AP VII a-c

IB Topic 4,6

Global Change

Key concepts

- Human activities can interfere with the environment on both a local and on a global scale.
- Global warming and climate change have severe effects on the environment.
- Human activities have caused the Earth to lose much of its biodiversity.
- Species and resources can be managed sustainably.

Key terms

biodiversity
carbon credit
climate change
deforestation
endangered species
ex-situ conservation
extinction
global warming
globalization
greenhouse effect
greenhouse gas
habitat restoration
Indicator organism
in-situ conservation
national park
ocean acidification
ozone depletion
seedbank
stratospheric ozone
threatened species
ultraviolet radiation

Objectives

- ☐ 1. Use the **KEY TERMS** to help you understand and complete these objectives.

Stratospheric Ozone — pages 205-206

- ☐ 2. Describe the role of stratospheric ozone in absorbing **ultraviolet** (UV) **radiation.** Outline the effects of UV radiation on living organisms.
- ☐ 3. Discuss the cause of stratospheric **ozone depletion**, its effects and efforts to reduce the rate of depletion.
- ☐ 4. Distinguish between stratospheric ozone and localized ozone pollution in the lower atmosphere.

Global Warming — pages 207-214

- ☐ 5. Explain what is meant by **global warming** and distinguish it from the **greenhouse effect**. Discuss measures to reduce global warming or its impact.
- ☐ 6. Describe the origins and relative effects of **greenhouse gases**.
- ☐ 7. Discuss effects of global warming on various environments and the plants and animals that inhabit them.
- ☐ 8. Explain the cause and effects of **ocean acidification**.

Loss of Biodiversity — pages 215-228

- ☐ 9. Explain what is meant by **biodiversity** and discuss the importance of preserving and managing it.
- ☐ 10. Identify regions of naturally occurring high biodiversity and describe the importance of these.
- ☐ 11. Use examples to help distinguish between a **threatened** and an **endangered species**.
- ☐ 12. Describe the role of national parks and reserves in preserving biodiversity.
- ☐ 13. Discuss the use of both ***in-situ*** and ***ex-situ*** conservation methods and the advantages and disadvantages of each.

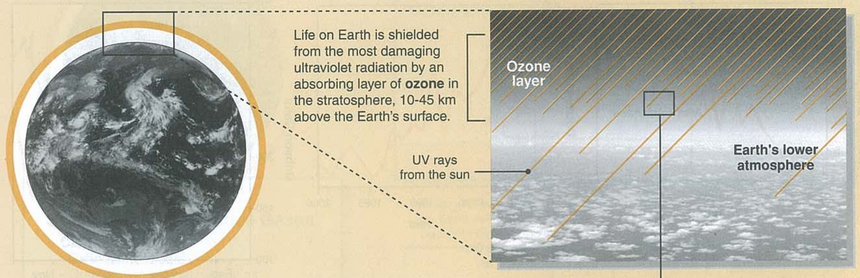
Periodicals: Listings for this chapter are on page 231

Weblinks: www.thebiozone.com/weblink/EnvSci-2764.html

Presentation Media Environmental Science: Pollution and Global Change

Stratospheric Ozone Depletion

In a band of the upper stratosphere, 17-26 km above the Earth's surface, exists a thin veil of renewable **ozone** (O_3). This ozone absorbs about 99% of the harmful incoming UV radiation from the sun and prevents it from reaching the Earth's surface. Apart from health problems, such as increasingly severe sunburns, increase in skin cancers, and more cataracts of the eye (in both humans and other animals), an increase in UV-B radiation is likely to cause immune system suppression in animals, lower crop yields, a decline in the productivity of forests and surface dwelling plankton, more smog, and changes in the global climate. Ozone is being depleted by a handful of human-produced chemicals (ozone depleting compounds or ODCs). The problem of **ozone depletion** was first detected in 1984. Researchers discovered that ozone in the upper stratosphere over Antarctica is destroyed during the Antarctic spring and early summer (September–December). Rather than a "hole", it is more a thinning, where ozone levels typically decrease by 50% to 100%. In 2000, the extent of the hole above Antarctica was the largest ever, but depletion levels were slightly less than 1999. Severe ozone loss has also been observed over the Arctic. During the winter of 1999-2000, Arctic ozone levels were depleted by 60% at an altitude of 18 km, up from around 45% in the previous winter. The primary cause for ozone depletion appears to be the increased use of chemicals such as chloro-fluoro-carbons (**CFCs**). Since 1987, nations have cut their consumption of ozone-depleting substances by 70%, although the phaseout is not complete and there is a significant black market in CFCs. **Free chlorine** in the stratosphere peaked around 1999 and is projected to decline for more than a century. Ozone loss is projected to diminish gradually until around 2050 when the polar ozone holes will return to 1975 levels. It will take another 100-200 years for full recovery to pre-1950 levels.



Sources of ozone depleting chemicals

The chemicals below drift up to the stratosphere, where ultraviolet radiation causes release of free chlorine, a highly reactive chemical.

