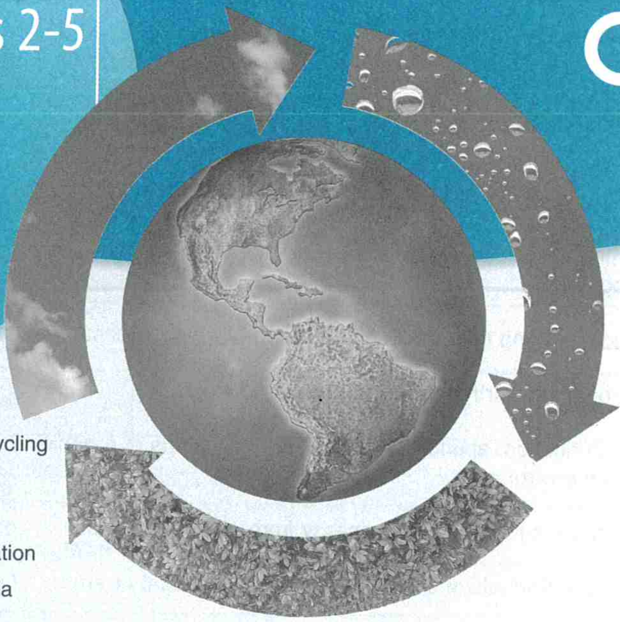
AP II d-e
IB Topics 2-5

Natural Ecosystem Change



Key terms

biogeochemical cycling
carbon cycle
climax community
cultural eutrophication
denitrifying bacteria
decomposer
eutrophication
hydrological cycle
keystone species
nitrifying bacteria
nitrogen cycle
nitrogen-fixing bacteria
nutrient cycling
phosphorus cycle
pioneer species
primary succession
resilience
secondary succession
sere
stability
sulfur cycle

Key concepts

- Nutrients and elements constantly cycle through the ecosystem in a complex series of reactions and interactions.
- Microbial activity plays fundamental roles in biogeochemical cycling.
- Ecological succession is a natural process by which an ecosystem changes over time.
- Ecological change can involve small and large scales and occur over short or long time spans.

Learning Objectives

☐ 1. Use the **KEY TERMS** to compile a glossary for this topic.

Ecosystem Stability

pages 69-71, 82-85

☐ 2. Explain how an **ecosystem**'s stability is related to its diversity, including reference to **keystone species**.

☐ 3. Use examples to help describe the process of **primary succession**, including the role of **pioneer species** (colonizing) and the characteristics of a **climax community**.

☐ 4. Use examples to help describe the process of **secondary succession** and characteristics that distinguish it from primary succession.

Biogeochemical Cycles

pages 72-81

☐ 5. Describe the **carbon cycle**, using arrows to show the direction of nutrient flow and labels to identify the processes involved. Describe how human activity may intervene in various aspects of the carbon cycle.

☐ 6. Describe the **nitrogen cycle**, using arrows to show the direction of nutrient flow. Describe the processes involved and the role of microorgansims in the cycle. Describe how human activity may intervene in the nitrogen cycle.

☐ 7. Identify and explain the role of **nitrifying bacteria**, **nitrogen-fixing bacteria** and **denitrifying bacteria** in the nitrogen cycle.

☐ 8. Describe the processes involved in nitrogen pollution and the environmental effects of nitrogen, including **eutrophication**.

☐ 9. Explain how **cultural eutrophication** is the acceleration of a natural process caused by human activities such as fertilizer use and effluent discharge.

☐ 10. Describe the **phosphorus cycle**, using arrows to show the direction of nutrient flow. Describe the processes involved and the role of microorganisms in the cycle. Contrast the phosphorus cycle with other biogeochemical cycles.

☐ 11. Describe the **sulfur cycle**. Identify the forms of sulfur at various stages. Use arrows to show the direction of nutrient flow and labels to identify the processes involved.

☐ 12. Describe the **hydrological** (water) **cycle**. Understand the way in which water is cycled between various reservoirs and describe the major processes involved including evaporation, condensation, precipitation and run-off.

Periodicals:
Listings for this chapter are on page 246

Weblinks:
www.thebiozone.com/weblink/EnvSci-3558.html

Ecosystem Stability

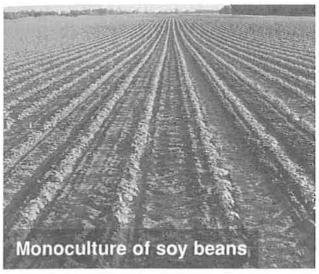
Ecological theory suggests that all species in an ecosystem contribute in some way to ecosystem function. Therefore, species loss past a certain point is likely to have a detrimental effect on the functioning of the ecosystem and on its ability to resist change (its **stability**). Although many species still await discovery, we do know that the rate of species extinction is increasing. Scientists estimate that human destruction of natural habitat is driving up to 100,000 species to extinction every year. This substantial loss of biodiversity has serious implications for the long term stability of many ecosystems.

Rainforests (above left) represent the highest diversity systems on Earth. Whilst they are generally resistant to disturbance, once degraded, (above) they have little ability to recover. The diversity of ecosystems at low latitudes is generally higher than that at high latitudes, where climates are harsher, niches are broader, and systems may be dependent on a small number of key species.

The Concept of Ecosystem Stability

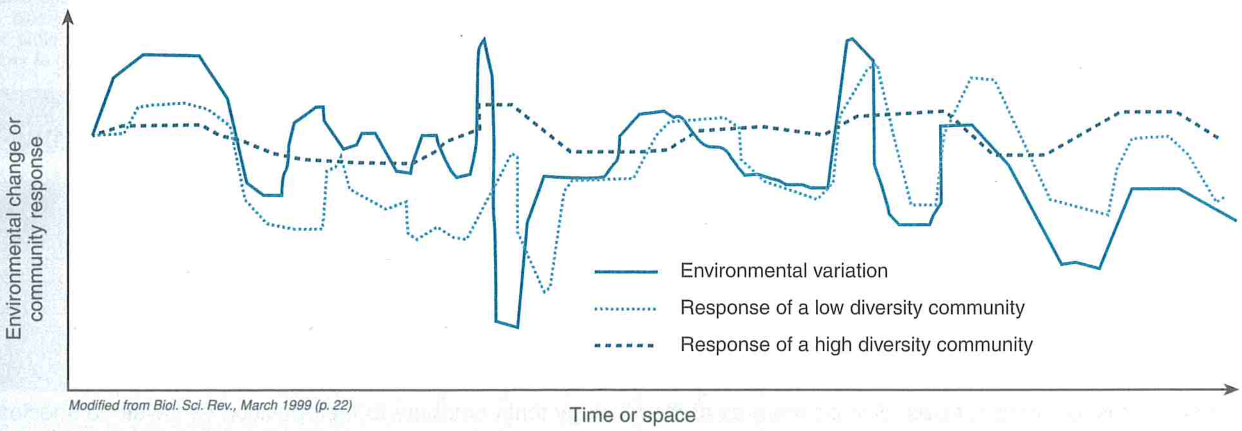
The stability of an ecosystem refers to its apparently unchanging nature over time. Ecosystem stability has various components, including **inertia** (the ability to resist disturbance) and **resilience** (the ability to recover from external disturbances).

