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Module 1

Chapter 1

Environment: includes all of Earth's biotic components and abiotic components.

- Scientific
- Ethical
- Political
- Economic
- Social relationships
- Institutions

Biotic: Living things. Animals, plants, forests, soils, microbes, and people that occupy the landscape.

Abiotic: Nonliving things with which we interact. Continents, oceans, clouds, rivers, and icecaps.

Federal government passed Canada's first **environmental legislation** in **1971**

Environment Canada: department of the federal government that is most directly responsible for the protection of the environment.

- Preserving and enhancing the quality of the natural environment
- Protecting and conserving renewable resources and water resources
- Enforcing Canada's sovereignty over our boundary waters
- Forecasting weather conditions and warnings

Environmental Science

- Study of how the natural world works
- How our environment affects us
- How we affect our environment.
- Interdisciplinary** field of study: one that employs concepts and techniques from numerous disciplines and brings research results from these disciplines together into a broad synthesis
- Encompasses the natural sciences and the social sciences
- Pursuit of scientific knowledge about the workings of the environment and our interactions with it

Environmental Scientists

- Strive to understand how Earth's natural systems function
- How humans are influence by those systems
- How we are influencing those systems
- Maintain an objective approach in their work

Science: systematic process for learning about the world and testing our understanding of it

- Informs and responds to political and social influences, without being overly influenced by them
- Human endeavour, can never be entirely free of political or social influence

Democratization of science, i.e. making the science of our world accessible and understandable to as many people as possible

Environmentalism: social movement dedicated to protecting the natural world (and humans) from undesirable changes brought about by human choices

Rapa Nui (story)

- Historical evidence that civilizations may crumble when pressures from population and consumption overwhelm resource availability

Jared Diamond

- 2005 book, *Collapse*
- Identified 5 critical factors to determine the survival of civilizations
 1. Climate change
 2. Hostile neighbours
 3. Trade partners
 4. Environmental problems
 5. Society's response to environmental problems (only factor that is wholly controllable. Crucial determinant of survival)

Natural resources: substances and energy sources provided by the environment that are of economic value, and that we need for survival and for the functioning of our modern society

- Lying on a continuum from the most to the least renewable

Renewable natural resources: natural resources that are replenishable over short periods

- Sunlight, wind, and wave energy are continuously replenished and essentially inexhaustible
- Renewable resources are sometimes called *stock and flow resources*

Non-living renewable resources include ground water and soil

- Continue to be available as long as they are not extracted more quickly than they are replenished.
- Rates of replenishment of such resources are limited by the rates of physical processes

Non-renewable resources: oil and coal. Not renewed on a humanly accessible time scale.

Resources such as fish, timber, ground water, and soil are renewable and can continue to be available if we are careful not to deplete or damage them.

Resource management: strategic decision-making and planning aimed at balancing the use of a resource with its protection and preservation

- Goal: balance the rate of use with the rate of renewal or regeneration

Non-renewable natural resources such as fossil fuels and mineral deposits

The natural environment supports the life and well-being of humans (and other organisms) by the provision of both goods and services

Goods: tangible material things that can be extracted from the environment.

- Food, water, mineral, and energy resources, and materials for shelter
- Not all goods are tradable commodities (crops, lumber, oil, and minerals)

Services: functions and processes that are useful or even vital in the support of living organisms

- Intangible* equivalent of goods
- Theoretically possible to assign dollar values to them (not always easy or straightforward)

Applying a value to environmental goods and services is fundamentally flawed

- Implies that nothing in the world has value unless it is valuable to humans
- Many argue that other species, the environment, the biosphere, and even the planet as a whole have intrinsic/existence value
- They are important and even possess rights simply because they exist, rather than by virtue of any utility that they provide for humans

Carrying capacity: measure of the ability of a system to support life

- Number of individuals that can be supported by an area of land
- When it is exceeded: population of that species will decline or collapse, or the system itself will be altered, damaged, or depleted

Tragedy of the Commons: each individual withdraws whatever benefits are available from the common property as quickly as possible until the resource becomes overused and depleted

- Carrying capacity of the pasture will be exceeded, and its food production capacity will collapse

How you perceive your environment, how you react to change, and what impact those changes may have on how you live your life is affected by:

- Who you are
- Where you live
- What you do
- Your income
- Your gender
- Your socioeconomic status

Periods of Societal Change triggered remarkable increases in population size, along with greatly increased environmental impacts

- Paleolithic Period:** 2.5 million years ago. Early humans began to shape and use stones as tools

-**Neolithic/Agricultural Revolution:** 10 to 12 thousand years ago. Transition from nomadic, hunter-gatherer lifestyle to a settled, agricultural way of life.

