APES Year In Review

Item	Description
1st Law of Thermodynamics	Law of Conservation of Energy: energy is neither created nor destroyed, it simply changes form (chemical, mechnical, electrical, sound, heat, light)
2nd Law of Thermodynamics	All spontaneous reactions result in an increase in entropy. With any chemical reaction there is an exhange of energy. Some of that exchange is in the form of waste heat.
Acid Rain & Deposition	$NO + H_2O \rightarrow HNO_3$ $SO_2 + H_2O \rightarrow H_2SO_4$ SO_4^{2-} and NO_3^- salts
Air Pollutants	Primary: Carbon Monoxide, Carbon Dioxide, Sulfur Dioxide, Nitrogen Monoxide and Nitrogen Dioxide, Most hydrocarbons, most suspended particles (dust) Secondary: Sulfur Trioxide, Nitric Acid, PANs, Nitrate salts, Sulfate salts, Ozone (O3), Hydrogen Peroxide, etc.
Atmosphere	Troposphere: 78% N_2, 20.9% O_2, <1.1% Other Ozone is bad here, most weather occurs here Stratosphere: Ozone is good here
Carbon Cycle	Photosynthesis: $6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$ Respiration: $C_6H_{12}O_6 + 6O_2 \rightarrow 6H_2O + 6CO_2$ Greatest Sink: Lithosphere in the form of fossil fuels Combustion: $C_xH_yO_z + O_2 \rightarrow CO_2 + H_2O$ Second Greatest Sink: Ocean *As ocean temperatures rise, gas solubility decreases
Diversity Index	H = -sum (Pi ln(Pi)) Where: Pi = relative abundance = ni / N ni = number of individuals in a species N = total number of individuals in all species Species Richness Measure R = s (the number of species) Species Eveness Measure E = H / ln(R)
Energy Efficiency	Efficiency = output / input x 100
Exponential Growth	$N_e = N_o e^{rt}$
Fusion vs. Fission	Fusion: two nuclei combine to form a large atomic nucleus thereby releasing energy. Fission: a nuclear reaction where one nucleus divides into smaller nuclei releasing energy.
Greenhouse Gases	Water Vapor (H_2O), Carbon dioxide (CO_2), Methane (CH_4), Nitrous oxide (N_2O), and Industrial Gases (CFC's such as Hydrofluorocarbons (HFCs), Perfluorocarbons (PFCs) and Sulfur hexafluoride (SF_6))
Gross Primary Productivity	GPP = NPP – cellular respiration Net Primary Productivity = total amount of energy available from photosynthesis
Half-life	The opposite of doubling time Fraction remaining = $1/2^{(t/T)}$ Number of half-life periods = t / T **T = Half Life and t = total time elapsed**

APES Year In Review

HIPPO	The greatest threats to biodiversity are: **H**abitat destruction **I**nvasive species **P**opulation growth **P**ollution, and **O**verfishing (overharvesting)
Hydrologic Cycle (Water Cycle)	Transpiration: water vapor released from plants Condensation, Evaporation, Deposition (snow), Precipitation, Runoff
Industrial Smog	$N_2 + O_2 + Heat \rightarrow NO + O_2 \rightarrow NO_2$ $NO_2 + UV \rightarrow O + O_2 \rightarrow O_3 +$ VOCs $\rightarrow$various organic pollutants $NO_2 + H_2O \rightarrow NO + HNO_3$ NO_2 + Hydrocarbons $\rightarrow$Peroxyacyl nitrates (PANs)
IPAT Model	Env.Impact = Population x Affluence x Technology
Nitrogen Cycle	Nitrogen Fixation: Ammonification: $N_2 + 3 H_2 \rightarrow 2NH_3$ (bacteria, Haber process) Nitrification: $NH_3 \rightarrow NH_4^+ \rightarrow NO_2^- \rightarrow NO_3^-$ Assimilation: uptake of NH_4^+ and NO_3^- by plant roots Denitrification: $NO_3^- \rightarrow NO_2^- \rightarrow N_2$ (bacteria)
Ozone Depletion	$CFCl_3 \rightarrow CFCl_2 + Cl$ $CF_2Cl_3 \rightarrow CF_2Cl + Cl.$ The chlorine atoms catalyze the decomposition of ozone, $Cl + O_3 \rightarrow ClO + O_2$ and ClO molecules further react with O generated due to photochemical decomposition of ozone: $O_3 + h\nu \rightarrow O + O_2$ $ClO + O \rightarrow Cl + O_2$ $O + O_3 \rightarrow O_2 + O_2$ Net Reaction: $2O_3 \rightarrow 3O_2$
Ozone Formation	$O_2 + h\nu \rightarrow O + O$ $O_2 + O \rightarrow O_3$ Net Reaction: $3O_2 \rightarrow 2O_3$
Phophorus Cycle	Elemental Phosphorus $\rightarrow PO_4^{3-}$ Limiting nutrient, tied to the rock cycle because there is no gaseous phase ATP $\rightarrow$ADP; component of DNA and amino acids
Photochemical Smog	Coal $\rightarrow C + O_2 \rightarrow CO + CO_2$ Coal $\rightarrow S + O_2 \rightarrow SO_2 \rightarrow SO_3 + H_2O \rightarrow H_2SO_4 + NH_3 \rightarrow (NH_4)_2SO_4$
Population Growth	Growth Rate = Crude Birth Rate – Crude Death Rate
Rule of 70	To calculate doubling time of a population, 70 / % growth = years to double
Sulfur Cycle	$SO_2 + H_2O \rightarrow H_2SO_4$ (acid rain and depostition) SO_4^{2-} assimilated into plants; DNA, RNA, amino acids, etc.

PEOPLE IN ENVIRONMENTAL SCIENCE HISTORY

The AP Environmental Science exam may include a few questions about specific people and their contribution to the field of environmental science or conservation. It is important to not only know who the person is, but to be able to identify his or her major contributions to the field of environmental science. This can include anything from literary works such as book and journal articles to scientific discoveries that have earned the Nobel Prize. The following are key people to know in alphabetical order by last name.

1. Rachel Carson: published *Silent Spring* in 1962; documented the environmental damage done by DDT and other pesticides. This book heightened public awareness at the start of the modern environmental movement.

2. Paul Ehrlich: a biologist who published *The Population Bomb* in 1968; discussed overpopulation and food production issues for future generations.

3. Garret Hardin: published "The Tragedy of the Commons" in the journal *Science* in 1968; argued that rational people will exploit shared resources (commons).

4. Aldo Leopold: wrote *A Sand County Almanac,* published a year after his death in 1948; promoted a 'Land Ethic' in which humans are ethically responsible for serving as the protector of nature.

5. Wangari Maathai: won the 2004 Nobel Peace Prize for "Green Belt" movement – planting trees in Kenya that provided food and fuel and improved conditions against soil erosion and desertification.

6. Thomas Malthus: a British economist who said, "human population cannot continue to increase. Consequences will be war, famine & pestilence (disease)."

7. John Muir: founded Sierra Club in 1892; fought unsuccessfully to prevent the damming of the Hetch Hetchy Valley in Yosemite National Park.

8. Gifford Pinchot: first chief of the United States Forest Service; advocated managing resources for multiple use using principles of sustainable yield.

9. Theodore Roosevelt: president of the United States from 1901 to 1909, well-known for his conservation efforts. He established the first National Wildlife Refuge at Pelican Island.

10. Sherwood Rowland and Mario Molina: in 1974, determined that CFCs destroy stratospheric (good) ozone.

11. E.O. Wilson: biologist who co-coined, with Robert MacArthur the theory of island biogeography, which identifies factors that regulate species richness on islands.

SUMMARY OF WELL-KNOWN CASE STUDIES IN ENVIRONMENTAL SCIENCE

There are several case studies in environmental science that have had a significant impact on public perception about the environment, and have influenced policy decisions and/or legislation. While it is important to also be familiar with your local or regional case studies, because the APES exam will be taken by students from all over the world, it will only include case studies that have had national or international significance. The following are brief synopses of several case studies to jog your memory; you may consult your textbook for more details.

Aral Sea, Uzbekistan/Kazakhstan (former Soviet Union) and Mono Lake, California: a large inland sea that is drying up; its salinity is rising as a result of water diversion for irrigating crops.

Ogallala Aquifer: the world's largest aquifer; under parts of Wyoming, South Dakota, Nebraska, Kansas, Colorado, Oklahoma, New Mexico, and Texas. It holds enough water to cover the United States with 1.5 feet of water. It is being depleted for agricultural and urban use.

Minamata, Japan: mental impairments, birth defects, and deaths caused by mercury dumped in Minamata Bay by a factory. The mercury was converted to methylmercury, bioaccumulated in fish, and biomagnified through food chains. Mercury entered humans who ate a traditional fish-based diet.

Aswan High Dam, Egypt: the silt that made the Nile region fertile fills the reservoir. Lack of irrigation controls causes waterlogging and salinization. The parasitic disease schistosomiasis thrives in the stagnant water of the reservoir.

Chesapeake Bay, Maryland/Virginia: the largest estuary in the United States; lies off the Atlantic Ocean between Maryland and Virginia, was declared a dead zone in the 1970s due to hypoxic conditions created from nutrient loading by fertilizers, which caused cultural eutrophication.

Love Canal Housing Development, Niagara Falls, New York: hazardous chemicals buried in an old canal leaked into homes and school yards. Led to the passage of the Comprehensive Environment Response, Compensation, and Liability Act (CERCLA), also known as the Superfund Act.

Three-Mile Island, Pennsylvania: on March 29, 1979, the emergency cooling system of a nuclear reactor was shut down erroneously by an operator. This led to a partial core meltdown. The containment structure worked well to retain all radioactive materials, but eventually some radioactive gas was purposely released to reduce pressure in the containment structure and avoid a more serious accident.

Bhopal, India: on December 2, 1984, poisonous methyl isocyanate gas was released accidentally by a Union Carbide pesticide plant killing about 5,000 people and causing serious health effects for 50,000-60,000.

Chernobyl, Ukraine: on April 26, 1986, an unauthorized safety test led to a fire and explosion at a nuclear power plant – as a result, millions of people in Europe are exposed to unsafe levels of radiation.

Valdez, Alaska: on March 24, 1989, the oil tanker Exxon Valdez hit a reef in Prince William Sound spilling 260,000 barrels of oil. It was the largest oil spill even in the U.S. waters.

Yucca Mountain, Nevada: the proposed site for permanent storage of high-level nuclear waste, 70 miles northwest of Las Vegas. Critics are concerned about the safety of transporting high-level radioactive waste to the site and the proximity of the site to a volcano and earthquake faults.

Three Gorges Dam, China: the world's largest dam on Yangtze River submerged ecosystems, cities, archeological sites, displaced two million people, and fragmented the river habitat.

Clinch River, Tennessee: the Tennessee Valley Authority's power plant near Knoxville had a wall breached in a retention pond holding sludge from the coal burning power plant. This released up to 1 billion gallons of mercury- and arsenic-containing sludge into the nearby Clinch River watershed.

SUMMARY OF ENVIRONMENTAL LAWS AND INTERNATIONAL TREATIES

The AP Environmental Science Exam may include multiple-choice questions regarding environmental laws or international treaties and conventions. You may also be asked to provide an appropriate environmental law on a free-response question. On the free-response questions, be sure to include a law that is applicable to the environmental issue at hand. Don't just select any environmental legislation assuming that it is appropriate for the question you are answering. It is important to remember some international environmental treaties and conventions have been ratified by the many countries but **not** by the United States. The AP exam will expect you to know in which treaties and conventions the United States is an active participant. Below are the main environmental laws or international treaties and conventions arranged in the categories similar to the units you have studied in your book.

INTRODUCTION TO ENVIRONMENTAL SCIENCE

National Environmental Policy Act (NEPA): requires federal agencies to integrate environmental values into their decision-making processes by considering the environmental impacts of their proposed actions; requires agencies to prepare an Environmental Impact Statement detailing impact to the surrounding environment.

CONSERVATION OF BIODIVERSITY

Endangered Species Act (ESA): identifies threatened and endangered species in the United States, and puts their protection ahead of economic considerations.

Convention on International Trade in Endangered Species (CITES): international treaty that lists species that cannot be hunted or commercially traded as live specimens or wildlife products.

Marine Mammal Protection Act: protects all marine mammals by prohibiting, with certain exceptions, the taking of marine mammals in U.S. waters and by U.S. citizens on the high seas, and the importation of marine mammals and marine mammal products in the United States.

Lacy Act: prohibits interstate transport of wild animals – dead or alive – without federal permit.

AGRICULTURE AND PESTICIDE USE

Federal Insecticide, Fungicide, Rodenticide Act (FIFRA): regulates the effectiveness of pesticides.

Food Quality Protection Act: sets pesticide limits in food, and all active and inactive ingredients must be screened for estrogenic/endocrine effects.

Persistent Organic Pollutants (POPs) Treaty (international treaty not ratified by the United States as of 2015): this treaty originated at the Stockholm convention. It is an international agreement to phase out 12 organic persistent pollutants, also known as the "dirty dozen," such as DDT and PCBs.

ENERGY AND MINING PRACTICES

Surface Mining Control and Reclamation Act: regulates coal mining activities in the United States and requires reclaiming of land after use.

Federal Mine Safety and Health Act: sets forth federal health and safety regulations for all coal and non-coal mining operations in the United States.

Energy Policy Act: this U.S. law provides incentives, typically in the form of government subsidies, for various energy resources including fossil fuels, and nuclear and alternative energy sources.

WATER RESOURCES AND POLLUTION

Safe Drinking Water Act: sets maximum contaminant level for pollutants that may have adverse effects on human health.

Clean Water Act: sets maximum permissible amounts of water pollutants that can be discharged into waterways. Main goals are to reduce surface water pollution into lakes, rivers, and streams.

Water Quality Act: amended the Clean Water Act by addressing storm water pollution issues – requires industrial storm water discharges and municipal sewage discharge facilities to acquire permits.

Ocean Dumping Ban Act: bans dumping of sewage sludge and industrial waste in the ocean.

AIR POLLUTION

Clean Air Act: sets emission standards for cars, addresses requirements for reducing ozone depletion and acid deposition.

Kyoto Protocol: international agreement (not ratified by the United States) intended to control global warming by setting greenhouse gas emissions targets for developed countries.

Montreal Protocol: international agreement that phases out ozone-depleting substances such as chlorofluorocarbons (CFCs) and hydrochlorofluorocarbons (HCFCs).

WASTE DISPOSAL

Resource Conservation and Recovery Act (RCRA): controls hazardous waste with cradle-to-grave system requirements.

Comprehensive Environmental Response, Compensation and Liability Act (CERCLA): identifies **Superfund** sites – designed to identify and clean up abandoned hazardous waste dump sites.

Nuclear Waste Policy Act: encourages development of a U.S. high-level nuclear waste repository site by 2015 (original proposed site was Yucca Mountain, Nevada).

Low-Level Radioactive Policy Act: requires all states to have facilities to handle low-level radioactive wastes.

Basel Convention: international treaty (not ratified by the United States) drafted as a result of hazardous waste from developed nations being shipped overseas to developing countries. It requires that developing countries must give full permission to accept hazardous waste.

Biogeochemical Cycles: Cycling of Matter in the Ecosystem

Six major elements, carbon, hydrogen, oxygen, nitrogen, phosphorus, and sulfur (C.H.O.N.P.S.), make up the majority of biomass in living organisms. It is important to remember that these elements will continuously cycle through living systems in different forms as biomass is consumed and assimilated, decomposed, or combusted (fossil fuels). For example, the carbon stored in the biomass of a tree can either consumed and stored as organic compounds in herbivores, recycled by bacteria or released as carbon dioxide, carbon monoxide, and hydrocarbons as we burn it for energy (fuel wood).

These vital elements, mostly in molecule or compound form, are persistently cycled through our air, water, soil, and biomass of living organisms by both biological and physical forces. The continuous renewal cycles of these various nutrients for living organisms are known as **biogeochemical cycles**. The major cycles include the carbon cycle, hydrologic cycle, nitrogen cycle, phosphorus cycle, and sulfur cycle. As these nutrients move through the ecosystem they may accumulate in specific locations for longer periods of time. The locations where nutrients collect are known as **reservoirs** for that particular nutrient and commonly include the atmosphere, water, or soil and rock. Unfortunately, human activities have also altered these natural cycles and these alterations will therefore impact population growth of organisms in communities.

Hydrologic Cycle

Water is a critical component to all living things. The water cycle helps to distribute and purify earth's vital quantity of this necessary compound. The dominant reservoirs of water exist as surface water (oceans, lakes, and rivers), groundwater, atmospheric gas, and polar ice caps and glaciers. The movement of water across the earth's surface has helped to shape and form the topography of the land we see today through erosion. The hydrologic cycle is powered by the energy of the sun, which triggers major processes of **evaporation**, **precipitation**, and **transpiration**. Evaporation changes liquid water into water vapor in the atmosphere. Most of the water vapor in the air from evaporation comes directly from the oceans. The majority of the water that evaporates from terrestrial areas comes from transpiration. Transpiration is a process by which water that is absorbed by plants, usually through the roots, evaporates into the atmosphere from the planet surface. Precipitation of water primarily becomes surface runoff that flows into lakes, rivers, and streams and eventually makes its way back to the oceans. Some surface runoff infiltrates past soil layers into areas of porous rock, sand, or gravel, known as **aquifers**, where it becomes part of the **groundwater system**.

Human Impacts on the Hydrologic Cycle

Withdrawal: We remove large amounts of water for special and industrial uses; often times faster than natural recharge can replace the water resource.

Increased chance of flooding: By removing large areas of wetlands or creating ne non-porous tracts of lands (parking lots, roads, buildings) we decrease the earth's natural absorptive abilities and increase erosion and the chance for flooding.

Deforestation: Clearing large amounts of vegetation for urban growth, agriculture, mining, etc., decreases transpiration rates, which can decrease precipitation in some areas as well as reduce infiltration of water into soils. This also increases the chance of flooding as well.

Carbon Cycle

Carbon is the backbone of the living world as it forms the organic monomers (chemical building blocks) that make up our larger organic macromolecules (polymers). This includes cellular components such as DNA, carbohydrates, proteins, lipids, and other important compounds that sustain life. In the biosphere, carbon is primarily exchanged as a carbon dioxide gas in a cycle between **producers** and **consumers**. Primary producers intake carbon dioxide during photosynthesis in order to produce complex carbohydrates such as glucose, cellulose, and starch. Aerobic respiration by consumers and decomposers then break down these carbohydrate and release carbon dioxide back into the atmosphere or aquatic system. Much of our carbon is stored in marine sediments. Carbon is also stored in **fossil fuels** that formed from the decomposition of organisms' remains that were exposed to intense heat and pressure over millions of years. Carbon stored in fossil fuels is not released and cycled as carbon dioxide in the atmosphere until it is extracted and burned for energy purposes. The major reservoirs of carbon dioxide include:

- **Oceans**: Oceanic sediments are the largest reservoir of earth's carbon. Like oxygen, carbon dioxide is also dissolved in aquatic ecosystems to support life's processes. Much dissolved carbon dioxide is converted to bicarbonate and carbonate ions. These ions typically combine with calcium to form calcium carbonate, which makes shells of marine organisms and sediments that over time form limestone rock.
- **Biosphere**: This reservoir includes carbon stored in freshwater systems, soil, and the biomass of living organisms.
- **Atmosphere**: Carbon dioxide gas makes up only a small portion of the troposphere (0.038%). However, this greenhouse gas acts as a natural thermostat for earth's surface temperature. Terrestrial producers and consumers will regulate the concentration of atmospheric carbon dioxide through photosynthesis and respiration.

Human Impacts on the Carbon Cycle

The major impact we have on the carbon cycle is increasing the carbon dioxide concentration in the atmosphere. This increase in this greenhouse gas is associated with global climate change. We mainly increase concentration of CO2 in two ways:

- Burning of Fossil Fuels: The burning of coal, oil, and natural gas for electrical, heating, and transportation purposes release large amounts of carbon in the form of CO2, that would otherwise be sequestered in the rock layers of earth.
- Clear-cutting: Removing large tracts of forest, especially in tropical regions, faster than they can grow back decreases the amount of carbon dioxide that is naturally stored in plants through photosynthesis.

Nitrogen Cycle

The nitrogen cycle is one of the most important nutrient cycles in ecosystems, as it is often a limiting factor for primary productivity. The largest reservoir for nitrogen is found in our atmosphere where nitrogen gas (N2) makes up 78% of the troposphere. Although nitrogen seems plentiful for primary producers, only two forms f nitrogen seems plentiful for primary producers, only two forms of nitrogen serve as nutrients, ammonium (NH4+) and nitrates (NO3-). Primary producers and consumers need these nitrogen compounds to build organic macromolecules such as proteins and nucleic acid, like DNA. The twp natural processes that can convert nitrogen gas into organic compounds producers can use are 1) lightning in the atmosphere and 2) nitrogen-fixing bacteria in the soil, water, and in the roots of some plants. The process by which primary producers take in inorganic nitrogen compounds and consumers take in organic nitrogen compounds and transform them into a part of their own body systems is known as **assimilation**.

Steps of the Nitrogen Cycle

Nitrogen Fixation: conversion, by bacteria in the soil and cyanobacteria in aquatic systems, of nitrogen gas (N2) in the atmosphere into ammonia and ammonium.

Ammonification: decomposers covert organic remains of organisms into detritus and eventually into inorganic ammonia and ammonium ions.

Nitrification: bacteria convert ammonia or ammonium ions in the soil into nitrate ions (NO3-) for plants to uptake.

Denitrification: bacteria primarily in the sediments of aquatic zones such as lakes, oceans, swamps, estuaries, and bogs, convert ammonia and ammonium ions into nitrogen gas (N2) and nitrous oxide (N2O), a greenhouse gas.

Human Impacts on the Nitrogen Cycle

Excess Nitrates: nitrates from animal feedlot waste and municipal sewage discharge *runs off into nearby waterways. These extra nutrients create anoxic, low dissolved oxygen, conditions in waterways which deplete the aquatic diversity (known as eutrophication).

Burning of Fossil Fuels: Burning of these fuels releases nitric oxide (NO) into the atmosphere where it is converted to nitrogen dioxide (NO2), a raw material for photochemical smog, and nitric acid (HNO3, a contributor to acid rain.

Using inorganic fertilizers: by adding large amounts of nitrogen-based inorganic fertilizers to agricultural systems, we increase denitrification by anaerobic bacteria. Through this process the bacteria release the greenhouse gas nitrous oxide (N_2O) into the atmosphere which further exacerbates climate change.

Phosphorus Cycle

Unlike other nutrient cycles we have discussed, the phosphorus cycle does not move through the atmosphere. This is because phosphorus does not exist in a gaseous phase on earth. Therefore, the largest reservoir of phosphorus is in oceanic sediments and terrestrial rock layers. Since this cycle depends on the erosion of sediments and rocks to release valuable phosphates (PO_4^{3-}) for producers, phosphate is considered a limiting factor for primary productivity. Phosphate is an important component of DNA, ATP (cellular energy), and the bones and teeth of vertebrates.

Human Impacts on the Phosphorus Cycle

Phosphate run-off: excess phosphate runs off into nearby waterways from sewage, mining waste, and fertilizers. Like nitrates, these excess phosphates can promote algal growth in aquatic systems, which eventually leads to low levels of oxygen and therefore depletes aquatic diversity (eutrophication).

Sulfur Cycle

The largest reservoir for sulfur exists in oceanic sediments, rock and mineral layers of the earth. Sulfur is emitted into the atmosphere in several ways- volcanic activity releases sulfur dioxide (SO_2), anaerobic bacteria release hydrogen sulfide (H_2S), and oceanic sea spray and forest fires emit particles of ammonium sulfate. Also, certain marine algae release volatile dimethyl sulfide that act as condensation nuclei in the atmosphere and can affect cloud cover, thereby impacting climate.

Human Impacts on the Sulfur Cycle

Release of Sulfur Dioxide: SO_2 is added to the atmosphere in several ways. Sulfur is an impurity in coal and petroleum. Therefore, the burning of coal and oil as well as the refinement of petroleum into gasoline are all processes that release the gas into the atmosphere. Once in the atmosphere, sulfur dioxide can form sulfuric acid (H_2SO_4). Sulfur dioxide can be removed before, during, or after the combustion process. This is not true of carbon dioxide gas created during combustion since it is formed from the carbon fuel itself.

SUMMARY OF BIOGEOCHEMICAL CYCLES (PJ Shlachtman)

CARBON CYCLE

- Is an atmospheric cycle.
- Carbon is required for formation of organic compounds in living things.
- C in carbon dioxide in atmosphere and in water is moved to C in glucose by photosynthesis by producers.
- C in glucose is moved to C in carbon dioxide by cellular respiration.
- C in glucose is moved to C in organic molecules by synthesis reactions in living things.
- C in organic molecules is moved to C in carbon dioxide by combustion.
- C in organic molecules in organisms is moved to C in fossil fuels over millions of years by pressure, heat, and bacterial action.
- C in limestone ($CaCO_3$) is released slowly to C in carbon dioxide when exposed to oxygen and/or water.
- Largest reservoir of carbon - sedimentary rocks (limestone)
  Second largest reservoir of carbon - ocean (dissolved carbon dioxide), living things in ocean.
- In water:

  $CO_2 + H_2O \rightarrow HCO_3^-$ (bicarbonate ions) + CO_3^{2-} (carbonate ions)

  $Ca^{2+} + CO_3^{2-} \rightarrow CaCO_3$ (calcium carbonate) in shells/skeletons of aquatic organisms

  $CaCO_3 \rightarrow$ buried, long period of time, pressure $\rightarrow$ limestone
- Human Impact:
  - Removal of vegetation reduces absorption of carbon dioxide for photosynthesis from atmosphere. Increases atmospheric CO_2.
  - Burning of fossil fuels increases atmospheric CO_2.
  - Increase in atmospheric CO_2 leads to increased Greenhouse Effect $\rightarrow$ Global Warming.

NITROGEN CYCLE

- Is an atmospheric cycle.
- Plants and animals cannot use free nitrogen gas in the atmosphere. They must have nitrogen in "fixed" form. Nitrogen is required for proteins, nucleic acids in living things.
- Free N_2 in atmosphere is "fixed" by nitrogen-fixing bacteria to NH_3 (ammonia):

  $N_2 + 3H_2 \rightarrow 2NH_3$
- Nitrogen fixing bacteria live in nodules on the roots of leguminous plants (soybeans, peas, clover, and alfalfa.)
- Water in the soil reacts with ammonia to form NH_4^+ (ammonium ion)
- Another species of bacteria can perform nitrification once ammonium has formed:

  $NH_4^+ \rightarrow NO_2^-$ (nitrite; toxic) $\rightarrow NO_3^-$ (nitrate; plant nutrient)
- Assimilation - absorption of ammonia, ammonium ion, nitrate for use by plants to make nucleic acids, proteins
- Animals get fixed nitrogen by eating plants or other animals.
- Plants and animals are broken down by still other bacteria that convert nitrogen-containing organic molecules in organisms to an inorganic form of nitrogen (ammonia or ammonium ion) = ammonification
- Once this ammonia has formed, still another group of bacteria can perform denitrification:

  NH_3 or $NH_4^+ \rightarrow NO_2^-$ and/or $NO_3^- \rightarrow N_2$ and N_2O (nitrous oxide)

- Nitrogen is often limiting factor in plant growth because ammonia, ammonium ion, nitrate are water-soluble: can be leached from soil.
- Human Intervention:
  - In the atmosphere:
    $N_2 + O_2 \rightarrow 2NO$ (nitric oxide) produced when burning fuel or forests.
    (Heat combines N_2 and O_2 present in atmosphere)
    $NO + O_2 \rightarrow NO_2$ (nitrogen dioxide gas)
    $NO_2 + H_2O \rightarrow HNO_3$ (nitric acid - dissolved in water causes acid deposition)
  - N_2O (nitrous oxide) released from decomposition of fertilize and waste.
  - Excess nitrogen added to aquatic systems by runoff of artificial fertilizer, farm waste, discharge of sewage. This stimulates growth of algae. Breakdown of algae by aerobic decomposers depletes water of oxygen.

