

Ecosystems

5.1 Introducing a small-scale ecosystem

On this spread you will find out about the components of a small-scale ecosystem in the UK

Example

What is an ecosystem?

An **ecosystem** is a natural system made up of plants, animals and the environment. There are often complex interrelationships (links) between the living and non-living components of an ecosystem. **Biotic** components are the living features of an ecosystem such as plants and fish. **Abiotic** components are non-living environmental factors such as climate (temperature and rainfall), soil, water temperature and light.

Ecosystems can be identified at different scales:

- a local small-scale ecosystem can be a pond (photo A), hedgerow or woodland
- a global-scale ecosystem can be a tropical rainforest or deciduous woodland. These global ecosystems are called biomes.

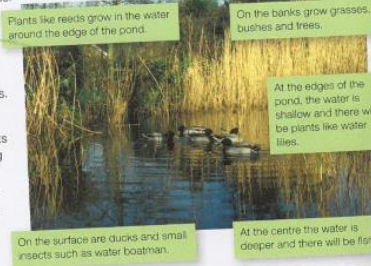
A freshwater pond ecosystem

Freshwater ponds provide a variety of habitats (homes) for plants and animals. There are big variations in the amount of light, water and oxygen available in different parts of a pond.

Diagram B shows how different habitats suit certain plants, insects and animals.

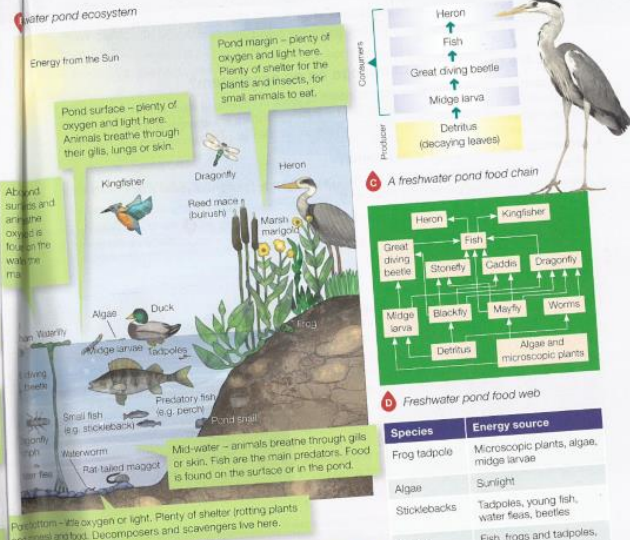
Here are some terms that you need to understand.

Term	Definition
Producers	Producers convert energy from the environment (mainly sunlight) into sugars (glucose). The most obvious producers are plants that convert energy from the Sun by photosynthesis.
Consumers	Consumers get energy from the sugars produced by the producers. A pond snail is a good example of a consumer because it eats plants.
Decomposers	Decomposers break down plant and animal material and return the nutrients to the soil. Bacteria and fungi are good examples of decomposers.
Food chain	A food chain shows the direct links (hence the term 'chain') between producers and consumers in the form of a simple line (diagram C).
Food web	A food web shows all the connections between producers and consumers in a rather more complex way (hence the term 'web' rather than 'chain') (diagram D).
Nutrient cycling	Nutrients are foods that are used by plants or animals to grow. There are two main sources of nutrients: <ul style="list-style-type: none"> • rainwater washes chemicals out of the atmosphere • weathered rock releases nutrients into the soil. When plants or animals die, the decomposers help to recycle the nutrients making them available once again for the growth of plants or animals. This is the nutrient cycle.



Each of these environments is an important habitat and forms part of the pond ecosystem

Ecosystems



Species	Energy source
Frog tadpole	Microscopic plants, algae, midge larvae
Algae	Sunlight
Sticklebacks	Tadpoles, young fish, water fleas, beetles
Heron	Fish, frogs and tadpoles, larger insects
Perch	Small fish (e.g. sticklebacks), beetles, water fleas

- #### ACTIVITIES
- Describe the pond ecosystem in photo A.
 - Identify a producer.
 - Why are ducks good examples of consumers?
 - Imagine that the pond became polluted. How would this impact on the ecosystem?
 - Where do most decomposers live in the pond ecosystem?
 - Why are decomposers important in nutrient recycling?
 - Look at table E. The organisms in the table form a food chain, but they are not in the correct order! Place them in the correct order – you have to decide who is eating who!

Practice question
Explain and describe the features of a small-scale ecosystem in the UK. (4 marks)

- #### Stretch yourself
- Find a food web diagram for a different small-scale ecosystem in the UK, such as a hedgerow or deciduous woodland.
- Identify the producers in your food web.
 - Use a colour or highlighter to show a food chain within the food web.

5.2 How does change affect ecosystems?

On this spread you will find out how changes to the ecosystem affect its components

What are the impacts of change on an ecosystem?

Ecosystems can take hundreds if not thousands of years to develop. If an ecosystem is to be sustainable it needs to be in balance. If there is a change to one of the components it may well have knock-on effects for the rest of the ecosystem.

What causes change to ecosystems?

Changes to an ecosystem can occur naturally or result from human activities. Change can take place on different scales:

- global-scale changes, such as climate change
- local-scale changes, such as changes to a habitat – for example, when a hedge is removed.

Natural changes

Ecosystems can adapt to slow natural changes with few harmful effects. But rapid changes can have serious impacts. Extreme weather events like droughts can be devastating to ponds and lakes. They could dry up in places, which changes the edge-of-pond environment (photo A). Plants will dry out and die. Fish, starved of oxygen, might not survive.

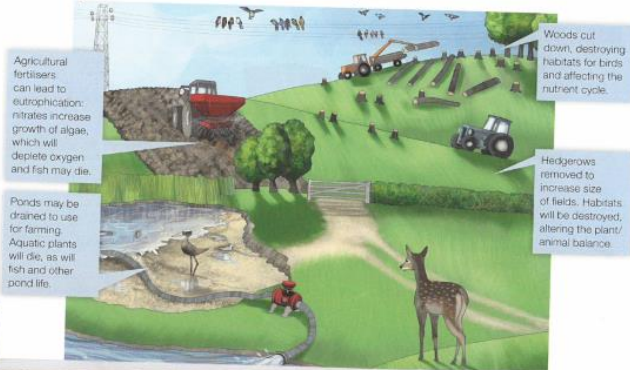
Changes due to human activities

Human activity can have many impacts on ecosystems (diagram B). Once a component has been changed it can have serious knock-on effects on the ecosystem.

A Pond in Brighton affected by drought, after a period of dry weather



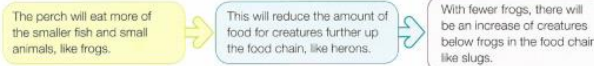
B The impact of human changes on small-scale ecosystems



Ecosystems

How can changes affect the pond ecosystem?

Look back to diagram B on page 53. What if the pond owner added some perch, a predator, to the ecosystem?