-**Industrial Revolution:** mid-1700s. Shift from rural life, animal-powered agriculture, and artisanal manufacturing to an urban society powered by fossil fuels. Marked the beginning of industrial-scale pollution and many other environmental and social problems. Since the start, atmospheric carbon dioxide concentrations have risen to a level not present for millions of years

-**Medical-Technological Revolution:** today. Advances in medicine and sanitation, the explosion of communication technologies, and the shift to modern agricultural practices have allowed more people to live longer, healthier lives. But, presented environmental challenges.

IPAT Model: represents our total impact on the environment as the product of population, affluence (consumption), and technology.

$$-I = P \times A \times T$$

Ecological Footprint (EF)

-Inverse of carrying capacity

-Measure of the land (and water) required to support an individual

Biocapacity: capacity of a terrestrial or aquatic system to be biologically productive and to absorb waste (i.e. carbon dioxide)

-Population exceeds or overshoots the biocapacity of a system, system is at risk of permanent damage

Our species are exceeding the biocapacity of the planet and depleting renewable resources faster than they are being replenished

Sustainability: guiding principle of modern environmental management

-**Sustainable development** requires all three sets of goals to be maximized

-Environmental goals

-Social goals

-Economic goals

It is society's poorer people who suffer the most from environmental degradation

Development

-Economists describe it as the use of natural resources for economic and social advancement

Biodiversity: cumulative number and diversity of living things.

-Declining dramatically

2008, group of scientists led by **Johan Rockstrom** from the **Stockholm Resilience Centre**

-Goal: how humanity is doing in managing its impacts on the environment

Group identified nine key systems that are crucially important to the Earth system as a whole

1. stratospheric ozone layer

2. biodiversity
3. toxic chemicals dispersion
4. climate change
5. ocean acidification
6. freshwater consumption and the global hydrological cycle
7. land system change
8. nitrogen and phosphorus inputs to the biosphere and oceans
9. atmospheric aerosol loading

-Important in maintaining earth and its life-supporting functions, their global influence, and for the potential for their rapid or irreversible change

-3 of the safe boundaries have been crossed: climate change, the nitrogen cycle, and biodiversity loss

-Scientists propose we have entered a new geological epoch, characterized by human impacts on environmental systems, **Anthropocene Epoch**

Readings

Definition of the Brundtland Report (<https://www.britannica.com/topic/Brundtland-Report>)

-Also called our common future

-Introduced the concept of sustainable development and described how it could be achieved

-Explored environmental degradation

-Attempted to understand the interconnections between social equity, economic growth, and environmental problems

-Developed policy solutions that integrated all three areas

-WCED (Brundtland Commission) to propose long-term solutions for bringing about sustainable development and continuing it in the 21st century

-Topics include: sustainable development, role of the international economy, population and human resources, food security, species and ecosystems, energy, industry, and proposed legal principles for environmental protection

-Most known for the definition of sustainable development: “Meets the needs of the present without sacrificing the ability of future generations to meet their needs”

-Prior to **Brundtland Report** people aware of human impact on the environment might have thought *sustainable development* to be an oxymoron

-Pointed out that the environmental impact of an additional individual born in an industrialized country was much greater than of one born in a developing country

Module 2

Chapter 2

March 11th 2011, **Tohoku earthquake** in Japan.

- Magnitude: 9.0 on the Richter scale
- ~16,000 people killed

Tsunami: powerful surge of sea water generated when an offshore earthquake displaces large volumes of rocks and sediment on the ocean bottom, pushing the overlying ocean water upward.

How Scientists Investigate the Environment

- They develop and refine their ideas about how the world works by designing tests to determine whether the ideas are supported by evidence
- Scientific inquiry is an incremental approach to the truth

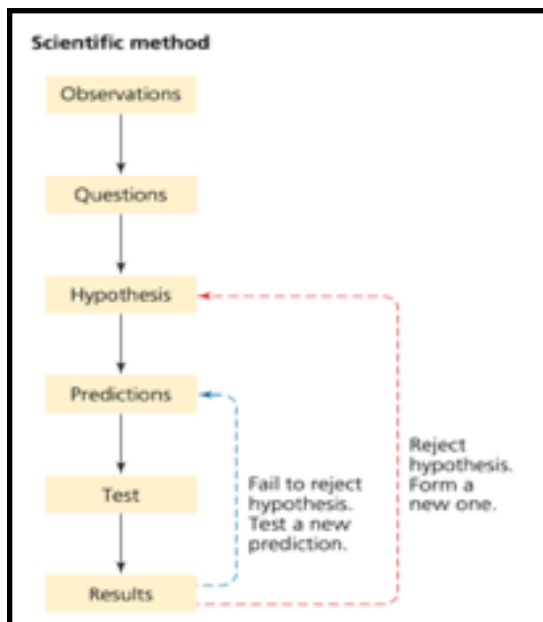
Scientific method: technique for testing ideas by making observations and by gathering evidence

Science is an active, creative, imaginative process.

Scientists from different fields also approach their work differently because they deal with dissimilar types of information.

