located within Canada (1) and is a small nucleated settlement found along the coastline of Cornwallis Island (1). It is located to the SE of Canada (1) and sits to the NW of Greenland (1)
Explain one reason why Antarctica is so dry (2)	Cold air doesn't hold much water vapour (1) /polar high pressure (1) means cold air is sinking(1) /continentality (1) – it is a large landmass far from the sea (1)
Between which lines of latitude do we find tropical rainforests? (1)	Tropic of Cancer and Capricorn
State two rules in place to prevent tourists from damaging Antarctica (2)	Group sizes restricted to 20/ keep 5m away from wildlife/give birds the right of way
Explain one reason why Antarctica is so cold (2)	High latitude (1) so the sunlight (insolation) hits the surface at a low angle (1)/ Snow and ice have a high albedo (reflectivity) (1) so 85% of the insolation is reflected back (1)
Total out of 20:	

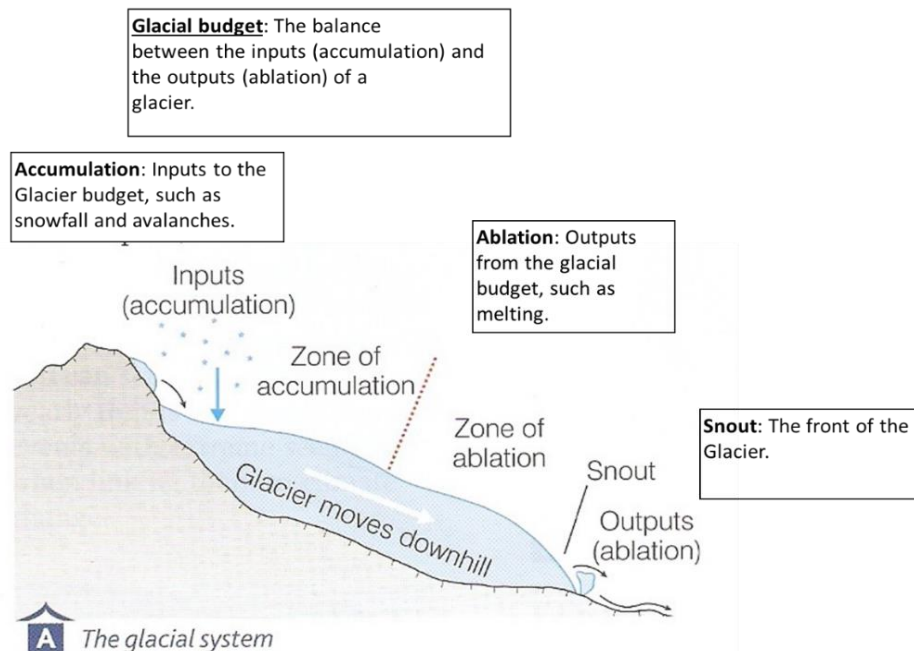
BQ3. WHAT IS THE CRYOSPHERE AND WHAT PROCESSES ARE TAKING PLACE?

What is the Cryosphere?

The term 'cryo' comes from the Greek word 'kryo', meaning cold. The cryosphere is the frozen water part of the earth's hydrological system.

How are glaciers formed?

- ❑ Glaciers are formed when snow is packed down into ice.
- ❑ Snowflakes collect or accumulate in a hollow in the mountainside.
- ❑ With more snowfalls, the weight compresses the snow together into solid ice of a much greater density.
- ❑ If the ice does not melt and snow continues to fall, the ice mass will become bigger and heavier.
- ❑ Then the force of gravity causes this large ice mass to move downhill, very slowly.



BQ3. WHAT IS THE CRYOSPHERE AND WHAT PROCESSES ARE TAKING PLACE?

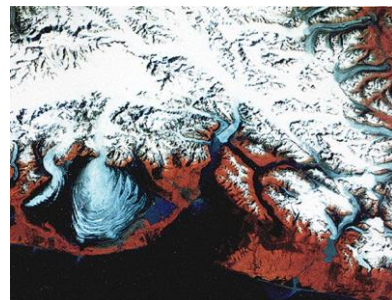
Arctic Glaciers

Glaciers are classified according to their size, shape and location. The Arctic region contains a wide range of different glaciers, including:

- ❑ **An ice sheet** – These dictate their own topography and are described as unconstrained. They extend more than 50,000 square km. e.g. Greenland Ice sheet
- ❑ **Icecaps** – These are local to region in scale, also dictate their own topography but are less than 50,000 square km e.g. Severny Island Ice cap, Russia
- ❑ **Valley glaciers** – variable in size and controlled by existing topography i.e. constrained. These have a larger length than width.
- ❑ **Piedmont glaciers** – Unconfined at the toe
- ❑ **Ice shelves** – Floating ice which is fed by ice sheets. They are found in Greenland

How does a glacier move and shape the land?

