

AP Environmental Science

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C O N N E X I O N S

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Table of Contents

1 FLOW OF ENERGY	1
2 CYCLING OF MATTER	5
3 THE SOLID EARTH	11
4 THE ATMOSPHERE	15
5 THE BIOSPHERE	21
6 HISTORY AND GLOBAL DISTRIBUTION	29
7 CARRYING CAPACITY	35
8 POPULATION GROWTH	39
9 WATER	41
10 MINERALS	47
11 SOILS	51
12 BIOLOGICAL	55
13 NON-RENEWABLE ENERGY SOURCES	59
14 RENEWABLE ENERGY SOURCES	63
15 LAND	67
16 AIR, WATER AND SOIL	71
17 SOLID WASTE	77
18 IMPACT ON HUMAN HEALTH	81
19 FIRST ORDER EFFECTS	85
20 HIGHER ORDER INTERACTIONS	91
21 ECONOMIC FORCES	95
22 CULTURAL AND AESTHETIC CONSIDERATIONS	99
23 ENVIRONMENTAL ETHICS	105
24 ENVIRONMENTAL LAWS & REGULATIONS	109
25 ISSUES AND OPTIONS	113
Index	119
Attributions	126

Chapter 1

FLOW OF ENERGY¹

1.1 THE FLOW OF ENERGY

1.2 INTRODUCTION

Energy is the ability to do **work**. Work is done when a force is applied to an object over a distance. Any moving object has **kinetic energy** or energy of motion, and it thus can do work. Similarly, work has to be done on an object to change its kinetic energy. The kinetic energy of an object of mass m and speed v is given by the relation $E = 1/2mv^2$.

Sometimes energy can be stored and used at a later time. For example, a compressed spring and water held back by a dam both have the potential to do work. They are said to possess **potential energy**. When the spring or water is released its potential energy is transformed into kinetic energy and other forms of energy such as heat. The energy associated to the gravitational force near the surface of the earth is potential energy. Other forms of energy are really combinations of kinetic and potential energy. Chemical energy, for example, is the electrical potential energy stored in atoms. Heat energy is a combination of the potential and kinetic energy of the particles in a substance.

1.3 FORMS OF ENERGY

Mechanical energy puts something in motion. It moves cars and lifts elevators. A machine uses mechanical energy to do work. The mechanical energy of a system is the sum of its kinetic and potential energy. Levers, which need a fulcrum to operate, are the simplest type of machine. Wheels, pulleys and inclined planes are the basic elements of most machines.

Chemical energy is the energy stored in molecules and chemical compounds, and is found in food, wood, coal, petroleum and other fuels. When the chemical bonds are broken, either by combustion or other chemical reactions, the stored chemical energy is released in the form of heat or light. For example, muscle cells contain glycogen. When the muscle does work the glycogen is broken down into glucose. When the chemical energy in the glucose is transferred to the muscle fibers some of the energy goes into the surroundings as heat.

Electrical energy is produced when unbalanced forces between electrons and protons in atoms create moving electrons called electric currents. For example, when we spin a copper wire through the poles of a magnet we induce the motion of electrons in the wire and produce electricity. Electricity can be used to perform work such as lighting a bulb, heating a cooking element on a stove or powering a motor. Note that electricity is a "secondary" source of energy. That means other sources of energy are needed to produce electricity.

¹This content is available online at <<http://cnx.org/content/m16468/1.2/>>.

Radiant energy is carried by waves. Changes in the internal energy of particles cause the atoms to emit energy in the form of electromagnetic radiation which includes visible light, ultraviolet (UV) radiation, infrared (IR) radiation, microwaves, radio waves, gamma rays, and X-rays. Electromagnetic radiation from the sun, particularly light, is of utmost importance in environmental systems because biogeochemical cycles and virtually all other processes on earth are driven by them.

Thermal energy or **Heat energy** is related to the motion or vibration of molecules in a substance. When a thermal system changes, heat flows in or out of the system. Heat energy flows from hot bodies to cold ones. Heat flow, like work, is an energy transfer. When heat flows into a substance it may increase the kinetic energy of the particles and thus elevate its temperature. Heat flow may also change the arrangement of the particles making up a substance by increasing their potential energy. This is what happens to water when it reaches a temperature of 100°C. The molecules of water move further away from each other, thereby changing the state of the water from a liquid to a gas. During the phase transition the temperature of the water does not change.

Nuclear Energy is energy that comes from the binding of the protons and neutrons that make up the nucleus of the atoms. It can be released from atoms in two different ways: nuclear fusion or nuclear fission. In **nuclear fusion**, energy is released when atoms are combined or fused together. This is how the sun produces energy. In **nuclear fission**, energy is released when atoms are split apart. Nuclear fission is used in nuclear power plants to produce electricity. Uranium 235 is the fuel used in most nuclear power plants because it undergoes a chain reaction extremely rapidly, resulting in the fission of trillions of atoms within a fraction of a second.

1.4 SOURCES AND SINKS

The source of energy for many processes occurring on the earth's surface comes from the sun. Radiating solar energy heats the earth unevenly, creating air movements in the atmosphere. Therefore, the sun drives the winds, ocean currents and the water cycle. Sunlight energy is used by plants to create chemical energy through a process called photosynthesis, and this supports the life and growth of plants. In addition, dead plant material decays, and over millions of years is converted into fossil fuels (oil, coal, etc.).

Today, we make use of various sources of energy found on earth to produce electricity. Using machines, we convert the energies of wind, biomass, fossil fuels, water, heat trapped in the earth (geothermal), nuclear and solar energy into usable electricity. The above sources of energy differ in amount, availability, time required for their formation and usefulness. For example, the energy released by one gram of uranium during nuclear fission is much larger than that produced during the combustion of an equal mass of coal.

US ENERGY PRODUCTION (Quadrillion BTU)

(Source: US DOE)	1975	2000
Coal	14.989 (24.4%)	22.663 (31.5%)
Natural Gas (dry)	19.640 (32.0%)	19.741 (27.5%)
Crude Oil	17.729 (28.9%)	12.383 (17.2%)
Nuclear	1.900 (3.1%)	8.009 (11.2%)
Hydroelectric	3.155 (5.1%)	2.841 (4.0%)
Natural Gas (plant liquid)	2.374 (3.9%)	2.607 (3.6%)
Geothermal	0.070 (0.1%)	0.319 (0.4%)
Other	1.499 (2.5%)	3.275 (4.6%)
TOTAL	61.356	71.838

Table 1.1

(Source: US Department of Energy)

An **energy sink** is anything that collects a significant quantity of energy that is either lost or not considered transferable in the system under study. Sources and sinks have to be included in an energy budget when accounting for the energy flowing into and out of a system.

1.5 CONSERVATION OF ENERGY

Though energy can be converted from one form to another, energy cannot be created or destroyed. This principle is called the "law of conservation of energy." For example, in a motorcycle, the chemical potential energy of the fuel changes to kinetic energy. In a radio, electricity is converted into kinetic energy and wave energy (sound).

Machines can be used to convert energy from one form to another. Though ideal machines conserve the mechanical energy of a system, some of the energy always turns into heat when using a machine. For example, heat generated by friction is hard to collect and transform into another form of energy. In this situation, heat energy is usually considered unusable or lost.

1.6 ENERGY UNITS

In the International System of Units (SI), the unit of work or energy is the **Joule (J)**. For very small amounts of energy, the erg (erg) is sometimes used. An **erg** is one ten millionth of a Joule:

$$1 \text{ Joule} = 10,000,000 \text{ ergs} \quad (1.1)$$

Power is the rate at which energy is used. The unit of power is the **Watt (W)**, named after James Watt, who perfected the steam engine:

$$1 \text{ Watt} = 1 \text{ Joule/second} \quad (1.2)$$

Power is sometimes measured in **horsepower (hp)**:

$$1 \text{ horsepower} = 746 \text{ Watts} \quad (1.3)$$

Electrical energy is generally expressed in **kilowatt-hours** (kWh):

$$1 \text{ kilowatt-hour} = 3,600,000 \text{ Joules} \quad (1.4)$$

It is important to realize that a kilowatt-hour is a unit of energy not power. For example, an iron rated at 2000 Watts would consume $2 \times 3.6 \times 10^6 \text{ J}$ of energy in 1 hour .

Heat energy is often measured in calories. One calorie (cal) is defined as the heat required to raise the temperature of 1 gram of water from 14.5 to 15.5 °C:

$$1 \text{ calorie} = 4.189 \text{ Joules} \quad (1.5)$$

An old, but still used unit of heat is the **British Thermal Unit** (BTU). It is defined as the heat energy required to raise the energy temperature of 1 pound of water from 63 to 64 °F.

Physical Quantity	Name	Symbol	SI Unit
Force	Newton	N	$\text{kg} \cdot \text{m}/\text{s}^2$
Energy	Joule	J	$\text{kg} \cdot \text{m}^2/\text{s}^2$
Power	Watt	W	$\text{kg} \cdot \text{m}^2/\text{s}^3$

Table 1.2

$$1 \text{ BTU} = 1055 \text{ Joules}$$

Chapter 2

CYCLING OF MATTER¹

2.1 CYCLING OF MATTER

2.1.1 INTRODUCTION

The earth's biogeochemical systems involve complex, dynamic processes that depend upon many factors. The three main factors upon which life on the earth depends are:

1. The one-way flow of solar energy into the earth's systems. As **radiant energy**, it is used by plants for food production. As heat, it warms the planet and powers the weather system. Eventually, the energy is lost into space in the form of **infrared radiation**. Most of the energy needed to cycle matter through earth's systems comes from the sun.
2. The cycling of matter. Because there are only finite amounts of nutrients available on the earth, they must be recycled in order to ensure the continued existence of living organisms.
3. The force of gravity. This allows the earth to maintain the atmosphere encompassing its surface and provides the driving force for the downward movement of materials in processes involving the cycling of matter.

These factors are critical components to the functioning of the earth's systems, and their functions are necessarily interconnected. The main matter-cycling systems involve important nutrients such as water, carbon, nitrogen and phosphorus.

2.1.2 WATER CYCLE

The earth is sometimes known as the "water planet" because over 70 percent of its surface is covered by **water**. The physical characteristics of water influence the way life on earth exists. These characteristics include:

- Water is a liquid at room temperature, and remains as such over a relatively wide temperature range (0-100° C). This range overlaps the annual mean temperature of most biological environments.
- It takes a relatively large amount of energy to raise the temperature of water (i.e., it has a high heat capacity). For this reason, the vast oceans act as a buffer against sudden changes in the average global temperature.
- Water has a very high heat of vaporization. Water evaporation thus provides a good means for an organism to dissipate unwanted heat.
- Water is a good solvent for many compounds and provides a good medium for chemical reactions. This includes biologically important compounds and reactions.

¹This content is available online at <<http://cnx.org/content/m16470/1.2/>>.

- Liquid water has a very high surface tension, the force holding the liquid surface together. This enables upward transport of water in plants and soil by capillary action.
- Solid water (ice) has a lower density than liquid water at the surface of the earth. As a result ice floats on the surface of rivers, lakes, and oceans after it forms, leaving liquid water below where fish and other organisms can continue to live. If ice were more dense than liquid water, it would sink, and bodies of water in cold climates might eventually freeze solid.

All living organisms require water for their continued existence. The water cycle (**hydrologic cycle**) is composed of the interconnections between water reservoirs in the environment and living organisms and the physical processes (e.g., evaporation and condensation) involved in its transport between those reservoirs. The oceans contain about 97 percent of the total water on the planet, which leaves about three percent as fresh water. Most of the fresh water is locked up in glacial and cap ice or buried deep in the earth where it is economically unfeasible to extract it. One estimate gives the amount of fresh water available for human use to be approximately 0.003 percent of the total amount of fresh water. However, this is actually a more than adequate supply, as long as the natural cycle of water is not severely disturbed by an outside force such as human activity.

There are several important processes that affect the transport of water in the water cycle. **Evaporation** is the process by which liquid water is converted to water vapor. The source of energy for this process is usually the sun. For example, the sun's radiation heats the surface water in a lake causing it to evaporate. The resulting water vapor is thus added to the atmosphere where it can be transported to another location. Two important effects of the evaporation are cooling and drying.

Transpiration is a process by which water evaporates from living plants. Water from the soil is absorbed by a plant's roots and transported to the leaves. There, some is lost as vapor to the atmosphere through small surface openings.

When water vapor in the atmosphere cools, it can transform into tiny droplets of liquid water. This process is called **condensation**, and it can occur as water vapor is transported into the cooler upper atmosphere. Dust and pollen in the atmosphere help to initiate the process by providing condensation centers. If the droplets remain small enough to be supported by air motions, they can group together to form a cloud. Condensation can also occur in the air near the ground as fog or on plant leaves as dew.

When condensed water droplets grow so large that the air can no longer support them against the pull of gravity, they fall to the earth. This is the process called **precipitation**.

If the water droplets fall as liquid, it is called rain. If the temperature of the surrounding air mass is cold enough to freeze the water droplets, the resultant precipitation can be called snow, sleet or hail, depending upon its morphology.

Water falling on the ground (e.g., as precipitation or irrigation), can move downslope over the surface (e.g., **surface runoff**) or penetrate the surface (e.g., **infiltration**). The amount of surface runoff and infiltration depends upon several factors: water infall rate, surface moisture, soil or rock texture, type and amount of surface cover (e.g., leaves and rooted plants), and surface topography. Surface runoff is the predominate process that occurs after precipitation, with most of the water flowing into streams and lakes. On a groundslope unprotected by vegetation, runoff can occur very rapidly and result in severe erosion.

Water that infiltrates the surface can move slowly downward through the layers of soil or porous rock in a process known as **percolation**. During this process, the water can dissolve minerals from the rock or soil as it passes through. The water collects in the pores of rocks as groundwater when it is stopped by an impermeable layer of rock. The upper limit of this **groundwater** is known as the **water table** and the region of water-logged rock is known as an **aquifer**. The groundwater may slowly flow downhill through rock pores until it exits the surface as a spring or seeps into a stream or lake.

Water is the essence of life. There would be no life as we know it without water. The vast oceans of water exert a powerful influence on the weather and climate. Water is also the agent by which the landforms are constantly reshaped. Therefore, the water cycle plays an important role in the balance of nature.

Human activity can disrupt the natural balance of the water cycle. The buildup of salts that results from irrigating with groundwater can cause soil infertility and irrigation can also deplete underground aquifers

causing land subsidence or salt water intrusion from the ocean. The clearing of land for farming, construction, or mining can increase surface runoff and erosion, thereby decreasing infiltration. Increasing human populations and their concentration in certain geographic localities will continue to stress water systems. Careful thought is needed on local, regional and global scales regarding the use and management of water resources for wetlands, agriculture, industry and home.

2.1.3 CARBON CYCLE

Carbon is the basic building block of all organic materials, and therefore, of living organisms. However, the vast majority of carbon resides as inorganic minerals in crustal rocks. Other reservoirs of carbon include the oceans and atmosphere. Several physical processes affect carbon as it moves from one reservoir to another. The inter-relationships of carbon and the biosphere, atmosphere, oceans and crustal earth – and the processes affecting it – are described by the **carbon cycle**.

The carbon cycle is actually comprised of several inter-connected cycles. The overall effect is that carbon is constantly recycled in the dynamic processes taking place in the atmosphere, at the surface and in the crust of the earth. For example, the combustion of wood transfers **carbon dioxide** to the atmosphere. The carbon dioxide is taken in by plants and converted to nutrients for growth and sustenance. Animals eat the plants for food and exhale carbon dioxide into the atmosphere when they breathe.

Atmospheric carbon dioxide dissolves in the ocean where it eventually precipitates as carbonate in sediments. The ocean sediments are subducted by the actions of **plate tectonics**, melted and then returned to the surface during volcanic activity. Carbon dioxide gas is released into the atmosphere during volcanic eruptions. Some of the carbon atoms in your body today may long ago have resided in a dinosaur's body, or perhaps were once buried deep in the earth's crust as carbonate rock minerals.

The main carbon cycling processes involving living organisms are photosynthesis and respiration. These processes are actually reciprocal to one another with regard to the cycling of carbon: photosynthesis removes carbon dioxide from the atmosphere and respiration returns it. A significant disruption of one process can therefore affect the amount of carbon dioxide in the atmosphere.

During a process called **photosynthesis**, raw materials are used to manufacture sugar. Photosynthesis occurs in the presence of **chlorophyll**, a green plant pigment that helps the plant utilize the energy from sunlight to drive the process. Although the overall process involves a series of reactions, the net reaction can be represented by the following:

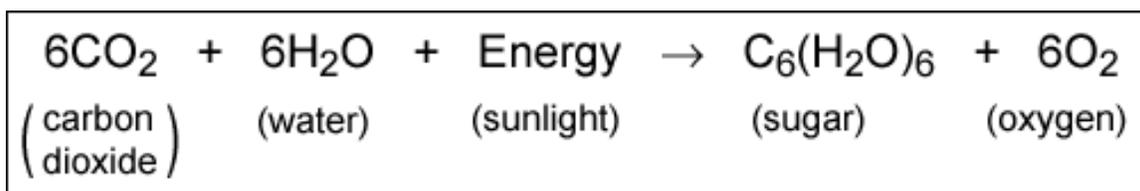


Figure 2.1

The sugar provides a source of energy for other plant processes and is also used for synthesizing materials necessary for plant growth and maintenance. The net effect with regard to carbon is that it is removed from the atmosphere and incorporated into the plant as organic materials.

The reciprocal process of photosynthesis is called respiration. The net result of this process is that sugar is broken down by oxygen into carbon dioxide and water. The net reaction is:

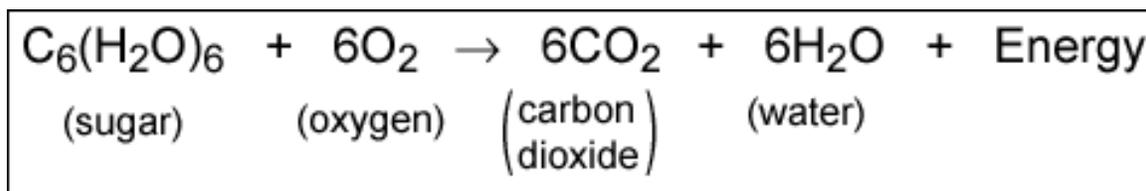


Figure 2.2

This process occurs not only in plants, but also in humans and animals. Unlike photosynthesis, respiration can occur during both the day and night. During respiration, carbon is removed from organic materials and expelled into the atmosphere as carbon dioxide.

Another process by which organic material is recycled is the decomposition of dead plants and animals. During this process, bacteria break down the complex organic compounds.

Carbon is released into the soil or water as inorganic material or into the atmosphere as gases. Decomposed plant material is sometimes buried and compressed between layers of sediments. After millions of years fossil fuels such as coal and oil are formed. When fossil fuels are burned, the carbon is returned to the atmosphere as carbon dioxide.

The carbon cycle is very important to the existence of life on earth. The daily maintenance of living organisms depends on the ready availability of different forms of carbon. Fossil fuels provide an important source of energy for humans, as well as the raw materials used for manufacturing plastics and other industrially important organic compounds. The component processes of the carbon cycle have provided living things with the necessary sources of carbon for hundreds of millions of years. If not for the recycling processes, carbon might long ago have become completely sequestered in crustal rocks and sediments, and life would no longer exist.

Human activity threatens to disrupt the natural cycle of carbon. Two important ways by which humans have affected the carbon cycle, especially in recent history, are: 1) the release of carbon dioxide into the atmosphere during the burning of fossil fuels, and 2) the clearing of trees and other plants (deforestation) that absorb carbon dioxide from the atmosphere during photosynthesis. The net effect of these actions is to increase the concentration of carbon dioxide in the atmosphere. It is estimated that global atmospheric carbon dioxide is increasing by about 0.4% annually. Carbon dioxide is a **greenhouse gas** (i.e., it prevents infrared radiation from the earth's surface from escaping into space). The heat is instead absorbed by the atmosphere. Many scientists believe that the increased carbon dioxide concentration in the atmosphere is resulting in global warming.

This global warming may in turn cause significant changes in global weather, which could negatively affect all life on earth. However, increased photosynthesis (resulting from the increase in the concentration of carbon dioxide) may somewhat counteract the effects. Unfortunately, the issues of fossil fuel burning, deforestation and global warming are intertwined with economic and political considerations. Furthermore, though much studied, the processes are still not well-understood and their ramifications cannot be predicted with confidence.

2.1.4 NITROGEN CYCLE

The element Nitrogen is important to living organisms and is used in the production of **amino acids**, **proteins** and **nucleic acids (DNA, RNA)**. Molecular nitrogen (N_2) is the most abundant gas in the atmosphere. However, only a few single-cell organisms are able to utilize this nitrogen form directly. These include the bacteria species **Rhizobium**, which lives on the root nodules of legumes, and **cyanobacteria** (sometimes called blue-green algae), which are ubiquitous to water and soil environments. In order for

multi-cellular organisms to use nitrogen, its molecular form (N_2) must be converted to other compounds, e.g., nitrates or ammonia. This process is known as **nitrogen fixation**. Microbial organisms such as cyanobacteria carry out most of the earth's nitrogen fixation. The industrial manufacture of fertilizers, emissions from combustion engines and nitrogen burning in lightning account for a smaller fraction.

The **nitrogen cycle** is largely dependent on microbial processes. Bacteria fix nitrogen from the atmosphere in the form of **ammonia (NH_3)** and convert the ammonia to **nitrate (NO_3^-)**.

Ammonia and nitrate are absorbed by plants through their roots. Humans and animals get their nitrogen supplies by eating plants or plant-eating animals. The nitrogen is returned to the cycle when bacteria decompose the waste or dead bodies of these higher organisms, and in the process, convert organic nitrogen into ammonia. In a process called **denitrification**, other bacteria convert ammonia and nitrate into molecular nitrogen and nitrous oxide (N_2O). Molecular nitrogen is thus returned to the atmosphere to start the cycle over again.

Humans have disturbed the nitrogen cycle in recent history by activities involving increased fixation of nitrogen. Most of this increased nitrogen fixation results from the commercial production of fertilizers and the increased burning of fuels (which converts molecular nitrogen to nitric oxide, NO). The use of commercial fertilizers on agricultural lands increases the runoff of nitrates into aquatic environments.

This increased nitrogen runoff stimulates the rapid growth of algae. When the algae die, the water becomes depleted in oxygen and other organisms die. This process is known as **eutrophication**. The excessive use of fertilizers also stimulates the microbial **denitrification** of nitrate to **nitrous oxide**. Increased atmospheric levels of nitrous oxide are thought to contribute to global warming. Nitric oxide added to the atmosphere combines with water to form **nitric acid (HNO_3)**, and when nitric acid dissolves in water droplets, it forms acid rain. Acid rain damages healthy trees, destroys aquatic systems and erodes building materials such as marble and limestone.

2.1.5 PHOSPHOROUS CYCLE

Phosphorus in earth systems is usually in the form of **phosphate (PO_4^{3-})**. In living organisms it is an essential constituent of cell membranes, nucleic acids and **ATP** (the carrier of energy for all life forms). It is also a component of bone and teeth in humans and animals. The **phosphorus cycle** is relatively simple compared to the other cycles of matter as fewer reservoirs and processes are involved. Phosphorus is not a nominal constituent of the atmosphere, existing there only in dust particles.

Most phosphorus occurs in crustal rocks or in ocean sediments. When phosphate-bearing rock is weathered, the phosphate is dissolved and ends up in rivers, lakes and soils. Plants take up phosphate from the soil, while animals ingest phosphorus by eating plants or plant-eating animals. Phosphate is returned to the soil via the decomposition of animal waste or plant and animal materials. This cycle repeats itself again and again. Some phosphorus is washed to the oceans where it eventually finds its way into the ocean-floor sediments.

The sediments become buried and form phosphate-bearing sedimentary rocks. When this rock is uplifted, exposed and weathered, the phosphate is again released for use by living organisms.

The movement of phosphorus from rock to living organisms is normally a very slow process, but some human activities speed up the process. Phosphate-bearing rock is often mined for use in the manufacture of fertilizers and detergents. This commercial production greatly accelerates the phosphorous cycle. In addition, runoff from agricultural land and the release of sewage into water systems can cause a local overload of phosphate. The increased availability of phosphate can cause overgrowth of algae. This reduces the oxygen level, causing eutrophication and the destruction of other aquatic species. Marine birds play a unique role in the phosphorous cycle. These birds take up phosphorous from ocean fish. Their droppings on land (**guano**) contain high levels of phosphorous and are sometimes mined for commercial use.

Chapter 3

THE SOLID EARTH¹

3.1 THE SOLID EARTH

3.1.1 EARTH'S FORMATION AND STRUCTURE

The earth formed approximately 4.6 billion years ago from a nebular cloud of dust and gas that surrounded the sun. As the gas cooled, more solids formed. The dusty material accreted to the nebular midplane where it formed progressively larger clumps. Eventually, bodies of several kilometers in diameter formed; these are known as **planetesimals**. The largest planetesimals grew fastest, at the expense of the smaller ones. This process continued until an earth-sized planet had formed.

Early in its formation, the earth must have been completely molten. The main source of heat at that time was probably the decay of naturally-occurring radioactive elements. As the earth cooled, density differences between the forming minerals caused the interior to become differentiated into three concentric zones: the crust, mantle and core. The crust extends downward from the surface to an average depth of 35 km where the mantle begins. The mantle extends down to a depth of 2900 km where the core begins. The core extends down to the center of the earth, a depth of about 6400 km from the surface.

The **core** makes up 16 percent of the volume of the earth and about 31 percent of the mass. It can be divided into two regions: a solid inner core and a liquid outer core. The inner core is probably mostly metallic iron alloyed with a small amount of nickel, as its density is somewhat greater than that of pure metallic iron. The outer core is similar in composition, but probably also contains small amounts of lighter elements, such as sulfur and oxygen, because its density is slightly less than that of pure metallic iron. The presence of the lighter elements depresses the freezing point and is probably responsible for the outer core's liquid state.

The **mantle** is the largest layer in the earth, making up about 82 percent of the volume and 68 percent of the mass of the earth. The mantle is dominated by magnesium and iron-rich (mafic) minerals. Heat from the core of the earth is transported to the crustal region by large-scale convection in the mantle. Near the top of the mantle is a region of partially melted rock called the **asthenosphere**. Numerous small-scale convection currents occur here as hot **magma** (i.e., molten rock) rises and cooler magma sinks due to differences in density.

The **crust** is the thinnest layer in the earth, making up only 1 percent of the mass and 2 percent of the volume. Relative to the rest of the earth, the crust is rich in elements such as silicon, aluminum, calcium, sodium and potassium. Crustal materials are very diverse, consisting of more than 2000 minerals. The less dense crust floats upon the mantle in two forms: the **continental crust** and the **oceanic crust**. The oceanic crust, which contains more **mafic minerals** is thinner and denser than the continental crust which contains minerals richer in silicon and aluminum. The thick continental crust has deep buoyant roots that help to support the higher elevations above. The crust contains the mineral resources and the fossil fuels

¹This content is available online at <<http://cnx.org/content/m16682/1.1/>>.

used by humans.

3.1.2 GEOLOGIC TIME SCALE

In order to describe the time relationships between rock formations and fossils, scientists developed a relative **geologic time scale** in which the earth's history is divided and subdivided into time divisions. The three eons (**Phanerozoic**, **Proterozoic**, and **Archean**) represent the largest time divisions (measured in billions of years). They in turn are subdivided into **Eras**, **Periods** and **Epochs**. Major discontinuities in the geologic record and in the corresponding biological (fossil) record are chosen as boundary lines between the different time segments. For example, the Cretaceous-Tertiary boundary (65 million years ago) marks a sudden mass extinction of species, including the dinosaurs. Through the use of modern quantitative techniques, some rocks and organic matter can be accurately dated using the decay of naturally-occurring radioactive isotopes. Therefore, absolute ages can be assigned to some parts of the geologic time scale.

3.1.3 THE LITHOSPHERE AND PLATE TECTONICS

The layer of the mantle above the asthenosphere plus the entire crust make up a region called the **lithosphere**. The lithosphere, and therefore, the earth's crust, is not a continuous shell, but is broken into a series of plates that independently "float" upon the asthenosphere, much like a raft on the ocean. These plates are in constant motion, typically moving a few centimeters a year, and are driven by convection in the mantle. The scientific theory that describes this phenomenon is called **plate tectonics**. According to the theory of plate tectonics, the lithosphere is comprised of some seven major plates and several smaller ones. Because these plates are in constant motion, interactions occur where plate boundaries meet.

A convergent (colliding) plate boundary occurs when two plates collide. If the convergent boundary involves two continental plates, the crust is compressed into high mountain ranges such as the Himalayas. If an oceanic plate and a continental plate collide, the oceanic crust (because it is more dense) is subducted under the continental crust. The region where subduction takes place is called a **subduction zone** and usually results in a deep ocean trench such as the "**Mariana Trench**" in the western Pacific ocean. The subducted crust melts and the resultant magma can rise to the surface and form a volcano. A **divergent plate** boundary occurs when two plates move away from each other. Magma upwelling from the mantle region is forced through the resulting cracks, forming new crust. The mid-ocean ridge in the Atlantic ocean is a region where new crustal material continually forms as plates diverge. Volcanoes can also occur at divergent boundaries. The island of Iceland is an example of such an occurrence. A third type of plate boundary is the **transform boundary**. This occurs when two plates slide past one another. This interaction can build up strain in the adjacent crustal regions, resulting in earthquakes when the strain is released. The San Andreas Fault in California is an example of a transform plate boundary.

3.2 GEOLOGICAL DISTURBANCES

3.2.1 VOLCANOES

An active **volcano** occurs when **magma (molten rock)** reaches the earth's surface through a crack or vent in the crust. Volcanic activity can involve the extrusion of lava on the surface, the ejection of solid rock and ash, and the release of water vapor or gas (carbon dioxide or sulfur dioxide). Volcanoes commonly occur near plate boundaries where the motion of the plates has created cracks in the lithosphere through which the magma can flow. About eighty percent of volcanoes occur at convergent plate boundaries where subducted material melts and rises through cracks in the crust. The Cascade Range was formed in this way.

Volcanoes can be classified according to the type and form of their ejecta. The basic types are: composite volcanoes, shield volcanoes, cinder cones, and lava domes. **Composite volcanoes** are steep-sided, symmetrical cones built of multiple layers of viscous lava and ash. Most composite volcanoes have a crater at the summit which contains the central vent. Lavas flow from breaks in the crater wall or from cracks on the flanks of the cone. Mt Fuji in Japan and Mt Ranier in Washington are examples of composite volcanoes.

Shield volcanoes are built almost entirely of highly fluid (low viscosity) lava flows. They form slowly from numerous flows that spread out over a wide area from a central vent. The resultant structure is a broad, gently sloping cone with a profile like a warrior's shield. Mt Kilauea in Hawaii is an example of a shield volcano.

Cinder cones are the simplest type of volcano. They form when lava blown violently into the area breaks into small fragments that solidify and fall as cinders. A steep-sided cone shape is formed around the vent, with a crater at the summit. Sunset Crater in Arizona is a cinder cone that formed less than a thousand years ago, disrupting the lives of the native inhabitants of the region.

Lava domes are formed when highly viscous lava is extruded from a vent and forms a rounded, steep-sided dome. The lava piles up around and on the vent instead of flowing away, mostly growing by expansion from within. Lava domes commonly occur within the craters or on the flanks of composite volcanoes.

3.2.2 EARTHQUAKES

An **earthquake** occurs when built up strain in a rock mass causes it to rupture suddenly. The region where the rupture occurs is called the **focus**. This is often deep below the surface of the crust. The point on the surface directly above the focus is called the **epicenter**. Destructive waves propagate outward from the region of the quake, traveling throughout the earth. The magnitude of an earthquake is a measure of the total amount of energy released. The first step in determining the magnitude is to measure the propagated waves using a device called a **seismograph**. Based on this information, the earthquake is given a number classification on a modified **Richter scale**. The scale is logarithmic, so a difference of one unit means a difference of ten-fold in wave intensity, which corresponds to an energy difference of 32-fold. The intensity of an earthquake is an indicator of the effect of an earthquake at a particular locale. The effect depends not only on the magnitude of the earthquake, but also the types of subsurface materials and the structure and design of surface structures.

Earthquakes generally occur along breaks in the rock mass known as **faults**, and most occur in regions near plate boundaries. Some 80 percent of all earthquakes occur near convergent plate boundaries, triggered by the interaction of the plates. Earthquakes are also often associated with volcanic activity due to the movement of sub-surface magma. When an earthquake occurs under the ocean, it can trigger a destructive tidal wave known as a **tsunami**.

3.2.3 ROCKS AND THE ROCK CYCLE

The earth's crust is composed of many kinds of rocks, each of which is made up of one or more minerals. Rocks can be classified into three basic groups: igneous, sedimentary, and metamorphic. **Igneous rocks** are the most common rock type found in the earth's crust. They form when magma cools and crystallizes subsurface (intrusive igneous rocks) or lava cools and crystallizes on the surface (extrusive igneous rocks). Granite is an example of an intrusive igneous rock, whereas basalt is an extrusive igneous rock.

Sedimentary rocks are formed by the consolidation of the weathered fragments of pre-existing rocks, by the precipitation of minerals from solution, or by compaction of the remains of living organisms. The processes involving weathered rock fragments include erosion and transport by wind, water or ice, followed by deposition as sediments. As the sediments accumulate over time, those at the bottom are compacted. They are cemented by minerals precipitated from solution and become rocks.

The process of compaction and cementation is known as **lithification**. Some common types of sedimentary rocks are limestone, shale, and sandstone. Gypsum represents a sedimentary rock precipitated from solution. Fossil fuels such as coal and oil shale are sedimentary rocks formed from organic matter.

Metamorphic rocks are formed when solid igneous, sedimentary or metamorphic rocks change in response to elevated temperature and pressure and/or chemically active fluids. This alteration usually occurs subsurface. It may involve a change in texture (recrystallization), a change in mineralogy or both. Marble is a metamorphosed form of limestone, while slate is transformed shale. Anthracite is a metamorphic form of coal.

The **rock cycle** illustrates connections between the earth's internal and external processes and how the three basic rock groups are related to one another. Internal processes include melting and metamorphism due to elevated temperature and pressure. Convective currents in the mantle keep the crust in constant motion (plate tectonics). Buried rocks are brought to the surface (uplift), and surface rocks and sediments are transported to the upper mantle region (subduction).

Two important external processes in the rock cycle are weathering and erosion. Weathering is the process by which rock materials are broken down into smaller pieces and/or chemically changed. Once rock materials are broken down into smaller pieces, they can be transported elsewhere in a process called erosion. The main vehicle of erosion is moving water, but wind and glaciers can also erode rock.

3.2.4 SOIL FORMATION

Soil is one of the earth's most precious and delicate resources. Its formation involves the weathering of parent materials (e.g., rocks) and biological activity. Soil has four principal components: water, eroded inorganic parent material, air, and organic matter (e.g., living and decaying organisms).

Soil formation begins with unconsolidated materials that are the products of **weathering**. These materials may be transported to the location of soil formation by processes such as wind or water, or may result from the weathering of underlying bedrock. The weathering process involves the disintegration and decomposition of the rock. It can be physical (e.g., water seeping into rock cracks and then freezing) or chemical (e.g., dissolution of minerals by acid rain). Physical processes are more prevalent in cold and dry climates, while chemical processes are more prevalent in warm or moist climates.

Soil materials tend to move vertically in the formation environment. Organic materials (e.g., leaf litter) and sediments can be added, while other materials (e.g., minerals) can be lost due to erosion and leaching. Living organisms (e.g., bacteria, fungi, worms, and insects) also become incorporated into the developing soil.

The living component of the soil breaks down other organic materials to release their nutrients (e.g., nitrogen, potassium and phosphorous). The nutrients are then used and recycled by growing plants and other organisms. This recycling of nutrients helps create and maintain a viable soil.

Several factors influence soil formation including: climate, parent material, biologic organisms, topography and time. The climate of an area (precipitation and temperature) may be the most important factor in soil formation. Temperature affects the rates of chemical reactions and rainfall affects soil pH and leaching. Parent material or bedrock varies from region to region and can affect the texture and pH of soils. Vegetation type affects the rate at which nutrients in the soil are recycled, the type and amount of organic matter in the soil, soil erosion, and the types and numbers of micro-organisms living in the soil.

Humans can also have a profound effect on soils through such activities as plowing, irrigating and mining. The topography of a region affects rainfall runoff, erosion and solar energy intake. Soil formation is a continuous process. Soils change with time as factors such as organic matter input and mineral content change. The process of making a soil suitable for use by humans can take tens of thousands of years. Unfortunately, the destruction of that soil can occur in a few short generations.

Chapter 4

THE ATMOSPHERE¹

4.1 THE ATMOSPHERE

4.1.1 INTRODUCTION

The **atmosphere**, the gaseous layer that surrounds the earth, formed over four billion years ago. During the evolution of the solid earth, volcanic eruptions released gases into the developing atmosphere. Assuming the outgassing was similar to that of modern volcanoes, the gases released included: water vapor (H₂O), carbon monoxide (CO), carbon dioxide (CO₂), hydrochloric acid (HCl), methane (CH₄), ammonia (NH₃), nitrogen (N₂) and sulfur gases. The atmosphere was reducing because there was no free oxygen. Most of the hydrogen and helium that outgassed would have eventually escaped into outer space due to the inability of the earth's gravity to hold on to their small masses. There may have also been significant contributions of volatiles from the massive meteoritic bombardments known to have occurred early in the earth's history.

Water vapor in the atmosphere condensed and rained down, eventually forming lakes and oceans. The oceans provided homes for the earliest organisms which were probably similar to cyanobacteria. Oxygen was released into the atmosphere by these early organisms, and carbon became sequestered in sedimentary rocks. This led to our current oxidizing atmosphere, which is mostly comprised of nitrogen (roughly 71 percent) and oxygen (roughly 28 percent). Water vapor, argon and carbon dioxide together comprise a much smaller fraction (roughly 1 percent). The atmosphere also contains several gases in trace amounts, such as helium, neon, methane and nitrous oxide. One very important trace gas is ozone, which absorbs harmful UV radiation from the sun.