- Natural scientist** (i.e. chemist) conducts research differently from a **social scientist** (i.e. sociologist)

Scientific method relies on the following **assumptions:**



- The universe functions in accordance with fixed natural laws that do not change from time to time or from place to place
- All events arise from some cause and, in turn, lead to other events
- We can use our senses and reasoning abilities to detect and describe natural laws that underlie and that cause-and-effect relationships we observe in nature
- See figure below

Hypothesis: educated guess to explain a phenomenon or answer a scientific question.

- Null hypothesis: a statement that the scientist expects no relationship between variables

Predictions: specific statements that can be directly and unequivocally tested

Experiment: activity designed to test a prediction by manipulating variables

- Variables:** conditions that can change
- Independent variable:** variable the scientist manipulates
- Dependent variable:** one that depends on the independent variable
- Experiments can establish **casual relationships:** showing that changes in one variable cause predictable changes in another variable

Controlled experiment: an experiment the scientist controls for the effects of all variables except the one being tested – the dependent variable.

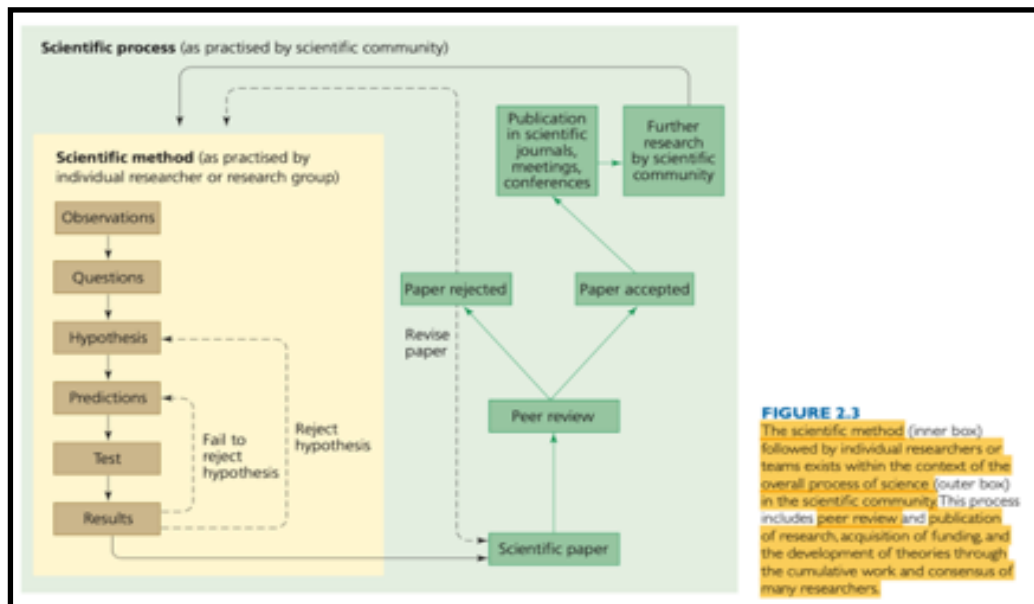
Control: to compare the results of the experiment to an identical circumstance that has not been manipulated

Correlation: searching for relationships and patterns among variables

- Correlation study is sometimes the best approach. But it is not as strong evidence of causal relationships from experimentation

Manipulative experiment: an experiment in which the researcher actively chooses and manipulates the independent variable

- Involves physics and chemistry
- Provide strong causal information



- Not always possible to use

Disciplines that do not fit the *physics model* of science sometimes rely on **natural experiments** instead

- Preserve real-world complexity that manipulative experiments may sacrifice
- Cannot show causation

Scientific method is embedded within a larger process that takes place at the level of the scientific community as a whole.

Theory is a widely accepted, well-tested explanation of one or more cause-and-effect relationships, which has been extensively validated by extensive research

- Consolidates many related hypotheses that have been tested and supported by a large body of experimental and observational data

Matter: all of the material in the universe that has mass and occupies space

- Solid, liquid, or gaseous
- Conservation of matter:** May be transformed from one type of substance into others, but cannot be created or destroyed

Element: chemical substance with a given set of properties

- Fundamental type of matter
- Cannot be broken down into substances that have other properties
- Those abundant in living organisms: carbon, nitrogen, hydrogen, and oxygen

Elements are composed of **atoms:** smallest components that maintain the chemical properties of that element

- Protons: + particles
- Neutrons: no electric charge
- Atoms have a defined number of protons: atomic number
- It's nucleus is surrounded by negatively charged particles known as electrons

Isotopes: atoms of the same element with differing numbers of neutrons

Molecules: combinations of two or more atoms

- A molecule composed of **atoms of two or more different elements** is called a **compound**

When atoms in a molecule share electrons, they generate a **covalent bond**

- If the strength of attraction between the atoms in a compound is sufficiently unequal, an electron may actually be transferred from one atom to another: **ionic bond**
- Ionic compounds** include salts (NaCl)

Elements, molecules, and compounds can also come together in mixtures without chemically bonding or reacting

- This mixture of two or more substances is called a **solution**

-Applicable to liquids, gases, and solids

Scientists think life originated in water and stayed there for 3 billion years before moving onto land

Hydrogen bond: oxygen atom of one water molecule is weakly attracted to the hydrogen atoms of another

Chemical structure give water several properties:

-Water remains liquid over a wide range of temperature. **Holds liquid form from 0°C to 100°C.** Water-based biological processes can occur in a very wide range of environmental conditions.