PHOSPHORUS CYCLE

- Phosphorus is required in the form of phosphate ions for nucleic acids, ATP, phospholipids in cell membranes, bones, teeth, shells of animals.
- PO_4^{3-} = Phosphate
- Is a sedimentary cycle - does not include the atmosphere.
- Phosphate on land and in ocean sediment released by weathering into water and taken up by plants. Can be limiting factor for plant growth - is present in artificial fertilizer.
- Animals get phosphorus by eating plants or other animals.
- Decomposition changes organic molecules with phosphorus back into phosphate which dissolves in water which returns the phosphorus to ocean sediment or deposited as rocks.
- Human intervention:
  - Mining of phosphate for fertilizers and soap causes disruption to ecosystems.
  - Removal of phosphorus from ecosystems by cutting down of vegetation. Most of phosphorus is taken up as biomass.
  - Excessive phosphate in runoff from fertilizer, discharge of sewage, farm waste causes growth of algae, etc. (same problem as nitrogen).

SULFUR CYCLE

- Is an atmospheric cycle.
- H_2S (hydrogen sulfide) and SO_2 (sulfur dioxide) released into atmosphere from natural (volcanoes) and non-natural sources.
  $H_2S + O_2 \rightarrow SO_2$
  $SO_2 + O_2 \rightarrow SO_3$ (sulfur trioxide) or
  $SO_2 + H_2O \rightarrow H_2SO_4$ (sulfuric acid) ----> acid deposition, sulfur returned to water and soil, taken up by plants, animals.
- Human intervention:
  - Sulfur-containing coal, when burned, releases SO_2 .
  - Other industrial processes.

WATER CYCLE

Important terms:

absolute humidity	dew point	relative humidity
aquifer	evaporation	runoff
condensation	infiltration	transpiration
condensation	percolation	water table
nuclei	precipitation	

Biome Clues

Taiga
Cold and wet (most of the precipitation falls in the summer)
Coniferous forests thrive
Winters are long
Elk, moose, deer, wolves, bears, lynx and wolverines thrive here

Tundra
A treeless marshy plain with grasses
Covers 1/5 of the earth's land surface
Very low annual precipitation and most of the water present is unavailable
Caribou, foxes, lemmings and owls thrive here

Desert
Sparse vegetation often with thorns
Drought is a limiting factor
Can be warm or cold
As a biome is most represented in the interiors of the continents

Rainforest
Plenty of rain and heat
No winter
Great diversity of animals
Not very fertile soil

Savanna
Grass is the predominant vegetation
Wide temperature variation throughout year
Seasonal drought
Open landscape with widely spaced trees

Temperate Grasslands
Rich growth of prairies
Often highly productive land when converted to agriculture
Bison are most at home here
Moderate climates half-way between the equator and the poles

Temperate Deciduous Forests
Mild climate with plenty of rain
Marked by deciduous trees that shed their leaves in the fall
Warm summers with cool winters
Deer, bears, beavers, and raccoons thrive here

154 Things to Know

BIODIVERSITY

1) Conservation: allowing the use of resources in a responsible manner

2) Preservation: setting aside areas and protecting them from human activities

3) Keystone species: species whose role in an ecosystem are more important than others (sea otters, sea stars, grizzly bears, prairie dogs)

4) Indicator species: species that serve as early warnings that an ecosystem is being damaged ex. trout

5) Characteristics of endangered species: small range, large territory, or live on an island

6) Endangered species: a group of organisms in danger of becoming extinct if the situation is not improved; population numbers have dropped below the critical number of organisms; North spotted Owl (loss of old growth forest), Bald Eagle (thinning of eggs caused by DDT), Piping Plover (nesting areas threatened by development), and many others

7) Invasive/Alien/Exotic species: non-native species to an area; often thrive and disrupt the ecosystem balance; examples: kudzu vine, purple loosestrife, African honeybee "killer bee", water hyacinth, fire ant, zebra mussel, gypsy moth, Asian Long Horned Beetle

CYCLES/PROCESSES

8) Parts of the hydrologic cycle: evaporation, transpiration, runoff, condensation, precipitation, infiltration

9) Nitrogen fixing: because atmospheric N_2 cannot be used directly by plants it must first be converted into ammonia (NH_3) by bacteria (*rhizobium* or cyanobacteria)

10) Ammonification: nitrogen is converted into ammonia by ammonifying bacteria; may occur when nitrogen in organic wastes in the soil are converted to ammonia or when atmospheric nitrogen (N_2) is converted to NH_3

11) Nitrification: ammonia (NH_3) is converted to nitrate ions $(NO_3)^-$

12) Assimilation: inorganic N_2 is converted into organic molecules such as DNA/amino acids & proteins - plants assimilate nitrogen as NH_4^+ or NO_3^- through their roots; animals (herbivores) assimilate organic nitrogen compounds by eating plants

13) Denitrification: bacteria convert nitrate $(NO_3)^-$ and nitrite $(NO_2)^-$ back into N_2 gas; bacteria convert ammonia (NH_3) back into N_2 or N_2O – typically accomplished by anaerobic bacteria

14) Phosphorus does not circulate as easily as nitrogen because: it does not exist as a gas, but is released by weathering of phosphate $(PO_4)^{3-}$ rocks; this is a SEDIMENTARY cycle – it is never found as a gas

15) How excess phosphorus is added to aquatic ecosystems: runoff of animal wastes, fertilizer, discharge of sewage; limiting factor in freshwater ecosystems; excess P leads to eutrophication

16) Photosynthesis: plants convert atmospheric carbon (CO_2) into complex carbohydrates (glucose $C_6H_{12}O_6$); energy is consumed and oxygen is released as a waste product

17) Aerobic respiration: O_2-consuming producers, consumers & decomposers break down complex organic compounds & convert C back into CO_2; energy is released and oxygen is consumed in the process

18) Anaerobic Respiration: break down of carbohydrates without oxygen – products are methane (CH_4), alcohols and other organics

19) Transpiration – process where water is absorbed by plant roots, moves up through plants, passes through pores (stomata) in leaves or other parts, evaporates into atm. as water vapor

20) Largest reservoirs of C: carbonate $(CO_3)^{2-}$ rocks first, oceans second

ECOLOGY

21) Sustainability: the ability to meet the current needs of humanity without compromising the ability of future generations to meet their needs

22) The Tragedy of the Commons: (1968 paper by ecologist Garret Hardin) "Freedom to breed" is bringing ruin to all. Global commons such as atmosphere & oceans are used by all and owned by none. When no individual has ownership, no one takes responsibility. Examples: overfishing in the oceans, over pumping of the Ogallala Aquifer

23) Natural selection: organisms that possess favorable adaptations survive and pass them onto the next generation

24) Energy flow in food webs or chains, through trophic systems: only 10% of the usable energy is transferred because usable energy lost as heat (second law); not all biomass is digested and absorbed; predators expend energy to catch prey; the 10% value is an average value

25) Biotic and abiotic: living and nonliving components of an ecosystem

26) Competition – a type of population interaction, usually over a limited resource – may be intraspecific or interspecific

27) Producer/Autotroph: photosynthetic or chemosynthetic life; Chemotroph – organism undergoing chemosynthesis – usually carried out by sulfur bacteria in aphotic zones in the ocean (deep ocean vents, etc.)

28) Primary succession: development of communities in a lifeless area not previously inhabited by life or those in which the soil profile is totally destroyed (lava flows); no soil substrate present; begins with lichen action

29) Secondary succession: life progresses where soil remains (clear-cut forest, fire, disturbed areas)

30) Mutualism: symbiotic relationship where both partners benefit and both participate

31) Commensalism: symbiotic relationship where one partner benefits & the other is unaffected or may benefit

32) Parasitism: relationship in which one partner obtains nutrients at the expense of the host

33) Biome: large distinct terrestrial region having similar climate, soil, plants & animals; terrestrial biomes determining factors are temperature and precipitation

34) Carrying capacity: the number of individuals (size of the population) that can be sustained in an area (supported by available resources in the environment)

35) R strategist: reproduce early in life; many small unprotected offspring; tend to be generalists, short lifespan

36) K strategist: reproduce late in life; few offspring; care for offspring; tend to be specialists, longer lifespan

37) Positive feedback: when a change in some condition triggers a response that intensifies the changing condition (warmer Earth - snow melts - less sunlight is reflected & more is absorbed, therefore warmer Earth)

38) Negative feedback: when a changing in some condition triggers a response that counteracts the changed condition (warmer Earth - more ocean evaporation - more stratus clouds - less sunlight reaches the ground - therefore cooler Earth)

39) Malthus: said human population increases exponentially, while food supplies increase arithmetically; factors that keep the population in check include war, famine & disease

40) Doubling time: rule of 70; 70 divided by the percent growth rate

41) Replacement level fertility: the number of children a couple must have to replace themselves (2.1 developed, 2.7 developing); biotic potential; total fertility rate (TFR)

42) World Population: ~ 6.8 billion U.S. Population: ~ 310 million

43) Preindustrial stage: (demographic transition) birth & death rates high, population grows slowly, infant mortality high

44) Transitional stage: (demographic transition) death rate lower, better health care, population grows fast

45) Industrial stage: (demographic transition) decline in birth rate, population growth slows

46) Postindustrial stage: (demographic transition) low birth & death rates

47) Age structure diagrams: broad base = rapid growth; narrow base = negative growth; uniform shape = zero growth; Major Age Cohorts → pre-reproductive, reproductive, post-reproductive

48) First and second most populated countries: China and India

49) Most important thing affecting population growth: low status of women

50) Ways to decrease birth rate: family planning, contraception, economic rewards and penalties

51) True cost / External costs: harmful environmental side effects that are not reflected in a product's price

ELECTRICITY

52) Cogeneration: using waste heat to make electricity

53) Electricity generated by fossil fuels, biomass or nuclear power: heat is produced which creates steam → steam turns a turbine → the mechanical energy from the turbine is converted to electrical energy in a generator and that energy is transmitted to homes through power lines

54) Hydroelectric power: potential energy of stored water is used to turn a turbine → the mechanical energy from the turbine is converted to electrical energy in a generator and that energy is transmitted to homes through power lines

ENERGY, GENERAL

55) Thermal gradient: spontaneous flow of heat from warmer to cooler bodies

56) Ionizing radiation: enough energy to dislodge electrons from atoms, forming ions; capable of causing cancer (gamma, Xrays, UV)

57) High Quality Energy: organized & concentrated; can perform useful work (fossil fuel & nuclear)

58) Low Quality Energy: disorganized, dispersed (heat in ocean or air wind, solar)

59) First Law of Thermodynamics: energy is neither created nor destroyed, but may be converted from one form to another (Law of Conservation of Energy)

60) Second Law of Thermodynamics: when energy is changed from one form to another, some useful energy is always degraded into lower quality energy, usually heat

61) Best solutions to energy shortage: conservation, increase efficiency, explore alternative energy options

62) Alternate energy sources: wind, solar, waves, biomass, geothermal, fuel cells

ENERGY, NUCLEAR

63) Natural radioactive decay: unstable radioisotopes decay releasing gamma rays, alpha particles, and beta particles

64) Half-life: the time it takes for ½ the mass of a radioisotope to decay

65) Estimate of how long a radioactive isotope must be stored until it decays to a safe level: approximately 10 half-lives

66) Nuclear Fission: nuclei of isotopes split apart when struck by neutrons

67) Nuclear Fusion: two isotopes of light elements (H) forced together at high temperatures till they fuse to form a heavier nucleus (He). Process is expensive; break-even point not reached yet; D + D _ He or D + T _ He

68) Mass deficit: not all matter is converted into matter in a fusion reaction – some (the mass deficit) is converted into energy. $E = mc^2$. Explains the energy released in a fusion reaction.

69) Major parts of a nuclear reactor: core, control rods, steam generator, turbine, containment building

70) Two most serious nuclear accidents: Chernobyl, Ukraine (1986) and Three Mile Island, PA (1979)

FOSSIL FUELS

71) Petroleum formation: microscopic aquatic organisms in sediments converted by heat and pressure into a mixture of hydrocarbons (animal remains)

72) Pros of petroleum: relatively cheap, easily transported, high-quality energy

73) Cons of petroleum: reserves will be depleted soon; pollution during drilling, transport and refining; burning makes CO_2

74) Steps in coal formation: peat, lignite, bituminous, anthracite

PESTS

75) Major insecticide groups (and examples): chlorinated hydrocarbons (DDT); organophosphates (malathion); carbamates (aldicarb)

76) Pesticide pros: saves lives from insect-transmitted disease, increases food supply, increases profits for farmers

77) Pesticide cons: genetic resistance, ecosystem imbalance, pesticide treadmill, persistence, bioaccumulation, biological magnification

78) Natural pest control: better agricultural practices, genetically resistant plants, natural enemies, biopesticides, sex attractants

79) In natural ecosystems, methods which control 50-90% of pests: predators, diseases, parasites

POLLUTION, AIR

80) Particulate matter:
Source: burning fossil fuels and diesel exhaust
Effect: reduces visibility & respiratory irritation
Reduction: filtering, electrostatic precipitators, alternative energy)

81) Nitrogen Oxides (NO_x):
Source: ~50% from transportation (exhaust), ~50% from industry
Effects: acidification of lakes, respiratory irritation, leads to photochemical smog & ozone formation
Equation for acid formation: $NO + O_2$ _ $NO_2 + H_2O$ _ HNO_3
Reduction: selective catalytic reduction unit, more efficient combustion processes like FBC (fluidized bed combustion), lower combustion temperatures, find alternatives to fossil fuels

82) Sulfur oxides (SO_x):
Source: coal burning
Effects: acid deposition, respiratory irritation, damages plants
Equation for acid formation: $SO_2 + O_2 = SO_3 + H_2O = H_2SO_4$
Reduction: scrubbers, burn low sulfur fuel)

83) Carbon oxides (CO and CO_2):
Source: auto exhaust, incomplete combustion
Effects: CO binds to hemoglobin, reducing blood's ability to carry O_2; CO_2 contributes to global warming
Reduction: catalytic converter, emissions testing, oxygenated fuel, mass transit, increase efficiencies, find alternatives to fossil fuels

84) Ozone (O_3):
Formation: secondary pollutant,
NO_2 + uv _ NO + O* O* + O_2 _ O_3, with VOCs (volatile organic compounds)
Effects: respiratory irritant, plant damage
Reduction: reduce NO and VOC emissions
Tropospheric ozone is BAD, stratospheric ozone is GOOD

85) Radon (Rn): naturally occurring colorless, odorless, radioactive gas, found in some types of soil and rock, can seep into homes and buildings, formed from the decay of uranium (U), causes cancer and is a problem in the Reading Prong area of PA. Radon decays to Polonium (Po), which is a solid. Po particles sit in lung tissue and are alpha (_) emitters. This leads to lung cancer.

86) Photochemical smog: formed by chemical reactions involving sunlight (NO, VOC, O*); associated with automobile traffic

87) Acid deposition: caused by sulfuric and nitric acids (H_2SO_4, HNO_3), resulting in lowered pH of surface waters, soil acidification and destruction of building materials

88) Greenhouse gases: Examples: H_2O, CO_2, O_3, chlorofluorocarbons (CFCs), methane (CH_4). Effect: they trap outgoing infrared (IR, heat) energy, causing Earth to warm

89) Effects of global warming: rising sea level (thermal expansion), extreme weather, drought, famine, extinctions

90) Stratospheric ozone depletion: caused by ozone-depleting chemicals (ODCs) such as CFCs, methyl chloroform or trichloromethane ($CHCl_3$), carbon tetrachloride (CCl_4), halon (haloalkanes), methyl bromide (CH_3Br)— all of which attack stratospheric ozone. The Cl or Br atoms "attack" the ozone molecules and cause the thinning of this layer. Global Agreement to decrease ODC – Montreal Protocol (1987)

91) Effects of ozone depletion: increased UV light that results in skin cancer, cataracts, decreased plant growth (inhibits photosynthesis, decline in Antarctic and Arctic phytoplankton population), impaired immune systems

92) Primary air pollutants: produced by humans & nature (CO,CO_2,SO_x,NO_x, hydrocarbons, particulates)

93) Secondary Air Pollutants: produced as a result of reactions that primary air pollutants undergo (include photochemical pollutants O_3, PAN and NO_2, and acids such as H_2SO_4 and HNO_3)

94) Sources of mercury: burning coal (25% of atmospheric deposition), compact fluorescent bulbs

95) Major source of sulfur: coal –burning power plants

POLLUTION, GENERAL

96) Point vs. non point sources: Point, from specific location such as a pipe. Non-point, from over an area such as runoff

POLLUTION, WATER

97) Chlorine: good= disinfection of water; bad = forms trihalomethanes when organics are present in the water; many systems now use chloramines to treat waste water before it is discharged. Alternatives to chlorine disinfection – ozone or UV light

98) Fecal coliform/*Enterococcus* bacteria: indicator of sewage contamination ; found in the intestines of all warm blooded mammals (coliform bacteria)

99) BOD: biological oxygen demand, amount of dissolved oxygen needed by aerobic decomposers to break down organic materials in water

100) Eutrophication: may result in rapid algal growth caused by an excess of nitrates $(NO_3)^-$ and phosphates $(PO_4)^{3-}$ in water

101) Hypoxia: when aquatic plants die, the BOD rises as aerobic decomposers break down the plants, the DO (dissolved O_2) drops & the water cannot support life; very low DO levels; dead zone in the Gulf of Mexico

102) Anoxic: no DO (dissolved O_2) in the water

SOIL/GEOLOGY

103) Surface mining: cheaper and can remove more minerals; less hazardous to workers

104) Ore: a rock that contains a large enough concentration of a mineral making it profitable to mine

105) Humus: organic, dark material remaining after decomposition by microorganisms

106) Leaching: removal of dissolved materials from soil by water moving downwards

107) Illuviation: deposit of leached material in lower soil layers (B horizon)

108) Loam: perfect agricultural soil with optimal portions of sand, silt, clay (40%, 40%, 20%)

109) Soil Profile, horizons in order: O – A – E – B – C –R

110) Organic fertilizer: slow-acting & long-lasting because the organic remains need time to be decomposed

111) Salinization of soil: in arid regions, water evaporates leaving salts behind

112) Volcano and Earthquake occurrence: at plate boundaries (divergent= spreading, mid-ocean ridges) (convergent= trenches) (transform= sliding, San Andreas)

113) Monoculture – cultivation of a single crop, usually in a large area

114) Food: wheat, rice and corn provide more than ½ of the calories in the food consumed by the world's people

TOXICOLOGY

115) LD50 (LD-50, LD_{50}): the amount of a chemical that kills 50% of the animals in a test population within 14 days of the initial dose

116) Threshold dose: the maximum dose that has no measurable effect on a given population

WATER

117) Percent water on earth by type: 97.5% seawater, 2.5% freshwater

118) Aquifer: any water-bearing layer in the ground; confined or artesian, unconfined or water table

119) Subsidence: land sinks as result of over pumping an aquifer

120) Cone of depression: lowering of the water table around a pumping well

121) Salt water intrusion: near the coast, over-pumping of groundwater causes saltwater to move into the aquifer

122) Ways to conserve water: agriculture = drip/trickle irrigation; industry = recycling; home = use gray water, repair leaks, low flow fixtures. reclaimed water for agriculture and golf courses

WASTE, HAZARDOUS and effects

123) Hazardous Waste (as defined by RCRA) – Mutagen, Teratogen, Carcinogen: (in order) causes hereditary changes through mutations; causes fetus deformities; causes cancer

124) Minamata Bay disease: (1932-1968, Japan) physical and mental impairments caused by methylmercury $(CH_3Hg)_+$ poisoning

125) Love Canal, NY: (1950s +) chemicals buried in old canal; school and homes built over it; caused birth defects and cancer

WASTE, SOLID

126) Main component of municipal solid waste (MSW): paper; most is landfilled

127) Sanitary landfill problems and solutions:
problem = leachate; solution = liner with collection system
problem = methane gas; solution = collect gas and burn
problem = volume of garbage; solution = compact and reduce

128) Incineration advantages: volume of waste reduced by 90%, and waste heat can be used

129) Incineration disadvantages: toxic emissions (polyvinyl chloride, dioxins), scrubbers and electrostatic precipitators needed, ash disposal (contains heavy metals)

130) Best way to solve waste problem: reduce the amounts of waste at the source (source reduction)

WEATHER/CLIMATE

131) ENSO: El Niño Southern Oscillation, see-sawing of air pressure over the S. Pacific

132) During an El Niño year: trade winds weaken & warm water sloshed back to SA

133) During a non El Niño year: easterly trade winds and ocean currents pool warm water in the western Pacific, allowing upwelling of nutrient rich water off the west coast of South America

134) Effects of El Niño: upwelling decreases disrupting food chains; N U.S. has mild winters, SW U.S. has increased rainfall, less Atlantic hurricanes

135) Temperature Inversion – layer of dense, cool air trapped under a layer of warm dense air, pollution in trapped layer may build to harmful levels; frequent in Los Angeles, California and Mexico City, Mexico

136) Forest Fires: Types – Surface, Crown, Ground (in order) usually burn only under growth and leaf litter on forest floor; hot fires, may start on ground but eventually leap from treetop to treetop; go underground, may smolder for days or weeks, difficult to detect and extinguish, i.e. peat bogs.

LEGISLATION: Note – original years of inception are included FYI

MINING

137) Surface Mining Control & Reclamation Act: (1977) requires coal strip mines to reclaim the land Madrid Protocol: (1991) Suspension of mineral exploration (mining) for 50 years in Antarctica

138) Madrid Protocol: (1991) Moratorium on mineral exploration for 50 years in Antarctica

WATER

139) Safe Drinking Water Act: (SDWA, 1974) set maximum contaminant levels for pollutants in drinking water that may have adverse effects on human health

140) Clean Water Act: (CWA, 1972) set maximum permissible amounts of water pollutants that can be discharged into waterways; aims to make surface waters swimmable and fishable

141) Ocean Dumping Ban Act: (1988) bans ocean dumping of sewage sludge and industrial waste in the ocean

AIR

142) Clean Air Act: (CAA, 1970) set emission standards for cars and limits for release of air pollutants

143) Kyoto Protocol: (2005) controlling global warming by setting greenhouse gas emissions targets for developed countries

144) Montreal Protocol: (1987) phase-out of ozone depleting substances

WASTE, SOLID AND HAZARDOUS

145) Resource Conservation & Recovery Act (RCRA): (1976) controls hazardous waste with a cradle-to-grave system

146) Comprehensive Environmental Response, Compensation & Liability Act (CERCLA): (1980) "Superfund," designed to identify and clean up abandoned hazardous waste dump sites

147) Nuclear Waste Policy Act: (1982) U.S. government must develop a high level nuclear waste site (Yucca Mtn)

148) Food Quality Protection Act (FQPA, 1996): set pesticide limits in food, & all active and inactive ingredients must be screened for estrogenic/endocrine effects

LIFE

149) Endangered Species Act: (1973) identifies threatened and endangered species in the U.S., and puts their protection ahead of economic considerations

150) Convention on International Trade in Endangered Species (CITES): (1973) lists species that cannot be commercially traded as live specimens or wildlife products

151) Magnuson-Stevens Act: (1976) Management of marine fisheries

152) Healthy Forest Initiative: (HFI, Healthy Forests Restoration Act of 2003) thin overstocked stands, clear away vegetation and trees to create shaded fuel breaks, provide funding and guidance to reduce or eliminate hazardous fuels in national forests, improve forest fire fighting, and research new methods to halt destructive insects

GENERAL

153) National Environmental Policy Act: (1969) Environmental Impact Statements must be done before any project affecting federal lands can be started

154) Stockholm Convention on Persistent Organic Pollutants: (2004) Seeks to protect human health from the 12 most toxic chemicals (includes 8 chlorinated hydrocarbon pesticides / DDT can be used for malaria control)

APES Review

Definitions

First Law of Thermodynamics: energy is neither created nor destroyed, but may be converted from one form to another.

Second Law of Thermodynamics: when energy is changed from one form to another, some useful energy is always degraded into lower quality energy (usually heat).

Ionizing radiation: radiation w/enough energy to free electrons from atoms forming ions, may cause cancer (ex. gamma, X-rays, UV).

High Quality Energy: organized & concentrated, can perform useful work (ex. fossil fuels & nuclear).

Low Quality Energy: disorganized, dispersed (ex. heat in ocean or air/wind, solar).

Natural radioactive decay: unstable radioisotopes decay releasing gamma rays, alpha & beta particles (ex. Radon).

Half-life: the time it takes for 1/2 of the mass of a radioisotope to decay. A radioactive isotope must be stored for approximately 10 half-lives until it decays to a safe level.

Nuclear Fission: nuclei of isotopes split apart when struck by neutrons.

Nuclear Fusion: 2 isotopes of light elements (H) forced together at high temperatures till they fuse to form a heavier nucleus. Happens in the Sun, very difficult to accomplish on Earth, prohibitively expensive.

Ore: a rock that contains a large enough concentration of a mineral making it profitable to mine.

Mineral Reserve: identified deposits currently profitable to extract.

Surface mining: cheaper, can remove more minerals, less hazardous to workers.

Humus: organic, dark material remaining after decomposition by microorganisms.

Leaching: removal of dissolved materials from soil by water moving downwards through soil.

Loam: perfect agricultural soil with equal portions of sand, silt, and clay.

Soil Conservation Methods: conservation tillage, crop rotation, contour plowing, organic fertilizers.

Soil Salinization: in arid regions, water evaporates leaving salts behind. (ex. Fertile crescent, southwestern US)

Water Logging: water completely saturates soil starves plant roots of oxygen, rots roots

Hydrologic Cycle Components: evaporation, transpiration, runoff, condensation, precipitation, and infiltration.

Watershed: all of the land that drains into a body of water.

Aquifer: underground layers of porous rock allow water to move slowly.

Cone of Depression: lowering of the water table around a pumping well.

Salt Water Intrusion: near the coast, overpumping of groundwater causes saltwater to move into the aquifer.

ENSO: El Nino Southern Oscillation, trade winds weaken & warm surface water moves toward South America. Diminished fisheries off South America, drought in western Pacific, increased precipitation in southwestern North America, fewer Atlantic hurricanes.

La Nina: "Normal" year, easterly trade winds and ocean currents pool warm water in the western Pacific, allowing upwelling of nutrient rich water off the West coast of South America.

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Nitrification: ammonia is converted to nitrate ions (NO_3^-).

Assimilation: inorganic N is converted into organic molecules such as DNA/amino acids & proteins.

Denitrification: bacteria convert ammonia back into N.

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Photosynthesis: plants convert CO_2 (atmospheric carbon) into complex carbohydrates (glucose $C_6H_{12}O_6$).

Aerobic Respiration: oxygen consuming producers, consumers & decomposers break down complex organic compounds & convert C back into CO_2.

Biotic: the living components of an ecosystem.

Abiotic: the nonliving components of an ecosystem.

Producer/Autotroph: organisms that make their own food—photosynthetic life (plants).

Trophic Levels: producers → primary consumer → secondaryconsumer → tertiary consumer.

Energy Flow through Food Webs: 10% of the usable energy is transferred to the next trophic level. Reason: usable energy lost as heat (2nd law of Thermodynamics), not all biomass is digested & absorbed, predators expend energy to catch prey.

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Commensalism: symbiotic relationship where one organism benefits & the other is unaffected.

Parasitism: relationship in which one organism (the parasite) obtains nutrients at the expense of the host.

Carrying Capacity: the number of individuals that can be sustained in an area.

r-strategist: reproductive strategy in which organisms reproduce early, bear many small, unprotected offspring (ex. insects, mice).

K-strategist: reproductive strategy in which organisms reproduce late, bear few, cared for offspring (ex. humans, elephants).

Natural Selection: organisms that possess favorable adaptations pass them onto the next generation.

Thomas Malthus: "human population cannot continue to increase. Consequences will be war, famine & pestilence (disease)."

Doubling Time: (rule of 70) doubling time equals 70 divided by percent growth rate. (ex. a population growing at 5% annually doubles in $70 \div 5 = 14$ years)

Replacement Level Fertility: the number of children a couple must have to replace themselves (averages 2.1 in more developed nations, 2.7 in less developed nations).

World Population: a little over 6 billion.

Demographic Transition Model:

Preindustrial stage: birth & death rates high, population grows slowly, infant mortality high.

Transitional stage: death rate (infant mortality) lower, birth rates remain high, better health care, population grows fast.

Industrial stage: decline in birth rate, population growth slows.

Postindustrial stage: low birth & death rates.

Age Structure Diagrams: broad base → rapid growth; narrow base → negative growth; uniform shape → zero growth

Most Populous Nations: (1) China; (2) India; (3) U.S.; (4) Indonesia

Low Status of Women: Most important factor keeping population growth rates high.

Methods to Decrease Birth Rates: family planning, contraception, economic rewards & penalties.

Composition of Water on Earth: 97.5% seawater, 2.5% freshwater.

Aquaculture: farming aquatic species, commonly salmon, shrimp, tilapia, oysters.