Evidence from both experimental and natural systems indicates that the most diverse ecosystems are also the most stable. This correlation is presumed to be a consequence of the large number of biotic interactions operating to buffer diverse systems against change. However, there is uncertainty over what level of diversity provides insurance against catastrophe. Ecosystems are very complex and stability probably relies more on the differential responses of all its species to variable conditions. Current thinking emphasises the role of multiple factors, including diversity, in dictating stability.

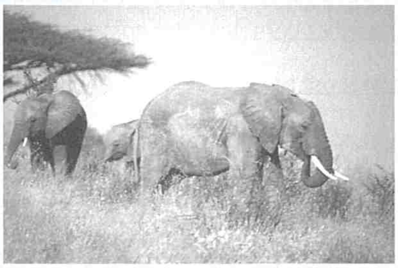


Single species crops (far left), represent low diversity systems that can be vulnerable to disease, pests, and disturbance. In contrast, natural grasslands (left) may appear on the surface to be homogeneous, but contain many species which vary in their predominance seasonally. Although they may be easily disturbed (e.g. by burning) they are very resilient and usually recover quickly.

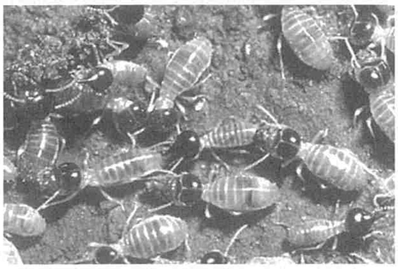
Community Response to Environmental Change



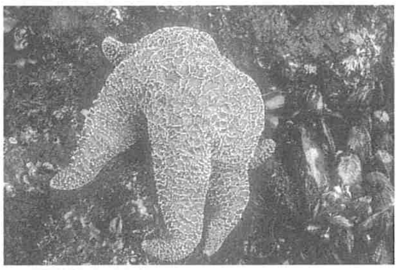
In models of ecosystem function, higher species diversity increases the stability of ecosystem functions such as productivity and nutrient cycling. In the graph above, note how the low diversity system varies more consistently with the environmental variation, whereas the high diversity system is buffered against major fluctuations. In any one ecosystem, some species may be more influential than others in the stability of the system. Such **keystone (key) species** have a disproportionate effect on ecosystem function due to their pivotal role in some ecosystem function such as nutrient recycling or production of plant biomass.



Elephants can change the entire vegetation structure of areas into which they migrate. Their pattern of grazing on taller plant species promotes a predominance of lower growing grasses with small leaves.



Termites are among the few larger soil organisms able (through a symbiosis with microbes) to break down plant cellulose. They have a profound effect on the rates of nutrient processing in tropical environments.



The starfish *Pisaster* occurs along the coasts of North America where it feeds on mussels. If it is removed, the mussels dominate, crowding out most algae and leading to a decrease in the number of herbivore species.

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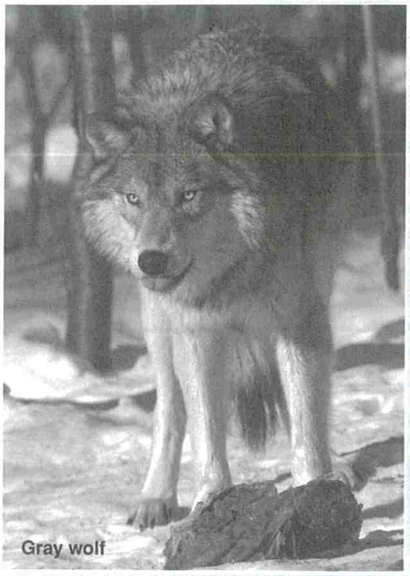
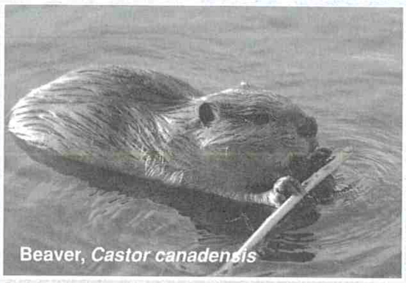
Periodicals: *Biodiversity and ecosystems*

Related activities: *Monitoring Water Quality, Loss of Biodiversity*

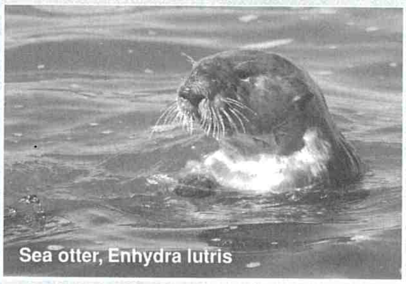
Keystone Species in North America



Gray wolf



Beaver, *Castor canadensis*



Sea otter, Enhydra lutris

Quaking aspen

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JB-BU

Gray or **timber wolves** (*Canis lupus*) are a keystone predator and were once widespread in North American ecosystems. Historically, wolves were eliminated from Yellowstone National Park because of their perceived threat to humans and livestock. As a result, elk populations increased to the point that they adversely affected other flora and fauna. Wolves have since been reintroduced to the park and balance is returning to the ecosystem.

Two smaller mammals are also important keystone species in North America. **Beavers** (top) play a crucial role in biodiversity and many species, including 43% of North America's endangered species, depend partly or entirely on beaver ponds. **Sea otters** are also critical to ecosystem function. When their numbers were decimated by the fur trade, sea urchin populations exploded and the kelp forests, on which many species depend, were destroyed.

Quaking aspen (*Populus tremuloides*) is one of the most widely distributed tree species in North America, and aspen communities are among the most biologically diverse in the region, with a rich understorey flora supporting an abundance of wildlife. Moose, elk, deer, black bear, and snowshoe hare browse its bark, and aspen groves support up to 34 species of birds, including ruffed grouse, which depends heavily on aspen for its winter survival.

For question 1 circle the letter with the correct answer:

1. Identify which of the following statements are correct:
   As the conditions in an ecosystem change:
   I. A high diversity community has little response
   II. A low diversity community has little response
   III. A high diversity community has a large response
   IV. A low diversity has a large response

   A. I and II
   B. II and III
   C. I and IV
   D. II and IV

2. Explain why **keystone species** are so important to ecosystem function: keyStone Species fill an ecological niche within a ecosystem making the enviroment habitable for the other Species within the ecosystem.

3. For each of the following species, discuss features of their biology that contribute to their position as keystone species:

   (a) Sea otter: Sea otters help to control Sea urchin populations whitch in turn helps to increse the level of kelp forests (an important habitat)

   (b) Beaver: Beavers create a unique habitat through their dams. this allows a plethora of Species to thrive in the Slower moving water contained by the dam.

   (c) Gray wolf: The grey wolf helps to control elk numbers. Exessive populations of elk can damage flora and fauna through over grazing.

   (d) Quaking aspen: This Species of tree provides habitat to a wide range of plants and animals through the Shade the canopy provides as well as through food provision from the trees bark.