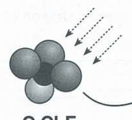
Chloro-fluoro-carbons (CFCs)
- Propellants for aerosol cans
- Coolants in air-conditioners
- Coolants (freon) in refrigerators
- Styrofoam insulation/packaging
- Medical sterilizers

Halons
- Used in many fire extinguishers

Methyl bromide
- Used as a fumigant in agriculture

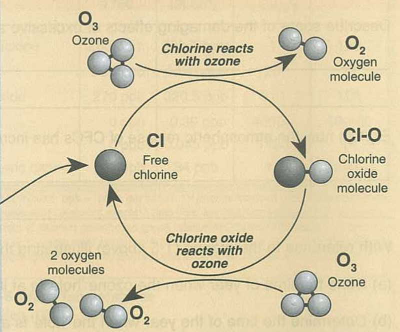
Methyl chloroform
- Used to degrease metals

Carbon tetrachloride
- Used in many industrial processes

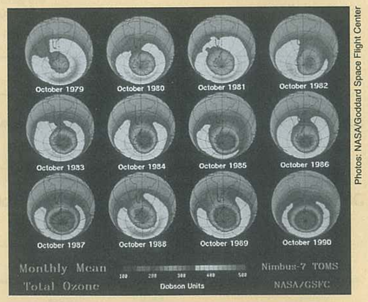


$C.Cl_3F$
Chlorofluorocarbon (CFC)

The destruction of ozone by free chlorine



A large 'hole' in the ozone layer develops over Antarctica each summer, dropping the ozone well below its normal level. The size and intensity of the hole is growing each year, as can be seen in the satellite photos on the right. In recent years, a similar hole has developed over the Arctic.



Photos: NASA/Goddard Space Flight Center

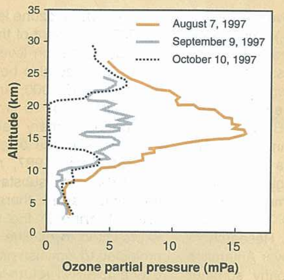
Dobson Unit (DU): A measurement of **column ozone** levels (the ozone between the Earth's surface and outer space). In the tropics, ozone levels are typically between 250 and 300 DU year-round. In temperate regions, seasonal variations can produce large swings in ozone levels. These variations occur even in the absence of ozone depletion. **Ozone depletion** refers to reductions in ozone below normal levels after accounting for seasonal cycles and other natural effects. For a graphical explanation, see NASA's TOMS site: ***http://toms.gsfc.nasa.gov/teacher/basics/dobson.html***

Characteristics of the ozone 'hole'

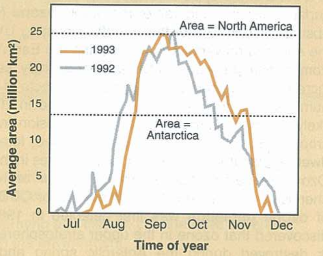
The ozone 'hole' (stratospheric ozone depletion) can be characterized using several measures. The five graphs on this page show how the size and intensity of the hole varies through the course of a year, as well as how the phenomenon has progressed over the last two decades. An explanation of the unit used to measure ozone concentration (Dobson units) is given on the opposite page. Graphs 2 and 5 illustrate readings taken between the South Pole (90° south) and 40° latitude.

Data supplied by NASA's Goddard Space Flight Center and the National Oceanic and Atmospheric Administration (NOAA) in the USA.

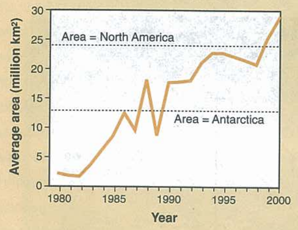
Graph 1: Ozone hole altitude profile



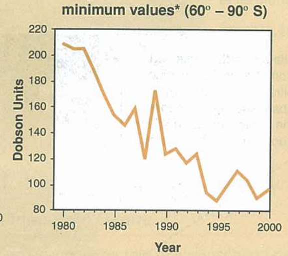
Graph 2: Antarctic ozone hole area (<220 DU, 40° – 90° South)



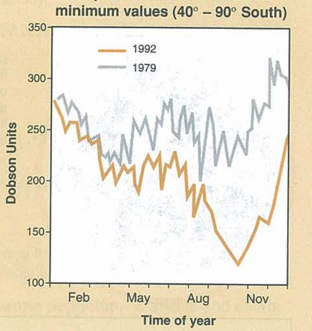
Graph 3: Change in area of the Antarctic ozone hole*



Graph 4: Antarctic ozone hole minimum values* (60° – 90° S)



Graph 5: Antarctic ozone hole minimum values (40° – 90° South)



* Date range in which samples were collected in each year: 7 Sep–13 Oct
The ozone 'hole' is defined as region with less than 220 Dobson units

Sources: NASA Goddard Space Flight Center; NOAA / CMDL

1. Describe some of the damaging effects of excessive amounts of ultraviolet radiation on living organisms:

2. Explain how the atmospheric release of CFCs has increased the penetration of UV radiation reaching the Earth's surface:

3. With reference to the graphs (1-5 above) illustrating the characteristics of the stratospheric ozone depletion problem:

   (a) State the time of year when the ozone 'hole' is at its greatest geographic extent:

   (b) Determine the time of the year when the 'hole' is at its most depleted (thinnest):