Avington Park lake, Winchester, Hampshire

Avington Park is a country estate close to Winchester in Hampshire. The lake in the grounds of the estate is of historical and ecological importance. Lack of maintenance in recent years resulted in the accumulation of silt and the growth of vegetation. This created an excellent habitat for birds, but the impressive view of the lake from the house had been lost.

Restoration of the lake was carried out in 2014 (photo C). The aim was to restore the lake as part of the landscape, and to preserve and improve its function as a habitat for birds. Restoration involved desilting and redefining the lake and creating new waterside habitats to attract nesting birds and waterfowl. Following its restoration, the lake can again be seen from the house, and has become a healthy ecosystem for a diverse range of wildlife.



C Avington Park lake restoration

ACTIVITIES

- 1 a What evidence can you find in photo A that the pond has been affected by drought?
b Suggest the effects of the drought on the pond margin. How could this affect the pond ecosystem?
c If the pond dried up completely, what effect would this have on the ecosystem?
- 2 a Select one change in diagram B. Describe how it could affect the ecosystem.
b Imagine the landowner cut down all the vegetation at the side of the pond to create a wooden deck for fishing. How might this affect the ecosystem?
- 3 a What were the changes that caused the Avington Park lake's poor condition?
b How has the pond been restored?

Stretch yourself

Frogs are an important part of the pond ecosystem. Imagine that disease wipes out all the frogs in a pond. Find out how this would affect the ecosystem in the short term and the long term.

Practice question

Using a named example, explain how change can have short-term and long-term effects on an ecosystem. (6 marks)

Think about it

Consider a pond near to where you live or close to school. To what extent is the pond a thriving and healthy ecosystem?

5.3 Introducing global ecosystems

On this spread you will find out about the distribution and characteristics of global ecosystems

The distribution of global ecosystems

Large-scale ecosystems are known as **global ecosystems** (or biomes). These are defined mainly by the dominant type of vegetation that grows in the region, such as tropical rainforest or **tundra**.

Global ecosystems form broad belts across the world from west to east, parallel to the lines of latitude (map **A**). This is because the climate and characteristics of ecosystems are determined by global atmospheric circulation (pages 22–3).

Variations in these west-to-east belts of vegetation are due to factors such as:

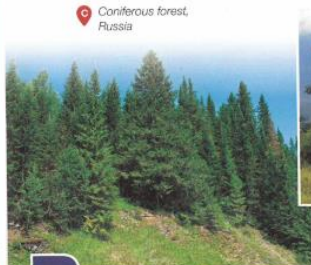
- ocean currents
- winds
- the distribution of land and sea.

These factors produce small variations in temperature and moisture which in turn affect the ecosystems. For example, the Mediterranean region – with its dry, hot summers and warm, wet winters – has its own global ecosystem.

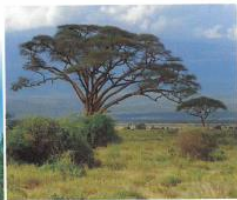
A Global ecosystems



B Sahara desert landscape



C Coniferous forest, Russia



D Tropical savanna, Kenya



E Alpine tundra, Peru

Ecosystems

The characteristics of global ecosystems

Global ecosystem	Location	Links to global atmospheric circulation
Tropical rainforest	Close to the Equator	High temperatures and heavy rainfall associated with equatorial low pressure belt creates ideal conditions for plants to grow. Rainforests cover 6 per cent of the Earth's land surface. More than half the world's species of plants and animals live in this global ecosystem. A quarter of all medicines come from rainforest plants.
Desert	Roughly 30° north and south of the Equator	Deserts cover one fifth of the world's land surface. Hot deserts are associated with the sub-tropical high pressure belts. Sinking air stops clouds from forming, resulting in high daytime temperatures, low night-time temperatures and low rainfall. Plants and animals have to be well adapted to survive in these conditions.
Polar	Arctic/Antarctic	Cold air sinks at the north and south Poles, resulting in very low temperatures and dry conditions. The main polar regions are Antarctica and Greenland where temperatures can fall below -50°C.
Deciduous and coniferous forests	Roughly 50–60° north of the Equator	Deciduous trees shed their leaves in winter to retain moisture. Coniferous trees are cone-bearing evergreens, retaining their leaves to maximise photosynthesis during the brief summer months. The UK's natural vegetation is deciduous forest. Further north, for example in Canada and Scandinavia, coniferous forests dominate as they are better suited to colder climates.
Temperate grassland	Roughly 30–40° north and south of the Equator. Inland away from coasts, with hot summers and cold winters.	This includes the vast areas of grassland in North America (prairies) and Eastern Europe (steppes). These areas experience warm, dry summers and cold winters. Grasses can tolerate these conditions and this land is mainly used for grazing animals.
Mediterranean	Roughly 40–45° north of the Equator. Also isolated locations south of the Equator (South Africa, Western Australia)	Countries around the Mediterranean enjoy hot, sunny and dry summers, with mild winters. This is due to the pressure belts migrating slightly north and south during the year. Mediterranean vegetation includes olive trees and fruit trees, such as lemons and oranges. Other parts of the world have a similar climate, for example California (USA), South Africa and parts of Australia.
Tropical grassland (savanna)	Between 15–30° north and south of the Equator.	The tropical climate in these low latitudes is characterised by distinct wet and dry seasons. The dry season can be very hot and wild fires can break out. Violent thunderstorms can occur during the wet season. Large herds of animals graze on these grasslands, along with predators such as lions and leopards.
Tundra	From the Arctic Circle to about 60–70° north (e.g. Canada, Northern Europe). There are only very small areas of tundra in the southern hemisphere due to the lack of land at these latitudes.	Tundra is characterised by low-growing plants adapted to retain heat and moisture in the cold, windy and dry conditions. These regions are found in northern Canada and across Northern Europe. It is a fragile ecosystem, easily damaged by humans and threatened by developments such as oil exploitation and tourism. Animals such as reindeer are adapted to survive the cold.

ACTIVITIES

- Describe the pattern of global ecosystems (biomes) in North America.
- Why do most global ecosystems form broad latitudinal belts across the world?
- Why is the Mediterranean popular with northern Europeans in both the summer and the winter?

Stretch yourself

Do some research to compare deciduous and coniferous forests. What are the characteristics of each ecosystem and how have plants and animals adapted?

Practice question

Describe the global pattern of the tundra ecosystem. (4 marks)

6 Tropical rainforests

6.1 Environmental characteristics of rainforests

On this spread you will find out about the environmental characteristics of tropical rainforests

If you were to enter a tropical rainforest you would need a torch and strong shoes, as it is dark and damp. It is also very noisy with the clicks, howls and whistles of insects and animals. You would have difficulty moving about because the vegetation is very lush and dense (photo A).

- The trees grow very tall, often up to 45m high.
- There is a great variety of wildlife – often up to 100 species in a single hectare!

Where are tropical rainforests found?

Tropical rainforests are found in a broad belt through the Tropics in:

- Central and South America
- South East Asia
- central Africa
- northern Australia.

(You can see these areas on map A on page 56.)

What is the climate like?

Tropical rainforests thrive in warm and wet conditions. The equatorial zone where they are found is characterised by high rainfall (over 2000mm a year) and high temperatures (averaging about 27 °C) throughout the year.