4. Giving examples, explain how the actions of humans to remove a keystone species might result in ecosystem change: Eradication of a Species can have a knock on effect to all other organisms that rely on the ecological niche that the keyStone Species fills

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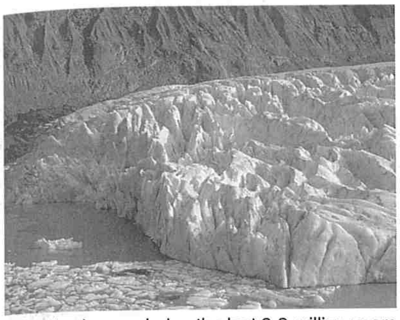
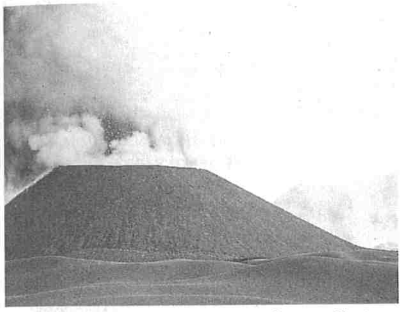
Environmental Change

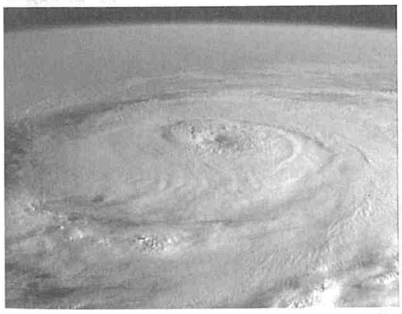
Environmental changes come from three sources: the **biosphere** itself, **geological forces** (crustal movements and plate tectonics), and **cosmic forces** (the movement of the moon around the Earth, and the Earth and planets around the sun). All three forces can cause cycles, steady states, and trends (directional changes) in the environment. Environmental trends (such as climate cooling) cause long term changes in communities. Some short term cycles may also influence patterns of behavior and growth in many species, regulating endogenous cyclical behavior patterns, called **biological rhythms**.



Climatic change during the last 2-3 million years has involved cycles of glacial and interglacial conditions. These cycles are largely the result of an interplay between astronomical cycles and atmospheric CO_2 concentrations.



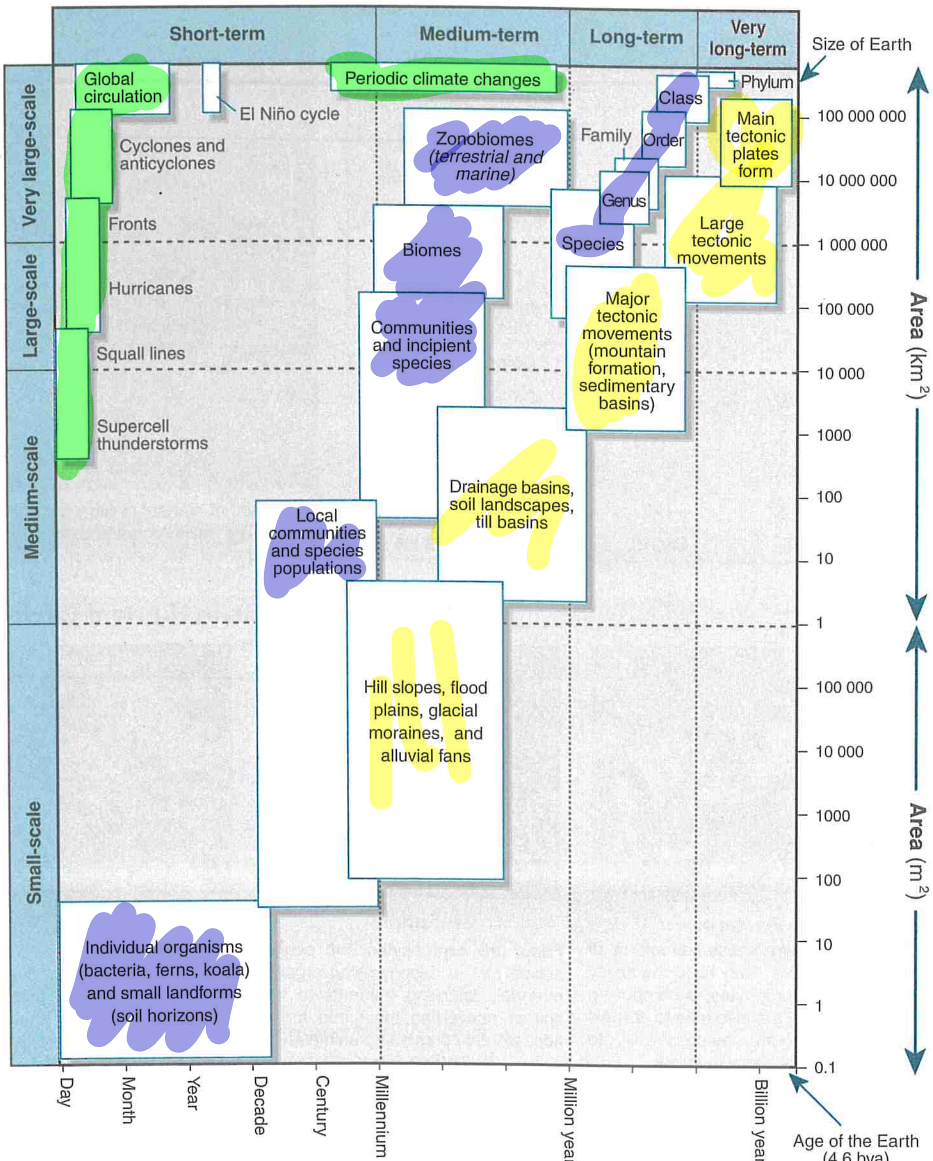
Volcanic eruptions may have a large effect on local biological communities. They may also cause prolonged changes to regional and global weather (e.g. Mount Pinatubo eruption, 1989).



Some weather patterns are responsible for subtle changes to ecosystems, such as the gradual onset of a drought. They may also provide large scale and forceful changes, such as those caused by hurricanes or cyclones.

Time scale and geographic extent of environmental change

(Time scale: horizontal axis / geographic extent: vertical axis)



Source: Modified from Huggett, R.J., 1997. *Environmental Change – The Evolving Ecosphere.*

TIME (years $\log_{10}$ scale)

1. Periodic long term changes in the Earth's orbit, a change in the sun's heat output, and continental drift may have been the cause of cycles of climate change in the distant past. These climate changes involved a cooling of the Earth:

   (a) Identify the term referring to these periods of global cooling: Ice ages

   (b) Describe two changes to the landscape that occurred during this period: Glacies More Commonplace.

2. On the diagram above, color-code each of the rectangles to indicate the four themes of environmental change:

   Climatic: ________ Ecological: ________ Tectonic: ________ Evolutionary: Most of

3. Explain to what extent these four types of environmental change are interlinked:

   Any changes to the climate causes knock on effects to other aspects of the environment often changing the climate in another way.