4.1.2 ATMOSPHERIC STRUCTURE

The earth's atmosphere extends outward to about 1,000 kilometers where it transitions to interplanetary space. However, most of the mass of the atmosphere (greater than 99 percent) is located within the first 40 kilometers. The sun and the earth are the main sources of radiant energy in the atmosphere. The sun's radiation spans the infrared, visible and ultraviolet light regions, while the earth's radiation is mostly infrared.

The vertical temperature profile of the atmosphere is variable and depends upon the types of radiation that affect each atmospheric layer. This, in turn, depends upon the chemical composition of that layer (mostly involving trace gases). Based on these factors, the atmosphere can be divided into four distinct layers: the troposphere, stratosphere, mesosphere, and thermosphere.

The **troposphere** is the atmospheric layer closest to the earth's surface. It extends about 8 - 16 kilometers from the earth's surface. The thickness of the layer varies a few km according to latitude and the season of the year. It is thicker near the equator and during the summer, and thinner near the poles and during the

¹This content is available online at <<http://cnx.org/content/m16687/1.1/>>.

winter. The troposphere contains the largest percentage of the mass of the atmosphere relative to the other layers. It also contains some 99 percent of the total water vapor of the atmosphere.

The temperature of the troposphere is warm (roughly 17°C) near the surface of the earth. This is due to the absorption of infrared radiation from the surface by water vapor and other greenhouse gases (e.g. carbon dioxide, nitrous oxide and methane) in the troposphere. The concentration of these gases decreases with altitude, and therefore, the heating effect is greatest near the surface. The temperature in the troposphere decreases at a rate of roughly 6.5°C per kilometer of altitude. The temperature at its upper boundary is very cold (roughly -60°C).

Because hot air rises and cold air falls, there is a constant convective overturn of material in the troposphere. Indeed, the name troposphere means "region of mixing." For this reason, all weather phenomena occur in the troposphere. Water vapor evaporated from the earth's surface condenses in the cooler upper regions of the troposphere and falls back to the surface as rain. Dust and pollutants injected into the troposphere become well mixed in the layer, but are eventually washed out by rainfall. The troposphere is therefore self cleaning.

A narrow zone at the top of the troposphere is called the **tropopause**. It effectively separates the underlying troposphere and the overlying stratosphere. The temperature in the tropopause is relatively constant. Strong eastward winds, known as the **jet stream**, also occur here.

The **stratosphere** is the next major atmospheric layer. This layer extends from the tropopause (roughly 12 kilometers) to roughly 50 kilometers above the earth's surface. The temperature profile of the stratosphere is quite different from that of the troposphere. The temperature remains relatively constant up to roughly 25 kilometers and then gradually increases up to the upper boundary of the layer. The amount of water vapor in the stratosphere is very low, so it is not an important factor in the temperature regulation of the layer. Instead, it is ozone (O_3) that causes the observed temperature inversion.

Most of the ozone in the atmosphere is contained in a layer of the stratosphere from roughly 20 to 30 kilometers. This ozone layer absorbs solar energy in the form of ultraviolet radiation (UV), and the energy is ultimately dissipated as heat in the stratosphere. This heat leads to the rise in temperature. Stratospheric ozone is also very important for living organisms on the surface of the earth as it protects them by absorbing most of the harmful UV radiation from the sun. Ozone is constantly being produced and destroyed in the stratosphere in a natural cycle. The basic reactions involving only oxygen (known as the "**Chapman Reactions**") are as follows:

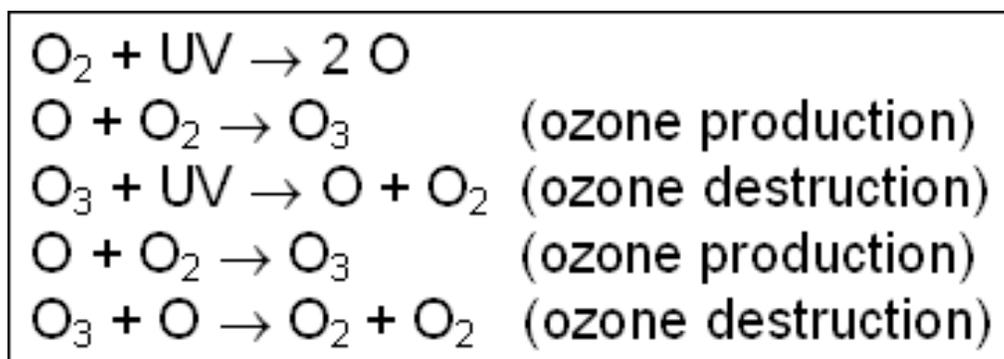


Figure 4.1

The **production of ozone** from molecular oxygen involves the absorption of high energy UV radiation (UVA) in the upper atmosphere. The **destruction of ozone** by absorption of UV radiation involves moderate and low energy radiation (UVB and UVC). Most of the production and destruction of ozone

occurs in the stratosphere at lower latitudes where the ultraviolet radiation is most intense.

Ozone is very unstable and is readily destroyed by reactions with other atmospheric species such as nitrogen, hydrogen, bromine, and chlorine. In fact, most ozone is destroyed in this way. The use of **chlorofluorocarbons (CFCs)** by humans in recent decades has greatly affected the natural ozone cycle by increasing the rate of its destruction due to reactions with chlorine. Because the temperature of the stratosphere rises with altitude, there is little convective mixing of the gases. The stratosphere is therefore very stable. Particles that are injected (such as volcanic ash) can stay aloft for many years without returning to the ground. The same is true for pollutants produced by humans. The upper boundary of the stratosphere is known as the **stratopause**, which is marked by a sudden decrease in temperature.

The third layer in the earth's atmosphere is called the **mesosphere**. It extends from the stratopause (about 50 kilometers) to roughly 85 kilometers above the earth's surface. Because the mesosphere has negligible amounts of water vapor and ozone for generating heat, the temperature drops across this layer. It is warmed from the bottom by the stratosphere. The air is very thin in this region with a density about 1/1000 that of the surface. With increasing altitude this layer becomes increasingly dominated by lighter gases, and in the outer reaches, the remaining gases become stratified by molecular weight.

The fourth layer, the **thermosphere**, extends outward from about 85 kilometers to about 600 kilometers. Its upper boundary is ill defined. The temperature in the thermosphere increases with altitude, up to 1500° C or more. The high temperatures are the result of absorption of intense solar radiation by the last remaining oxygen molecules. The temperature can vary substantially depending upon the level of solar activity.

The lower region of the thermosphere (up to about 550 kilometers) is also known as the **ionosphere**. Because of the high temperatures in this region, gas particles become ionized. The ionosphere is important because it reflects radio waves from the earth's surface, allowing long-distance radio communication. The visual atmospheric phenomenon known as the northern lights also occurs in this region. The outer region of the atmosphere is known as the **exosphere**. The exosphere represents the final transition between the atmosphere and interplanetary space. It extends about 1000 kilometers and contains mainly helium and hydrogen. Most satellites operate in this region.

Solar radiation is the main energy source for atmospheric heating. The atmosphere heats up when water vapor and other greenhouse gases in the troposphere absorb infrared radiation either directly from the sun or re-radiated from the earth's surface. Heat from the sun also evaporates ocean water and transfers heat to the atmosphere. The earth's surface temperature varies with latitude. This is due to uneven heating of the earth's surface. The region near the equator receives direct sunlight, whereas sunlight strikes the higher latitudes at an angle and is scattered and spread out over a larger area. The angle at which sunlight strikes the higher latitudes varies during the year due to the fact that the earth's equatorial plane is tilted 23.5° relative to its orbital plane around the sun. This variation is responsible for the different seasons experienced by the non-equatorial latitudes.

4.1.3 WIND

Convecting air masses in the troposphere create air currents known as **winds**, due to horizontal differences in air pressure. Winds flow from a region of higher pressure to one of a lower pressure. Global air movement begins in the equatorial region because it receives more solar radiation. The general flow of air from the equator to the poles and back is disrupted, though, by the rotation of the earth. The earth's surface travels faster beneath the atmosphere at the equator and slower at the poles. This causes air masses moving to the north to be deflected to the right, and air masses moving south to be deflected to the left. This is known as the "**Coriolis Effect**." The result is the creation of six huge **convection cells** situated at different latitudes. Belts of prevailing surface winds form and distribute air and moisture over the earth.

Jet streams are extremely strong bands of winds that form in or near the tropopause due to large air pressure differentials. Wind speeds can reach as high as 200 kilometers per hour. In North America, there are two main jet streams: the polar jet stream, which occurs between the westerlies and the polar easterlies, and the subtropical jet stream, which occurs between the trade winds and the westerlies.

4.1.4 WEATHER

The term **weather** refers to the short term changes in the physical characteristics of the troposphere. These physical characteristics include: temperature, air pressure, humidity, precipitation, cloud cover, wind speed and direction. Radiant energy from the sun is the power source for weather. It drives the convective mixing in the troposphere which determines the atmospheric and surface weather conditions.

Certain atmospheric conditions can lead to extreme weather phenomena such as thunderstorms, floods, tornadoes and hurricanes. A **thunderstorm** forms in a region of atmospheric instability, often occurring at the boundary between cold and warm fronts. Warm, moist air rises rapidly (updraft) while cooler air flows down to the surface (downdraft). Thunderstorms produce intense rainfall, lightning and thunder. If the atmospheric instability is very large and there is a large increase in wind strength with altitude (vertical wind shear), the thunderstorm may become severe. A severe thunderstorm can produce flash floods, hail, violent surface winds and tornadoes.

Floods can occur when atmospheric conditions allow a storm to remain in a given area for a length of time, or when a severe thunderstorm dumps very large amounts of rainfall in a short time period. When the ground becomes saturated with water, the excess runoff flows into low-lying areas or rivers and causes flooding.

A **tornado** begins in a severe thunderstorm. Vertical wind shear causes the updraft in the storm to rotate and form a funnel. The rotational wind speeds increase and vertical stretching occurs due to angular momentum. As air is drawn into the funnel core, it cools rapidly and condenses to form a visible funnel cloud. The funnel cloud descends to the surface as more air is drawn in. Wind speeds in tornadoes can reach several hundred miles per hour. Tornadoes are most prevalent in the Great Plains region of the United States, forming when cold dry polar air from Canada collides with warm moist tropical air from the Gulf of Mexico.

A **cyclone** is an area of low pressure with winds blowing counter-clockwise (Northern Hemisphere) or clockwise (Southern Hemisphere) around it. Tropical cyclones are given different names depending on their wind speed. The strongest tropical cyclones in the Atlantic Ocean (wind speed exceeds 74 miles per hour) are called **hurricanes**. These storms are called **typhoons** (Pacific Ocean) or cyclones (Indian Ocean) in other parts of the world. Hurricanes are the most powerful of all weather systems, characterized by strong winds and heavy rain over wide areas. They form over the warm tropical ocean and quickly lose intensity when they move over land. Hurricanes affecting the continental United States generally occur from June through November.

4.1.5 OCEAN CURRENTS

The surface of the earth is over 71 percent water, so it is not surprising that oceans have a significant effect on the weather and climate. Because of the high heat capacity of water, the ocean acts as a temperature buffer. That is why coastal climates are less extreme than inland climates. Most of the radiant heat from the sun is absorbed by ocean surface waters and ocean currents help distribute this heat.

Currents are the movement of water in a predictable pattern. Surface ocean currents are driven mostly by prevailing winds. The "Coriolis Effect" causes the currents to flow in circular patterns. These currents help transport heat from the tropics to the higher latitudes. Two large surface currents near the United States are the California current along the west coast and the Gulf Stream along the east coast. Deep ocean currents are driven by differences in water temperature and density. They move in a convective pattern.

The less dense (lower salinity) warm water in the equatorial regions rises and moves towards the polar regions, while more dense (higher salinity) cold water in the polar regions sinks and moves towards the equatorial regions. Sometimes this cold deep water moves back to the surface along a coastline in a process known as **upwelling**. This cold deep water is rich in nutrients that support productive fishing grounds.

About every three to seven years, warm water from the western equatorial Pacific moves to the eastern equatorial Pacific due to weakened trade winds. The eastern Pacific Ocean thus becomes warmer than usual for a period of about a year. This is known as **El Niño**. El Niño prevents the nutrient-rich, cold-water upwellings along the western coast of South America. It also impacts the global weather conditions. Some

regions receive heavier than usual rainfall, while other regions suffer drought conditions with lower than usual rainfall.

Probably the most important part of weather is **precipitation** as rainfall or snowfall. Water from the vast salty oceans evaporates and falls over land as fresh water. It is rainfall that provides fresh water for land plants, and land animals. Winter snowfall in mountainous regions provides a stored supply of fresh water which melts and flows into streams during the spring and summer.

Atmospheric clouds are the generators of precipitation. Clouds form when a rising air mass cools and the temperature and humidity are right for condensation to occur. Condensation does not occur spontaneously, but instead requires a **condensation nuclei**. These are tiny (less than $1\mu\text{m}$) dust or smoke particles. The condensation droplet is small enough (about $20\mu\text{m}$) that it is supported by the atmosphere against the pull of gravity. The visible result of these condensation droplets is a cloud.

Under the right conditions, droplets may continue to grow by continued condensation onto the droplet and/or coalescence with other droplets through collisions. When the droplets become sufficiently large they begin to fall as precipitation. Typical raindrops are about 2 mm in diameter. Depending upon the temperature of the cloud and the temperature profile of the atmosphere from the cloud to the earth's surface, various types of precipitation can occur: rain, freezing rain, sleet or snow. Very strong storms can produce relatively large chunks of ice called **hailstones**.

4.1.6 CLIMATE

Climate can be thought of as a measure of a region's average weather over a period of time. In defining a climate, the geography and size of the region must be taken into account. A micro-climate might involve a backyard in the city. A macroclimate might cover a group of states. When the entire earth is involved, it is a global climate. Several factors control large scale climates such as latitude (solar radiation intensity), distribution of land and water, pattern of prevailing winds, heat exchange by ocean currents, location of global high and low pressure regions, altitude and location of mountain barriers.

The most widely used scheme for classifying climate is the **Köppen System**. This scheme uses average annual and monthly temperature and precipitation to define five climate types:

1.	tropical moist climates: average monthly temperature is always greater than 18°C
2.	dry climates: deficient precipitation most of the year
3.	moist mid-latitude climates with mild winters
4.	moist mid-latitude climates with severe winters
5.	polar climates: extremely cold winters and summers.

Table 4.1

Using the Köppen system and the seasonal dominance of large scale air masses (e.g., maritime or continental), the earth's climate zones can be grouped as follows:

1.	tropical wet
2.	tropical wet and dry
3.	tropical desert
4.	mid-latitude wet
5.	mid-latitude dry summer
6.	mid-latitude dry winter
7.	polar wet
8.	dry and polar desert

Table 4.2

Los Angeles has a mid-latitude dry summer climate, whereas New Orleans has a mid-latitude wet climate.

Data from natural climate records (e.g. ocean sediments, tree rings, Antarctic ice cores) show that the earth's climate constantly changed in the past, with alternating periods of colder and warmer climates. The most recent ice age ended only about 10,000 years ago. The natural system controlling climate is very complex. It consists of a large number of feedback mechanisms that involve processes and interactions within and between the atmosphere, biosphere and the solid earth.

Some of the natural causes of global climate change include plate tectonics (land mass and ocean current changes), volcanic activity (atmospheric dust and greenhouse gases), and long-term variations in the earth's orbit and the angle of its rotation axis (absolute and spatial variations in solar radiation).

More recently, anthropogenic (human) factors may be affecting the global climate. Since the late 19th century, the average temperature of the earth has increased about 0.3 to 0.6^o C. Many scientists believe this global warming trend is the result of the increased release of greenhouse gases (e.g., CO₂) into the atmosphere from the combustion of fossil fuels.

Chapter 5

THE BIOSPHERE¹

5.1 THE BIOSPHERE

5.1.1 INTRODUCTION

The **biosphere** is the region of the earth that encompasses all living organisms: plants, animals and bacteria. It is a feature that distinguishes the earth from the other planets in the solar system. "Bio" means life, and the term biosphere was first coined by a Russian scientist (Vladimir Vernadsky) in the 1920s. Another term sometimes used is **ecosphere** ("eco" meaning home). The biosphere includes the outer region of the earth (the **lithosphere**) and the lower region of the atmosphere (the **troposphere**). It also includes the **hydrosphere**, the region of lakes, oceans, streams, ice and clouds comprising the earth's water resources. Traditionally, the biosphere is considered to extend from the bottom of the oceans to the highest mountaintops, a layer with an average thickness of about 20 kilometers. Scientists now know that some forms of microbes live at great depths, sometimes several thousand meters into the earth's crust.

Nonetheless, the biosphere is a very tiny region on the scale of the whole earth, analogous to the thickness of the skin on an apple. The bulk of living organisms actually live within a smaller fraction of the biosphere, from about 500 meters below the ocean's surface to about 6 kilometers above sea level.

Dynamic interactions occur between the **biotic region** (biosphere) and the **abiotic regions** (atmosphere, lithosphere and hydrosphere) of the earth. Energy, water, gases and nutrients are exchanged between the regions on various spatial and time scales. Such exchanges depend upon, and can be altered by, the environments of the regions. For example, the chemical processes of early life on earth (e.g. photosynthesis, respiration, carbonate formation) transformed the reducing ancient atmosphere into the oxidizing (free oxygen) environment of today. The interactive processes between the biosphere and the abiotic regions work to maintain a kind of planetary equilibrium. These processes, as well as those that might disrupt this equilibrium, involve a range of scientific and socioeconomic issues.

The study of the relationships of living organisms with one another and with their environment is the science known as **ecology**. The word ecology comes from the Greek words oikos and logos, and literally means "study of the home." The ecology of the earth can be studied at various levels: an individual (organism), a **population**, a **community**, an **ecosystem**, a **biome** or the entire **biosphere**. The variety of living organisms that inhabit an environment is a measure of its **biodiversity**.

5.1.2 ORGANISMS

Life evolved after oceans formed, as the ocean environment provided the necessary nutrients and support medium for the initial simple organisms. It also protected them from the harsh atmospheric UV radiation. As organisms became more complex they eventually became capable of living on land. However, this could

¹This content is available online at <<http://cnx.org/content/m16693/1.1/>>.

not occur until the atmosphere became oxidizing and a protective ozone layer formed which blocked the harmful UV radiation. Over roughly the last four billion years, organisms have diversified and adapted to all kinds of environments, from the icy regions near the poles to the warm tropics near the equator, and from deep in the rocky crust of the earth to the upper reaches of the troposphere.

Despite their diversity, all living organisms share certain characteristics: they all replicate and all use DNA to accomplish the replication process. Based on the structure of their cells, organisms can be classified into two types: eukaryotes and prokaryotes.

The main difference between them is that a **eukaryote** has a nucleus, which contains its DNA, while a **prokaryote** does not have a nucleus, but instead its DNA is free-floating in the cell. Bacteria are **prokaryotes**, and humans are eukaryotes. Organisms can also be classified according to how they acquire energy. **Autotrophs** are "self feeders" that use light or chemical energy to make food. Plants are autotrophs. **Heterotrophs** (i.e. "other feeders") obtain energy by eating other organisms, or their remains. Bacteria and animals are heterotrophs. Groups of organisms that are physically and genetically related can be classified into **species**. There are millions of species on the earth, most of them unstudied and many of them unknown. Insects and microorganisms comprise the majority of species, while humans and other mammals comprise only a tiny fraction. In an ecological study, a single member of a species or organism is known as an **individual**.

5.1.3 POPULATIONS AND COMMUNITIES

A number of individuals of the same species in a given area constitute a **population**. The number typically ranges anywhere from a few individuals to several thousand individuals. Bacterial populations can number in the millions. Populations live in a place or environment called a **habitat**. All of the populations of species in a given region together make up a **community**. In an area of tropical grassland, a community might be made up of grasses, shrubs, insects, rodents and various species of hooved mammals.

The populations and communities found in a particular environment are determined by abiotic and biotic **limiting factors**. These are the factors that most affect the success of populations. Abiotic limiting factors involve the physical and chemical characteristics of the environment. Some of these factors include: amounts of sunlight, annual rainfall, available nutrients, oxygen levels and temperature. For example, the amount of annual rainfall may determine whether a region is a grassland or forest, which in turn, affects the types of animals living there.

Each population in a community has a **range of tolerance** for an abiotic limiting factor. There are also certain maximum and minimum requirements known as **tolerance limits**, above and below which no member of a population is able to survive. The range of an abiotic factor that results in the largest population of a species is known as the **optimum range** for that factor. Some populations may have a narrow range of tolerance for one factor. For example, a freshwater fish species may have a narrow tolerance range for dissolved oxygen in the water. If the lake in which that fish species lives undergoes eutrophication, the species will die. This fish species can therefore act as an **indicator species**, because its presence or absence is a strict indicator of the condition of the lake with regard to dissolved oxygen content.

Biotic limiting factors involve interactions between different populations, such as competition for food and habitat. For example, an increase in the population of a meat-eating predator might result in a decrease in the population of its plant-eating prey, which in turn might result in an increase in the plant population the prey feeds on. Sometimes, the presence of a certain species may significantly affect the community make up. Such a species is known as a **keystone species**. For example, a beaver builds a dam on a stream and causes the meadow behind it to flood. A starfish keeps mussels from dominating a rocky beach, thereby allowing many other species to exist there.

5.1.4 ECOSYSTEMS

An **ecosystem** is a community of living organisms interacting with each other and their environment. Ecosystems occur in all sizes. A tidal pool, a pond, a river, an alpine meadow and an oak forest are all examples of ecosystems. Organisms living in a particular ecosystem are adapted to the prevailing abiotic

and biotic conditions. Abiotic conditions involve both physical and chemical factors (e.g., sunlight, water, temperature, soil, prevailing wind, latitude and elevation). In order to understand the flow of energy and matter within an ecosystem, it is necessary to study the feeding relationships of the living organisms within it.

Living organisms in an ecosystem are usually grouped according to how they obtain food. Autotrophs that make their own food are known as **producers**, while heterotrophs that eat other organisms, living or dead, are known as **consumers**. The producers include land and aquatic plants, algae and microscopic phytoplankton in the ocean. They all make their own food by using chemicals and energy sources from their environment.

For example, plants use photosynthesis to manufacture sugar (glucose) from carbon dioxide and water. Using this sugar and other nutrients (e.g., nitrogen, phosphorus) assimilated by their roots, plants produce a variety of organic materials. These materials include: starches, lipids, proteins and nucleic acids. Energy from sunlight is thus fixed as food used by themselves and by consumers.

The consumers are classed into different groups depending on the source of their food. **Herbivores** (e.g. deer, squirrels) feed on plants and are known as primary consumers. **Carnivores** (e.g. lions, hawks, killer whales) feed on other consumers and can be classified as **secondary consumers**. They feed on primary consumers. **Tertiary consumers** feed on other carnivores. Some organisms known as **omnivores** (e.g., bears, rats and humans) feed on both plants and animals. Organisms that feed on dead organisms are called **scavengers** (e.g., vultures, ants and flies). **Detritivores** (detritus feeders, e.g. earthworms, termites, crabs) feed on organic wastes or fragments of dead organisms.

Decomposers (e.g. bacteria, fungi) also feed on organic waste and dead organisms, but they digest the materials outside their bodies. The decomposers play a crucial role in recycling nutrients, as they reduce complex organic matter into inorganic nutrients that can be used by producers. If an organic substance can be broken down by decomposers, it is called **biodegradable**.

In every ecosystem, each consumer level depends upon lower-level organisms (e.g. a primary consumer depends upon a producer, a secondary consumer depends upon a primary consumer and a tertiary consumer depends upon a secondary consumer). All of these levels, from producer to tertiary consumer, form what is known as a **food chain**. A community has many food chains that are interwoven into a complex **food web**. The amount of organic material in a food web is referred to as its **biomass**. When one organism eats another, chemical energy stored in biomass is transferred from one level of the food chain to the next. Most of the consumed biomass is not converted into biomass of the consumer. Only a small portion of the useable energy is actually transferred to the next level, typically 10 percent. Each higher level of the food chain represents a cumulative loss of useable energy. The result is a **pyramid of energy flow**, with producers forming the base level.

Assuming 10 percent efficiency at each level, the tertiary consumer level would use only 0.1 percent of the energy available at the initial producer level. Because there is less energy available high on the energy pyramid, there are fewer top-level consumers. A disruption of the producer base of a food chain, therefore, has its greatest effect on the top-level consumer.

Ecosystem populations constantly fluctuate in response to changes in the environment, such as rainfall, mean temperature, and available sunlight. Normally, such changes are not drastic enough to significantly alter ecosystems, but catastrophic events such as floods, fires and volcanoes can devastate communities and ecosystems. It may be long after such a catastrophic event before a new, mature ecosystem can become established. After severe disturbance the make up of a community is changed. The resulting community of species changes, as early, post disturbance, fast-growing species are out-competed by other species. This natural process is called **ecological succession**. It involves two types of succession: **primary succession** and **secondary succession**.

Primary succession is the development of the first biota in a given region where no life is found. An example is of this is the surrounding areas where volcanic lava has completely covered a region or has built up a new island in the ocean. Initially, only **pioneer species** can survive there, typically **lichens** and **mosses**, which are able to withstand poor conditions. They are able to survive in highly exposed areas with limited water and nutrients. Lichen, which is made up of both a fungus and an alga, survives by

mutualism. The fungus produces an acid, which acts to further dissolve the barren rock. The alga uses those exposed nutrients, along with photosynthesis, to produce food for both. Grass seeds may land in the cracks, carried by wind or birds. The grass grows, further cracking the rocks, and upon completing its own life cycle, contributes organic matter to the crumbling rock to make soil. In time, larger plants, such as shrubs and trees may inhabit the area, offering habitats and niches to immigrating animal life. When the maximum biota that the ecosystem can support is reached, the **climax community** prevails. This occurs after hundreds if not thousands of years depending on the climate and location.

Secondary succession begins at a different point, when an existing ecosystem's community of species is removed by fire, deforestation, or a bulldozer's work in a vacant lot, leaving only soil. The first few centimeters of this soil may have taken 1000 years to develop from solid rock. It may be rich in humus, organic waste, and may be stocked with ready seeds of future plants. Secondary succession is also a new beginning, but one with a much quicker regrowth of organisms. Depending on the environment, succession to a climax community may only require 100 to 200 years with normal climate conditions, with communities progressing through stages of **early plant** and **animal species**, **mid-species** and **late successional species**. Some ecosystems, however, can never be regained.

5.1.5 BIOMES

The biosphere can be divided into relatively large regions called biomes. A biome has a distinct climate and certain living organisms (especially vegetation) characteristic to the region and may contain many ecosystems. The key factors determining climate are average annual precipitation and temperature. These factors, in turn, depend on the geography of the region, such as the latitude and elevation of the region, and mountainous barriers. The major types of biomes include: **aquatic**, **desert**, **forest**, **grassland** and **tundra**. Biomes have no distinct boundaries. Instead, there is a transition zone called an ecotone, which contains a variety of plants and animals. For example, an ecotone might be a transition region between a grassland and a desert, with species from both.

Water covers a major portion of the earth's surface, so aquatic biomes contain a rich diversity of plants and animals. **Aquatic biomes** can be subdivided into two basic types: **freshwater** and **marine**.

Freshwater has a low salt concentration, usually less than 1 percent, and occurs in several types of regions: ponds and lakes, streams and rivers, and wetlands. **Ponds and lakes** range in size, and small ponds may be seasonal. They sometimes have limited species diversity due to isolation from other water environments. They can get their water from precipitation, surface runoff, rivers, and springs. **Streams and rivers** are bodies of flowing water moving in one general direction (i.e., downstream). Streams and rivers start at their upstream headwaters, which could be springs, snowmelt or even lakes. They continue downstream to their mouths, which may be another stream, river, lake or ocean. The environment of a stream or river may change along its length, ranging from clear, cool water near the head, to warm, sediment-rich water near the mouth. The greatest diversity of living organisms usually occurs in the middle region. Wetlands are places of still water that support aquatic plants, such as cattails, pond lilies and cypress trees. Types of wetlands include marshes, swamps and bogs. **Wetlands** have the highest diversity of species with many species of birds, fur-bearing mammals, amphibians and reptiles. Some wetlands, such as salt marshes, are not freshwater regions.

Marine regions cover nearly three-fourths of the earth's surface. Marine bodies are salty, having approximately 35 grams of dissolved salt per liter of water (3.5 percent). **Oceans** are very large marine bodies that dominate the earth's surface and hold the largest ecosystems. They contain a rich diversity of living organisms. Ocean regions can be separated into four major zones: **intertidal**, **pelagic**, **benthic** and **abyssal**. The intertidal zone is where the ocean meets the land. Sometimes, it is submerged and at other times exposed, depending upon waves and tides. The pelagic zone includes the open ocean further away from land. The benthic zone is the region below the pelagic zone, but not including the very deepest parts of the ocean. The bottom of this zone consists of sediments. The deepest parts of the ocean are known as the abyssal zone. This zone is very cold (near freezing temperatures), and under great pressure from the overlying mass of water. Mid-ocean ridges occur on the ocean floor in abyssal zones. **Coral reefs** are found in the warm, clear, shallow waters of tropical oceans around islands or along continental coastlines.

They are mostly formed from calcium carbonate produced by living coral. Reefs provide food and shelter for other organisms and protect shorelines from erosion. Estuaries are partially enclosed areas where fresh water and silt from streams or rivers mix with salty ocean water. They represent a transition from land to sea and from freshwater to saltwater. Estuaries are biologically very productive areas and provide homes for a wide variety of plants, birds and animals.

Deserts are dry areas where evaporation usually exceeds precipitation. Rainfall is low – less than 25 centimeters per year – and can be highly variable and seasonal. The low humidity results in temperature extremes between day and night. Deserts can be hot or cold. **Hot deserts** (e.g. the Sonoran) are very hot in the summer and have relatively high temperatures throughout the year and have seasonal rainfall. **Cold deserts** (e.g. the Gobi) are characterized by cold winters and low but year-round precipitation. Deserts have relatively little vegetation and the substrate consists mostly of sand, gravel or rocks. The transition regions between deserts and grasslands are sometimes called **semiarid deserts** (e.g. the Great Basin of the western United States).

Grasslands cover regions where moderate rainfall is sufficient for the growth of grasses, but not enough for stands of trees. There are two main types of grasslands: **tropical grasslands** (savannas) and **temperate grasslands**. Tropical grasslands occur in warm climates such as Africa and very limited regions of Australia. They have a few scattered trees and shrubs, but their distinct rainy and dry seasons prevent the formation of tropical forests. Lower rainfall, more variable winter-through-summer temperatures and a near lack of trees characterize temperate grasslands. Prairies are temperate grasslands at fairly high elevation. They may be dominated by long or short grass species. The vast prairies originally covering central North America, or the Great Plains, were the result of favorable climate conditions created by their high elevation and proximity to the Rocky Mountains. Because temperate grasslands are treeless, relatively flat and have rich soil, most have been replaced by farmland.

Forests are dominated by trees and can be divided into three types: **tropical forests**, **temperate forests** and **boreal forests**. Tropical forests are always warm and wet and are found at lower latitudes. Their annual precipitation is very high, although some regions may have distinct wet and dry seasons. Tropical forests have the highest biodiversity of this biome. Temperate forests occur at mid-latitudes (i.e., North America), and therefore have distinct seasons. Summers are warm and winters are cold. The temperate forests have suffered considerable alteration by humans, who have cleared much of the forest land for fuel, building materials and agricultural use. Boreal forests are located in higher latitudes, like Siberia, where they are known as "**taiga**." They have very long, cold winters and a short summer season when most of the precipitation occurs. Boreal forests represent the largest biome on the continents.

Very low temperatures, little precipitation and low biodiversity characterize tundra. Its vegetation is very simple, with virtually no trees. The tundra can be divided into two different types: **arctic tundra** and **alpine tundra**. The arctic tundra occurs in polar regions. It has a very short summer growing season. Water collects in ponds and bogs, and the ground has a subsurface layer of permanently frozen soil known as permafrost. Alpine tundra is found at high elevations in tall mountains. The temperatures are not as low as in the arctic tundra, and it has a longer summer growing season.

5.1.6 EVOLUTION OF LIFE

Wherever they are found in the biosphere, living organisms are necessarily linked to their environment. **Ecosystems** are dynamic and communities change over time in response to abiotic or biotic changes in the environment. For example, the climate may become warmer or colder, wetter or drier, or the food chain may be disrupted by the loss of a particular population or the introduction of a new one. Species must be able to adapt to these changes in order to survive. As they adapt, the organisms themselves undergo change. **Evolution** is the gradual change in the genetic makeup of a population of a species over time. It is important to note that it is the population that evolves, rather than individuals.

A species evolves to a particular niche either by adapting to use a niche's environment or adapting to avoid competition with another species. Recall that no two species can occupy the exact same niche in an ecosystem. The availability of resources is pivotal.

In the case of five warbler species which all consume insects of the same tree, to survive each species needs to gather its food (insects) in different parts of that tree. This avoids competition and the possible extinction of one or more species. Therefore, one of the bird species will adapt to hunting at the treetops; another the lowest branches; another the mid-section. In this way, these species have evolved into different, yet similar, niches. All five species in this way can survive by adapting to a narrow niche. Organisms with a narrow niche are called **specialized species**. Another example is a species that may evolve to a narrow niche by consuming only one type of leaf, such as the Giant Panda, which consumes bamboo leaves.

This strategy allows it to co-exist with another consumer by not competing with it. In both cases, species with a narrow niche are often vulnerable to extinction because they typically cannot respond to changes in the environment. Evolving to a new niche would take too much time for the specialized species under the duress of a drought, for example.

On the other hand, a species that can use many foods and locations in which to hunt or gather are known as **generalized species**. In the event of a drought, a generalized species such as a cockroach may be more successful in finding alternative forms of food, and will survive and reproduce.

Yet another form of evolution is **co-evolution**, where species adapt to one another by interacting closely. This relationship can be a predator-prey type of interaction. Prey is at risk, but as a species it has evolved chemical defenses or behaviors. On the other hand, co-evolution can be a mutualistic relationship, often characterized by the ants and an acacia tree of South America. The acacia provides ants with food and a habitat, and its large projecting thorns provides protection from predators. The ants, in turn, protect the tree by attacking any animal landing on it and by clearing vegetation at its base. So closely evolved are the species that neither can exist without the other.

Similar ecosystems may offer similar niches to organisms, that are adapted or evolved to that niche. **Convergent evolution** is the development of similar adaptations in two species occupying different yet similar ecosystems. Two species evolve independently to respond to the demands of their ecosystem, and they develop the same mechanism to do so. What emerges are adaptations that resemble look-alikes: Wings of birds and bats are similar, but evolved separately to meet the demands of flying through air. The dolphin, a mammal, shares adaptations that allow for movement through water with the extinct reptile ichthyosaur. They have similar streamlined shapes of fins, head, and nose, which make the bodies better suited for swimming.

Natural selection is another process that depends on an organism's ability to survive in a changing environment. While evolution is the gradual change of the genetic makeup over time, natural selection is the force that favors a beneficial set of genes.

For example, birds migrating to an island face competition for the insects on a tropical tree. One genetic pool of a new generation may include a longer beak, which allows the bird to reach into a tropical flower for its nectar. When high populations of birds compete for insects, this ability to use the niche of collecting nectar favors that bird's survival. The long-beaked gene is passed to the next generation and the next, because birds can coexist with the insect-gathering birds by using a different niche. Through reproduction of the surviving longer-beaked birds, natural selection favors its adaptability.

A species, family or larger group of organisms may eventually come to the end of its evolutionary line. This is known as **extinction**. While bad news for those that become extinct, it's a natural occurrence that has been taking place since the beginning of life on earth. Extinctions of species are constantly occurring at some background rate, which is normally matched by speciation. Thus, in the natural world, there is a constant turnover of species.

Occasionally large numbers of species have become extinct over a relatively short geologic time period. The largest **mass extinction** event in the earth's history occurred at the end of the Permian period, 245 million years ago. As many as 96 percent of all marine species were lost, while on land more than 75 percent of all vertebrate families became extinct. Although, the actual cause of that extinction is unclear, the consensus is that climate change, resulting from sea level change and increased volcanic activity, was an important factor. The most famous of all mass extinctions occurred at the boundary of the Cretaceous and Tertiary periods, 65 million years ago. About 85 percent of species became extinct, including all of the dinosaurs. Most scientists believe that the impact of a small asteroid near the Yucatan Peninsula in Mexico

triggered that extinction event. The impact probably induced a dramatic change in the world climate.

The most serious extinction of mammals occurred about 11,000 years ago, as the last Ice Age was ending. Over a period of just a few centuries, most of the large mammals around the world, such as the mammoth, became extinct. While climate change may have been a factor in their extinction, a new force had also emerged on the earth - modern humans. Humans, aided by new, sharp-pointed weapons and hunting techniques, may have hurried the demise of the large land mammals. Over the years, human activity has continued to send many species to an early extinction. The best known examples are the passenger pigeon and the dodo bird, but numerous other species, many of them unknown, are killed off by over harvesting and other human-caused habitat destruction, degradation and fragmentation.

Chapter 6

HISTORY AND GLOBAL DISTRIBUTION¹

6.1 HISTORY AND GLOBAL DISTRIBUTION

6.1.1 INTRODUCTION

A population is a group of individuals living together in a given area at a given time. Changes in populations are termed **population dynamics**. The current human population is made up of all of the people who currently share the earth. The first humans walked the planet millions of years ago. Since that time, the number of humans living on the planet and where they live has constantly changed over time. Every birth and death is a part of human population dynamics. Each time a person moves from one location to another, the spatial arrangement of the population is changed, and this, too, is an element of population dynamics. While humans are unique in many ways as a species, they are subject to many of the same limiting forces and unexpected events of all populations of organisms.

In 1999, the human population crossed the six billion mark. At current growth rates, the population will double within 50 years. Long ago, when the human population was small, the doubling of the population had little impact on the human population or its environment. However, with the size of today's population, the effect of doubling the population is quite significant. Already, most of the people of the world do not have adequate clean water, food, housing and medical care, and these deficiencies are at least partially the result of over population. As the population continues to grow, competition for resources will increase. Natural disasters and political conflicts will exacerbate the problems, especially in the more stressed regions of developing nations. The survivors of this competition will likely be determined by factors such as place of birth and educational opportunities.