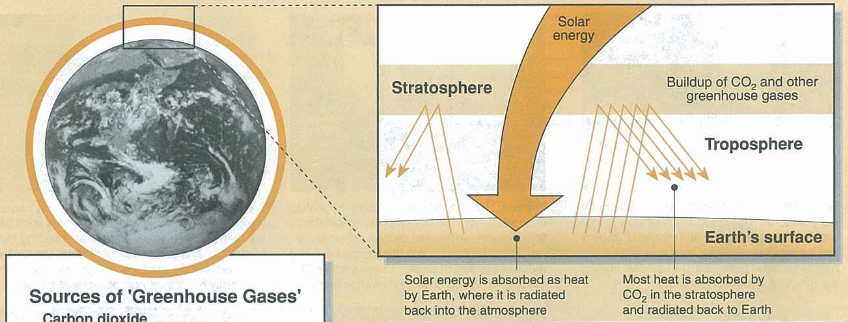
   (c) Describe the trend over the last two decades of changes to the abundance of stratospheric ozone over Antarctica:

   (d) Describe the changes in stratospheric ozone with altitude between August and October 1997 in Graph 1 (above):

4. Discuss some of the political and commercial problems associated with reducing the use of ozone depleting chemicals:

Global Warming

The Earth's atmosphere comprises a mix of gases including nitrogen, oxygen, and water vapor. Small quantities of carbon dioxide (CO_2), methane, and a number of other 'trace' gases are also present. The term 'greenhouse effect' describes the natural process by which heat is retained within the atmosphere by these 'greenhouse gases', which act as a thermal blanket around the Earth, letting in sunlight, but trapping the heat that would normally radiate back into space. The greenhouse effect results in the Earth having a mean surface temperature of about 15°C, 33°C warmer than it would have without an atmosphere. About 75% of the natural greenhouse effect is due to water vapor. The next most significant agent is CO_2. Fluctuations in the Earth's surface temperature as a result of climate shifts are normal, and the current period of warming climate is partly explained by the recovery after the most recent ice age that finished 10 000 years ago. However since the mid 20th century, the Earth's surface temperature has been increasing. This phenomenon is called global warming and the majority of researchers attribute it to the increase in atmospheric levels of CO_2 and other greenhouse gases emitted into the atmosphere as a result of human activity (i.e. it is anthropogenic). Nine of the ten warmest years on record were in the 2000s (1998 being the third warmest on record). Global surface temperatures in 2005 set a new record but are now tied with 2010 as being the hottest years on record.



Sources of 'Greenhouse Gases'

Carbon dioxide
- Exhaust from cars
- Combustion of coal, wood, oil
- Burning rainforests

Methane
- Plant debris and growing vegetation
- Belching and flatus of cows

Chloro-fluoro-carbons (CFCs)
- Leaking coolant from refrigerators
- Leaking coolant from air conditioners

Nitrous oxide
- Car exhaust

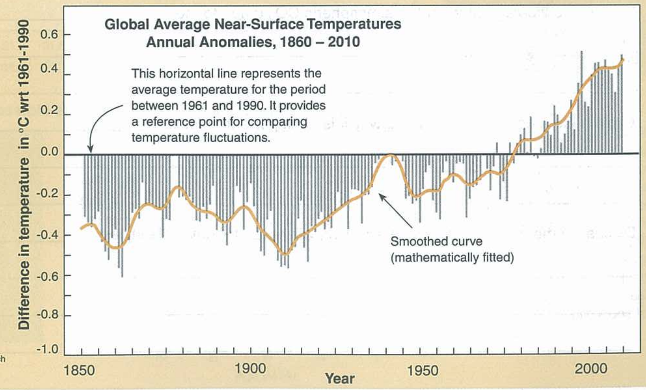
Tropospheric ozone*
- Triggered by car exhaust (smog)

*Tropospheric ozone is found in the lower atmosphere (not to be confused with ozone in the stratosphere)

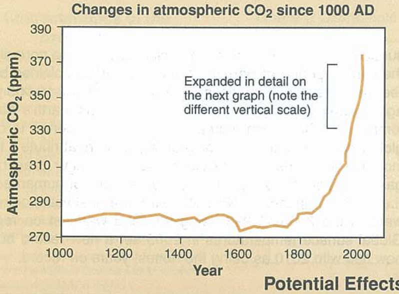
Greenhouse gas	Tropospheric conc. Pre-industrial 1750	Tropospheric conc. Present day (2008*)	Global warming potential *(compared to CO_2)¶*	Atmos-pheric lifetime *(years)§*
Carbon dioxide	280 ppm	383.9 ppm	1	120
Methane	700 ppb	1796 ppb	25	12
Nitrous oxide	270 ppb	320.5 ppb	310	120
CFCs	0 ppb	0.39 ppb	4000+	50-100
HFCs‡	0 ppb	0.045 ppb	1430	14
Tropospheric ozone	25 ppb	34 ppb	17	hours

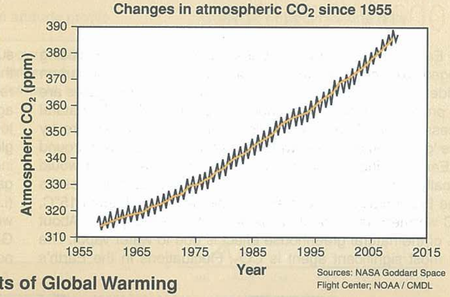
ppm = parts per million; **ppb** = parts per billion; ‡Hydrofluorcarbons were introduced in the last decade to replace CFCs as refrigerants; * Data from July 2007-June 2008. ¶ Figures contrast the radiative effect of different greenhouse gases relative to CO_2 over 100 years, e.g. over 100 years, methane is 25 times more potent as a greenhouse gas than CO_2 § How long the gas persists in the atmosphere. *Source: CO_2 Information Analysis Centre, Oak Ridge National Laboratory, USA.*

This graph shows how the mean temperature for each year from 1860-2010 (bars) compares with the average temperature between 1961 and 1990. The black line represents the fitted curve and shows the general trend indicated by the annual data. Most anomalies since 1977 have been above normal; warmer than the long term mean, indicating that global temperatures are tracking upwards. The decade 2001-2010 has been the warmest on record.