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Related activities: Ecosystem Stability, Primary Succession, Secondary Succession

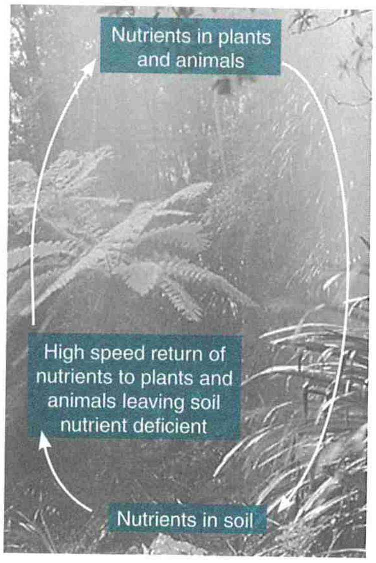
Nutrient Cycles

Nutrient cycling is an important part of every ecosystem. Elements essential for the efficient operation of living systems move through the environment through the processes of uptake and deposition. Commonly, nutrients must be in an ionic (rather than elemental) form in order for plants and animals to have access to them. Some bacteria have the ability to convert elemental forms of nutrients, such as sulfur, into ionic forms and so play an important role in making nutrients available to plants and animals.

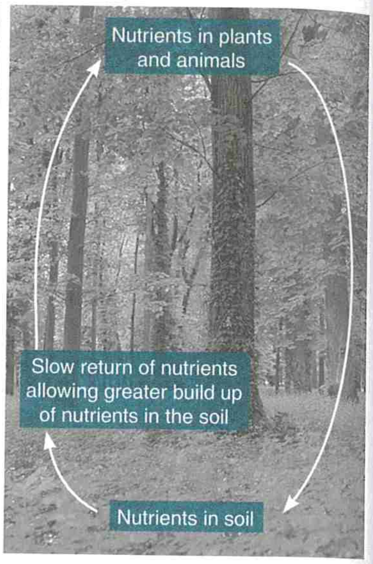
Essential Nutrients

Macronutrient	Common form	Function
Carbon (C)	CO_2	Organic molecules
Oxygen (O)	O_2	Respiration
Hydrogen (H)	H_2O	Cellular hydration
Nitrogen (N)	N_2, NO_3^-, NH_4^+	Proteins, nucleic acids
Potassium (K)	K^+	Principal ion in cells
Phosphorus (P)	$H_2PO_4^-$, HPO_4^{2-}	Nucleic acids, lipids
Calcium (Ca)	Ca^{2+}	Membrane permeability
Magnesium (Mg)	Mg^{2+}	Chlorophyll
Sulfur (S)	SO_4^{2-}	Proteins
Micronutrient	**Common form**	**Function**
Iron (Fe)	Fe^{2+}, Fe^{3+}	Chlorophyll, blood
Manganese (Mn)	Mn^{2+}	Enzyme activation
Molybdenum (Mo)	MoO_4^-	Nitrogen metabolism
Copper (Cu)	Cu^{2+}	Enzyme activation
Sodium (Na)	Na^+	Ion in cells
Silicon (Si)	$Si(OH)_4$	Support tissues

Tropical Rainforest

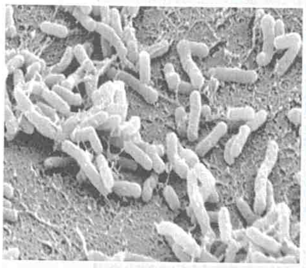


Temperate Woodland



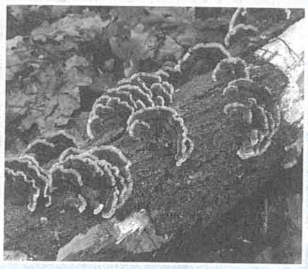
The speed of nutrient cycling can vary markedly. Some nutrients are cycled slowly, others quickly. The environment and diversity of an ecosystem can also have a large effect on the speed at which nutrients are recycled.

The Role of Organisms in Nutrient Cycling


Shirley Owens MSU

Bacteria

Bacteria play an essential role in all nutrient cycles. They have the ability to act as saprophytes, decomposing material, but are also able to convert nutrients from inaccessible to biologically accessible forms.

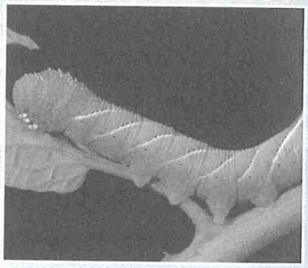


Fungi

Fungi are saprophytes and play a critical role in decomposing organic material, returning nutrients to the soil or converting them into forms accessible to plants and animals.

Plants

Plants have an important role in absorbing many nutrients from the soil and making them directly available to browsing animals. They also add their own decaying matter to soils.



Animals

Animals utilize and break down materials from bacteria, plants, and fungi and return the nutrients to soils and water via their wastes and when they die.

1. Describe the role of each of the following in nutrient cycling:

(a) Bacteria: They act as saprophytes decomposing organic matter.

(b) Fungi: They also act as decomposers making nutrients biologically available.

(c) Plants: Plants take up nutrients from soil making them available to animals.

(d) Animals: Animals break down material and return nutrients to the soil

2. Why are soils in tropical rainforests nutrient deficient relative to soils in temperate woodlands? There is so much life in rainforests that nutrients are rapidly recycled.

3. Distinguish between macronutrients and micronutrients: Macro nutrients are more prevalent. They consist of carbohydrates, lipids, and proteins. Micro nutrients are much less prevalent and are made up of vitamins and minerals.

Related activities: The Carbon Cycle, The Nitrogen Cycle, The Phosphorus Cycle, The Sulfur Cycle