Look at table B. It provides climatic information for the weather station at Manaus, in the Amazonian rainforest in Brazil.

- The temperature is high and constant throughout the year. This is because the powerful Sun is overhead for most of the time.
- The rainfall is high. This is because the global atmospheric circulation causes an area of low pressure to form at the Equator. The rising air creates clouds and triggers heavy rain.
- Rainfall varies throughout the year, with a distinct wet season lasting about six months. This is due to a period of intense rainfall when the equatorial low pressure area is directly overhead.

B Climate data for Manaus, Brazil

Maths skills

- Use the data in table B to draw a climate graph for Manaus showing temperature and rainfall.
- Shade the gap between the average minimum and maximum temperature lines. This is the temperature range.
 - How will you show humidity and sunshine information on your graph?

Month	Temperature (°C)		Rainfall (mm)	Relative humidity	Sunshine (average hours per day)
	Max.	Min.			
January	31	24	249	89	4
February	31	24	231	89	4
March	31	24	262	89	4
April	31	24	221	90	4
May	31	24	170	89	5
June	31	24	84	87	7
July	32	24	58	87	8
August	33	24	36	85	8
September	33	24	46	84	6
October	33	24	107	85	7
November	33	24	142	86	6
December	32	24	203	88	5



A Rainforest vegetation

What are the soils like?

Tropical rainforest soils are surprisingly infertile. Most nutrients are found at the surface, where dead leaves decompose rapidly in the hot and humid conditions. Many trees and plants have shallow roots to absorb these nutrients. Fungi growing on the roots transfer nutrients straight from the air. This is a good example of nutrient cycling.

Heavy rainfall can quickly dissolve and carry away nutrients. This is called leaching. It leaves behind an infertile red, iron-rich soil called latosol.

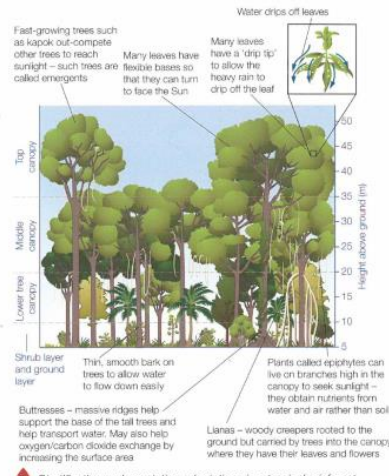
What plants and animals are there?

Tropical rainforests support the largest number of species of any biome. Over half of all plant and animal species on the planet live on just 7 per cent of the land surface. Tropical rainforests have a huge biodiversity, providing habitats for an enormous range of species.

- Birds live in the canopy (branches) feeding on nectar from flowers.
- Mammals, like monkeys and sloths, are well adapted to living in the trees.
- Animals like deer and rodents live on the forest floor.

How have plants adapted to rainforests?

A tropical rainforest is made up of layers (diagram C). The majority of plant and animal species are found in the canopy where there is most light. In contrast, the forest floor is dark and a rainforest is a very fragile ecosystem. Plants and animals (biotic factors), along with fungi and bacteria on the forest floor, enjoy a close but fragile relationship with the abiotic factors such as soils, temperature and moisture. Small changes to biotic or abiotic factors, such as deforestation or water pollution, can have serious knock-on effects on the entire ecosystem.



C Stratification and vegetation adaptations in a tropical rainforest

Stretch yourself

Imagine you're a conservationist working in a tropical rainforest. Give a two-minute presentation on the importance of soil in the tropical rainforest biome.

Practice question

Describe and explain the main plant adaptations in a tropical rainforest environment. (6 marks)

ACTIVITIES

- 1 a Draw the areas of tropical rainforest (map A, page 56) onto a blank outline map of the world. Use an atlas to label the countries or regions (e.g. Ecuador, the Amazon, etc.) where tropical rainforests are found.
b Write a paragraph describing the distribution of tropical rainforests. Link their distribution to global atmospheric circulation (diagram B on page 22).
- 2 Select three species of plants or trees from diagram C. Describe how each has special adaptations so that it can thrive in this environment.

6.2 Causes of deforestation in Malaysia

On this spread you will find out about the causes of deforestation in Malaysia

Case study

About Malaysia

- Malaysia is a country in South East Asia.
- It is made up of Peninsular Malaysia and East Malaysia, which is part of the island of Borneo.
- The natural vegetation in Malaysia is tropical rainforest.
- 67 per cent of Malaysia's land is covered by rainforest.



A The location of Malaysia

Deforestation in Malaysia

'Orang-utan' means 'person of the forest'. They are losing their natural habitat. As natural rainforest in Malaysia is destroyed, many young orang-utans are killed or orphaned (photo B).

Deforestation is the cutting down of trees, often on a very large scale. The timber is a highly valued export. Deforestation means the land can be used for other profit-making enterprises, like cattle ranching, commercial farming, the production of rubber and palm oil.

The rate of deforestation in Malaysia is increasing faster than in any tropical country in the world. Between 2000 and 2013, Malaysia's total forest loss was an area larger than Denmark!



B A young orphaned orang-utan

Did you know?

Between 1990 and 2004 orang-utans in Borneo lost habitat twice the size of Wales.

ACTIVITIES

- Complete a spider diagram to show the causes of deforestation in Malaysia. Use photos to illustrate your diagram.
- Write a two-minute news report about deforestation in Malaysia. Focus on where it is, why it's important and how it has been destroyed.

Stretch yourself

Investigate commercial oil palm farming in Malaysia.

- What is oil palm used for?
- How is rainforest cleared to make way for this type of farming?
- What damage is done to habitats and the natural environment?

Practice question

Photo D shows a hydroelectric dam in Sarawak, Malaysia. Evaluate two possible environmental impacts of developments like the Bakun Dam. (4 marks)

Tropical rainforests

What are the threats to Malaysia's rainforests?

Logging

Malaysia became the world's largest exporter of tropical wood in the 1980s. Clear felling, where all trees are chopped down in an area, was common. This led to the total destruction of forest habitats.

Recently, clear felling has largely been replaced by **selective logging** (photo C), where only fully-grown trees are cut down. Trees that have important ecological value are left unharmed.

Road building



C Road construction and logging in Sarawak, east Malaysia

Roads are constructed to provide access to mining areas, new settlements and energy projects.

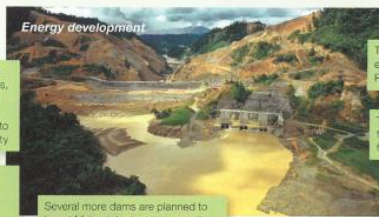
Logging requires road construction to bring in machinery and take away the timber.

Energy development

In 2011, after five decades of delays, the controversial Bakun Dam in Sarawak started to generate electricity.

The Bakun Dam (205 m) is Asia's highest dam outside China.

Several more dams are planned to boost Malaysia's electricity supplies.



D The Bakun Dam

The dam supplies energy for industrialised Peninsular Malaysia.

The dam's reservoir flooded over 700 km² of forests and farmland.