Source: Hadley Center for Prediction and Research





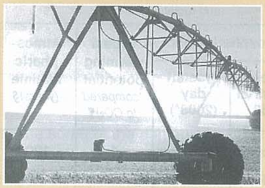
Sources: NASA Goddard Space Flight Center; NOAA / CMDL

Potential Effects of Global Warming

Sea levels are expected to rise by 50 cm by the year 2100. This is the result of the thermal expansion of ocean water and melting of glaciers and ice shelves. Warming may also expand the habitat for many pests, e.g. mosquitoes, shifting the range of infectious diseases.

Forests: Higher temperatures and precipitation changes could increase forest susceptibility to fire, disease, and insect damage. Forest fires release more carbon into the atmosphere and reduces the size of carbon sinks. A richer CO_2 atmosphere will reduce transpiration in plants.

Weather patterns: Global warming may cause regional changes in weather patterns such as El Niño and La Nina, as well as affecting the intensity and frequency of storms. Driven by higher ocean surface temperatures, high intensity hurricanes now occur more frequently.



Water resources: Changes in precipitation and increased evaporation will affect water availability for irrigation, industrial use, drinking, and electricity generation.

Agriculture: Climate change may threaten the viability of important crop-growing regions. Paradoxically, climate change can cause both too much and too little rain.

The ice-albedo effect: Ice has a stabilizing effect on global climate, reflecting nearly all the sun's energy that hits it. As polar ice melts, more of that energy is absorbed by the Earth.

1. Calculate the increase (as a %) in the 'greenhouse gases' between the pre-industrial era and the 2008 measurements (use the data from the table, see facing page). **HINT**: The calculation for carbon dioxide is: (383.9 - 280) ÷ 280 x 100 =

   (a) Carbon dioxide: ______________ (b) Methane: ______________ (c) Nitrous oxide: ______________

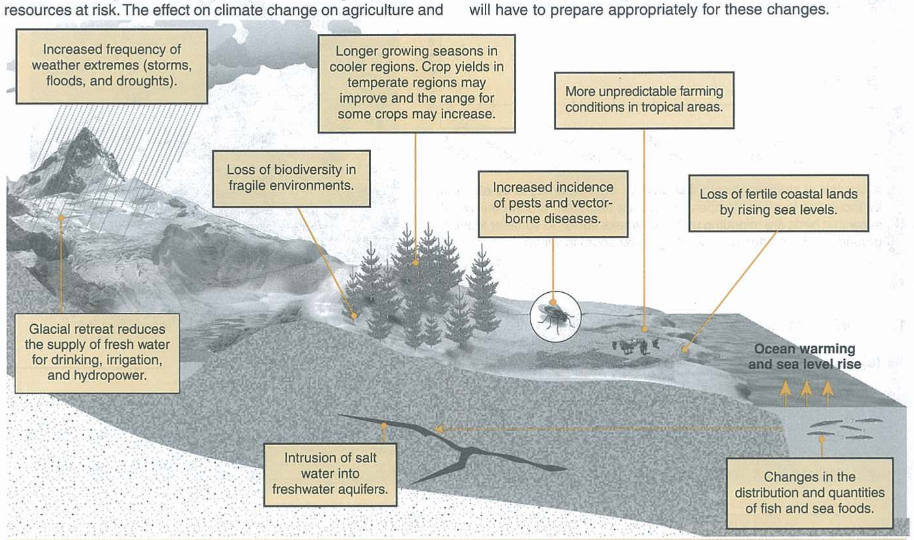
2. Explain the zig-zag nature of the atmospheric CO_2 graph to the above right. ______________

3. Explain the greenhouse effect and why it is an important process: ______________

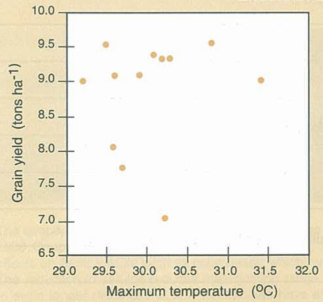
4. Discuss some of the effects global warming will have on human life styles: ______________

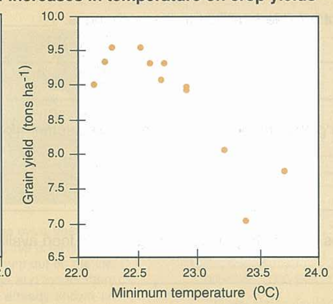
Effects of Global Warming

Climate warming is not only an environmental issue; its consequences are interconnected globally and it has implications for economic growth, food security, and world health. A rise in average global temperatures puts greater pressure on species already at risk to adapt, and species loss will accelerate. At least 40% of the world's economy and 80% of the needs of the poor are derived from biological resources, yet the capacity of the current systems to adapt to climate changes puts these resources at risk. The effect on climate change on agriculture and food security depends on a combination of many factors. Higher temperatures can stress plants but will also prolong growing seasons and allow a wider range of crops to be grown. Higher levels of CO_2 speed plant growth and increase resilience to water stress, but warmer temperatures will also extend the range of pests and diseases. Overall, changes in rainfall, increased frequency of severe climatic events, and more soil erosion will influence patterns of agriculture and disease incidence. Humans will have to prepare appropriately for these changes.