-**Water exhibits strong cohesion.** Facilitates the transport of chemicals, nutrients, and waste, in plants and animals and in the physical environment

-It has a **high heat capacity.** Can absorb a large amount of heat with only small changes in its temperature. Helps stabilize systems (organisms, ponds, lakes, or climate systems) against change.

-**Ice is less dense than liquid water.** In ice, each molecule is connected to neighboring molecules by stable hydrogen bonds that form a spacious crystal lattice. Liquid water, the molecules are closer together and less well organized. Ice floats on water because of this.

Floating ice has an insulating effect that can prevent water bodies from freezing solid in the winter.

-Water **cooled to 4°C increases in density.** But, when **cooled below 4°C** it becomes gradually **less dense.** Surface water cooled below 4°C by winter air will tend to remain at the surface – promoting formation of ice.

-Water molecules bond well with other polar molecules. Positive end of one molecule bonds readily to the negative end of another. **Water can hold in solution, or dissolve, many other molecules.**

-**Transparency to light.** Without this, there would be no photosynthesis – an ultimate source of energy for almost all organisms living in water.

Water is known to be a **universal solvent** as it is able to dissolve many things.

Aqueous solution: a solution in which water is present as a solvent

-Small number of water molecules dissociate and form **hydrogen ions** and **hydroxide ions.**

-Product of these ion **concentrations** are **always the same**

-Concentration of one increases, the concentration of the other decreases

-Pure water contains equal numbers of these ions, being **neutral**

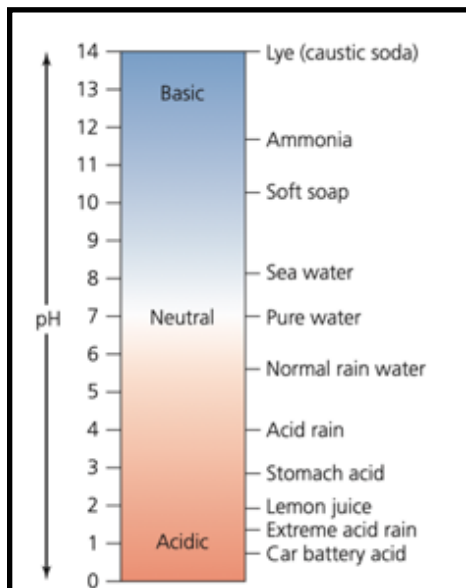
Acidic: H⁺ concentration is greater than the OH⁻ concentration

-The stronger the acid, the more readily dissociation occurs and H⁺ ions are released

Basic: OH⁻ concentration is greater than the H⁺ concentration

pH Scale:

Organic compounds: consist of carbon atoms joined by covalent bonds



-Often joined with other elements: nitrogen, oxygen, sulphur, and phosphorus

Inorganic compounds: are not organic because they lack the carbon-carbon bonds

-Water

Hydrocarbons: consists of carbon and hydrogen

- Other elements may enter the compound, as impurities
- Smallest (lightest-weight) exist in a gaseous state at normal temperatures and pressures
- Larger (heavier) hydrocarbons are liquids
- Hydrocarbons more than 20 carbon atoms are normally solids

Polymers: organic compounds sometimes combine to form long chains of repeated molecules

- Proteins, nucleic acids, and carbohydrates
- Lipids: not polymers but fundamental to life

Proteins, nucleic acids, carbohydrates, and lipids are referred to as **macromolecules** because of their large size

Proteins: consist of long chains of organic molecules called amino acids

- Organisms combine up to 20 different types of amino acids into long chains to build proteins
- Folding pattern affects the protein's function
- Some proteins help produce tissues (skin, hair, muscles, and tendons), store energy, transport substances, act in immune system, and act as hormones.
- They can also serve as enzymes, molecules that catalyze, or promote, certain chemical reactions, such as digestion

Nucleic acids: direct the production of proteins

- DNA & RNA carry the hereditary information for organisms and are responsible for passing traits from parents to offspring

- Composed of **nucleotides:** structural units made of a sugar molecule, a phosphate group, and a nitrogenous base

- Genes:** Regions of DNA coding for particular proteins that perform particular functions

Carbohydrates: consist of atoms of carbon, hydrogen, and oxygen.