- ❑ Glaciers erode by plucking. Melted water at the base and sides of the glacier freezes onto the surrounding rock. As the glacier moves, the rock which is embedded in the ice is pulled away.



Glaciers also erode by abrasion. The bits of rock which are embedded in the ice from plucking and freeze-thaw weathering scrape and grind against the rock at the base and sides of the glacier, wearing it away. This process is a bit like sand paper!

BIG Q4. WHAT ARE THE PERIGLACIAL PROCESSES AFFECTING THE ARCTIC?

Periglacial processes

Parts of the Arctic that are not permanently frozen, where the less extreme climate means that ice and snow melt for a period during the summer months, are described as being periglacial.

How does permafrost form?

When ground temperatures drop to 0°C (32°F), the water trapped in sediment, soil, and pores of rocks turns to ice. Once frozen, it is considered frozen ground. When ground remains frozen for at least two consecutive years, it is known as permafrost. Ground that freezes and thaws every year is called seasonally frozen.

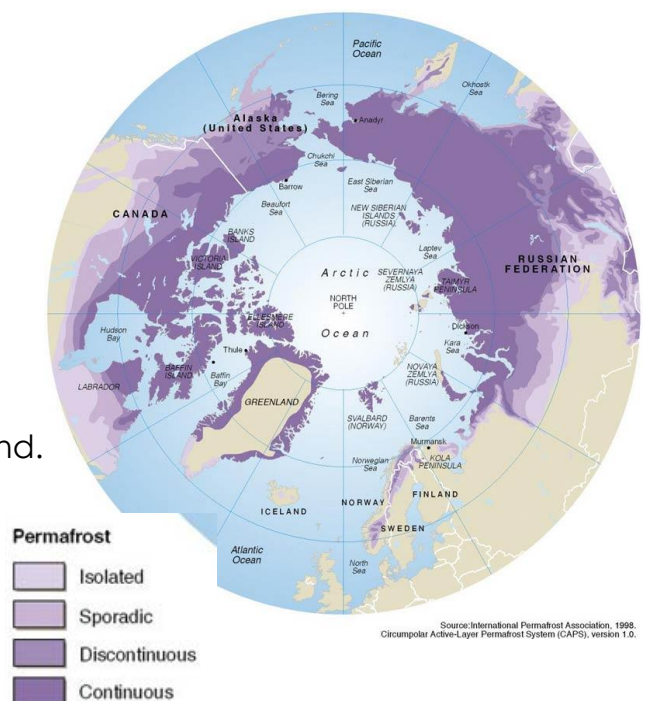
There are different types of permafrost:

Continuous: an area which is underlain by permafrost with very few unfrozen areas and a mean annual temperature of less than -5°C.

Discontinuous: Alpine permafrost is discontinuous permafrost that exists on the tops of mountains, where the ground stays very cold.

Sporadic: an area which is mostly unfrozen due to a mean annual temperature of just below 0°C, but has occasional patches of frozen ground.

Isolated: Less than 10% of the surface has permafrost under it



BIG Q4. WHAT ARE THE PERIGLACIAL PROCESSES AFFECTING THE ARCTIC?

How are the animals living in the tundra adapted to the conditions here?

Because of the extreme conditions in the Arctic animals, birds and plants have had to adapt to many different environments.

Animal adaptations

Polar bear: Polar bears have large feet, to help them walk on snow. They also have oily fur and a layer of blubber 5-15 cm thick, lying beneath the skin.

Reindeer: Reindeer have wide hooves fringed with fur that act like snowshoes, spreading their weight, so they can walk on deep snow without sinking.

Husky: Greenland dogs have small feet, which splay out and spread the weight so they don't sink into the snow.



Periglacial landforms



A Pingo is a dome shaped mound of earth with a core of ice. Formed by hydrostatic pressure, where the pressure of freezing water causes upward movement of the ground above.



Scree slope is an accumulation of broken rock debris (talus) at the foot of a slope. Formed by frost-shattering, breaking off pieces of rock due to the pressure exerted by repeated freezing and thawing of water that enters the cracks in rocks.

BQ5: WHY IS THE ARCTIC SUCH A SENSITIVE ENVIRONMENT?