Point Source: source from specific location such as pipe or smokestack

Non-Point Source (Area/Dispersed Source): source spread over an area such as agricultural/feedlot runoff, urban runoff, traffic.

Primary Sewage Treatment: first step of sewage treatment; eliminates most particulate material from raw sewage using grates, screens, and gravity (settling).

Secondary Sewage Treatment: second step of sewage treatment; bacteria breakdown organic waste, aeration accelerates the process.

BOD: Biological Oxygen Demand, amount of dissolved oxygen needed by aerobic decomposers to break down organic materials.

Eutrophication: rapid algal growth (algal bloom) caused by an excess of nitrogen & phosphorus, blocks sunlight, causing the death/decomposition of aquatic plants, decreasing dissolved oxygen (DO), suffocating fish.

Hypoxia: water with very low dissolved oxygen levels, the end result of eutrophication, for example.

CAFE standards: Corporate Average Fuel Economy standards enacted into law in 1975, established fuel efficiency standards for passenger cars and light trucks. The fuel economy ratings for a manufacturer's entire line of passenger cars must currently average at least 27.5 mpg for the manufacturer to comply with the standard.

Primary Air Pollutants: produced by humans & nature (CO, CO_2, SO_2, NO, hydrocarbons, particulates).

Secondary Air Pollutants: formed by reaction of primary pollutants.

Particulate Matter: sources include burning fossil fuels and car exhaust. Effects include reduced visibility, respiratory irritation. Methods of reduction include filtering, electrostatic precipitators, alternative energy).

Nitrogen Oxides: (NO_x) Major source is auto exhaust. Primary and secondary effects include acidification of lakes, respiratory irritation, leads to smog and ozone. Reduced using catalytic converters.

Equation for acid formation: $NO + O_2 \rightarrow NO_2 + H_2O \rightarrow HNO_3$.

Ozone: Secondary pollutant, $NO_2 + UV \rightarrow NO + O$; $O + O_2 \rightarrow O_3$, with VOCs. Causes respiratory irritation and plant damage. Reduced by reducing NO emissions and VOCs.

Sulfur Oxides: (SO_x) Primary source is coal burning. Primary and secondary effects include acid deposition, respiratory irritation, plant damage. Reduction methods include: scrubbers, burn low sulfur fuel.

Equation for acid formation: $SO_2 + O_2 \rightarrow SO_3 + H_2O \rightarrow H_2SO_4$

Carbon Dioxide: (CO_2) Sources include the combustion of fossil fuels. Effects: greenhouse gas–contributes to global warming. Reduction accomplished by increased fuel efficiency (gas mileage), mass transit (reduction).

Carbon Monoxide: (CO) Sources include incomplete combustion of fossil fuels. Effects: binds to hemoglobin reducing bloods ability to carry O_2. Reduction accomplished by catalytic converters, oxygenated fuel, mass transit (reduction).

Photochemical Smog: formed by chemical reactions involving sunlight (NO, VOC, O_2)

Acid Deposition: caused by sulfuric and nitric acids resulting in lowered pH of surface waters

Greenhouse Gases: Most significant: H_2O, CO_2, methane (CH_4), CFCs. Trap outgoing infrared energy (heat) causing earth to warm.

Greenhouse Effect: a vital process, required for life to exist on Earth. If accelerated, bad, leads to global warming.

Effects of Global Warming: rising sea level (due to thermal expansion not melting ice), extreme weather, droughts (famine), and extinctions.

Ozone Depletion: caused by CFCs, methyl chloroform, carbon tetrachloride, halon, methyl bromide all of which attack stratospheric ozone. Negative effects of ozone depletion include increased UV, skin cancer, cataracts, and decreased plant growth.

Municipal Solid Waste: is mostly paper and mostly put into landfills.

Sanitary Landfill: problems include leachate, which is solved using a liner with a collection system; methane gas, which may be collected and burned; and the volume of garbage, which may be compacted and/or reduced.

Incineration: Advantages–volume of waste reduced by 90% and waste heat can be used. Disadvantages–toxic emissions (polyvinyl chloride, dioxin), scrubbers and electrostatic precipitators needed, ash disposal.

Best Solution for Waste Problem: reduce the amount of waste at the source.

Brownfield: abandoned industrial sites.

Keystone Species: species whose role in an ecosystem is more important than others.

Indicator Species: species that serve as early warnings that an ecosystem is being damaged.

In Natural Ecosystems: 50-90% of pest species are kept under control by: predators, diseases, parasites.

Major Insecticide Groups: chlorinated hydrocarbons—ex. DDT; organophosphates—ex. malathion; carbamates—ex. aldicarb

Pesticide Pros: saves lives from insect transmitted disease, increases food supply, and increases profits for farmers. Cons: genetic resistance, ecosystem imbalance, pesticide treadmill, persistence, bioaccumulation, and biological magnification.

Natural Pest Control: better agricultural practices, genetically resistant plants, natural enemies, and biopesticides, sex attractants.

Genetically Modified Organisms (GMOs): new organisms created by altering the genetic material (DNA) of existing organisms; usually in an attempt to remove undesirable or create desirable characteristics in the new organism.

Electricity Generation: steam, from water boiled by fossils fuels or nuclear energy, or falling water is used to turn a generator.

Petroleum (Crude Oil) Formation: microscopic aquatic organisms in sediments converted by heat & pressure into a mixture of hydrocarbons.

Petroleum Pros: cheap, easily transported, high-quality energy. Cons: reserves depleted soon, pollution during drilling, transport and refining, land subsidence, burning oil produces CO_2.

Coal Formation: prehistoric plants buried un-decomposed in oxygen-depleted water of swamps/bogs converted by heat and pressure.

Ranks of Coal: peat, lignite, bituminous coal, anthracite coal.

Nuclear Reactor: consists of a core, control rods, moderator, steam generator, turbine, containment building.

Alternate Energy Sources: wind, solar, waves, biomass, geothermal, fuel cells

Remediation: return a contaminated area to its original state.

LD-50: the amount of a chemical that kills 50% of the animals in a test population

Troposphere: first layer of atmosphere 0-10 miles above the Earth's surface. Contains weather, greenhouse gases (bad ozone).

Stratosphere: second layer of atmosphere 10-30 miles above the Earth's surface. Contains protective ozone layer (good ozone).

Inversion Layer (Temperature Inversion): a warm layer of air above a cooler layer traps pollutants close to the Earth's surface.

Mutagen: substances that cause changes in DNA; may result in hereditary changes.

Teratogen: substances that cause fetus deformities (birth defects).

Carcinogen: substances that cause cancer.

Dioxin: one of the most toxic human-made chemicals. Stable, long-lived, by-product of herbicide production enters environment as fallout from the incineration of municipal and medical waste and persists for many years.

PCBs (Polychlorinated Biphenyls): Stable, long-lived, carcinogenic chlorinated hydrocarbons. Produced by the electronics industry.

Multiple Use Public Lands: National Forest & National Resource lands.

Moderately Restricted Use Public Lands: National Wildlife Refuges

Restricted Use Public Lands: National Parks & National Wilderness Preservation System

Divergent Plate Boundaries: tectonic plates spreading apart, new crust being formed (ex. mid-ocean ridges, rift valleys).

Convergent Plate Boundaries: tectonic plates with the oldest crustal material on Earth moving together, one moving under another (ex. mid-ocean trenches). Mineral deposits and volcanoes are most abundant at convergent plate boundaries

Transform Fault: tectonic plates sliding past one another (ex. San Andreas fault).

Endangered Species

Most Endangered Species: have a small range, require large territory, have long generations, have a very specialized niche, or live on an island.

Atlantic Salmon: interbreeding with and competition from escaped farm-raised salmon from the aquaculture industry threaten the wild salmon population.

California Condor: reasons for decline include shootings, poisoning, lead poisoning, collisions with power lines, egg collecting, pesticides, habitat loss, and the decline of large and medium-size native mammals due to encroachments of agriculture and urbanization.

Delhi Sands Flower-Loving Fly: a 1-inch long insect currently restricted to only 12 known populations in San Bernardino and Riverside counties. An estimated 98% of its habitat has been converted to residential, agricultural, and commercial use.

Florida Panther: hunting and development that resulted in habitat loss and fragmentation.

Gray Wolf: subject of predator eradication programs sponsored by the Federal government. Prior to Endangered Species Act (1973), exterminated from the lower 48 states except for a few hundred inhabiting extreme northeastern Minnesota and a small number on Isle Royale, Michigan

Grizzly Bear: conflict with humans and development that resulted in habitat loss and fragmentation

Piping Plover: predation and human disturbance are thought to be the main causes of the plover's decline. It is listed as endangered in the Great Lakes region and as threatened in the Great Plains and on the Atlantic coast

Manatee: initial population decreases resulted from overharvesting for meat, oil, and leather. Today, heavy mortality occurs from accidental collisions with boats and barges, and from canal lock operations.

Whooping Crane: drainage of wetlands, conversion of grasslands to agriculture, and hunting for feathers.

NOT Endangered Species

American Alligator: overhunting and destruction of habitat caused original listing, removed from the list of endangered species by the Fish and Wildlife Service in 1987.

Bald Eagle: ingested DDT by eating contaminated fish. The pesticide caused the shells of the bird's eggs to thin and resulted in nesting failures. Loss of nesting habitat and hunting for feathers also contributed to the population decline. Reclassified from endangered to threatened (1995).

Peregrine Falcon: ingested DDT by eating smaller birds, which had eaten contaminated prey. The pesticide caused the shells of the bird's eggs to thin and resulted in nesting failures. Removed from the list of endangered species by the Fish and Wildlife Service in August 1999.

Gray Whale: the eastern North Pacific stock of gray whale has the distinction of being the first population of a marine mammal species to be removed from the List of Endangered and Threatened Species.

Biomes

Biome: large distinct terrestrial region having similar climate, soil, plants & animals.

Tropical Rain Forests: characterized by the greatest diversity of species, believed to include many undiscovered species. Occur near the equator. Soils tend to be low in nutrients. Distinct seasonality: winter is absent, and only two seasons are present (rainy and dry).

Temperate Forests: occur in eastern North America, Japan, northeastern Asia, and western and central Europe. Dominated by tall deciduous trees. Well-defined seasons include a distinct winter. Logged extensively, only scattered remnants of original temperate forests remain.

Boreal Forests or Taiga: represent the largest terrestrial biome. Dominated by needleleaf, coniferous trees. Found in the cold climates of Eurasia and North America: two-thirds in Siberia with the rest in Scandinavia, Alaska, and Canada. Seasons are divided into short, moist, and moderately warm summers and long, cold, and dry winters. Extensive logging may soon cause their disappearance.

Temperate Shrub Lands: occurs along the coast of Southern California and the Mediterranean region. Characterized by areas of Chaparral–miniature woodlands dominated by dense stands of shrubs.

Savannas: grassland with scattered individual trees. Cover almost half the surface of Africa and large areas of Australia, South America, and India. Warm or hot climates where the annual rainfall is 20-50 inches per year. The rainfall is concentrated in six or eight months of the year, followed by a long period of drought when fires can occur.

Temperate Grasslands: dominated by grasses, trees and large shrubs are absent. Temperatures vary more from summer to winter, and the amount of rainfall is less than in savannas. Temperate grasslands have hot summers and cold winters. Occur in South Africa, Hungary, Argentina, the steppes of the former Soviet Union, and the plains and prairies of central North America.

Deserts: covers about one fifth of the Earth's surface and occur where rainfall is less than 50 cm/year. Most deserts occur at low latitudes, have a considerable amount of specialized vegetation, as well as specialized animals. Soils have abundant nutrients, need only water to become productive, and have little or no organic matter. Common disturbances include occasional fires or cold weather, and sudden, infrequent, but intense rains that cause flooding.

Tundra: treeless plains that are the coldest of all the biomes. Occur in the arctic and Antarctica. Dominated by lichens, mosses, sedges, and dwarfed shrubs Characterized by extremely cold climate, permanently frozen ground (permafrost) low biotic diversity, simple vegetation structure, limitation of drainage, short season of growth and reproduction.

Wetlands: areas of standing water wet all or most of the year that support aquatic plants including marshes, swamps, and bogs. Species diversity is very high. Includes bogs, swamps, sloughs, marshes

Fresh Water: defined as having a low salt concentration (less than 1%). Plants and animals are adjusted to the low salt content and would not be able to survive in areas of high salt concentration (i.e., ocean). There are different types of freshwater regions: ponds and lakes, streams and rivers, and estuaries.

Oceans: the largest of all the ecosystems. The ocean regions are separated into separate zones: intertidal, pelagic, abyssal, and benthic. All four zones have a great diversity of species.

Places to Know

Chernobyl, Ukraine: April 26, 1986, unauthorized safety test (irony), leads to fire and explosion at nuclear power plant—millions exposed to unsafe levels of radiation.

Three-Mile Island, Pennsylvania: March 29, 1979, nuclear power plant loses cooling water 50% of core melts, radioactive materials escape into atmosphere, near meltdown (disaster).

Yucca Mountain, Nevada: controversial as proposed site for permanent storage of high-level nuclear waste, 70-miles northwest of Las Vegas, near volcano and earthquake faults.

Aral Sea, Uzbekistan/Kazakhstan (former Soviet Union): large inland sea is drying up as a result of water diversion.

Love Canal, NY: chemicals buried in old canal, school and homes built over it led to birth defects and cancers.

Aswan High Dam, Egypt: the silt that made the Nile region fertile fills the reservoir. Lack of irrigation controls causes waterlogging and salinization. The parasitic disease schistosomiasis thrives in the stagnant water of the reservoir.

Three Gorges Dam, China: world's largest dam on Yangtze River will drown ecosystems, cities, archeological sites, fragment habitats, and displace 2 million people.

Ogallala Aquifer: world's largest aquifer; under parts of Wyoming, South Dakota, Nebraska, Kansas, Colorado, Oklahoma, New Mexico, and Texas (the Midwest). Holds enough water to cover the U.S. with 1.5 feet of water. Being depleted for agricultural and urban use.

Minamata, Japan: mental impairments, birth defects, and deaths were caused by mercury dumped in Minamata Bay by factory. Mercury entered humans through their diet (fish).

Bhopal, India: December 2,1984, methyl isocyanate released accidentally by Union Carbide pesticide plant kills over 5,000.

Valdez, Alaska: March 24, 1989, tanker Exxon Valdez hits submerged rocks in Prince William Sound—worst oil spill in US waters.

Environmental Laws and Treaties

Safe Drinking Water Act: set maximum contaminant levels for pollutants that may have adverse effects on human health.

Ocean Dumping Ban Act: bans ocean dumping of sewage sludge & industrial waste.

National Wild and Scenic Rivers Act: protects rivers with due to aesthetic, recreational, wildlife, historical, or cultural reasons.

Clean Water Act: set maximum permissible amounts of water pollutants that can be discharged into waterways. Aim: to make surface waters swimmable and fishable.

Surface Mining Control & Reclamation Act: requires coal strip mines to reclaim the land.

National Environmental Policy Act (NEPA): Environmental Impact Statements must be done before any project affecting federal lands can be started.

Clean Air Act: Set emission standards for cars, and limits for release of air pollutants.

Kyoto Protocol: controlling global warming by setting greenhouse gas emissions targets for developed countries.

Montreal Protocol: phase out of ozone depleting substances.

Resource Conservation & Recovery Act (RCRA): controls hazardous waste with a cradle to grave system.

Comprehensive Environmental Response, Compensation & Liability Act (CERCLA): The "Superfund" act, designed to identify and clean up abandoned hazardous waste dumpsites.

Endangered Species Act: identifies threatened and endangered species in the US, and puts their protection ahead of economic considerations.

Convention on International Trade in Endangered Species: (CITES) lists species that cannot be commercially traded as live specimens or wildlife products.

Lacey Act: prohibits interstate transport of wild animals dead or alive without federal permit.

U.S. Marine Mammal Protection Act: prohibits taking marine mammals in U.S. waters and by U.S. citizens, and the importing marine mammals and marine mammal products into the U.S.

Federal Insecticide, Fungicide, and Rodenticide Act: regulates the effectiveness of pesticides.

Food Quality Protection Act: set pesticide limits in food, & all active and inactive ingredients must be screened for estrogenic/endocrine effects.

Low-Level Radioactive Policy Act: all states must have facilities to handle low-level radioactive wastes.

Nuclear Waste Policy Act: US government must develop a high level nuclear waste site by 2015 (see Yucca Mountain).

People to Know

Rachel Carson: published *Silent Spring* in 1962; documented the environmental damage done by DDT and other pesticides. Which heightened public awareness at the start of the modern environmental movement.

John Muir: founded Sierra Club in 1892; fought unsuccessfully to prevent the damming of the Hetch Hetchy Valley in Yosemite National Park.

Gifford Pinchot: first chief of the US Forest Service; advocated managing resources for multiple use using principles of sustainable yield.

Garrett Hardin: published "The Tragedy of the Commons" in the journal *Science* in 1968; argued that rational people will exploit shared resources (commons).

Aldo Leopold: wrote *A Sand County Almanac* published a year after his death in 1948; promoted a "Land Ethic" in which humans are ethically responsible for serving as the protectors of nature.

Sherwood Rowland & Mario Molina: in 1974, determine that CFCs destroy stratospheric (good) ozone.

Biomes

Type of Forest	Locations	Characteristics
Tropical Rain Forests	Typically found along the equator but also found from the equator to 30°N and 30°S Brazil, Central America, Indonesia, Central Africa	■ year-round consistently warm temperatures, high humidity, and heavy rainfall ■ dominated by broadleaf evergreen plants ■ high primary productivity and biodiversity ■ distinct strata (zones) such as canopy, emergent, sapling, and ground, provide habitat space for the abundance of life ■ poor soil quality due to low concentrations of stored nutrients
Temperate Deciduous Forests	Found between 30° and 60° north and south latitudes Eastern United States, most of Europe	■ moderate temperatures that fluctuate with seasons ■ dominated by a few species of broadleaf deciduous trees such as maple, beech, oak, and hickory ■ trees go dormant in winter by dropping their leaves in the fall ■ slow rate of decomposition of leaves provides abundant leaf litter and nutrients stored in the soil
Taigas (Boreal Forests)	Found just south of the Arctic tundra in northern regions of North America (Canada), Asia, and Europe	■ winters are long, dry, and extremely cold ■ dominated by a few species of conifers such as pine, hemlock, cedar, and spruce ■ trees have small, waxy, needle-shaped leaves to survive the cold winters ■ plant diversity is low ■ slow decomposition of needles; nutrient poor, acidic soils

Ecological Roles of Mountains: Although mountain ranges are not classified as one of our major biomes, they have dramatic impacts on our ecosystems by

- often providing habitat for many endemic species that are found nowhere else in the world
- helping to regulate earth's climate due to snow and ice reflecting solar radiation back into space
- melting mountain-top snowpack each spring and summer, providing surface water in streams for use by animals

Type of Grassland	Locations	Characteristics
Tropical Grassland (Savannas)	Largely found in Eastern Africa and also parts of South America and Australia	warm temperatures and alternating warm and dry seasons (will experience several months of little/no rainfall) large grazing herbivores such as gazelles, zebras, wildebeests plants have deep roots to utilize groundwater supplies
Temperate Grasslands (tall-grass and short-grass prairies)	Found in midwestern and western United States and Canada; also found in parts of South America and Russia	rainfall determines whether it is a tall-grass or a short-grass prairie (tall-grass prairies receive almost three times as much rain as short-grass) winters are cold, summers are hot and dry as grasses die and decompose annually, large amounts of organic matter accumulates in the soil, making this area highly productive for crops high winds and rapid evaporation promote fires in the summer and fall that eliminate other competing species
Cold Grasslands (Arctic tundra)	Found just south of the Arctic tundra in northern regions of North America (Canada), Asia, and Europe	frigid, treeless plains that are covered with snow and ice much of the year extreme cold forms **permafrost**—underground soil in which captured water stays frozen for more than two consecutive years vegetation is limited to low-growing grasses, moss, and lichen animals, such as Arctic foxes and wolves, have adaptations such as thick coats of fur to survive the harsh climate

Type of Desert	Locations	Characteristics
Tropical Deserts	Cover much of northern Africa (the Sahara), and parts of the Middle East (Saudi Arabia)	- surface areas have little vegetation and are dominated by rocks and sand that are often blown about by frequent windstorms - extremely high daytime temperatures
Temperate Deserts	Found in the southwestern United States (Mojave and Sonoran deserts)	- receive more precipitation than tropical deserts - characterized by patchy drought-resistant shrubs, cacti, and other succulents - have high daytime and low nighttime temperatures
Cold Deserts	Area of the United States known as the Great Basin (Idaho, Utah); Gobi desert in northern China and southern Mongolia	- vegetation is very sparse - winters are extremely cold

AQUATIC LIFE ZONES

Approximately 71% of the earth's surface is covered with saltwater. We divide the saltwater realm into four areas known as the Atlantic, Pacific, Indian, and Arctic oceans. Some basic abiotic factors help influence the presence of life in aquatic systems. These factors include sunlight, dissolved oxygen, and how clear the water is. **Turbidity** is the measure of how cloudy the water is due to suspended sediments or solids and greatly reduces sunlight from reaching photosynthetic organisms. **Salinity**, the concentration of dissolved salts in a given volume of water, also regulates aquatic life. Aquatic ecosystems are therefore divided into two life zones—freshwater and marine.

OCEANS AS NATURAL CAPITAL

The ocean provides us with many vital ecological benefits. We also harvest and utilize the vast resources present in the ocean, providing humans with numerous economic benefits.

ECOLOGICAL BENEFITS

- provides habitats and nursery areas
- moderates climate
- absorbs CO_2
- reduces storm impact (estuaries, mangroves)

Water Pollution

Type and Effects	Examples	Major Sources
Infectious agents (pathogens) Cause diseases	Bacteria, viruses, protozoa, parasites	Human and animal wastes
Oxygen-demanding wastes Deplete dissolved oxygen needed by aquatic species	Biodegradable animal wastes and plant debris	Sewage, animal feedlots, food processing facilities, pulp mills
Plant nutrients Cause excessive growth of algae and other species	Nitrates (NO_3^-) and phosphates (PO_4^{3-})	Sewage, animal wastes, inorganic fertilizers
Organic chemicals Add toxins to aquatic systems	Oil, gasoline, plastics, pesticides, cleaning solvents	Industry, farms, households
Inorganic chemicals Add toxins to aquatic systems	Acids, bases, salts, metal compounds	Industry, households, surface runoff
Sediments Disrupt photosynthesis, food webs, other processes	Soil, silt	Land erosion
Heavy metals Cause cancer, disrupt immune and endocrine systems	Lead, mercury, arsenic	Unlined landfills, household chemicals, mining refuse, industrial discharges
Thermal Make some species vulnerable to disease	Heat	Electric power and industrial plants

Human health is at risk when exposed to infectious diseases from inadequate sanitation practices of drinking water as well as lack of water for adequate hygiene. Each year millions of people, mostly younger children, die from preventable diseases like diarrhea from unclean water used for drinking and hygiene. One method scientists use to detect the presence of infectious agents in water is to test for colonies of **fecal coliform**. Coliform bacteria, such as *E. coli*, that live in animal and human intestines, do not always cause disease but can indicate when water has come in contact with waste that could potentially carry disease-causing bacteria.

Type of Organism	Disease	Effects
Bacteria	Typhoid fever	Diarrhea, severe vomiting, enlarged spleen, inflamed intestine; often fatal if untreated
	Cholera	Diarrhea, severe vomiting, dehydration; often fatal if untreated
	Bacterial dysentery	Diarrhea, bleeding; rarely fatal except in infants without proper treatment
	Enteritis	Severe stomach pain, nausea, vomiting; rarely fatal
Viruses	Infectious hepatitis (Type B)	Fever, severe headache, loss of appetite, abdominal pain, jaundice, enlarged liver; rarely fatal but may cause permanent liver damage
	Poliomyelitis	Fever, diarrhea, backache, sore throat, aches in limbs; can infect spinal cord and cause paralysis and muscle weakness
Parasitic protozoa	Amoebic dysentery	Severe diarrhea, headache, abdominal pain, chills, fever; if not treated can cause liver abscess, bowel perforation, and death
	Giardiasis	Diarrhea, abdominal cramps, flatulence, belching, fatigue
	Cryptosporidium	Severe diarrhea, cramps for up to 3 weeks, and possible death for people with weakened immune systems
Parasitic worms	Schistosomiasis	Abdominal pain, skin rash, anemia, chronic fatigue, and chronic general ill health
	Ancylostomiasis	Severe anemia and possible symptoms of bronchial infection

Toxic Chemicals

Chemical Toxin	Sources	Human or Wildlife Health Impact
PCBs	- used as electrical insulators, fire retardant materials, pesticides, and as adhesives (banned in the U.S.)	- neurotoxin causing brain damage in fetuses - endocrine disruptor causing reproductive cancers
DDT	- a commonly used pesticide in the U.S. prior to banning it in 1972 - still used in developing countries to control malaria and pests	- biomagnifies in the food chain of ecosystems - causes reproductive damages and cancers in avian (bird) populations
Phthalates	- group of chemicals used in the production of plastics - used as solvents in many products such as vinyl flooring, adhesives, detergents, and some personal care products like soap and shampoo	- causes reproductive damage and cancers
Atrazine	- one of the most widely used pesticides in the U.S. - herbicide primarily used to control weed populations in the Midwest	- this pesticide is currently being monitored by the EPA to determine if it is linked to endocrine cancers in humans and amphibians
Bisphenol A	- a chemical building block for plastic consumer goods such as water bottles, food containers, and microwaveable dishes	- some evidence suggests exposure can lead to neurological damage and reproductive cancers
Heavy Metals (mercury, arsenic, lead, cadmium)	- heavy metal pollution is often generated from smelting metals and incineration of municipal waste - elemental mercury is used in batteries and fluorescent lights - inorganic mercury released from coal burning is converted to toxic methylmercury by bacteria	- heavy metals often biomagnify in the food chain - cause neurological damage especially to fetuses - can be carcinogenic

Chemical Toxin	Sources	Human or Wildlife Health Impact
Benzene	emissions from burning coal and oil and tobacco smoke	short-term exposure causes dizziness and nausea long-term exposure causes damage to the liver and reproductive system, cancer, and birth defects
Vinyl Chloride	is a precursor to making polyvinyl chloride (PVC), which is commonly used in building materials and many consumer products	causes cancers, especially liver cancers can do damage to central nervous system is known to cause birth defects
Asbestos	a naturally occurring silicate mineral formerly used in insulation materials for its fire-retarding properties	known to cause cancer
Dioxins	a class of chemical compounds formed during incineration of waste materials and also in the manufacturing process of some herbicides	accumulate in fatty tissue of organisms (bioaccumulation) carcinogen causes reproductive damages

LEGISLATION THAT REGULATES CHEMICAL TOXINS*

Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA): Gives the EPA the authority to regulate the sale, packaging, distribution, and disposal of pesticides. The EPA also has the right to suspend the use of pesticides that are found to pose unreasonable risks to humans or wildlife.

Federal Food, Drug, and Cosmetic Act: Allows the EPA to set tolerance levels for pesticide residue on food for human consumption as well as on feed meant for livestock consumption.

Food Quality Protection Act of 1996: This law amended the two aforementioned laws. It outlines more requirements for assessing tolerance levels for pesticides. It also provides extra funding for the protection of infants and children.

* Legislation that regulates air and water chemical toxins will be covered in Chapters 6 and 8, respectively.