6.1.2 POPULATION GROWTH

Human populations are not stagnant. They naturally change in size, density and predominance of age groups in response to environmental factors such as resources availability and disease, as well as social and cultural factors. The increases and decreases in human population size make up what is known as **human population dynamics**. If resources are not limited, then populations experience exponential growth. A plot of **exponential growth** over time resembles a "J" curve. Absolute numbers are relatively small at first along the base of the **J curve**, but the population rapidly skyrockets when the critical time near the stem of the J curve is reached.

For most of the history of modern humans (*Homo sapiens*), people were hunter-gatherers. Food, especially meat from large mammals, was usually plentiful. However, populations were small because the nomadic life

¹This content is available online at <<http://cnx.org/content/m16700/1.1/>>.

did not favor large family sizes. During those times, the human population was probably not more than a few million worldwide. It was still in the base of the J growth curve.

With the end of the last Ice Age, roughly 10,000 years ago, the climates worldwide changed and many large mammals that had been the mainstay of human diet became extinct. This forced a change in diet and lifestyle, from one of the nomadic hunter-gatherer to that of a more stationary agricultural society.

Humans began cultivating food and started eating more plants and less meat. Having larger families was possible with the more stationary lifestyle. In fact, having a large family increasingly became an asset, as extra hands were needed for maintaining crops and homes. As agriculture became the mainstay of human life, the population increased.

As the population increased, people began living in villages, then in towns and finally in cities. This led to problems associated with overcrowded conditions, such as the buildup of wastes, poverty and disease. Large families were no longer advantageous. Infanticide was common during medieval times in Europe, and communicable diseases also limited the human population numbers. Easily spread in crowded, rat-infested urban areas, Black Death, the first major outbreak of the Bubonic Plague (1347-1351) drastically reduced the populations in Europe and Asia, possibly by as much as 50 percent.

Starting in the 17th Century, advances in science, medicine, agriculture and industry allowed rapid growth of human population and infanticide again became a common practice.

The next big influence on the human population occurred with the start of the Industrial Revolution in the late 18th century. With the advent of factories, children became valuable labor resources, thereby contributing to survival, and family sizes increased. The resulting population boom was further aided by improvements in agricultural technology that led to increased food production. Medical advancements increased control over disease and lengthened the average lifespan. By the early 19th century, the human population worldwide reached one billion. It was now in the stem of the J curve graph. As the world approached the 20th century, the human population was growing at an exponential rate.

During the 20th century, another important event in human population dynamics occurred. The birth rates in the highly developed countries decreased dramatically. Factors contributing to this decrease included: a rise in the standard of living, the availability of practical birth control methods and the establishment of child education and labor laws. These factors made large families economically impractical. In Japan, the birth rate has been so low in recent years that the government and corporations are worried about future labor shortages. Therefore, they are actively encouraging population growth. In contrast, the populations in less well-developed countries continue to soar. Worldwide, the human population currently exceeds six billion and continues to grow exponentially. How much more the world population will grow is a topic of intense speculation. One thing is certain: exponential growth cannot continue forever, as earth's resources are limited.

6.1.3 POPULATION DEMOGRAPHICS

Human **demography** (population change) is usually described in terms of the births and deaths per 1000 people. When births of an area exceed deaths, population increases. When the births of an area are fewer than deaths, the population decreases. The annual rate at which the size of a population changes is:

$$\text{Natural Population Change Rate (\%)} = \frac{(\text{Births} - \text{Deaths})}{1000} \times 100$$

Figure 6.1

During the year 2000, the birth rate for the world was 22 and the death rate was 9. Thus, the world's population grew at a rate of 1.3 percent. The annual rate of population change for a particular city or region is also affected by **immigration** (movement of people into a region) and **emigration** (movement out of a region).

$$\text{Population Change Rate} = \left(\text{Birth rate} + \text{Immigration rate} \right) - \left(\text{Death rate} + \text{Emigration rate} \right)$$

Figure 6.2

Highly industrialized nations, like the United States, Canada, Japan and Germany, generally have low birth and death rates. Annual rates of natural population change vary from -0.1% to 0.5%. In some industrial nations (e.g. Germany and Russia) death rates exceed birth rates so the net population decreases over time. Newly industrialized countries (e.g. South Korea, Mexico and China) have moderate birth rates and low death rates. The low death rates result from better sanitation, better health care and stable food production that accompany industrialization. The annual rates of natural population change are about 1 percent to 2 percent in these countries. Countries with limited industrial development (e.g. Pakistan and Ethiopia) tend to have high birth rates and moderate to low death rates. These nations are growing rapidly with annual rates of natural population change exceeding 2 percent.

Several factors influence **human fertility**. Important factors influencing birth and fertility rates in human populations are: affluence, average marriage age, availability of birth control, family labor needs, cultural beliefs, religious beliefs and the cost of raising and educating children.

The rapid growth of the world's population over the past 100 years is mainly results from a decline in death rates. Reasons for the drop in death rates include: better nutrition, fewer infant deaths, increased average life span and improvements in medical technology.

As countries become developed and industrialized, they experience a movement from high population growth to low population growth. Both death and birth rates decline.

These countries usually move from rapid population growth, to slow growth, to zero growth and finally to a reduction in population. This shift in growth rate with development is called the "**demographic transition**." Four distinct stages occur during the transition: pre-industrial, transitional, industrial and post-industrial.

During the **pre-industrial stage**, harsh living conditions result in a high birth rate and a high death rate. The population grows very slowly, if at all. The **transitional stage** begins shortly after industrialization. During this phase, the death rate drops because of increased food production and better sanitation and health conditions, but, the birth rate remains high. Therefore, the population grows rapidly.

During the **industrial stage**, industrialization is well established in the country. The birth rate drops and eventually approaches the death rate. Couples in cities realize that children are expensive to raise and that having large families restrict their job opportunities. The **post-industrial** stage occurs when the birth rate declines even further to equal the death rate, thus population growth reaches zero. The birth rate may eventually fall below the death rate, resulting in negative population growth.

The United States and most European countries have experienced this gradual transition over the past 150 years. The transition moves much faster for today's developing countries. This is because improvements in preventive health and medical care in recent decades have dramatically reduced mortality – especially infant mortality – and increased life expectancy. In a growing number of countries, couples are having fewer children than the two they need to "replace" themselves. However, even if the level of "**replacement fertility**" were reached today, populations would continue to grow for several decades because of the large numbers of people now entering their reproductive years.

As a result of reduced fertility and mortality, there will be a gradual demographic shift in all countries over the next few decades towards an older population. In developed countries, the proportion of people over age 65 has increased from 8 to 14 percent since 1950, and is expected to reach 25 percent by 2050. Within the next 35 years, those over age 65 will represent 30 percent or more of the populations in Japan and Germany. In some countries, the number of residents over age 85 will more than double.

6.1.4 PATTERNS OF RESOURCE USE

Humans have always made an impact on the environment through their use of resources. Early humans were primarily hunter-gatherers who used tools to survive. They fashioned wood and stone tools for hunting and food preparation, and used fire for cooking. Early humans developed methods for changing habitat to suit their needs and herding wild animals. As time passed, humans developed more tools and techniques and came to rely on that technology in their daily lives. Although the tools of early humans were primitive by today's standards, they significantly affected the environment and probably hastened the extinction of some large Ice Age mammals.

After the end of the last Ice Age, some eight to 10,000 years ago, humans began domesticating wild animals and plants. The first known instance of farming started in a region extending from southeastern Turkey to western Iran, known as the **fertile crescent**.

These early farmers domesticated crops such as chickpea, bitter vetch, grapes, olives, barley, emmer wheat, lentils, and flax. They hybridized wheat for making bread from wild grass and emmer wheat. They also domesticated animals such as sheep, goats, cattle and pigs. The fertile crescent's unique diversity of wild crops and animals offered humans a mix of basic agricultural commodities that allowed a revolution in the development of human society. With a reliable food supply, humans were able to stay in one place and be assured of having a constant supply of carbohydrates, protein, milk and oil. They had animals for transportation and plant and animal materials for producing clothing and rope. Agricultural economies soon displaced hunter-gatherer economies. Within 2,000 years, farming ranged from Pakistan to southern Italy.

Most early agriculture was subsistence farming in which farmers grew only enough food to feed their families. Agriculture underwent another important revolution about 5,000 years ago with the invention of the plow. The plow allowed humans to clear and farm larger plots of land than was otherwise possible. This increased the food supply and a concomitant increase in human population growth. More efficient farming methods also resulted in urbanization because a few farmers could produce a large surplus of food to feed those in the urban areas.

Over the last 10,000 years, land clearing for agriculture has destroyed and degraded the habitats of many species of plants and animals. Today, growing populations in less developed countries are rapidly clearing tropical forests and savannas for agricultural use. These tropical rainforests and savannas provide habitat for most of the earth's species. It has become clear that modern agricultural practices are not sustainable. Once-fertile areas are becoming infertile because of overgrazing, erosion and nutrient depletion. Furthermore, modern agriculture requires large inputs of energy and fertilizers, usually produced from nonrenewable fossil fuels.

The next major cultural change, the **Industrial Revolution**, began in England in the mid-18th century. It involved a shift from small-scale production of goods by hand to large-scale production of goods by machines. Industrial production of goods increased the consumption of natural resources such as minerals fuel, timber and water by cities. After World War I, more efficient mass production techniques were developed, and industrialization became prevalent in the economies of the United States, Canada, Japan and western Europe.

Advanced industrialization leads to many changes in human society, and some of those changes negatively affect the supply of natural resources and result in environmental degradation. These changes include: increased production and consumption of goods by humans, dependence on non-renewable resources such as oil and coal, production of synthetic materials (which may be toxic or non-biodegradable) and consumption of large amounts of energy at home and work.

Other changes may have positive benefits. These include: creation and mass production of useful and affordable products, significant increases in the average **Gross National Product** per person, large increases

in agricultural productivity, sharp rises in average life expectancy and a gradual decline in population growth rates.

The information age was born with the invention of miniaturized electronics such as integrated circuits and computer central processing units. This stage in human development has changed and continues to change society as we know it. Information and communication have become the most-valued resources. This shift in turn, may lessen our influence on the earth's environment through reduced natural resource consumption. For instance, in recent years energy use in the United States has not increased to the extent expected from economic growth. Online shopping, telecommuting and other Internet activities may be lessening human energy consumption.

By making good use of information technologies, less developed countries may be able to reduce potential environmental problems as their economies expand in the future. With so much information easily available, developing countries may not repeat the environmental mistakes that more developed countries made as they became industrialized.

Chapter 7

CARRYING CAPACITY¹

7.1 CARRYING CAPACITY

7.1.1 INTRODUCTION

The human carrying capacity is a concept explored by many people, most famously Thomas Robert Malthus (1766 - 1834), for hundreds of years. **Carrying capacity, "K,"** refers to the number of individuals of a population that can be sustained indefinitely by a given area. At carrying capacity, the population will have an impact on the resources of the given area, but not to the point where the area can no longer sustain the population. Just as a population of wildebeest or algae has a carrying capacity, so does a human population.

Humans, while subject to the same ecological constraints as any other species (a need for nutrients, water, etc.), have some features as individuals and some as a population that make them a unique species. Unlike most other organisms, humans have the capacity to alter their number of offspring, level of resource consumption and distribution. While most women around the world could potentially have the same number of children during their lives, the number they actually have is affected by many factors. Depending upon technological, cultural, economic and educational factors, people around the world have families of different sizes. Additionally, unlike other organisms, humans invent and alter technology, which allows them to change their environment. This ability makes it difficult to determine the human K.

7.1.2 EFFECTS OF TECHNOLOGY AND THE ENVIRONMENT

When scholars in the 1700's estimated the total number of people that today earth could sustain, they were living in a very different world than our world. Today airplanes can transport people and food half way around the world in a matter of hours, not weeks or months, as was the case with ships in the 1700s. Today we have sophisticated, powered farm equipment that can rapidly plow, plant, fertilize and harvest acres of crops a day. One farmer can cultivate hundreds of acres of land. This is a far cry from the draft-animal plowing, hand planting and hand harvesting performed by farmers in the 1700s. Additionally, synthetic fertilizers, pesticides and modern irrigation methods allow us to produce crops on formerly marginal lands and increase the productivity of other agricultural lands. With the increase in the amount of land that each individual can farm, the food production has increased. This increased food production, in turn, has increased the potential human K relative to estimates from the 1700s.

Whereas technological advances have increased the human K, changes in environmental conditions could potentially decrease it. For example, a global or even a large regional change in the climate could reduce K below current estimates. Coastal flooding due to rising ocean levels associated with global warming and desertification of agricultural lands resulting from poor farming practices or natural climate variation could cause food production to be less than that upon which the human carrying capacity was originally estimated.

¹This content is available online at <<http://cnx.org/content/m16710/1.1/>>.

There are those who believe that advances in technology and other knowledge will continue to provide the means to feed virtually any human population size. Those who subscribe to this philosophy believe that this continuous innovation will "save us" from ourselves and changes in the environment.

Others believe that technology will itself reach a limit to its capabilities. This group argues that resources on earth – including physical space – are limited and that eventually we must learn to live within our means. Aside from the physical limitations of the earth's natural resources and food production capabilities, we must consider the conditions we are willing to live with.

7.1.3 EFFECT OF STANDARD OF LIVING

Given the wherewithal to do so, humans have aesthetic expectations in their daily lives. This is a consideration that is less evident in other species. While the earth might be able to hold many more than the current human population of six billion (estimates of the human K with current technology go as high as 50 billion) at some point people will find it unacceptable to live with the crowding and pollution issues associated with a dramatic increase in population. The qualitative measure of a person's or population's quality of life is called its **standard of living**. It is associated not only with aesthetics of surroundings and levels of noise, air and water pollution, but also with levels of resource consumption.

Americans have one of the world's highest standards of living. While there are many who live in poverty in the United States, on average we have relatively small families, large homes, many possessions, plentiful food supplies, clean water and good medical care. This is not the case in most of the developing world.

While many nations have larger average family sizes, they have smaller homes, fewer possessions and less food. Supplies of clean water may be scarce and medical care may be inadequate. All people desire to have adequate resources to provide good care for their families, and thus population in most developing countries are striving for standard of living of developed nations.

Is it possible for all six billion people on earth to live at the same level of resource use as in the United States, Japan and Western Europe? With current technology, the answer is "no." However, this does not mean that the people of one nation are more or less entitled to a given standard of living than those of another. What it does mean for citizens of nations like the United States is that we must reduce our current use of resources. Of all of the food purchased by the average American family, 10 percent is wasted. In addition, because most Americans are not vegetarians, we tend to eat high on the food chain, which requires more resources than a vegetarian diet.

Calculation of ecological efficiency indicate that from one trophic level on the food chain to the next, there is only a 10 percent efficiency in the transfer of energy. Thus people who predominately eat more grains, fruits and vegetables are getting more out of the energy required to produce the food than those who eat a lot of meat. The calories that a person gets from beef are much fewer than the calories in the grain required to raise the cattle. The person is better off skipping the middleman – or middle cow in this case – and eating the grain. This is why many more people can be sustained on a diet that consists of a larger percentage of rice, millet or wheat, rather than of fish, beef or chicken.

In addition to resources used to provide food, Americans use disproportionate amounts of natural resources such as trees (for paper, furniture and building, among other things) and fossil fuels (for automobiles, homes and industry). We also produce a great amount of "quick waste." Packaging that comes on food in the grocery store is a good example of quick waste. The hard plastic packaging used for snack foods that is immediately removed and thrown away and plastic grocery bags are both examples of quick waste. Thus, patronizing fast food restaurants increases resource consumption and solid waste production at the same time.

The good news for the environment (from both a solid waste and a resource use standpoint) is that we can easily reduce the amount of goods and resources that we use and waste without drastically affecting our standard of living. By properly inflating car tires, America could save millions of barrels of oil annually. If we were to use more renewable energy resources – like solar and wind power as opposed to petroleum and nuclear energy –there would be a reduced need to extract non-renewable resources from the earth. The amount of packaging used for goods could also be reduced. Reusable canvas bags could be used for shopping and plastic and paper grocery bags could be reused.

At home, many waste materials could be recycled, instead of being thrown away. These relatively easy steps could reduce the overall ecological impact that each person has on the earth. This impact is sometimes termed a person's **ecological footprint**. The smaller each person's ecological footprint, the greater the standard of living possible for each person.

Chapter 8

POPULATION GROWTH¹

8.1 POPULATION GROWTH

8.1.1 INTRODUCTION

Families in developing nations are often larger, but less resource intensive (e.g., they use fewer resources per person) than those in more developed nations. However, increasingly human populations wish to have a "western" standard of living. An increase in the world's average standard of living significantly lowers the potential human carrying capacity of the earth. Therefore, in order to reduce their impact as a species, humans must not only reduce the resources they use per person, they must also reduce their average family size.

Determining ways to reduce family size requires an understanding of the many factors determining family size and the resultant population dynamics of the region.

Many economic and cultural influences affect family size. Depending upon the prevailing cultural values and economic forces, a nation's people can be induced to have larger or smaller families.

Although human population dynamics are often considered on a global scale, factors that affect population growth vary in different parts of the world. Therefore, it is essential to understand the different forces acting on people throughout the world.

8.1.2 ECONOMIC FACTORS

Some of the factors influencing family size – and therefore population growth – are economic ones. These factors are probably the most easily understood. For instance, a rural agricultural family in a developing country that relies upon a plow pulled by a water buffalo needs many family members to take care of the planting, harvesting and marketing of crops. A family of three would not provide enough labor to sustain the family business.

In contrast, families in developed countries tend to be small for economic reasons. It is expensive to raise children at the relatively high standard of living found in such countries. Considerable resources must be devoted to food, clothes, transportation, entertainment and schooling. A large proportion of children from developed countries attend college, thus adding even more to the expense. Therefore, it is economically prudent in such countries for families to have few children.

Obviously, there are technological and educational ways to negate the need for many children. If the farm family in a developing country is able to obtain better farming tools and information, they can improve the farm's production by irrigating crops and by using techniques such as crop rotation (e.g., planting different crops in different years to maintain soil fertility, prevent erosion and maximize yields). With the acquisition

¹This content is available online at <<http://cnx.org/content/m16720/1.1/>>.

of such new tools and farming techniques, fewer family members are required to work the same amount of land. The land may even become more productive, even with less manual labor.

Additional economic factors – such as the cost of medical care and retirement care – also play a role in family size. If a family is unable to afford adequate medical care, then family planning services and birth control materials may not be attainable. Also, when mortality rates for children are high and significant numbers of children do not live to adulthood, there is a strong motivation to have as many children as possible.

Doing so ensures that some of the children will live to help in the family business, and provide a link to posterity

Without national social security programs like those in the United States and Sweden, the elderly in developing countries rely on younger, working members of their families to support them in their retirement. A larger family means a more secure future. The expense of a national social security program also acts to reduce family size in a country, as the high taxes imposed on workers to support the system makes supporting large families difficult.

8.1.3 CULTURAL FACTORS

Around the globe, **cultural factors** influence family size and as a result, affect population growth rate. From a cultural standpoint, religion can have a profound effect on family planning. Many religions promote large families as a way to further the religion or to glorify a higher power. For example, Orthodox Judaism encourages large families in order to perpetuate Judaism. Roman Catholicism promotes large families for the same reason, and forbids the use of any "artificial" means of birth control. Devout followers of a religion with such values often have large families even in the face of other factors, such as economic ones. This can be seen in countries like Israel (Judaism) and Brazil (Catholicism), which have high percentages of religious followers in their populations. Both countries have high birth rates and high population growth rates.

Various factors involving women can also affect family sizes. These factors include: education and employment opportunities available to women, the marriage age of women and the societal acceptance of birth control methods. These factors are sometimes strongly influenced by society's cultural attitudes towards women.

Around the world, statistics indicate that with higher levels of education, women are more likely to be employed outside the home; in addition, higher marriage age of women and the greater the acceptance of birth control methods, the smaller the family size. It is clear that increasing educational and professional opportunities for women would reduce overall population growth and improve standards of living worldwide.

Chapter 9

WATER¹

9.1 WATER

9.1.1 INTRODUCTION

Water is an abundant substance on earth and covers 71 percent of the earth's surface. Earth's water consists of three percent freshwater and 97 percent saltwater. All living organisms require water in order to live. In fact, they are mostly comprised of water. Water is also important for other reasons: as an agent of erosion it changes the morphology of the land; it acts as a buffer against extreme climate changes when present as a large body of water, and it helps flush away and dilute pollutants in the environment.

The physical characteristics of water influence the way life on earth exists. The unique characteristics of water are:

1. Water is a liquid at room temperature and over a relatively wide temperature range (0 -100°C). This wide range encompasses the annual mean temperature of most biological environments.
2. A relatively large amount of energy is required to raise the temperature of water (i.e., it has a high **heat capacity**). As a result of this property, large bodies of water act as buffers against extreme fluctuations in the climate, water makes as an excellent industrial coolant, and it helps protect living organisms against sudden temperature changes in the environment.
3. Water has a very high heat of vaporization. Water evaporation helps distribute heat globally; it provides an organism with the means to dissipate unwanted heat.
4. Water is a good solvent and provides a good medium for chemical reactions, including those that are biologically important. Water carries nutrients to an organism's cells and flushes away waste products, and it allows the flow of ions necessary for muscle and nerve functions in animals.
5. Liquid water has a very high **surface tension**, the force holding the liquid surface together. This, along with its ability to adhere to surfaces, enables the upward transport of water in plants and soil by capillary action.
6. Solid water (ice) has a lower density than liquid water at the surface of the earth. If ice were denser than liquid water, it would sink rather than float, and bodies of water in cold climates would eventually freeze solid, killing the organisms living in them.

Freshwater comprises only about three percent of the earth's total water supply and is found as either surface water or groundwater. Surface water starts as precipitation. That portion of precipitation which does not infiltrate the ground is called **runoff**. Runoff flows into streams and lakes.

The drainage basin from which water drains is called a **watershed**. Precipitation that infiltrates the ground and becomes trapped in cracks and pores of the soil and rock is called **groundwater**. If groundwater is stopped by an impermeable barrier of rock, it can accumulate until the porous region becomes saturated.

¹This content is available online at <<http://cnx.org/content/m16727/1.1/>>.

The top of this accumulation is known as the **water table**. Porous layers of sand and rock through which groundwater flows are called **aquifers**.

Most freshwater is locked up in frozen glaciers or deep groundwater where it is not useable by most living organisms. Only a tiny fraction of the earth's total water supply is therefore usable freshwater. Still, the amount available is sufficient to maintain life because of the natural water cycle. In the water cycle, water constantly accumulates, becomes purified, and is redistributed. Unfortunately, as human populations across the globe increase, their activities threaten to overwhelm the natural cycle and degrade the quality of available water.

9.1.2 AGRICULTURAL WATER USE

Agriculture is the single largest user of water in the world. Most of that water is used for irrigating crops. **Irrigation** is the process of transporting water from one area to another for the purpose of growing crops. The water used for irrigation usually comes from rivers or from groundwater pumped from wells. The main reason for irrigating crops is that it increases yields. It also allows the farming of marginal land in arid regions that would normally not support crops. There are several methods of irrigation: flood irrigation, furrow irrigation, drip irrigation and center pivot irrigation.

Flood irrigation involves the flooding of a crop area located on generally flat land. This gravity flow method of water is relatively easy to implement, especially if the natural flooding of river plains is utilized, and therefore is cost-effective. However, much of the water used in flood irrigation is lost, either by evaporation or by percolation into soil adjacent to the intended area of irrigation. Because farmland must be flat for flood irrigation to be used, flood irrigation is only practical in certain areas (e.g. river flood plains and bottomlands). In addition, because land is completely flooded, salts from the irrigation water can buildup in the soil, eventually rendering it infertile.

Furrow irrigation also involves gravity flow of water on relatively flat land. However, in this form of irrigation, the water flow is confined to furrows or ditches between rows of crops. This allows better control of the water and, therefore, less water is needed and less is wasted. Because water can be delivered to the furrows from pipes, the land does not need to be completely flat. However, furrow irrigation involves higher operating costs than flood irrigation due to the increased labor and equipment required. It, too, involves large evaporative loss.

Drip irrigation involves delivering small amounts of water directly to individual plants. Water is released through perforated tubing mounted above or below ground near the roots of individual plants. This method was originally developed in Israel for use in arid regions having limited water available for irrigation. It is highly efficient, with little waste of water. Some disadvantages of drip irrigation are the high costs of installation and maintenance of the system. Therefore, it is only practical for use on high-value cash crops.

Center-pivot sprinkler systems deliver water to crops from sprinklers mounted on a long boom, which rotates about a center pivot. Water is pumped to the pivot from a nearby irrigation well. This system has the advantage that it is very mobile and can be moved from one field to another as needed. It can also be used on uneven cropland, as the moving boom can follow the contours of the land. Center-pivot systems are widely used in the western plains and southwest regions of the United States. With proper management, properly designed systems can be almost as efficient as drip irrigation systems. Center-pivot systems have high initial costs and require a nearby irrigation well capable of providing a sufficiently high flow. Constant irrigation with well water can also lead to salinization of the soil.

9.1.3 DOMESTIC AND INDUSTRIAL WATER USE

Water is important for all types of industries (i.e., manufacturing, transportation and mining). Manufacturing sites are often located near sources of water. Among other properties, water is an excellent and inexpensive solvent and coolant. Many manufactured liquid products have water as their main ingredient. Chemical solutions used in industrial and mining processes usually have an aqueous base. Manufacturing equipment is cooled by water and cleaned with water. Water is even used as a means of transporting goods

from one place to another in manufacturing. Nuclear power plants use water to moderate and cool the reactor core as well as to generate electricity. Industry would literally come to a standstill without water.

People use water for domestic purposes such as personal hygiene, food preparation, cleaning, and gardening. Developed countries, especially the United States, tend to use a great deal of water for domestic purposes.

Water used for personal hygiene accounts for the bulk of domestic water use. For example, the water used in a single day in sinks, showers, and toilets in Los Angeles would fill a large football stadium. Humans require a reliable supply of potable water; otherwise serious health problems involving water-borne diseases can occur. This requires the establishment and maintenance of municipal water treatment plants in large populated areas.

Much clean water is wasted in industrial and domestic use. In the United States this is mainly due to the generally low cost of water. Providing sufficient quantities of clean water in large population areas is becoming a growing problem, though. Conservation measures can minimize the problem: redesigning manufacturing processes to use less water; using vegetation for landscaping in arid regions that requires less water; using water-conserving showers and toilets and reusing gray water for irrigation purposes.

9.1.4 CONTROL OF WATER RESOURCES

Households and industry both depend on reliable supplies of clean water. Therefore, the management and protection of water resources is important. Constructing dams across flowing rivers or streams and impounding the water in reservoirs is a popular way to control water resources. Dams have several advantages: they allow long-term water storage for agricultural, industrial and domestic use; they can provide hydroelectric power production and downstream flood control. However, dams disrupt ecosystems, they often displace human populations and destroy good farmland, and eventually they fill with silt.

Humans often tap into the natural water cycle by collecting water in man-made reservoirs or by digging wells to remove groundwater. Water from those sources is channeled into rivers, man-made canals or pipelines and transported to cities or agricultural lands. Such diversion of water resources can seriously affect the regions from which water is taken.

For example, the Owens Valley region of California became a desert after water projects diverted most of the Sierra Nevada runoff to the Los Angeles metropolitan area. This brings up the question of who owns (or has the rights to) water resources.

Water rights are usually established by law. In the eastern United States, the "**Doctrine of Riparian Rights**" is the basis of rights of use. Anyone whose land is next to a flowing stream can use the water as long as some is left for people downstream. Things are handled differently in the western United States, which uses a "first-come, first-served" approach known as the "**Principle of Prior Appropriation**" is used. By using water from a stream, the original user establishes a legal right for the ongoing use of the water volume originally taken. Unfortunately, when there is insufficient water in a stream, downstream users suffer.

The case of the Colorado River highlights the problem of water rights. The federal government built a series of dams along the Colorado River, which drains a huge area of the southwestern United States and northern Mexico. The purpose of the project was to provide water for cities and towns in this arid area and for crop irrigation. However, as more and more water was withdrawn from these dams, less water was available downstream. Only a limited volume of water reached the Mexican border and this was saline and unusable. The Mexican government complained that their country was being denied use of water that was partly theirs, and as a result a desalinization plant was built to provide a flow of usable water.

Common law generally gives property owners rights to the groundwater below their land. However, a problem can arise in a situation where several property owners tap into the same groundwater source. The Ogallala Aquifer, which stretches from Wyoming to Texas, is used extensively by farmers for irrigation. However, this use is leading to groundwater depletion, as the aquifer has a very slow recharge rate. In such cases as this, a general plan of water use is needed to conserve water resources for future use.

9.2 Water Diversion

Water is necessary for all life, as well as for human agriculture and industry. Great effort and expense has gone into diverting water from where it occurs naturally to where people need it to be. The large-scale redistribution of such a vital resource has consequences for both people and the environment. The three projects summarized below illustrate the costs and benefits and complex issues involved in water diversion.

9.3 Garrison Diversion Project

The purpose of the Garrison Diversion Project was to divert water from the Missouri River to the Red River in North Dakota, along the way irrigating more than a million acres of prairie, attracting new residents and industries, and providing recreation opportunities.

Construction began in the 1940s, and although \$600 million has been spent, only 120 miles of canals and a few pumping stations have been built. The project has not been completed due to financial problems and widespread objections from environmentalists, neighboring states, and Canada. Some object to flooding rare prairie habitats. Many are concerned that moving water from one watershed to another will also transfer non-native and invasive species that could attack native organisms, devastate habitats, and cause economic harm to fishing and other industries. As construction and maintenance costs skyrocketed, taxpayers expressed concern that excessive public money was being spent on a project with limited public benefits.

9.4 Melamchi Water Supply Project

The Kathmandu Valley in Nepal is an important urban center with insufficient water supplies. One million people receive piped water for just a few hours a day. Groundwater reservoirs are being drained, and water quality is quite low. The Melamchi Water Supply Project will divert water to Kathmandu through a 28 km tunnel from the Melamchi River in a neighboring valley. Expected to cost a half a billion dollars, the project will include improved water treatment and distribution facilities.

While the water problems in the Kathmandu Valley are severe, the project is controversial. Proponents say it will improve public health and hygiene and stimulate the local economy without harming the Melamchi River ecosystem. Opponents suggest that the environmental safeguards are inadequate and that a number of people will be displaced. Perhaps their biggest objection is that the project will privatize the water supply and raise costs beyond the reach of the poor. They claim that cheaper and more efficient alternatives have been ignored at the insistence of international banks, and that debt on project loans will cripple the economy.

9.5 South to North Water Diversion Project

Many of the major cities in China are suffering from severe water shortages, especially in the northern part of the country. Overuse and industrial discharge has caused severe water pollution. The South to North Water Diversion project is designed to shift enormous amounts of water from rivers in southern China to the dry but populous northern half of the country. New pollution control and treatment facilities to be constructed at the same time should improve water quality throughout the country.

The diversion will be accomplished by the creation of three rivers constructed by man, each more than 1,000 km long. They will together channel nearly 50 billion cubic meters of water annually, creating the largest water diversion project in history. Construction is expected to take 10 years and cost \$60 billion, but after 2 years of work, the diversion is already over budget.

Such a massive shift in water resources will have large environmental consequences throughout the system. Water levels in rivers and marshes will drop sharply in the south and rise in the north. People and wildlife will be displaced along the courses of the new rivers.

Despite its staggering scale, the South to North Project alone will not be sufficient to solve water shortages. China still will need to increase water conservation programs, make industries and agriculture more water efficient, and raise public awareness of sustainable water practices.

Chapter 10

MINERALS¹

10.1 MINERALS

10.1.1 INTRODUCTION

The earth's crust is composed of many kinds of rocks, each of which is an aggregate of one or more minerals. In geology, the term mineral describes any naturally-occurring solid substance with a specific composition and crystal structure. A mineral's **composition** refers to the kinds and proportions of elements making up the mineral. The way these elements are packed together determines the structure of the mineral. More than 3,500 different minerals have been identified. There are only 12 common elements (oxygen, silicon, aluminum, iron, calcium, magnesium, sodium, potassium, titanium, hydrogen, manganese, phosphorus) that occur in the earth's crust. They have abundances of 0.1 percent or more. All other naturally occurring elements are found in very minor or trace amounts.

Silicon and oxygen are the most abundant crustal elements, together comprising more than 70 percent by weight. It is therefore not surprising that the most abundant crustal minerals are the silicates (e.g. olivine, Mg_2SiO_4), followed by the oxides (e.g. hematite, Fe_2O_3).

Other important types of minerals include: the **carbonates** (e.g. calcite, $CaCO_3$) the **sulfides** (e.g. galena, PbS) and the **sulfates** (e.g. anhydrite, $CaSO_4$). Most of the abundant minerals in the earth's crust are not of commercial value. Economically valuable minerals (metallic and nonmetallic) that provide the raw materials for industry tend to be rare and hard to find. Therefore, considerable effort and skill is necessary for finding where they occur and extracting them in sufficient quantities.

10.1.2 ECONOMIC VALUE OF MINERALS

Minerals that are of economic value can be classified as **metallic** or **nonmetallic**. Metallic minerals are those from which valuable metals (e.g. iron, copper) can be extracted for commercial use. Metals that are considered geochemically abundant occur at crustal abundances of 0.1 percent or more (e.g. iron, aluminum, manganese, magnesium, titanium). Metals that are considered geochemically scarce occur at crustal abundances of less than 0.1 percent (e.g. nickel, copper, zinc, platinum metals). Some important metallic minerals are: hematite (a source of iron), bauxite (a source of aluminum), sphalerite (a source of zinc) and galena (a source of lead). Metallic minerals occasionally but rarely occur as a single element (e.g. native gold or copper).

Nonmetallic minerals are valuable, not for the metals they contain, but for their properties as chemical compounds. Because they are commonly used in industry, they are also often referred to as industrial minerals. They are classified according to their use. Some industrial minerals are used as sources of important chemicals (e.g. halite for sodium chloride and borax for borates). Some are used for building materials (e.g.

¹This content is available online at <<http://cnx.org/content/m16728/1.1/>>.

gypsum for plaster and kaolin for bricks). Others are used for making fertilizers (e.g. apatite for phosphate and sylvite for potassium). Still others are used as abrasives (e.g. diamond and corundum).

10.1.3 MINERAL DEPOSITS

Minerals are everywhere around us. For example, the ocean is estimated to contain more than 70 million tons of gold. Yet, it would be much too expensive to recover that gold because of its very low concentration in the water. Minerals must be concentrated into deposits to make their collection economically feasible. A mineral deposit containing one or more minerals that can be extracted profitably is called an **ore**. Many minerals are commonly found together (e.g. quartz and gold; molybdenum, tin and tungsten; copper, lead and zinc; platinum and palladium). Because various geologic processes can create local enrichments of minerals, mineral deposits can be classified according to the concentration process that formed them. The five basic types of mineral deposits are: **hydrothermal**, **magmatic**, **sedimentary**, **placer** and **residual**.

Hydrothermal mineral deposits are formed when minerals are deposited by hot, aqueous solutions flowing through fractures and pore spaces of crustal rock. Many famous ore bodies have resulted from **hydrothermal** deposition, including the tin mines in Cornwall, England and the copper mines in Arizona and Utah. **Magmatic** mineral deposits are formed when processes such as partial melting and fractional crystallization occur during the melting and cooling of rocks. Pegmatite rocks formed by fractional crystallization can contain high concentrations of lithium, beryllium and cesium. Layers of chromite (chrome ore) were also formed by igneous processes in the famous Bushveld Igneous Complex in South Africa.

Several mineral concentration processes involve sedimentation or weathering. Water soluble salts can form **sedimentary** mineral deposits when they precipitate during evaporation of lake or seawater (evaporate deposits). Important deposits of industrial minerals were formed in this manner, including the borax deposits at Death Valley and Searles Lake, and the marine deposits of gypsum found in many states.

Minerals with a high specific gravity (e.g. gold, platinum, diamonds) can be concentrated by flowing water in placer deposits found in stream beds and along shorelines. The most famous gold **placer** deposits occur in the Witwatersrand basin of South Africa. **Residual** mineral deposits can form when weathering processes remove water soluble minerals from an area, leaving a concentration of less soluble minerals. The aluminum ore, bauxite, was originally formed in this manner under tropical weathering conditions. The best known bauxite deposit in the United States occurs in Arkansas.

10.1.4 MINERAL UTILIZATION

Minerals are not evenly distributed in the earth's crust. Mineral **ores** are found in just a relatively few areas, because it takes a special set of circumstances to create them. Therefore, the signs of a mineral deposit are often small and difficult to recognize. Locating deposits requires experience and knowledge. Geologists can search for years before finding an economic mineral deposit. Deposit size, its mineral content, extracting efficiency, processing costs and market value of the processed minerals are all factors that determine if a mineral deposit can be profitably developed. For example, when the market price of copper increased significantly in the 1970s, some marginal or low-grade copper deposits suddenly became profitable ore bodies.

After a potentially profitable mineral deposit is located, it is mined by one of several techniques. Which technique is used depends upon the type of deposit and whether the deposit is shallow and thus suitable for surface mining or deep and thus requiring sub-surface mining.

Surface mining techniques include: open-pit mining, area strip mining, contour strip mining and hydraulic mining. **Open-pit mining** involves digging a large, terraced hole in the ground in order to remove a near-surface ore body. This technique is used in copper ore mines in Arizona and Utah and iron ore mines in Minnesota.

Area strip mining is used in relatively flat areas. The overburden of soil and rock is removed from a large trench in order to expose the ore body. After the minerals are removed, the old trench is filled and a new trench is dug. This process is repeated until the available ore is exhausted. **Contour strip mining** is a similar technique except that it is used on hilly or mountainous terrains. A series of terraces are cut into the side of a slope, with the overburden from each new terrace being dumped into the old one below.

Hydraulic mining is used in places such as the Amazon in order to extract gold from hillsides. Powerful, high-pressure streams of water are used to blast away soil and rock containing gold, which is then separated from the runoff. This process is very damaging to the environment, as entire hills are eroded away and streams become clogged with sediment. If land subjected to any of these surface mining techniques is not properly restored after its use, then it leaves an unsightly scar on the land and is highly susceptible to erosion.