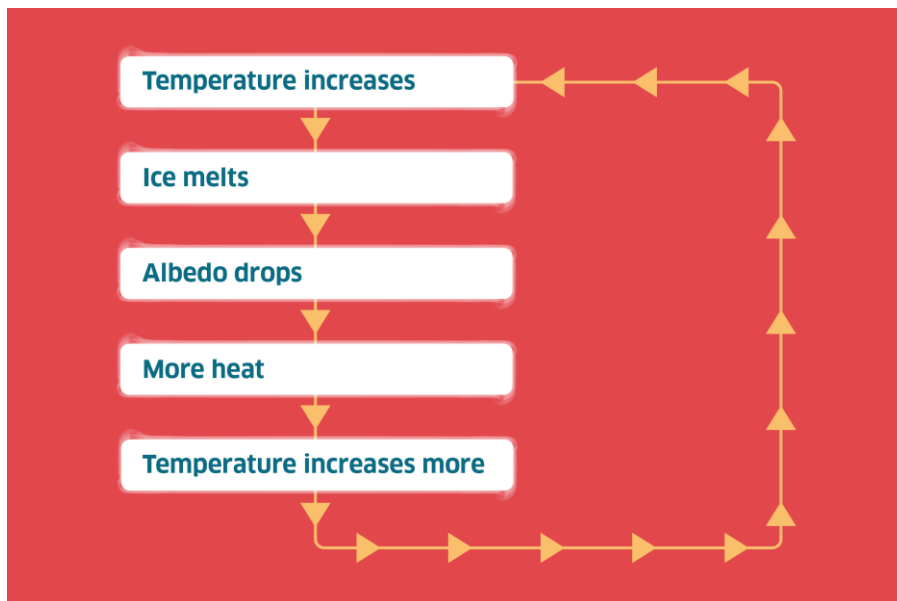
Climate systems

The Polar Regions provide important cooling processes for the world climate system. Global atmospheric and ocean circulations transfer energy from the equator towards the poles and bring cooler air and water down to the equator.

Why is the Arctic so sensitive?

Feedback mechanisms respond to changes in atmospheric, ocean and surface conditions all over the world. Sometimes the feedback can increase the effects of the process (positive +), sometimes it can restore conditions to their original state (negative -).

Positive feedback loop



POLAR HOMEWORK 2: ANSWER THE FOLLOWING

Define the term 'Cryosphere' (1)	
Define the term 'ablation' (1)	
Define the term ' accumulation zone' (1)	
State two types of Arctic glaciers (1)	
Explain the formation of a glacier (4)	
How does permafrost form? (3)	
Name two of the types of permafrost (2)	
Outline two ways that plants are adapted to the Arctic tundra? (2)	
Outline two ways that animals are adapted to the Arctic tundra? (2)	
What is a pingo? (2)	
What percentage of the Northern Hemisphere land is covered by seasonally frozen ground? (1)	
Total out of 20:	

POLAR HOMEWORK 2: CHECK YOUR ANSWERS

Define the term 'Cryosphere' (1)	The cryosphere is the frozen water part of the earth's hydrological system.
Define the term 'ablation' (1)	A general term for any mass loss from a glacier
Define the term 'accumulation zone' (1)	The area where more mass is gained than lost over a period of time.
State two types of Arctic glaciers (1)	Ice sheet/ Ice cap/ Valley glaciers/ Piedmont glacier/ ice shelves
Explain the formation of a glacier (4)	Snowflakes collect or accumulate in a hollow in the mountainside (1). With more snowfalls, the weight compresses the snow together into solid ice (1). The ice mass will become bigger and heavier (1). Then the force of gravity causes this large ice mass to move downhill, very slowly. (1)
How does permafrost form? (3)	When ground temperatures drop to 0°C (32°F) (1), the water trapped in sediment, soil, and pores of rocks turns to ice (1). When ground remains frozen for at least two consecutive years, it is known as permafrost. (1)
Name two of the types of permafrost (2)	Continuous/ discontinuous/ sporadic/ isolated
Outline two ways that plants are adapted to the Arctic tundra? (2)	Low-growing and cushion-like / Hairy stems/ Thick waxy leaves / Shallow roots / The ability to flower and produce seeds in a short period of time
Outline two ways that animals are adapted to the Arctic tundra? (2)	Polar bears have large feet to spread their weight/ Reindeer have wide hooves that act like snowshoes/ Husky dogs have small feet that splay out
What is a pingo? (2)	A Pingo is a dome shaped mound of earth with a core of ice (1). Formed by the pressure of freezing water causes upward movement of the ground above. (1)
What percentage of the Northern Hemisphere land is covered by seasonally frozen ground? (1)	50%
Total out of 20:	

BQ6. WHAT ARE THE IMPACTS OF CLIMATE CHANGE IN THE ARCTIC?