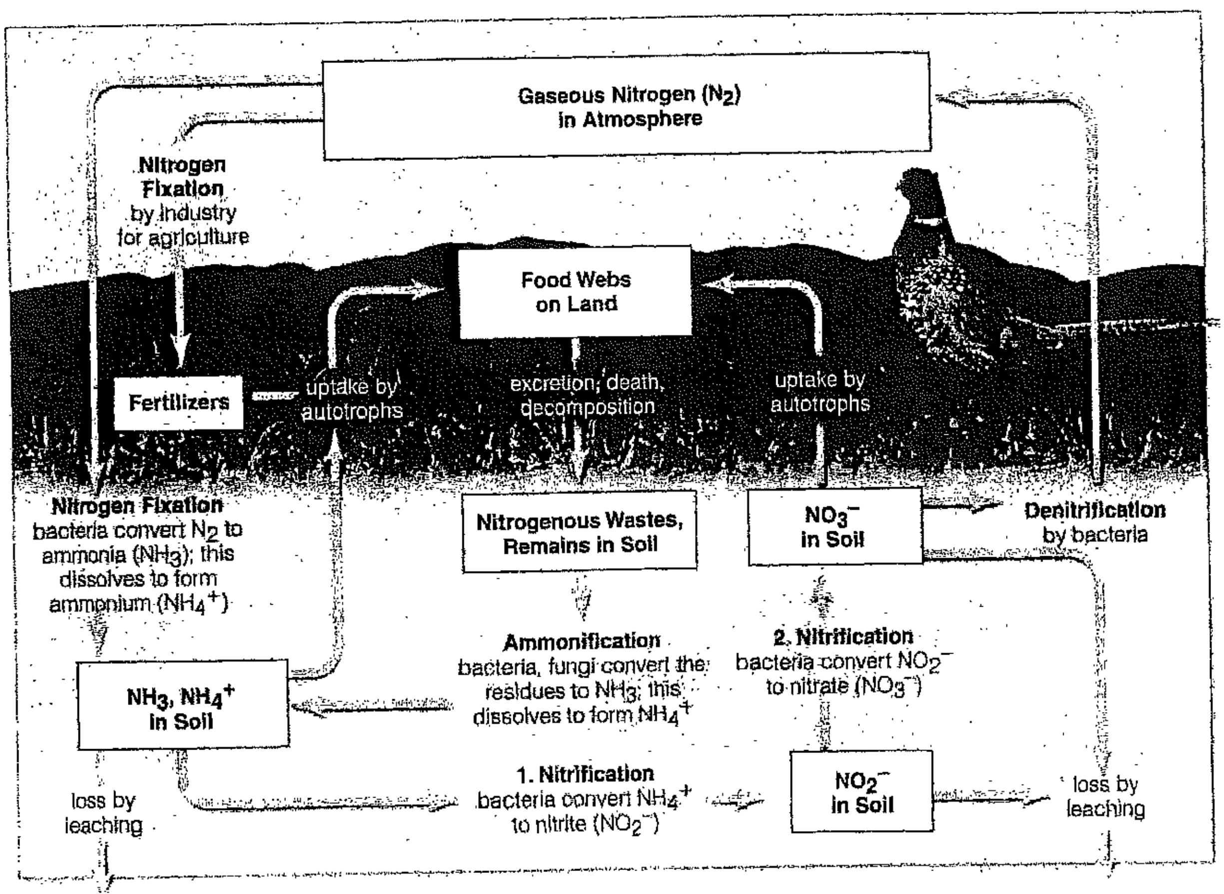
FIGURES -&- DIAGRAMS

ENVIRONMENTAL SCIENCE AP: FIGURES AND DIAGRAMS

TEXT SOURCE: G. TYLER MILLER 12TH EDITION LIVING IN THE ENVIRONMENT
- REPRINT PERMISSION -

Element	Main nonliving reservoir	Main forms in living organisms	Other nonliving reservoir
Carbon (C)	***Atmospheric:*** carbon dioxide (CO_2)	Carbohydrates $(CH_2O)_n$ and all other organic molecules	***Hydrologic:*** dissolved carbonate (CO_3^{2-}) and bicarbonate (HCO_3^-) ***Sedimentary:*** carbon-containing minerals in rocks
Nitrogen (N)	***Atmospheric:*** nitrogen gas (N_2)	Proteins and other nitrogen-containing organic molecules	***Hydrologic:*** dissolved ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-) in water and soils
Phosphorus (P)	***Sedimentary:*** phosphate (PO_4^{3-}) containing minerals in rocks	DNA, other nucleic acids (e.g., ATP), and phospholipids	***Hydrologic:*** dissolved phosphate (PO_4^{3-})
Sulfur (S)	***Sedimentary:*** rocks (e.g., iron disulfide and pyrite) and minerals (e.g., sulfate [SO_4^{2-}])	Sulfur-containing amino acids in most proteins, and some vitamins	***Atmospheric:*** hydrogen sulfide (H_2S), sulfur dioxide (SO_2), sulfur trioxide (SO_3), and sulfuric acid (H_2SO_4) ***Hydrologic:*** sulfate (SO_4^{2-}) and sulfuric acid (H_2SO_4)

Major nonliving and living storehouses of elemental nutrients.



Greatly simplified model of the nitrogen cycle in a terrestrial ecosystem. Nitrogen reservoirs are shown as boxes and processes changing one form of nitrogen to another are shown in unboxed print. (From Biology: The Unity and Diversity of Life, 9/e by Starr & Taggart ©2001)

CASE STUDY

Effects of Deforestation on Nutrient Cycling

In the 1960s, F. H. Bormann of Yale University, Gene Likens of Cornell University, and their colleagues began carrying out a controlled experiment to compare the loss of water and nutrients from an uncut forest ecosystem (the control system) with one that was stripped of its trees (the experimental system).

To do this, V-shaped concrete catchment dams were built across the creeks at the bottom of several valleys in the Hubbard Brook Experimental Forest in New Hampshire. The dams were anchored on impenetrable bedrock so that all surface water leaving each forested valley ecosystem had to flow across the dams, where its volume and dissolved nutrient content could be measured.

The first project was to measure the amounts of water that entered and left an undisturbed (control) forest and the amount of dissolved nutrients in this inflow and outflow. These baseline data showed that an undisturbed mature forest ecosystem is very efficient at retaining chemical nutrients.

The next experiment was to disturb the system and observe any changes that occurred. One winter the investigators cut down all trees and shrubs in one valley. They left them where they fell and were careful not to disturb the soil. The cut area was sprayed with herbicides to prevent regrowth. The inflow and outflow of water and nutrients in this modified experimental valley were then compared with those in the control valley for 3 years.

With no plants to absorb and transpire water from the soil, water runoff in the deforested valley increased by 30–40%. As this excess water ran rapidly over the surface of the ground, it eroded soil and carried nutrients out of the ecosystem. Overall, the loss of minerals from the cut forest was six to eight times that in a nearby undisturbed forest.

For example, chemical analysis of the water flowing through the dams showed a 60-fold rise in the concentration of nitrate ions (NO_3^-; Figure 4-31). So much nitrogen as nitrate (NO_3^-) was lost from the experimental valley that (1) the water flowing out of it was unsafe to drink, and (2) the overfertilized stream below this valley became covered with populations of cyanobacteria and algae. After a few years, however, vegetation grew back and nitrate levels returned to normal (Figure 4-31).

Critical Thinking

What do you think would be the effect on phosphate levels in runoff water from a Hubbard Brook valley whose trees were destroyed by a major forest fire?

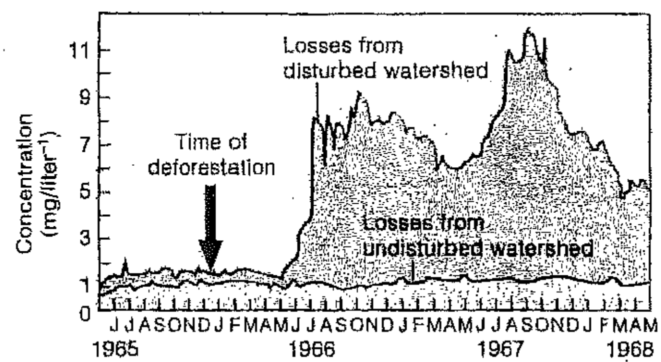
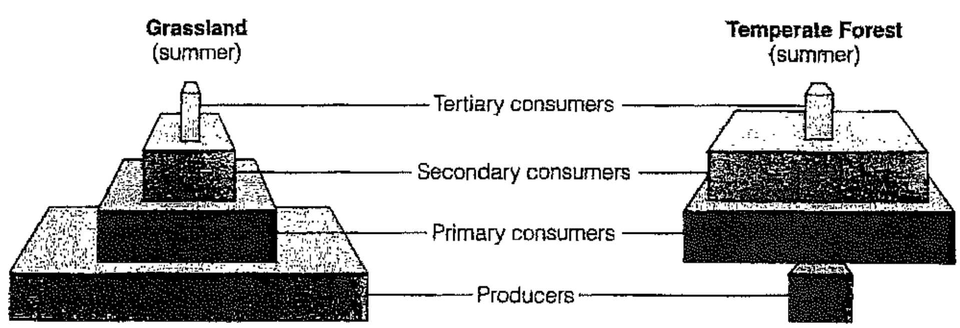
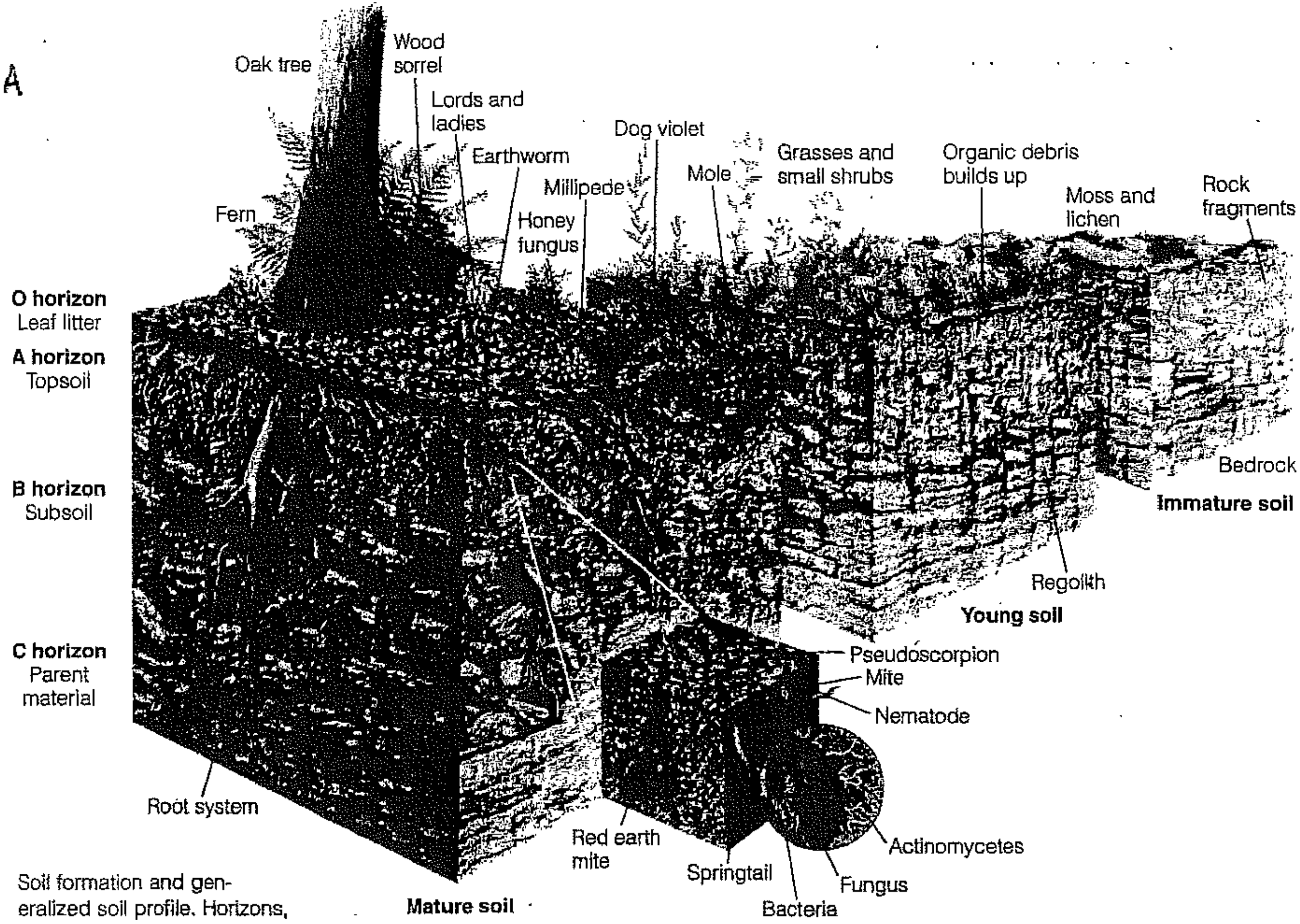


Figure 4-31 Loss of nitrate ions (NO_3^-) from a deforested watershed in the Hubbard Brook Experimental Forest in New Hampshire. The concentration of nitrate ions in runoff from the deforested experimental watershed was many times greater than in a nearby unlogged watershed used as a control. (Data from F. H. Bormann and Gene Likens: Presentation from *Biology: Concepts and Applications* 4/e by Cecie Starr ©2000)



Generalized graphs of *numbers of organisms* in the various trophic levels for two ecosystems.

2 A



Soil formation and generalized soil profile. Horizons, or layers, vary in number, composition, and thickness, depending on the type of soil. (From *Earth* by Derek Elsom, 1992. Copyright © 1992 by Marshall Editions Developments Limited. New York: Macmillan. Used by permission.)

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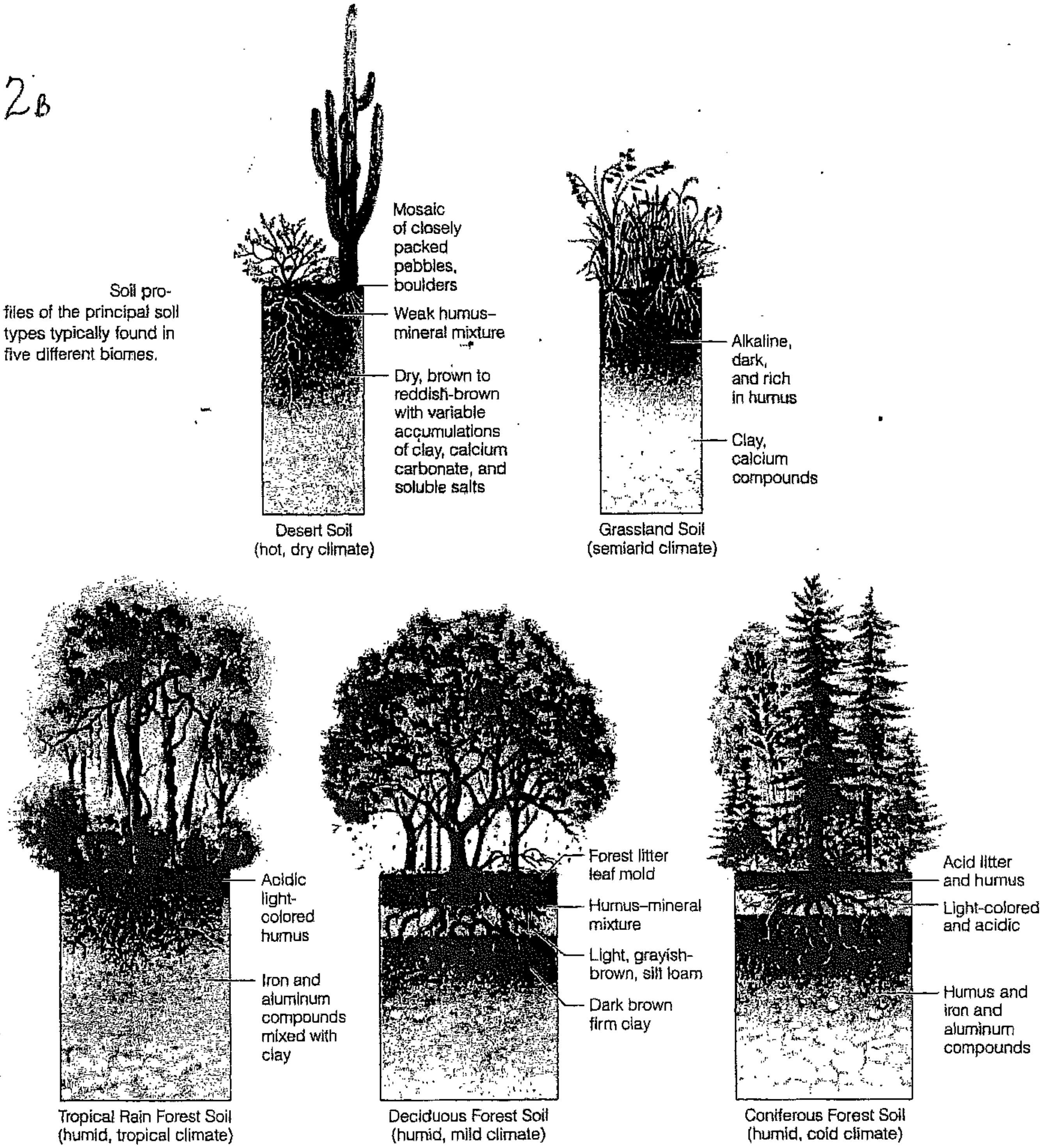
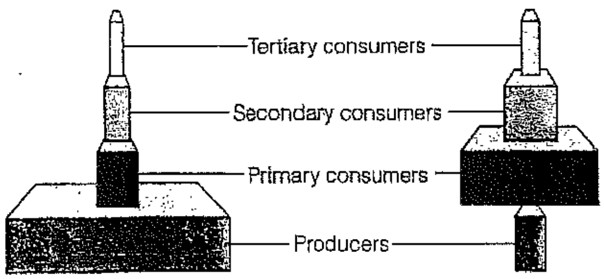
2B



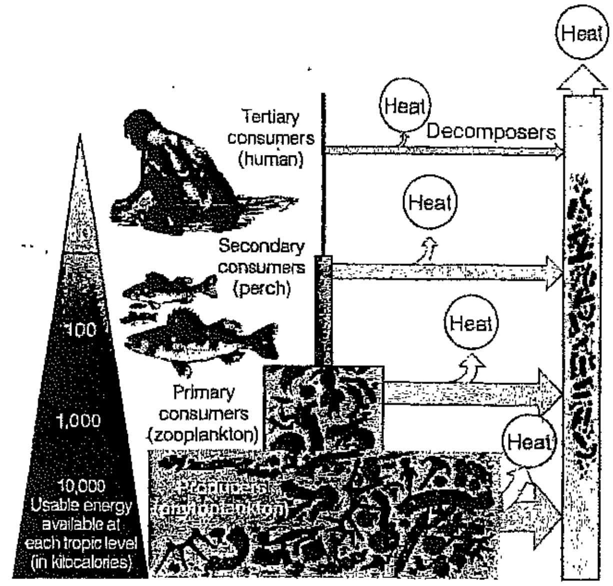
Soil profiles of the principal soil types typically found in five different biomes.

4

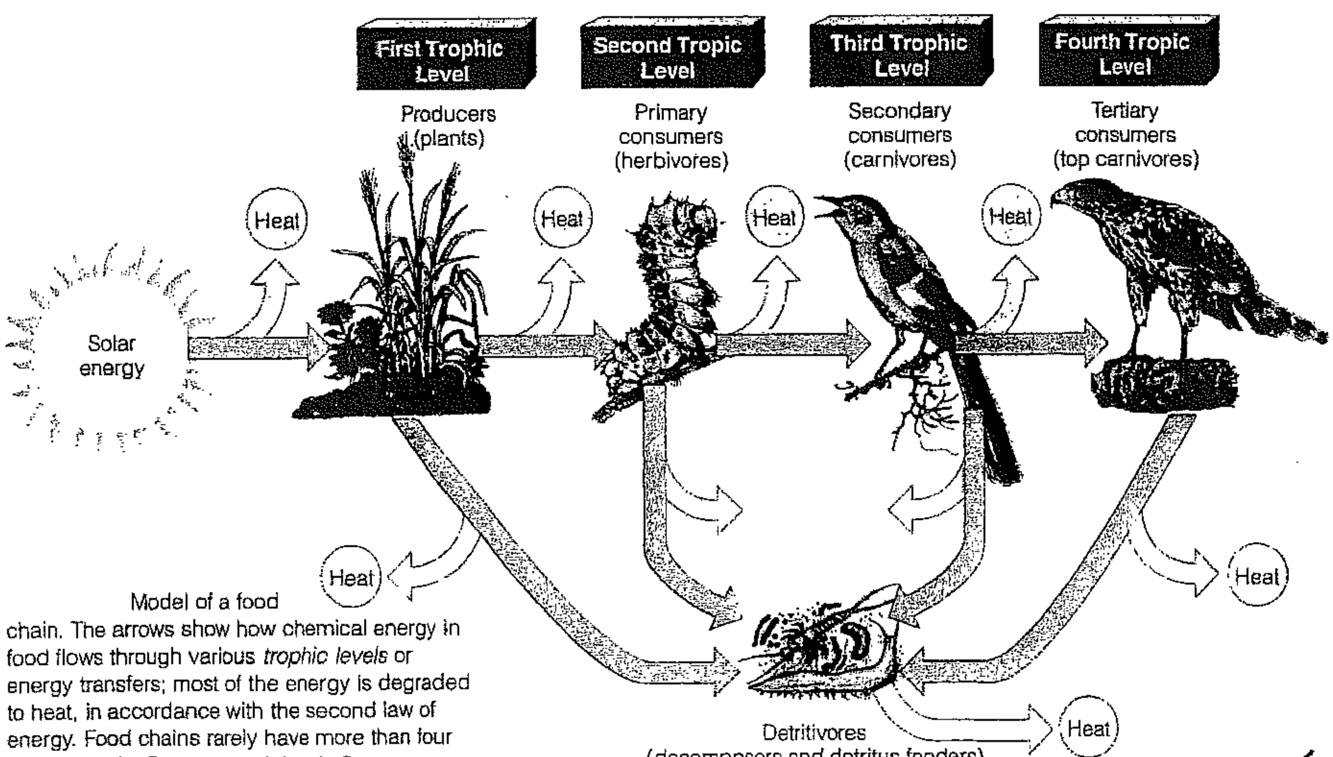
3 AND 4



Generalized graphs of *biomass of organisms* in the various trophic levels for two ecosystems. The size of each tier in this conceptual model represents the dry weight per square meter of all organisms at that trophic level.



Generalized *pyramid of energy flow* showing the decrease in usable energy available at each succeeding trophic level in a food chain or web. In nature, ecological efficiency varies from 5% to 20%, with 10% efficiency being common. This model assumes a 10% ecological efficiency (90% loss in usable energy to the environment, in the form of low-quality heat) with each transfer from one trophic level to another. Because of the degradation of energy quality required by the second law of energy, these models always have a pyramidal shape.



Model of a food chain. The arrows show how chemical energy in food flows through various *trophic levels* or energy transfers; most of the energy is degraded to heat, in accordance with the second law of energy. Food chains rarely have more than four trophic levels. Can you explain why?

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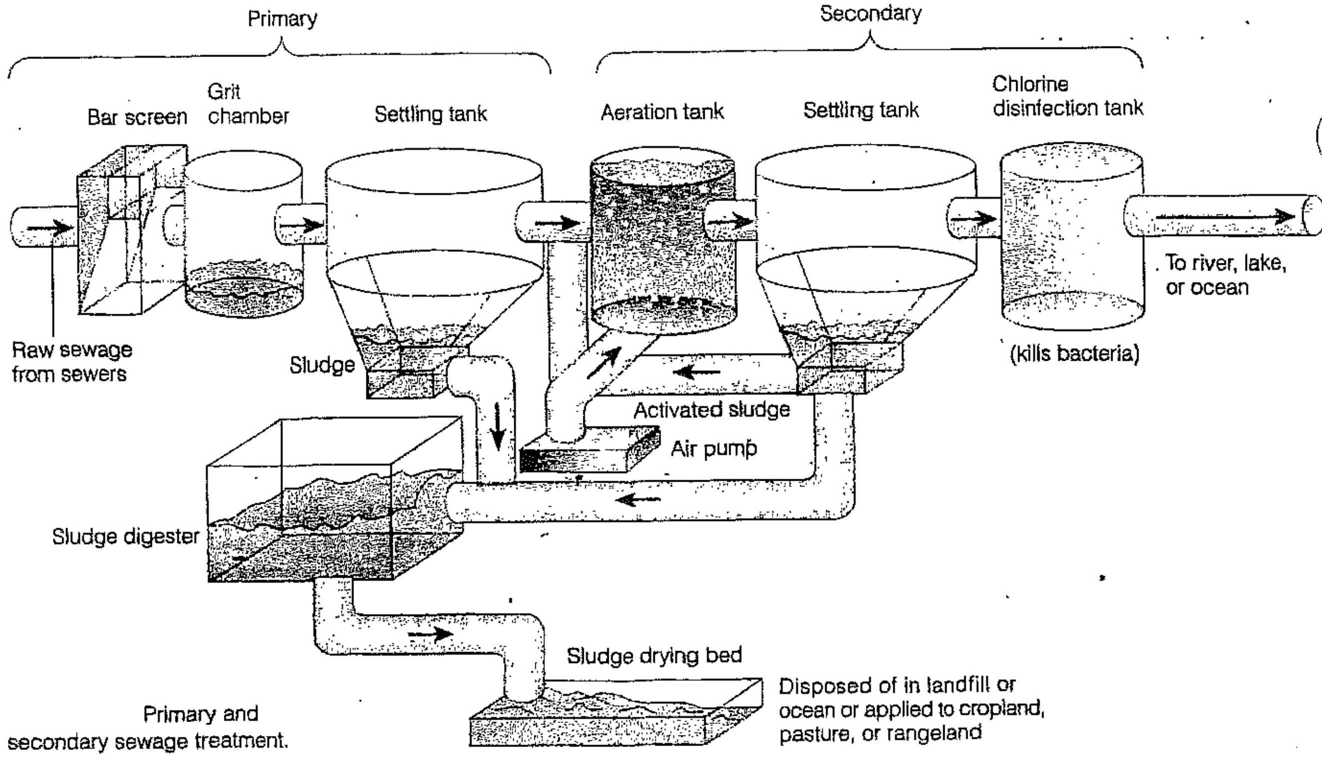
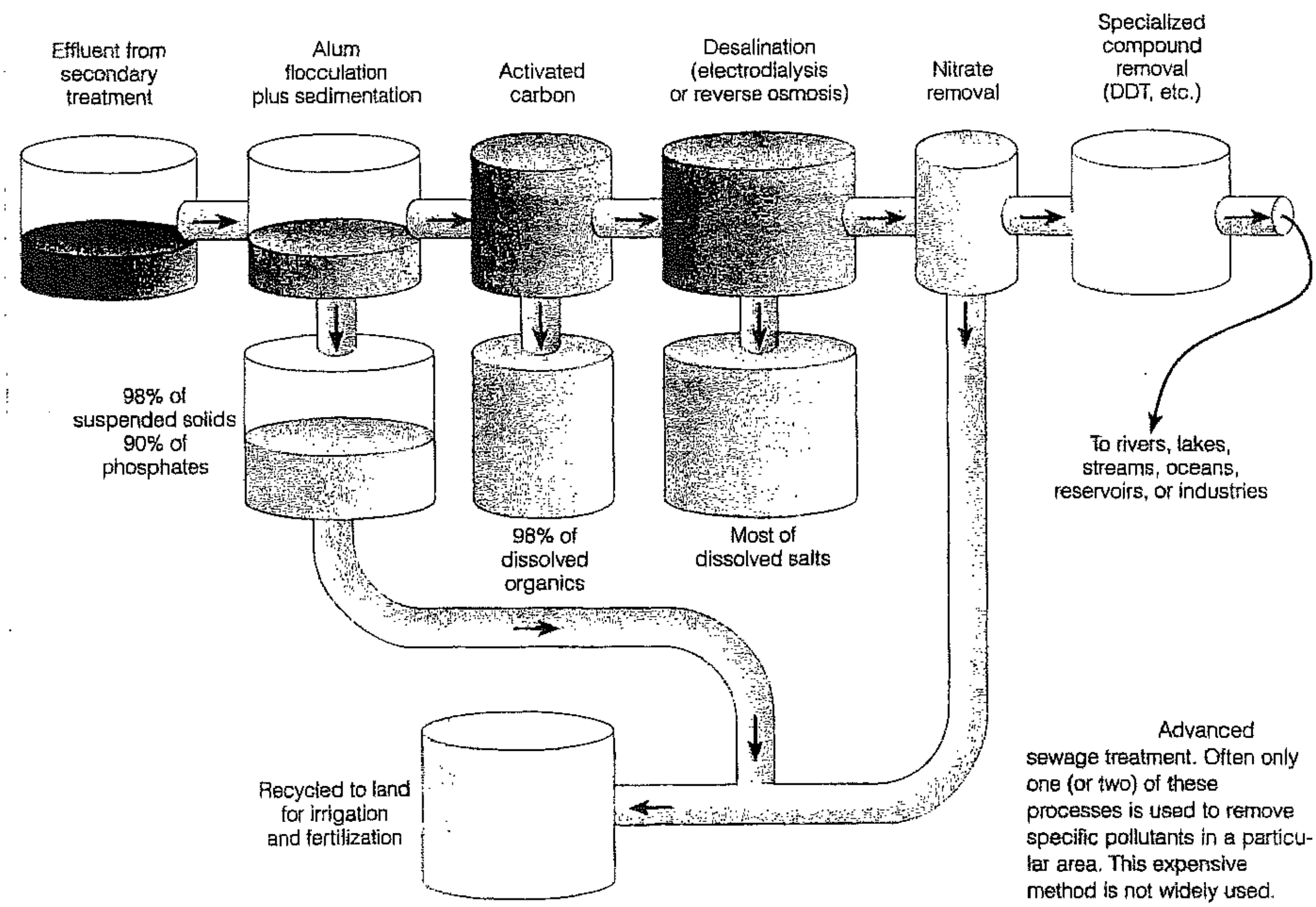


Primary and secondary sewage treatment.