Some mineral deposits are too deep to be surface mined and therefore require a **sub-surface mining** method. In the traditional sub surface method a deep vertical shaft is dug and tunnels are dug horizontally outward from the shaft into the ore body. The ore is removed and transported to the surface. The deepest such subsurface mines (deeper than 3500 m) in the world are located in the Witwatersrand basin of South Africa, where gold is mined. This type of mining is less disturbing to the land surface than surface mining. It also usually produces fewer waste materials. However, it is more expensive and more dangerous than surface mining methods.

A newer form of subsurface mining known as **in-situ mining** is designed to co-exist with other land uses, such as agriculture. An in-situ mine typically consists of a series of injection wells and recovery wells built with acid-resistant concrete and polyvinyl chloride casing. A weak acid solution is pumped into the ore body in order to dissolve the minerals. Then, the metal-rich solution is drawn up through the recovery wells for processing at a refining facility. This method is used for the in-situ mining of copper ore.

Once an ore has been mined, it must be processed to extract pure metal. Processes for extracting metal include smelting, electrowinning and heap leaching. In preparation for the **smelting** process, the ore is crushed and concentrated by a flotation method. The concentrated ore is melted in a smelting furnace where impurities are either burned-off as gas or separated as molten slag. This step is usually repeated several times to increase the purity of the metal.

For the **electrowinning** method ore or mine tailings are first leached with a weak acid solution to remove the desired metal. An electric current is passed through the solution and pure metal is electroplated onto a starter cathode made of the same metal. Copper can be refined from oxide ore by this method. In addition, copper metal initially produced by the smelting method can be purified further by using a similar electrolytic procedure.

Gold is sometimes extracted from ore by the **heap leaching** process. A large pile of crushed ore is sprayed with a cyanide solution. As the solution percolates through the ore it dissolves the gold. The solution is then collected and the gold extracted from it. All of the refining methods can damage the environment. Smelters produce large amounts of air pollution in the form of sulfur dioxide which leads to acid rain. Leaching methods can pollute streams with toxic chemicals that kill wildlife.

10.1.5 MINERAL SUFFICIENCY AND THE FUTURE

Mineral resources are essential to life as we know it. A nation cannot be prosperous without a reliable source of minerals, and no country has all the mineral resources it requires. The United States has about 5 percent of the world's population and 7 percent of the world's land area, but uses about 30 percent of the world's mineral resources. It imports a large percentage of its minerals; in some cases sufficient quantities are unavailable in the U.S., and in others they are cheaper to buy from other countries. Certain minerals, particularly those that are primarily imported and considered of vital importance, are stockpiled by the United States in order to protect against embargoes or other political crises. These strategic minerals include: bauxite, chromium, cobalt, manganese and platinum.

Because minerals are produced slowly over geologic time scales, they are considered non-renewable resources. The estimated mineral deposits that are economically feasible to mine are known as mineral reserves. The growing use of mineral resources throughout the world raises the question of how long these reserves will last. Most minerals are in sufficient supply to last for many years, but a few (e.g. gold, silver, lead, tungsten and zinc) are expected to fall short of demand in the near future. Currently, reserves for a particular mineral usually increase as the price for that mineral increases. This is because the higher price makes it economically feasible to mine some previously unprofitable deposits, which then shifts these deposits to the reserves. However, in the long term this will not be the case because mineral deposits are ultimately finite.

There are ways to help prolong the life of known mineral reserves. Conservation is an obvious method for stretching reserves. If you use less, you need less. Recycling helps increase the amount of time a mineral or metal remains in use, which decreases the demand for new production. It also saves considerable energy, because manufacturing products from recycled metals (e.g. aluminum, copper) uses less energy than manufacturing them from raw materials. Government legislation that encourages conservation and recycling is also helpful. The current "General Mining Act of 1872," however, does just the opposite. It allows mining companies to purchase government land very inexpensively and not pay any royalties for minerals extracted from that land. As a result, mineral prices are kept artificially low which discourages conservation and recycling.

Chapter 11

SOILS¹

11.1 SOILS

11.1.1 INTRODUCTION

Soil plays an important role in land ecosystems. In order for a community of producers and consumers to become established on land, soil must be present. Furthermore, soil quality is often a limiting factor for population growth in ecosystems. Soil is a complex mixture of inorganic materials, organic materials, microorganisms, water and air. Its formation begins with the weathering of bedrock or the transport of sediments from another area. These small grains of rock accumulate on the surface of the earth. There they are mixed with organic matter called **humus**, which results from the decomposition of the waste and dead tissue of organisms. Infiltrating rainwater and air also contribute to the mixture and become trapped in pore spaces. This formation process is very slow (hundreds to thousands of years), and thus soil loss or degradation can be very detrimental to a community.

11.1.2 SOIL PROFILE

Mature soils are layered. These layers are known as **soil horizons**, and each has a distinct texture and composition. A typical soil has a soil profile consisting of four horizons, which are designated: O, A, B and C. The **O horizon** is the top layer at the earth's surface. It consists of surface litter, such as fallen leaves (duff), sticks and other plant material, animal waste and dead organisms. A distinct O horizon may not exist in all soil environments (e.g., desert soil). Below the O horizon is the **A horizon**, which is also known as **topsoil**. This layer contains organic humus, which usually gives it a distinctive dark color. The **B horizon**, or sub-soil is the next layer down from the surface. It consists mostly of inorganic rock materials such as sand, silt and clay. The **C horizon** sits atop bedrock and therefore is made up of weathered rock fragments. The bedrock is the source of the parent inorganic materials found in the soil.

The O horizon protects the underlying topsoil from erosion and moisture loss by evaporation. The O and A horizons in typical mature soils have an abundance of microorganisms (e.g. fungi, bacteria), earthworms and insects. These organisms decompose the organic material from dead organisms and animal waste into inorganic nutrients useable by plants. The organic humus in the A horizon aids in holding water and nutrients, making it the most fertile layer. Therefore, plants with shallow roots are anchored in the A horizon. Water seeping through the upper layers may dissolve water-soluble minerals and transport them to lower layers in a process called **leaching**. Very fine clay particles can also be transported by seeping water and accumulate in the subsoil layer. The accumulation of clay particles and leached minerals can lead to compaction of the B horizon. This compaction can limit the flow of water through the layer and cause the soil above to become waterlogged.

¹This content is available online at <<http://cnx.org/content/m16466/1.2/>>.

The B horizon is not as fertile as the A horizon, but deep-rooted plants can utilize the water and minerals leached into this layer. The C horizon represents a transition zone between the bedrock and the soil. It lacks organic material, but may be saturated with groundwater that is unable to move deeper due to the solid barrier of bedrock below.

Different types of soil may have different numbers of horizons, and the composition and thickness of those horizons may vary from soil to soil. The type of soil depends on a number of factors including: the type of parent rock material, the type of vegetation, the availability of organic matter, water and minerals, and the climate. Grassland and desert soils lack a significant O horizon as they generally have no leaf litter. **Grassland soil** may have a very thick, fertile A horizon, while desert and tropical rain forest soils may have very thin, nutrient poor A horizons. The A horizons in coniferous forests may be severely leached.

11.1.3 SOIL CHARACTERISTICS

Most soil consists of weathered inorganic rock material. The relative amounts of different sizes and types of rock particles or grains determines the texture of the soil. The three main types of rock grains found in soil are: **sand**, **silt** and **clay**. Sand grains have the largest grain sizes (0.05 - 2.0 mm) of the three. Silt particles are fine-grained (0.05-0.002 mm) and clay particles are very fine-grained (<0.002 mm). Sand grains give soil its gritty feel, and clay particles make it sticky. Soils are named according to where their sand silt and clay composition plots on a soil structure triangle. Various regions of the triangle are given different names. A soil containing about 20:40:40 mixture of clay, silt and sand plot A typical loam soil is made up of about a 20:40:40 mixture of clay, silt and sand. If the percentage of sand is a little higher, the soil is called a **sandy loam**, and if the percentage of silt is a little higher the soil is a **silty loam**.

The texture of the soil determines its porosity and permeability. **Soil porosity** is a measure of the volume of pore spaces between soil grains per volume of soil and determines the water and air (oxygen) holding capacity of the soil. Coarse grains with large pores provide better aeration and fine grains with small pores provide good water retention.

The average pore size determines the soil permeability or ease with which water can infiltrate the soil. Sandy soils have low porosities and high permeabilities (i.e. water is not retained well, but flows through them easily, and aeration is good). On the other hand, clay soils have high porosities and low permeabilities (i.e. water is retained very well, but does not flow through it easily and aeration is poor). Soil texture is therefore important in determining what type of vegetation thrives on a particular soil.

The soil structure or "tilth" is related to the soil texture. **Soil tilth** describes how the various components of the soil cling together into clumps. It is determined by the amount of clay and humus in the soil. The physical and chemical properties of clay and humus enable them to adhere to other particles in the soil, thus forming large aggregates. These same properties also help protect the soil from nutrient leaching. Soils lacking clay and humus are very loose and are easily blown or shifted by the wind (i.e. sand dunes in the desert).

11.1.4 SOIL FERTILITY AND pH

There are 16 elements essential for plant growth. Plants obtain three of them primarily from air and water: carbon, hydrogen and oxygen. The other 13 elements generally come from the soil. These essential elements for plant growth can be grouped into three types: **primary macronutrients** (nitrogen, potassium, phosphorus), **secondary macronutrients** (calcium, magnesium, sulfur) and **micronutrients** (boron, chlorine, iron, manganese, copper, zinc, molybdenum). The available primary macronutrients in the soil are usually the limiting factor in plant growth. In undisturbed soils, these macronutrients are replenished by the natural cycles of matter. In farmed soils, they are removed from the natural cycle in such large amounts when crops are harvested that they usually must be replaced by supplementary means (e.g. fertilizer). Because micronutrients are required by plants in much lower quantities, they are often naturally maintained in the soil in sufficient quantities to make supplementation with fertilizers unnecessary.

An important factor affecting soil fertility is soil **pH** (the negative log of the hydrogen ion concentration). Soil pH is a measure of the acidity or alkalinity of the soil solution. On the pH scale (0 to 14) a value of

seven represents a neutral solution; a value less than seven represents an **acidic solution** and a value greater than seven represents an **alkaline solution**. Soil pH affects the health of microorganisms in the soil and controls the availability of nutrients in the soil solution. Strongly acidic soils (less than 5.5) hinder the growth of bacteria that decompose organic matter in the soil. This results in a buildup of undecomposed organic matter, which leaves important nutrients such as nitrogen in forms that are unusable by plants.

Soil pH also affects the solubility of nutrient-bearing minerals. This is important because the nutrients must be dissolved in solution for plants to assimilate them through their roots. Most minerals are more soluble in slightly acidic soils than in neutral or slightly alkaline soils.

Strongly acid soils (pH four to five), though, can result in high concentrations of aluminum, iron and manganese in the soil solution, which may inhibit the growth of some plants. Other plants, however, such as blueberries, thrive in strongly acidic soil. At high pH (greater than 8.5) many micronutrients such as copper and iron become limited. Phosphorus becomes limited at both low and high pH. A soil pH range of approximately six to eight is conducive to the growth of most plants.

11.1.5 SOIL DEGRADATION

Soil can take hundreds or thousands of years to mature. Therefore, once fertile topsoil is lost, it is not easily replaced. **Soil degradation** refers to deterioration in the quality of the soil and the concomitant reduction in its capacity to produce. Soils are degraded primarily by erosion, organic matter loss, nutrient loss and salinization. Such processes often arise from poor soil management during agricultural activities. In extreme cases, soil degradation can lead to desertification (conversion of land to desert-like conditions) of croplands and rangelands in semi-arid regions.

Erosion is the biggest cause of soil degradation. Soil productivity is reduced as a result of losses of nutrients, water storage capacity and organic matter. The two agents of erosion are wind and water, which act to remove the finer particles from the soil. This leads to soil compaction and poor soil tilth. Human activities such as construction, logging, and off-road vehicle use promote erosion by removing the natural vegetation cover protecting the soil.

Agricultural practices such as overgrazing and leaving plowed fields bare for extended periods contribute to farmland erosion. Each year, an estimated two billion metric tons of soil are eroded from farmlands in the United States alone. The soil transported by the erosion processes can also create problems elsewhere (e.g. by clogging waterways and filling ditches and low-lying land areas).

Wind erosion occurs mostly in flat, dry areas and moist, sandy areas along bodies of water. Wind not only removes soil, but also dries and degrades the soil structure. During the 1930s, poor cultivation and grazing practices – coupled with severe drought conditions – led to severe wind erosion of soil in a region of the Great Plains that became known as the "Dust Bowl." Wind stripped large areas of farmlands of topsoil, and formed clouds of dust that traveled as far as the eastern United States.

Water erosion is the most prevalent type of erosion. It occurs in several forms: rain splash erosion, sheet erosion, rill erosion and gully erosion. **Rain splash** erosion occurs when the force of individual raindrops hitting uncovered ground splashes soil particles into the air. These detached particles are more easily transported and can be further splashed down slope, causing deterioration of the soil structure. **Sheet erosion** occurs when water moves down slope as a thin film and removes a uniform layer of soil. **Rill erosion** is the most common form of water erosion and often develops from sheet erosion. Soil is removed as water flows through little streamlets across the land. **Gully erosion** occurs when rills enlarge and flow together, forming a deep gully.

When considerable quantities of salt accumulate in the soil in a process known as **salinization**, many plants are unable to grow properly or even survive. This is especially a problem in irrigated farmland. Groundwater used for irrigation contains small amounts of dissolved salts. Irrigation water that is not absorbed into the soil evaporates, leaving the salts behind. This process repeats itself and eventually severe salinization of the soil occurs. A related problem is water logging of the soil. When cropland is irrigated with excessive amounts of water in order to leach salts that have accumulated in the soil, the excess water is sometimes unable to drain away properly. In this case it accumulates underground and causes a rise in the subsurface water table. If the saline water rises to the level of the plant roots, plant growth is inhibited.

11.1.6 SOIL CONSERVATION

Because soil degradation is often caused by human activity, soil conservation usually requires changes in those activities. Soil conservation is very important to agriculture, so various conservation methods have been devised to halt or minimize soil degradation during farming. These methods include: construction of windbreaks, no-till farming, contour farming, terracing, strip cropping and agroforestry.

Creating windbreaks by planting tall trees along the perimeter of farm fields can help control the effects of wind erosion. **Windbreaks** reduce wind speed at ground level, an important factor in wind erosion. They also help trap snow in the winter months, leaving soil less exposed. As a side benefit, windbreaks also provide a habitat for birds and animals. One drawback is that windbreaks can be costly to farmers because they reduce the amount of available cropland.

One of the easiest ways to prevent wind and water erosion of croplands is to minimize the amount of **tillage**, or turning over of the soil. In **no-till agriculture** (also called conservation tillage), the land is disturbed as little as possible by leaving crop residue in the fields. Special seed drills inject new seeds and fertilizer into the unplowed soil. A drawback of this method is that the crop residue can serve as a good habitat for insect pests and plant diseases.

Contour farming involves plowing and planting crop rows along the natural contours of gently sloping land. The lines of crop rows perpendicular to the slope help to slow water runoff and thus inhibit the formation of rills and gullies. **Terracing** is a common technique used to control water erosion on more steeply sloped hills and mountains. Broad, level terraces are constructed along the contours of the slopes, and these act as dams trapping water for crops and reducing runoff.

Strip cropping involves the planting of different crops on alternating strips of land. One crop is usually a row crop such as corn, while the other is a ground-covering crop such as alfalfa. The cover crop helps reduce water runoff and traps soil eroded from the row crop. If the cover crop is a nitrogen-fixing plant (e.g. alfalfa, soybeans), then alternating the strips from one planting to the next can also help maintain topsoil fertility.

Agroforestry is the process of planting rows of trees interspersed with a cash crop. Besides helping to prevent wind and water erosion of the soil, the trees provide shade which helps promote soil moisture retention. Decaying tree litter also provides some nutrients for the interplanted crops. The trees themselves may provide a cash crop. For example, fruit or nut trees may be planted with a grain crop.

Chapter 12

BIOLOGICAL¹

12.1 BIOLOGICAL

12.1.1 INTRODUCTION

The needs of humans and the living organisms and processes that comprise the biosphere are inextricably connected. Because of this connection the proper management of biological resources requires that genetic diversity and suitable habitats be maintained. There is a growing realization that diversity in biological systems is fundamental to agricultural production and food security. Unfortunately, the diversity of plants and animals and of the habitats in which they live is currently being drastically reduced. The predominant methods used in agriculture are seriously eroding the genetic diversity of plants and livestock. The variety of species and genes of living organisms – and the habitats and ecosystems in which those organisms live – are important resources that must be utilized in a sustainable fashion through conservation. **Conservation** is not just a matter of protecting wildlife in nature reserves. It also involves safeguarding the natural systems that purify water, recycle nutrients, maintain soil fertility, yield food, and protect genetic diversity.

12.1.2 NATURAL AREAS

Natural areas, or **wilderness areas**, comprise ecosystems in which human activity has not significantly affected the plant and animal populations or their environment. Natural processes predominate. According to the "Wilderness Act of 1964," wilderness areas are defined as being those areas where the nearest road is at least five miles away and where no permanent buildings stand. According to the 1898 writings of Naturalist John Muir, "In God's wilderness lies the hope of the world – the great fresh, unblighted, unredeemed wilderness."

More than 100 million acres of land are now preserved as wilderness under this act. Sparsely populated Alaska contains the largest chunk of wilderness areas, over half of it. Although wilderness areas are scattered among most of the lower 48 states, the largest percentage is found in the western states. Few undesignated areas in the contiguous states remain that would qualify as wilderness.

California contains significant wilderness areas, with over 4 million acres of National Forest Wilderness areas, and 1.5 million acres of mostly desert wilderness in the Mojave Desert National Preserve. Because of the large population of the state, the demand for recreational use of these areas is very high. Heavy demand for the use of a relatively few natural areas is a problem throughout the contiguous states. It is not an easy task for natural resource managers to manage these natural areas in a way that conserves biological diversity and ecosystem integrity, while supporting a sustainable and balanced level of human use.

It is important to preserve natural areas for several reasons. Some people, especially Native Americans, feel a cultural connection to the wilderness through their ancestors that once lived there. Wilderness areas

¹This content is available online at <<http://cnx.org/content/m16729/1.2/>>.

are also of economic importance. Outdoor recreation activities such as hiking and camping benefit tourist industries and manufacturers of outdoor clothes and equipment.

Most importantly, the ecological importance of natural areas is worth preserving. Wilderness areas help maintain ecosystem diversity. They protect watersheds, help to improve air quality and provide a natural undisturbed laboratory for scientific study.

12.1.3 GENETIC DIVERSITY

Whereas ecosystem diversity is a measure of variability among populations of species, **genetic diversity** refers to variability among individuals within a single species population. A gene represents the fundamental physical unit of heredity, and each individual in a species a different mix of genes. This genetic diversity – or variation within species allows populations to adapt to changes in environmental conditions. Millions of years of adaptive change may be encoded in the genes of a species population, and it is those genes that provide the basis for future adaptations.

Loss of genetic diversity makes a species less able to reproduce successfully and less adaptable to a changing environment. Small populations of species are especially susceptible to loss of genetic diversity. When a species loses too many individuals, it becomes genetically uniform. Some of the causes for the loss in genetic diversity include: inbreeding among closely related individuals, and genetic drift in which the genes of a few individuals, eventually dominate in a population.

Genetic diversity is important to agriculture. Much of the world's agriculture is based on introduced or hybrid crop strains, as opposed to native or **wild strains**. The main purpose of using hybrid strains is to increase productivity. Unfortunately, this approved results in only a few hybrid crop strains being used for commercial agriculture. These hybrid crops lack the genetic diversity of the many wild strains, and the resistance of hybrids to pests and disease is generally much lower. Therefore, it is necessary to protect and conserve the wild strains as a genetic library, from which one can draw the genetic information necessary for producing improved and more resistant hybrid strains. A similar situation exists in livestock breeding, except that the loss of genetic diversity in livestock has even more severe consequences. Many livestock breeds are near extinction because of the policy of favoring a few specialized breeds. It is clear that human activity is primarily responsible for the genetic erosion of plant and animal populations.

12.1.4 FOOD RESOURCES

The three major sources of food for humans are: croplands, rangelands and fisheries. **Croplands** provide the bulk of human food. Even though there are thousands of edible plants in the world, only four **staple crops** (wheat, rice, corn and potatoes) account for most of the caloric intake of humans. Some animals raised for meat, milk and eggs (e.g. cattle, pigs, poultry) are also fed grain from croplands. **Rangelands** provide another source of meat and milk from grazing animals (e.g. cattle, sheep, goats). **Fisheries** provide fish, which are a major source of animal protein in the world, especially in Asia and coastal areas. For mainly economic reasons, the diets of most people in the world consist of staple grains. As people become more affluent, they tend to consume more meat, eggs, milk and cheese.

There are two types of food production: **traditional agriculture** and **industrialized agriculture**. Industrialized agriculture is known as high input agriculture because it utilizes large amounts commercial fertilizers, pesticides, water and fossil fuels. Large fields of single crops (**monoculture**) are planted, and the plants are selectively bred to produce high yields. The large amounts of grain produced by this method also foster the production of large numbers of livestock animals in feedlots. Most of the food produced by industrialized methods is sold by farmers for income. This type of food production is most common in developed countries because of the technology and high expenses involved. However, large industrialized plantations specializing in a single cash crop (e.g. a crop specifically raised for income such as bananas, cocoa, coffee) are found in some developing countries.

Traditional agriculture is the most widely practiced form of food production, occurring mostly in developing countries. It can be classified further as either traditional subsistence or traditional intensive agriculture.

The differences between the two involve the relative amounts of resources input and food produced. **Subsistence agriculture** uses only human and animal labor and only produces enough food for the farmer's family.

Traditional, **intensive agriculture** utilizes more human and animal labor, fertilizers and irrigated water. It may also involve growing methods such as **intercropping** designed to maintain soil fertility. Intercropping involves planting two crops simultaneously (e.g., a nitrogen-fixing legume crop with a grain crop). The increased production resulting from the more intensive methods provides enough food for the farmer's family and for selling to others in the local area.

Rangelands tend to be grasslands in semiarid to arid regions that are not suited to growing crops without irrigation. The grasses provide food for grazing animals such as cattle and sheep. These animals not only provide meat for food, but are also a valuable source of leather and wool. In regions with regular rainfall, livestock can be raised in set areas of open range. In more arid climates, nomadic herding of livestock may be necessary in order to find sufficient supplies of grass.

Overgrazing of rangeland by livestock can result in desertification of the area. In developed countries, livestock raised on rangeland are often fattened with grain in feedlots before slaughter.

The ocean provides the biggest location of fisheries. Commercial methods used to harvest these fisheries depend upon the types of fish (e.g. surface dwelling, bottom dwelling) being produced and their tendency to form schools. Trawlers drag nets along the ocean bottom to catch bottom dwelling (demersal) fish such as cod and shellfish such as shrimp. Large schools of surface dwelling (pelagic) fish, such as tuna, are caught by purse-seine fishing in which a net surrounds them and then closes like a drawstring purse. Drift nets up to tens of kilometers long hang like curtains below the surface and entangle almost anything that comes in contact with it. The major problem with all of these fishing methods is that they tend to kill large numbers of unwanted fish and marine mammals that are inadvertently caught.

An alternative to ocean fishing is **aquaculture**, a method in which fish and shellfish are deliberately raised for food. There are two types of aquaculture: fish farming and fish ranching. With **fish farming**, the fish or shellfish (e.g. carp, catfish, oysters) are raised in closed ponds or tanks with a controlled environment. When they reach maturity they are harvested. **Fish ranching** is used with species such as salmon that live one part of their lives in freshwater and the other part in salt water (**anadromous species**). Salmon are raised in captivity for a few years and then released. They are harvested when they return to spawn. Some of the disadvantages of aquaculture include the need for supplying large amounts of food and water, and disposal of the large amounts of waste that are produced.

12.2 Algae into Oil, Bones into Stones

Scientists and textbooks tend to separate biological and geological entities and processes, but the complex cycling of matter on Earth actually blurs those categories. Indeed, some of our most important energy and mineral resources have biological origins. As a consequence, the location and size of these resources depends upon the distribution and productivity of ancient habitats.

12.2.1 Petroleum

Petroleum is a generic term for oil and natural gas, and their products. Petroleum doesn't look organic, but it is derived from the remains of countless marine organisms. It begins with blooms of microscopic algae and other plankton in oceans and large lakes. These organisms sink when they die, and if the seafloor or lakebed they land on has low oxygen and high sedimentation, they can be buried in mud before they decompose. At depth and over time, heat and pressure begin to convert the organic molecules into hydrocarbons. The hydrocarbons begin to liquefy into oil at 50-60 ° C, and vaporize into methane at 100 ° C. If the temperature exceeds 200 ° C, they break down and disappear.

Where petroleum is abundant, it can be pumped from below ground and refined into fuels such as gasoline, propane, jet fuel, and heating oil, and into tar and asphalt. Petroleum is also a component of plastics, dyes, synthetic fibers, fertilizers, compact discs, cosmetics, and explosives.

Petroleum is extremely useful, but it is unevenly distributed around the world, and reserves are being depleted rapidly. Petroleum formation is a complex process that requires just the right biological conditions to produce sufficient plankton, and just the right geologic conditions to preserve and cook the organic matter. The entire sequence takes a million years or more. Because many countries, like the United States, have very limited deposits, and because all petroleum reserves are being drained rapidly, conservation and alternatives are gaining importance. For instance, worn highway asphalt is now being reprocessed and replaced rather than discarded. Plastic recycling is becoming more widespread. Wind, solar, nuclear, geothermal, and hydroelectric power is increasing.

12.2.2 Limestone

Limestone is a type of rock made of calcium carbonate. Although few things seem less life-like than rocks, most limestone is actually biogenic, formed from the shells and skeletons and excretions of marine invertebrates. In the shallows around tropical islands and continents, warm clear water, strong sunlight, and abundant nutrients allow mollusks, crustaceans, and plankton to flourish. When these creatures die or molt, their hard parts fall to the sea floor. As the remains pile up, the weight of the overlying debris compacts the deepest layers. Cements precipitate out of groundwater, fusing the individual fragments into solid rock. Some limestone goes no further, so that the component shells remain distinct and clearly visible. In other limestone, subject to more intense heat and pressure, the organic material is recrystallized into a featureless mass.

Limestone is widely used in industrial processes. Crushed limestone is a component of cement, paper, plastic, and paint, and is used to adjust the pH of soil and water. Whole limestone that retains visible shell material is used for decorative stonework. Common blackboard chalk is a limestone made from microscopic skeletons.

Limestone is extremely abundant, making up about 10-15% of all sedimentary rocks on Earth, so that even though it is heavily used, its reserve are not being significantly depleted.

Chapter 13

NON-RENEWABLE ENERGY SOURCES¹

13.1 NON-RENEWABLE ENERGY SOURCES

13.1.1 INTRODUCTION

Sufficient, reliable sources of energy are a necessity for industrialized nations. Energy is used for heating, cooking, transportation and manufacturing. Energy can be generally classified as non-renewable and renewable. Over 85% of the energy used in the world is from non-renewable supplies. Most developed nations are dependent on **non-renewable** energy sources such as fossil fuels (coal and oil) and nuclear power. These sources are called non-renewable because they cannot be renewed or regenerated quickly enough to keep pace with their use. Some sources of energy are renewable or potentially renewable. Examples of renewable energy sources are: solar, geothermal, hydroelectric, biomass, and wind. Renewable energy sources are more commonly by used in developing nations.

Industrialized societies depend on non-renewable energy sources. Fossil fuels are the most commonly used types of non-renewable energy. They were formed when incompletely decomposed plant and animal matter was buried in the earth's crust and converted into carbon-rich material that is useable as fuel. This process occurred over millions of years. The three main types of fossil fuels are coal, oil, and natural gas. Two other less-used sources of fossil fuels are oil shales and tar sands.

13.1.2 COAL

Coal is the most abundant fossil fuel in the world with an estimated reserve of one trillion metric tons. Most of the world's coal reserves exist in Eastern Europe and Asia, but the United States also has considerable reserves. Coal formed slowly over millions of years from the buried remains of ancient swamp plants. During the formation of coal, carbonaceous matter was first compressed into a spongy material called "peat," which is about 90% water. As the peat became more deeply buried, the increased pressure and temperature turned it into coal.

Different types of coal resulted from differences in the pressure and temperature that prevailed during formation. The softest coal (about 50% carbon), which also has the lowest energy output, is called **lignite**. Lignite has the highest water content (about 50%) and relatively low amounts of smog-causing sulfur. With increasing temperature and pressure, lignite is transformed into bituminous coal (about 85% carbon and 3% water). Anthracite (almost 100% carbon) is the hardest coal and also produces the greatest energy when burned. Less than 1% of the coal found in the United States is anthracite. Most of the coal found in the

¹This content is available online at <<http://cnx.org/content/m16730/1.1/>>.

United States is **bituminous**. Unfortunately, bituminous coal has the highest sulfur content of all the coal types. When the coal is burned, the pollutant sulfur dioxide is released into the atmosphere.

Coal mining creates several environmental problems. Coal is most cheaply mined from near-surface deposits using strip mining techniques. **Strip-mining** causes considerable environmental damage in the forms of erosion and habitat destruction. **Sub-surface mining** of coal is less damaging to the surface environment, but is much more hazardous for the miners due to tunnel collapses and gas explosions. Currently, the world is consuming coal at a rate of about 5 billion metric tons per year. The main use of coal is for power generation, because it is a relatively inexpensive way to produce power.

Coal is used to produce over 50% of the electricity in the United States. In addition to electricity production, coal is sometimes used for heating and cooking in less developed countries and in rural areas of developed countries. If consumption continues at the same rate, the current reserves will last for more than 200 years. The burning of coal results in significant atmospheric pollution. The sulfur contained in coal forms sulfur dioxide when burned. Harmful nitrogen oxides, heavy metals, and carbon dioxide are also released into the air during coal burning. The harmful emissions can be reduced by installing scrubbers and electrostatic precipitators in the smokestacks of power plants. The toxic ash remaining after coal burning is also an environmental concern and is usually disposed into landfills.

13.1.3 OIL

Crude oil or liquid petroleum, is a fossil fuel that is refined into many different energy products (e.g., gasoline, diesel fuel, jet fuel, heating oil). Oil forms underground in rock such as **shale**, which is rich in organic materials. After the oil forms, it migrates upward into porous reservoir rock such as sandstone or limestone, where it can become trapped by an overlying impermeable cap rock. Wells are drilled into these oil reservoirs to remove the gas and oil. Over 70 percent of oil fields are found near tectonic plate boundaries, because the conditions there are conducive to oil formation.

Oil recovery can involve more than one stage. The primary stage involves pumping oil from reservoirs under the normal reservoir pressure. About 25 percent of the oil in a reservoir can be removed during this stage. The secondary recovery stage involves injecting hot water into the reservoir around the well. This water forces the remaining oil toward the area of the well from which it can be recovered. Sometimes a tertiary method of recovery is used in order to remove as much oil as possible. This involves pumping steam, carbon dioxide gas or nitrogen gas into the reservoir to force the remaining oil toward the well. Tertiary recovery is very expensive and can cost up to half of the value of oil removed. Carbon dioxide used in this method remains sequestered in the deep reservoir, thus mitigating its potential greenhouse effect on the atmosphere. The refining process required to convert crude oil into useable hydrocarbon compounds involves boiling the crude and separating the gases in a process known as fractional distillation. Besides its use as a source of energy, oil also provides base material for plastics, provides asphalt for roads and is a source of industrial chemicals.

Over 50 percent of the world's oil is found in the Middle East; sizeable additional reserves occur in North America. Most known oil reserves are already being exploited, and oil is being used at a rate that exceeds the rate of discovery of new sources. If the consumption rate continues to increase and no significant new sources are found, oil supplies may be exhausted in another 30 years or so.

Despite its limited supply, oil is a relatively inexpensive fuel source. It is a preferred fuel source over coal. An equivalent amount of oil produces more kilowatts of energy than coal. It also burns cleaner, producing about 50 percent less sulfur dioxide.

Oil, however, does cause environmental problems. The burning of oil releases atmospheric pollutants such as sulfur dioxide, nitrogen oxides, carbon dioxide and carbon monoxide. These gases are smog-precursors that pollute the air and greenhouse gases that contribute to global warming. Another environmental issue associated with the use of oil is the impact of oil drilling. Substantial oil reserves lie under the ocean. Oil spill accidents involving drilling platforms kill marine organisms and birds. Some reserves such as those in northern Alaska occur in wilderness areas. The building of roads, structures and pipelines to support oil recovery operations can severely impact the wildlife in those natural areas.

13.1.4 NATURAL GAS

Natural gas production is often a by-product of oil recovery, as the two commonly share underground reservoirs. Natural gas is a mixture of gases, the most common being **methane** (CH_4). It also contains some **ethane** (C_2H_6), **propane** (C_3H_8), and **butane** (C_4H_{10}). Natural gas is usually not contaminated with sulfur and is therefore the cleanest burning fossil fuel. After recovery, propane and butane are removed from the natural gas and made into **liquefied petroleum gas (LPG)**. LPG is shipped in special pressurized tanks as a fuel source for areas not directly served by natural gas pipelines (e.g., rural communities). The remaining natural gas is further refined to remove impurities and water vapor, and then transported in pressurized pipelines. The United States has over 300,000 miles of natural gas pipelines. Natural gas is highly flammable and is odorless. The characteristic smell associated with natural gas is actually that of minute quantities of a smelly sulfur compound (**ethyl mercaptan**) which is added during refining to warn consumers of gas leaks.

The use of natural gas is growing rapidly. Besides being a clean burning fuel source, natural gas is easy and inexpensive to transport once pipelines are in place. In developed countries, natural gas is used primarily for heating, cooking, and powering vehicles. It is also used in a process for making ammonia fertilizer. The current estimate of natural gas reserves is about 100 million metric tons. At current usage levels, this supply will last an estimated 100 years. Most of the world's natural gas reserves are found in Eastern Europe and the Middle East.

13.1.5 OIL SHALE AND TAR SANDS

Oil shale and tar sands are the least utilized fossil fuel sources. **Oil shale** is sedimentary rock with very fine pores that contain **kerogen**, a carbon-based, waxy substance. If shale is heated to 490°C , the kerogen vaporizes and can then be condensed as shale oil, a thick viscous liquid. This shale oil is generally further refined into usable oil products. Production of shale oil requires large amounts of energy for mining and processing the shale. Indeed about a half barrel of oil is required to extract every barrel of shale oil. Oil shale is plentiful, with estimated reserves totaling 3 trillion barrels of recoverable shale oil. These reserves alone could satisfy the world's oil needs for about 100 years. Environmental problems associated with oil shale recovery include: large amounts of water needed for processing, disposal of toxic waste water, and disruption of large areas of surface lands.

Tar sand is a type of sedimentary rock that is impregnated with a very thick crude oil. This thick crude does not flow easily and thus normal oil recovery methods cannot be used to mine it. If tar sands are near the surface, they can be mined directly. In order to extract the oil from deep-seated tar sands, however, steam must be injected into the reservoir to make the oil flow better and push it toward the recovery well. The energy cost for producing a barrel of tar sand is similar to that for oil shale. The largest tar-sand deposit in the world is in Canada and contains enough material (about 500 billion barrels) to supply the world with oil for about 15 years. However, because of environmental concerns and high production costs these tar sand fields are not being fully utilized.

13.1.6 NUCLEAR POWER

In most electric power plants, water is heated and converted into steam, which drives a turbine-generator to produce electricity. Fossil-fueled power plants produce heat by burning coal, oil, or natural gas. In a **nuclear power plant**, the **fission of uranium atoms** in the reactor provides the heat to produce steam for generating electricity.

Several commercial reactor designs are currently in use in the United States. The most widely used design consists of a heavy steel pressure vessel surrounding a reactor core. The **reactor core** contains the uranium fuel, which is formed into cylindrical ceramic pellets and sealed in long metal tubes called **fuel rods**. Thousands of fuel rods form the reactor core. Heat is produced in a nuclear reactor when neutrons strike uranium atoms, causing them to split in a continuous chain reaction. **Control rods**, which are made of a material such as boron that absorbs neutrons, are placed among the fuel assemblies.

When the neutron-absorbing control rods are pulled out of the core, more neutrons become available for fission and the chain reaction speeds up, producing more heat. When they are inserted into the core, fewer neutrons are available for fission, and the chain reaction slows or stops, reducing the heat generated. Heat is removed from the reactor core area by water flowing through it in a closed pressurized loop. The heat is transferred to a second water loop through a heat exchanger. The water also serves to slow down, or "moderate" the neutrons which is necessary for sustaining the fission reactions. The second loop is kept at a lower pressure, allowing the water to boil and create steam, which is used to power the turbine-generator and produce electricity.

Originally, nuclear energy was expected to be a clean and cheap source of energy. Nuclear fission does not produce atmospheric pollution or greenhouse gases and its proponents expected that nuclear energy would be cheaper and last longer than fossil fuels. Unfortunately, because of construction cost overruns, poor management, and numerous regulations, nuclear power ended up being much more expensive than predicted. The nuclear accidents at Three Mile Island in Pennsylvania and the Chernobyl Nuclear Plant in the Ukraine raised concerns about the safety of nuclear power. Furthermore, the problem of safely disposing of spent nuclear fuel remains unresolved. The United States has not built a new nuclear facility in over twenty years, but with continued energy crises across the country that situation may change.

Chapter 14

RENEWABLE ENERGY SOURCES¹

14.1 RENEWABLE ENERGY SOURCES

14.1.1 INTRODUCTION

Renewable energy sources are often considered alternative sources because, in general, most industrialized countries do not rely on them as their main energy source. Instead, they tend to rely on non-renewable sources such as fossil fuels or nuclear power. Because the energy crisis in the United States during the 1970s, dwindling supplies of fossil fuels and hazards associated with nuclear power, usage of renewable energy sources such as solar energy, hydroelectric, wind, biomass, and geothermal has grown.