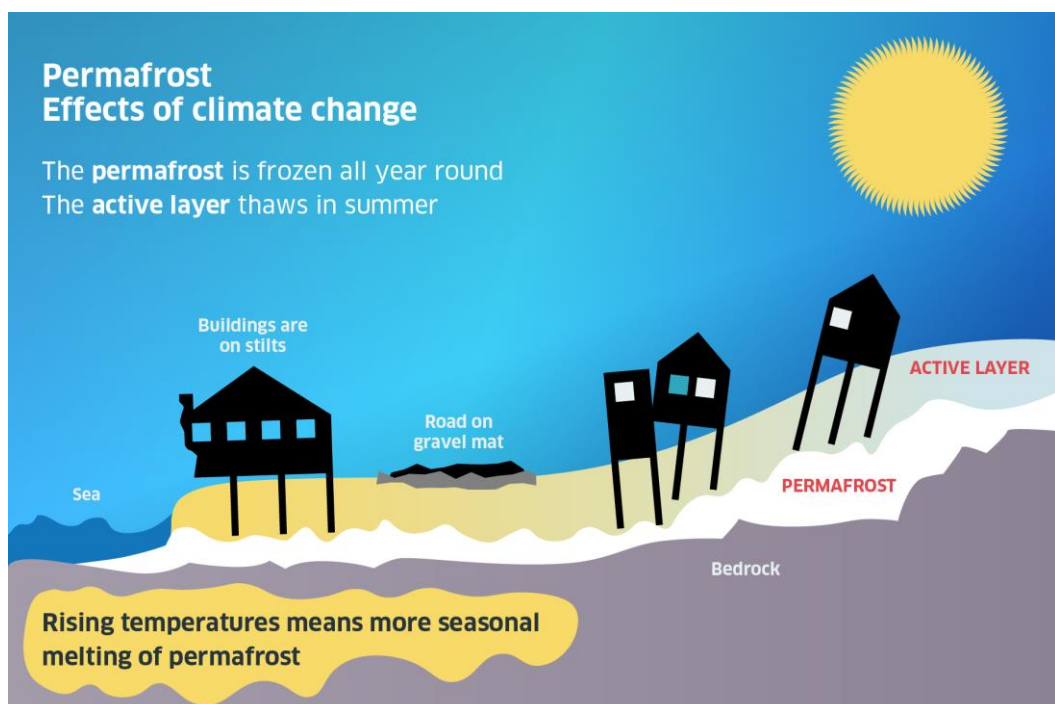
The Greenland ice sheet

The Greenland ice sheet is the largest body of freshwater ice in the Northern Hemisphere. In the future, this ice sheet will respond to climate change more intensely than other areas of the Arctic.

Arctic soils contain a lot of carbon in the form of partially decomposed organic matter. As the permafrost layer thaws, this carbon is released into the atmosphere as carbon dioxide and methane, adding still more greenhouse emissions to the atmosphere.

What happens next in the Arctic?

- ☐ People, animals and plants that live in the Arctic environment will have to adapt to these changes, in some cases quickly!
- ☐ Invasive species of fish and invertebrates colonise the freshwater and marine environments as they become warmer but animals, especially those that use the ice for breeding such as the polar bear and the walrus will take longer to adapt.

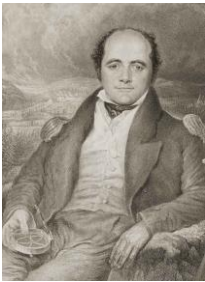


BQ7. WHY IS THE NORTHWEST PASSAGE IMPORTANT?

The Northwest Passage – a water route through the islands of northern Canada connecting the Atlantic and Pacific oceans. The Northwest Passage is 7,000 kilometres shorter than the current shipping route through the Panama Canal. That's about two weeks saved in travelling time.



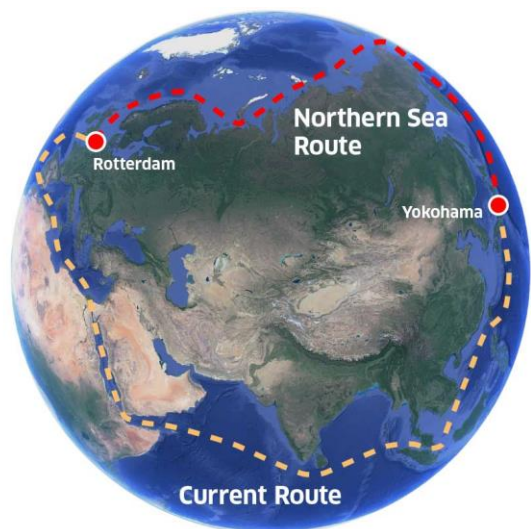
1570s, British explorer **Martin Frobisher** was one of the first Europeans to try to find the passage. However, he didn't make it past the inlet that now bears his name.



1845 to 1848. **Sir John Franklin** took a crew of 134 men and three years' worth of supplies. The explorers never returned.



1903 Roald Amundsen used a 21-metre fishing boat the Gjoa to travel its entire length.



BQ8. WHAT ARE THE NORTHERN LIGHTS?

In the early 17th century, the astronomer and scientist Galileo Galilei named this phenomenon the Aurora Borealis. Aurora was the Roman goddess of dawn, and Boreas was the Greek name for the north wind.

What causes the Northern Lights?