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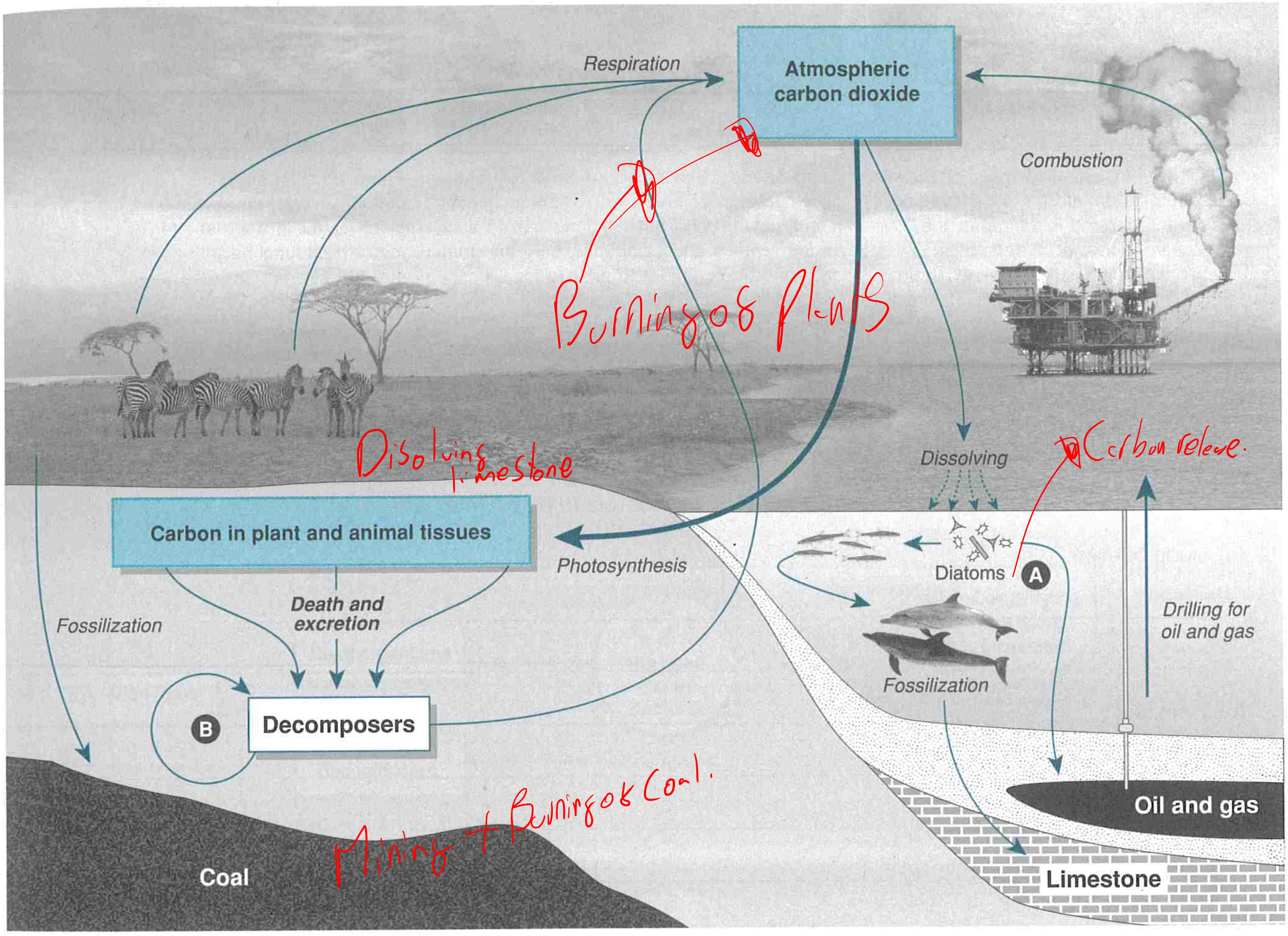
The Carbon Cycle

Carbon is an essential element in living systems, providing the chemical framework to form the molecules that make up living organisms (e.g. proteins, carbohydrates, fats, and nucleic acids). Carbon also makes up approximately 0.03% of the atmosphere as the gas carbon dioxide (CO_2), and it is present in the ocean as carbonate and bicarbonate, and in rocks such as limestone. Carbon cycles between the living (biotic) and non-living (abiotic) environment: it is fixed in the process of photosynthesis and returned to the atmosphere in respiration. Carbon may remain locked up in biotic or abiotic systems for long periods of time as, for example, in the wood of trees or in fossil fuels such as coal or oil. Human activity has disturbed the balance of the carbon cycle (the global carbon budget) through activities such as combustion (e.g. the burning of wood and **fossil fuels**) and deforestation.



1. In the diagram above, add **arrows** and **labels** to show the following activities:

   (a) Dissolving of limestone by acid rain
   (b) Release of carbon from the marine food chain
   (c) Mining and burning of coal
   (d) Burning of plant material.

2. Describe the **biological origin** of the following geological deposits:

   (a) Coal: Plant matter that has decomposed under high pressure.

   (b) Oil: Dead marine animals that decomposed under high pressure.

   (c) Limestone: Dead animals under medium presure.

3. Describe the two processes that release carbon into the atmosphere: Combustion. respiration

4. Name the four geological reservoirs (sinks), in the diagram above, that can act as a source of carbon:

   (a) Plants
   (b) Coal
   (c) Oil
   (d) Atmospheric CO2

5. (a) Identify the process carried out by diatoms at point [**A**]: Carbon fixation

   (b) Identify the process carried out by decomposers at [**B**]: Decomposition

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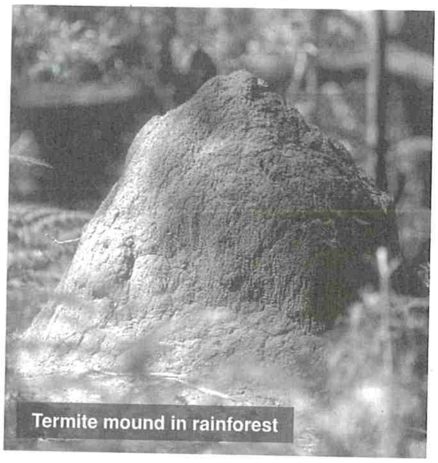
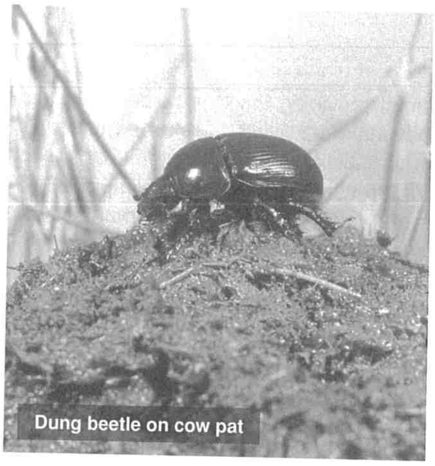
Periodicals:
A user's guide to the carbon cycle

Related activities: *Oil, Coal, Global Warming*

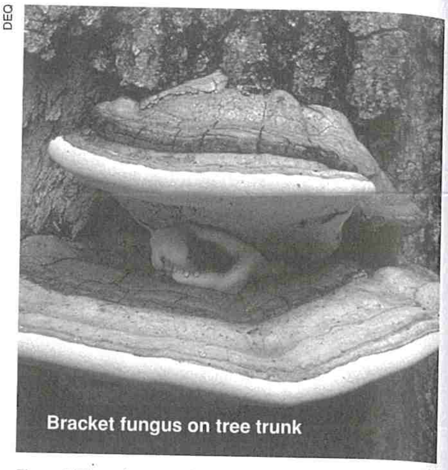


Termite mound in rainforest



Dung beetle on cow pat

DEQ



Bracket fungus on tree trunk

Termites: These insects play an important role in nutrient recycling. With the aid of symbiotic protozoans and bacteria in their guts, they can digest the tough cellulose of woody tissues in trees. Termites fulfill a vital function in breaking down the endless rain of debris in tropical rainforests.

Dung beetles: Beetles play a major role in the decomposition of animal dung. Some beetles merely eat the dung, but true dung beetles, such as the scarabs and *Geotrupes*, bury the dung and lay their eggs in it to provide food for the beetle grubs during their development.

Fungi: Together with decomposing bacteria, fungi perform an important role in breaking down dead plant matter in the leaf litter of forests. Some mycorrhizal fungi have been found to link up to the root systems of trees where an exchange of nutrients occurs (a mutualistic relationship).