Renewable energy comes from the sun (considered an "unlimited" supply) or other sources that can theoretically be renewed at least as quickly as they are consumed. If used at a sustainable rate, these sources will be available for consumption for thousands of years or longer. Unfortunately, some potentially renewable energy sources, such as biomass and geothermal, are actually being depleted in some areas because the usage rate exceeds the renewal rate.

14.1.2 SOLAR ENERGY

Solar energy is the ultimate energy source driving the earth. Though only one billionth of the energy that leaves the sun actually reaches the earth's surface, this is more than enough to meet the world's energy requirements. In fact, all other sources of energy, renewable and non-renewable, are actually stored forms of solar energy. The process of directly converting solar energy to heat or electricity is considered a renewable energy source. Solar energy represents an essentially unlimited supply of energy as the sun will long outlast human civilization on earth. The difficulties lie in harnessing the energy. Solar energy has been used for centuries to heat homes and water, and modern technology (photovoltaic cells) has provided a way to produce electricity from sunlight.

There are two basic forms of radiant solar energy use: passive and active. **Passive solar energy** systems are static, and do not require the input of energy in the form of moving parts or pumping fluids to utilize the sun's energy. Buildings can be designed to capture and collect the sun's energy directly. Materials are selected for their special characteristics: glass allows the sun to enter the building to provide light and heat; water and stone materials have high heat capacities. They can absorb large amounts of solar energy during the day, which can then be used during the night. A southern exposure greenhouse with glass windows and a concrete floor is an example of a passive solar heating system. **Active solar energy** systems require the input of some energy to drive mechanical devices (e.g., solar panels), which collect the energy and pump fluids used to store and distribute the energy. Solar panels are generally mounted on a south or west-facing

¹This content is available online at <<http://cnx.org/content/m16731/1.1/>>.

roof. A solar panel usually consists of a glass-faced, sealed, insulated box with a black matte interior finish. Inside are coils full of a heat-collecting liquid medium (usually water, sometimes augmented by antifreeze).

The sun heats the water in the coils, which is pumped to coils in a heat transfer tank containing water. The water in the tank is heated and then either stored or pumped through the building to heat rooms or supply hot water to taps in the building.

Photovoltaic cells generate electricity from sunlight. Hundreds of cells are linked together to provide the required flow of current. The electricity can be used directly or stored in storage batteries. Because photovoltaic cells have no moving parts, they are clean, quiet, and durable. Early photovoltaic cells were extremely expensive, making the cost of solar electric panels prohibitive. The recent development of inexpensive semiconductor materials has helped greatly lower the cost to the point where solar electric panels can compete much better cost-wise with traditionally-produced electricity.

Though solar energy itself is free, large costs can be associated with the equipment. The building costs for a house heated by passive solar energy may initially be more expensive. The glass, stone materials, and excellent insulation necessary for the system to work properly tend to be more costly than conventional building materials. A long-term comparison of utility bills, though, generally reveals noticeable savings. The solar panels used in active solar energy can be expensive to purchase, install and maintain. Leaks can occur in the extensive network of pipes required, thereby causing additional expense. The biggest drawback of any solar energy system is that it requires a consistent supply of sunlight to work. Most parts of the world have less than ideal conditions for a solar-only home because of their latitude or climate. Therefore, it is usually necessary for solar houses to have conventional backup systems (e.g. a gas furnace or hot-water heater). This double-system requirement further adds to its cost.

14.1.3 HYDROELECTRIC ENERGY

Hydroelectric power is generated by using the energy of flowing water to power generating turbines for producing electricity. Most hydroelectric power is generated by dams across large-flow rivers. A dam built across river creates a reservoir behind it. The height of the water behind the dam is greater than that below the dam, representing stored potential energy. When water flows down through the penstock of the dam, driving the turbines, some of this potential energy is converted into electricity. Hydroelectric power, like other alternative sources, is clean and relatively cheap over the long term even with initial construction costs and upkeep. But because the river's normal flow rate is reduced by the dam, sediments normally carried downstream by the water are instead deposited in the reservoir. Eventually, the sediment can clog the penstocks and render the dam useless for power generation.

Large-scale dams can have a significant impact on the regional environment. When the river is initially dammed, farmlands are sometimes flooded and entire populations of people and wildlife are displaced by the rising waters behind the dam. In some cases, the reservoir can flood hundreds or thousands of square kilometers. The decreased flow downstream from the dam can also negatively impact human and wildlife populations living downstream. In addition, the dam can act as a barrier to fish that must travel upstream to spawn. Aquatic organisms are frequently caught and killed in the penstock and the out-take pipes. Because of the large surface area of the reservoir, the local climate can change due to the large amount of evaporation occurring.

14.1.4 WIND POWER

Wind is the result of the sun's uneven heating of the atmosphere. Warm air expands and rises, and cool air contracts and sinks. This movement of the air is called wind. Wind has been used as an energy source for millennia. It has been used to pump water, to power ships, and to mill grains. Areas with constant and strong winds can be used by wind turbines to generate electricity. In the United States, the state of California has about 20,000 **wind turbines**, and produces the most wind-generated electricity. Wind energy does not produce air pollution, can be virtually limitless, and is relatively inexpensive to produce. There is an initial cost of manufacturing the wind turbine and the costs associated with upkeep and repairs, but the wind itself is free.

The major drawbacks of wind-powered generators are they require lots of open land and a fairly constant wind supply. Less than 15% of the United States is suitable for generating wind energy.

Windmills are also noisy, and some people consider them aesthetically unappealing and label them as visual pollution. Migrating birds and insects can become entangled and killed by the turning blades. However, the land used for windmill farms can be simultaneously used for other purposes such as ranching, farming and recreation.

14.1.5 BIOMASS ENERGY

Biomass energy is the oldest energy source used by humans. Biomass is the organic matter that composes the tissues of plants and animals. Until the Industrial Revolution prompted a shift to fossil fuels in the mid 18th century, it was the world's dominant fuel source. Biomass can be burned for heating and cooking, and even generating electricity. The most common source of biomass energy is from the burning of wood, but energy can also be generated by burning animal manure (dung), herbaceous plant material (non-wood), peat (partially decomposed plant and animal tissues), or converted biomass such as charcoal (wood that has been partially burned to produce a coal-like substance). Biomass can also be converted into a liquid biofuel such as ethanol or methanol. Currently, about 15 percent of the world's energy comes from biomass.

Biomass is a potentially renewable energy source. Unfortunately, trees that are cut for firewood are frequently not replanted. In order to be used sustainably, one tree must be planted for every one cut down.

Biomass is most frequently used as a fuel source in developing nations, but with the decline of fossil fuel availability and the increase in fossil fuel prices, biomass is increasingly being used as a fuel source in developed nations. One example of biomass energy in developed nations is the burning of municipal solid waste. In the United States, several plants have been constructed to burn urban biomass waste and use the energy to generate electricity.

The use of biomass as a fuel source has serious environmental effects. When harvested trees are not replanted, soil erosion can occur. The loss of photosynthetic activity results in increased amounts of carbon dioxide in the atmosphere and can contribute to global warming. The burning of biomass also produces carbon dioxide and deprives the soil of nutrients it normally would have received from the decomposition of the organic matter. Burning releases particulate matter (such as ash) into the air which can cause respiratory health problems.

14.1.6 GEOTHERMAL ENERGY

Geothermal energy uses heat from the earth's internal geologic processes in order to produce electricity or provide heating. One source of geothermal energy is steam. Groundwater percolates down through cracks in the subsurface rocks until it reaches rocks heated by underlying magma, and the heat converts the water to steam. Sometimes this steam makes its way back to the surface in the form of a geyser or hot spring. Wells can be dug to tap the steam reservoir and bring it to the surface, to drive generating turbines and produce electricity. Hot water can be circulated to heat buildings. Regions near tectonic plate boundaries have the best potential for geothermal activity.

The western portion of the United States is most conducive for geothermal energy sources, and over half of the electricity used by the city of San Francisco comes from the Geysers, a natural geothermal field in Northern California. California produces about 50 percent of the world's electricity that comes from geothermal sources.

Entire cities in Iceland, which is located in a volcanically active region near a mid-ocean ridge, are heated by geothermal energy. The Rift Valley region of East Africa also has geothermal power plants. Geothermal energy may not always be renewable in a particular region if the steam is withdrawn at a rate faster than it can be replenished, or if the heating source cools off. The energy produced by the Geysers region of California is already in decline because the heavy use is causing the underground heat source to cool.

Geothermal energy recovery can be less environmentally invasive than engaging in recovery methods for non-renewable energy sources. Although it is relatively environmentally friendly, it is not practical for all situations. Only limited geographic regions are capable of producing geothermal energy that is economically

viable. Therefore, it will probably never become a major source of energy. The cost and energy requirements for tapping and transporting steam and hot water are high. Hydrogen sulfide, a toxic air pollutant that smells like rotten eggs, is also often associated with geothermal activity.

Chapter 15

LAND¹

15.1 LAND

15.1.1 INTRODUCTION

The concept of land use (i.e., the way a particular piece of land is utilized by humans and other living organisms), seems at first glance a simple and straightforward subject on the surface. Humans use land to build cities where they live (residential land) and work (commercial land). They use land for growing crops and raising livestock (agricultural land) for food. Forestland provides fuel for energy and lumber for building. Humans use land for play (recreational land) and set some of it aside as exclusive wildlife habitat (wilderness land). But no matter how land is used by humans and other living species, humans ultimately decide how land is used. Given the nature of humans, land use involves a complex interplay of environmental parameters, economic needs and often politics.

15.1.2 RESIDENTIAL AND COMMERCIAL LANDS

About half of the earth's human inhabitants live in urban areas. These urban areas include residential land for homes and commercial land for businesses. The number of people living in urban areas continues to grow each year, and as a result, the amount of land used for residential and commercial use is also increasing. Cities in the United States usually require that residential land be separated from commercial land. This has been a factor in the development of urban sprawl, the low-density housing developments surrounding many cities and towns.

A city grows in three basic ways: concentric, sector and multiple nuclei. In the **concentric city model**, the city develops outward from a central business district in a set of concentric rings (i.e., New York City). Commercial areas are concentrated in the central district, while the outer rings are typically residential areas. A **sector city** develops outward in pie-shaped wedges or strips (i.e., the Silicon Valley region south of San Francisco).

This type of growth results when commercial and residential areas are built up along major transportation routes. A **multiple-nuclei** city evolves with several commercial centers or satellite communities scattered over the urban region instead of a single central business district. The Los Angeles metropolitan area is a good example of a multiple-nuclei city.

Much of the land converted to residential and commercial use in cities was formerly used for agricultural purposes or consisted of ecologically important areas such as wetlands. Cities are built on such land as a result of conventional land use planning, which encourages substantial urban growth for purely economic reasons (i.e., as a means of increasing the tax base). Unfortunately, when economic factors are the only one

¹This content is available online at <<http://cnx.org/content/m16732/1.1/>>.

considered, degrading effects to the environment are generally disregarded. Some cities now use a smart-growth model in which development of urban areas is designed to strike a balance between economic needs and safeguarding the environment.

One city design approach used to control urban growth is establishing **greenbelts** around the city peripheries. Greenbelts provide habitat such as forest areas for animals and open space for human recreation, while blocking the outward growth of the city. Another method used to lessen the effects of urban sprawl is the **cluster development model** for new residential areas. In this design housing is concentrated in a restricted portion of a tract, leaving the rest of the land in a relatively natural state with trees, open space and waterways.

15.1.3 AGRICULTURAL AND FOREST LANDS

Less than half of the land area in the world (and in the United States) is used for agriculture. The majority of agricultural lands are **rangeland** or **pasture**. Rangelands are unsuitable for growing grain crops for a variety of reasons: the land may be too rocky or too steep, or the climate may be too cool or too dry. Livestock grazing is the major agricultural use of rangeland and pasture. Together, rangeland and pasture comprise about 35 percent of non-federal land (526 million acres) in the United States. Most of the nation's rangelands are in vast areas of the western states with arid to semi-arid climates. Pastures, which are smaller managed grassy areas, are found on farms throughout the United States.

Croplands are important because they account for the bulk of food production. About 20 percent of the land in the United States (about 400 million acres) is croplands, with the highest concentrations in the central United States. About 70 percent of all cropland in the United States is classified as prime farmland.

Prime farmland is land that has a growing season, a water supply from precipitation or irrigation, and sufficiently rich soil to sustain high yields when managed according to modern farming methods. Cropland may become prime farmland with the addition of the irrigation or flooding protection needed to sustain high yields. Farmlands in the eastern and southern United States are generally smaller and produce a greater variety of crops than those in the Corn Belt and Great Plains, where a few major grain crops predominate.

In countries throughout the world, agricultural land is being lost for various reasons. Some land is being lost to other uses such as housing developments, commercial developments and roads. Unfortunately, this change in use is taking from us much prime agricultural land. In the United States, federal programs exist that encourage farmers to stop farming agricultural lands defined as sensitive, which pose a risk of environmental degradation. In an attempt to help preserve prime farmland in the United States, some local and state governments and private organizations have programs to purchase easements on cropland that restricts nonagricultural use.

Such croplands are temporarily or permanently retired from active production and are planted with perennial grasses or trees. Millions of acres of agricultural land in semiarid regions are lost each year due to a phenomenon called **desertification**. This occurs when once-productive land becomes too arid for agricultural use because of climate change or poor land management (i.e., overgrazing of rangeland, erosion of croplands).

Years ago, the standard practice for replacing lost agricultural lands or increasing overall production in many countries was to develop new farmland from formerly uncultivated land. But now, areas of potentially arable land are shrinking in most countries. Most of the uncultivated land that does remain is marginal, with poor soils and either too little rainfall or too much.

Tropical rainforests are being logged at a fast rate to provide farmland. However, soils in rainforests are nutrient poor and prone to erosion by frequent tropical rains. Destruction of rainforest regions may also contribute to global environmental problems such as global warming. Forests of all kinds are very important ecologically. As major biomes, they provide a habitat for living species and support the food webs for those species. Forests play an environmental role by recycling nutrients (i.e., carbon, nitrogen) and generating oxygen through photosynthesis. They even influence local climatic conditions by affecting air humidity through evaporation and transpiration processes. Economically, forests are also very important.

Humans have utilized forests for thousands of years as a source of energy (i.e., fuel), building materials (lumber) and pulpwood for paper, and these uses remain important. When forestlands hold valuable mineral

resources beneath them, they may be cleared to provide access to the minerals.

The United States Forest Service defines forestlands as lands that consist of at least 10 percent trees of any size. They include: transition zones (such as areas between heavily forested and nonforested lands) and forest areas adjacent to urban areas. In the western states they include pinyon-juniper and chaparral areas. Forests cover about one-third of the United States, which is about 70 percent of their extent when European settlement began in the 17th century. About 42 percent of U.S. forestlands are publicly owned. Of these, about 15 percent are in national parks or wilderness areas and are thus protected from timber harvest.

Other public forestlands are managed for various uses: recreation, grazing, watershed protection, timber production, wildlife habitat, and mining. Forests in the western states are predominantly publicly owned, while those in eastern states are predominantly privately owned.

Forests can be classified by their relative maturity. **Old-growth forests** have been undisturbed for hundreds of years. They contain numerous dead trees and fallen logs which provide species habitats and are eventually recycled through decay. **Second-growth forests** are less mature and occur when the original ecological community in a region is destroyed, either by human land-clearing activities or by natural disasters (i.e., fires, storms, volcanic eruptions). Humans sometimes create artificial forests in the form of tree farms. Usually only one tree species is planted in a tree farm. After maturing enough to be of economic value, the trees are harvested and new trees planted in their place.

Forest trees can be harvested by different methods: selective cutting, seed-tree cutting, strip cutting and clear cutting. Most of these methods have distinct effects on the ecology of the harvested area. Selective cutting is usually least damaging to the local ecosystem. In this method of harvesting, trees that are moderate to fully mature are cut singly or in small groups. This approach allows most of the trees to remain, which helps maintain habitats and prevent soil erosion and allows uninterrupted recreational use. However, in tropical forests when only the biggest and best trees are removed, selective cutting can lead to significant ecosystem damage. Because the canopy of a tropical forest is thick and intertwined, the removal of one large tree damages a considerable area around it.

Other harvesting methods involve removal of most or all of the trees in a given area. **Seed-tree cutting** removes most of the trees in an area, leaving only a few scattered trees to provide seeds for regrowth. The remaining trees provide some habitat for animals and help reduce soil erosion. However, when seed trees are cut, the forest loses its diversity and is often converted to a tree farm.

Clear cutting and **strip cutting** both remove all trees in an area. Clear-cutting usually involves large areas of land resulting in the concomitant destruction of a large area of wildlife habitat. The logged areas are susceptible to severe erosion, especially when the clear cutting occurs on slopes. With strip cutting, trees are removed from consecutive narrow strips of land. The strips are removed over a period of years and as a result some trees (uncut or regrowth) are always available for animal habitat. The cut area is partially protected from erosion by the uncut or regrowth trees in the adjacent areas.

15.1.4 RECREATIONAL AND WILDERNESS LANDS

An important human-centered benefit of undeveloped land is their recreational value. Every year, millions of people visit recreational lands such as parks and wilderness areas to experience attractions of the great outdoors: hiking among the giant sequoias in California, traveling on a photo safari in Kenya or just picnicking at a local county park. Besides providing people with obvious health benefits and aesthetic pleasures, recreational lands also generate considerable tourist money for government and local economies.

The United States has set aside more land for public recreational use than any other country. Several different federal organizations provide lands for recreational use: the National Forest System, the U.S. Fish and Wildlife Service, the National Park System and the National Wilderness Preservation System. The National Forest System manages more than 170 forestlands and grasslands, which are available for activities such as camping, fishing, hiking and hunting.

The U.S. Fish and Wildlife Service manage more than 500 National Wildlife Refuges, which not only protect animal habitats and breeding areas but also provide recreational facilities. The National Park System manages more than 380 parks, recreation areas, seashores, trails, monuments, memorials, battlefields and

other historic sites. The National Wilderness Preservation System manages more than 630 roadless areas through the aforementioned government services as well as through the Bureau of Land Management.

The **National Park System** consists of more than 80 million acres nationwide. The largest national park is Wrangell-St. Elias National Park and Preserve in Alaska with over 13 million acres. California has eight national parks: Channel Islands, Death Valley, Joshua Tree, Lassen, Redwood, Sequoia, Kings Canyon and Yosemite. Many national parks such as Yosemite, Yellowstone and the Grand Canyon are such popular recreation destinations that the ecosystems of those parks are being severely tested by human activities.

Every state has also set aside significant amounts of land for recreational use. The California State Park System manages more than one million acres of parklands including: coastal wetlands, estuaries, scenic coastlines, lakes, mountains and desert areas. California's largest state park is Anza-Borrego Desert State Park, which is the largest state park in the United States with 600,000 acres. The stated mission of the California State Park System is: "To provide for the health, inspiration and education of the people of California by helping to preserve the state's extraordinary biological diversity, protecting its most valued natural and cultural resources and creating opportunities for high-quality outdoor recreation."

This is the basic goal of all recreational lands: to manage and conserve natural ecosystems, while supporting a sustainable and balanced level of human use of those areas. Unfortunately, it is a goal which is sometimes difficult to achieve due to the increasing popularity and use of recreational lands.

The "**Wilderness Act of 1964**" created the world's first wilderness system in the United States. Presently, the **National Wilderness Preservation System** contains more than 100 million acres of land that will forever remain wild. A wide range of recreation, scientific and outdoor activities are available in wilderness lands. Mining operations and livestock grazing are permitted to continue in certain wilderness areas where such operations existed prior to an area's designation. Hunting and fishing are also allowed in wilderness areas (except in national parks).

For most people, wilderness lands provide a means for various forms of recreation: hiking, horseback riding, bird watching, fishing, and hunting. People can escape the stress of modern-day life and enjoy an undisturbed look at nature. Wilderness lands provide an essential habitat for a wide array of fish, wildlife, and plants, and are particularly important in protecting endangered species. For scientists, wilderness lands serve as natural laboratories, where studies can be performed that would not be possible in developed areas.

Several other types of public lands complement the designated wilderness land system. These include: national forest roadless areas, national trails system, natural research areas and state and private wilderness lands. The national forest roadless areas consist of millions of acres of wild, undeveloped land without roads that exist on National Forest land outside of designated wilderness lands.

The "**National Trail System**," established by Congress in 1968, includes trails in wilderness areas and other public lands. **Research Natural Areas** located throughout the country on public lands serve as outdoor laboratories to study natural systems. They are intended in part to serve as gene pools for rare and endangered species and as examples of significant natural ecosystems. Some wilderness lands are maintained by states or private organizations. For example, the state of New York has long preserved a region of the Adirondacks as wilderness.

On an international level, important wilderness lands have been designated by the United Nations through its "**Man and the Biosphere Program**." This program was established in 1973 to protect examples of major natural regions throughout the world, and provide opportunities for ecological research and education.

Biosphere reserves are organized into three interrelated zones: the **core area**, the **buffer zone** and the **transition area**. The core area contains the landscape and ecosystems to be preserved. The buffer zone is an area where activities are controlled to protect the core area. The outer transition area contains a variety of agricultural activities, human settlements and other uses. Local communities, conservation agencies, scientists and private enterprises that have a stake in the management of the region work together to make the reserves work. Mt Kenya in Africa and the Galapagos Islands are examples of wilderness areas protected under this provision.

Chapter 16

AIR, WATER AND SOIL¹

16.1 AIR, WATER AND SOIL

16.1.1 INTRODUCTION

Human activities release a variety of substances into the biosphere, many of which negatively affect the environment. Pollutants discharged into the environment can accumulate in the air, water, or soil. Chemicals discharged into the air that have a direct impact on the environment are called **primary pollutants**. These primary pollutants sometimes react with other chemicals in the air to produce secondary pollutants.

A wide variety of chemicals and organisms are discharged into lakes, rivers and oceans daily. Left untreated, this sewage and industrial waste has a serious impact on the water quality, not only in the immediate area, but also downstream.

16.1.2 AIR POLLUTANTS

The eight classes of air pollutants are: oxides of carbon, sulfur and nitrogen, volatile organic compounds, suspended particulate matter, photochemical oxidants, radioactive substances and hazardous air pollutants. **Oxides of carbon** include **carbon monoxide** (CO) and **carbon dioxide** (CO₂). Carbon monoxide, a primary pollutant, is mainly produced by the incomplete combustion of fossil fuels. It is also present in cigarette smoke. The colorless, odorless gas is poisonous to air-breathing animals. Carbon monoxide binds to hemoglobin, impeding delivery of oxygen to cells. This causes dizziness, nausea, drowsiness, and headaches; at high concentrations it can cause death. Carbon monoxide pollution from automobiles can be reduced through the use of catalytic converters and oxygenated fuels.

Carbon dioxide is produced by the complete combustion of fossil fuels. It is considered a greenhouse gas because it heats up the atmosphere by absorbing infrared radiation. As a result of this characteristic, excess amounts of carbon dioxide in the atmosphere may contribute to global warming. Carbon dioxide can also react with water in the atmosphere and produce slightly acidic rain. Carbon dioxide emissions can be reduced by limiting the amount of fossil fuels burned.

Oxides of sulfur include **sulfur dioxide** (SO₂) and **sulfur trioxide** (SO₃). Sulfur oxides are primarily produced by the combustion of coal and oil. Oxides of sulfur have a characteristic rotten egg odor, and inhalation of them can lead to respiratory system damage. They react with atmospheric water to produce sulfuric acid, which precipitates as acid rain or acid fog. Acid rain is a secondary pollutant that acidifies lakes and streams, rendering the water unfit for aquatic life. It also corrodes metals, and dissolves limestone and marble structures. Oxides of sulfur can be removed from industrial smokestack gases by "scrubbing" the emissions, by electrostatically precipitating the sulfur, by filtration, or by combining them with water, thereby producing sulfuric acid which can be used commercially.

¹This content is available online at <<http://cnx.org/content/m16733/1.1/>>.

Oxides of nitrogen include: **nitric oxide** (NO), **nitrogen dioxide** (NO₂), and **nitrous oxide** (N₂O). Nitric oxide is a clear, colorless gas formed during the combustion of fossil fuels. Nitrogen dioxide forms when nitric oxide reacts with atmospheric oxygen; the reddish-brown pungent gas is considered to be a secondary pollutant. Exposure to oxides of nitrogen can cause lung damage, aggravate asthma and bronchitis, and increase susceptibility to the flu and colds. Nitrogen dioxide can combine with atmospheric water to form nitric acid, which is precipitated as acid rain. Nitrogen dioxide is also a key ingredient in the formation of photochemical smog, and nitrous oxide is a greenhouse gas. Automobile emissions of these pollutants can be reduced by catalytic converters which convert them to molecular nitrogen and oxygen.

Volatile organic compounds (VOCs) include **hydrocarbons** such as methane (CH₄), propane (C₃H₈), and octane (C₈H₁₈), and **chlorofluorocarbons (CFCs)** such as dichlorodifluoromethane (CCl₂F₂).

Hydrocarbons are released into the atmosphere in automobile exhaust and from the evaporation of gasoline. They contribute to the formation of **photochemical smog**. Chlorofluorocarbons were used as propellants for aerosols and as refrigerants until it was discovered they can cause depletion of the protective ozone layer. Volatile organic compound emissions can be reduced by using vapor-recovery gasoline nozzles at service stations and by burning oxygenated gasoline in automobile engines.

Suspended particulate matter consists of tiny particles of dust, soot, asbestos, and salts, and of microscopic droplets of liquids such as sulfuric acid and pesticides. Sources of these pollutants include the combustion of fossil fuel (e.g. diesel engines) and road and building construction activity. Exposure to these particles can lead to respiratory irritation, reduction of lung capacity, lung cancer, and emphysema.

Photochemical oxidants are primarily produced during the formation of photochemical smog. **Ozone** (O₃) is a highly reactive, irritating gas that causes breathing problems, as well as eye, nose, and throat irritation. It also aggravates asthma, bronchitis, and heart disease. Ozone and other photochemical oxidants can damage or kill plants, reduce visibility, and degrade rubber, paint, and clothes. Photochemical oxidants are secondary pollutants, and can be controlled by reducing the amount of nitrogen dioxide in the atmosphere.

Radioactive substances include radon-222, iodine-131, and strontium-90. **Radon** is gas produced during the decay of uranium that is naturally present in rocks and building materials made with these rocks. It is known to cause lung cancer in humans. The other radioisotopes are produced by nuclear power plants (iodine-131) or are contained in the fallout from atmospheric nuclear testing (strontium-90). They can be introduced into the food chain through plants and become incorporated in the tissues of humans and other animals. Their ionizing radiation can produce cancers, especially those related to the thyroid and bone.

Hazardous air pollutants include **benzene** (C₆H₆) and **carbon tetrachloride** (CCl₄). Benzene is a common organic solvent with numerous industrial uses. Carbon tetrachloride was formerly used as a solvent in the dry cleaning business. It is still used in industrial processes. Exposure to these compounds can cause cancer, birth defects and central nervous system problems.

16.1.3 WATER POLLUTANTS

The eight classes of water pollutants are: infectious agents, oxygen-depleting wastes, inorganic chemicals, organic chemicals, plant nutrient pollutants, sediments, radioactive materials and thermal pollution. Infectious agents such as bacteria, viruses, and parasitic worms enter water from human and animal waste, and cause diseases such as typhoid fever, cholera, hepatitis, amoebic dysentery, and schistosomiasis, a condition marked by blood loss and tissue damage.

Oxygen-depleting wastes include animal manure in feedlot and farm runoff, plant debris, industrial discharge, and urban sewage. They are consumed by aerobic bacteria. Excessive growth of these organisms can deplete water of dissolved oxygen which leads to eutrophication and the eventual death of oxygen-consuming aquatic life.

Inorganic chemical pollutants include mineral acids, toxic metals such as lead, cadmium, mercury, and hexavalent chromium, and mineral salts. They are found in industrial discharge, chemicals in household wastewater, and seepage from municipal dumps and landfills. The presence of inorganic chemical pollutants in water can render it undrinkable, as well as cause cancer and birth defects. In addition, sufficient concen-

trations of these chemicals in water can kill fish and other aquatic life, cause lower crop yields due to plant damage, and corrode metals.

Organic chemical pollutants encompass a wide variety of compounds including oil, gasoline, pesticides, and organic solvents. They all degrade the quality of the water into which they are discharged. Sources of these pollutants include industrial discharge and runoff from farms and urban areas. Sometimes these chemicals enter aquatic ecosystems directly when sprayed on lakes and ponds (e.g. for mosquito control). These types of chemicals can cause cancer, damage the central nervous system and cause birth defects in humans.

Plant nutrient pollutants are found mainly in urban sewage, runoff from farms and gardens, and household wastewater. These chemicals include nitrates (NO_3^-), phosphates (PO_4^{3-}) and ammonium (NH_4^+) salts commonly found in fertilizers and detergents. Too much plant nutrients in the water can cause excessive algae growth in lakes or ponds. This, in turn, results in the production of large amounts of oxygen-depleting wastes. The subsequent loss of dissolved oxygen causes eutrophication of the lakes or ponds.

Erosion of soils is the main process contributing **sediments**, or **silts**, to water bodies. Sediments can cloud the water of streams and rivers, reducing the amount of available sunlight to aquatic plants. The concurrent reduction in photosynthesis can disrupt the local ecosystem. Soil from croplands deposited in lakes and streams can carry pesticides, bacteria, and other substances that are harmful to aquatic life. Sediments can also fill up or clog lakes, reservoirs, and waterways limiting human use and disrupting habitats.

Radioactive materials such as iodine-131 and strontium-90 are found in nuclear power plant effluents and fallout from atmospheric nuclear testing. They can be introduced into the food chain through plants and become incorporated in body tissues of humans and animals. Their ionizing radiation can produce cancers, especially in the thyroid and bone where they tend to concentrate.

A power generating plant commonly discharges water used for cooling into a nearby river, lake, or ocean. Because the discharged water can be significantly warmer than the ambient environment, it represents a source of **thermal pollution**. Industrial discharges are also sources of thermal pollution. The increased temperature of the water may locally deplete dissolved oxygen and exceed the range of tolerance of some aquatic species, thus disrupting the local ecosystem.

Processing water in treatment plants can reduce the amounts of infectious agents, oxygen-depleting wastes, inorganic chemicals, organic chemicals and plant nutrients. Bans and restrictions on the use of certain chemicals, such as those on DDT and hexavalent chromium compounds, are also very helpful in reducing the amounts of these chemicals in the environment. By limiting exposure to these harmful substances, their negative effects on humans and local ecosystems can be greatly reduced.

16.1.4 SOIL POLLUTANTS

The persistence of pesticides in the soil is related to how quickly these chemicals degrade in the environment. There are three ways pesticides are degraded in the soil: **biodegradation**, **chemical degradation**, and **photochemical degradation**. Microorganism activity plays the predominant role in the biodegradation of pesticides. Water plays an important role in the chemical degradation of pesticides (e.g. some pesticides are hydrolyzed on the surfaces of minerals by water). Exposure to sunlight can also degrade some pesticides.

A variety of pesticides are used to control insects, weeds, fungi, and mildew in agricultural, garden, and household environments. There are three classes of pesticides: **insecticides**, which kill insects; **herbicides**, which kill plants; and **fungicides**, which kill fungi. Each of these classes includes different types of chemicals. These chemicals differ in chemical composition, chemical action, toxicity, and persistence (residence time) in the environment. Some of these pesticides can bioaccumulate (e.g. they concentrate in specific plant and animal tissues and organs). Pesticides can accumulate in the soil if their structures are not easily broken down in the environment. Besides rendering the soil toxic to other living organisms, these pesticides may leach out into the groundwater, polluting water supplies.

The five classes of insecticides are: chlorinated hydrocarbons, organophosphates, carbamates, botanicals and synthetic botanicals. **Chlorinated hydrocarbons** such as DDT, are highly toxic in birds and fishes, but have relatively low toxicity in mammals. They persist in the environment, lasting for many months or years. Because of their toxicity and persistence, their use as insecticides has been somewhat restricted.

Organophosphates, such as **Malathion**, are more poisonous than other types of insecticides, but have much shorter residence times in the environment. Thus, they do not persist in the environment and cannot bioaccumulate. **Carbamates**, such as **Sevin**, are generally less toxic to mammals than are organophosphates. They also have a relatively low persistence in the environment and usually do not bioaccumulate. **Botanicals**, such as **camphor**, are derived from plant sources. Many of these compounds are toxic to mammals, birds, and aquatic life. Their persistence in the environment is relatively low, and as a result bioaccumulation is not a problem. **Synthetic botanicals**, such as **Allethrin**, generally have a low toxicity for mammals, birds, and aquatic life, but it is unclear how persistent they are and whether or not they bioaccumulate.

The three classes of herbicides are: contact chemicals, systemic chemicals and soil sterilants. Most herbicides do not persist in the soil for very long. **Contact chemicals** are applied directly to plants, and cause rapid cell membrane deterioration. One such herbicide, Paraquat, received notoriety when it was used as a defoliant on marijuana fields. Paraquat is toxic to humans, but does not bioaccumulate. **Systemic chemicals**, such as Alar, are taken up by the roots and foliage of plants, and are of low to moderate toxicity to mammals and birds; some systemic herbicides are highly toxic to fishes. These compounds do not have a tendency to bioaccumulate. **Soil sterilants** such as **Diphenamid**, render the soil in which the plants lives toxic. These chemicals have a low toxicity in animals, and do not bioaccumulate.

Fungicides are used to kill or inhibit the growth of fungi. They can be separated into two categories: protectants and systemics. Protectant fungicides, such as Captan, protect the plant against infection at the site of application, but do not penetrate into the plant. System fungicides, such as Sovran, are absorbed through the plant's roots and leaves and prevent disease from developing on parts of the plant away from the site of application. Fungicides are not very toxic and are moderately persistent in the environment.

Soil can absorb vast amount of pollutants besides pesticides every year. Sulfuric acid rain is converted in soil to sulfates and nitric acid rain produces nitrates in the soil. Both of these can function as plant nutrient pollutants. Suspended particulate matter from the atmosphere can accumulate in the soil, bringing with it other pollutants such as toxic metals and radioactive materials.

16.1.5 Point and Non-point Pollution Sources

Environmental regulations are designed to control the amounts and effects of pollutants released by agricultural, industrial, and domestic activities. These laws recognize two categories of pollution and polluters – point source and non-point source.

Point Source Pollution

Point sources are single, discrete locations or facilities that emit pollution, like a factory, smokestack, pipe, tunnel, ditch, container, automobile engine, or well.

Because point sources can be precisely located, the discharge of pollutants from them is relatively easy to monitor and control. The United States Environmental Protection Agency, or EPA, sets emission standards for particular chemicals and compounds. Then, outflow from the point source is sampled, and the pollutants in it are measured precisely to ensure that discharge levels are in compliance with regulations.

New techniques to reduce emissions from point sources are more likely to be developed because their effectiveness can be evaluated quickly and directly and because point source polluters have an obvious financial incentive to reduce waste and avoid regulatory fines.

Non-point Source Pollution

Non-point sources are diffuse and widespread. Contaminants are swept into waterways by rainfall and snowmelt or blown into the air by the wind. They come from multiple sources, such as vehicles dripping oil onto roads and parking lots, pesticides used on lawns and parks and fields, wastes deposited by livestock and pets, or soil disturbed by construction or plowing.

Non-point source pollution is more difficult to regulate than point source emissions. Contamination is measured not at the source, but at the destination. Samples are collected from the air, soil, and water, or from the blood and tissues of organisms in polluted areas. The contribution of various non-point sources to these pollution levels can only be estimated. EPA regulations cannot be directed at specific individuals or businesses and are instead generally directed at municipalities. For example, federal standards are set

for allowable levels of chemicals in drinking water, and communities are responsible for treating their water until it meets those standards.

It can be difficult to reduce many types of non-point source pollution because most of the people who contribute to it are not directly faced with legal or financial consequences. Individuals must be persuaded that their activities are causing ecological harm and that they should alter their behavior or spend their money to remedy the situation. Once they do, they may have to wait a long time for noticeable environmental results.

16.1.6 Parts per million (ppm) and Micrograms per milliliter (ug/mL)

Very small quantities of some chemicals can have a large impact on organisms. Because of this, substances that are present in trace amounts, such as nutrients and contaminants, are usually measured and recorded using very small units. Two of the most common measures are parts per million and micrograms per milliliter.

Micrograms per milliliter (ug/mL)

Micrograms per milliliter, or ug/mL, measures mass per volume. It is generally used to measure the concentration of a substance dissolved or suspended in a liquid. One microgram is one millionth of a gram (1 ug = 0.0000001 g), and one milliliter is one thousandth of a liter.

Parts per million (ppm)

Parts per million, abbreviated as ppm, is a unitless measure of proportion. It is obtained by dividing the amount of a substance in a sample by the amount of the entire sample, and then multiplying by 10⁶. In other words, if some quantity of gas, liquid, or solid is divided into one million parts, the number of those parts made up of any specific substance is the ppm of that substance. For example, if 1 mL of gasoline is mixed with 999,999 mL of water, the water contains 1 ppm of gas.

Concentration Equivalents

Since a microgram is one millionth of a gram, and a milliliter of water equals one gram of water, ug/mL is equivalent to parts per million. Ppm is also equivalent to many other proportional measurements, including milligrams per liter (mg/L), milligrams per kilogram (mg/Kg), and pounds per acre (lb/acre). But parts per million is often more useful in describing and comparing trace amounts of chemicals because it eliminates specific units and is applicable to liquids, solids, and gases.

Examples

Both ppm and ug/mL can be used to describe the amount of particulate dust in a sample of air:

If the total particulate dust in a one liter volume of air is 5 mg, there is 5 ppm of particulate dust in the air that was sampled, since mg/L (milligrams per liter) = ppm.

How much dye should you add to one gallon of water to achieve a final 500 ppm mixture?

Concentration Measurements and Environmental Regulations

Because many toxins begin to have negative environmental effects at very low levels, their abundance in ppm or ug/mL are used to set the limits of pollutants that are legally permitted in stack smoke, discharge water, soil contamination, and so on. For example, coal fired power plants may be limited to a discharge of 0.5 ppm of SO₂ in the stack smoke. If a plant's emissions exceed that amount, it may be in violation of local or federal air quality standards and could be subject to a fine.