1. These colourful lights are the result of interactions between solar storms from the sun and the earth's outer atmosphere.
2. During the day solar storms from the sun blow an array of particles, called solar winds.
3. The solar wind is given out by the sun from time to time. The earth comes in between the path of these solar wind particles.
4. These particles are filled with energy. Many electrons and protons from these particles get trapped in the polar regions of the Earth.
5. The Earth's atmosphere is made up of two main gases, oxygen and nitrogen. These electrons and protons from the solar winds, full of energy, collide with the oxygen and nitrogen atoms in the Earth's atmosphere and they become electrically charged.
6. This charging produces a display of lights in the sky- the Aurora Borealis.



POLAR HOMEWORK 3: ANSWER THE FOLLOWING

Over the past 30 years how much has the sea ice decline in the Arctic (1)	
What is used to map the extent of ice cover in the Arctic? (1)	
Why are people concerned about thawing permafrost? (2)	
When was the Northwest passage first travelled through? (1)	
How much shorter is the NW passage than the Panama Canal? (1)	
Who has sovereignty over the NW passage? (1)	
Who named the Aurora Borealis? (1)	
What is the difference between plucking and abrasion (4)	
Describe how the process of freeze-thaw weathering breaks down rocks in glacial environments. (3)	
What is the difference between a physical and behavioural adaptation? (2)	
Why is the Arctic not classified as a continent? (1)	
Total out of 18:	

POLAR HOMEWORK 3: CHECK YOUR ANSWERS

Over the past 30 years how much has the sea ice decline in the Arctic (1)	8%
What is used to map the extent of ice cover in the Arctic? (1)	CryoSat 2
Why are people concerned about thawing permafrost? (2)	As the permafrost layer thaws, this carbon is released into the atmosphere (1) as carbon dioxide and methane, adding still more greenhouse emissions to the atmosphere. (1)
When was the Northwest passage first travelled through? (1)	1903
How much shorter is the NW passage than the Panama Canal? (1)	7,000km or two weeks
Who has sovereignty over the NW passage? (1)	Canada
Who named the Aurora Borealis? (1)	Galileo Galilei
What is the difference between plucking and abrasion (4)	Plucking is the sticking of ice to rock in the glacier (1) which is then pulled out as the glacier moves downhill. (1) /Abrasion is the wearing away of rock within the glacier by the movement of the glacier downhill (1) – like sandpaper wearing away rock. (1)
Describe how the process of freeze-thaw weathering breaks down rocks in glacial environments. (3)	The changing temperatures melts ice / snow and the meltwater gets into cracks into the rock. (1) This water freezes when the temperatures drop below 0°C. The ice expands causing the rock to break apart by a few millimetres. (1) The process repeats until the rock breaks apart and large crevasses are left behind. (1)
What is the difference between a physical and behavioural adaptation? (2)	A physical adaption is some type of structural modification made to a part of the body. (1) A Behavioral Adaptation is something an animal does - how it acts – (1)
Why is the Arctic not classified as a continent? (1)	As there is no one landmass, it is a collection of countries spread over three continents.
Total out of 18	

BQ9 & B10. WHAT IMPACT IS THE DEMAND FOR ENERGY HAVING ON THE POLAR REGIONS?

Patterns and trends in use of energy resources

- During the Industrial Revolution, advances in automation and transport caused a significant increase in the amount of fossil fuels extracted and burnt.
- In the 20th century, electricity became a convenient way of distributing energy. This powered a wide range of devices and applications such as lighting, heating, computing technologies and operating machinery.
- Demand for energy varies with the time of year and the time of day. During early evening a lot of energy is needed for heating, lighting and cooking but overnight there is very little needed while people sleep. During winter there is more heating and lighting required than in summertime.