E Slash and burn



Mineral extraction

Mining (mainly tin and smelting) is common in Peninsular Malaysia. Rainforest has been cleared for mining and road construction. Drilling for oil and gas has recently started on Borneo.

Population pressure

In the past, poor urban people were encouraged by the government to move into the countryside from the rapidly growing cities. This is called transmigration. Between 1956 and the 1980s, about 15 000 hectares of rainforest was felled for the settlers. Many then set up plantations.

Commercial farming

Malaysia is the largest exporter of palm oil in the world. During the 1970s, large areas of land were converted to palm oil plantations. Plantation owners receive 10-year tax incentives, so increasing amounts of land have been converted to plantations.

Subsistence farming

Tribal people living in the rainforest practise subsistence farming. Traditionally, local communities would hunt and gather food from the forest and grow some food crops in cleared pockets of forest. This type of farming is small scale and sustainable.

One method of clearing land is 'slash and burn' (photo E). This involves the use of fire to clear the land. The burning creates valuable nutrients that help plants to grow. These fires can grow out of control, destroying large areas of forest.

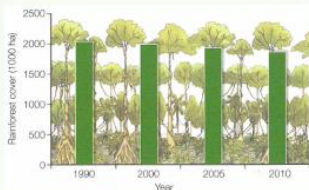
6.3 Impacts of deforestation in Malaysia

On this spread you will find out about the impacts of deforestation in Malaysia

Case study

Impacts of deforestation in Malaysia

Photo C shows a rainforest landscape devastated by deforestation. Imagine all the habitats that have been destroyed. Notice that the trees have been reduced to stumps. The hillslopes have been stripped of vegetation, exposing the soil to erosion by rain and wind. Chart A shows the impact of deforestation on the area covered by Malaysia's rainforest.



A The size of Malaysia's rainforest, 1990-2010

Soil erosion

Soil takes thousands of years to form – but it can be stripped away in a matter of hours. Removal of trees and plants by wind and rain is called **soil erosion**. The roots of trees and plants bind the soil together. So deforestation means that soil can easily become loose and erode away.

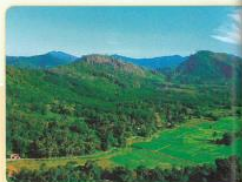
Loss of biodiversity

Biodiversity is a measure of the variety of plants and animals in a particular ecosystem. Rainforests are the most biodiverse ecosystem in the world. Deforestation destroys the ecosystem and the many habitats that exist on the ground and in the trees. This reduces the biodiversity.

Biodiversity in the Main Range, Peninsular Malaysia

The Main Range is an upland region stretching for 500 km along the backbone of Peninsular Malaysia. This region is important because:

- it is the largest area of continuous forest left in Peninsular Malaysia (photo B)
- the forests are particularly rich in their biodiversity, with over 600 species
- the highland forests are home to over 25 per cent of all plant species found in Malaysia
- there are still many undiscovered plants that have medicinal qualities that could provide cures for diseases.



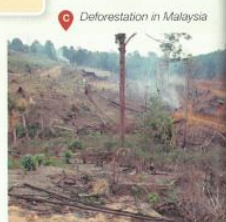
B Main Range Mountains, Peninsular Malaysia

Contribution to climate change

Deforestation can have an impact on local and global climates. During photosynthesis, trees absorb CO₂ and emit oxygen. CO₂ is a greenhouse gas that is partly responsible for global warming. By absorbing CO₂, trees store the carbon and help to reduce the rate of global warming.

So, deforestation can affect climate because:

- trees give off moisture by the process of transpiration; deforestation reduces the moisture in the air resulting in a drier climate
- the process of evaporation uses up heat and cools the air; if trees are cut down, this cooling ceases and temperatures rise.



C Deforestation in Malaysia

Economic development

Deforestation in many parts of the world is driven by profit. However, whilst deforestation may result in short-term economic gains, it may lead to long-term losses.

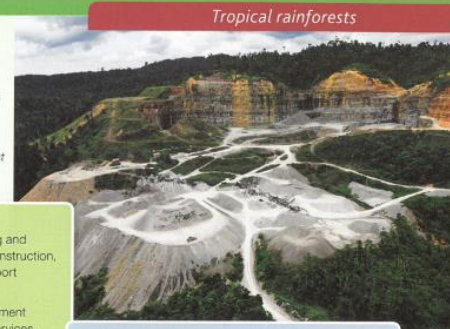


Economic gains

- Development of land for mining, farming and energy will lead to jobs both directly (construction, farming) and indirectly (supply and support industries)
- Companies will pay taxes to the government which can be used to improve public services, such as education and water supply
- Improved transport **infrastructure** opens up new areas for industrial development and tourism
- Products such as oil palm and rubber provide raw materials for processing industries
- Hydro-electric power will provide cheap and plentiful energy
- Minerals such as gold are very valuable

Economic losses

- Pollution of water sources and an increasingly dry climate may result in water shortages.
- Fires can cause harmful pollution. They can burn out of control, destroying vast areas of valuable forest.
- Rising temperatures could devastate some forms of farming such as growing tea, fruit and flowers
- Plants that could bring huge medical benefits and high profits may become extinct
- Climate change could have economic costs as people have to adapt to living in a warmer world
- The number of tourists attracted by rainforests could decrease



Tropical rainforests

ACTIVITIES

- Study photo C
 - Describe the environment in the foreground.
 - Are there signs of slash and burn farming? What are they?
 - How might soil erosion become a problem in the future?
 - How do you think this forest clearance will have affected the species living in the forest?
- Describe and explain the effects of deforestation on climate change.
- Make a poster, with a photo showing deforestation in Malaysia. Add a series of colour-coded text boxes explaining possible economic gains and losses.

Stretch yourself

- Write a report about the Main Range in Peninsular Malaysia.
- What are the characteristics of its biodiversity?
 - Why is it considered to be a special area?
- Illustrate your account with labelled photos.

Practice question

Explain, with reference to an example, why it is important to retain biodiversity. (4 marks)

6.4 Managing tropical rainforests

Tropical rainforests

6.4 Managing tropical rainforests

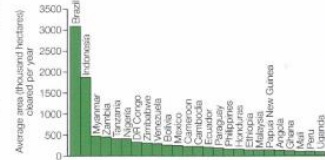
On this spread you will find out about rates of deforestation and why rainforests need to be protected

What are the rates of deforestation?

Tropical rainforests are perhaps the most endangered ecosystem on Earth. Every two seconds an area of rainforest the size of a football field (about one hectare) is being destroyed. That's over 1500 hectares an hour!

- Tropical rainforests once covered over 15.5 million km². The figure is now just over 6.2 million km².
- An area of rainforest the size of China has been lost.

Look at graph A. The fastest rates of deforestation are in Brazil and Indonesia. These countries account for over 40 per cent of the world's deforestation. But deforestation in Brazil is decreasing, and in Indonesia it is increasing.