- Glucose:** provides energy that fuels plant and animal cells. Serves as a building block for complex carbohydrates

- Cellulose:** complex carbohydrate found in leaves, bark, stems, and roots of plants, as well as some bacteria, fungi and algae. Important organic compound.

Lipids: they do not dissolve in water

- Fats and oils

- Convenient forms of energy storage

- Resembles gasoline as it effectively stores energy and releases it when its burned

- Phospholipids** are similar to fats but have one **hydrophobic** (water repellent) side and one **hydrophilic** (water attracting) side, allowing them to be the primary component of animal cell membranes.

Synthetic polymers are human made, which are called plastics.

- Versatile and resist chemical breakdown

- Make our lives easier

- Waste and pollution they create when we discard them is long-lasting

Energy: capacity to change the position, physical composition, or temperature of matter

- A force that can accomplish work

Types of Energy:

Potential energy: energy of position

- Chemical energy:** is potential energy held in the bonds between atoms

- Can occur as nuclear binding energy and as stored mechanical energy

Kinetic energy: energy of motion

- Thermal energy

- Light energy

- Electrical energy

- Sound energy

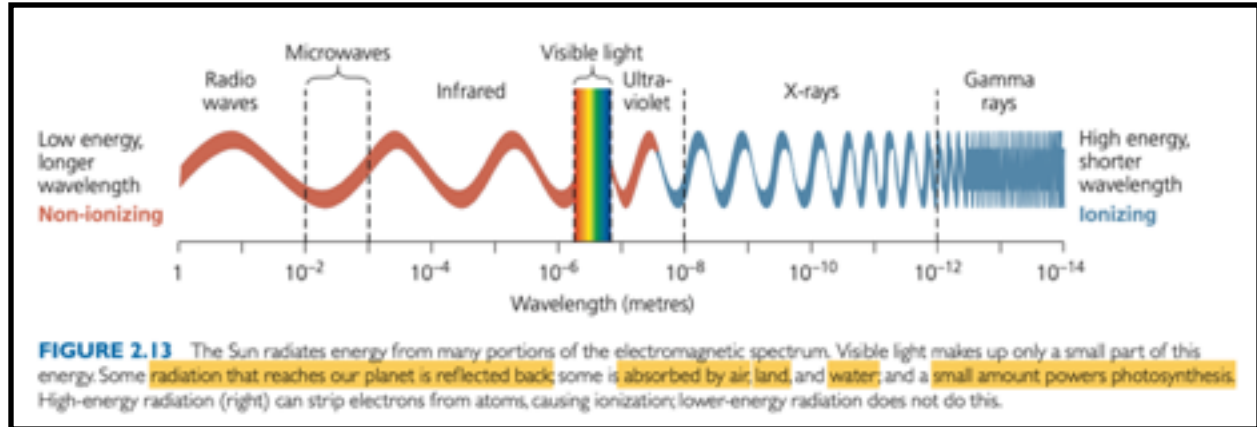
- Involves movement of electrons, atoms, molecules, or objects

First law of thermodynamics: energy can change from one form to another, but it cannot be created or destroyed

Second law of thermodynamics: nature or quality of the energy will change from a more-ordered state to a less-ordered state if no force counteracts this tendency

-In every transfer of energy, some energy is lost. Not destroyed, but converted into a less-usable form

Electromagnetic spectrum: range of wavelengths of radiation from shortest (gamma radiation) to longest (radio waves)



- Sun releases radiation from the electromagnetic spectrum
- Some is visible light
- Most energy is reflected and absorbed

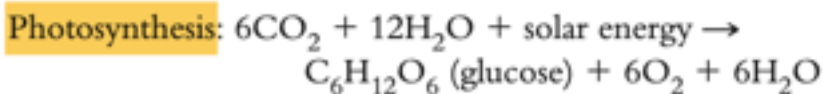
Autotrophs: organisms that produce their own food from the Sun's energy

- Primary producers
- Green plants, algae, and cyanobacteria

Photoautotrophs: turn light energy from the Sun into chemical energy via the process of photosynthesis

Photosynthesis: sunlight powers a series of chemical reactions that convert carbon dioxide and water into sugars, transforming low-quality energy from the Sun into high-quality energy the organism can use

- Turns light energy from the sun into chemical energy
- Green plants can draw up water from the ground through their roots, absorb CO₂ from the



air through their leaves, and harness sunlight

Heterotrophs: organisms that gain their energy by feeding on other organisms

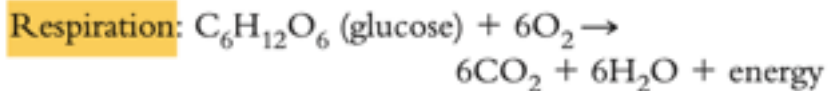
- Consumers
- Eat plants: primary consumers
- Eat animals that have eaten plants: secondary consumers

Cellular Respiration: to release the chemical energy of glucose, cells use the reactivity of oxygen to convert glucose back into its original starting materials