Advanced sewage treatment. Often only one (or two) of these processes is used to remove specific pollutants in a particular area. This expensive method is not widely used.

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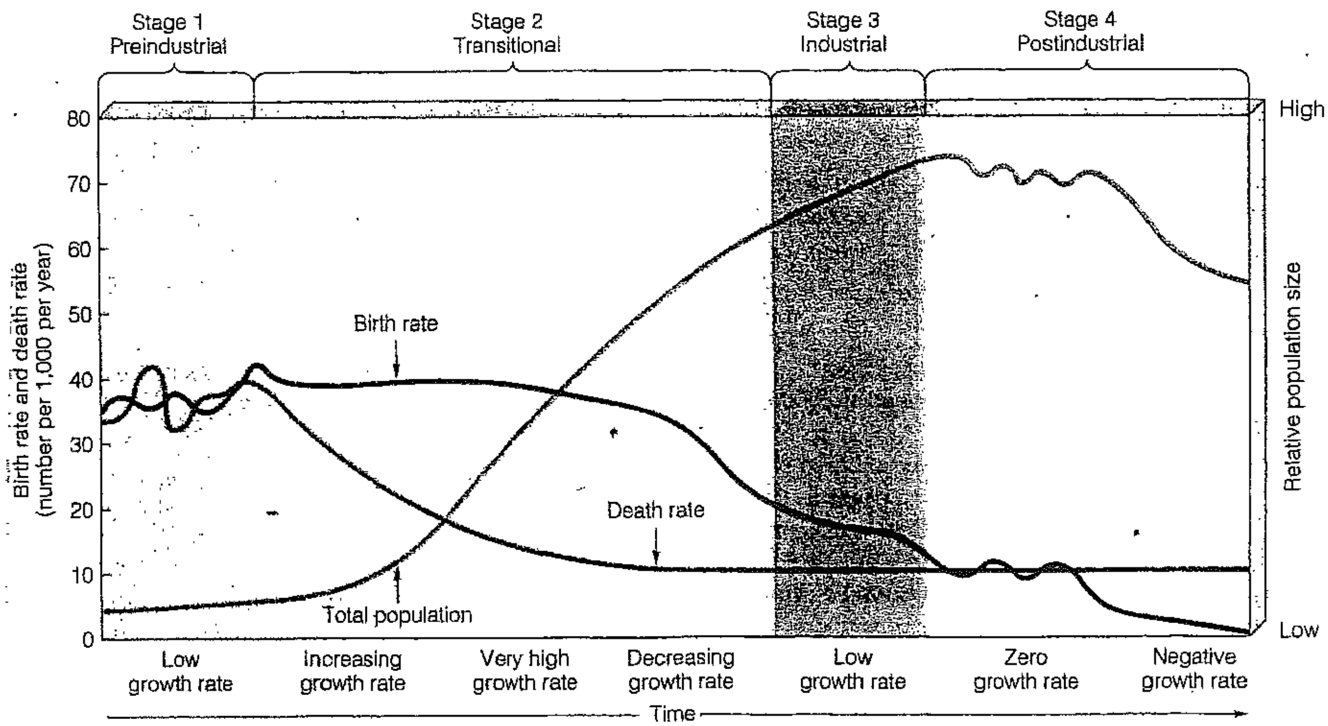

Generalized model of the demographic transition. (Data from United Nations)

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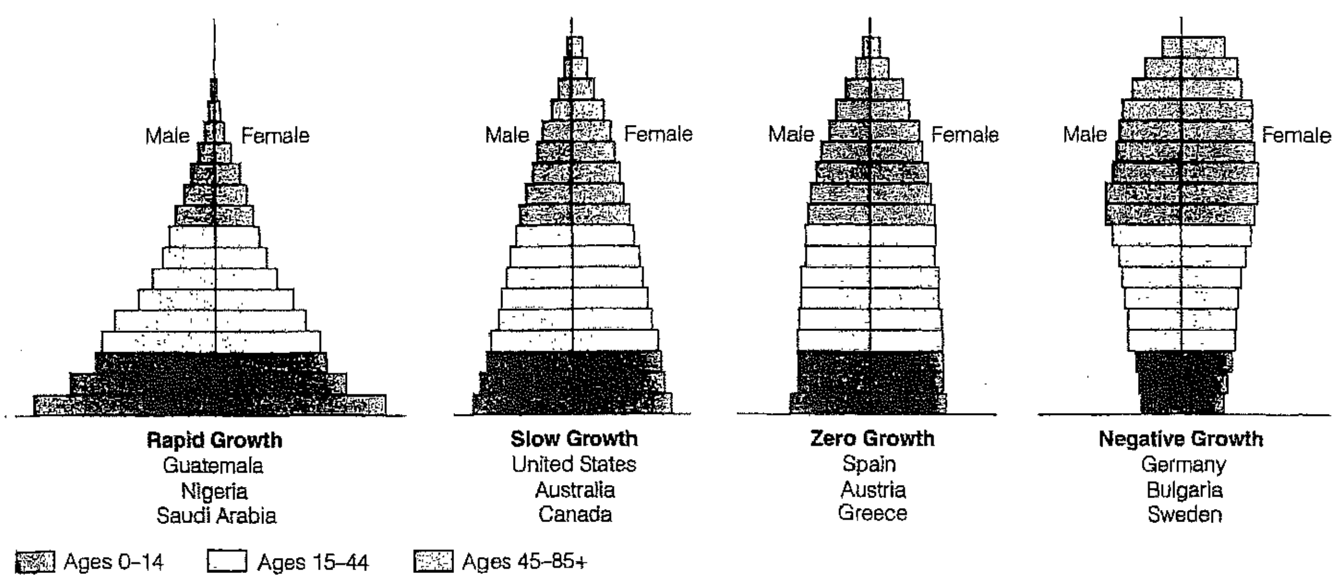

Generalized population age structure diagrams for countries with rapid (1.5-3%), slow (0.3-1.4%), zero (0-0.2%), and negative population growth rates. (Data from Population Reference Bureau)

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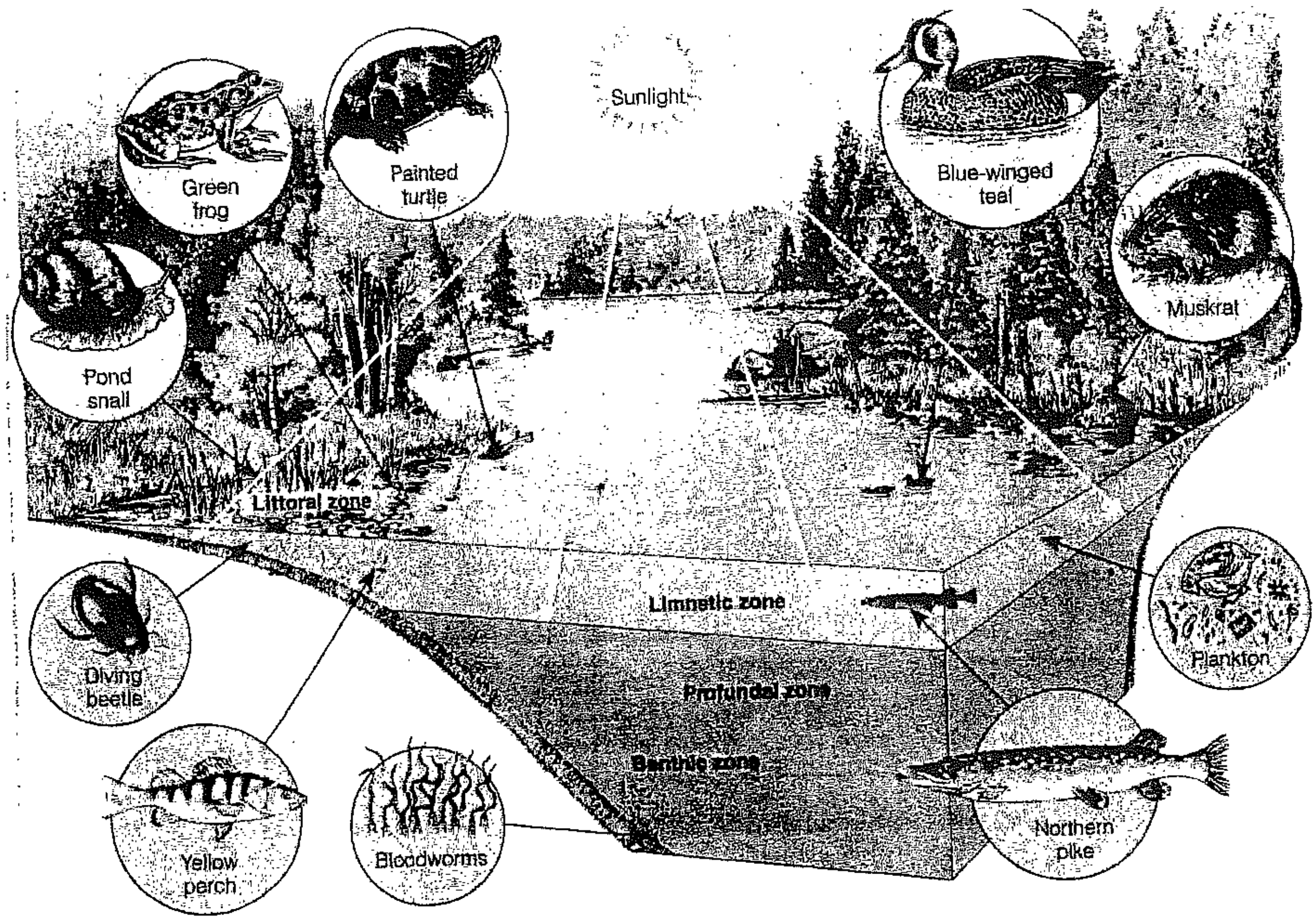
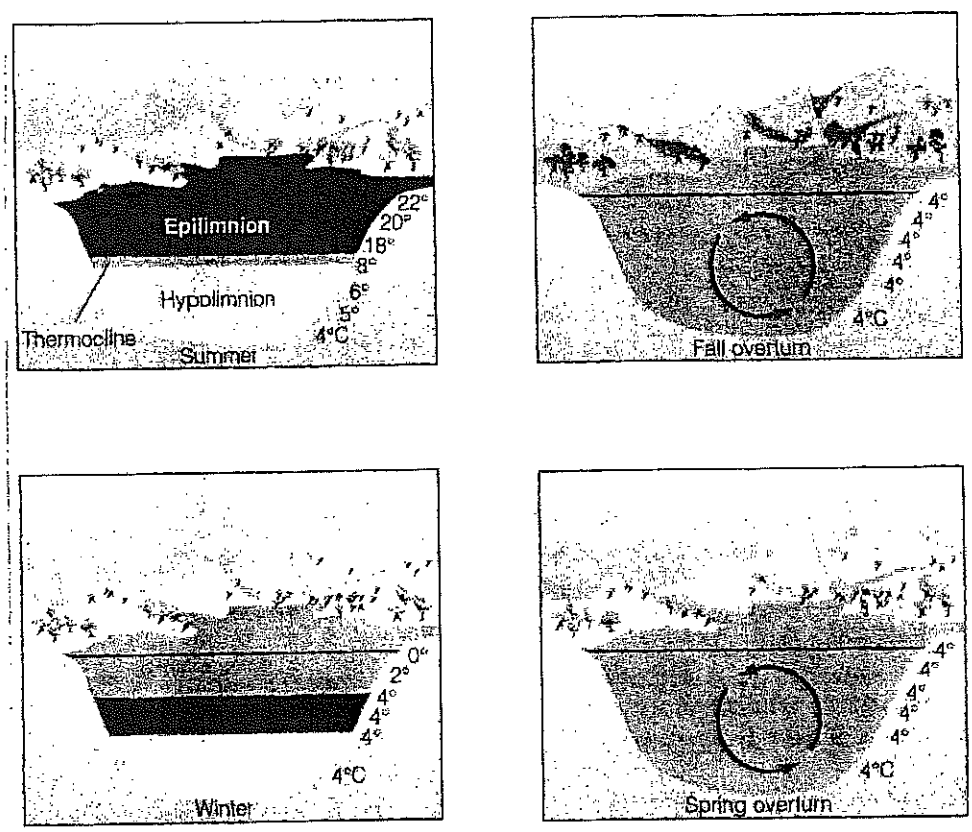


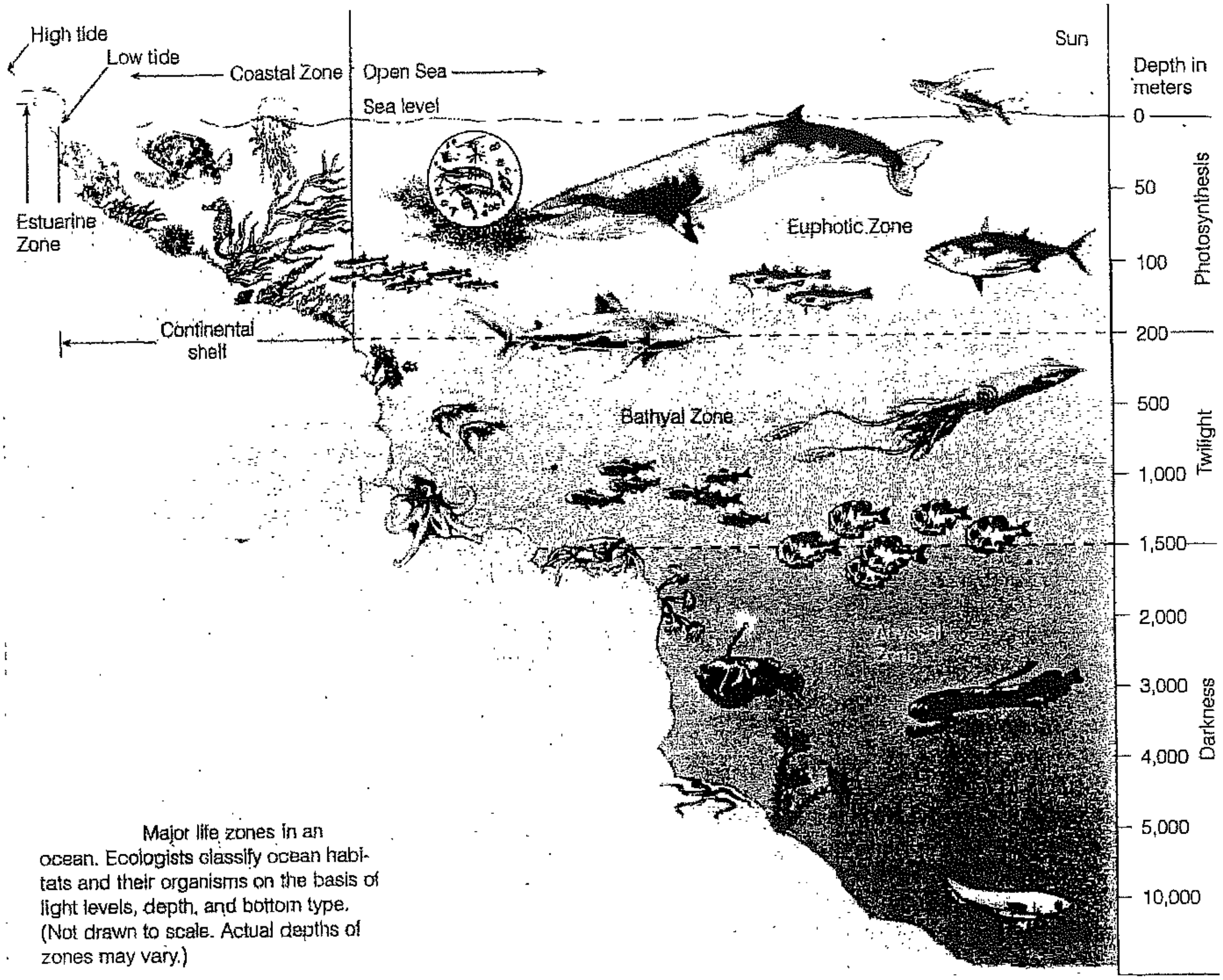
The distinct zones of life in a fairly deep temperate zone lake.



Dissolved O_2 concentration ■ High □ Medium □ Low

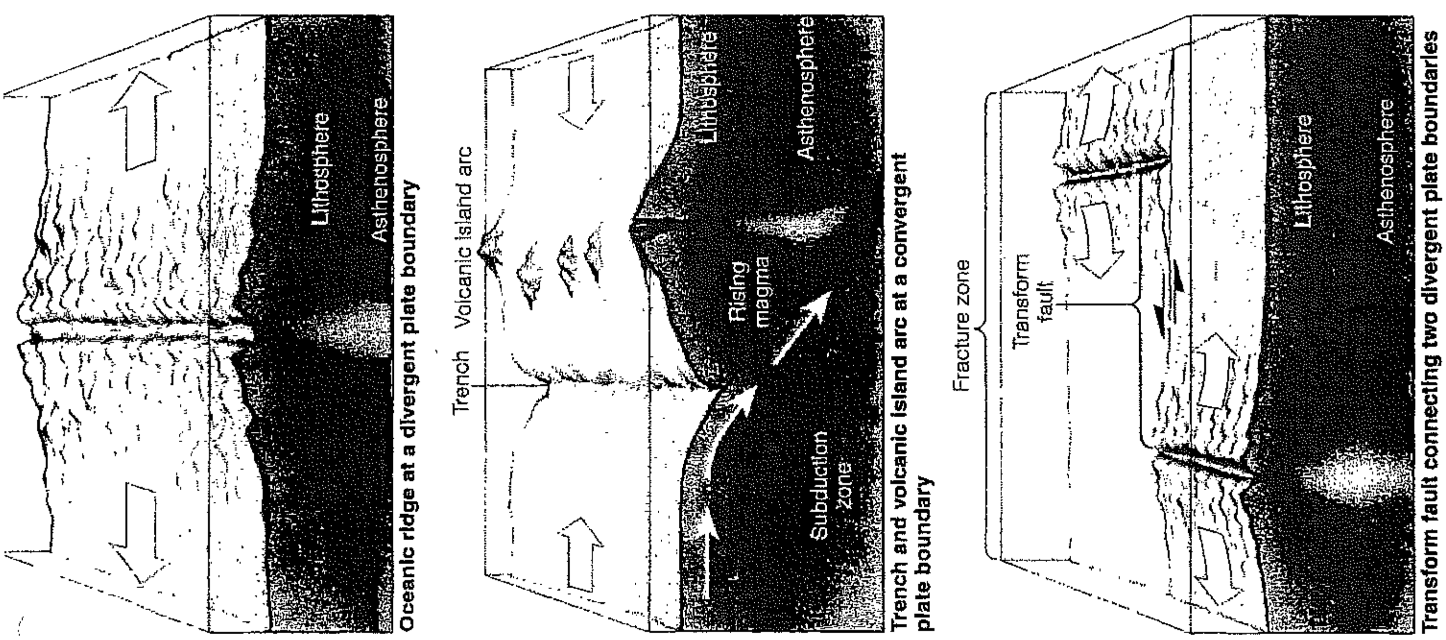
During the summer and winter, the water in deep temperate zone lakes becomes stratified into different temperature layers, which do not mix. Twice a year, in the fall and spring, the waters at all layers of these lakes mix in overturns that equalize the temperature at all depths. These overturns bring **(1)** oxygen from the surface water to the lake bottom and **(2)** nutrients from the lake bottom to the surface waters.

8



Major life zones in an ocean. Ecologists classify ocean habitats and their organisms on the basis of light levels, depth, and bottom type. (Not drawn to scale. Actual depths of zones may vary.)

12



Types of boundaries between the earth's lithospheric plates. All three boundary types occur both in oceans and on continents

12

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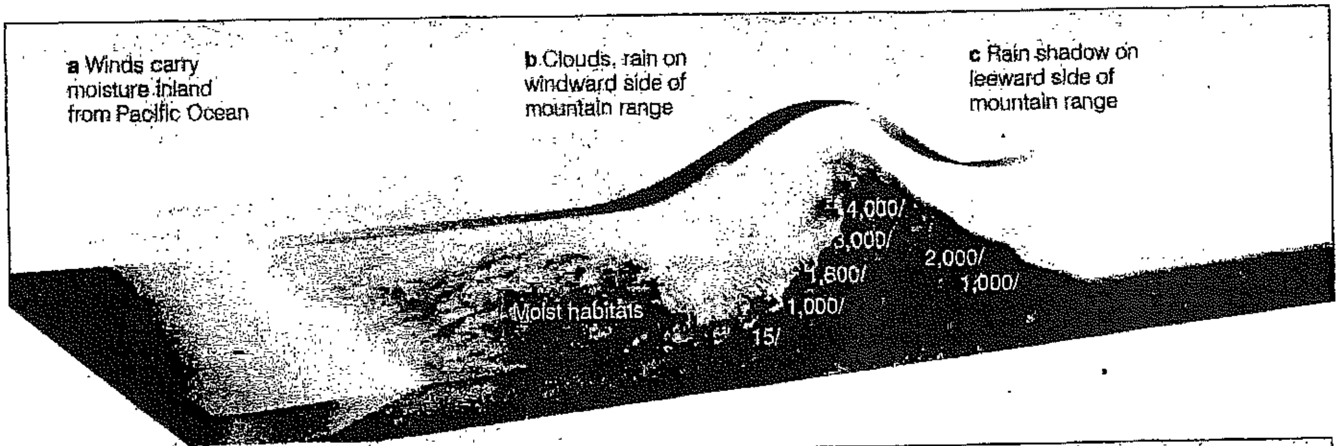
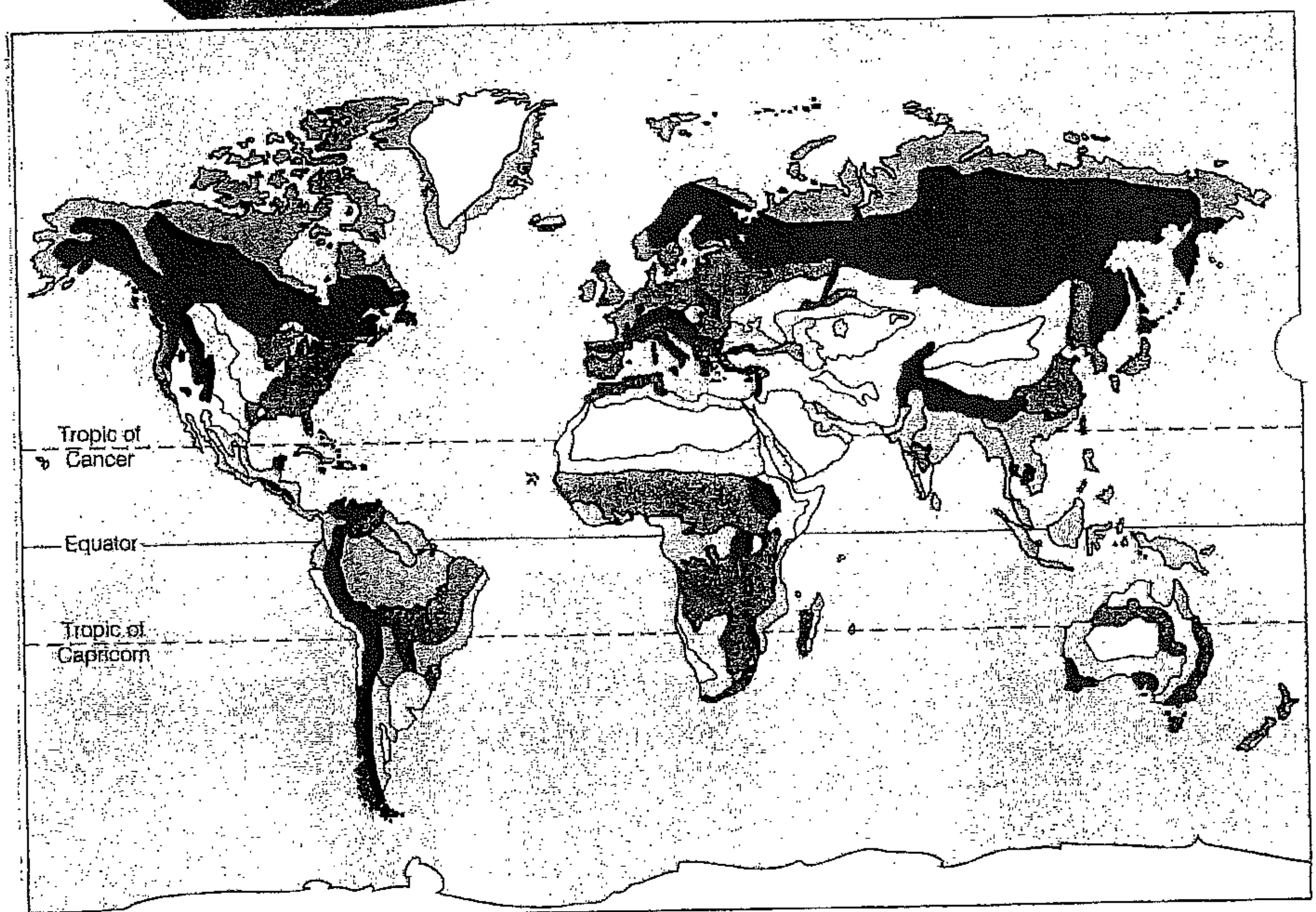
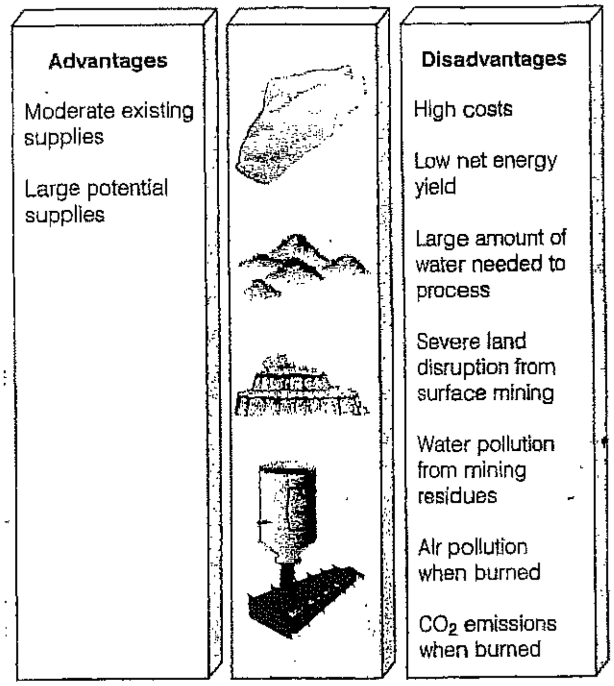
The rain shadow effect is a reduction of rainfall on the side of high mountains facing away from prevailing surface winds. It occurs when warm, moist air in prevailing onshore winds loses most of its moisture as rain and snow on the windward (wind-facing) slopes of a mountain range. This leads to semiarid and arid conditions on the leeward side of the mountain range and the land beyond. The Mojave Desert, east of the Sierra Nevada in California, is produced by this effect. Blue numbers represent average annual precipitation (in centimeters) in California's Sierra Nevada, and white numbers signify elevation (in meters). (From *Biology: Concepts and Principles*, 4th ed. by Cecie Starr ©2000)



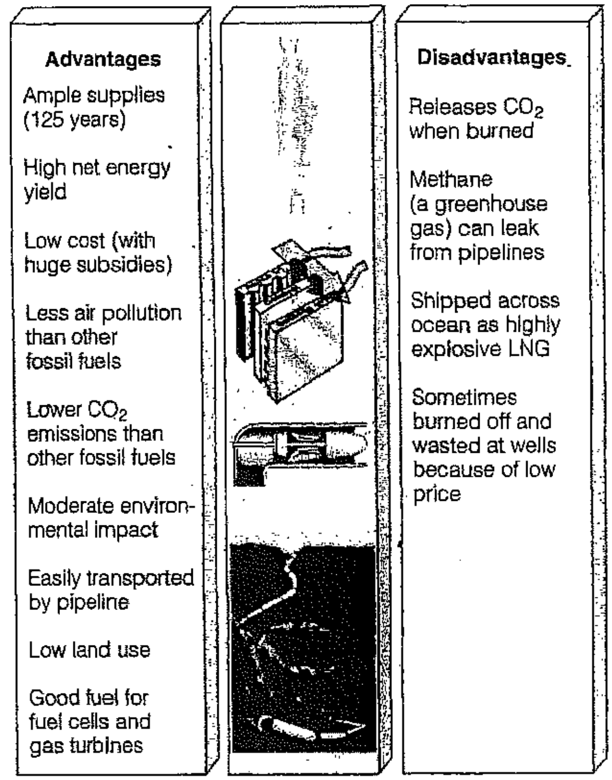


- Arctic tundra (polar grasslands)
- Boreal forest (taiga), evergreen coniferous forest (e.g., montane coniferous forest)
- Temperate deciduous forest
- Temperate grassland
- Dry woodlands and shrublands (chaparral)
- Desert
- Tropical rain forest, tropical evergreen forest
- Tropical deciduous forest
- Tropical scrub forest
- Tropical savanna, thorn forest
- Semidesert, arid grassland
- Mountains (complex zonation)
- Ice

The earth's major biomes—the main types of natural vegetation in different undisturbed land areas-result primarily from differences in climate. Each biome contains many ecosystems whose communities have adapted to differences in climate, soil, and other environmental factors. In reality, people have removed or altered much of this natural vegetation in some areas for farming, livestock grazing, lumber and fuelwood, mining, and construction, thereby altering the biomes

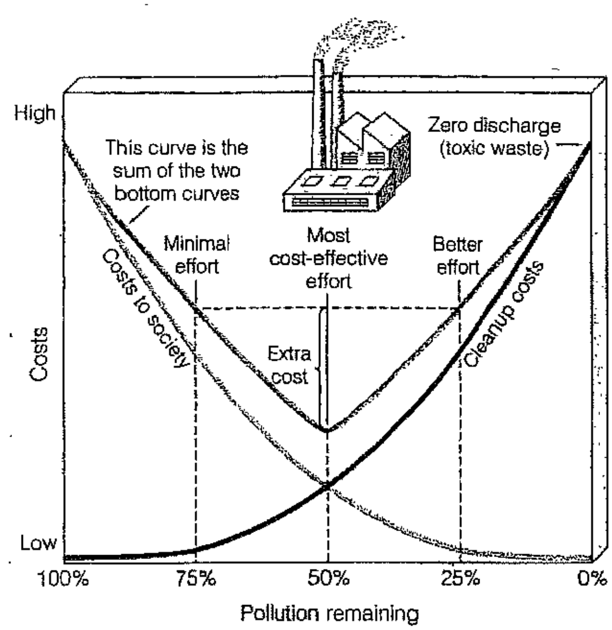


Advantages and disadvantages of using heavy oils from oil shale and tar sand as energy resources.