Effects of increases in temperature on crop yields



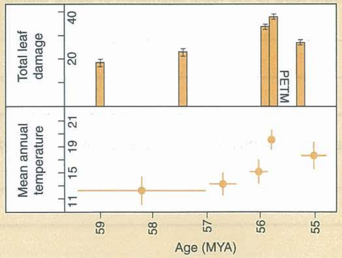


Studies on the grain production of rice have shown that maximum daytime temperatures have little effect on crop yield. However minimum night time temperatures lower crop yield by as much as 5% for every 0.5°C increase in temperature.

Source: Peng S. *et.al.* PNAS 2004

Possible effects of increases in temperature on crop damage

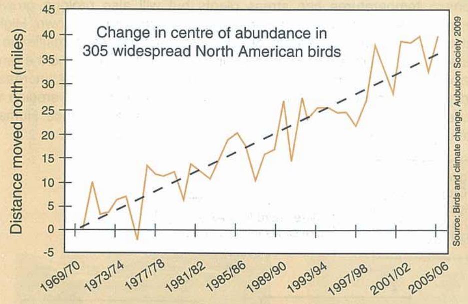
Source: Currano *et.al.* PNAS 2007



The fossil record shows that global temperatures rose sharply around 56 million years ago. Studies of fossil leaves with insect browse damage indicate that leaf damage peaked at the same time as the Paleocene Eocene Thermal Maximum (PETM). This gives some historical evidence that as temperatures increase, plant damage caused by insects also rises. This could have implications for agricultural crops.

Periodicals: The big thaw
Related activities: Global Warming
RA 2

Effects of increases in temperature on animal populations



A number of studies indicate that animals are beginning to be affected by increases in global temperatures. Data sets from around the world show that birds are migrating up to two weeks earlier to summer feeding grounds and are often not migrating as far south in winter.

Animals living at altitude are also affected by warming climates and are being forced to shift their normal range. As temperatures increase, the snow line increases in altitude pushing alpine animals to higher altitudes. In some areas of North America this has resulting the local extinction of the North American pika (*Ochotona princeps*).

1. Global warming is likely to affect the physical environment as well as both the plants and animals inhabiting it:

(a) Describe some of the likely effects of global warming on physical aspects of the environment: ___

(b) Describe the effects that global warming may have on plant crops: ___

(c) Suggest how farmers might be able to adjust to these changes: ___

(d) Describe how increases in global temperatures have affected some migratory birds: ___

(e) Explain how these changes in migratory patterns might affect food availability for these populations: ___

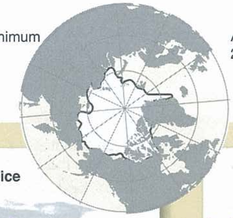
(f) Explain how global warming could lead to the local extinction of some alpine species: ___

2. Discuss the historical evidence that insect populations are affected by global temperature: ___

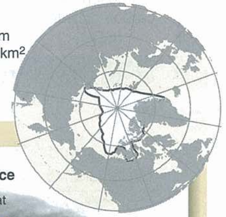
Ice Sheet Melting

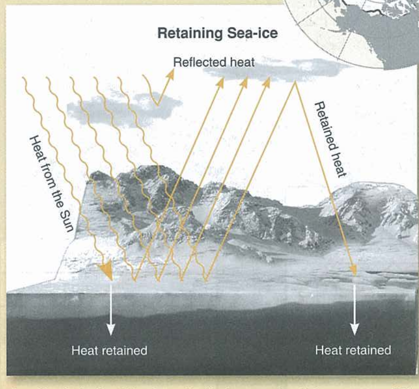
The surface temperature of the Earth is in part regulated by the amount of ice on its surface, which reflects a large amount of heat into space. However, the area and thickness of the polar sea-ice is rapidly decreasing. From 1980 to 2008 the Arctic summer sea-ice minimum almost halved, decreasing by more than 3 million square kilometers. This melting of sea-ice can trigger a cycle where less heat is reflected into space during summer, warming seawater and reducing the area and thickness of ice forming in the winter. At the current rate of reduction, it is estimated that there may be no summer sea-ice left in the Arctic by 2050.

Arctic sea-ice summer minimum
1980: 7.8 million km²

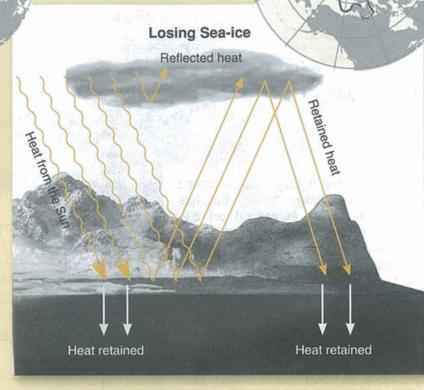


Arctic sea-ice summer minimum
2007: Record low: 4.33 million km²





The **albedo** (reflectivity of sea-ice) helps to maintain its presence. Thin sea-ice has a lower albedo than thick sea-ice. More heat is reflected when sea-ice is thick and covers a greater area. This helps to regulate the temperature of the sea, keeping it cool.