- Reverse photosynthesis
- Oxidizes glucose to produce carbon dioxide and water

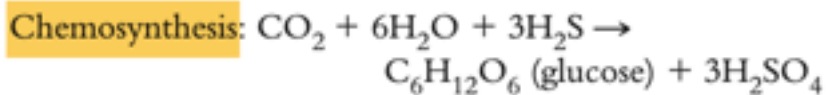
Geothermal energy: heat that emanates from Earth's interior

- Powered by radioactivity: natural phenomenon that involves the release of radiation by radioisotopes as their nuclei spontaneously decay



Chemosynthesis: bacteria in deep-sea vents use the chemical-bond energy of hydrogen sulphide (H₂S) to transform inorganic carbon into organic carbon compounds

- Energy from this reaction passes through heterotrophs and they gain nutrition from **chemoautotrophic** bacteria that use the oxidation of chemicals like H₂S as a source of energy to generate organic matter



Core: planet's center

- Dense
- Consists of iron, solid in the inner core, and molten in the outer core

Mantle: surrounds the core

- Thick layer of rock
- Upper mantle: **asthenosphere** contains a softer rock
- Lithosphere:** harder rock above the asthenosphere. Includes the uppermost mantle and the **crust**

Crust: thin, brittle, low-density layer of rock that covers Earth's surface

- What we live on

Intense heat from inside the planet rises from core mantle crust

- This heat drives great movements in the mantle, pushing the mantle rock upward (warms) and downward (cools)
- Process is called **convection**

Plate tectonics: movement of lithospheric plates

- Planet consists of 15 major tectonic plates

Three main types of plate boundaries: **divergent**, **transform** and **convergent**

Divergent: tectonic plates move apart from one another

- Magma rises upward to the surface, forming new crust as it cools and solidifies

Transform: tectonic plates move past one another laterally

- Plate boundaries that are marked by strike-slip faults

-**Fault:** fracture in Earth's crust, along which the blocks of rock on either side are displaced relative to one another

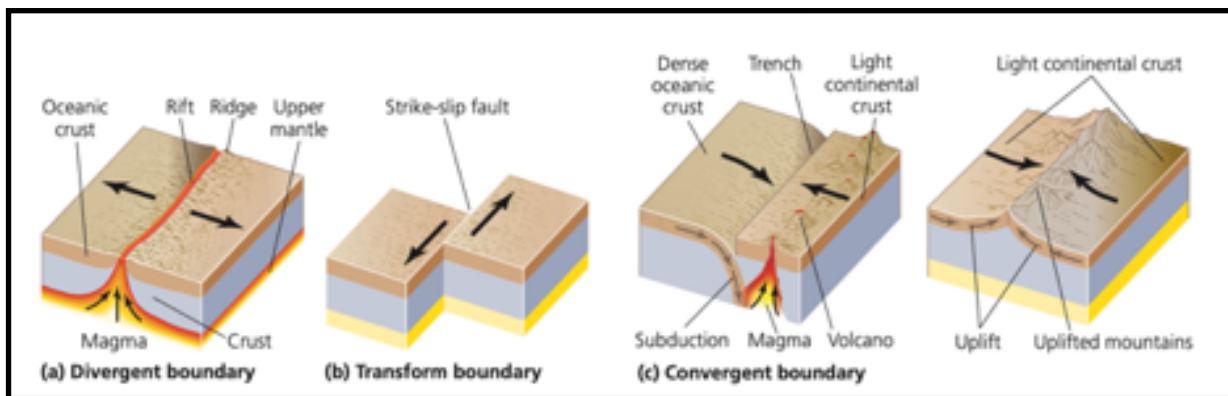
- Two plates meet along a strike-slip fault, they **slip and grind alongside one another horizontally**, in opposite directions

- Creates friction and generates earthquakes**

Convergent: plates move toward one another

- Come together, converge or collide
- One plate may be subducted beneath another, leading to volcanism
- If only continental plates are involved, high mountain ranges are formed: **continental collision**

Ring of fire: the system of subduction zones and other plate boundaries that encircles the Pacific ocean



- Circum-Pacific
- Matches patterns of the plate boundaries

Earthquakes: manifestation of the tremendous power of plate tectonic motion

- Along plate boundaries, and other places where faults occur, built-up pressure is relieved in fits and starts

-Each release of energy causes an earthquake

Landslides: large amounts of rock or soil flow, fall, or slide downhill

-Severe and often sudden manifestation of mass wasting

-**Mass wasting:** the downslope movement of soil and rock due to gravity

Rock cycle: rocks and the minerals that compose them are heated, melted, cooled, broken down, and reassembled

-Understanding the rock cycle enables us to appreciate the formation and conservation of soils, mineral resources, fossil fuels, groundwater sources, geothermal energy sources, and help predict natural hazards