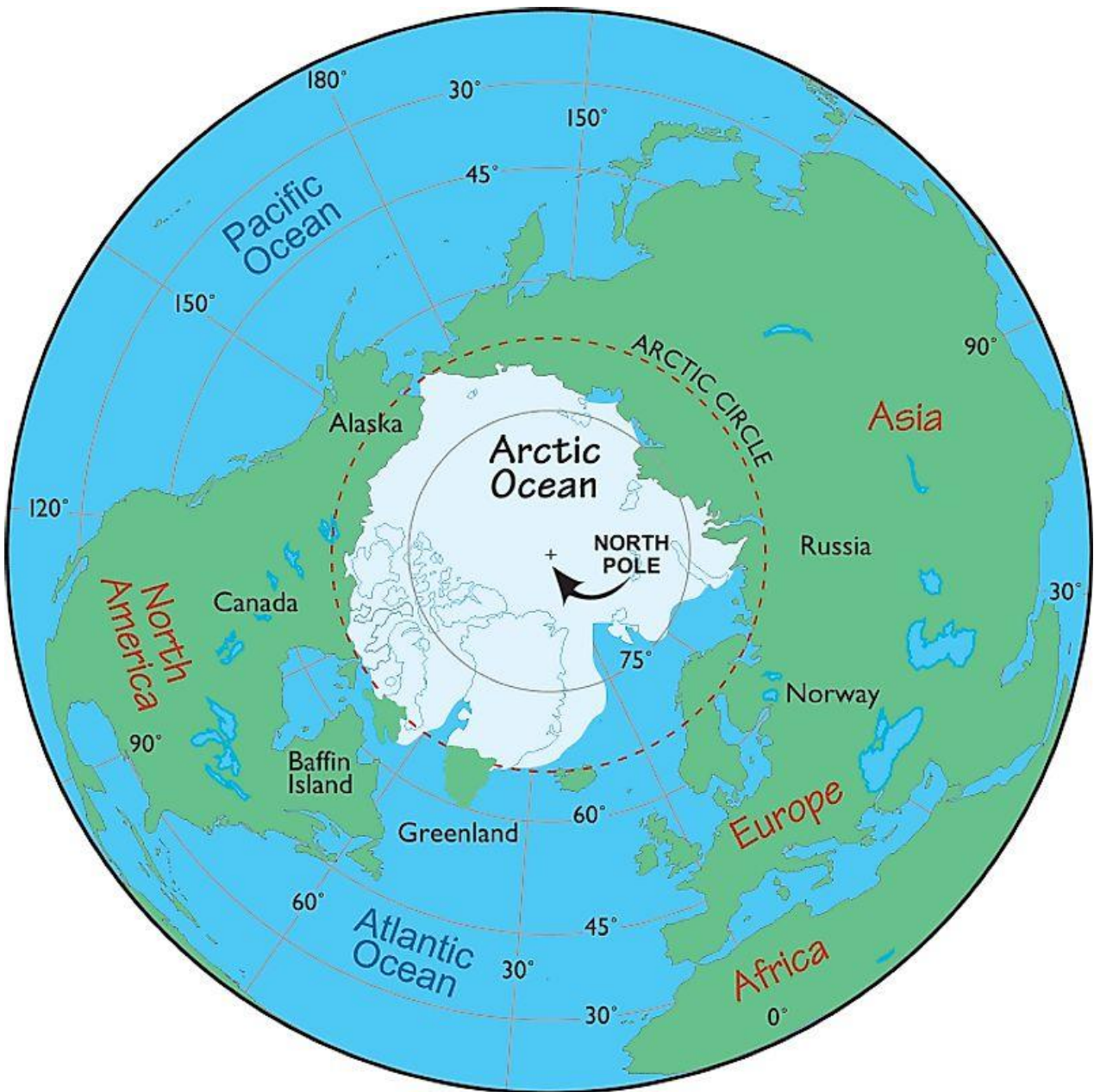
Antarctica

Extracting oil from Antarctica has been too expensive to consider in the past. However, as the price of oil increases and the availability of oil decreases, countries look to Antarctica as a possible location for supply. However to protect the environment, extraction of oil and minerals is **banned for 50 years** through the Antarctic treaty.

Arctic

- ❑ The northern Polar Regions contain of fossil fuels -- namely, oil and natural gas.
- ❑ Geologists estimate that the Arctic houses approximately **13 percent** of the world's undiscovered **petroleum** reserves, plus about **30 percent** of its undiscovered **natural gas reserves**.

MAPS - ARCTIC



PREPARING FOR YOUR ASSESSMENT

Locational Knowledge

- ☐ Polar Regions location in the world
- ☐ Countries in the Arctic Ocean
- ☐ Physical features in the Polar Regions

Physical Geography

- ☐ How to define the Arctic
- ☐ The countries from in the Arctic Circle
- ☐ Definition of the cryosphere and its elements
- ☐ How glaciers are formed
- ☐ Different types of Arctic glaciers
- ☐ Periglacial environments and their processes
- ☐ Adaptations of plants in the Arctic environment
- ☐ Adaptations of animals in the Arctic environment
- ☐ Role of the Arctic in the world climate system
- ☐ Importance of feedback mechanisms
- ☐ Impact of climate change in the Arctic
- ☐ The causes of the Northern lights

Skills

- ☐ Plot and describe a climate graph for Nunavut in the Arctic
- ☐ Distribution of periglacial environments
- ☐ Describing changes in Arctic vegetation patterns

Human Geography

- ☐ People who live in the Arctic regions
- ☐ The importance of the Northwest passage
- ☐ The myths surrounding the Northern lights
- ☐ The impact of energy demand on the polar regions