As sea-ice retreats, more non-reflective surface is exposed. Heat is retained instead of being reflected, warming both the air and water and causing sea-ice to form later in the autumn than usual. Thinner and less reflective ice forms and perpetuates the cycle.

The temperature in the Arctic has been above average every year since 1988. Coupled with the reduction in summer sea-ice, this is having dire effects on Arctic wildlife such as polar bears, which hunt out on the ice. The reduction in sea-ice reduces their hunting range and forces them to swim longer distances to firm ice. Studies have already shown an increase in drowning deaths of polar bears.

Average* Arctic air temperature fluctuations

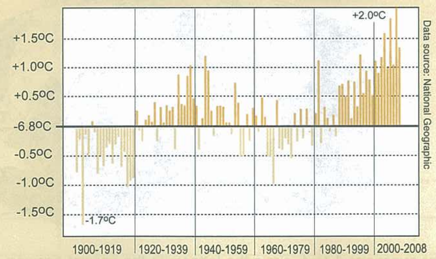


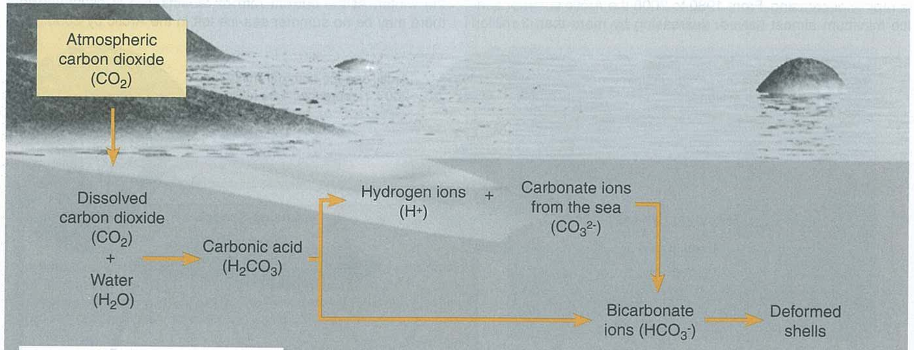
*Figure shows deviation from the average annual surface air temperature over land. Average calculated on the years 1961-2000.

1. Explain how low sea-ice albedo and volume affects the next year's sea-ice cover: ___

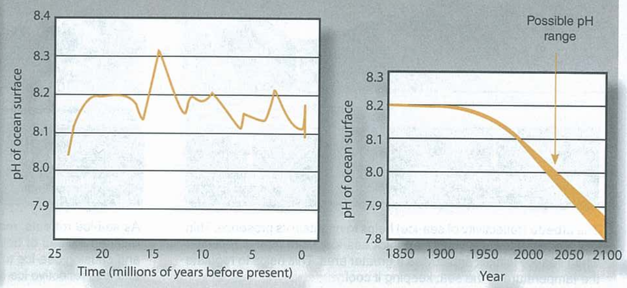
2. Discuss the effects of decreasing summer sea-ice on polar wildlife: ___

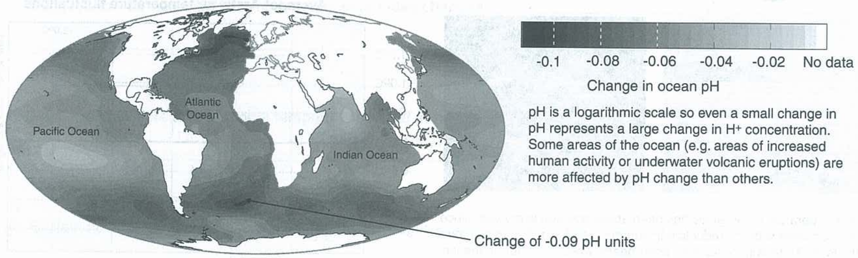
Ocean Acidification

The oceans act as a **carbon sink**, absorbing much of the CO_2 produced by burning fossil fuels. When CO_2 reacts with water it forms carbonic acid, which decreases the pH of the oceans. This could have major effects on marine life, especially shell making organisms. Ocean acidification is relative term, referring to the oceans becoming less basic as the pH decreases.



The pH of the oceans has fluctuated throughout geologic history but has always remained at around pH 8.2. Recent studies have measured current ocean pH at around 8.0. Increases in atmospheric CO_2 levels cause more CO_2 to dissolve into ocean waters. This reacts with water to form carbonic acid and lowers the pH of the water. The carbonic acid dissociates into HCO_3^- and H^+ ions. CO_3^{2-} ions from the ocean waters react with the extra H^+ ions to form more HCO_3^- ions. This process lowers the CO_3^{2-} ions available to shell-making organisms, leading to thinner and deformed shells.





pH is a logarithmic scale so even a small change in pH represents a large change in H^+ concentration. Some areas of the ocean (e.g. areas of increased human activity or underwater volcanic eruptions) are more affected by pH change than others.