16.1.7 Pollution Effects on Wildlife

Not unreasonably, we tend to be most concerned by the impact of pollution on human health and interests. However, there is growing documentation of the harm pollution is inflicting on wildlife. The following are just a small sample.

Pesticides

The pesticide DDT was banned in the U.S. in 1972 because it caused raptor eggs to thin and break. But residual DDT and other persistent organochlorine pesticides continue to impact wildlife today. Additionally, DDT is still used in many other countries as the most effective control of malaria-bearing mosquitoes.

Prescription Drugs

Prescription drugs, caffeine, and other medications can pass through both the human body and sewage treatment facilities, and are now present in many waterways. Some of these may be toxic to aquatic life. Others, especially steroids, estrogen, testosterone and similar regulatory hormones, are likely to interfere with the development of organisms.

Heavy Metals

When hunters shoot animals with lead shot, but do not recover the dead or injured animals, the shot is eventually ingested by other wildlife. The lead is concentrated as it passes up the food chain, and the top predators, especially raptors, get lead poisoning. Many states now require the use of steel shot.

Mining wastes also release toxic levels of substances like lead and mercury into waterways.

Water Acidification

Acid rain and snow is produced from the burning of high-sulfur coals in electrical power plants. Acid mine run-off is caused by the reaction of rainwater with mine tailings. Acidification can sterilize water bodies, killing off all aquatic flora and fauna. When wildfowl and other wildlife ingest this water, they can be poisoned by heavy metals.

Dioxin

Dioxin is generated by burning wastes and in the production of some papers and plastics. It accumulates in animal fats and concentrates up the food chain, and has been linked to cancers and reproductive issues in a number of species.

Oil Spills

Oil spills have immediate devastating effects – marine mammals and waterfowl coated with oil drown, are poisoned, or die of hypothermia. Balls of oil that sink to the seafloor can smother organisms. Less obvious effects include tumors and reproductive damage in fishes and crustaceans caused by oil byproducts.

Noise Pollution

Chronic noise pollution from low-flying aircraft, snowmobiles, motorcycles, and traffic can cause wildlife to abandon habitats, lose reproductive function, and become more vulnerable to predation due to loss of hearing.

Light Pollution

Light pollution at night disorients bats, insects, and migratory birds.

Eutrophication

Eutrophication results from the addition of enriching agents – detergents, fertilizers, and organic wastes – to water bodies. Explosive growth and subsequent decay of algae use up available oxygen, which in turn suffocates aquatic animals and plants. The change in water chemistry can also drive out native species.

Sedimentation

Sediments eroded during construction or agricultural practices are washed into waterways, damaging fish spawning grounds and smothering bottom dwelling organisms.

16.1.8 Summary

Studies of the effects of pollution on wildlife are of more than academic interest. Like the proverbial canary in the coal mine, disease and damage in the natural world is often a harbinger of similar danger to ourselves.

Chapter 17

SOLID WASTE¹

17.1 SOLID WASTE

17.1.1 INTRODUCTION

In natural systems, there is no such thing as waste. Everything flows in a natural cycle of use and reuse. Living organisms consume materials and eventually return them to the environment, usually in a different form, for reuse. **Solid waste** (or trash) is a human concept. It refers to a variety of discarded materials, not liquid or gas, that are deemed useless or worthless. However, what is worthless to one person may be of value to someone else, and solid wastes can be considered to be misplaced resources. Learning effective ways to reduce the amount of wastes produced and to recycle valuable resources contained in the wastes is important if humans wish to maintain a livable and sustainable environment.

Solid waste disposal has been an issue facing humans since they began living together in large, permanent settlements. With the migration of people to urban settings, the volume of solid waste in concentrated areas greatly increased.

Ancient cultures dealt with waste disposal in various ways: they dumped it outside their settlements, incorporated some of it into flooring and building materials, and recycled some of it. Dumping and/or burning solid waste has been a standard practice over the centuries. Most communities in the United States dumped or burned their trash until the 1960s, when the Solid Waste Disposal Act of 1965 (part of the Clean Air Act) required environmentally sound disposal of waste materials.

17.1.2 SOURCES AND TYPES OF SOLID WASTE

There are two basic sources of solid wastes: non-municipal and municipal. **Non-municipal solid waste** is the discarded solid material from industry, agriculture, mining, and oil and gas production. It makes up almost 99 percent of all the waste in the United States. Some common items that are classified as non-municipal waste are: construction materials (roofing shingles, electrical fixtures, bricks); waste-water sludge; incinerator residues; ash; scrubber sludge; oil/gas/mining waste; railroad ties, and pesticide containers.

Municipal solid waste is made up of discarded solid materials from residences, businesses, and city buildings. It makes up a small percentage of waste in the United States, only a little more than one percent of the total. Municipal solid waste consists of materials from plastics to food scraps. The most common waste product is paper (about 40 percent of the total).

Other common components are: yard waste (green waste), plastics, metals, wood, glass and food waste. The composition of the municipal wastes can vary from region to region and from season to season. Food waste, which includes animal and vegetable wastes resulting from the preparation and consumption of food, is commonly known as garbage.

¹This content is available online at <<http://cnx.org/content/m16734/1.1/>>.

Some solid wastes are detrimental to the health and well-being of humans. These materials are classified as hazardous wastes. Hazardous wastes are defined as materials which are toxic, **carcinogenic** (cause cancer), **mutagenic** (cause DNA mutations), **teratogenic** (cause birth defects), highly flammable, corrosive or explosive. Although hazardous wastes in the United States are supposedly regulated, some obviously hazardous solid wastes are excluded from strict regulation; these include: mining, hazardous household and small business wastes.

17.1.3 WASTE DISPOSAL METHODS

Most solid waste is either sent to **landfills** (dumped) or to **incinerators** (burned). Ocean dumping has also been a popular way for coastal communities to dispose of their solid wastes. In this method, large barges carry waste out to sea and dump it into the ocean. That practice is now banned in the United States due to pollution problems it created. Most municipal and non-municipal waste (about 60%) is sent to landfills. Landfills are popular because they are relatively easy to operate and can handle a lot of waste material. There are two types of landfills: sanitary landfills and secure landfills.

In a **sanitary landfill** solid wastes are spread out and compacted in a hole, canyon area or a giant mound. Modern sanitary landfills are lined with layers of clay, sand and plastic. Each day after garbage is dumped in the landfill, it is covered with clay or plastic to prevent redistribution by animals or the wind.

Rainwater that percolates through a sanitary landfill is collected in the bottom liner. This liquid leachate may contain toxic chemicals such as dioxin, mercury, and pesticides. Therefore, it is removed to prevent contamination of local aquifers. The groundwater near the landfill is closely monitored for signs of contamination from the leachate.

As the buried wastes are decomposed by bacteria, gases such as methane and carbon dioxide are produced. Because methane gas is very flammable, it is usually collected with other gases by a system of pipes, separated and then either burned off or used as a source of energy (e.g., home heating and cooking, generating electricity). Other gases such as ammonia and hydrogen sulfide may also be released by the landfill, contributing to air pollution. These gases are also monitored and, if necessary, collected for disposal. Finally, when the landfill reaches its capacity, it is sealed with more layers of clay and sand. Gas and water monitoring activities, though, must continue past the useful life of the landfill.

Secure landfills are designed to handle hazardous wastes. They are basically the same design as sanitary landfills, but they have thicker plastic and clay liners. Also, wastes are segregated and stored according to type, typically in barrels, which prevents the mixing of incompatible wastes. Some hazardous waste in the United States is sent to foreign countries for disposal. Developing countries are willing to accept this waste to raise needed monies. Recent treaties by the U.N. Environment Programme have addressed the international transport of such hazardous wastes.

Federal regulation mandates that landfills cannot be located near faults, floodplains, wetlands or other bodies of water. In many areas, finding landfill space is not a problem, but in some heavily populated areas it is difficult to find suitable sites. There are, of course, other problems associated with landfills. The liners may eventually leak and contaminate groundwater with toxic leachate. Landfills also produce polluting gases, and landfill vehicle traffic can be a source of noise and particulate pollutants for any nearby community.

About 15 percent of the municipal solid waste in the United States is incinerated. **Incineration** is the burning of solid wastes at high temperatures ($>1000^{\circ}\text{C}$). Though particulate matter, such as ash, remains after the incineration, the sheer volume of the waste is reduced by about 85 percent. Ash is much more compact than unburned solid waste. In addition to the volume reduction of the waste, the heat from the trash that is incinerated in large-scale facilities can be used to produce electric power. This process is called waste-to-energy. There are two kinds of waste-to-energy systems: mass burn incinerators and refuse-derived incinerators.

In **mass burn incinerators** all of the solid waste is incinerated. The heat from the incineration process is used to produce steam. This steam is used to drive electric power generators. Acid gases from the burning are removed by chemical scrubbers.

Any particulates in the combustion gases are removed by electrostatic precipitators. The cleaned gases are then released into the atmosphere through a tall stack. The ashes from the combustion are sent to a

landfill for disposal.

It is best if only combustible items (paper, wood products, and plastics) are burned. In a **refuse-derived incinerator**, non-combustible materials are separated from the waste. Items such as glass and metals may be recycled. The combustible wastes are then formed into fuel pellets which can be burned in standard steam boilers. This system has the advantage of removing potentially harmful materials from waste before it is burned. It also provides for some recycling of materials.

As with any combustion process, the main environmental concern is air quality. Incineration releases various air pollutants (particulates, sulfur dioxide, nitrogen oxides, and methane) into the atmosphere. Heavy metals (e.g., lead, mercury) and other chemical toxins (e.g., dioxins) can also be released. Many communities do not want incinerators within their city limits. Incinerators are also costly to build and to maintain when compared to landfills.

Chapter 18

IMPACT ON HUMAN HEALTH¹

18.1 IMPACT ON HUMAN HEALTH

18.1.1 INTRODUCTION

When environmental conditions are degraded such that the range of tolerance is exceeded, there will be a significant impact on human health. Our industrialized society dumps huge amounts of pollutants and toxic wastes into the earth's biosphere without fully considering the consequences. Such actions seriously degrade the health of the earth's ecosystems, and this degradation ultimately affects the health and well-being of human populations.

18.1.2 AGENTS

For most of human history, **biological agents** were the most significant factor in health. These included pathogenic (disease causing) organisms such as bacteria, viruses, protozoa, and internal parasites. In modern times, cardiovascular diseases, cancer, and accidents are the leading killers in most parts of the world. However, infectious diseases still cause about 22 million deaths a year, mostly in undeveloped countries. These diseases include: tuberculosis, malaria, pneumonia, influenza, whooping cough, dysentery and Acquired Immune Deficiency Syndrome (AIDS). Most of those affected are children. Malnutrition, unclean water, poor sanitary conditions and lack of proper medical care all play roles in these deaths.

Compounding the problems of infectious diseases are factors such as drug-resistant pathogens, insecticide-resistant carriers and overpopulation. Overuse of antibiotics have allowed pathogens to develop a resistance to drugs. For example, tuberculosis (TB) was nearly eliminated in most parts of the world, but drug-resistant strains have now reversed that trend. Another example is malaria. The insecticide DDT was widely used to control malaria-carrying mosquito populations in tropical regions. However, after many years the mosquitoes developed a natural resistance to DDT and again spread the disease widely. Anti-malarial medicines were also over prescribed, which allowed the malaria pathogen to become drug-resistant.

In our industrialized society, **chemical agents** also have significant effects on human health. Toxic heavy metals, dioxins, pesticides, and endocrine disrupters are examples of these chemical agents. Heavy metals (e.g., mercury, lead, cadmium, bismuth, selenium, chromium, thallium) are typically produced as by-products of mining and manufacturing processes. All of them biomagnify (i.e., they become more concentrated in species with increasing food chain level). Mercury from polluted water can accumulate in swordfish to levels toxic to humans. When toxic **heavy metals** get into the body, they accumulate in tissues and may eventually cause sickness or death. Studies show that people with above-average lead levels in their bones have an increased risk of developing attention deficit disorder and aggressive behavior. Lead can also damage brain cells and affect muscular coordination.

¹This content is available online at <<http://cnx.org/content/m16736/1.1/>>.

Dioxins are organic compounds, usually produced as a byproduct of herbicide production. They are stable compounds and can accumulate in the environment. Dioxins also biomagnify through the food chain and can cause birth defects and death in wildlife. Although dioxin is known to be extremely toxic to mammals, its low-level effects on the human body are not well known. The infamous Agent Orange used as a defoliant during the Vietnam war contained a dioxin component. Many veterans from that war suffer from a variety of medical problems attributed to Agent Orange exposure.

Pesticides are used throughout the world to increase crop yields and as a deterrent to insect-borne diseases. The pesticide DDT was widely used for decades. It was seen as an ideal pesticide because it is inexpensive and breaks down slowly in the environment. Unfortunately, the latter characteristic allows it to biomagnify through the food chain. Populations of bird species at the top of the food chain, e.g., eagles and pelicans, are greatly affected by DDT in the environment. When these birds have sufficient levels of DDT, the shells of their eggs are so thin that they break, making reproduction impossible. After DDT was banned in the United States in 1972, affected bird populations made noticeable recoveries.

According to the World Health Organization, more than three million people are poisoned by pesticides each year, mostly in undeveloped countries, and about 220,000 of them die. Long-term exposure to pesticides by farm workers and workers in pesticide factories seems to be positively correlated with an increased risk of developing various cancers.

Heavy metals, dioxins and pesticides may all be **endocrine disrupters**. Endocrine disrupters interfere with the functions of hormones in the human body, especially those controlling growth and reproduction. They do this by mimicking certain hormones and sending false messages to the body. Because they are active even in low concentrations, endocrine disrupters may cause problems in relatively low doses. Some of the effects include low sperm count and sterility in males. Since 1940, sperm counts have dropped 50 percent in human males, possibly the result of exposure to endocrine disrupters.

18.1.3 EFFECTS

An **acute effect** of a substance is one that occurs rapidly after exposure to a large amount of that substance. A **chronic effect** of a substance results from exposure to small amounts of a substance over a long period of time. In such a case, the effect may not be immediately obvious. Chronic effects are difficult to measure, as the effects may not be seen for years. Long-term exposure to cigarette smoking, low level radiation exposure, and moderate alcohol use are all thought to produce chronic effects.

For centuries, scientists have known that just about any substance is toxic in sufficient quantities. For example, small amounts of selenium are required by living organisms for proper functioning, but large amounts may cause cancer. The effect of a certain chemical on an individual depends on the dose (amount) of the chemical. This relationship is often illustrated by a dose-response curve which shows the relationship between dose and the response of the individual.

Lethal doses in humans have been determined for many substances from information gathered from records of homicides and accidental poisonings. Much of the dose-response information also comes from animal testing. Mice, rats, monkeys, hamsters, pigeons, and guinea pigs are commonly used for dose-response testing. A population of laboratory animals is exposed to measured doses under controlled conditions and the effects noted and analyzed. Animal testing poses numerous problems, however. For instance, the tests may be painful to animals, and unrelated species can react differently to the same toxin. In addition, the many differences between test animals and humans makes extrapolating test results to humans very difficult.

A dose that is lethal to 50 percent of a population of test animals is called the lethal dose-50 percent or LD-50. Determination of the LD-50 is required for new synthetic chemicals in order to give a measure of their toxicity. A dose that causes 50 percent of a population to exhibit any significant response (e.g., hair loss, stunted development) is referred to as the effective dose-50 percent or ED-50.

Some toxins have a threshold amount below which there is no apparent effect on the exposed population. Some scientists believe that all toxins should be kept at a zero-level threshold because their effects at low levels are not well known. That is because of the synergy effect in which one substance exacerbates the effects of another. For example, if cigarette smoking increases lung cancer rates 20 times and occupational

asbestos exposure also increases lung cancer rates 20 times, then smoking and working in an asbestos plant may increase lung cancer rates up to 400 times.

18.1.4 RELATIVE RISKS

Risk assessment helps us estimate the probability that an undesirable event will occur. This enables us to set priorities and manage risks in an effective way. The four steps of risk assessment are:

1. Identification of the hazard.
2. Dose-response assessment. Find the relationship between the dose of a substance and the seriousness of its effect on a population.
3. Exposure assessment. Estimate the amount of exposure humans have to a particular substance.
4. Risk characterization. Combine data from the dose-response assessment and the exposure assessment.

Risk management of a substance evaluates its risk assessment in conjunction with relevant political, social, and economic considerations in order to make regulatory decisions about the substance. In our society political, social, and economic considerations tend to count more than the risk assessment information. Signs of this are evident everywhere. People listen to loud music even though the levels are known to damage hearing. They smoke cigarettes that they know can cause cancer and heart disease.

People are often not logical in making choices. An example of this is a smoker who drinks bottled water because she is afraid tap water is unhealthy. Risk assessments have shown that a person is 1.8 million times more likely to get cancer from smoking than from drinking tap water. One possible explanation for this behavior is that people feel they can control their smoking if they choose to, but risks over which people have no control, such as public water supplies and nuclear wastes, tend to evoke more fearful responses. Because risk management deals with the unknown, it often is only loosely related to science.

Chapter 19

FIRST ORDER EFFECTS¹

19.1 FIRST ORDER EFFECTS

19.1.1 INTRODUCTION

The various components of earth's systems interact with one another through the flow of matter and energy. For example, mass (carbon dioxide and oxygen gases) is exchanged between the biosphere and atmosphere during plant photosynthesis. Gases move across the ocean-atmosphere interface. Bacteria in the soil decompose wastes, providing nutrients for plants and returning gases to the atmosphere. Furthermore, studies of Antarctic and Greenland ice cores show a correlation between abrupt climate changes and storm activities in the Atlantic and Pacific oceans during historical times. All of these processes are linked by natural cycles established over billions of years of the earth's history.

Humans have only been present for a tiny fraction of earth's history, and for much of that time their presence had little impact on the global environment. However, in recent history, the human population has grown and developed to the point where it is no longer a relatively passive presence in earth's systems. People have greatly increased their use of air, water, land and other natural resources during the last 200 years. Their industrial and agricultural activities have affected the atmosphere, the water cycle, and the climate. Each year large quantities of carbon dioxide and pollutants are added to the atmosphere and water systems due to fossil fuel burning and industrial processes. Ecological systems have been altered as well. The size of natural ecosystems has shrunk as people increase their use of the land. Plants and animals have been changed by human agricultural practices. Clearly humans are changing the global environment and climate. What is unclear is whether earth's systems can adjust to these changes.

19.1.2 ATMOSPHERE

The earth is much like a big greenhouse. Energy, in the form of sunlight, passes through its atmosphere, though the clouds, water and land reflect some of that energy back into space, some sunlight is absorbed, converted to heat and radiated back into the atmosphere as infrared radiation. Much of this infrared radiation is absorbed by atmospheric carbon dioxide and other gases rather than radiated into space. The process is similar to that of a greenhouse, with infrared-absorbing gases such as carbon dioxide and methane acting as panes of glass to trap the infrared heat. For this reason, these gases are known as **greenhouse gases**. The net result of this process is that the atmosphere is warmed.

For more than a century, scientists have pondered the possible effects that change in the amounts of greenhouse gases like carbon dioxide would have on the earth's climate. One notable theory that has arisen from this is that of the **greenhouse effect**. According to this theory, if the concentration of carbon dioxide in the atmosphere steadily increases, then the atmosphere will trap more and more heat. This could cause

¹This content is available online at <<http://cnx.org/content/m16738/1.1/>>.

the earth's mean surface temperature to rise over time. Concerns over possible climate effects led to efforts to monitor carbon dioxide levels. Monitoring began in the late 1950's, with monitoring stations being set up in Alaska, Antarctica and Hawaii.

The Mauna Loa, Hawaii, station has been operating since 1958. The data compiled there for more than 40 years show some interesting trends in the concentration of carbon dioxide in the atmosphere. Carbon dioxide concentration varies cyclically by season, with highs occurring during Fall and lows during the Spring. This follows the normal life cycle of plants during the year and their associated photosynthetic output. Superimposed over these seasonal variations is a long-term gradual increase in carbon dioxide concentration. What causes this long-term increase? Will the trend continue?

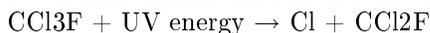
Humans consume large amounts of fossil fuels in order to drive their highly industrialized society. The burning of coal, oil and natural gas releases considerable quantities of carbon dioxide into the atmosphere. In a relatively short time, humans have released organic carbon into the atmosphere that took hundreds of millions of years to store in sedimentary rocks. Deforestation by humans – especially in tropical areas – is also a source of net carbon dioxide increase in the atmosphere. The burning of trees produces carbon dioxide directly, and the removal of the trees also results in less carbon dioxide being removed from the atmosphere by photosynthesis.

However, it is not clear as to the overall role of the terrestrial biosphere with regard to the carbon dioxide problem. Forests have regrown in some regions of the world (e.g., the northeastern United States). These added forests increase carbon dioxide removal from the atmosphere. Furthermore, some experiments suggest that rising carbon dioxide concentrations in the atmosphere may stimulate plant growth in general. If true, this would also lead to an increase in carbon sequestration by plant life. Models used to predict future levels of carbon dioxide in the atmosphere depend on an accurate knowledge of all relevant carbon sources and sinks. Questions still remain as to the size, location and magnitude of these. Therefore, considerable uncertainty remains as to whether the carbon dioxide concentration in the atmosphere will continue to increase, will instead decrease, or will become constant.

Carbon dioxide is not the only greenhouse gas that could significantly affect the global climate. Methane gas could also be a major player. It is released as a by-product of organic decomposition by microbial activity, especially from landfills. It is a pollutant resulting from the use of fossil fuels, and is even produced by cattle. The largest deposits of methane gas, however, may be the oceans and vast tundra wastelands. In cold water, for example, methane can form crystal structures somewhat similar to water ice known as **clathrates**. Clathrates are known to occur on the edges of the oceans' continental shelves. They also occur in the permafrost of tundra regions. When warmer temperatures occur, the clathrates destabilize, releasing the stored methane. The increase in the greenhouse effect that would result from the release of methane from clathrates on the continental shelves and in permafrost worldwide could equal that from the carbon dioxide produced from the burning of all the world's coal reserves.

The buildup of greenhouse gases is not the only atmospheric concern. The concentration of **chlorofluorocarbons** (CFC's) in the atmosphere has increased since they were first synthesized more than 70 years ago.

These compounds have been used as refrigerant gases, aerosol propellants, electronic component cleaners and for blowing bubbles in styrofoam. Most of their uses involve their eventual release into the atmosphere. Because they are chemically very inert and insoluble in water, they are also not easily removed from the atmosphere by normal processes such as rainfall. Therefore, the concentration of CFCs in the atmosphere increase with continued release. When CFCs eventually rise into the stratosphere, they can be broken down by UV radiation from the sun as follows:



The free chlorine that is produced can react with ozone, which is also present in the stratosphere. This has important consequences for living organisms on the surface of the earth.

Ozone in the stratosphere protects living organisms by absorbing most of the harmful UV radiation from the sun. This ozone is constantly produced and destroyed in a natural cycle. The basic reactions involving only oxygen (known as the **Chapman Reactions**) are as follows:

$O_2 + UV \rightarrow 2 O$
$O + O_2 \rightarrow O_3$ (ozone production)
$O_3 + UV \rightarrow O + O_2$ (ozone destruction)
$O + O_2 \rightarrow O_3$ (ozone production)
$O_3 + O \rightarrow O_2 + O_2$ (ozone destruction)

Table 19.1

During the 1960s, measurements of atmospheric ozone showed that it was being destroyed faster than could be accounted for by the natural cycle alone. It was determined that other, faster reactions were controlling the ozone concentrations in the stratosphere. Among the most important of these were those involving the Cl atoms produced from the breakdown of CFC's:

$Cl + O_3 \rightarrow ClO + O_2$
$ClO + O \rightarrow Cl + O_2$

Table 19.2

Because the normal fate of the O atom in the above reaction would be to form another ozone molecule, the net result of both reactions is the elimination of one ozone molecule and one would-be ozone molecule. Furthermore, at the end of the reaction the Cl atom is free to start the destructive cycle over again. By this catalytic chain reaction, one Cl atom can destroy about 100,000 ozone molecules before other processes remove it.

Ozone destruction caused by CFCs has resulted in the formation of "holes" in the stratospheric ozone layer over the polar regions, where the layer is thinnest. In 1987, the "Montreal Protocol" set forth a worldwide process to reduce and eventually to eliminate the use of CFC's.

It has apparently been successful, as current observations show that the increase in CFCs in the stratosphere is leveling off. Unfortunately, it will be many years before ozone levels will return to normal because of the long atmospheric lifetime (50 to 100 years) of the CFCs already present.

Curiously, although ozone in the stratosphere is beneficial to life on earth, ozone in the lower atmosphere (troposphere) can harm life by aggravating respiratory ailments in humans and damaging plants. Ozone in the troposphere is produced naturally by lightning. It is also a secondary pollutant produced by photochemical reactions involving primary pollutants such as nitrogen oxides. Smoggy cities such as Los Angeles suffer from considerable **ozone pollution**. Research studies have shown that biomass burning is also a major source of ozone pollution. Ozone is produced photochemically from precursor molecules released during the burning of forests and grasslands. Biomass burning is mainly concentrated in tropical regions. Indeed, satellite observations of South America and New Guinea show that tropospheric ozone is increasing in those areas where biomass burning is prevalent.

19.1.3 OCEANS

In order to understand the role the oceans may play in **global climate change** requires an understanding of the dynamics of ocean circulation changes. Global ocean circulation is controlled by **thermohaline circulation**. It is driven by differences in the density of seawater, which is determined by the temperature (thermo) and salinity (haline) of the seawater. In the Atlantic, thermohaline circulation transports warm and very saline water to the North. There, the water cools and sinks into the deep ocean. This newly formed deep water subsequently moves southward. Dense water also sinks near Antarctica. The cold, dense waters from the North Atlantic and Antarctica gradually warm and return to the surface, throughout the

world's oceans. The entire system moves like a giant conveyor belt. The movement is very slow (roughly 0.1 meters-per-second), but the flow is equivalent to that of 100 Amazon rivers.

This circulation system provides western Europe with comparatively warm sea surface temperatures along the coast and contributes to its mild winters. Ocean circulation models show that the thermohaline circulation is coupled to the carbon dioxide content of the atmosphere, and thus to the greenhouse effect. Increases in carbon dioxide in the atmosphere can lead to a slowing or a complete breakdown of the circulation system. One might expect temperatures over western Europe to decrease in such a scenario. However, any such change would be superimposed on warming from the enhanced greenhouse effect. Therefore, there may be little change in temperature over western Europe, and any cooling could be restricted to the ocean area away from land. The potential effects of such circulation changes on marine ecosystems are largely unknown, but would probably be significant. Furthermore, if circulation in the oceans is reduced, their ability to absorb carbon dioxide will also be reduced. This would make the effect of human-produced carbon dioxide emissions even more pronounced.

19.1.4 BIOTA

Biodiversity is an important part of any ecosystem. The earth's biodiversity is significantly affected by human activities. These activities often lead to biodiversity loss. This loss can result from a number of factors including: habitat destruction, introduction of exotics, and over-harvesting. Of these, habitat destruction is probably the most important. Humans destroy habitats for many reasons: agricultural expansion, urban expansion, road construction and reservoir construction. Larger regions than those directly destroyed are generally affected because of the resulting habitat fragmentation. Habitat fragmentation results in large populations being broken into smaller populations, which may be isolated from one another and may not be large enough to survive.

For example, the Aswan High Dam of Egypt was constructed because the desire to increase the supply of water for irrigation and power was considered paramount. The environmental side effects, however, have been enormous and include the spread of the disease **schistosomiasis** by snails that live in the irrigation channels; loss of land in the delta of the Nile River from erosion once the former sediment load of the river was no longer available for land building; and a variety of other consequences. The advisability agencies concerned with international development to seek the best environmental advice is now generally accepted, but implementation of this understanding has been slow.

When the rate of exploitation or utilization of a species exceeds its capacity to maintain a viable population, **over-harvesting** results. Living resources such as forests and wildlife are usually considered renewable resources. However, they can become non-renewable if over-harvested. Over-harvesting and habitat loss often occur together, because the removal of an organism from its environment can have a detrimental impact on the environment itself.

Humans have historically exploited plant and animal species to maximize short-term benefits, usually at the expense of being able to sustain the species in the long-term. A classic example of over-harvesting involves the passenger pigeon. It was once thought to be the most populous bird on earth, with numbers into the billions. Early settlers in North America hunted the bird for food. The hunting was so intense, that the bird disappeared from the wild by 1900 and was extinct by 1914. The American buffalo nearly suffered the same fate. Originally numbering in the tens of millions, fewer than 1000 were left by 1890. The species has, however, made a comeback in reserves and private ranches and is no longer considered threatened.

The fishing industry has a long history of over-harvesting its resources. The California sardine industry peaked in the 1930's. By the late 1950s, the sardines were gone as were the canneries in Monterey. The Peruvian anchovy fishery boomed in the 1960s and collapsed in the 1970s. Over-harvesting of fish has only increased over the years, as ships have become bigger and more "efficient" methods of harvesting fish (e.g. the purse-seine net,) have been developed. By the mid-1990s, over 40 percent of the species in American fisheries were over harvested.

Over-harvesting of tropical forests is currently a worldwide problem. More efficient methods for harvesting and transporting have made it profitable to remove trees from previously inaccessible areas. Mahogany trees are over harvested by loggers in the tropical forests of Brazil, Bolivia, Peru, Nicaragua and Guatemala.

Many other types of tropical trees once considered worthless are now valuable sources of pulp, chipboard, fiberboard and cellulose for plastics production. Developing nations are often willing to sign over timber rights to foreign companies for needed hard currency. Logging operations also act as a catalyst for tropical deforestation. Farmers use roads built by logging companies to reach remote areas, which are then cleared of forests and used for ranching and agriculture.

When a species is transplanted into an environment to which it is not native, it is known as an **introduced exotic**. Whenever man has settled far away from home, he has tried to introduce his familiar animals and plants. Long ago, European explorers released goats and pigs into their colonies to provide a supply of familiar animal protein. Many exotics are accidentally introduced. Often, the introduction of exotics has disastrous effects on the native flora and fauna. Their new habitat may have fewer predators or diseases that affect them, and as a result so their populations grow out of control. Organisms they prey upon may not have evolved defense mechanisms to them and native species may not be successful in competing with them for space or food.

Some of the most abundant wild animals and plants in the United States are introduced species. For example, starlings, eucalyptus trees and many types of grasses are introduced exotics. Most insect and plant pests are exotic species. The kudzu vine, a Japanese species introduced in 1876, to shade porches of southern mansions and widely planted in the 1940's to control erosion, grows so rapidly (up to one foot per day) that it kills forests by entirely covering trees and shrubs. The gypsy moth was brought from France in 1869 by an entomologist who hoped to interbreed them with silk moths. They escaped and established a colony that invaded all of the New England states, defoliating trees of many different kinds. Exotics are a factor contributing to the endangered or threatened status of many animals and plants in the U.S.

19.1.5 Dangers of Bird Migration

All creatures are threatened by habitat degradation and destruction. For migrating birds, the problem is vastly compounded. Birds travel thousands of miles between summer and winter homes, and environmental disruptions anywhere along the route or at either destination can be deadly. Indeed, massive declines in many bird populations have been documented over recent decades.

Many of the species common in the United States are **Neotropical** – they breed in North America in the summer, then over winter in Central or South America. These songbirds, waterfowl, raptors, and shorebirds, who follow the same migration routes their ancestors did, face many hazards along the way. Night-time lighting (light pollution) can disorient them. Collisions with airplanes, wires, and buildings can kill and injure them.

Once the birds arrive at their destination, or when they stop in-route, they need food, water, and a place to rest. But urban sprawl is encroaching on bird habitat, and food and water supplies are contaminated by pollution.

Recently, a new problem has arisen. For migrating birds, timing is everything – they must arrive at their summer breeding grounds when food supplies are at their peak, so that they can rebuild their body fat and reproduce successfully. Global warming is beginning to upset the delicate balance between the lifecycles of plants and insects and birds. In some areas, birds are showing up early, before flowers open or insects hatch, and finding very little to eat.

Fortunately, many people value birds and several conservation efforts are underway, including:

- Creation of protective shelter belts and hedgerows around fields and community open space
- Easements to provide native habitat for birds in human activity areas
- Timing of insecticide applications to avoid loss of the food base during bird movement in the spring and fall
- Preservation of the quality and quantity of community wetlands
- Minimization of practices that negatively impact birds

In addition, many seek to coordinate activities along the migratory flyways to increase the success of the migrating birds. Although humans are working to create natural reserves, the problem of human impact on migratory birds still needs to be addressed to a significant degree.

Chapter 20

HIGHER ORDER INTERACTIONS¹

20.1 HIGHER ORDER INTERACTIONS

20.1.1 INTRODUCTION

Although humans have had the capability to monitor earth's systems effectively only relatively recently, previous global environmental events have not gone unrecorded. Climate indicators exist in various forms (e.g., pollen in lake-bottom sediments, patterns in tree-rings, air bubbles frozen in glacial ice and growth rings in coral). These indicators show that significant environmental changes have occurred throughout earth's history. These changes occurred slowly, over relatively long periods of time. However, human activities are altering earth's systems at an accelerated pace. Large-scale pollution, increased natural resource consumption and the destruction of plant and animal species and their habitats by humans are causing significant changes of global proportions.

Human-caused global changes include: depletion of stratospheric ozone, increased carbon dioxide concentration in the atmosphere and habitat destruction. The consequences of these changes include: global warming, increased levels of solar UV radiation, increased sea levels and loss of biodiversity. The ramifications of these phenomena are far-reaching and potentially devastating to all life on earth, including humans. Awareness of this has prompted an international effort to increase scientific understanding of global changes and their effects. Most scientists agree on certain points:

- Greenhouse gases absorb and then emit infrared radiation.
- Atmospheric concentrations of carbon dioxide, methane and chlorofluorocarbons (CFCs) have increased significantly above pre-industrial levels, and the increase is directly attributable to human activities.
- Increased concentrations of greenhouse gases produce a net heating effect on the earth.
- Globally, average surface air temperatures are about 0.5 °C higher than those in the 19th century.
- Many centuries will pass before carbon dioxide concentrations will return to normal levels, even if all human-caused emissions are stopped entirely.
- The return of CFC concentrations to their pre-industrial levels will take more than a century, even with a halt in human-caused emissions.

While a general consensus has been reached on the above points, no such consensus has been reached on the extent to which these changes are affecting the global environment and what course they will follow in the future. The scientific community can only infer what will happen from predictive models based upon their knowledge of relevant environmental processes. This knowledge is often limited because the processes involved and their relationships are exceedingly complex. Moreover, the distinct possibility exists that not all processes are even known.

¹This content is available online at <<http://cnx.org/content/m16740/1.1/>>.

20.1.2 ATMOSPHERE

The atmosphere surrounding the earth is both a part and a product of life. Humans have significantly affected the atmosphere. For example, huge amounts of carbon dioxide and methane, among other compounds, are added annually to the atmosphere due to anthropogenic uses of fossil fuels. For many years, CFC's were indiscriminately released into the atmosphere. The addition of these chemical pollutants to the atmosphere raises concerns about how the changes in the atmosphere may affect life on earth.

The most immediate effect of increased amounts of greenhouse gases in the atmosphere is **global warming**. The global mean surface temperature is expected to rise 1 to 3°C by the middle of the 21st century. The extent of the warming will depend in part upon atmospheric water vapor levels and cloud cover feedback processes. Heating of the atmosphere can impact the global climate in several ways.

The rate of water evaporation will increase as the environment warms, and this will lead to increases in the global mean precipitation. A warmer, wetter atmosphere may subsequently cause an increase in the frequency of tropical storms, which can cause flooding. In addition to deaths from famine and drowning, floods can bring with them cholera and diseases spread by mosquitoes, such as malaria and yellow fever. Atmospheric heating could also cause severe heat waves, and projections indicate that heat-related deaths may double by 2020.

High-altitude cooling, caused by the combination of reduced stratospheric ozone concentrations and increased carbon dioxide concentrations, may lower the upper-stratospheric temperatures by as much as 8 to 20°C. This cooling could change the atmosphere's circulation patterns. In addition, scientists believe that stratospheric **ozone depletion** could have a serious negative impact on the health of humans, plants and animals. This is due to the concomitant **increase in UV radiation**, particularly UV-B, that reaches the surface of the earth when stratospheric ozone levels decrease.

Humans DNA is susceptible to damage by UV-B radiation, and exposure can cause skin cancer. Studies indicate that a 10 percent reduction in stratospheric ozone could give rise to an additional 20,000 skin cancer cases each year. Other consequences to humans include suppression of the human immune system and increases in the occurrence of eye cataracts. Plants respond adversely to exposure to UV-B radiation, with reduced leaf area, reduced shoot length and decreases in the rate of photosynthesis. Such responses could significantly decrease the yields of agricultural crops. UV-B radiation can kill plankton in the ocean, which in turn could severely impact marine food chains. Increased exposure to UV-B radiation also appears to kill developing embryos in the eggs of some reptiles and amphibians.

20.1.3 OCEAN

Even a moderate increase in global temperature can melt significant amounts of snow and ice, shrinking glaciers and the polar ice caps. This affects sea levels. Inasmuch as 50 percent of the world's human population lives within 50 kilometers of the sea, the effects of even a moderate rise in sea levels – on the order of a meter or less – would be significant. Research suggests that **rising sea levels** will flood some coastal wetlands and communities, and will amplify the impacts of storm surges, in which sea levels rise because of severe storm winds. Increased precipitation in high northern latitudes may reduce the salinity and density of the ocean waters there, which in turn will influence global ocean (thermohaline) circulation.

Coral reefs are directly affected by the amount of carbon dioxide in the atmosphere, global temperature change and increased UV radiation. An increase in atmospheric carbon dioxide leads to a decrease of carbonate ion in the seawater. This decrease can cause a reduction in the rate of coral reef formation, or, in extreme cases, could cause coral reefs to dissolve. A phenomenon known as **coral bleaching**, which can be fatal to a coral colony, is caused by unusually high or low temperatures, high or low salinity or high amounts of UV radiation. The first two of these are linked to global warming and the last could result from stratospheric ozone depletion.