A Rates of tropical deforestation, 2010-15

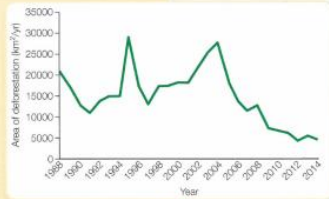
Deforestation in Brazil

The rates of deforestation in Brazil have varied a lot since 1988 (graph B). Historically, small-scale farming was largely responsible for deforestation in Brazil.

However, most deforestation now involves large landowners and big companies. Most rainforest has been cleared for cattle ranching.

Since 2004, the rate of deforestation in Brazil has fallen by nearly 80 per cent to the lowest levels on record. There are several reasons for this:

- the Brazilian government has cracked down on illegal deforestation
- Brazil is leading the world in conservation – over half of the Amazon is now protected
- Brazil is committed to reducing carbon emissions to tackle climate change
- consumer pressure not to use products from deforested areas has led to a decline in cattle ranching.



B Deforestation in the Brazilian Amazon, 1988-2014

Maths skills

Use the information on the right to draw a pie chart. (Remember: To calculate degrees, multiply each percentage by 3.6.)

- Shade each segment a different colour.
- Write the name of the country and the percentage alongside each segment.

Brazil	27	Tanzania	4	Zimbabwe	3
Indonesia	17	Nigeria	4	Venezuela	3
Myanmar	4	DR Congo	3	Other tropical countries	31
Zambia	4				

Tropical rainforests

Why should tropical rainforests be protected?

There are several reasons why tropical rainforests should be protected from further deforestation.

- Biodiversity**
Tropical rainforests contain half of all the plants and animals in the world. They are home to thousands of different species. Some plants may become extinct before they have even been discovered.
- Climate change**
Rainforests absorb and store carbon dioxide, a gas that is partly responsible for climate change.
- Climate**
Known as the 'lungs of the world', 28 per cent of the world's oxygen comes from the rainforests. They prevent the climate from becoming too hot and dry.
- Medicine**
Around 25 per cent of all medicines come from rainforest plants. More than 2000 tropical forest plants have anti-cancer properties.
- Resources**
Tropical rainforest trees provide valuable hardwoods as well as nuts, fruit and rubber.
- Water**
Rainforests are important sources for clean water – 20 per cent of the world's fresh water comes from the Amazon Basin.
- People**
Indigenous tribes live in harmony in the world's rainforests making use of the forest's resources without causing any long-term harm.

The Achuar people in the Peruvian Amazon

The Achuar are a primitive tribe of about 11 000 people. They live in small communities and rely on the resources of the rainforest for their buildings, food and fuel (photo C). They treat the rainforest with respect as their lives depend upon it.

There are rich reserves of oil in this region. Oil companies want permission to explore and drill for oil. If this happens the Achuar will lose some of their traditional lands, and may see their environment damaged by oil pollution.

The Achuar are resistant to oil exploration. They have had success in defending their land. In 2012, the oil company Talisman Energy stopped their oil exploration in the region.



C A traditional Achuar hut

ACTIVITIES

- Study graph A. Why do you think that most deforestation happens in Brazil and Indonesia?
- Study graph B.
 - Describe the trend in deforestation since 2005.
 - Why do you think the rate of deforestation has decreased recently?
- Outline reasons why rainforests should be protected.

Stretch yourself

- Find out about the Achuar people.
- What effect is deforestation having on the tribe?
 - What are the main threats to their continued life in the Peruvian rainforest?

Practice question

'The rainforest is more valuable when left intact than when destroyed.' Using a case study, use examples to support or challenge this view. (9 marks)

6.5 Sustainable management of tropical rainforests

On this spread you will find out about different strategies for managing rainforests sustainably

How can rainforests be managed sustainably?

To protect the world's tropical rainforests they need to be managed **sustainably**. There are two main reasons for this:

- to ensure that rainforests remain a lasting resource for future generations
- to allow valuable rainforest resources to be used without causing long-term damage to the environment.

Tribes like the Achuar (see page 65) have been managing rainforests sustainably. It is the large companies, wealthy landowners and illegal loggers whose drive for profit can result in unsustainable practices.

Selective logging and replanting

The most damaging form of deforestation is **clear felling**. All trees, big and small, are chopped down in the area being cleared. This completely destroys the ecosystem.

A more sustainable approach to logging involves **selective logging** (diagram A). Managed carefully, this technique – which was introduced in Malaysia in 1977 – is completely sustainable.

Conservation and education

Rainforest can be preserved in conservation areas, such as national parks or nature reserves. These areas can be used for education, scientific research and tourism.

Recently, large international businesses have supported conservation projects in exchange for carrying out scientific research or the provision of raw materials.

Givaudan

Givaudan is a Swiss perfume company. It works with Conservation International, and aims to protect 148 000 hectares of rainforest in the Caura Basin, Venezuela. Local Aripao people are encouraged to harvest and market tonka beans (photo B), which have a caramel-like smell. A warehouse where beans can be dried and stored was built in 2012. This improves their quality and increases their value.

- 2 years before felling:** Pre-felling study to identify what is there.
- 1 year before felling:** Trees marked for felling. Arrows painted on trees to indicate direction of felling to avoid damaging other valuable trees.
- Felling:** Trees felled by licence-holders.
- 3–6 months after felling:** Survey to check what has been felled. Prosecution may result from illegal felling.
- 2 years after felling:** Treatment plan drawn up to restore forest.
- 5–10 years after felling:** Remedial and regeneration work by state forestry officials. Replacement trees planted.
- 30–40 years after felling:** Cycle begins again.



A Malaysia's Selective Management System

B Tonka beans



Tropical rainforests

Ecotourism

Countries like Costa Rica, Belize and Malaysia have promoted their forests for **ecotourism**. Ecotourism aims to introduce people to the natural world, to benefit local communities and protect the environment for the future. Through income generated by ecotourism, local people and governments benefit from retaining and protecting their rainforest trees. This is a more sustainable option than cutting them down for short-term profit.

International agreements

Rainforests are now understood to be of global importance. They absorb carbon dioxide from the atmosphere, releasing oxygen and maintaining levels of humidity. International agreements have been made to help protect rainforests.

Hardwood forestry

The Forest Stewardship Council (FSC) is an international organisation that promotes sustainable forestry. Products sourced from sustainably managed forests carry the FSC label.

The FSC tries to educate manufacturers and consumers about the need to buy sustainable hardwood like mahogany. It aims to reduce demand for the rare and valuable hardwoods.

Debt reduction

Some countries have borrowed money to fund developments. To pay off these debts some have raised money from massive deforestation programmes. Recently, some donor countries and organisations have reduced debts in return for agreement that rainforests will not be deforested. This has become known as 'debt-for-nature swapping'.



C Tourist accommodation in an eco-lodge

Carbon sinks

In 2008, the Gola Forest on Sierra Leone's southern border with Liberia became a protected national park (photo D).

The park plays a significant role in reducing global warming. It acts as a carbon sink by absorbing carbon dioxide from the air.



D Scientists in Sierra Leone's Gola Forest

ACTIVITIES

- Why is Malaysia's Selective Management System a good example of sustainable management?
- How can encouraging people to make commercial use of forest products like the tonka bean (photo B) help conserve rainforests?
- How can we as consumers help to conserve rainforests?