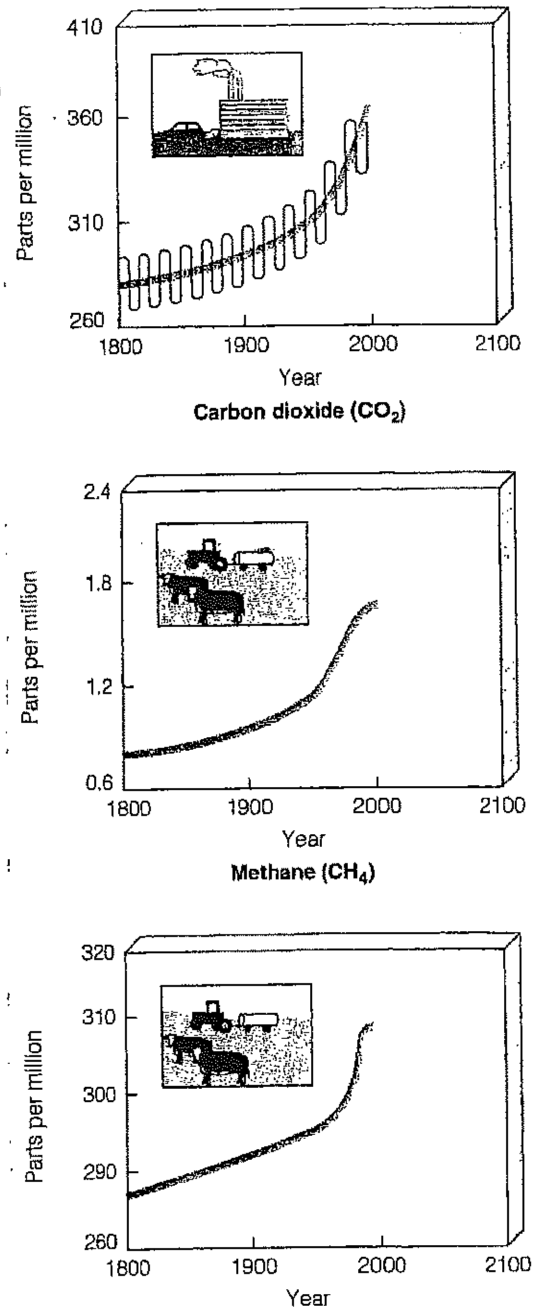


Advantages and disadvantages of using conventional natural gas as an energy resource.

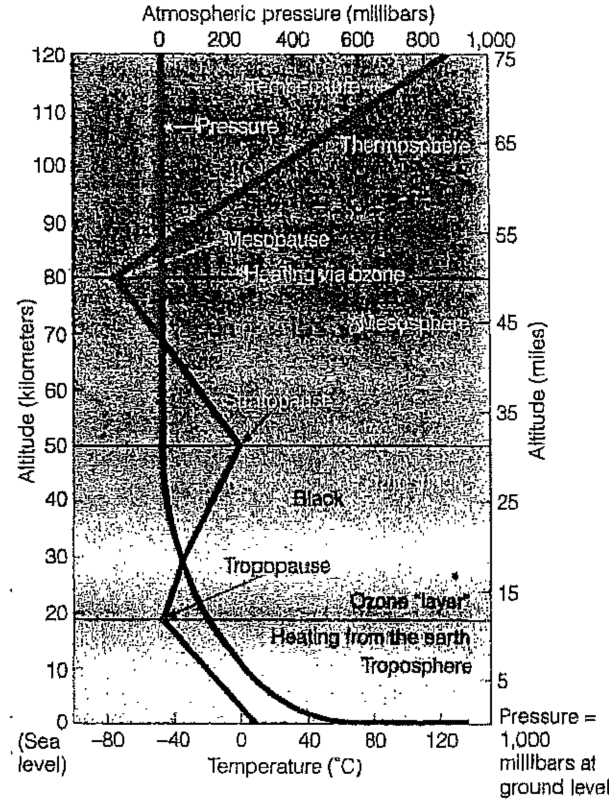
14



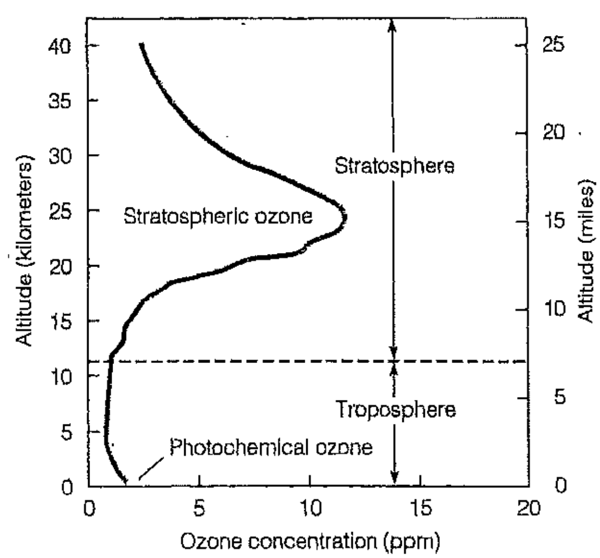
Finding the optimum level of pollution. This graph shows the optimum level at 50%, but the actual level varies depending on the pollutant.



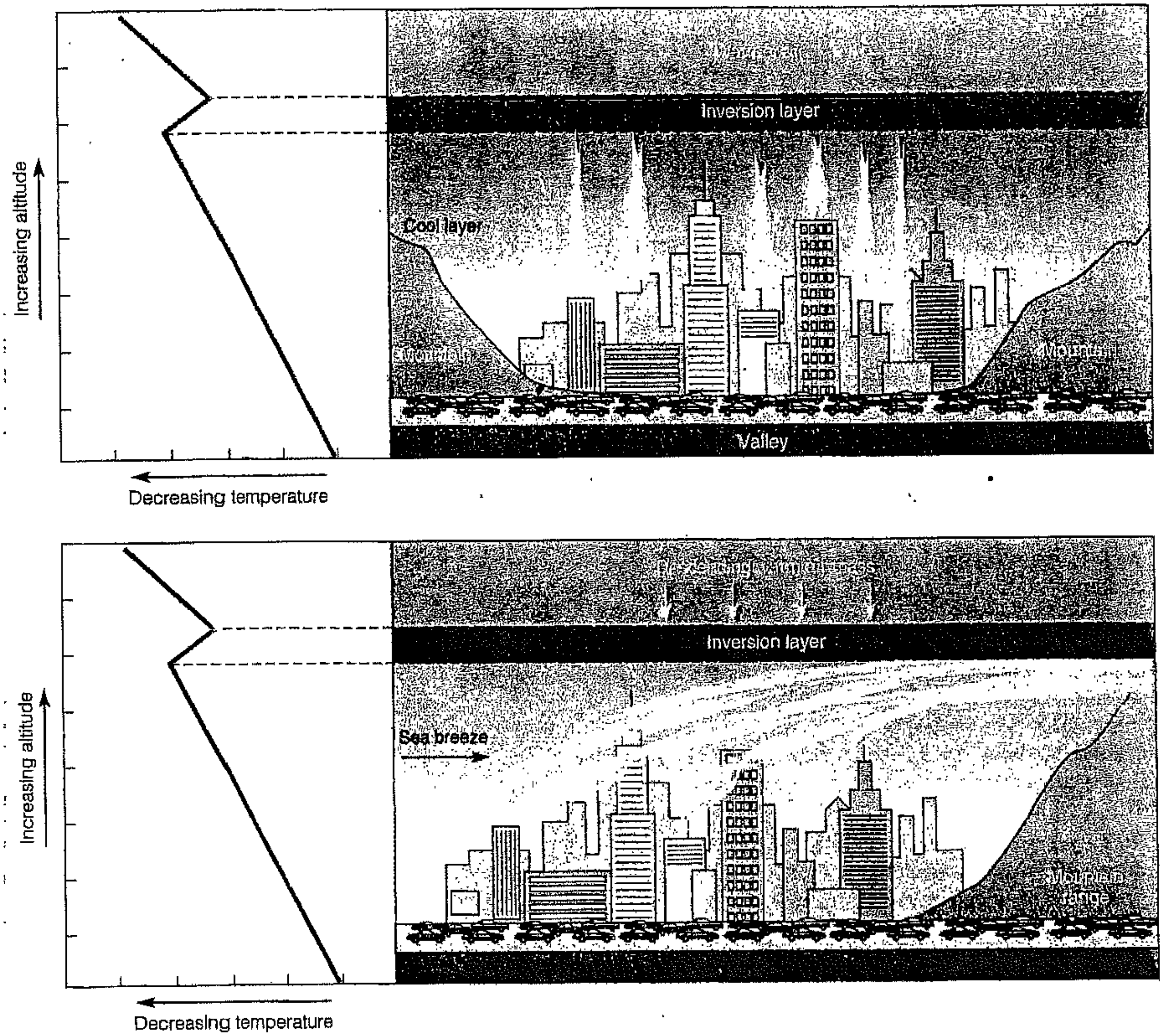
Increases in average concentrations of the greenhouse gases carbon dioxide, methane, and nitrous oxide in the troposphere between 1860 and 1999. (Data from Intergovernmental Panel on Climate Change, National Center for Atmospheric Research, and World Resources Institute)



The earth's current atmosphere consists of several layers. The average temperature of atmosphere varies with altitude (red line). The average temperature of the atmosphere at the earth's surface is determined by a combination of **(1)** *natural heating* by incoming sunlight and certain greenhouse gases that release absorbed energy as heat into the lower troposphere (the natural *greenhouse effect*, Figure 6-13, p. 128) and **(2)** *natural* cooling by surface evaporation of water and convection processes that transfer heat to higher altitudes and latitudes (Figure 6-7, p. 125, and Figure 6-8, p. 126). Most UV radiation from the sun is absorbed by ozone (O_3), which is found primarily in the stratosphere in the *ozone layer* between 17 and 26 kilometers (10 to 16 miles) above sea level.



Average distribution and concentrations of ozone in the troposphere and stratosphere. *Beneficial ozone* that forms in the stratosphere protects life on earth by filtering out of the incoming harmful ultraviolet radiation emitted by the sun. *Harmful* or *photochemical* ozone forms in the troposphere when various air pollutants undergo chemical reactions under the influence of sunlight. Ozone in this portion of the atmosphere near the earth's surface damages plants, lung tissues,



Topography and weather conditions that can create more frequent and prolonged *radiation temperature inversions*, in which a layer of warm air sits atop a cooler layer of air near the ground. In such cases, pollutant concentrations in the air near the earth's surface can build up to harmful levels. The top figure shows how air pollutants can build up in the air near the ground in a valley surrounded by mountains. The bottom figure shows how frequent and prolonged radiation temperature inversions can occur in an area (such as Los Angeles, California) with a sunny climate, light winds, mountains on three sides, and the ocean on the other. The layer of descending warm air (bottom) prevents ascending air currents from dispersing and diluting pollutants from the cooler air near the ground. Because of their topography, Los Angeles in the United States and Mexico City in Mexico have frequent thermal inversions, many of them prolonged during the summer.

Schematic of a waste-to-energy incinerator with pollution controls that burns mixed solid waste and recovers some of the energy to produce steam used for heating or producing electricity. (Adapted from EPA, *Let's Reduce and Recycle*)

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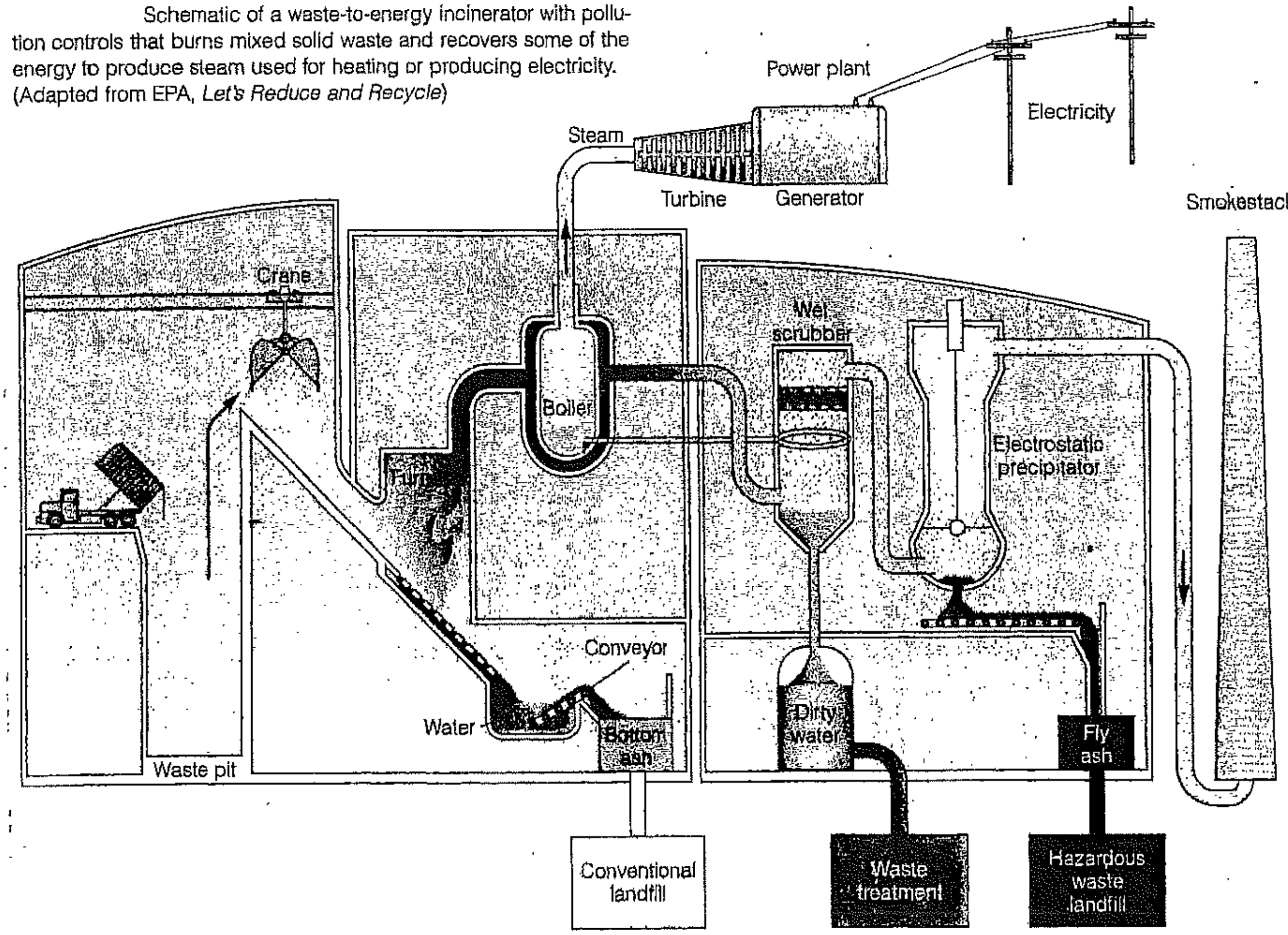
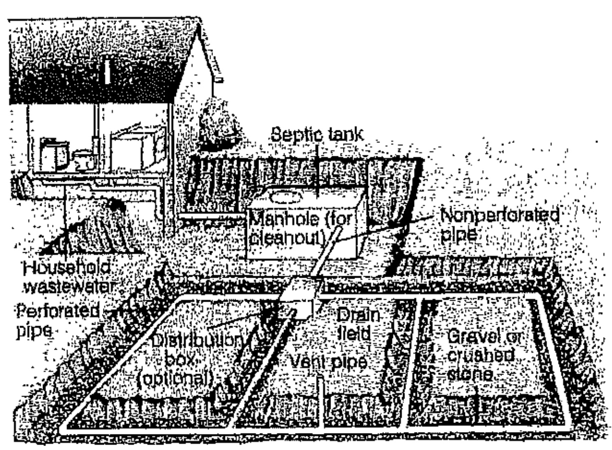


Septic tank system used for disposal of domestic sewage and wastewater in rural and suburban areas. This system traps greases and large solids and discharges the remaining wastes over a large drainage field. As these wastes percolate downward, the soil filters out some potential pollutants, and soil bacteria decompose biodegradable materials. To be effective, septic tank systems must be **(1)** properly installed in soils with adequate drainage, **(2)** not placed too close together or too near well sites, and **(3)** pumped out when the settling tank becomes full.



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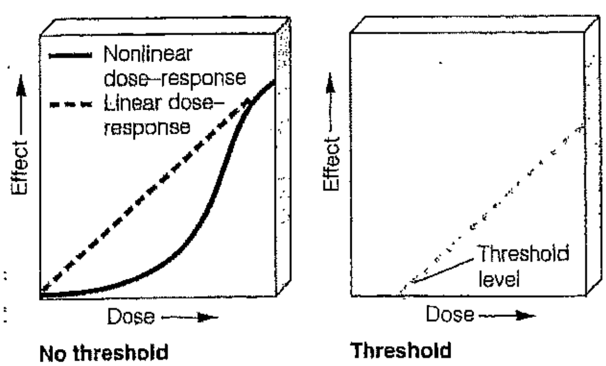

Hypothetical dose–response curves. The linear and nonlinear curves in the left graph show that exposure to any dosage of a chemical or ionizing radiation has a harmful effect that increases with the dosage. The curve on the right shows that a harmful effect occurs only when the dosage exceeds a certain *threshold level.* There is much uncertainty about which of these models applies to various harmful agents because of the difficulty in estimating the response to very low dosages. (Adapted from *Environmental Science,* 5/E by Chiras, p. 352, fig. 19.12. Copyright ©1998 by Wadsworth)

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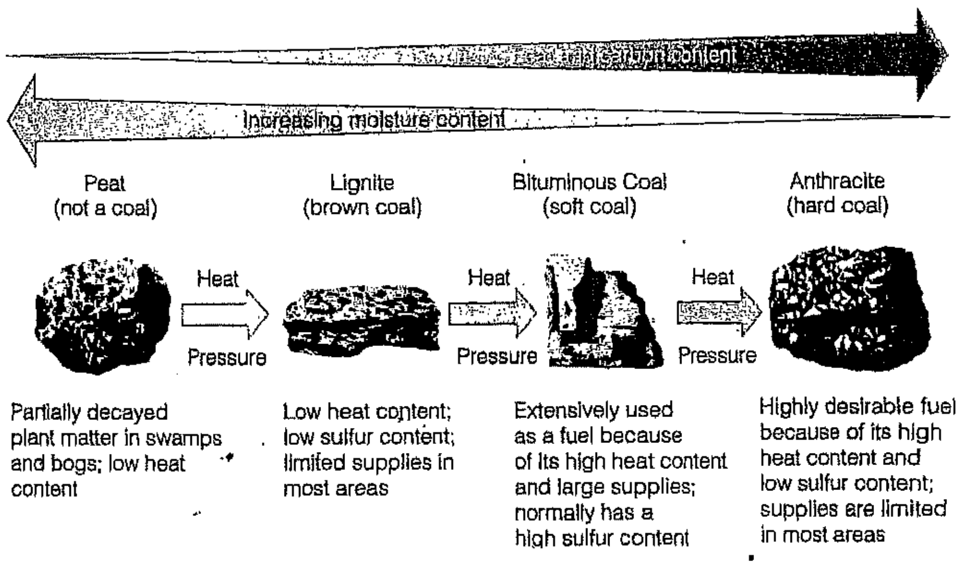
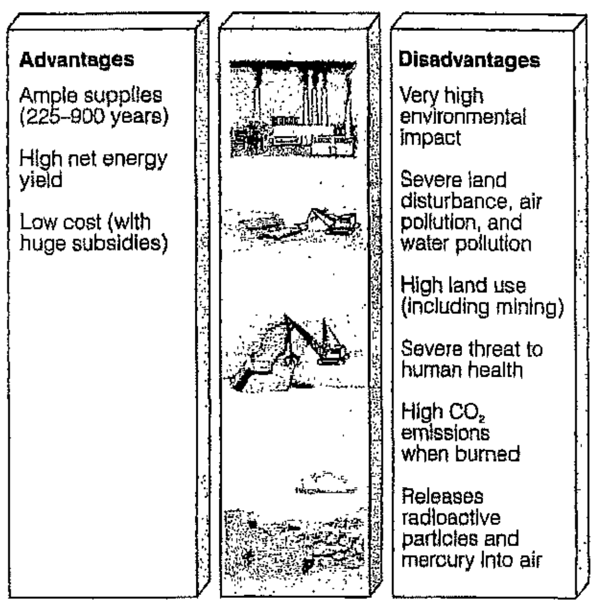
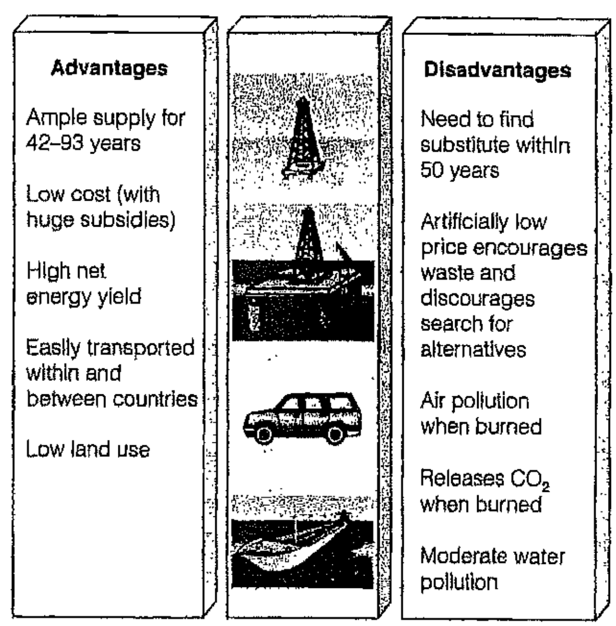
22

Stages in coal formation over millions of years. Peat is a soil material made of moist, partially decomposed organic matter. Lignite and bituminous coal are sedimentary rocks, whereas anthracite is a metamorphic rock.





Advantages and disadvantages of using coal as an energy resource.



Advantages and disadvantages of using conventional oil as an energy resource.

16

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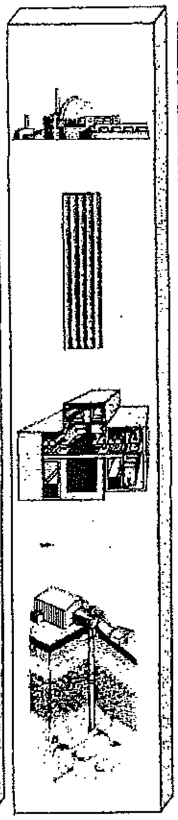
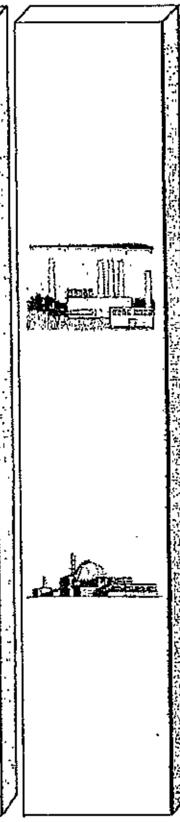


Advantages	Disadvantages
Large fuel supply	High cost (even with large subsidies)
Low environmental impact (without accidents)	Low net energy yield
Emits 1/6 as much CO_2 as coal	High environmental impact (with major accidents)
Moderate land disruption and water pollution (without accidents)	Catastrophic accidents can happen (Chernobyl)
Moderate land use	No acceptable solution for long-term storage of radioactive wastes and decommissioning worn-out plants
Low risk of accidents because of multiple safety systems (except in 35 poorly designed and run reactors in former Soviet Union and Eastern Europe)	Spreads knowledge and technology for building nuclear weapons

Advantages and disadvantages of using nuclear power to produce electricity. This evaluation includes the entire nuclear fuel cycle (Figure 14-33).

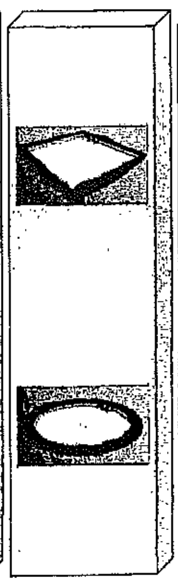
22



Coal	Nuclear
Ample supply	Ample supply of uranium
High net energy yield	Low net energy yield
Very high air pollution	Low air pollution (mostly from fuel reprocessing)
High CO_2 emissions	Low CO_2 emissions (mostly from fuel reprocessing)
65,000 to 200,000 deaths per year in U.S.	About 6,000 deaths per year in U.S.
High land disruption from surface mining	Much lower land disruption from surface mining
High land use	Moderate land use
Low cost (with huge subsidies)	High cost (with huge subsidies)

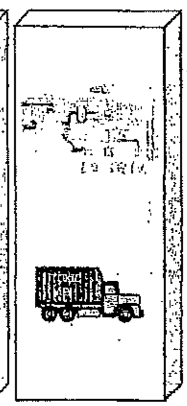
Comparison of the risks of using nuclear power and coal-burning plants to produce electricity.

25



Advantages	Disadvantages
Inexpensive	Groundwater contamination from leaking liners (or no lining)
Can store wastes indefinitely with secure double liners	Air pollution from volatile organic compounds
	Overflow from flooding
	Disruption and leakage from earthquakes
	Promotes waste production

Advantages and disadvantages of storing liquid hazardous wastes in surface impoundments.