6. Predict the consequences to carbon cycling if there were no decomposers present in an ecosystem: Carbon wouldnt be recycled meaning that eventually there would be a shortage of carbon.

7. Explain how each of the three organisms listed below has a role to play in the carbon cycle:
   (a) Dung beetles: Dung beetles convert animal dung into fertile soil.
   (b) Termites: Termites help to decompose woody fibers found in trees.
   (c) Fungi: Fungi acts as a decomposer helping to reduced dead organic matter back into soil.

8. Using specific examples, explain the role of insects in carbon cycling: Insects such as termites help to break down organic materials back into soil where it can be used by plants. Termites in particular help to break down woody fibers.

9. In natural circumstances, accumulated reserves of carbon such as peat, coal and oil represent a **sink** or natural diversion from the cycle. Eventually the carbon in these sinks returns to the cycle through the action of geological processes which return deposits to the surface for oxidation.
   (a) Describe the effects human activity on the amount of carbon stored in sinks: Humans utilize carbon stored in carbon sinks for energy. Extraction of carbon from sinks occurs anthropogenically.
   (b) Describe two **global effects** of this activity: This has lead to a rise in carbon dioxide levels in the atmosphere causing the globe to heat up.
   (c) Suggest what could be done to prevent or alleviate these effects: fossil fuels should stop being used as our primary source of energy helping to reduce excess CO_2 from being produced.

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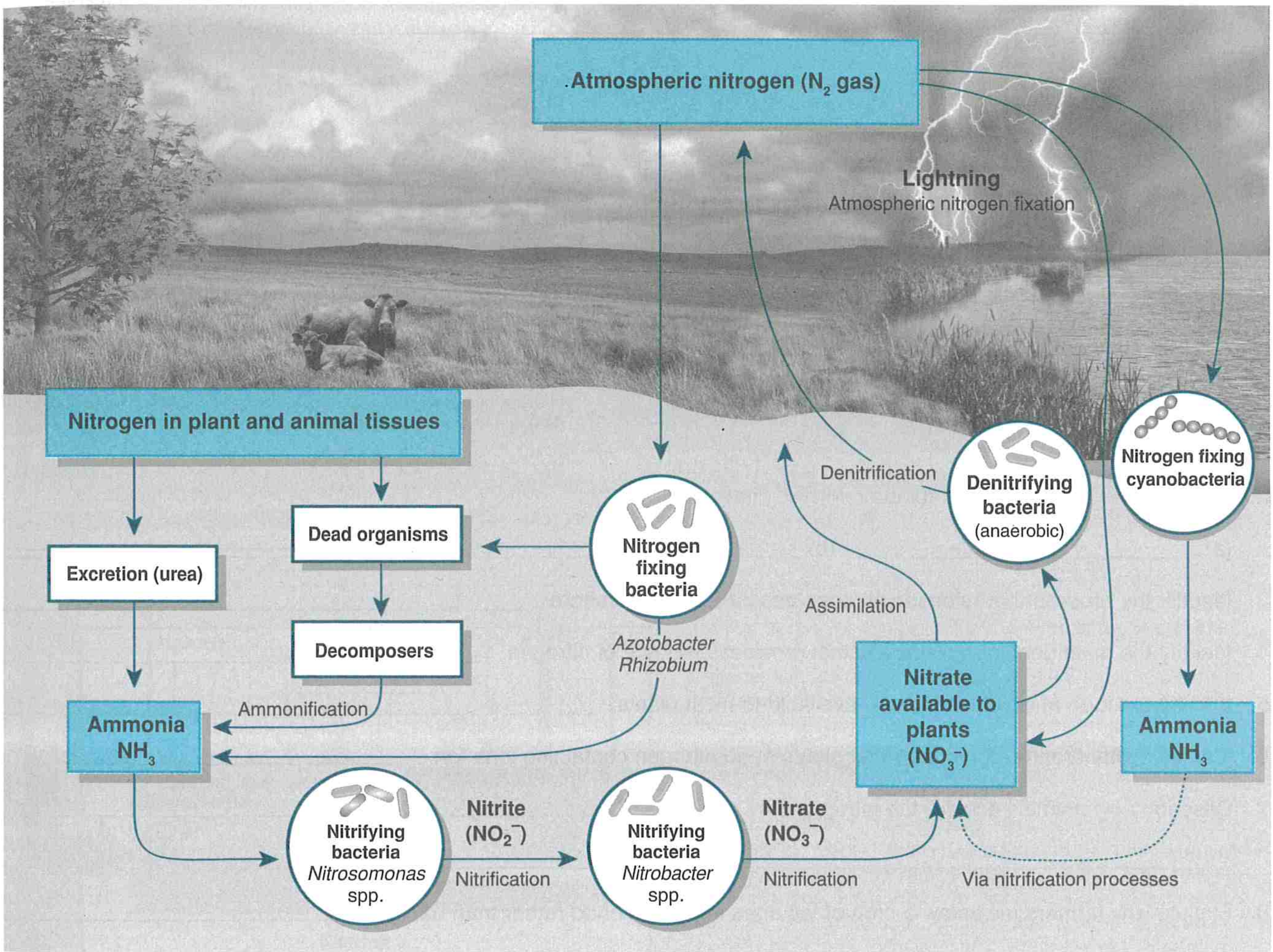
The Nitrogen Cycle

Nitrogen is a crucial element for all living things, forming an essential part of the structure of proteins and nucleic acids. The Earth's atmosphere is about 80% nitrogen gas (N_2), but molecular nitrogen is so stable that it is only rarely available directly to organisms and is often in short supply in biological systems. Bacteria play an important role in transferring nitrogen between the biotic and abiotic environments. Some bacteria are able to fix atmospheric nitrogen, while others convert ammonia to nitrate and thus make it available for incorporation into plant and animal tissues. Nitrogen-fixing bacteria are found living freely in the soil *(Azotobacter)* and living symbiotically with some plants in root nodules *(Rhizobium)*. Lightning discharges also cause the oxidation of nitrogen gas to nitrate which ends up in the soil. Denitrifying bacteria reverse this activity and return fixed nitrogen to the atmosphere. Humans intervene in the nitrogen cycle by producing, and applying to the land, large amounts of nitrogen fertilizer. Some applied fertilizer is from organic sources (e.g. green crops and manures) but much of it is inorganic, produced from atmospheric nitrogen using an energy-expensive industrial process. Overuse of nitrogen fertilizers may lead to excessive nutrient enrichment of water. This human-induced enrichment and the increase in productivity associated with it, which includes excessive bacterial and algal growth, is called **cultural eutrophication**.



1. Describe five instances in the nitrogen cycle where **bacterial** action is important. Include the name of each of the processes and the changes to the form of nitrogen involved:

(a) Nitrogen fixing Cyanobacteria Converts atmospheric Nitrogen into Ammonia

(b) Nitrifying bacteria Converts this ammonia into Nitrate available to plants.

(c) Denitrifying bacteria Converts this Nitrate into Atmospheric nitrogen.