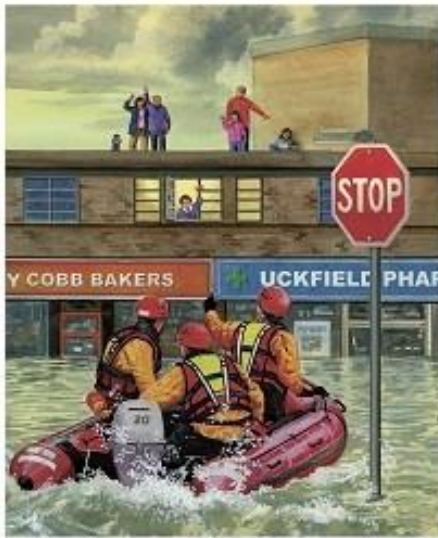
WIDER READING



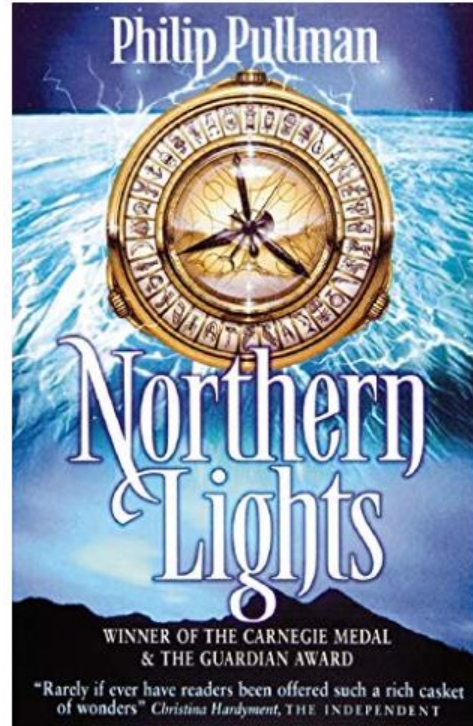
Wider reading is a vital skill in geography in order to extend your knowledge. For each book listed here that you read, write a book report outlining your thoughts and you will **receive 30 house points**.

Climate Change

HRH The Prince of Wales
Tony Juniper
Emily Shuckburgh



A Ladybird Expert Book



SHACKLETON'S JOURNEY



William Grill
FLYING EYE BOOKS



guided READING

For each guided reading completed with questions, you will receive 10 house points.

AS THE CLIMATE WARMS, HOW MUCH, AND HOW QUICKLY, WILL EARTH'S GLACIERS MELT?

If we don't have it, we don't need it," pronounces Daniel Fagre as we throw on our backpacks. We're armed with crampons, ice axes, rope, GPS receivers, and bear spray to ward off grizzlies, and we're trudging toward Sperry Glacier in Glacier National Park, Montana. I fall in step with Fagre and two other research scientists from the U.S. Geological Survey Global Change Research Program. They're doing what they've been doing for more than a decade: measuring how the park's storied glaciers are melting.

So far, the results have been positively chilling. When President Taft created Glacier National Park in 1910, it was home to an estimated 150 glaciers. Since then the number has decreased to fewer than 30, and most of those remaining have shrunk in area by two-thirds. Fagre predicts that within 30 years most if not all of the park's namesake glaciers will disappear.

"Things that normally happen in geologic time are happening during the span of a human lifetime," says Fagre. "It's like watching the Statue of Liberty melt."

Scientists who assess the planet's health see indisputable evidence that Earth has been getting warmer, in some cases rapidly. Most believe that human activity, in particular the burning of fossil fuels and the resulting buildup of greenhouse gases in the atmosphere, have influenced this warming trend. In the past decade scientists have documented record-high average annual surface temperatures and have been observing other signs of change all over the planet: in the distribution of ice, and in the salinity, levels, and temperatures of the oceans.

"This glacier used to be closer," Fagre declares as we crest a steep section, his glasses fogged from exertion. He's only half joking. A trailside sign notes that since 1901, Sperry Glacier has shrunk from more than 800 acres (320 hectares) to 300 acres (120 hectares). "That's out of date," Fagre says, stopping to catch his breath. "It's now less than 250 acres (100 hectares)."

Everywhere on Earth ice is changing. The famed snows of Kilimanjaro have melted more than 80 percent since 1912. Glaciers in the Garhwal Himalaya in India are retreating so fast that researchers believe that most central and eastern Himalayan glaciers could virtually disappear by 2035.

Arctic sea ice has thinned significantly over the past half century, and its extent has declined by about 10 percent in the past 30 years. NASA's repeated laser altimeter readings show the edges of Greenland's ice sheet shrinking. Spring freshwater ice breakup in the Northern Hemisphere now occurs nine days earlier than it did 150 years ago, and autumn freeze-up ten days later. Thawing permafrost has caused the ground to subside more than 15 feet (4.6 meters) in parts of Alaska. From the Arctic to Peru, from Switzerland to the equatorial glaciers of Man Jaya in Indonesia, massive ice fields, monstrous glaciers, and sea ice are disappearing, fast.