Advantages	Disadvantages
Reduced trash volume	High cost
Less need for landfills	Air pollution (especially toxic dioxins)
Low water pollution	Produces a highly toxic ash
	Encourages waste production

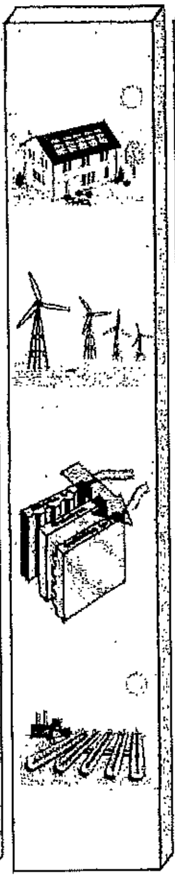
Advantages and disadvantages of incinerating solid and hazardous waste.

23

Major advantages and disadvantages of using direct and indirect solar energy systems to produce heat and electricity. Specific advantages and disadvantages of different direct and indirect solar and other renewable energy systems are discussed in this chapter.

Advantages

- Save money (wind)
- Reduce air pollution (99% less than coal)
- Greatly reduce CO_2 emissions
- Reduce dependence on imported oil
- Last as long as coal and nuclear plants (30–40 years)
- Land use less than for coal
- Low land use with new solar cell and window glass system
- Backup and storage devices available (such as gas turbines, batteries, and flywheels)
- Backup need reduced by distributing and storing solar-produced hydrogen gas



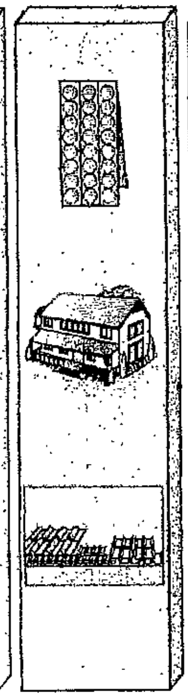
Disadvantages

- Making solar cells produces toxic chemicals
- Solar systems last only 30–40 years
- Take large amounts of land because of diffuse nature of sunlight
- Can damage fragile desert ecosystems used to collect solar energy
- Need backup systems at night and during cloudy and rainy weather

23

Advantages

- Fairly high net energy
- Work on cloudy days
- Quick installation
- Easily expanded or moved
- No CO_2 emissions
- Low environmental impact
- Last 20–40 years
- Low land use (if on roof)



Disadvantages

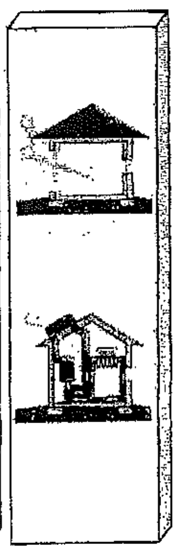
- Need access to sun
- Sun access can be blocked
- Low efficiency
- Need electricity storage system or backup
- High land use (solar cell power plants) could disrupt desert areas
- High costs (but should be competitive in 5–15 years)
- DC current must be converted to AC

Advantages and disadvantages of using solar cells to produce electricity.

23

Advantages

- Energy is free
- Net energy is moderate (active) to high (passive)
- Quick installation
- No CO_2 emissions
- Very low air and water pollution
- Very low land disturbance (built into roof or window)
- Moderate cost (passive)



Disadvantages

- Need access to sun 60% of time
- Blockage of sun access by other structures
- Need heat storage system
- High cost (active)
- Active system needs maintenance and repair
- Active collectors unattractive

Advantages and disadvantages of heating a house with passive or active solar energy.

23

Advantages

- Moderate net energy
- Moderate environmental impact
- No CO_2 emissions
- Fast construction (1–2 years)
- Costs reduced with natural gas turbine backup

Disadvantages

- Low efficiency
- High costs
- Needs backup or storage system
- Need access to sun most of the time
- High land use
- May disturb desert areas

Advantages and disadvantages of using solar energy to generate high-temperature heat and electricity.

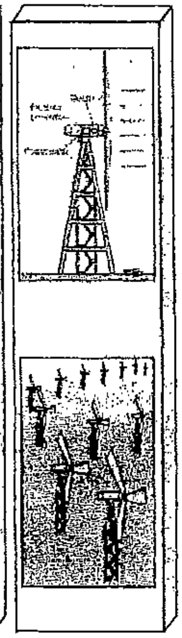
18

23

Advantages and disadvantages of using wind to produce electricity. Wind power experts project that by 2050 wind power could supply more than 10% of the world's electricity and 10–25% of the electricity used in the United States.

Advantages

- Moderate to high net energy
- High efficiency
- Moderate capital cost
- Low electricity cost (and falling)
- Very low environmental impact
- No CO_2 emissions
- Quick construction
- Easily expanded



Disadvantages

- Steady winds needed
- Backup systems when needed winds are low
- High land use for wind farm
- Visual pollution
- Noise when located near populated areas
- May interfere in flights of migratory birds and kill birds of prey

23

Advantages

- Moderate to high net energy
- High efficiency (80%)
- Low-cost electricity
- Long life span
- No CO_2 emissions during operation
- May provide flood control below dam
- Provides water for year-round irrigation

Disadvantages

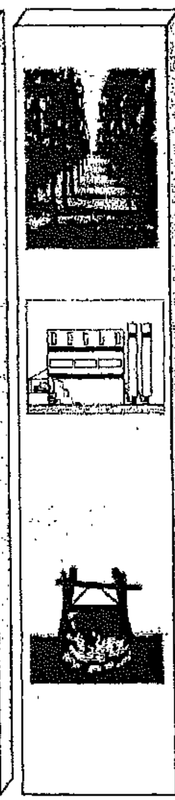
- High construction costs
- High environmental impact
- High CO_2 emissions from biomass decay in shallow tropical reservoirs
- Floods natural areas
- Converts land habitat to lake habitat
- Danger of collapse
- Uproots people
- Decreases fish harvest below dam
- Decreases flow of natural fertilizer (silt) to land below dam

Advantages and disadvantages of using large dams and reservoirs to produce electricity.

23

Advantages

- Large potential supply
- Moderate costs
- No net CO_2 increase if harvested and burned sustainably
- Plantation can be located on semiarid land not needed for crops
- Plantation can help restore degraded lands



Disadvantages

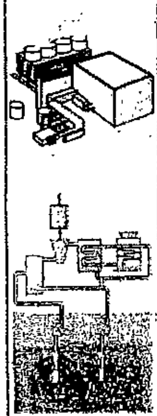
- Nonrenewable if harvested unsustainably
- Moderate to high environmental impact
- CO_2 emissions if harvested and burned unsustainably
- Low photosynthetic efficiency
- Soil erosion, water pollution, and loss of wildlife habitat
- Plantations could compete with cropland
- Often burned in inefficient and polluting open-fires and stoves

General advantages and disadvantages of burning solid biomass as a fuel.

23

Advantages

- Very high efficiency
- Moderate net energy at accessible sites
- Lower CO_2 emissions than fossil fuels
- Low cost at favorable sites
- Low land use
- Low land disturbance
- Moderate environmental impact



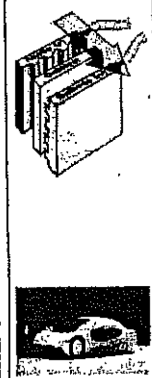
Disadvantages

- Scarcity of suitable sites
- Depleted if used too rapidly
- CO_2 emissions
- Moderate to high local air pollution
- Noise and odor (H_2S)

Advantages and disadvantages of using geothermal energy for space heating and to produce electricity or high-temperature heat for industrial processes.

Advantages

- Can be produced from water
- Low environmental impact
- No CO_2 emissions
- Good substitute for oil
- Competitive price if environmental and social costs are included in cost comparisons
- Easier to store than electricity
- Safer than gasoline and natural gas
- High efficiency (65–95%) in fuel cells



Disadvantages

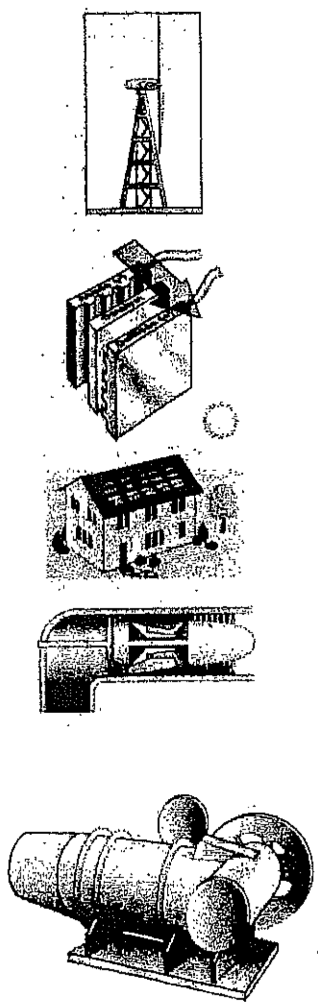
- Not found in nature
- Energy is needed to produce fuel
- Negative net energy
- High costs (but expected to come down)
- Short driving range for current fuel cell cars

Advantages and disadvantages of using hydrogen as a fuel for vehicles and for providing heat and electricity.

23

23

- Small modular units
- Fast factory production
- Fast installation (hours to days)
- Can add or remove modules as needed
- High energy efficiency (60–80%)
- Low or no CO_2 emissions
- Low air pollution emissions
- Reliable
- Easy to repair
- Much less vulnerable to power outages
- Useful anywhere
- Especially useful in rural areas in developing countries with no power
- Can use locally available renewable energy resources
- Easily financed (costs included in mortgage and commercial loan)



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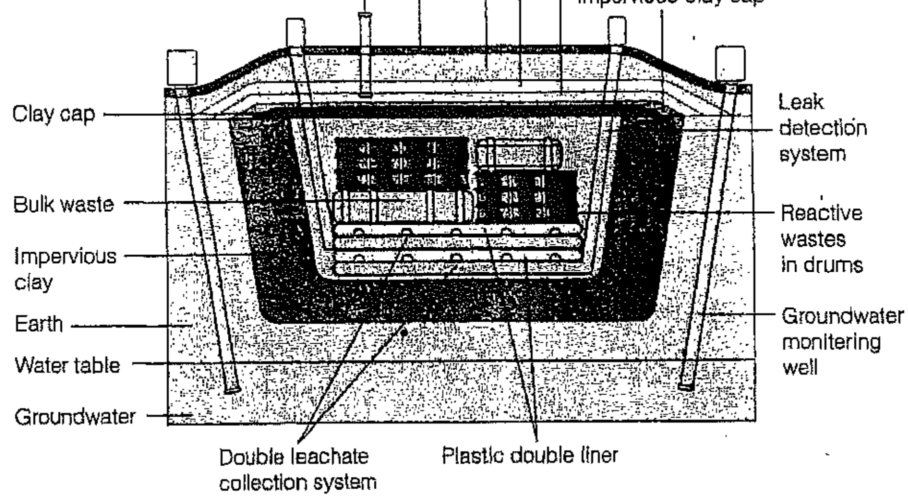
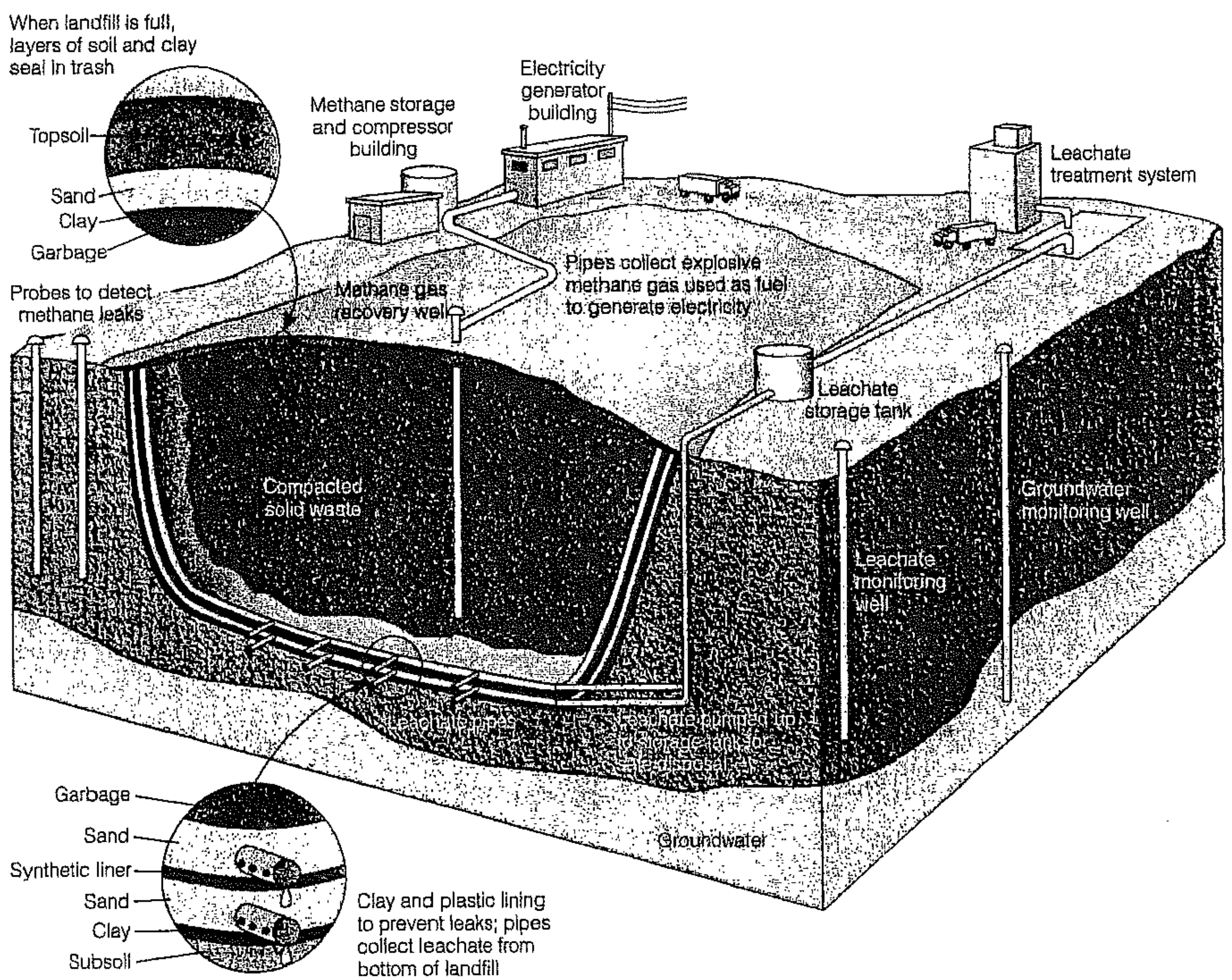
Some advantages of micropower systems.

25



Secure hazardous-waste landfill.

21



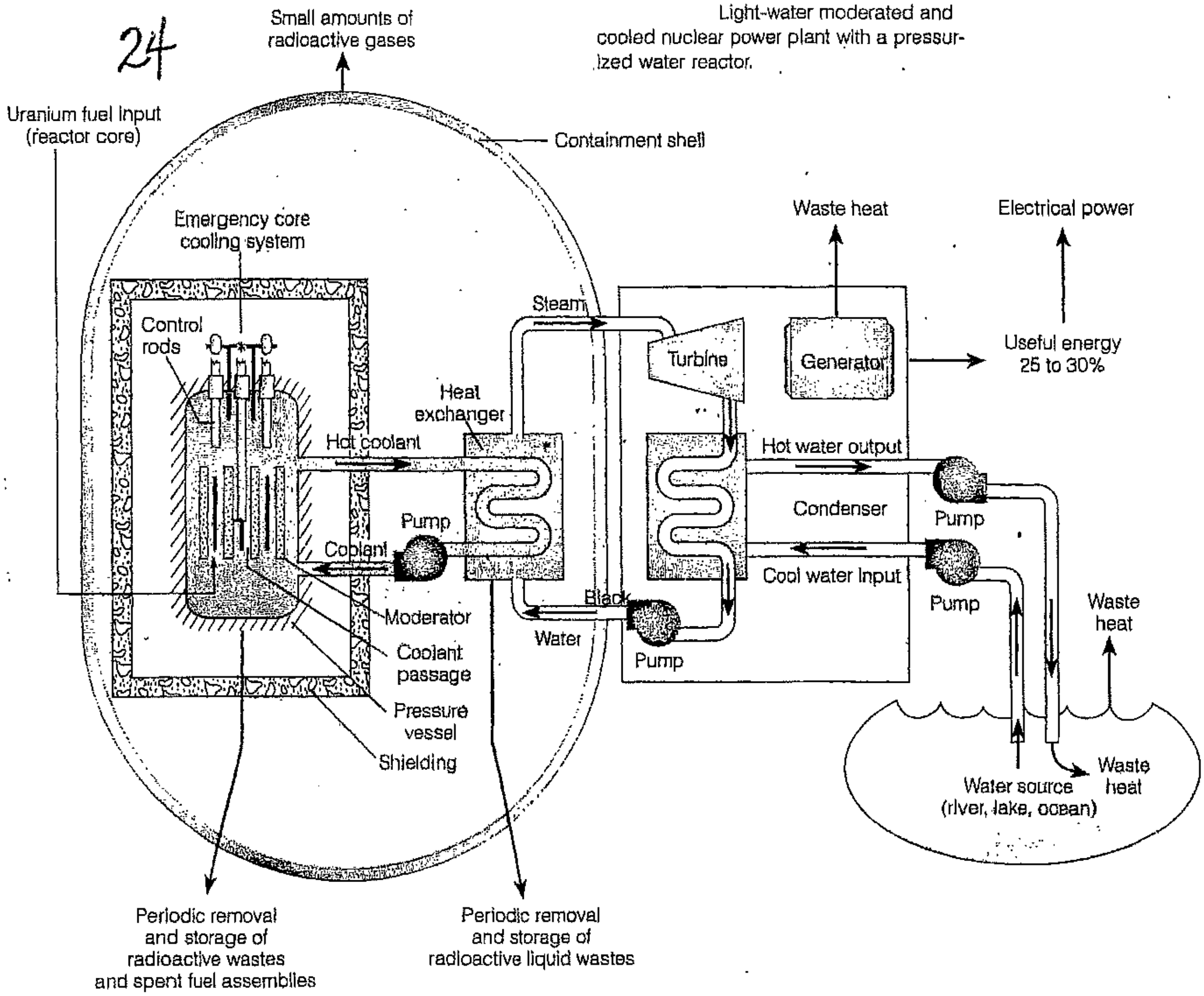
State-of-the-art sanitary landfills are designed to eliminate or minimize environmental problems that plague older landfills. Even such state-of-the-art landfills are expected to leak eventually, passing both the effects of contamination and cleanup costs on to future generations.

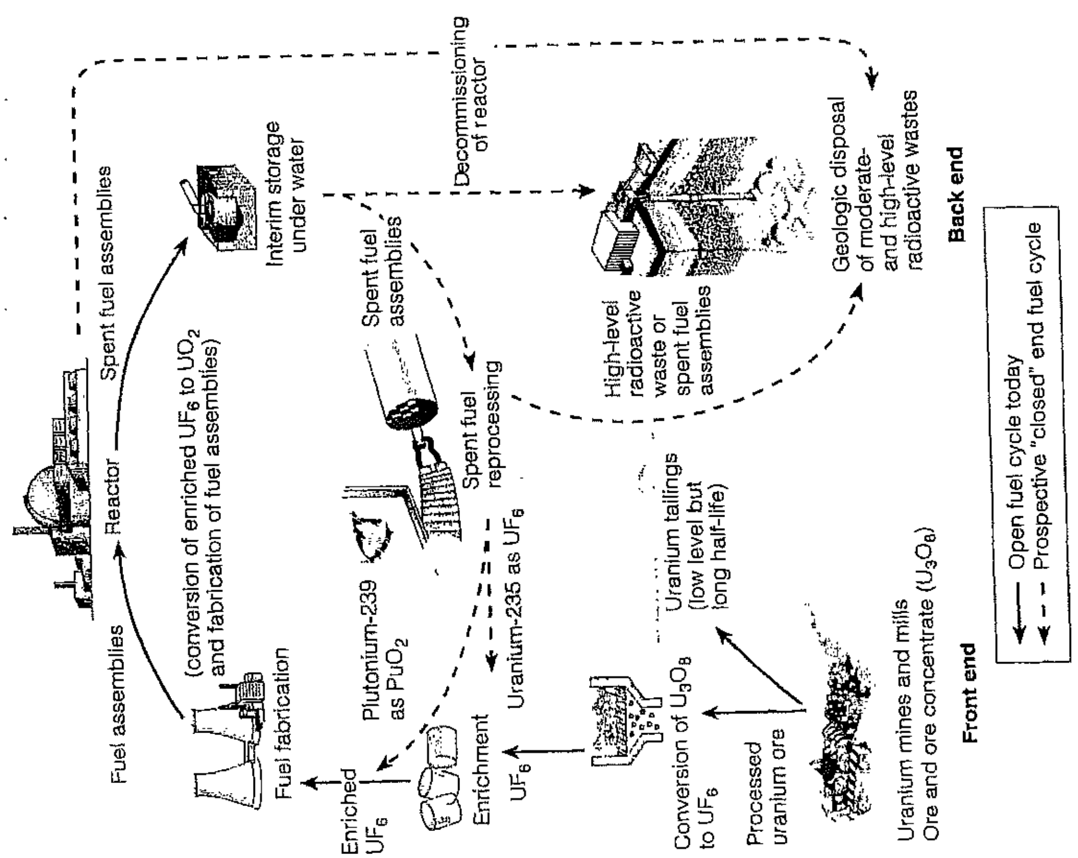
Evaluation of Alternatives to Gasoline

Advantages	Disadvantages
Compressed Natural Gas	
Fairly abundant, inexpensive domestic and global supplies	Large fuel tank needed; one-fourth the range
Low hydrocarbon, CO, and CO_2 emissions	Expensive engine modification needed ($2,000)
Vehicle development advanced; well suited for fleet vehicles	New filling stations needed
Reduced engine maintenance	Nonrenewable resource
Electricity	
Renewable if not generated from fossil fuels or nuclear power	Limited range and power
Zero vehicle emissions	Batteries expensive
Electric grid in place	Slow refueling (6–8 hours)
Efficient and quiet	Power plant emissions if generated from coal or oil
Reformulated Gasoline (Oxygenated Fuel)	
No new filling stations needed	Nonrenewable resource
Low to moderate CO emissions reduction	Dependence on imported oil perpetuated
No engine modification needed	No CO_2 emission reduction
	Higher cost
	Groundwater contaminated by leakage and spills (especially by MTBE, a possible human carcinogen)
	No longer needed because of improved emission control system
A-55 (55% water, 45% naphtha)	
Can be sold in conventional filling station	Not yet widely available
Much lower emissions of nitrogen oxide and particulates than diesel fuel	Independent tests needed to verify pollution reduction claims
Cannot explode or catch fire	Refineries may limit supply or drive up price of less-profitable naphtha
Lower cost (25–50%)	Large amounts of water needed to produce
Naphtha produces 90% less pollution at refineries than gasoline or diesel fuel	
Low-cost engine modification ($300 for cars, $1000 for trucks and buses	
Modified engine can run A-55, gasoline of diesel	
Methanol	
High octane	Large fuel tank needed; one-half the range
Reduction of CO_2 emissions (total amount depends on method of production)	Corrosive to metal, rubber, plastic
Reduced total air pollution (30–40%)	Increased emissions of potentially carcinogenic formaldehyde
	High CO_2 emissions if generated by coal
	High capital cost to produce
	Hard to start in cold weather
Ethanol	
High octane	Large fuel tank needed; lower range
Reduction of CO_2 emissions (total amount depends on distillation process and efficiency of crop growing)	Much higher cost
Reduction of CO emissions	Corn supply limited
Potentially renewable	Competition with food growing for cropland
	Smog formation possible
	Corrosive
	Hard to start in cold weather
Solar–Hydrogen	
Renewable if produced using solar energy	Nonrenewable if generated by fossil fuels or nuclear power
Lower flammability than gasoline	Large fuel tank needed
Virtually emission-free	No distribution system in place
No emissions of CO_2	Engine redesign needed
Nontoxic	Currently expensive

24

Light-water moderated and cooled nuclear power plant with a pressurized water reactor.





The nuclear fuel cycle.

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Characteristic	Examples
Low reproductive rate (K-strategist)	Blue whale, giant panda, rhinoceros
Specialized niche	Blue whale, giant panda, Everglades kite
Narrow distribution	Many island species, elephant seal, desert pupfish
Feeds at high trophic level	Bengal tiger, bald eagle, grizzly bear
Fixed migratory patterns	Blue whale, whooping crane, sea turtles
Rare	Many island species, African violet, some orchids
Commercially valuable	Snow leopard, tiger, elephant, rhinoceros, rare plants and birds
Large territories	California condor, grizzly bear, Florida panther

Characteristics of species that are prone to extinction.

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Characteristics of Successful Invader Species	Characteristics of Ecosystems Vulnerable to Invader Species
• High reproductive rate, short generation time (r-selected species)	• Similar climate to habitat of invader
• Pioneer species	• Absence of predators on invading species
• Long lived	• Early successional species
• High dispersal rate	• Low diversity of native species
• Release growth-inhibiting chemicals into soil	• Absence of fire
• Generalists	• Disturbed by human activities
• High genetic variability	

Some general characteristics of successful invader species and communities vulnerable to invading species.

Major Characteristics of Global Warming and Ozone Depletion

Characteristic	Global Warming	Ozone Depletion
Region of atmosphere involved	Troposphere.	Stratosphere.
Major substances involved	CO_2, CH_4, N_2O (greenhouse gases).	O_3, O_2, chlorofluorocarbons (CFCs).
Interaction with radiation	Molecules of greenhouse gases absorb infared (IR) radiation from the earth's surface, vibrate, and release longer-wavelength IR radiation (heat) into the lower troposphere. This natural greenhouse effect helps warm the lower troposphere (Figure 6-13, p. 128).	About 95% of incoming ultraviolet (UV) radiation from the sun is absorbed by O_3 molecules in the stratosphere and does not reach the earth's surface (Figure 4-8, p. 75).
Nature of problem	Increasing concentrations of greenhouse gases in the troposphere from burning fossil fuels, deforestation, and agriculture could be enhancing the natural greenhouse effect and raising the earth's average surface temperature.	CFCs and other ozone-depleting chemicals released into the troposphere by human activities have made their way to the stratosphere, where they decrease O_3 concentration. This can allow more harmful UV radiation to reach the earth's surface.
Possible consequences	Changes in climate, agricultural productivity, water supplies, and sea level.	Increased incidence of skin cancer, eye cataracts, and immune system suppression and damage to crops and phytoplankton.
Possible responses	Decrease fossil fuel use and deforestation.	Eliminate CFCs and other ozone-depleting chemicals and find acceptable substitutes.