Stretch yourself

Find out more about the Gola Forest National Park and its rainforest conservation projects. What do you think its donors get out of the deal? Is it a 'win-win' situation?

Practice question

Describe and explain two benefits of international cooperation in sustainably managing tropical rainforests. (4 marks)

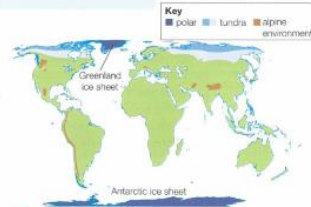
8 Cold environments

8.1 Characteristics of cold environments

On this spread you will find out about the characteristics of cold environments

What are cold environments?

Cold environments experience temperatures that are at or below zero degrees Celsius for long periods of time. In the most extreme cold environments, such as the Antarctic, temperatures will be below zero throughout the year. Less extreme cold environments, such as northern Canada and parts of Iceland, simply experience very cold winters.



A The location of the world's cold environments

Characteristics of cold environments

Climate

- Winter temperatures often fall below -50°C
- These areas have low precipitation (snow) totals.

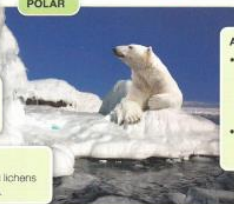
Soils

Permanently covered by ice so soils are permanently frozen.

Plants

Some plants such as mosses and lichens are found on the fringes of the ice.

POLAR



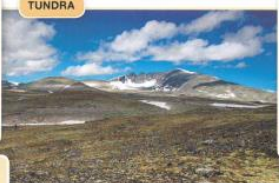
Animals

- Polar bears are well adapted to the polar environment. To retain heat they have thick fur, an insulating layer of fat, with a black nose and foot pads to absorb sunshine.
- In the Antarctic, penguins lay their eggs on land and bring up their young before returning to the ocean.

Climate

- This climate is less extreme. Winter temperatures may drop to -20°C .
- The brief summers can be quite warm.
- Amounts of precipitation – mainly snow – can be high in coastal regions.

TUNDRA



Soils

- Soils are frozen (permafrost) but in summer will melt closer to the surface.
- Soils are generally infertile. Water draining through soils removes nutrients.
- Soils become waterlogged because water is trapped by permafrost.

Plants

- Low-growing flowering plants such as bearberry, Arctic moss and tufted saxifrage.
- Low bushes and small trees may grow in warmer regions.

Animals

- With more food options and a less extreme climate, several animals live here, including the Arctic fox and Arctic hare.
- Birds such as ptarmigans and insects such as midges and mosquitoes are abundant in the summer.

Cold environments

How does vegetation adapt to cold environments?

Few plants, if any, are found in polar regions, but a wide variety of plants live in tundra environments. This is because they have evolved a number of special adaptations to cope with the low temperatures, strong winds and dry conditions. For example:

- flowering and seed formation happens in a short time so that reproduction can take place during the short summers
- plants are low-growing and cushion-like to protect and insulate them from the strong dry winds
- hairy stems help to keep plants warm
- thin and waxy leaves reduce water loss.

Did you know?
In the Antarctic, temperatures will plunge to -60°C or below in the winter!

How does the bearberry adapt to cold environments?

The bearberry is a plant with red berries and bright green waxy leaves. It is one of the tundra's most abundant plants. The bearberry thrives in the tundra environment because it has evolved a number of adaptations (photo D).



D The bearberry plant

Very low-growing (5–15 cm off the ground) to enable it to survive the strong winds

Stems have a thick bark for stability in the windy conditions

Small leathery leaves help retain water in this dry environment

Hairy stems help to retain heat and keep the plant safe from very low temperatures

Bright red berries are eaten by birds and owls and this helps to distribute the seeds

Month	Temperature ($^{\circ}\text{C}$)		Rainfall (mm)
	Maximum	Minimum	
January	-7	-11	26
February	-7	-14	25
March	-9	-15	24
April	-5	-12	15
May	-1	-5	20
June	4	1	19
July	7	4	25
August	6	3	40
September	3	0	36
October	-1	-5	39
November	-3	-8	37
December	-6	-10	31

B Climate data for Spitzbergen, Svalbard

Maths skills

Use table B to help you answer the following questions.

- What is the average annual precipitation on Spitzbergen?
- How does this compare to London's average annual precipitation (600mm)?
- Write a few short sentences describing the climate of Spitzbergen.

Stretch yourself

Carry out some research online to answer the following questions:

- How are polar bears and penguins able to survive in polar environments?
- What adaptations do animals have in tundra environments?

Practice question

Explain the features of plants and soils in the tundra environment. (4 marks)

ACTIVITIES

- a Draw the extent of the polar and tundra environments (map A) onto a blank world map outline.

b Label the main countries and regions that have these environments.
- a Use table B to add notes describing the climate and soils of these two cold environments.

b Describe how vegetation has adapted to cold environments.

8.2 Opportunities for development in Svalbard

On this spread you will find out about the opportunities for development in Svalbard

Case study

Where is Svalbard?

Svalbard is a Norwegian territory in the Arctic Ocean and the most northerly permanently inhabited group of islands in the world.

Much of Svalbard experiences a polar climate with 60 per cent of the land covered by glaciers. The rest of the land is tundra much of which is frozen. There is no arable farming and there are no trees – it is just too cold! Svalbard has:

- five major islands, the largest of which is Spitzbergen
- a population of about 2700, most living in the main town of Longyearbyen
- more polar bears and snowmobiles than people.



A Location of Svalbard

What are the opportunities for development in Svalbard?

Mineral extraction

Svalbard has rich reserves of coal, but mining on Svalbard is a controversial issue. Environmental groups are against it as burning coal is a major source of greenhouse gases. However, coal mining is vital to the economy of Svalbard because:

- it is the main economic activity
- more than 300 people are employed in the mines and as support staff. In recent years the industry has faced a decline due to lower world coal prices and some jobs have been lost.



B The new Lunckefjell coal mine near Svea

In 2014 a new mine opened near Svea (photo B). To gain access to the new mine, a road had to be constructed over a glacier!

Energy developments

Some of the coal mined on Svalbard is burned to generate electricity in the Longyearbyen power station (photo C). It is Norway's only coal-fired power station and supplies all of Svalbard's energy needs. Environmentalists believe the power station should be closed down and renewable sources should be explored. The most likely future source is **geothermal energy**, tapping into the heat of the earth and using it to generate electricity.

Like Iceland, which uses mainly geothermal energy, Svalbard is located close to the Mid-Atlantic Ridge, a constructive plate margin. Here the Earth's crust is thin and hot rocks are close to the surface.

Another future option involves capturing carbon dioxide from burning coal and circulating this instead of water to generate electricity. This is called **carbon capture and storage** (page 46).



C The coal-fired power station at Longyearbyen

Cold environments

Fishing

The cold waters of the Barents Sea south of Svalbard (map A) are one of the richest fishing grounds in the world (photo D).