Rock: solid aggregate

-Naturally occurring

-Composed of mineral grains and fragments

-**Mineral:** naturally occurring solid element or inorganic compound that has a crystal structure, a specific chemical composition, and distinct physical properties

Igneous Rock: rock that forms when magma or lava cools

-**Intrusive** or **Plutonic:** magma cools slowly and solidifies while it is below Earth's surface (granite)

-**Extrusive** or **Volcanic:** molten rock is ejected or extruded from a volcano, it cools quickly

Weathering: stripping off one tiny grain (or large chunk) after another

-Caused by forces of wind, water, freezing, thawing, and chemical dissolution

-Through erosion weathered particles of rock are blown, washed, dissolved or transported away

-The transported particles are called **sediment**

Sedimentary rock: formed when sediments are physically pressed together and dissolved minerals seep through sediments and bind the sediment particles together

-**Lithification:** formation of rock through these processes of compaction and cementation

Metamorphic rock: rock is subjected to great heat or pressure, altering its form

Sequestration: long-term storage of carbon

Heterotrophic hypothesis:

-Life evolved from a primordial soup of simple inorganic chemicals (CO₂, O, N) dissolved in the ocean's surface waters or tidal shallows

-Proposes that life forms used organic compounds from their environment as an energy source

Panspermia hypothesis:

- Microbes from elsewhere in the solar system travelled on meteorites that crashed to Earth, “seeding” our planet with life
- Rejected this for a while but in 1969 a meteorite fell in Australia and contained many amino acids

Chemoautotrophic hypothesis:

- Life originated at deep-sea hydrothermal vents

Module 4

Chapter 9

Actions that threaten species and habitats have complex social, economic, and political roots.

- We must understand all of these aspects if we are to develop viable solutions that will contribute to the conservation of species and habitats.

Saving the Polar Bear

- There will be no polar ice by 2060
- COSEWIC: polar bear would not be listed as a threatened species
- Polar bears coming into contact and interbreeding with other types of bears
- Polar bears are appearing more frequently in human settlements
- Traditional Inuit hunting practices are being affected by the loss of sea ice

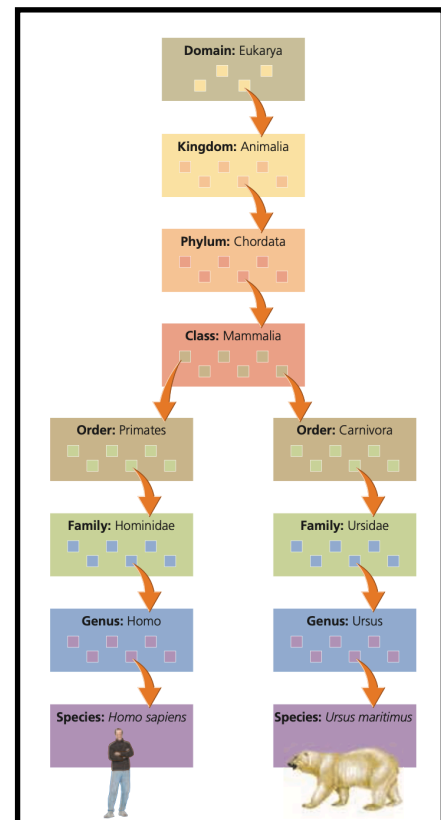
Biological Diversity

- Biodiversity
- Sum total of all organisms in an area, taking into account the diversity of species, their genes, their populations, and their communities
- Species diversity, genetic diversity, & ecosystem diversity

Species

- Distinct type of organism
- A set of individuals that uniquely share certain characteristics and can breed with one another to produce fertile offspring
- Differing criteria to delineate species boundaries: common ancestry or ability to interbreed (examples)
- Every species is given a two-part Latin-based scientific name denoting its genus & species

Taxonomists



- Scientists who classify species
- Use an organism's physical appearance and genetic makeup to determine its species
- Group species into a hierarchy of categories meant to reflect evolutionary relationships

Subspecies

- Populations of a species that occur in a different geographic areas and differ from one another in some characteristics
- Formed by the same processes that drive speciation but result when divergence does not proceed far enough to create separate species

Insects show a predominance over all other forms of life, in terms of number of species.