(d) Nitrogen fixing bacteria Converts nitrogen in the atmosphere into Amonia

(e)

ISBN: 978-1-927173-55-8

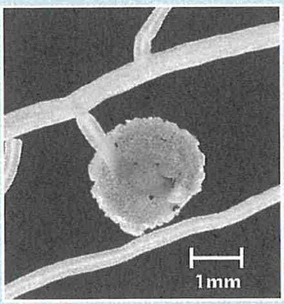
Periodicals: *Microbes and nitrogen cycling*

Related activities: *Nitrogen Pollution, Water Pollution*
Weblinks: *Nitrogen Cycle Animation*

Nitrogen Fixation in Root Nodules

Root nodules are a root **symbiosis** between a higher plant and a bacterium. The bacteria fix atmospheric nitrogen and are extremely important to the nutrition of many plants, including the economically important legume family. Root nodules are extensions of the root tissue caused by entry of a bacterium. In legumes, this bacterium is *Rhizobium*. Other bacterial genera are involved in the root nodule symbioses in non-legume species.

The bacteria in these symbioses live in the nodule where they fix atmospheric nitrogen and provide the plant with most, or all, of its nitrogen requirements. In return, they have access to a rich supply of carbohydrate. The fixation of atmospheric nitrogen to ammonia occurs within the nodule, using the enzyme **nitrogenase**. Nitrogenase is inhibited by oxygen and the nodule provides a low O_2 environment in which fixation can occur.



WBS

Two examples of legume nodules caused by *Rhizobium*. The photographs above show the size of a single nodule (left), and the nodules forming clusters around the roots of *Acacia* (right).

Human Intervention in the Nitrogen Cycle

Until about sixty years ago, microbial nitrogen fixation (left) was the only mechanism by which nitrogen could be made available to plants. However, during WW II, Fritz Haber developed the **Haber process** whereby nitrogen and hydrogen gas are combined to form gaseous ammonia. The ammonia is converted into ammonium salts and sold as inorganic fertilizer. Its application has revolutionized agriculture by increasing crop yields.

As well as adding nitrogen fertilizers to the land, humans use anaerobic bacteria to break down livestock wastes and release NH_3 into the soil. They also intervene in the nitrogen cycle by discharging **effluent** into waterways. Nitrogen is removed from the land through burning, which releases nitrogen oxides into the atmosphere. It is also lost by mining, harvesting crops, and irrigation, which leaches nitrate ions from the soil.

Two examples of human intervention in the nitrogen cycle. The photographs above show the aerial application of a commercial fertilizer (left), and the harvesting of an agricultural crop (right).

2. Identify three processes that **fix** atmospheric nitrogen:

   (a) Lightning (b) Amonisication (c) Urea.

3. Identify the process that releases nitrogen gas into the atmosphere: Denitrification.

4. Identify the main geological reservoir that provides a source of nitrogen:

5. Identify the form in which nitrogen is available to most plants: NO_3^-

6. Identify a vital organic compound that plants need nitrogen containing ions for:

7. Describe how animals acquire the nitrogen they need: Through the consumption of plants.

8. Explain why farmers may plow a crop of legumes into the ground rather than harvest it: To allow more nitrogen to enter the ground.

9. Describe five ways in which humans may intervene in the nitrogen cycle and the effects of these interventions:

   (a) Effluent leaching water can cause algea blooms depleting the water of oxygen.

   (b)

   (c)

   (d)

   (e)

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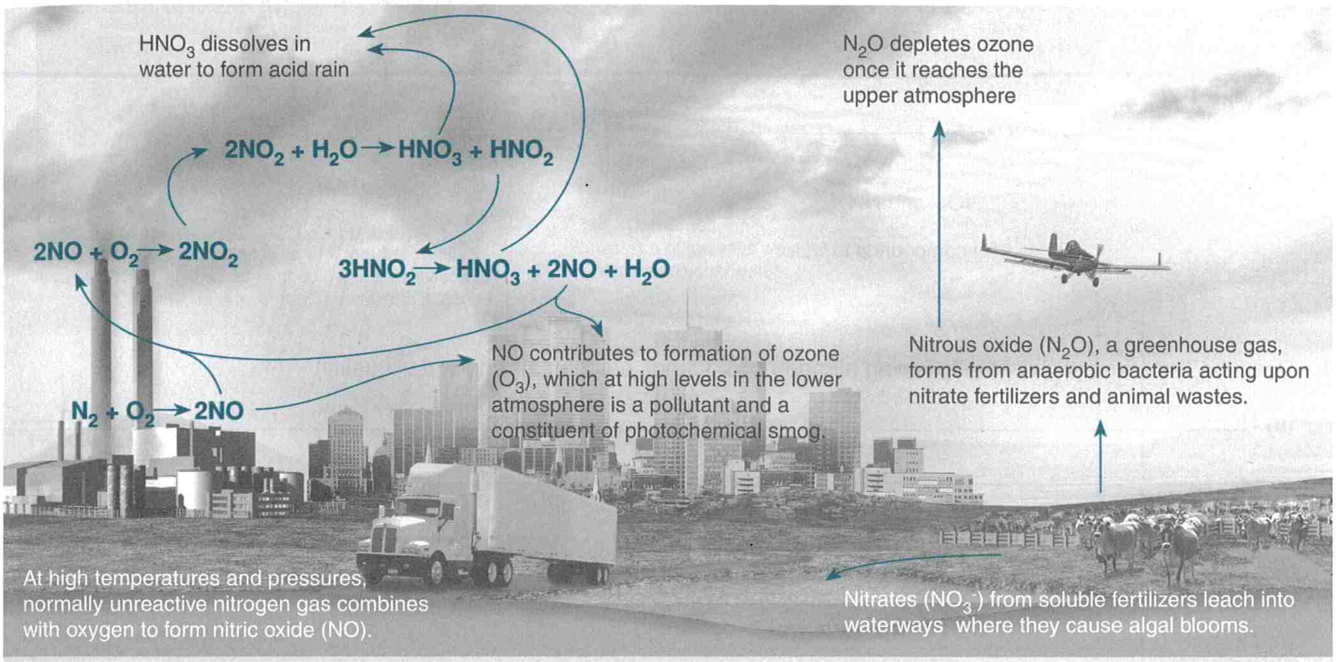
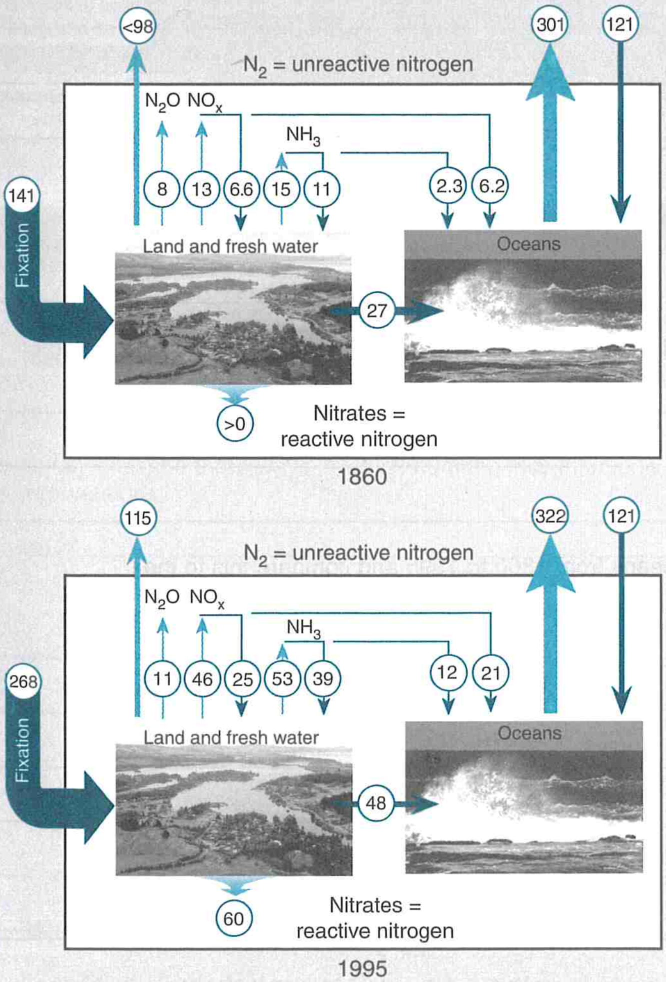
Nitrogen Pollution