For questions 1 to 4, circle the letter with the correct answer:

1. Ocean acidification is the process of:
   A. The pH of the oceans rising
   B. The oceans absorbing CO_2
   C. Decreasing concentrations of HCO_3^- ions
   D. The oceans becoming less alkaline

2. Ocean acidification has the effect of:
   A. Increasing the CO_2 absorbed by the oceans
   B. Dissolving seashells
   C. Decreasing the CO_3^{2-} ions available to shell making organisms
   D. Increasing the pH of the oceans

3. The oceanic area most affected by ocean acidification is:
   A. The Indian Ocean, near Australia
   B. The North Atlantic Ocean, near Greenland
   C. The North Pacific near Japan
   D. The Southern Ocean, near Antarctica

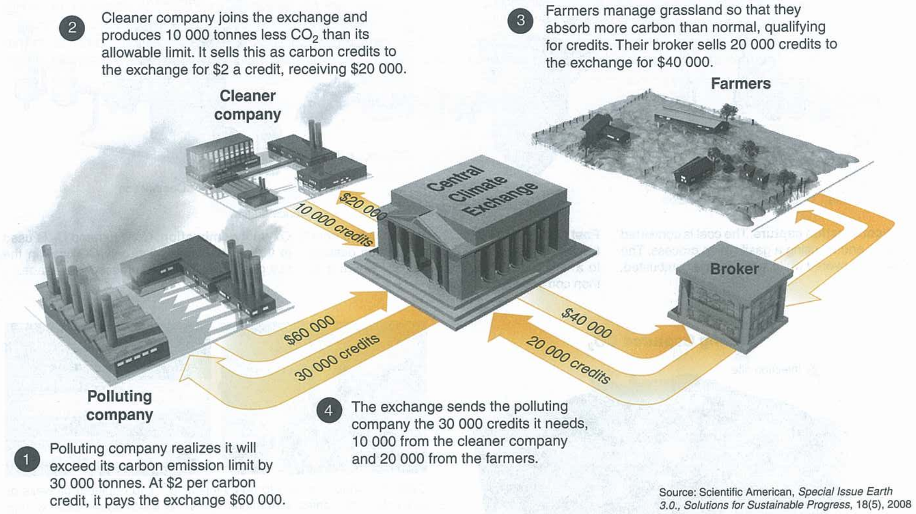
4. Even allowing for error, ocean pH in 2100 is predicted to be:
   A. 7.8 Below
   B. 7.9
   C. The same as presently
   D. About the same as 22 mya

5. Describe the relationship between ocean acidity and ocean pH: ______________________________

____

Carbon Trading

Reducing carbon dioxide emissions is a challenge in a world mostly powered by carbon based fossil fuels. One of the proposed strategies to deal with carbon dioxide emissions is the carbon trading scheme based on **carbon credits**. Certain parts of industry, such as forestry and farming, can produce carbon credits by growing plant material. Other companies can buy these carbon credits to offset the carbon dioxide they produce. Each 1000 kg of carbon dioxide is given a credit and these may be bought or sold on an exchange. The value of the carbon credit depends on the demand for and the quality of the credit.



Source: Scientific American, *Special Issue Earth 3.0., Solutions for Sustainable Progress*, 18(5), 2008

Advantages of trading carbon credits	Disadvantages of trading carbon credits
• Caps the amount of carbon dioxide emissions produced. • Makes polluting companies pay a penalty. • May force companies to become more efficient. • Companies that are less polluting or more efficient can sell their extra credits for financial benefit.	• Like any stock market, prices will fluctuate. Very high or low prices will remove incentives to use trade credits. • Many credits are not regulated and may not actually be producing any offsets at all. • The scheme may give large, highly profitable companies a free rein to pollute as they can easily afford credits with expenses being passed on to the consumer.

1. Explain how farmlands are able to generate carbon credits: ______________________________

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2. Explain the process of trading credits: ______________________________

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3. Discuss the advantages and disadvantages of a carbon trading system: ______________________________

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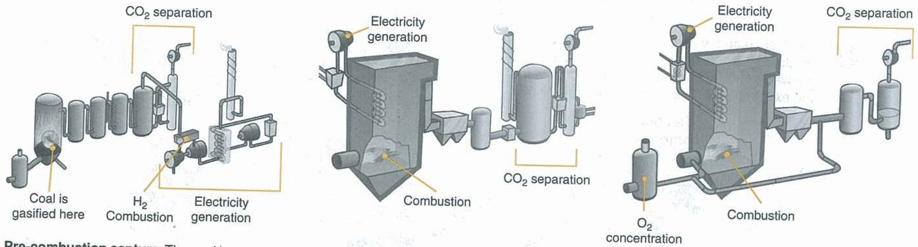
Carbon Capture and Storage

Coal and oil fired power stations produce around 60% of the world's electricity needs and have traditionally been a major source of air pollution. Even power stations using high quality coal and oil release huge volumes of CO_2 into the atmosphere. This is beginning to be addressed by systems that capture the CO_2 produced so that it can be stored or used for other purposes.

Schematics of Possible Carbon Capture Systems

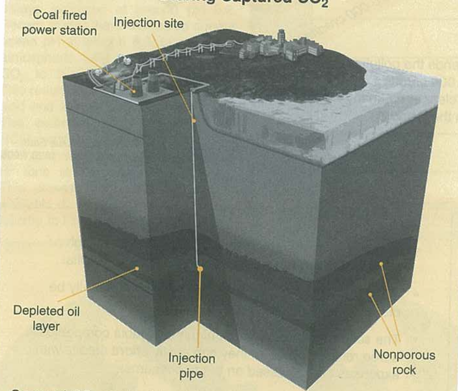


Pre-combustion capture: The coal is converted to CO_2 and H_2 using a gasification process, The CO_2 is recovered while the H_2 gas is combusted.