Scientists at the National Center for Atmospheric Research have reported that global warming may accentuate the effects of El Niño events. The name **El Niño** refers to the warm phase of a large oscillation, known as the **El Niño/Southern Oscillation (ENSO)**, in which the surface temperature of the central/eastern part of the tropical Pacific warms. This is accompanied by changes in winds and rainfall

patterns. Abnormally dry conditions occur over northern Australia, Indonesia and the Philippines. Drier than normal conditions are also found in southeastern Africa and northern Brazil.

Wetter than normal conditions are observed along the west coast of tropical South America, the North American Gulf Coast and southern Brazil. The warm El Niño phase typically lasts for eight to 10 months. The entire ENSO cycle usually lasts about three to seven years. Over the past century, El Niño events have become more frequent and have caused greater climate changes paralleling the rise in global temperature.

20.1.4 BIOTA

The variety of life on earth is its **biodiversity**. The number of species of plants, animals, microorganisms, the enormous diversity of genes in these species, the different ecosystems on the planet – such as deserts, rainforests and coral reefs – are all part of a biologically diverse earth. There is a link between biodiversity and climate change. Rapid global warming can affect an ecosystem's chances to adapt naturally in several ways. A species may be incapable of migrating far enough to reach a hospitable climate when faced with significant global warming. Existing habitat may be lost during progressive shifts of climatic conditions. Species diversity may be reduced as a result of reductions in habitat size. The fate of many species in a rapidly warming world will likely depend on their ability to migrate from increasingly less favorable climatic conditions to new areas that meet their physical, biological and climatic needs.

Human activity plays a major role in the loss of biodiversity. Forests and wetlands are converted to agricultural and urban land use. Logging has cleared most of the virgin forests of the contiguous 48 states. The biologically diverse tropical forests are currently being rapidly destroyed as the land is converted to farming or cleared by logging and mining operations. On agricultural land, large fields of monoculture crops replace the diverse plant life that once was there. The United States has lost nearly all of the original tall-grass prairie that once covered the Great Plains. Hunting has driven species such as wolves and grizzly bears that were once widespread over the western United States to a few isolated reserves. Large land mammals such as rhinoceri and elephants have had their ranges greatly diminished in Asia and Africa by habitat destruction. Selective breeding by farmers has reduced the genetic diversity of livestock animals. Introduced exotic species have driven out native plants and animals.

One of the biggest side effects of the loss of biodiversity is the premature extinction of species. Small changes in the competitive ability of a species in one part of a food web may lead to extinctions in other parts, as changes in population density are magnified by predator-prey or host-parasite interactions. Human activities such as habitat destruction, introduction of exotics and over-harvesting are also causing large numbers of premature extinctions. It is estimated that about one-third of the plant species in the United States are threatened by extinction. Countless unknown species of plants and animals are lost every year because of the destruction of tropical forests. Plants that might hold the ingredients for new medicines are instead lost forever.

High biodiversity contributes to the stability of an ecosystem. Each species, no matter how small, plays an important role. Diversity enables ecosystems to avoid and recover from a variety of disasters. Almost all cultures have in some way recognized the importance that Nature and its biological diversity have upon them.

Chapter 21

ECONOMIC FORCES¹

21.1 ECONOMIC FORCES

21.1.1 INTRODUCTION

Economics is the process by which humans manage their environment and its resources. The process is made up of a system of production, distribution and consumption of goods and services. **Natural resources** provide the raw materials and energy for producing economic goods, while **human resources** provide the necessary skill and labor to carry out the process. Different societies manage their economies in different ways. In a traditional economy, people are self-sufficient (i.e., they produce their own goods), but in a **pure command economy** the government controls all steps in the economic process.

Capitalist countries such as the United States have a system that is largely based on a **pure market economy**. Buyers and sellers make economic decisions based on the **Principle of Supply and Demand**. Sellers supply goods and buyers create demand for goods. These two roles are often in conflict: buyers want to buy goods at low prices and sellers want to sell goods at high prices. However, the two sides eventually compromise on a price at which buyers can find sellers willing to sell and sellers can find buyers willing to buy. This is known as the **market equilibrium price**. The equilibrium price can be considered as the intersection of the supply and demand curves.

Most countries strive to increase their capacities to produce goods and services and consider doing so as a positive sign of development. Economic growth is stimulated by population growth, which in turn increases the consumption of natural resources and increases the per capita consumption of goods and services. Various indicators are used to measure economic growth. One of them is the **Gross National Product (GNP)**, which represents the total market value of final goods and services produced by a country during a given period (usually one year). Unfortunately, GNP does not take into account the global nature of many companies. If a company produces goods in a foreign country, then the "home" country does not really benefit from that production. Thus, if Pepsi bottles and sells soda in Japan, those revenues should not be included in the GNP of the United States. The **GDP (Gross Domestic Product)** provides a better indicator of the health of a country's economy. This measure refers to the value of the goods and services produced within the boundaries of an economy during a given period of time.

Both the GNP and Gross Domestic Product (GDP) are economic measures and indicate nothing about social or environmental conditions within a country. They are not measures of the quality of life. In fact, severe environmental problems can actually raise the GNP and GDP, because the funds used to clean up environmental messes (such as hazardous waste sites) help to create new jobs and increase the consumption of natural resources. The **United Nations Human Development Index** is an estimate of the quality of life in a country based on three indicators: life expectancy, literacy rate and per capita GNP.

¹This content is available online at <<http://cnx.org/content/m16741/1.1/>>.

21.1.2 EXTERNAL COSTS

Economic activity generally affects the environment, usually negatively. Natural resources are used, and large amounts of waste are produced. These side effects can be seen as ways in which the actions of a producer impact the well being of a bystander. The market fails to allocate adequate resources to address such external costs because it is only concerned with buyers and sellers, not with the well being of the environment. Only direct (or internal) costs are considered relevant. External costs are harmful social or environmental effects caused by the production or consumption of economic goods. Governments may take action to help alleviate the effects of economic activity.

When external costs occur, a company's private production cost and the social cost of production are at odds. The firm does not consider the cost of pollution cleanup to be relevant, while society does. The social costs of production include the negative effects of pollution and the cost of treatment. As a result, the social costs end up exceeding the private production costs. When external pollution and treatment costs are included in the production cost of the product, the supply curve intersects the demand curve at a higher price point. As a result of the higher price there will be less demand for the product and less pollution produced.

For example, exhaust pollutants from automobiles adversely affect the health and welfare of the human population. However, oil companies consider their cost of producing gasoline to include only their exploration and production costs. Therefore, any measures to reduce exhaust pollutants represent an external cost. The government tries to help reduce the problem of exhaust pollutants by setting emissions and fuel-efficiency standards for automobiles. It also collects a gasoline tax that increases the final price of gasoline, which may encourage people to drive less.

Sometimes, pollution results from the production process because no property rights are involved. For example, if a paper manufacturer dumps waste in a privately owned pond, the landowner generally takes legal action against the paper firm, claiming compensation for a specific loss in property value caused by the industrial pollution. In contrast, the air and most waterways are not owned by individuals or businesses, but instead are considered to be public goods. Because no property rights are involved the generation of pollution does not affect supply and demand.

Firms have an incentive to use public goods in the production process because doing so does not cost anything. If the paper manufacturer can minimize production costs by dumping wastes for free into the local river then it will do so. The consequences of this pollution include adverse impacts on the fish and animal populations that depend on the water, degradation of the surrounding environment, decrease in the quality of water used in recreation and business, human health problems and the need for extensive treatment of drinking water by downstream communities. An important role of the government is to protect public goods, especially those with multiple uses, from pollution by companies seeking to minimize company costs and to maximize profits. People desire clean water for recreation and drinking, and the government must act to protect the broad interests of society from the narrow profit-driven focus of companies.

One way to "internalize" some of the external costs of pollution is for the government to tax pollution. A pollution tax would require that polluting firms pay a tax based on the air, water and land pollution that they generate. This tax would raise the private production cost of a company to include to the social cost of production. In addition, the generated tax revenues could be used by the government to help mitigate the effects of pollution. The main drawback of such a tax is that it would discourage economic activity by increasing costs to the companies. For example, a tax on coal and oil would increase the cost of electricity and gasoline. Taxed companies would be forced to scale back production in response to these higher costs, and investments and employment would suffer. The trick is to set the tax at a level at which economic loss does not exceed the environmental benefits realized.

Tradable Pollution Permits (TPPs) are an alternative to pollution taxes. In 1994, the United States government inaugurated a program to reduce sulfur dioxide emissions by requiring that companies have a permit for each ton of sulfur dioxide they emit. Companies were allocated TPPs based on their historical level of sulfur dioxide emissions. The program allows TPPs to be bought and sold among the companies. Therefore, a company can invest in scrubbers or use more expensive low sulfur coal to reduce its sulfur dioxide emissions and then sell its excess permits, offsetting part of the cost of reducing the pollution.

21.1.3 COST-BENEFIT ANALYSES

Ideally, one would like to live in a perfect world with zero pollution. Unfortunately, this is not possible with current technology. People drive cars and trucks, and most of these vehicles have internal combustion engines, which emit pollutants. Unless gasoline or diesel powered vehicles are completely banned, that pollution will persist. However, a few electric vehicles are starting to appear on the road, although they are impractical for long distance use or heavy hauling. Obviously, most people are not going to give up their internal combustion engine vehicles in the near future. People generally accept that some pollution is a result of living in a modern society. The critical issue, then, is how much pollution control is economically practical. A cost-benefit analysis provides an estimate of the most economically efficient level of pollution reduction that is practical.

A **cost-benefit analysis** looks at the social benefits (e.g., health and environmental benefits) that can be derived from pollution reduction versus the cost of achieving that reduction. As the pollution reduction increases, so does the money required to reduce pollution further. It may not be very expensive to clean up the bulk of most pollutants. However, as the reduction in pollutants approaches 100 percent (i.e., zero emissions), the marginal cost of each additional unit of pollution reduction rises dramatically. If public funds are used for pollution control, there is a limit to how much money can be spent before the budgets of other important public services (e.g., police, fire and parks departments) are negatively impacted. A balance must therefore be found between the social benefits of pollution reduction and the cost of pollution reduction. The proper balance between costs and benefits represents the optimum economic level of pollution reduction.

The optimum level is not static, but can change as circumstances change. As technology improves over time, the cost of pollution reduction may decrease. Likewise, as the hazards of pollution become better known, the perceived benefits to be derived from pollution reduction may also increase. In either case, the optimum level of pollution reduction will then increase and a greater level of pollution reduction will be considered economically feasible. The eco-efficiency program at the 3M Corporation is an example of how the optimum level of pollution reduction can be raised through better management and design of manufacturing processes. Over the time period 1990 to 2000, the company reduced its air pollution by 88 percent, water pollution by 82 percent and waste generation by 35 percent.

One problem with using cost-benefit analyses for determining the optimum level of pollution reduction is that it assumes all benefits can be labeled with a price tag. However, aesthetic benefits from pollution reduction cannot be priced, and yet they are just as important as others. The beauty of a clear-running stream and the quiet solitude of a wilderness area cannot be measured in dollars and cents.

Chapter 22

CULTURAL AND AESTHETIC CONSIDERATIONS¹

22.1 CULTURAL AND AESTHETIC CONSIDERATIONS

22.1.1 INTRODUCTION

The world's industrialized countries are undergoing many changes as they move to the later stages of the Industrial Revolution. Economies are becoming more information based, and capital is being measured not only in terms of tangible products and human workers, but also in terms of social and intellectual assets. For example, the makeup of the **Gross Domestic Product (GDP)** for the United States has gradually changed from being mainly manufactured goods to one with services predominating. Computer software and many other services, which are not easily categorized under the old economic system, now represent the largest sector of the United States' economy.

This change in economic thinking has brought about a deeper awareness of the natural processes and ecological assets found in nature. Society is slowly shifting to an industrial model that includes recycling. Such closed-loop production encompasses the principles of waste-reduction, re-manufacturing and re-use. Conventional industrial economics considered air, water and the earth's natural cycles to be "free" goods. However, such thought led to considerable external environmental and social costs. With the rise of environmentally responsible economics, there is a movement to change to full-cost pricing of goods, which includes the social and environmental costs of production.

Attempts have been made to overhaul economic indicators such as the GDP to take into account intangible assets and intellectual property. In 1994, the Clinton Administration attempted to integrate environmental factors into the GDP. The World Bank in 1995 redefined its Wealth Index. A nation's wealth now consists of 60 percent human capital (social and intellectual assets), 20 percent environmental capital (natural assets), and 20 percent built capital (tangible assets). These **green GDP** figures are intended to provide a better measure of the quality of life in a country than the traditional GDP, which looked only at tangible economic factors. However, such methods fail to take into account other areas that affect the quality of life in a country, such as human rights, health and education.

In attempts to develop a better measure of the quality of life of a region, separate sets of economic, environmental and social indicators have been devised. The reasoning of this is that it is better to consider several separate indicators, rather than try to create a single, catch-all index. This approach does not require the difficult, if not impossible, attempt to place monetary values on all factors. The Calvert-Henderson Group chose twelve separate quality of life indicators: education, employment, energy, environment, health, human rights, income, infrastructure, national security, public safety, recreation and shelter. Although separate, each indicator is related to the others, and all are based on readily available demographic data.

¹This content is available online at <<http://cnx.org/content/m16742/1.1/>>.

22.1.2 CATEGORIZING COUNTRIES

Countries are categorized by a variety of methods. During the Cold War period, the United States government categorized countries according to each government's ideology and capitalistic development. In this system, the "First World" included the capitalist countries; the "Second World" included the communist countries and the poorer countries were labeled as "Third World." With the end of the Cold War, this system has been discarded.

Current classification models utilize economic (and sometimes other) factors in their determination. One two-tiered classification system developed by the World Bank classifies countries as **developing** and **developed**. According to the World Bank classification, **developing countries** are those with low or middle levels of GNP per capita. More than 80 percent of the world's population lives in the more than 100 developing countries. A few countries, such as Israel, Kuwait and Singapore, are also classified as developing countries, despite their high per capita income. This is either because of the structure of their economies, or because their governments officially classify themselves as such. **Developed countries** are those that have a large stock of physical capital and in which most people have a high standard of living. Some economists consider middle-income countries as developed countries when they have transitional economies that are highly industrialized.

A three-tiered classification system was developed to categorize countries more precisely, especially those that are not easily classified as either developing or developed. These three categories are: **less developed country (LDC)**, **moderately developed country (MDC)** and **highly developed country (HDC)**. Criteria used to determine a country's category include: GNP per capita, transportation and communication facilities, energy consumption, literacy and unemployment.

A country categorized as an LDC has a marginal physical environment. Most African countries and many Asian countries are categorized as LDC. An LDC has the following characteristics: low energy production and consumption, mostly subsistence farming, a large percentage of the population is under 15, a high infant mortality rate, poorly developed trade and transportation inadequate medical facilities, a low literacy rate, a high unemployment rate and a very low per capita GNP.

Countries such as the United States, Japan, and most of the Western European countries are categorized as HDC. HDCs are characterized by: extensive trade, advanced internal communication systems, highly developed transportation networks, high energy production and consumption, advanced medical facilities, low population growth, political stability and a high per capita GNP. The MDCs have characteristics that fit into both the LDC and HDC categories, but have a moderate per capita GNP. Saudi Arabia, Brazil and Mexico are considered MDCs.

In a way, progress of less developed countries is determined somewhat, if not actively undermined, by the developed countries. Because developed countries are the more technologically advanced, they are able to maintain their advantage relative to less developed countries. One way they accomplish this is through "brain drain." With brain drain, the best educated people in less developed countries move to developed countries where they have better opportunities to improve their standard of living. Another way is for developed countries to exploit the natural and human resources of less developed countries. Developing countries generally desperately need the capital that developed countries can give them. Because environmental issues often take a backseat to economic issues, environmental disaster can follow.

An example of exploitation by a foreign corporation occurred in Bhopal, India. Because of the availability of cheap labor and lax environmental laws, it was economically advantageous to locate a Union Carbide chemical plant there. One day in 1984, a cloud of poisonous methyl isocyanate was accidentally released from the plant, killing most of the unprotected people in the adjacent areas. Houses near the plant were mostly of poor families and streets near the plant were populated with many homeless men, women and children. Several thousand people were killed in this disaster. Even after the settlement of lawsuits stemming from the accident, the injured and relatives of the dead received little compensation. Many of the homeless were completely ignored.

In its rush toward development, Bangladesh has established a program of intense use of land, forest, fisheries and water resources. This has led to severe environmental degradation: loss of soil fertility, excessive extraction of groundwater for irrigation, and increased air and water pollution. The lowering of water tables

throughout the land, in particular, has led to pollution of ground water by arsenic. As many as 40 million people in Bangladesh may be exposed to toxic levels of arsenic present in many of the nation's six million private and public wells. The country does not have the economic resources for adequate testing of wells to determine which are poisoned and which are safe. Because of this, millions may die of cancer or "arsenicosis."

Some idealistic people believe that a definition of a developed country must include factors such as conservation and quality of life and that a truly developed country would not exploit a large fraction of the world's resources. Accordingly, characteristics of such a developed country might include: economic prosperity of all people, regardless of gender or age, sustainable use of resources and more controlled use of technology to ensure a high quality of life for all people. An economically and technologically developed country such as the United States would not qualify as being a truly developed country by these criteria.

22.1.3 ENVIRONMENTAL JUSTICE

Whenever a community is faced with the potential of an environmentally undesirable facility, such as the placement of a hazardous waste dump in its midst, the usual response from residents is: "Not in my back yard!" Such a response is known as the NIMBY principle. Such reactions are usually reactions to visions of previous environmental irresponsibility: uncontrolled dumping of noxious industrial wastes and rusty steel drums oozing hazardous chemicals into the environment. Such occurrences were all too real in the past and some are still taking place. It is now possible – and much more common – to build environmentally sound, state-of-the-art disposal facilities. However, the NIMBY principle usually prevents the construction of such new facilities. Instead, hazardous waste facilities tend to be built upon pre-existing, already contaminated sites, even though the geology of such locations may be less favorable for containment than potential new sites.

During the 1980's minority groups protested that hazardous waste sites were preferentially sited in minority neighborhoods. In 1987, **Benjamin Chavis** of the United Church of Christ Commission for Racism and Justice coined the term environmental racism to describe such a practice. The charges generally failed to consider whether the facility or the demography of the area came first. Most hazardous waste sites are located on property that was used as disposal sites long before modern facilities and disposal methods were available. Areas around such sites are typically depressed economically, often as a result of past disposal activities. Persons with low incomes are often constrained to live in such undesirable, but affordable, areas. The problem more likely resulted from one of insensitivity rather than racism. Indeed, the ethnic makeup of potential disposal facilities was most likely not considered when the sites were chosen.

Decisions in citing hazardous waste facilities are generally made on the basis of economics, geological suitability and the political climate. For example, a site must have a soil type and geological profile that prevents hazardous materials from moving into local aquifers. The cost of land is also an important consideration. The high cost of buying land would make it economically unfeasible to build a hazardous waste site in Beverly Hills. Some communities have seen a hazardous waste facility as a way of improving their local economy and quality of life. Emelle County, Alabama had illiteracy and infant mortality rates that were among the highest in the nation. A landfill constructed there provided jobs and revenue that ultimately helped to reduce both figures.

In an ideal world, there would be no hazardous waste facilities, but we do not live in an ideal world. Unfortunately, we live in a world plagued by years of rampant pollution and hazardous waste dumping. Our industrialized society has necessarily produced wastes during the manufacture of products for our basic needs. Until technology can find a way to manage (or eliminate) hazardous waste, disposal facilities will be necessary to protect both humans and the environment. By the same token, this problem must be addressed. Industry and society must become more socially sensitive in the selection of future hazardous waste sites. All humans who help produce hazardous wastes must share the burden of dealing with those wastes, not just the poor and minorities.

22.1.4 INDIGENOUS PEOPLE

Since the end of the 15th century, most of the world's frontiers have been claimed and colonized by established nations. Invariably, these conquered frontiers were home to peoples indigenous to those regions. Some were wiped out or assimilated by the invaders, while others survived while trying to maintain their unique cultures and way of life. The United Nations officially classifies indigenous people as those "having an historical continuity with pre-invasion and pre-colonial societies," and "consider themselves distinct from other sectors of the societies now prevailing in those territories or parts of them." Furthermore, indigenous people are "determined to preserve, develop and transmit to future generations, their ancestral territories, and their ethnic identity, as the basis of their continued existence as peoples in accordance with their own cultural patterns, social institutions and legal systems." A few of the many groups of indigenous people around the world are: the many tribes of Native Americans (i.e., Navajo, Sioux) in the contiguous 48 states; the Eskimos of the arctic region from Siberia to Canada; the rainforest tribes in Brazil and the Ainu of northern Japan.

Many problems face indigenous people, including: lack of human rights, exploitation of their traditional lands and themselves, and degradation of their culture. In response to the problems faced by these people, the United Nations proclaimed an "International Decade of the World's Indigenous People" beginning in 1994. The main objective of this proclamation, according to the United Nations, is "the strengthening of international cooperation for the solution of problems faced by indigenous people in such areas as human rights, the environment, development, health, culture and education." Its major goal is to protect the rights of indigenous people. Such protection would enable them to retain their cultural identity, such as their language and social customs, while participating in the political, economic and social activities of the region in which they reside.

Despite the lofty U.N. goals, the rights and feelings of indigenous people are often ignored or minimized, even by supposedly culturally sensitive developed countries. In the United States many of those in the federal government are pushing to exploit oil resources in the Arctic National Wildlife Refuge on the northern coast of Alaska. The "Gwich'in," an indigenous people who rely culturally and spiritually on the herds of caribou that live in the region, claim that drilling in the region would devastate their way of life. Thousands of years of culture would be destroyed for a few months' supply of oil. Drilling efforts have been stymied in the past, but mostly out of concern for environmental factors and not necessarily the needs of the indigenous people. Curiously, another group of indigenous people, the "Inupiat Eskimo," favor oil drilling in the Arctic National Wildlife Refuge. Because they own considerable amounts of land adjacent to the refuge, they would potentially reap economic benefits from the development of the region.

In the Canadian region encompassing Labrador and northeastern Quebec, the Innu Nation has battled the Canadian Department of National Defense (DND) to prevent supersonic test flights over their hunting territory. The Innu Nation asserts that such flights are potentially harmful to Innu hunters and wildlife in the path of such flights. The nature of Innu hunting includes travelling over long distances and staying out on the land for long periods of time. The Innu Nation claims that low-level supersonic fly-overs generate shock waves, which can irreversibly damage the ears and lungs of anyone in the direct flight path. They also claim that the DND has made no serious efforts to warn the Innu people of the possible dangers.

In the rainforest regions of Brazil, indigenous peoples of several tribes are working together to strengthen their common concern over the impact of large development projects on their traditional lands. Such projects range from the construction of dams and hydroelectric power plants to the alteration of the natural courses of rivers to provide commercial waterways. The government of Brazil touts development of the Tocantins-Araguaia waterway as a means to facilitate river navigation in the eastern Amazon. It will promote agricultural development in Brazil's heartland and in the eastern Amazon by providing access to markets of grains, fuel and fertilizers. However, the waterway will negatively impact fifteen indigenous peoples who object that the changes in the natural rivers will cause the death of the fish and animals upon which they depend for survival.

The heart of most environmental conflicts faced by governments usually involves what constitutes proper and sustainable levels of development. For many indigenous peoples, sustainable development constitutes an integrated wholeness, where no single action is separate from others. They believe that sustainable development requires the maintenance and continuity of life, from generation to generation and that humans

are not isolated entities, but are part of larger communities, which include the seas, rivers, mountains, trees, fish, animals and ancestral spirits. These, along with the sun, moon and cosmos, constitute a whole. From the point of view of indigenous people, sustainable development is a process that must integrate spiritual, cultural, economic, social, political, territorial and philosophical ideals.

Chapter 23

ENVIRONMENTAL ETHICS¹

23.1 ENVIRONMENTAL ETHICS

23.1.1 INTRODUCTION

The concept of **ethics** involves standards of conduct. These standards help to distinguish between behavior that is considered right and that which is considered wrong. As we all know, it is not always easy to distinguish between right and wrong, as there is no universal code of ethics. For example, a poor farmer clears an area of rainforest in order to grow crops. Some would not oppose this action, because the act allows the farmer to provide a livelihood for his family. Others would oppose the action, claiming that the deforestation will contribute to soil erosion and global warming. Right and wrong are usually determined by an individual's **morals**, and to change the ethics of an entire society, it is necessary to change the individual ethics of a majority of the people in that society.

The ways in which humans interact with the land and its natural resources are determined by ethical attitudes and behaviors. Early European settlers in North America rapidly consumed the natural resources of the land. After they depleted one area, they moved westward to new frontiers. Their attitude towards the land was that of a **frontier ethic**. A frontier ethic assumes that the earth has an unlimited supply of resources. If resources run out in one area, more can be found elsewhere or alternatively human ingenuity will find substitutes. This attitude sees humans as masters who manage the planet. The frontier ethic is completely **anthropocentric** (human-centered), for only the needs of humans are considered.

Most industrialized societies experience population and economic growth that are based upon this frontier ethic, assuming that infinite resources exist to support continued growth indefinitely. In fact, economic growth is considered a measure of how well a society is doing. The late economist Julian Simon pointed out that life on earth has never been better, and that population growth means more creative minds to solve future problems and give us an even better standard of living. However, now that the human population has passed six billion and few frontiers are left, many are beginning to question the frontier ethic. Such people are moving toward an **environmental ethic**, which includes humans as part of the natural community rather than managers of it. Such an ethic places limits on human activities (e.g., uncontrolled resource use), that may adversely affect the natural community.

Some of those still subscribing to the frontier ethic suggest that outer space may be the new frontier. If we run out of resources (or space) on earth, they argue, we can simply populate other planets. This seems an unlikely solution, as even the most aggressive colonization plan would be incapable of transferring people to extraterrestrial colonies at a significant rate. Natural population growth on earth would outpace the colonization effort. A more likely scenario would be that space could provide the resources (e.g. from asteroid mining) that might help to sustain human existence on earth.

¹This content is available online at <<http://cnx.org/content/m16743/1.1/>>.

23.1.2 SUSTAINABLE ETHIC

A **sustainable ethic** is an environmental ethic by which people treat the earth as if its resources are limited. This ethic assumes that the earth's resources are not unlimited and that humans must use and conserve resources in a manner that allows their continued use in the future. A sustainable ethic also assumes that humans are a part of the natural environment and that we suffer when the health of a natural ecosystem is impaired. A sustainable ethic includes the following tenets:

- The earth has a limited supply of resources.
- Humans must conserve resources.
- Humans share the earth's resources with other living things.
- Growth is not sustainable.
- Humans are a part of nature.
- Humans are affected by natural laws.
- Humans succeed best when they maintain the integrity of natural processes and cooperate with nature.

For example, if a fuel shortage occurs, how can the problem be solved in a way that is consistent with a sustainable ethic? The solutions might include finding new ways to conserve oil or developing renewable energy alternatives. A sustainable ethic attitude in the face of such a problem would be that if drilling for oil damages the ecosystem, then that damage will affect the human population as well. A sustainable ethic can be either anthropocentric or **biocentric** (life-centered). An advocate for conserving oil resources may consider all oil resources as the property of humans. Using oil resources wisely so that future generations have access to them is an attitude consistent with an anthropocentric ethic. Using resources wisely to prevent ecological damage is in accord with a biocentric ethic.

23.1.3 LAND ETHIC

Aldo Leopold, an American wildlife natural historian and philosopher, advocated a biocentric ethic in his book, *A Sand County Almanac*. He suggested that humans had always considered land as property, just as ancient Greeks considered slaves as property. He believed that mistreatment of land (or of slaves) makes little economic or moral sense, much as today the concept of slavery is considered immoral. All humans are merely one component of an ethical framework. Leopold suggested that land be included in an ethical framework, calling this the **land ethic**.

“The land ethic simply enlarges the boundary of the community to include soils, waters, plants and animals; or collectively, the land. In short, a land ethic changes the role of *Homo sapiens* from conqueror of the land-community to plain member and citizen of it. It implies respect for his fellow members, and also respect for the community as such.” (Aldo Leopold, 1949)

Leopold divided conservationists into two groups: one group that regards the soil as a commodity and the other that regards the land as biota, with a broad interpretation of its function. If we apply this idea to the field of forestry, the first group of conservationists would grow trees like cabbages, while the second group would strive to maintain a natural ecosystem. Leopold maintained that the conservation movement must be based upon more than just economic necessity. Species with no discernible economic value to humans

may be an integral part of a functioning ecosystem. The land ethic respects all parts of the natural world regardless of their utility, and decisions based upon that ethic result in more stable biological communities.

“Anything is right when it tends to preserve the integrity, stability and beauty of the biotic community. It is wrong when it tends to do otherwise.” (Aldo Leopold, 1949)

Leopold had two interpretations of an ethic: ecologically, it limits freedom of action in the struggle for existence; while philosophically, it differentiates social from anti-social conduct. An ethic results in cooperation, and Leopold maintained that cooperation should include the land.

23.1.4 HETCH HETCHY VALLEY

In 1913, the Hetch Hetchy Valley – located in Yosemite National Park in California – was the site of a conflict between two factions, one with an anthropocentric ethic and the other, a biocentric ethic. As the last American frontiers were settled, the rate of forest destruction started to concern the public. The conservation movement gained momentum, but quickly broke into two factions. One faction, led by **Gifford Pinchot**, Chief Forester under Teddy Roosevelt, advocated utilitarian conservation (i.e., conservation of resources for the good of the public). The other faction, led by John Muir, advocated **preservation** of forests and other wilderness for their inherent value. Both groups rejected the first tenet of frontier ethics, the assumption that resources are limitless. However, the conservationists agreed with the rest of the tenets of frontier ethics, while the preservationists agreed with the tenets of the sustainable ethic.

The Hetch Hetchy Valley was part of a protected National Park, but after the devastating fires of the 1906 San Francisco earthquake, residents of San Francisco wanted to dam the valley to provide their city with a stable supply of water. Gifford Pinchot favored the dam.

“As to my attitude regarding the proposed use of Hetch Hetchy by the city of San Francisco...I am fully persuaded that... the injury...by substituting a lake for the present swampy floor of the valley...is altogether unimportant compared with the benefits to be derived from it's use as a reservoir.

“The fundamental principle of the whole conservation policy is that of use, to take every part of the land and its resources and put it to that use in which it will serve the most people.” (Gifford Pinchot, 1913)

John Muir, the founder of the Sierra Club and a great lover of wilderness, led the fight against the dam. He saw wilderness as having an **intrinsic value**, separate from its **utilitarian** value to people. He advocated preservation of wild places for their inherent beauty and for the sake of the creatures that live there. The issue aroused the American public, who were becoming increasingly alarmed at the growth of cities and the destruction of the landscape for the sake of commercial enterprises. Key senators received thousands of letters of protest.

“These temple destroyers, devotees of ravaging commercialism, seem to have a perfect contempt for Nature, and instead of lifting their eyes to the God of the Mountains, lift them to the Almighty Dollar.” (John Muir, 1912)

Despite public protest, Congress voted to dam the valley. The preservationists lost the fight for the Hetch Hetchy Valley, but their questioning of traditional American values had some lasting effects. In 1916, Congress passed the “**National Park System Organic Act**,” which declared that parks were to be maintained in a manner that left them unimpaired for future generations. As we use our public lands, we continue to debate whether we should be guided by preservationism or conservationism.

23.1.5 THE TRAGEDY OF THE COMMONS

In his essay, *The Tragedy of the Commons*, **Garrett Hardin** (1968) looked at what happens when humans do not limit their actions by including the land as part of their ethic. The tragedy of the commons develops in the following way: Picture a pasture open to all. It is to be expected that each herdsman will try to keep as many cattle as possible on the commons. Such an arrangement may work satisfactorily for centuries, because tribal wars, poaching and disease keep the numbers of both man and beast well below the carrying capacity of the land. Finally, however, comes the day of reckoning (i.e., the day when the long-desired goal of social stability becomes a reality). At this point, the inherent logic of the commons remorselessly generates tragedy.

As a rational being, each herdsman seeks to maximize his gain. Explicitly or implicitly, more or less consciously, he asks: "What is the utility to me of adding one more animal to my herd?" This utility has both negative and positive components. The positive component is a function of the increment of one animal. Since the herdsman receives all the proceeds from the sale of the additional animal, the positive utility is nearly +1. The negative component is a function of the additional overgrazing created by one more animal. However, as the effects of overgrazing are shared by all of the herdsmen, the negative utility for any particular decision-making herdsman is only a fraction of -1.

The sum of the utilities leads the rational herdsman to conclude that the only sensible course for him to pursue is to add another animal to his herd, and then another, and so forth. However, this same conclusion is reached by each and every rational herdsman sharing the commons. Therein lies the tragedy: each man is locked into a system that compels him to increase his herd, without limit, in a world that is limited. Ruin is the destination toward which all men rush, each pursuing his own best interest in a society that believes in the freedom of the commons. Freedom in the commons brings ruin to all.

Hardin went on to apply the situation to modern commons. The public must deal with the overgrazing of public lands, the overuse of public forests and parks and the depletion of fish populations in the ocean. Individuals and companies are restricted from using a river as a common dumping ground for sewage and from fouling the air with pollution. Hardin also strongly recommended restraining population growth.

The "Tragedy of the Commons" is applicable to the environmental problem of global warming. The atmosphere is certainly a commons into which many countries are dumping excess carbon dioxide from the burning of fossil fuels. Although we know that the generation of greenhouse gases will have damaging effects upon the entire globe, we continue to burn fossil fuels. As a country, the immediate benefit from the continued use of fossil fuels is seen as a positive component. All countries, however, will share the negative long-term effects.

Chapter 24

ENVIRONMENTAL LAWS & REGULATIONS¹

24.1 ENVIRONMENTAL LAWS & REGULATIONS

24.1.1 INTRODUCTION

Although environmental laws are generally considered a 20th century phenomenon, attempts have been made to legislate environmental controls throughout history. In 2,700 B.C., the middle-eastern civilization in Ur passed laws protecting the few remaining forests in the region. In 80 A.D., the Roman Senate passed a law to protect water stored for dry periods so it could be used for street and sewer cleaning. During American colonial times, **Benjamin Franklin** argued for "public rights" laws to protect the citizens of Philadelphia against industrial pollution produced by animal hide tanners.

Significant environmental action began at the beginning of the 20th century. In 1906, Congress passed the "Antiquities Act," which authorizes the president to protect areas of federal lands as national monuments. A few years later, **Alice Hamilton** pushed for government regulations concerning toxic industrial chemicals. She fought, unsuccessfully, to ban the use of lead in gasoline. She also supported the legal actions taken by women who were dying of cancer from their exposure to the radium then used in glow-in-the-dark watch dials. During the early 1960's, biologist **Rachel Carson** pointed out the need to regulate pesticides such as DDT to protect the health of wildlife and humans.

With the establishment of the **Environmental Protection Agency (EPA)** in 1970, environmental law became a field substantial enough to occupy lawyers on a full-time basis. Since then, federal and state governments have passed numerous laws and created a vast network of complicated rules and regulations regarding environmental issues. Moreover, international organizations and agencies including the **United Nations**, the **World Bank**, and the **World Trade Organization** have also contributed environmental rules and regulations.

Because of the legal and technical complexities of the subjects covered by environmental laws, persons dealing with such laws must be knowledgeable in the areas of law, science and public policy. Environmental laws today encompass a wide range of subjects such as air and water quality, hazardous wastes and biodiversity. The purpose of these environmental laws is to prevent, minimize, remedy and punish actions that threaten or damage the environment and those that live in it. However, some people believe that these laws unreasonably limit the freedom of people, organizations, corporations and government agencies by placing controls on their actions.

¹This content is available online at <<http://cnx.org/content/m16744/1.1/>>.

24.1.2 FEDERAL LAWS

Early attempts by Congress to enact laws affecting the environment included the **Antiquities Act** in 1906, the **National Park Service Act** in 1916, the **Federal Insecticide, Fungicide and Rodenticide Act** in 1947 and the **Water Pollution Control Act** in 1956. The **Wilderness Act** of 1964, protected large areas of pristine federal lands from development and ushered in the new age of environmental activism that began in the 1960's. However, it was the **National Environmental Policy Act (NEPA)** enacted in 1969 and the formation of the Environmental Protection Agency (EPA) in 1970 that started environmental legislation in earnest. The main objective of these two federal enactments was to assure that the environment would be protected from both public and private actions that failed to take into account the costs of damage inflicted on the environment.

Many consider NEPA to be the most far-reaching environmental legislation ever passed by Congress. The basic purpose of NEPA is to force governmental agencies to comprehensively consider the effects of their decisions on the environment. This is effected by requiring agencies to prepare detailed **Environmental Impact Statements** (EIS) for proposed projects. The EPA is the government's environmental watchdog. It is charged with monitoring and analyzing the state of the environment, conducting research, and working closely with state and local governments to devise pollution control policies. The EPA is also empowered to enforce those environmental policies. Unfortunately, the agency is sometimes caught up in conflicts between the public wanting more regulation for environmental reasons and businesses wanting less regulation for economic reasons. Consequently, the development of a new regulation can take many years.

Since 1970, Congress has enacted several important environmental laws, all of which include provisions to protect the environment and natural resources. Some of the more notable laws include:

- The **Federal Clean Air Act** (1970, 1977 & 1990) established national standards for regulating the emission of pollutants from stationary and mobile sources.
- The **Federal Water Pollution Control Act** (1972) amended by the **Clean Water Act** (1977, 1987), established water quality standards; provides for the regulation of the discharge of pollutants into navigable waters and for the protection of wetlands.
- The **Federal Safe Drinking Water Act** (1974, 1977 & 1986) set drinking water standards for levels of pollutants; authorizing the regulation of the discharge of pollutants into underground drinking water sources.
- The **Toxic Substances Control Act** (1976) provided for the regulation of chemical substances by the EPA and the safety testing of new chemicals.
- The **Resource Conservation and Recovery Act** (1976) established cradle-to-grave regulations for the handling of hazardous wastes.
- The **Comprehensive Environmental Response, Compensation and Liability Act** (1980), also known as the **Superfund** program, provided for the cleanup of the worst toxic waste sites.
- The **Food Security Act** (1985, 1990) later amended by the **Federal Agriculture Improvement and Reform Act** (1996), discouraged cultivation of environmentally sensitive lands, especially wetlands, and authorized incentives for farmers to withdraw highly erodible lands from production.