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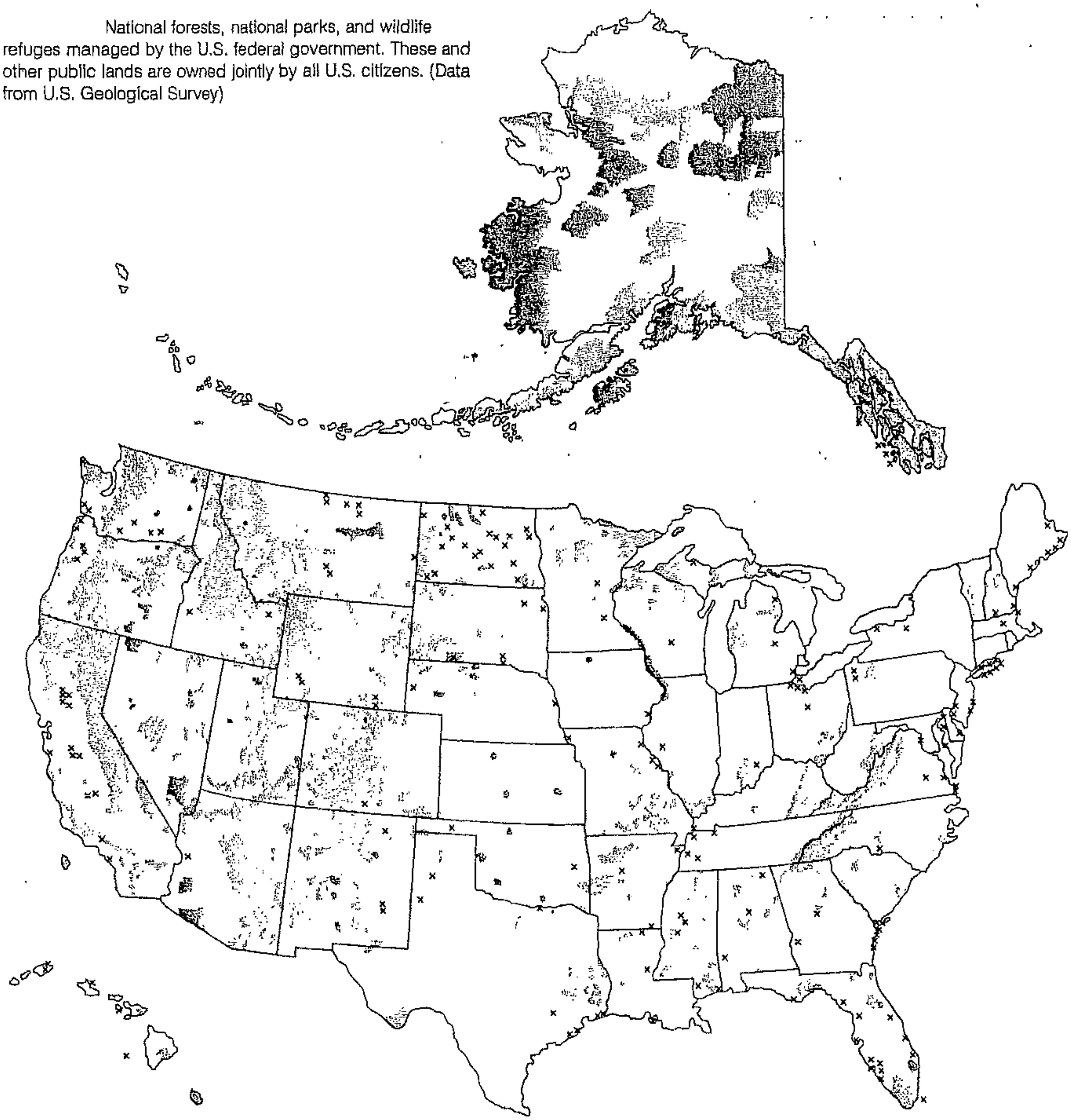
National forests, national parks, and wildlife refuges managed by the U.S. federal government. These and other public lands are owned jointly by all U.S. citizens. (Data from U.S. Geological Survey)



National parks and preserves

National forests

National wildlife refuges

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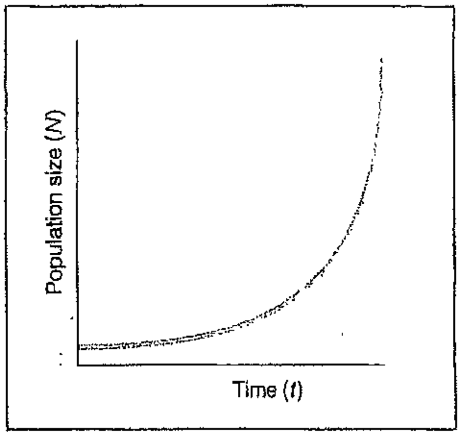
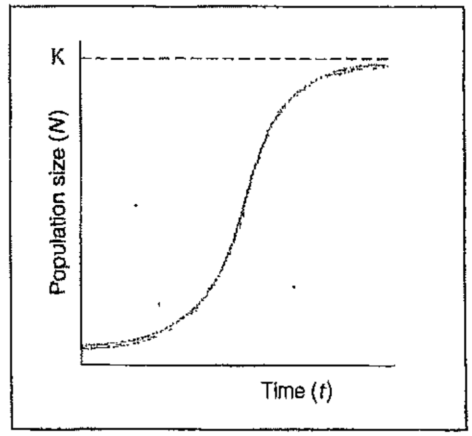
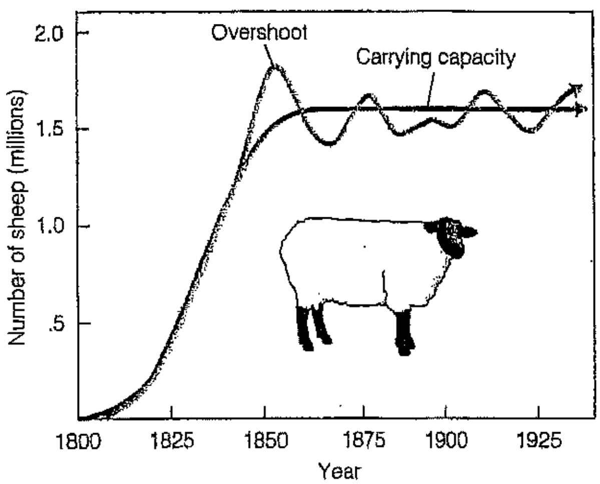


(a) Exponential Growth

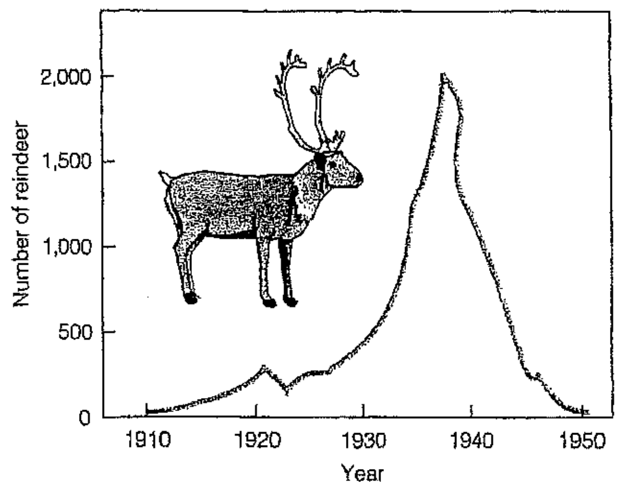


(b) Logistic Growth

Theoretical population growth curves. **(a)** *Exponential growth*, in which the population's growth rate increases with time. Exponential growth occurs when resources are not limiting and a population can grow at its *intrinsic rate of increase* (r). Exponential growth of a population cannot continue forever because eventually some factor limits population growth. **(b)** *Logistic growth*, in which the growth rate decreases as the population gets larger. With time, the population size stabilizes at or near the *carrying capacity* (K) of its environment.



Logistic growth of a sheep population on the island of Tasmania between 1800 and 1925. After sheep were introduced in 1800 their population grew exponentially because of ample food. By 1855 they overshot the land's carrying capac-



Exponential growth, overshoot, and population crash

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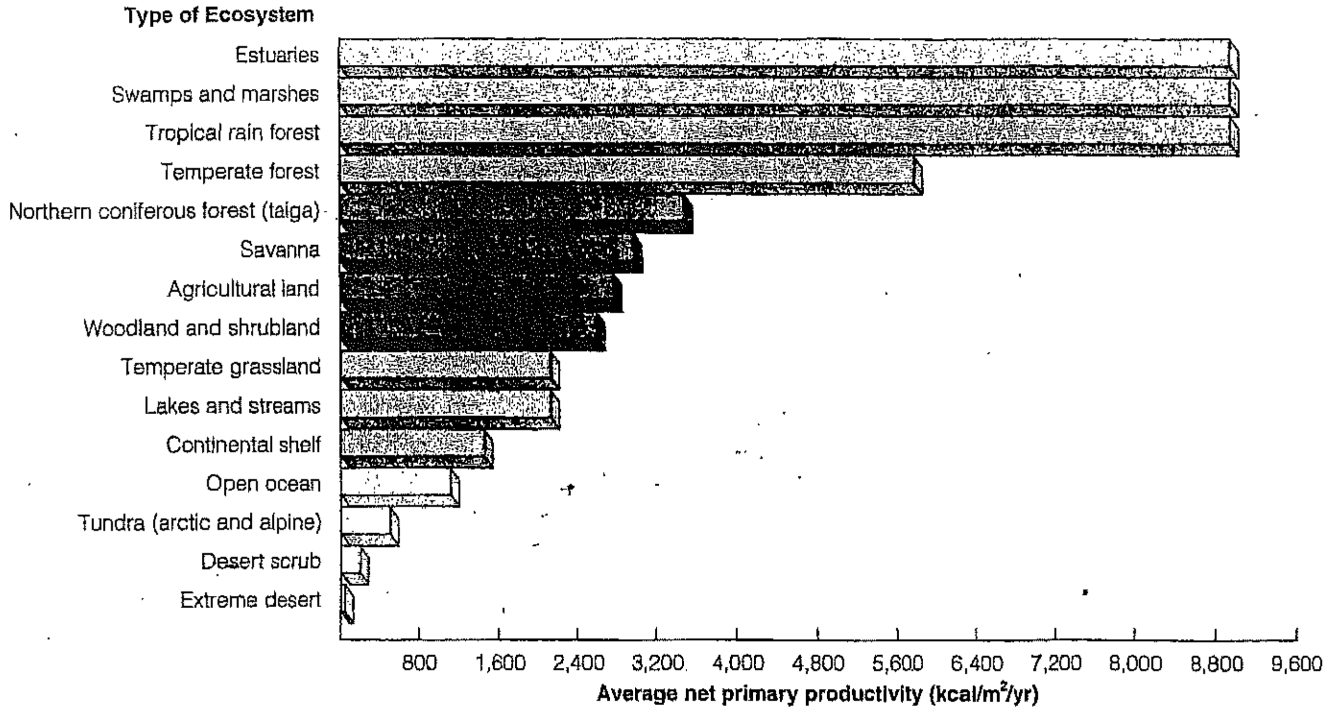

Estimated annual average *net primary productivity* (NPP) per unit of area in major life zones and ecosystems, expressed as kilocalories of energy produced per square meter per year (kcal/m²/yr). (Data from *Communities and Ecosystems*, 2/E by R. H. Whittaker, 1975, New York: Macmillan,)

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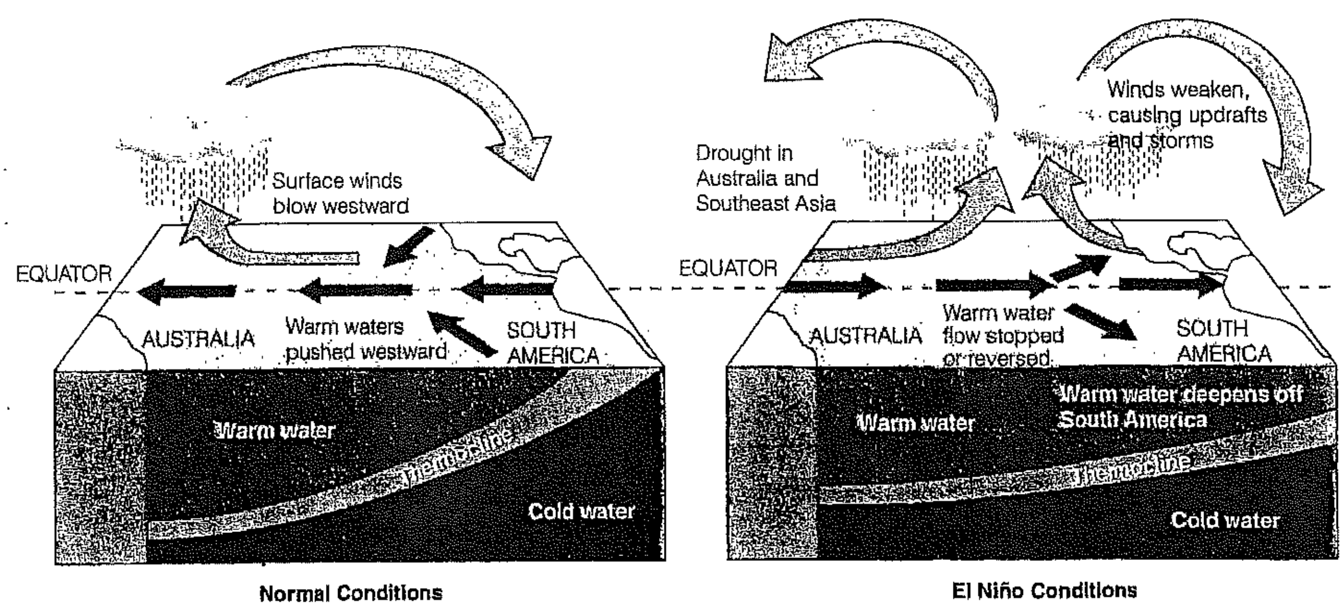

Normal surface winds blowing westward cause shore upwellings of cold, nutrient-rich bottom water in the tropical Pacific Ocean near the coast of Peru (left). The warm and cold water are separated by a zone of gradual temperature change called the *thermocline*. Every few years a climate shift known as the El Niño-Southern Oscillation (ENSO) disrupts this pattern. Westward surface winds weaken, which depresses the coastal upwellings and warms the surface waters off South America (right). When an ENSO lasts 12 months or longer, it severely disrupts populations of plankton, fish, and seabirds in upwelling areas and can trigger extreme weather changes over much of the globe

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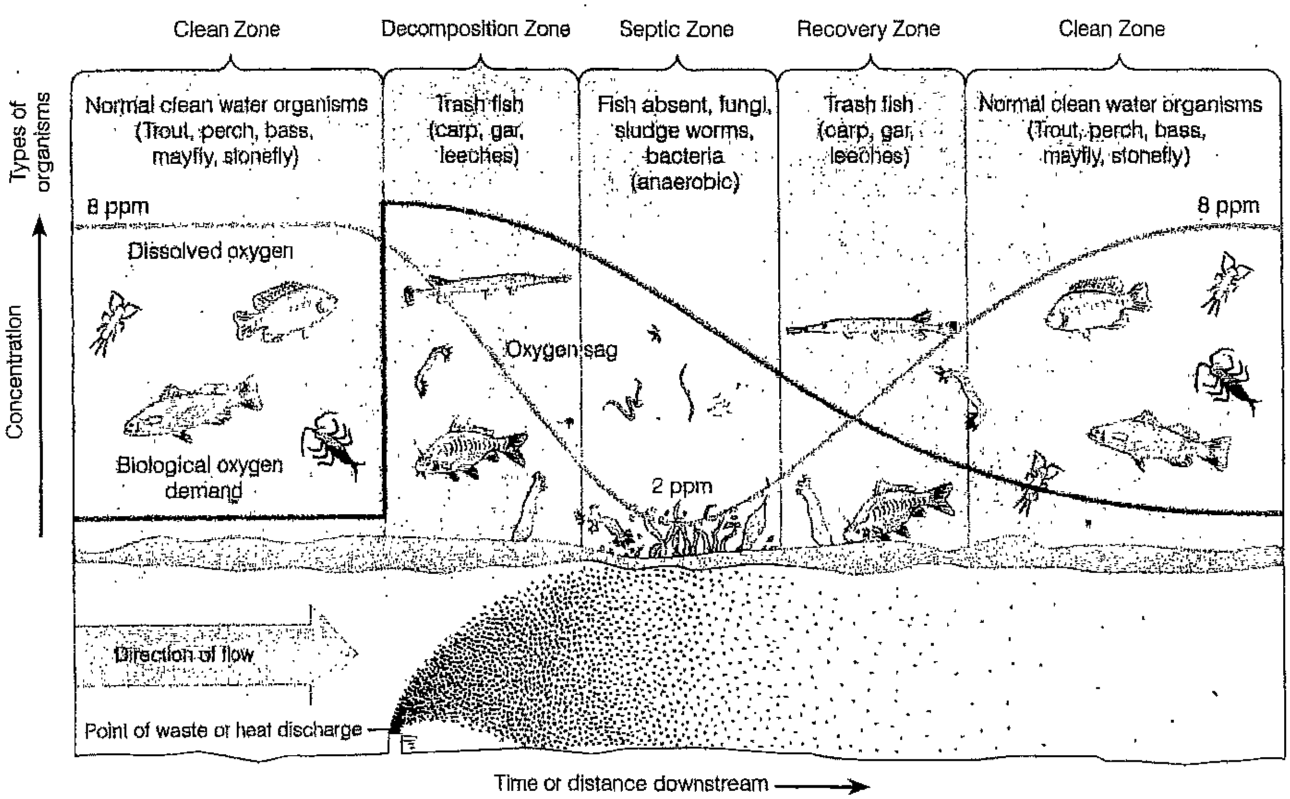
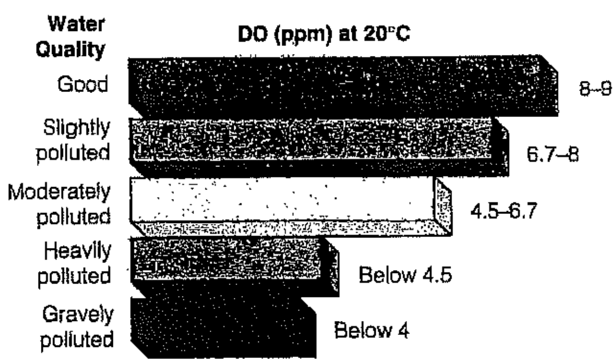


Dilution and decay of degradable, oxygen-demanding wastes and heat, showing the oxygen sag curve (orange) and the curve of oxygen demand (blue). Depending on flow rates and the amount of pollutants, streams recover from oxygen-demanding wastes and heat if they are given enough time and are not overloaded.

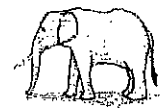


Water quality and dissolved oxygen (DO) content in parts per million (ppm) at 20°C (68°F). Only a few fish species can survive in water with less than 4 ppm of dissolved oxygen at this temperature.

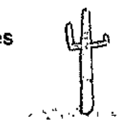
r-Selected Species

cockroach — dandelion

- Many small offspring
- Little or no parental care and protection of offspring
- Early reproductive age
- Most offspring die before reaching reproductive age
- Small adults
- Adapted to unstable climate and environmental conditions
- High population growth rate (r)
- Population size fluctuates wildly above and below carrying capacity (K)
- Generalist niche
- Low ability to compete
- Early successional species



K-Selected Species



elephant — saguaro

- Fewer, larger offspring
- High parental care and protection of offspring
- Later reproductive age
- Most offspring survive to reproductive age
- Larger adults
- Adapted to stable climate and environmental conditions
- Lower population growth rate (r)
- Population size fairly stable and usually close to carrying capacity (K)
- Specialist niche
- High ability to compete
- Late successional species

· Generalized characteristics of r-selected or opportunist species and K-selected or competitor species. Many species have characteristics between these two extremes.

Wolf and Moose Interactions on Isle Royale

For decades wildlife biologists have been studying the relationship between the moose and wolf populations on Isle Royale, an island in Lake Superior between Minnesota in the United States and Ontario in Canada (Figure 9-9).

In the early 1900s, a small herd of moose wandered across the frozen ice of Lake Superior to this island. With an abundance of food, the moose population exploded (Figure 9-9). In 1928, a wildlife biologist visiting the island successfully predicted that the large moose population would soon crash because the moose had stripped the island of most of its preferred food plants.

Sometime during the 1940s timber wolves (probably a single pair) reached Isle Royale by traveling over the ice from the Canadian mainland during winter. They reproduced and slowly grew in numbers. During winter the wolves hunt in packs and concentrate on killing the old, sick, and young moose. These individuals are the easiest to kill without undue risk because the moose is the wolf's largest and most dangerous prey. Once a target moose is selected, the wolves encircle it and try to get it to run so they can attack it from behind.

Since 1958, wildlife biologists have been tracking the populations of the two species (Figure 9-9). You might think that the wolves would have completely exterminated the moose, but instead the two species have been interacting in what appears to be an oscillating predator–prey cycle (Figure 9-9). If the wolves could drive the moose to extinction they probably would, but the moose are too formidable for this to happen.

Since 1980 the wolf population declined from a high of about 50 and has fluctuated between 12 and 25 individuals. Possible reasons for this decline are (1) a canine virus introduced to wolves by dogs and (2) a low reproduction rate because of a lack of genetic variability from inbreeding.

With the decline in wolves, the moose population rose sharply until 1995. Then it crashed from a combination of lack of food, poor reproduction, a severe winter, and a tick infestation. By 1999 the wolf population, with plenty of weakened prey, had grown to 25. If their population continues to grow, they may hold the moose numbers in check and allow damaged vegetation to recover and begin a new cycle of interactions.

Critical Thinking

What is the primary ecological lesson to be learned from the moose–wolf interaction on Isle Royale?

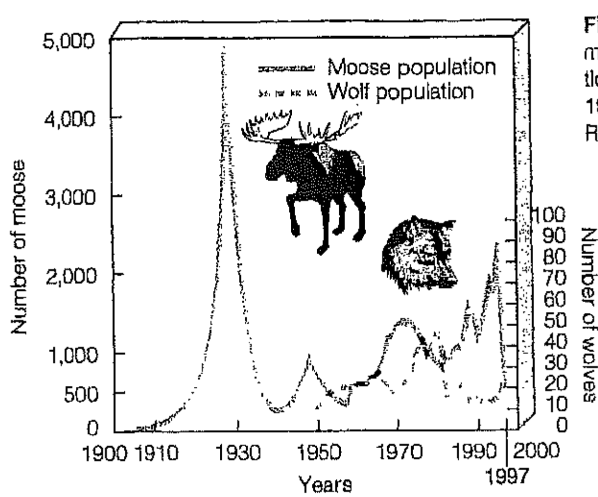
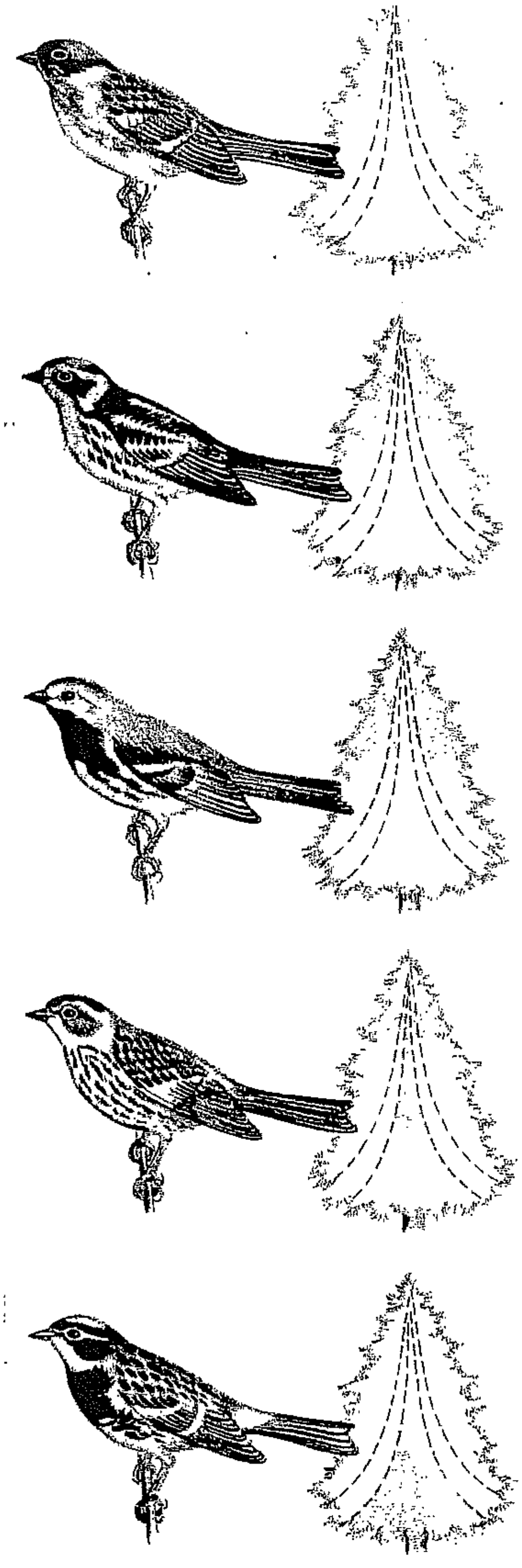
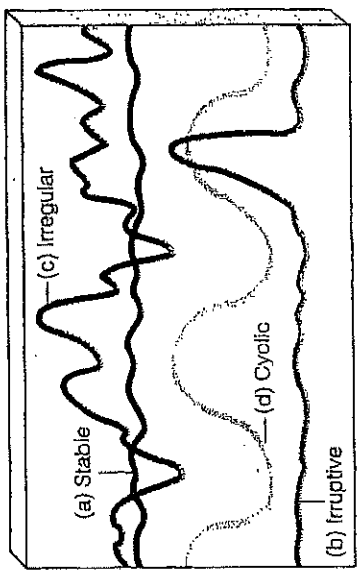


Figure 9-9 Changes in moose and wolf populations on Isle Royale from 1900 to 1999. (Data from Rolf O. Peterson, 1995)

Resource partitioning of five species of common insect-eating warblers in spruce forests of Maine. Each species minimizes competition with the others for food by spending at least half its feeding time in a distinct portion (shaded areas) of the spruce trees; each also consumes somewhat different insect species. (After "Population Ecology of Some Warblers in Northeastern Coniferous Forests," by R. H. MacArthur, 1958, *Ecology*, Vol. 36, 533–36)



General types of simplified population change curves found in nature. **(a)** The population size of a species with a fairly *stable* population fluctuates slightly above and below its carrying capacity. **(b)** The populations of some species may occasionally explode, or *irrupt*, to a high peak and then crash to a more stable lower level. **(c)** The population sizes of some species change irregularly for mostly unknown reasons. **(d)** Other species undergo sharp increases in their numbers, followed by crashes over fairly regular time intervals. Predators sometimes are blamed, but the actual causes of such boom-bust cycles are poorly understood.



Land and Biodiversity

Loss of cropland

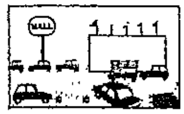
Loss of forests and grasslands

Loss of wetlands

Loss and fragmentation of wildlife habitats

Increased wildlife roadkill

Increased soil erosion



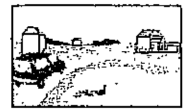
Human Health and Aesthetics

Contaminated drinking water and air

Noise pollution

Sky illumination at night

Traffic congestion



Water

Increased runoff

Increased surface water and groundwater pollution

Increased use of surface water and groundwater

Decreased storage of surface water and groundwater

Increased flooding

Decreased natural sewage treatment

Energy, Air, and Climate

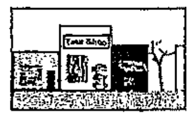
Increased energy use and waste

Increased air pollution

Increased greenhouse gas emissions

Enhanced global warming

Warmer microclimate (heat island effect)



Economic Effects

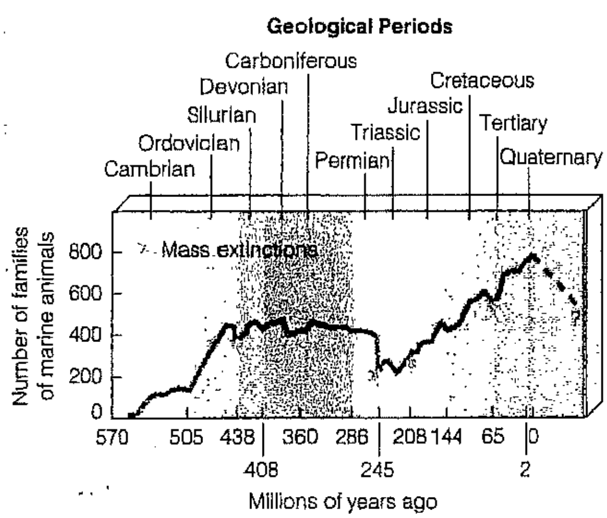
Higher taxes

Decline of downtown business districts

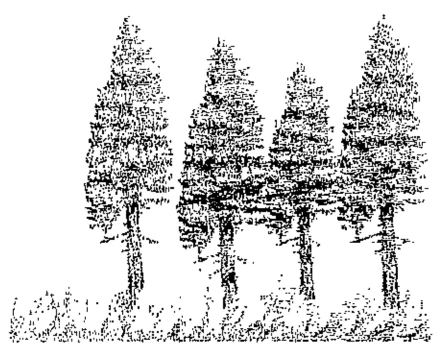
Increased unemployment in central city

Loss of tax base in central city

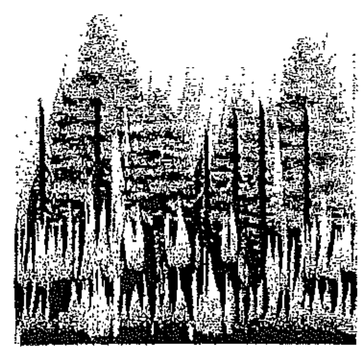
Some of the undesirable impacts of urban sprawl.



Fossils and radioactive dating indicate that five major mass extinctions have taken place in the past 500 million years. Many scientists believe that we are now in the midst of a sixth mass extinction, caused primarily by human activities.



Surface fire



Crown fire

Surface fires (left) usually burn undergrowth and leaf litter on a forest floor and can help prevent more destructive *crown fires* (right) by removing flammabl ground material. Sometimes carefully controlled surface fires are deliberately set to prevent buildup of flammable ground material in forests.