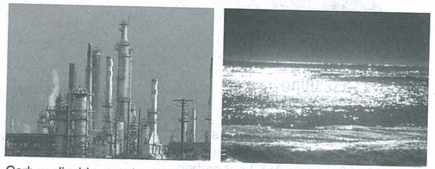
Post combustion capture: CO_2 is washed from the flue gas after combustion. It is then passed to a desorber to re-gasify the CO_2, where it is then compressed for storage.

Oxyfuel combustion: Concentrated O_2 is used in the furnace, producing only CO_2 gas in the flue gas. This is then compressed for storage.

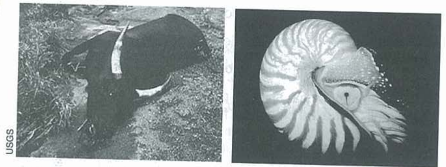
Storing Captured CO_2



Captured CO_2 can be injected into porous strata between nonporous layers. Power stations near to injection sites can pipe the recovered CO_2 to the injected well. Other stations will need to transport the CO_2 to the site. The transportation of the CO_2 will, however, produce less CO_2 than that captured by the power station.



Carbon dioxide can be stored by injecting it into depleted oil wells or other deep geological formations, releasing it into deep ocean waters or reacting it with minerals to form carbonates which can be stored as solids. The CO_2 can also be used as a starting point for the production of synthetic fuels.



There are a number of potential risks associated with CO_2 storage. Deep ocean storage risks lowering ocean pH, while storing CO_2 in geological formations risks sudden release of large quantities of CO_2 if the rock proves unstable. This could be deadly to nearby animal life.

1. Describe the differences and similarities in the three types of carbon dioxide capture systems: ______________________________

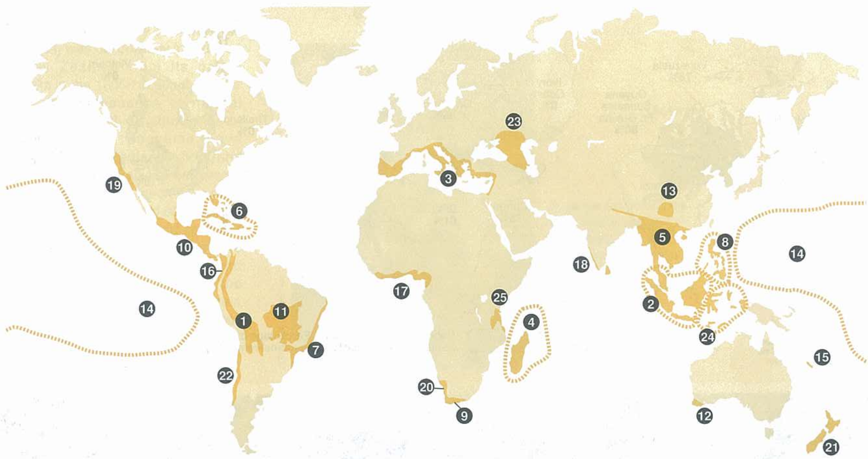
2. Describe how captured carbon dioxide might be used or stored: ______________________________

3. Discuss some of the potential problems with capturing and storing carbon dioxide: ______________________________

Loss of Biodiversity

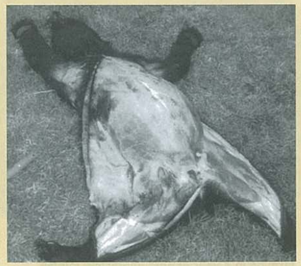
The species is the basic unit by which we measure biological diversity or **biodiversity**. Biodiversity is not distributed evenly on Earth, being consistently richer in the tropics and concentrated more in some areas than in others. Conservation International recognises 25 **biodiversity hotspots**. These are biologically diverse and ecologically distinct regions under the greatest threat of destruction. They are identified on the basis of the number of species present, the amount of **endemism**, and the extent to which the species are threatened. More than a third of the planet's known terrestrial plant and animal species are found in these 25 regions, which cover only 1.4% of the Earth's land area. Unfortunately, biodiversity hotspots often occur near areas of dense human habitation and rapid human population growth. Most are located in the tropics and most are forests. Loss of biodiversity reduces the stability and resilience of natural ecosystems and decreases the ability of their communities to adapt to changing environmental conditions. With increasing pressure on natural areas from urbanisation, roading, and other human encroachment, maintaining species diversity is paramount and should concern us all today.

Biodiversity Hotspots



Threats to Biodiversity

Habitat destruction is one of the greatest threats to willife. Deliberate destruction, such as logging, removes thousands of hectares of habitat a year, but accidental destriction, such as oil spills and industrial accidents, can be almost as bad.



Illegal trade in species (for food, body parts, or for the exotic pet trade) is pushing some species to the brink of extinction. Despite international bans on trade, illegal trade in primates, parrots, reptiles, and big cats (among others) continues.

Pollution and the pressure of human populations on natural habitats threatens biodiversity in many regions. Environmental pollutants may accumulate through food chains or cause harm directly, as with this bird trapped in oil.

1. Use your research tools (e.g. textbook, internet, or encyclopaedia) to identify each of the 25 biodiversity hotspots illustrated in the diagram above. For each region, summarise the characteristics that have resulted in it being identified as a biodiversity hotspot. Present your summary as a short report and attach it to this page of your workbook.

2. Identify the threat to biodiversity that you perceive to be the most important and explain your choice: ______________________________