The application, or enforcement, of an environmental law is not always straightforward, and problems can arise. Often, the biggest problem is that Congress fails to allocate the funds necessary for implementing or enforcing the laws. Administrative red tape may make it impossible to enforce a regulation in a timely manner. It also may be unclear as to which agency (or branch of an agency) is responsible for enforcing a particular regulation. Furthermore, agency personnel decline to enforce a regulation for political reasons.

24.1.3 STATE LAWS

Most states, like California, have enacted their own environmental laws and established agencies to enforce them. California faced some of its first environmental challenges in the mid-1800's, with regard to debris from the hydraulic mining of gold. Water quality concerns, dangers of flooding, negative impact on agriculture and hazards to navigation prompted the state to act.

Some of California's environmental regulations preceded similar federal laws. For example, California established the nation's first air quality program in the 1950s. Much of the federal Clean Air Act amendments of 1990 were based upon the **California Clean Air Act of 1988**. California also pioneered advances in vehicle emission controls, control of toxic air pollutants and control of stationary pollution sources before federal efforts in those areas. The **Porter-Cologne Act of 1970**, upon which the state's water quality program is based, also served as the model for the federal Clean Water Act.

California's state environmental regulations are sometimes more stringent than the federal laws (e.g., the California Clean Air Act and vehicle emissions standards). In other program areas, no comparable federal legislation exists. For example, the California **Integrated Waste Management Act** established a comprehensive, statewide system of permitting, inspections, enforcement and maintenance for solid waste facilities and sets minimum standards for solid waste handling and disposal to protect air, water and land from pollution. Also, **Proposition 65 (Safe Drinking Water and Toxic Enforcement Act)** requires the Governor to publish a list of chemicals that are known to the State of California to cause cancer, birth defects or other reproductive harm.

Despite the state's leadership in environmental programs and laws, the creation of a cabinet-level environmental agency in California lagged more than two decades behind the establishment of the federal EPA. Originally, organization of California's environmental quality programs was highly fragmented. Each separate program handled a specific environmental problem (e.g., the **Air Resources Board**), with enforcement responsibility falling to both state and local governments. It was not until 1991 that a California EPA was finally established and united the separate programs under one agency.

24.1.4 INTERNATIONAL TREATIES AND CONVENTIONS

Conventions, or treaties, generally set forth international environmental regulations. These conventions and treaties often result from efforts by international organizations such as the **United Nations (UN)** or the **World Bank**. However, it is often difficult, if not impossible, to enforce these regulations because of the sovereign rights of countries. In addition rules and regulations set forth in such agreements may be no more than non-binding recommendations, and often countries are exempted from regulations due to economic or cultural reasons. Despite these shortcomings, the international community has achieved some success via its environmental agreements. These include an international convention that placed a moratorium on whaling (1986) and a treaty that banned the ocean dumping of wastes (1991).

The UN often facilitates international environmental efforts. In 1991, the UN enacted an **Antarctica Treaty**, which prohibits mining of the region, limits pollution of the environment and protects its animal species. The United Nations Environment Program (UNEP) is a branch of the UN that specifically deals with worldwide environmental problems. It has helped with several key efforts at global environmental regulations:

- **The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer.** As a result of this global agreement, industrialized countries have ceased or reduced the production and consumption of ozone-depleting substances such as chlorofluorocarbons.
- **The Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade.** This agreement enhances the world's technical knowledge and expertise on hazardous chemicals management.

- **The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES)**. This agreement protects over 30,000 of the world's endangered species.
- In 1995 **UNEP and the International Olympic Committee (IOC)** signed a partnership agreement to develop environmental guidelines for sports federations and countries bidding to host the Olympic games.
- **The Rotterdam Convention** (1998) addressed the growing trade in hazardous pesticides and chemicals. Importing countries must now give explicit informed consent before hazardous chemicals can cross their borders.
- **The International Declaration on Cleaner Production** (1998). The signatories commit their countries to implement cleaner industrial production and subsequent monitoring efforts.

In 1992, the UN member nations committed their resources to limiting greenhouse gas (e.g., carbon dioxide) emissions at or below 1990 levels, as put forth by the **UN Framework Convention on Climate Change**. Unfortunately, the agreement was non-binding and by the mid-1990's, it had had no effect on carbon emissions. The 1997 **Kyoto Protocol** was a binding resolution to reduce greenhouse gases. Although the United States initially supported the resolution, the Senate failed to ratify the treaty, and by 2001 the resolution was opposed by President Bush as threatening the United States economy.

Chapter 25

ISSUES AND OPTIONS¹

25.1 ISSUES AND OPTIONS

25.1.1 INTRODUCTION

Environmental issues are a concern of many, if not most, Americans. However, there is considerable disagreement on how such issues should be handled. Different people can interpret even a very general issue such as conservation very differently. Some believe that conservation means limiting the use of resources to allow a resource to last longer. Others see the conservation of resources as a way to maximize benefits to humans. This utilitarian approach to conservation policy, would place no value on saving endangered species that provide no direct benefit to humans. At the other extreme, some envision conservation as meaning the protection of resources without regard to profit or material benefit to humans. This view places the preservation as being of the utmost importance, and is sometimes viewed as elitist.

Even the simplest strategies for dealing with environmental issues cannot be carried out without the expenditure of time, effort and money. It follows that environmental policy decisions that are adopted by a country are usually made within the context of the level of affluence and education of that country. This is especially true when it comes to conservation issues. A developed country like the United States can afford to set aside and manage wilderness areas or place restrictions on timber cutting, mining and oil drilling on public lands. However, a developing country must contend with insufficient funds to meet the basic needs of its people. This often leads to short-sighted decisions that allow exploitation of its forests and other natural resources. The need for hard cash overrides the need to conserve.

The development and promotion of a platform on environmental issues requires careful planning and well-conceived education programs. Political backing is a necessity for implementing such a platform, as well as for garnering the legislative powers to enforce rules and guidelines. Politicians were for the most part disinterested in environmental issues until the 1970's. The main reason for this was that issues such as conservation were perceived as long-term issues, and political concerns are mostly short term, changing as the administrations changed. However, politicians realized that they had to formulate some medium or long-term strategies, when a rise in international environmental activism forced them to consider these issues.

25.1.2 RESOURCE USE

Before the arrival of European settlers, the indigenous people of the North American continent lived in relative harmony with their environment. Although they hunted animals and some raised crops using slash and burn techniques, they had little impact on the environment because their populations were relatively small. This situation changed after European colonists settled what is now the eastern coast of the United

¹This content is available online at <<http://cnx.org/content/m16773/1.1/>>.

States. As their numbers grew, they moved westward. The settlers clear cut forests as they moved through the frontier regions, leaving denuded landscapes. Farmers grew crops until the soil became infertile and then moved on to other locations. People used water resources freely without giving much thought to conservation. The common approach was that of exploitation of the seemingly endless natural resources the country offered.

However, this tradition of exploitation began to change as the United States became industrialized and urbanized. As early as the late 18th century, people such as George Washington and Thomas Jefferson began experimenting with crop rotation and soil conservation techniques. During the 19th century, growing cities developed waterworks to supply clean water. Some people began to realize the importance of conserving natural resources such as water. By 1900, various American scientists, politicians and business leaders voiced concerns about the depletion of the forests, soil and other natural resources.

The term conservation was first applied to water resources. Much of the western United States was arid, and government scientists developed the idea of building dams to impound water from spring floods. They reasoned that the water could then be used year round for irrigation and other purposes. Use of the term quickly spread to include all natural resources. Conservation emerged from the 19th century as a form of applied science. It involved the scientific planning of the use of natural resources. Conservation leaders came from fields like forestry, agronomy, geology, and hydrology. An early proponent was Gifford Pinchot, the first head of the United States Forest Service. The conservation principles of that time contrasted with those espoused by proponents of preservation.

Preservationists wanted natural areas preserved and protected from any type of human development. The leading preservationist of the time was John Muir. Because of their different views, the preservation movement and the conservation movement were sometimes at odds with each other. The most publicized controversy of the early 20th century concerned the plan to build a dam to flood the beautiful Hetch-Hetchy valley to supply the city of San Francisco with fresh water. The dam, supported by conservationists and opposed by preservationists, was eventually built. President Theodore Roosevelt supported both conservation and preservation. He vigorously expanded the nation's infant system of national parks and monuments in order to protect pristine natural areas from exploitation.

The main issues of resource conservation today differ from those at the turn of the 20th century. During the 1960's the general public became concerned with the problems of pollution. The effects of pesticides such as DDT on wildlife were documented in a book (*Silent Spring*) by Rachel Carson. There were highly publicized environmental incidents in Lake Erie (severe water pollution), New York City (air pollution) and Santa Barbara (oil spill). Events such as these fueled the start of a new environmental movement. This movement generally supports the concept that resource conservation includes maintaining the quality of those resources. This movement continues today and supports such issues as government clean-up of old areas of pollution, reduction of current emission levels of pollution and protection of remaining pristine environments.

25.1.3 RESTORATION ECOLOGY

Humans have deforested the land, stripped its surface to remove its mineral resources, exploited its grasslands and drained its wetlands, all to sustain the growing human population. Rivers have been straightened, diverted and dammed to provide humans with water, transportation, flood control, electric power and recreational facilities. However, when ecosystems are overexploited they degenerate. Healthy ecosystems are necessary in order to sustain the earth's soil, water and air resources. Some people feel that environmental degradation should be reversed through restoration ecology (i.e., the restoration of degraded environments to healthy ecosystems). However, the concepts involved are varied.

The modern concept of reclamation involves an attempt to return a damaged ecosystem to some kind of productive use that is socially acceptable. For example, a mined area might be converted to pastureland or an orchard. In this process rehabilitation of the mined area also occurs, making the land more visually pleasing. Historically, the term "reclamation" was used to describe the alteration of a native ecosystem to one of value to humans, such as the filling of a wetlands area in order to provide land for urban housing.

Today, such an action might be considered environmental degradation. Because of the conflicting definitions, the use of the term reclamation can be confusing.

Sometimes, actions can be taken to avoid, reduce or compensate for the effects of environmental damage. Such mitigation efforts have been taken by the Army Corps of Engineers during construction projects. The native plants are removed from a site before construction begins and transplanted at a special holding site. After the construction project is completed, the native plants are restored using those from the holding site. Another example of mitigation might involve the creation or enhancement of wetlands in one area, in order to compensate for permitted wetland losses in another area. Mitigation often goes hand-in-hand with restoration. Texaco, in conjunction with environmental groups and the United States Fish and Wildlife Service, restored 500 acres of agricultural lands in the lower Mississippi Delta to bottomland hardwoods. Texaco received environmental credits for the mitigating effects of the new woodlands on air quality.

Restoration involves returning an altered or degraded site to its approximate condition before alteration. This includes restoring related physical, chemical and biological characteristics. Full restoration involves the complete return of a site to its original state. Restoring an ecosystem to its full productive health is not an easy task. It requires a broad interdisciplinary approach involving many different scientific fields of study (e.g., biology, ecology, hydrology and geology). Inherent in restoration projects are important though questionable and often unrealistic assumptions: historical environmental conditions can be recreated, existing ecosystems can be replaced, the physical environment can be altered in order to support the desired plants and animals, the desired plants and animals will become established, and the ecosystem will be able to sustain itself.

Besides physical processes, socio-economic factors must also be considered in a restoration project. Actions of humans have historically been important in shaping ecosystems, and are important in determining the success of restoration efforts. Because the cost to restore an individual site can involve millions of dollars, government support is a necessity. Even with the best efforts, restoration projects can sometimes be hampered by unexpected events. An effort by one environmental group to restore a savannah ecosystem in Illinois was blocked by another environmental group that objected to the removal of the trees from the area.

25.1.4 ENVIRONMENTAL INVOLVEMENT

"Never doubt that a small group of thoughtful, committed citizens can change the world: indeed it's the only thing that ever has." - Margaret Mead

The environmental movement had its beginnings in the early 1960's, when biologist Rachel Carlson published her book "The Silent Spring." The book highlighted the harmful effects of pesticides on wildlife. Soon there was a growing grassroots campaign demanding that the government act to protect the environment. There was also an increase in the popularity of established conservation groups such as the Sierra Club and the Wilderness Society. The early years of the movement led to such milestones as the passage of the "Wilderness Act" in 1964 and the "Land and Water Conservation Act" in 1965, as well as the establishment of the Environmental Protection Agency in 1970.

Environmental groups in the United States carry out a variety of activities: lobbying for new environmental laws, lobbying against harmful projects, acting as pollution watchdogs, actively protecting land and wildlife and educating the public on environmental issues. Some more radical groups such as "Earth First!" add civil disobedience and sabotage to their environmental activities. Greenpeace is one of the largest international environmental groups and is probably best known for its efforts to stop continued commercial whaling by Japan and Norway.

An anti-environmentalist movement, the "Wise Use Movement," is a coalition of timber and mining companies and cattle ranchers. The members advocate logging, mining, grazing and developing all public lands, regardless of the environmental consequences. Throughout the 1990's the group attempted to repeal or weaken many environmental laws and discredit environmental groups. Their efforts were largely thwarted; however, they were able to block some proposed environmental legislation.

Although strength in numbers is always an effective strategy when taking on environmental issues, individuals can also make significant inroads in environmental activism. In 1978, a lone woman living in the Love Canal area of Niagara Falls, New York, awakened the nation to the dangers of hazardous waste dumps.

Working first at the local level, then the state level and finally the national level, she lobbied governments to take action to protect people from the toxic chemicals contained in such dumps. Her efforts led to the creation of a national Superfund in 1980 to cleanup and regulate hazardous waste sites.

People who want to make their voices heard on environmental issues can do so in a number of ways. Locally, they can send letters to the editors of community newspapers to reach a wide audience. Public hearings and community meetings also provide opportunities to make a strong vocal statement. On a larger political scale, a typed or handwritten letter to a government official is particularly effective. Faxing the letter to the official is another option. Telephone calls to legislators show that the callers care enough to spend a little money, and also offers an unparalleled opportunity for immediate feedback. However, it is not always easy to actually get connected to the recipient. E-mails are less personal than regular letters, but they are very convenient and they have the potential to mobilize hundreds or thousands of messages, making it an indispensable tool for the environmental activist.

25.1.5 Sustainability

Sustainability refers to practices that allow current populations to meet their needs without impacting the ability of future generations to meet their own needs. The idea was developed to describe the long-term use of natural resources but has been expanded to include a diversity of situations, including community structures, economic policies, and social justice. Sustainability is a relatively new concept that is becoming a common ideal but is not yet widely practiced.

25.1.6 Non-renewable Resources

The use of non-renewable resources is by definition, unsustainable. The use of fossil fuels is a prime example. Industrial societies rely on oil and natural gas to power manufacturing, propel vehicles, heat homes, and cook meals. In addition, many goods, like plastics, are partially made of petroleum products. Ongoing geologic processes are continuing to produce fossil fuels, as they have for millennia, but the rate at which we are using them far outstrips the rate at which natural cycles regenerate them. Some scientists project that oil and gas reserves will be largely drained in 50 – 200 years. Future generations will have to find other sources of energy.

25.1.7 Environmental Degradation

Some practices are not sustainable because they cause severe environmental damage. For example, some modern agricultural methods actually destroy the soil they rely on, so that farms flourish for a time but then must be abandoned. Desert lands can grow crops if they are intensively irrigated. But when irrigation water evaporates in hot climates, the soil becomes more and more salty, until plant growth is stunted. In the tropics, when rainforests are chopped down to make way for crops, soils lose the steady nutrient supply the forest provided and soon become infertile.

25.1.8 Renewable Resources

Renewable resources can be used far into the future. Wind power is a type of renewable energy. Windmills, which turn in the wind to spin turbines that generate electricity, don't use up or diminish the air. And the supply of wind is renewed every day, when uneven solar heating of the Earth causes hot air to rise and cold air to sink.

25.1.9 Best Management Practices

Best management practices are techniques and methods designed to minimize environmental impacts. In agriculture, these practices include growing native crops or those suited to local conditions, rotating crops,

minimizing soil tilling, and reducing pesticide use. With proper care, soils can remain fertile and healthy for many years.

25.1.10 Environmental Remediation

For many thousands of years, ever since they built the first campfire, human activity has generated air, water, and soil pollution. For most of human history, however, these contaminants had relatively little environmental impact. But over the last few centuries, pollution levels skyrocketed as a result of population growth and the Industrial Revolution. As a result, regulations have been enacted to control emissions. Even where these are effective in curbing current pollution sources, high levels of contamination may exist from past activity. And new contamination can occur through industrial accidents or other inadvertent releases of toxic substances. Danger to human health from both historic and modern contamination requires that cleanup measures be implemented. This is the purpose of environmental remediation.

25.1.11 Contamination Sources

Just under 300 million tons of hazardous wastes are produced each year in the United States. Although the safe disposal of wastes is mandated, accidental releases do occur, and sometimes regulations are ignored. Some of the most widespread or dangerous pollutants that require remediation come from mining, fuel spills and leaks, and radioactive materials.

Heavy metals (copper, lead, mercury, and zinc) can leach into soil and water from mine tunnels, tailings, and spoil piles. Acid mine drainage is caused by reaction of mine wastes, such as sulfides, with rainfall or groundwater to produce acids, like sulfuric acid. The Environmental Protection Agency estimates that 40% of the watersheds in the western United States are contaminated by mine run-off.

Organic contamination can result from discharge of solvents to groundwater systems, natural gas or fuel spills, and above-ground and underground storage tank leakage.

Radioactive contamination of soils, water, and air can result from mining activity, processing of radioactive ores, and improper disposal of laboratory waste and spent fuel rods used at nuclear power plants. The best-known example of radioactive contamination is the Chernobyl disaster. In 1986, workers at a Russian nuclear power plant ignored safety procedures during a reactor test, and the fuel rods superheated the cooling water to cause an explosion that killed 30 people and released a huge cloud of radioactive steam. Although more than 100,000 people were evacuated from around the plant, a dramatic increase in cancer rates among the population has occurred. As the steam cloud dispersed into the atmosphere, increases in radioactivity were measured over much of the northern hemisphere.

25.1.12 Remediation Efforts

Many communities are struggling to find the funds and technological expertise needed to clean up polluted areas. Some settings, such as brownfields, can be reclaimed fairly easily. Other areas, because of their size or the extreme toxicity of their contaminants, require very expensive, complex, and long-term remediation. Many of these have been designated as Superfund sites.

Brownfields are abandoned industrial or commercial facilities or blighted urban areas that need to be cleansed of contamination before they can be redeveloped.

Superfund sites are areas with the most toxic contamination in the United States. The contamination may not only make the site itself too dangerous to inhabit, but often leaks toxic levels of pollutants into the surrounding soil, water, or air. An example of a Superfund site is Love Canal in Niagara Falls, New York. The canal was a chemical waste dump for many years, then in the 1950's was covered with soil and sold to the city. Over time, many homes and a school were built over the former dump. In the 1970's, heavy rains raised the water table and carried contaminants back to the surface. Residents noticed foul smells, and gardens and trees turned black and died. Soon after, rates of birth defects, cancer, and other illnesses began to rise sharply. In 1977, the State of New York and the federal government began remediation work. Buildings were removed, and all residents were bought out and relocated, contaminated deposits and soils

were excavated, and remaining soils and groundwater were treated and sealed off to prevent further spread of the contamination. Remediation activities have now been completed at this site.

25.1.13 Remediation Methods

The type of pollution and the medium affected (air, water, or soil) determine remediation methods. Methods include incineration, absorption onto carbon, ion exchange, chemical precipitation, isolation, or bioremediation. Bioremediation is the use of plants, bacteria, or fungus to “digest” the contaminant to a non-toxic or less toxic form. All of these methods tend to be expensive and time-consuming.

Remediation is aimed at neutralization, containment, and/or removal of the contaminant. The goal is to prevent the spread of the pollution, or to reduce it to levels that will not appreciably risk human health. Many times, it is physically impossible or financially unfeasible to completely clear all contamination. Often, experts and the public disagree on how clean is clean enough.

Index of Keywords and Terms

Keywords are listed by the section with that keyword (page numbers are in parentheses). Keywords do not necessarily appear in the text of the page. They are merely associated with that section. *Ex.* apples, § 1.1 (1) **Terms** are referenced by the page they appear on. *Ex.* apples, 1

- " "Mariana Trench", 12
- ((HNO₃), 9
- A** A horizon, 51
 abiotic regions, 21
 abyssal, 24
 acidic solution, 53
 Active solar energy, 63
 acute effect, 82
 Agriculture, 42
 Agroforestry, 54
 Air Resources Board, 111
 Aldo Leopold, 106
 Alice Hamilton, 109
 alkaline solution, 53
 Allethrin, 74
 alpine tundra, 25
 amino acids, 8
 ammonia (NH₃), 9
 anadromous species, 57
 animal species, 24
 Antarctica Treaty, 111
 anthropocentric, 105
 Antiquities Act, 110
 AP, § 1(1), § 2(5), § 3(11), § 4(15), § 5(21),
 § 6(29), § 7(35), § 8(39), § 9(41), § 10(47),
 § 11(51), § 12(55), § 13(59), § 14(63), § 15(67),
 § 16(71), § 17(77), § 18(81), § 19(85), § 20(91),
 § 21(95), § 22(99), § 23(105), § 24(109),
 § 25(113)
 aquaculture, 57
 aquatic, 24
 Aquatic biomes, 24
 aquifer, 6
 aquifers, 42
 Archean, 12
 arctic tundra, 25
 Area strip mining, 48
 asthenosphere, 11
 atmosphere, 15
 Atmospheric clouds, 19
- ATP, 9
 Autotrophs, 22
- B** B horizon, 51
 Benjamin Chavis, 101
 Benjamin Franklin, 109
 benthic, 24
 benzene, 72
 biocentric, 106
 biodegradable, 23
 biodegradation, 73
 biodiversity, 21, 88, 93
 biological agents, 81
 biomass, 23
 Biomass energy, 65
 biome, 21
 biosphere, 21, 21
 Biosphere reserves, 70
 biotic region, 21
 bituminous, 60
 boreal forests, 25
 Botanicals, 74
 British Thermal Unit, 4
 Brownfields, 117
 buffer zone, 70
 butane, 61
- C** C horizon, 51
 California Clean Air Act of 1988, 111
 camphor, 74
 Carbamates, 74
 carbon cycle, 7
 carbon dioxide, 7, 71
 carbon monoxide, 71
 carbon tetrachloride, 72
 carbonates, 47
 carcinogenic, 78
 Carnivores, 23
 Carrying capacity, "K", 35
 Center-pivot sprinkler systems, 42
 Chapman Reactions, 16, 86
 chemical agents, 81

- chemical degradation, 73
 - Chemical energy, 1
 - Chlorinated hydrocarbons, 73
 - chlorofluorocarbons, 86
 - chlorofluorocarbons (CFCs), 17, 72
 - chlorophyll, 7
 - chronic effect, 82
 - Cinder cones, 13
 - clathrates, 86
 - clay, 52
 - Clean Water Act, 110
 - Clear cutting, 69
 - Climate, 19
 - climax community, 24
 - cluster development model, 68
 - co-evolution, 26
 - Cold deserts, 25
 - community, 21, 22
 - Compensation and Liability Act, 110
 - Composite volcanoes, 12
 - composition, 47
 - Comprehensive Environmental Response, 110
 - Concentration Equivalents, 75
 - Concentration Measurements and Environmental Regulations, 75
 - concentric city model, 67
 - condensation, 6
 - condensation nuclei, 19
 - Conservation, 55
 - consumers, 23
 - Contact chemicals, 74
 - continental crust, 11
 - Contour farming, 54
 - Contour strip mining, 48
 - Control rods, 61
 - convection cells, 17
 - Convergent evolution, 26
 - coral bleaching, 92
 - Coral reefs, 24
 - core, 11
 - core area, 70
 - Coriolis Effect, 17
 - cost-benefit analysis, 97
 - Croplands, 56
 - Crude oil, 60
 - crust, 11
 - cultural factors, 40
 - cyanobacteria, 8
 - cyclone, 18
- D** Decomposers, 23
- demographic transition, 31
 - demography, 30
 - denitrification, 9, 9
 - desert, 24
 - desertification, 68
 - Deserts, 25
 - destruction of ozone, 16
 - Detritivores, 23
 - developed, 100
 - Developed countries, 100
 - developing, 100
 - developing countries, 100
 - Dioxin, 76
 - Dioxins, 81
 - Diphenamid, 74
 - divergent plate, 12
 - DNA, RNA, 8
 - Doctrine of Riparian Rights, 43
 - Drip irrigation, 42
- E**
- early plant, 24
 - earthquake, 13
 - ecological footprint, 37
 - ecological succession, 23
 - ecology, 21
 - Economics, 95
 - ecosphere, 21
 - ecosystem, 21, 22
 - Ecosystems, 25
 - El Niño, 18, 92
 - El Niño/Southern Oscillation (ENSO), 92
 - Electrical ene, 4
 - Electrical energy, 1
 - electrowinning, 49
 - emigration, 31
 - endocrine disrupters, 82
 - Energy, 1
 - energy sink, 3
 - Environment, § 1(1), § 2(5), § 3(11), § 4(15), § 5(21), § 6(29), § 7(35), § 8(39), § 9(41), § 10(47), § 11(51), § 12(55), § 13(59), § 14(63), § 15(67), § 16(71), § 17(77), § 18(81), § 19(85), § 20(91), § 21(95), § 22(99), § 23(105), § 24(109), § 25(113)
 - environmental ethic, 105
 - Environmental Impact Statements, 110
 - Environmental Protection Agency (EPA), 109
 - epicenter, 13
 - Epochs, 12
 - Eras, 12
 - erg, 3
 - Erosion, 53
 - ethane, 61

- ethics, 105
 - ethyl mercaptan, 61
 - eukaryote, 22
 - eutrophication, 9, 76
 - Evaporation, 6
 - Evolution, 25
 - Examples, 75
 - exosphere, 17
 - exponential growth, 29
 - extinction, 26
- F**
- faults, 13
 - Federal Agriculture Improvement and Reform Act, 110
 - Federal Clean Air Act, 110
 - Federal Insecticide, 110
 - Federal Safe Drinking Water Act, 110
 - Federal Water Pollution Control Act, 110
 - fertile crescent, 32
 - fish farming, 57
 - Fish ranching, 57
 - Fisheries, 56
 - fission of uranium atoms, 61
 - Flood irrigation, 42
 - Floods, 18
 - focus, 13
 - food chain, 23
 - Food Security Act, 110
 - food web, 23
 - forest, 24
 - freshwater, 24
 - frontier ethic, 105
 - fuel rods, 61
 - Fungicide and Rodenticide Act, 110
 - fungicides, 73
 - Furrow irrigation, 42
- G**
- Garrett Hardin, 107
 - GDP (Gross Domestic Product), 95
 - generalized species, 26
 - genetic diversity, 56
 - geologic time scale, 12
 - Geothermal energy, 65
 - Gifford Pinchot, 107
 - global climate change, 87
 - global warming, 92
 - grassland, 24
 - Grassland soil, 52
 - Grasslands, 25
 - green GDP, 99
 - greenbelts, 68
 - greenhouse effect, 85
 - greenhouse gas, 8
 - greenhouse gases, 85
 - Gross Domestic Product (GDP), 99
 - Gross National Product, 32
 - Gross National Product (GNP), 95
 - groundwater, 6, 41
 - guano, 9
 - Gully erosion, 53
- H**
- habitat, 22
 - hailstones, 19
 - heap leaching, 49
 - heat capacity, 41
 - Heat energy, 2
 - Heavy Metals, 76, 81
 - herbicides, 73
 - Herbivores, 23
 - Heterotrophs, 22
 - highly developed country (HDC), 100
 - horsepower, 3
 - Hot deserts, 25
 - human fertility, 31
 - human population dynamics, 29
 - human resources, 95
 - humus, 51
 - hurricanes, 18
 - Hydraulic mining, 48
 - hydrocarbons, 72
 - Hydroelectric power, 64
 - hydrologic cycle, 6
 - hydrosphere, 21
 - hydrothermal, 48, 48
- I**
- Igneous rocks, 13
 - immigration, 31
 - in-situ mining, 49
 - Incineration, 78
 - incinerators, 78
 - increase in UV radiation, 92
 - indicator species, 22
 - individual, 22
 - Industrial Revolution, 32
 - industrial stage, 31
 - industrialized agriculture, 56
 - infiltration, 6
 - infrared radiation, 5
 - Inorganic chemical pollutants, 72
 - insecticides, 73
 - Integrated Waste Management Act, 111
 - intensive agriculture, 57
 - intercropping, 57
 - intertidal, 24

- intrinsic value, 107
- introduced exotic, 89
- ionosphere, 17
- Irrigation, 42
- J** J curve, 29
- jet stream, 16
- Jet streams, 17
- Joule, 3
- K** kerogen, 61
- keystone species, 22
- kilowatt-hours, 4
- kinetic energy, 1
- Kyoto Protocol, 112
- Köppen System, 19
- L** land ethic, 106
- landfills, 78
- late successional species, 24
- Lava domes, 13
- leaching, 51
- less developed country (LDC), 100
- Lethal doses, 82
- lichens, 23
- Light Pollution, 76
- lignite, 59
- limiting factors, 22
- liquefied petroleum gas, 61
- lithification, 13
- lithosphere, 12, 21
- LPG, 61
- M** mafic minerals, 11
- magma, 11, 12
- magmatic, 48, 48
- Malathion, 74
- Man and the Biosphere Program, 70
- mantle, 11
- marine, 24
- Marine regions, 24
- market equilibrium price, 95
- mass burn incinerators, 78
- mass extinction, 26
- Mechanical energy, 1
- mesosphere, 17
- metallic, 47
- Metamorphic rocks, 13
- methane, 61
- Micrograms per milliliter (ug/mL), 75
- micronutrients, 52
- mid-species, 24
- moderately developed country (MDC), 100
- molten rock, 12
- monoculture, 56
- morals, 105
- mosses, 23
- multiple-nuclei, 67
- Municipal solid waste, 77
- mutagenic, 78
- N** National Environmental Policy Act (NEPA), 110
- National Park Service Act, 110
- National Park System, 70
- National Park System Organic Act, 107
- National Trail System, 70
- National Wilderness Preservation System, 70
- Natural gas, 61
- Natural resources, 95
- Natural selection, 26
- Neotropical, 89
- nitrate (NO₃-), 9
- nitric acid, 9
- nitric oxide, 72
- nitrogen cycle, 9
- nitrogen dioxide, 72
- nitrogen fixation, 9
- nitrous oxide, 9, 72
- no-till agriculture, 54
- Noise Pollution, 76
- Non-municipal solid waste, 77
- Non-point Source Pollution, 74
- non-renewable, 59
- nonmetallic, 47
- Nuclear Energy, 2
- nuclear fission, 2
- nuclear fusion, 2
- nuclear power plant, 61
- nucleic acids, 8
- O** O horizon, 51
- oceanic crust, 11
- Oceans, 24
- Oil recovery, 60
- Oil shale, 61
- Oil Spills, 76
- Old-growth forests, 69
- omnivores, 23
- Open-pit mining, 48
- optimum range, 22
- ore, 48
- ores, 48
- Organic chemical pollutants, 73
- Organophosphates, 74

- over-harvesting, 88
 - Oxides of carbon, 71
 - Oxides of nitrogen, 71
 - Oxides of sulfur, 71
 - Oxygen-depleting wastes, 72
 - Ozone, 72, 86
 - ozone depletion, 92
 - Ozone destruction, 87
 - ozone pollution, 87
- P**
- Parts per million (ppm), 75
 - Passive solar energy, 63
 - pasture, 68
 - pelagic, 24
 - percolation, 6
 - Periods, 12
 - Pesticides, 75, 82
 - pH, 52
 - Phanerozoic, 12
 - phosphate (PO₄³⁻), 9
 - Phosphorus, 9
 - phosphorus cycle, 9
 - photochemical degradation, 73
 - Photochemical oxidants, 72
 - photochemical smog, 72
 - photosynthesis, 7
 - Photovoltaic, 64
 - pioneer species, 23
 - placer, 48, 48
 - planetesimals, 11
 - Plant nutrient pollutants, 73
 - plate tectonics, 7, 12
 - Point Source Pollution, 74
 - Ponds and lakes, 24
 - population, 21, 22
 - population dynamics, 29
 - Porter-Cologne Act of 1970, 111
 - post-industrial, 31
 - potential energy, 1
 - Power, 3
 - pre-industrial stage, 31
 - precipitation, 6, 19
 - Prescription Drugs, 75
 - preservation, 107
 - primary macronutrients, 52
 - primary pollutants, 71
 - primary succession, 23
 - Prime farmland, 68
 - Principle of Prior Appropriation, 43
 - Principle of Supply and Demand, 95
 - producers, 23
 - production of ozone, 16
 - prokaryote, 22
 - prokaryotes, 22
 - propane, 61
 - Proposition 65, 111
 - proteins, 8
 - Proterozoic, 12
 - pure command economy, 95
 - pure market economy, 95
 - pyramid of energy flow, 23
- R**
- Rachel Carson, 109
 - Radiant energy, 2, 5
 - Radon, 72
 - Rain splash, 53
 - range of tolerance, 22
 - rangeland, 68
 - Rangelands, 56
 - reactor core, 61
 - refuse-derived incinerator, 79
 - Renewable energy, 63
 - replacement fertility, 31
 - Research Natural Areas, 70
 - residual, 48, 48
 - Resource Conservation and Recovery Act, 110
 - Rhizobium, 8
 - Richter scale, 13
 - Rill erosion, 53
 - rising sea levels, 92
 - Risk assessment, 83
 - Risk management, 83
 - rock cycle, 14
 - runoff, 41
- S**
- Safe Drinking Water and Toxic Enforcement Act, 111
 - salinization, 53
 - sand, 52
 - sandy loam, 52
 - sanitary landfill, 78
 - scavengers, 23
 - schistosomiasis, 88
 - Science, § 1(1), § 2(5), § 3(11), § 4(15), § 5(21), § 6(29), § 7(35), § 8(39), § 9(41), § 10(47), § 11(51), § 12(55), § 13(59), § 14(63), § 15(67), § 16(71), § 17(77), § 18(81), § 19(85), § 20(91), § 21(95), § 22(99), § 23(105), § 24(109), § 25(113)
 - Second-growth forests, 69
 - secondary consumers, 23
 - secondary macronutrients, 52
 - secondary succession, 23
 - sector city, 67

- Secure landfills, 78
 sedimentary, 48, 48
 Sedimentary rocks, 13
 Sedimentation, 76
 sediments, 73
 Seed-tree cutting, 69
 seismograph, 13
 semiarid deserts, 25
 Sevin, 74
 shale, 60
 Sheet erosion, 53
 Shield volcanoes, 12
 silt, 52
 silts, 73
 silty loam, 52
 smelting, 49
 Soil degradation, 53
 Soil formation, 14
 soil horizons, 51
 Soil porosity, 52
 Soil sterilants, 74
 Soil tith, 52
 Solar energy, 63
 Solar radiation, 17
 Solid waste, 77
 specialized species, 26
 species, 22
 standard of living, 36
 staple crops, 56
 stratopause, 17
 stratosphere, 16
 Streams and rivers, 24
 Strip cropping, 54
 strip cutting, 69
 Strip-mining, 60
 sub-surface mining, 49, 60
 subduction zone, 12
 Subsistence agriculture, 57
 sulfates, 47
 sulfides, 47
 sulfur dioxide, 71
 sulfur trioxide, 71
 Superfund, 110
 Superfund sites, 117
 surface runoff, 6
 surface tension, 41
 Suspended particulate matter, 72
 sustainable ethic, 106
 Synthetic botanicals, 74
 Systemic chemicals, 74
- T** taiga, 25
- Tar sand, 61
 temperate forests, 25
 temperate grasslands, 25
 teratogenic, 78
 Terracing, 54
 Tertiary consumers, 23
 The 1987 Montreal Protocol on Substances that Deplete the Ozone Layer, 111
 The Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES), 112
 The International Declaration on Cleaner Production, 112
 The Prior Informed Consent Procedure for Certain Hazardous Chemicals and Pesticides in International Trade, 111
 The Rotterdam Convention, 112
 Thermal energy, 2
 thermal pollution, 73
 thermohaline circulation, 87
 thermosphere, 17
 thunderstorm, 18
 tillage, 54
 tolerance limits, 22
 topsoil, 51
 tornado, 18
 Toxic Substances Control Act, 110
 Tradable Pollution Permits (TPPs), 96
 traditional agriculture, 56
 transform boundary, 12
 transition area, 70
 transitional stage, 31
 Transpiration, 6
 tropical forests, 25
 tropical grasslands, 25
 tropopause, 16
 troposphere, 15, 21
 tsunamis, 13
 tundra, 24
 typhoons, 18
- U** UCCP, § 1(1), § 2(5), § 3(11), § 4(15), § 5(21), § 6(29), § 7(35), § 8(39), § 9(41), § 10(47), § 11(51), § 12(55), § 13(59), § 14(63), § 15(67), § 16(71), § 17(77), § 18(81), § 19(85), § 20(91), § 21(95), § 22(99), § 23(105), § 24(109), § 25(113)
 UN Framework Convention on Climate Change, 112
 UNEP and the International Olympic Committee (IOC), 112
 United Nations, 109

- United Nations (UN), 111
 - United Nations Human Development Index, 95
 - upwelling, 18
 - utilitarian, 107
- V** Volatile organic compounds (VOCs), 72
- volcano, 12
- W** water, 5, 41
- Water Acidification, 76
 - Water erosion, 53
 - Water Pollution Control Act, 110
 - water table, 6, 42
 - watershed, 41
- Watt, 3
 - weather, 18
 - weathering, 14
 - Wetlands, 24
 - wild strains, 56
 - Wilderness Act, 110
 - Wilderness Act of 1964, 70
 - wilderness areas, 55
 - wind turbines, 64
 - Windbreaks, 54
 - winds, 17
 - work, 1
 - World Bank, 109, 111
 - World Trade Organization, 109

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