Apart from cod, there are an estimated 150 species of fish here, including herring and haddock. These waters are extremely important breeding and nursery grounds for fish stocks and need to be protected from pollution.

Fishing in the Barents Sea is jointly controlled and monitored by Norway and Russia to ensure that fishing is sustainable and the ecosystem is protected.

Tourism

Tourism in Svalbard has grown in recent years as people seek to explore extreme natural environments.

- In 2011, 70 000 people visited Longyearbyen and 30 000 of these were cruise passengers.
- The harbour at Longyearbyen has been enlarged to cope with the increase in the number of cruise ships.
- Tourism provides around 300 jobs for local people.
- Most tourists come from Norway and most visit as part of organised tours.

Tourists visit Svalbard to explore the natural environment – the glaciers, fjords and the wildlife, especially polar bears. Adventure tourism is becoming more popular with activities such as hiking, kayaking and snow mobile safaris (photo E). In the winter, tourists visit to experience the amazing Northern Lights.

Did you know?
If you have recently eaten cod and chips, there is a good chance that the cod came from the Barents Sea which has the largest stocks of cod in the world!



D Svalbard fishing trawlers

ACTIVITIES

- 1 Describe the location of Svalbard.
- 2 Photo B shows Svalbard's newest coal mine.
 - a Do you think coal is extracted from the surface or from below ground? Explain your answer.
 - b What evidence suggests this is a difficult environment in which to operate a coal mine?
 - c How does coal mining benefit the people of Svalbard?
 - d Can you suggest any environmental problems associated with coal mining?
- 3 How does Svalbard benefit from the abundant fish stocks in the Barents Sea?



E Adventure tourism in Svalbard

Stretch yourself

- Carry out further research about tourism in Svalbard.
- Why has Svalbard become a popular tourist destination in recent years?
 - Why is tourism being promoted?
 - How can tourism bring both benefits and problems?

Practice question

Explain why sustainable fishing requires international cooperation. (2 marks)

8.3 Challenges of development in Svalbard

On this spread you will find out about the challenges of development in Svalbard

Case study

What are the challenges for development?

There are several challenges that need to be overcome when living and working in such an extreme environment (photo A).

How can homes be kept warm during the very cold winters?



How is water connected to homes and how is it prevented from freezing?

How is sewage and waste water removed from people's homes?

How do people travel around when roads are covered by snow?

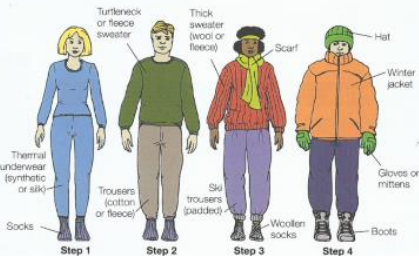
How can roads be constructed and maintained?

A Challenges of living and working in Svalbard

Did you know?
The sun sets in Longyearbyen on 25 October and does not rise again for four months – on 8 March!

Extreme temperatures

Even in Longyearbyen winter temperatures can fall below -30°C . In the northern glacial regions, it can be even colder. Such extreme temperatures make it dangerous to work outside, with a serious risk of frostbite. People have to dress very warmly (diagram B) and this can make outdoor work very slow and difficult. Imagine trying to build a house or work on the roads wearing several layers of thick clothes and gloves!



B Dressing for extreme cold

Construction

There are many forms of construction that have been carried out in Svalbard:

- ♦ building houses, shops and offices
- ♦ constructing and maintaining roads
- ♦ constructing and enlarging harbour facilities for fishing vessels and cruise ships
- ♦ constructing buildings and mining operations to extract coal.

Working outdoors in extreme temperatures and also in limited light during the winter is very demanding. As a result most construction work is carried out during the brief summer period.

Cold environments

The frozen ground (permafrost) can provide good solid foundations but it has to be protected from melting. If the top surface of the permafrost melts, then it becomes unstable and could lead to buildings and roads cracking or even collapsing.

Most roads are dirt or gravel roads raised up above the ground surface (photo C). These roads are relatively cheap and easy to maintain from year to year.

Services

Services include water, electricity and sanitation. These are very important both to the resident population and also to tourists who expect comfortable living conditions with warm rooms and hot showers.

Unlike the UK most services are provided to individual buildings by overground heated water and sewage pipes (photo D). They need to be kept off the ground to prevent them causing any possible thawing of the permafrost and to allow easy maintenance.

Accessibility

Svalbard is located in a remote part of Europe and can only be reached by plane or ship. The islands themselves are inaccessible and almost all transport systems are restricted to the immediate area around Longyearbyen.

- ♦ There is one airport close to Longyearbyen capable of handling international flights from Norway and Russia. Smaller aircraft can be used to connect to other islands.
- ♦ There is 50 km of road in Longyearbyen. No roads serve the other outlying communities.
- ♦ Most people use snowmobiles, particularly in the winter (photo E).



C Wheeled dog sled on a dirt road near Longyearbyen



D Overground service pipes



E Snowmobiles parked in Longyearbyen

ACTIVITIES

- 1 a. What are the challenges facing people living in Longyearbyen (photo A)?
b. Can you think of any other challenges suggested by the photo?
2. Diagram B comes from the Svalbard Tourist Board.
a. How many layers of clothing are suggested for the body and legs?
b. Why is 'layering' a good idea to keep warm?
c. What is suggested to keep your feet warm?
d. Why is it important to instruct tourists on how to dress when visiting Svalbard?
e. How might dressing for extreme cold make it difficult to work outside?
3. Why are services such as heated water and sewage connected to houses by overground pipes?
4. Suggest why snowmobiles are the most commonly used form of transport in the winter (photo E).

Stretch yourself

Imagine that you were going to visit Svalbard on a school trip in September. Find out what weather conditions you might expect and research appropriate clothes to cope with these conditions. Consider what footwear would be best suited for walking on rocks and snow.

Practice question

Explain how cold environments like Svalbard can provide challenges for development. (6 marks)

8.4 Cold environments under threat

On this spread you will find out how cold environments are at risk from economic activities and why these wilderness areas need protecting

Why are cold environments fragile?

Cold environments are extremely fragile and they can be easily damaged by human activities. Tundra vegetation (photo **A**) takes a very long time to become established. It is a very delicate ecosystem that can be easily disturbed.

Relatively minor developments – such as constructing a footpath – can have serious long-term effects.

Tundra is a **fragile environment** and can take a very long time to recover from any damage that is done by human activity.

Off-road vehicle damage in Alaska

Off-road vehicle driving is a popular tourist activity in the Alaskan wilderness. People may be hunting wild animals or simply want to travel to a remote area for walking or fishing.

Most off-road driving takes place in the summer when the snow has melted. Warmer temperatures melt the upper surface of the soil making it extremely soggy. Photo **B** was taken in Alaska's Wrangell-St Elias National Park. Notice how a single vehicle can leave deep tyre tracks through the swampy tundra. As other vehicles skirt the muddy pools, damage extends over a large area.

It will take many years – possibly decades – for this land to recover from damage that may have taken just a few minutes to cause.

Did you know?

If you stand on the ground in the tundra, your footprint could still be there in 70 years' time!