When temperatures rise and ice melts, more water flows to the seas from glaciers and ice caps, and ocean water warms and expands in volume. This combination of effects has played the major role in raising average global sea level between four and eight inches (10 and 20 centimeters) in the past hundred years, according to the Intergovernmental Panel on Climate Change (IPCC).

Scientists point out that sea levels have risen and fallen substantially over Earth's 4.6-billion-year history. But the recent rate of global sea level rise has departed from the average rate of the past two to three thousand years and is rising more rapidly—about one-tenth of an inch a year. A continuation or acceleration of that trend has the potential to cause striking changes in the world's coastlines

What equipment is needed for an ice trek?

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What are “grizzlies” and how can their threat be reduced?

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Name the organisations involved in researching glacier change in Montana, USA.

.....

When was Glacier National Park created and how many glaciers where there then?

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.....

Watching the glaciers melt is happening so quickly, what is it compared to?

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.....

.....

How much has Sperry Glacier shrunk since 1901?

.....

How many acres is the glacier's area now?

.....

Name other parts of the world that are changing and describe what is happening there

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Why will melting glaciers affect sea levels?

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What do the letters IPCC stand for?

.....

What other questions do you have now that you have read this article?

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RECORD ICE LOSS IN GREENLAND

The ice sheet lost a record 1m tonnes of ice per minute in 2019

The Greenland ice sheet lost a record amount of ice in 2019, equivalent to a million tonnes per minute across the year, satellite data shows.

The climate crisis is heating the Arctic at double the rate in lower latitudes, and the ice cap is the biggest single contributor to sea level rise, which already imperils coasts around the world. The ice sheet shrank by 532bn tonnes last year as its surface melted and glaciers fell into the ocean and would have filled seven Olympic-sized swimming pools per second.

The satellite data has been collected since 2003. The 2019 loss was double the annual average since then of 255bn tonnes. Almost that amount was lost in July 2019 alone.

Scientists knew that ice loss from Greenland had been accelerating fast in recent decades and that there had been high rates of melting in 2019. But the satellite data accounts for new snowfall and allows the net loss to be calculated. The researchers said the scale of the 2019 loss was shocking and was likely to be the biggest in centuries or even millennia.

If the entire Greenland ice sheet melts, sea level would rise by six metres. But the researchers said it was not certain that the sheet had passed the point of no return and that cutting carbon emissions will slow the melting, which would take centuries to complete.

The scientists attributed the extreme ice loss in 2019 to "blocking patterns" of weather that kept warm air over Greenland for longer periods. These are becoming increasingly frequent as the world heats up. Almost 96% of the ice sheet underwent melting at some point in 2019, compared with an average of 64% between 1981 and 2010.

Snowfall in Greenland was low in 2019, also due to the blocking pattern, meaning relatively little new ice was added. "The real message is that the ice sheet is strongly out of balance," Sasgen said.

Weather data and computer models allow for losses to be calculated back to 1948. "If we look at the record melt years, the top five occurred in the last 10 years, and that is a concern. But we know what to do about it: reduce CO2 emissions."

Sasgen said a further worry was feedback mechanisms that increase ice loss, including meltwater weakening the ice sheet and speeding its fall into the ocean. Hotter weather also melts the white snow on top of the sheet, revealing darker ice below, which absorbs more of the sun's heat.

RECORD ICE LOSS IN GREENLAND

“Since meltwater is freshwater, it dilutes the salt content of the surrounding ocean, which contributes to slowing the Gulf stream system,” Rahmstorf said. “If we wanted to make the 500bn tonnes of freshwater added in 2019 as salty as ocean water, about 200,000 Panamax-class cargo ships full of salt would need to dump their load into the Atlantic.”

Despite the rapid melting, the Greenland ice sheet is not necessarily doomed to melt entirely. Firstly, as glaciers retreat they lose contact with warmer ocean waters and therefore melt less. Secondly, the melting of the sheet with warm air takes centuries, during which time the rise in global temperatures might be reversed.

“If we reduce CO2, we will reduce Arctic warming and we will therefore also reduce the sea level rise contribution from the Greenland ice sheet,” Sasgen said. “So even though it might eventually disappear in large part, it happens much slower, which would be better as it would allow more time for the 600 million people living near coasts to move away.”

Why is the Greenland Ice Sheet significant in terms of sea level rise?

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How much faster is are higher latitudes warming compared to equatorial regions?

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How does the 2019 loss compare to previous years?

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How much would sea levels rise by if the Greenland ice sheet melted? Why is this significant?

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What caused the record amounts of ice loss?

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How is ice normally built up on ice sheets?

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RECORD ICE LOSS IN GREENLAND

How many record melt years have there been this decade?

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What might trigger a negative feedback loop?

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How does ice melt affect ocean currents? Why is this important in the context of climate change?

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Why might the Greenland ice sheet not be 'doomed'?

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What is the main (or indeed, only) way we can slow or stop ice melt?

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List any terms here that you are unfamiliar with:

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