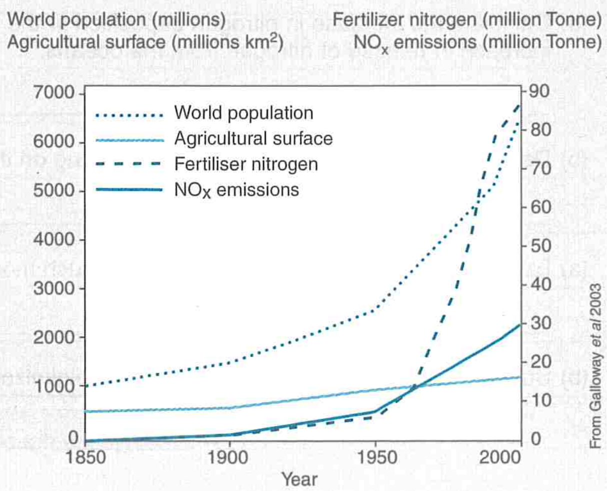
The effect of excess nitrogen compounds on the environment is varied. Depending on the compound formed, nitrogen can cause smog in cities or algal blooms in lakes and seas. Nitrogen gas makes up almost 80% of the atmosphere but is unreactive at normal pressure and temperature. At the high pressures and temperatures reached in factories and combustion engines nitrogen gas forms nitric oxide along with other nitrogen oxides, most of which contribute to atmospheric pollution. Nitrates in fertilizers are washed into ground water by rain and slowly make their way to lakes and rivers and eventually out to sea. This process can take time to become noticeable as ground water can take many decades to reach a waterway. In many places where nitrate effects are only just becoming apparent, the immediate cessation of their use could take a long time to have any effect as it might take many years before the last of the ground water carrying the nitrates reaches a waterway.





Changes in nitrogen inputs and outputs between 1860 and 1995 in million Tonne (modified from Galloway *et al* 2004)

Early last century, the Haber-Bosch process made nitrate fertilizers readily available for the first time. Since then, the use of nitrogen fertilizers has increased at an almost exponential rate. Importantly, this has led to an increase in the levels of nitrogen in land and water by up to 60 times those of 100 years ago. This extra nitrogen load is one of the causes of accelerated enrichment (**eutrophication**) of lakes and coastal waters. An increase in algal production also results in higher decomposer activity and, consequently, oxygen depletion, fish deaths, and depletion of aquatic biodiversity. Many aquatic microorganisms also produce toxins, which may accumulate in the water, fish, and shellfish. The diagrams (left) show the increase in nitrates in water sources from 1860 to 1995. The rate at which nitrates are added has increased faster than the rate at which nitrates are returned to the atmosphere as unreactive N_2 gas. This has led to the widespread accumulation of nitrogen.



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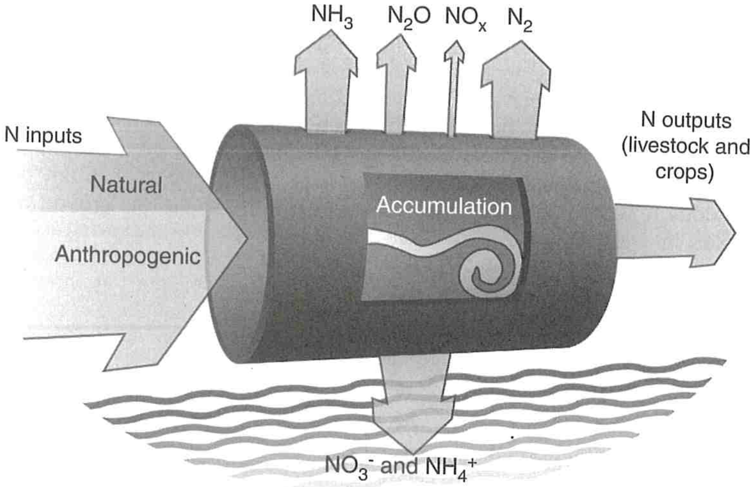
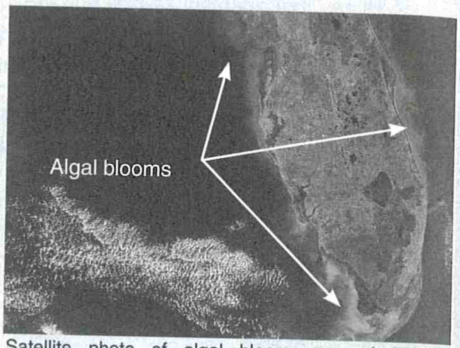


From O. Oenema *et al* 2007

The "hole in the pipe" model (left) demonstrates inefficiencies in nitrogen fertilizer use. Nitrogen that is added to the soil and not immediately taken up by plants is washed into waterways or released into the air by bacterial action. These losses can be minimized to an extent by using slow release fertilizers during periods of wet weather and by careful irrigation practices.



Satellite photo of algal blooms around Florida. Excessive nitrogen contributes to algal blooms in both coastal and inlands waters. *Image: NASA*

1. Describe the effect each of the following nitrogen compounds have on air and water quality:

(a) NO: ______

(b) N_2O: ______

(c) NO_2: ______

(d) NO_3^-: ______

2. Explain why the formation of NO can cause large scale and long term environmental problems: ______

3. Explain why an immediate halt in the use of nitrogen fertilizers will not cause an immediate stop in their effects: ______

4. (a) Calculate the increase in nitrogen deposition in the oceans from 1860 to 1995 and compare this to the increase in release of nitrogen from the oceans: ______

(b) Describe the effect these increases are having on the oceans: ______

5. (a) Explain why nitrogen inputs tend to be so much more than outputs in livestock and crops: ______

(b) Suggest how the nitrogen losses could be minimized: ______

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