A Autumn tundra landscape, northern Canada



B Damage by off-road vehicles in Alaska



Trees killed by the oil spill

Risk of fire, either started deliberately or by a lightning strike

River has become polluted and is now totally lifeless

C Oil-polluted river in Siberia, Russia

Electricity pylons will have resulted in tree clearance and environmental damage

Oil has leaked from this broken pipeline

River edge habitats polluted and destroyed – the vegetation may never recover

Cold environments

How can cold environments be harmed by economic development?

Cold environments have rich reserves of oil, gas and other precious minerals such as gold. Oil and gas in particular are in high demand as a source of energy and countries are keen to exploit their resources for the economic benefits. To extract these resources, roads have to be constructed through forests and across the tundra and supply bases built. Housing for hundreds of workers also needs to be constructed. All this can have a huge impact on the environment.

Photo **C** is an example of one of the worst environmental disasters that can happen in cold environments – an oil spill. The damage to rivers and other natural ecosystems resulting from oil spills is long-lasting. It is hard to imagine this landscape ever recovering.

Why do cold environments need to be protected?

Many indigenous people live a traditional life here. For example, the Inuit who live in Arctic Alaska, Canada and Greenland depend on the wildlife and survive by hunting and fishing.

Cold environments are home to many birds, animals and plants, such as penguins, polar bears, the Arctic fox and many species of tundra vegetation.

D The small town of Ooqertarsuaq, Greenland

Unpolluted and unspoilt, cold environments are important outdoor laboratories for scientific research such as the effects of climate change.

Their beauty and potential for adventure activities attracts tourists who bring huge benefits to countries such as Norway (Svalbard), Iceland and Alaska.

They provide opportunities for forestry and fishing.

ACTIVITIES

- Describe the vegetation in photo **A**.
 - Are there any signs of human activity?
 - How might people use and damage this environment?
 - Why is it important that this environment is protected?
- Imagine photo **B** is to be used in an environmental campaign against off-road driving. Write a short account (no more than 100 words) to run alongside the photo describing the harmful effects of off-road driving in a tundra environment.
- What could be done to stop oil leaks such as the one shown in photo **C**?
- Use the information in figure **D** along with your own research to design an information poster to explain why cold environments need protecting. Use captioned photos to illustrate your poster.

Stretch yourself

Find other examples of how human activities have damaged fragile cold environments. Find at least two photographs that illustrate the problems caused and add labels to describe what has happened and what the impact has been.

Practice question

Outline three possible environmental impacts of economic development on cold environments. (6 marks)

8.5 Managing cold environments

On this spread you will find out about strategies to reduce the risks to cold environments

How can the risk to cold environments be reduced?

Cold environments offer many opportunities for economic development. To ensure that they do not suffer any long-term damage, they need to be managed sustainably. This can be done through:

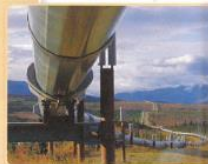
- the use of technology
- the work of conservation groups.
- action by governments

The use of technology – the trans-Alaskan pipeline

In 1969 oil was discovered at Prudhoe Bay on the north coast of Alaska (map **A**). Winter sea ice in the Arctic Ocean prevented oil being transported by tanker so an alternative way had to be found. In 1974 the trans-Alaskan pipeline was opened. It enabled oil to be transported the 1300 km from Prudhoe Bay to the port of Valdez (photo **B**). Technology has been used to reduce its impact on the environment (table **C**).



Problem	Technological solution
The pipeline crosses rivers and mountains such as the Brooks Range	Pumping stations keep the oil moving. The pipeline passes beneath rivers to minimise the impact on the landscape.
Oil from the ground is very hot (49°C) which helps it to flow, but could melt the permafrost.	The pipeline is raised and insulated to retain heat and prevent it melting the permafrost.
Possible cracks caused by earthquakes can cause oil leaks	The pipeline is supported and can slide if earthquakes happen. The flow of oil stops automatically if there is a leak.
Large herds of animals such as caribou migrate across the route of the pipeline.	The pipeline is raised to allow caribou to migrate underneath.



C Using technology to overcome problems in constructing the trans-Alaskan pipeline

B The trans-Alaskan pipeline

Action by governments – Alaska, USA

The United States government has been involved in the protection of Alaska ever since oil was discovered there in the 1960s.

- The National Environmental Policy Act, ensuring that companies involved with the extraction and transportation of oil protect the natural environment and recognise the rights of native people.
- The creation of the Western Arctic Reserve (map **A**) – a 9 million-hectare protected wilderness managed by the Department of the Interior. Home to thousands of caribou, millions of migratory birds, musk ox, wolves and even polar bears. Drilling for oil is kept away from sensitive areas.
- The National Oceanic and Atmospheric Administration (NOAA) oversees sustainable fisheries in Alaska and protects marine habitats.

Cold environments

International agreements – the Antarctic Treaty

In 1959 the Antarctic Treaty was signed by countries with territorial claims to Antarctica. Its main aim is to protect the natural environment of the largest wilderness on Earth (photo **D**). Despite the discovery of valuable minerals, the Antarctic Treaty has been successful in preventing economic development. The Treaty:

- recognises the importance of the continent for scientific research, particularly into climate change
- controls tourism and keeps disturbance to a minimum.



D Antarctica – the world's last great wilderness

Conservation groups – WWF in Canada

The World Wildlife Fund (WWF) is a conservation group that helps to protect Arctic environments in Canada. It provides scientific information, expertise and resources. The WWF:

- works with local communities to manage critical ecosystems, for example the Beaufort Sea
- supports scientific research to help protect important species such as polar bears, narwhal and Greenland shark
- works with oil companies, local Inuit organisations and government regulators to plan for a sustainable future for the Arctic.

Think about it

Polar bears live along the northern coast of Alaska and western Canada. Their population has declined by 40% in just 10 years. What are the possible reasons?

Should cold environments be protected as wilderness areas?

A wilderness is a wild and unspoiled area unaffected by human activity. There are few true wilderness areas left – mainly rainforests, deserts or cold environments (photo **D**). There are strong arguments for and against protecting wilderness areas from economic development (table **E**).

Arguments in favour

- Wilderness areas are fragile and are easily damaged by economic activities.
- Untouched natural environments form important outdoor laboratories for scientific research.
- Rare plants and animals will be protected.

Arguments against

- Cold environments are rich in resources, such as oil, precious minerals, fish and timber.
- Over 4 million people already live in the Arctic in balance with the environment.
- Technology now allows cold environments to be exploited with less impact.

E Should cold environments be protected as wilderness areas?

ACTIVITIES

- Why was the trans-Alaskan pipeline built?
- Why is it important to prevent permafrost melting?
- How is the US government helping to protect cold environments in Alaska?
- Suggest why the Antarctic Treaty is such an important international agreement.

Stretch yourself

Work in small groups. Read table **E**. Do you think cold environments should be treated as wilderness areas, and protected from economic development? Give your reasons.

Practice question

Using a case study, explain how different strategies can help reduce environmental damage in cold environments. (9 marks)