- About 40% of insects are beetles

Genetic Diversity

- Encompasses the varieties in DNA present among individuals within species, subspecies, and populations
- Provides the raw material for adaptation to changes in local condition
- Populations with more genetic diversity may stand better chances of persisting because their variation better enables them to cope with environmental change
- Populations with depressed genetic diversity may be more vulnerable to disease and may suffer **inbreeding depression**

Inbreeding Depression

- Occurs when genetically similar parents mate and produce weak or defective offspring

Genetic Bottleneck

- A dramatic decrease in population can cause this
- When a limited variety of genetic material is available to be passed along by the small number of surviving individuals to their descendants
- Even if the population number rebounds, the basic genetic diversity of the population will be limited
- Limits the ability of the organism to adapt

Species Diversity

- To quantify the number and variety of species in the world or in a particular region
- Two components of species diversity: species richness & evenness
- **Species Richness**: the number of species in a particular area
- **Evenness/Relative Abundance**: the extent to which the population numbers of individuals of each different species are equal or skewed
- Speciation generates new species, adding to global species richness
- Extinction, the disappearance of a species, decreases species richness
- Immigration, emigration, and extirpation, may increase or decrease species richness locally
- Only speciation and extinction change it in a global sense

Immigration: migration of a species into an area

Emigration: migration of a species away from an area

Ecosystem and Habitat Diversity

- Ecosystem diversity: number and variety of ecosystems in a given area based on variations in climate, topography, soil type
- Ecosystem diversity is directly related to the community types and habitat availability within the specified area (some call it habitat diversity)
- Direct influence on species richness because a wide range and variety of habitats provide opportunities for species to specialize
- Human disturbance can sometimes increase habitat diversity, therefore species diversity may be higher in disturbed areas
- At larger scales, human disturbance decreases diversity because species that rely on large unbroken expanses of single habitat will disappear

Latitudinal Gradient

- Species richness generally increases as one approaches the equators
- Pattern of variation with latitude
- Plant productivity and climate stability play key roles
- Greater amounts of solar energy, heat, and humidity at tropical latitudes lead to more plant growth
- Tropical dry forests and rain forests tend to support far more species than tundra and boreal forests

Generalists

- Species that can deal with a wide range of circumstances but that do no single thing extremely well
- Variable environmental conditions favour generalists

Specialists

- Organisms with very well specialized niches that do particular things very well
- Stable conditions favour specialists

Estimating Species Numbers

- Terry Erwin: pioneered Tree Fogging method
- Insecticide is sprayed into a tree where new species are suspected, and the insects that fall are captured in a tarp, described, and counted, and any new species are identified and sampled
- Yasuni National Park & Biosphere Reserve in Ecuador: most biodiverse place on Earth
- This area is also the focus of intense oil exploitation, which puts much unique habitat at risk
- Margot Bass: 1st comprehensive study of biodiversity in the Yasuni Area
- Found that it is uniquely situated in a location where species richness centres for all four taxonomic groups meet and overlap
- **Species richness centres:** highest biodiversity areas
- The protected area of Yasuni covers just 14% of this particularly important species richness area
- Diego Mosquera installed 20 or so motion-triggered cameras to capture on film many species that are difficult or impossible to see in person, as well as some unusual animal behaviour
- 63 identifiable species

Extinction: occurs when the last member of a species dies and the species ceases to exist

- Once lost, a species can never return
- Occurs when environmental conditions change rapidly or severely enough that a species cannot adapt genetically to the change

Extirpation: the disappearance of a particular population from a given area, but not the entire species globally

Endangered: a species that is in imminent danger of extirpation or extinction

Threatened: likely to become endangered in the near future, if limiting factors are not reversed

Species at Risk Act (SARA)

- Four categories above are the main classifications used by this Canadian act

Palaeontologists estimate that roughly 99% of all species that have ever lived are not extinct

- Leaving only about 1% as the wealth of species on our planet today
- In the past 440 million years, our planet has experienced five distinct episodes of *mass extinction* each of which has eliminated at least half of existing species

Background rate of extinction= natural extinctions for a variety of reasons

- 1 species out of 1000 mammal and marine species would go extinct every 1000 to 10 000 years
- 1 extinction per 1 to 10 million species for mammals and marine species

Mass Extinction Episodes

- 5 in total in the past
- Past 440 million years, mass extinctions have eliminated at least 50% of all species
- Ordovician, Devonian, Permo-Triassic, End-Triassic, Cretaceous-Tertiary

Cretaceous Period

- 65 million years ago
- When the global side effects of a large asteroid impact drove the dinosaurs and many other groups to extinction

Permian Period

- The most severe episode occurred at the end of this period
- 248 million years ago
- 54% of all families, 90% of all species, and 95% of marine species went extinct

Vulnerable

- Species that are of particular concern because of characteristics that make them particularly sensitive to human activities or natural events
- Golden toad (eventually became extinct)

Endemic

- When it occurs nowhere else on the planet
- The golden toad was endemic to the Monteverde cloud forest
- Endemic species face relatively high risks of extinction because all of their members belong to a single, sometimes small, population

Humans may have started a 6th mass extinction

- Biodiversity at all levels is currently being lost as a result of human impacts, most irretrievably in the extinction of species
- Today's ongoing mass extinction is different
- Humans are causing it
- Humans will suffer as a result of it
- May be happening even more rapidly than some of the previous "Big Five" mass extinctions

Major causes of biodiversity loss

- Global extinction rate is 100 to 1000 times greater than background rate
- **The Red List** = an updated list of species facing high risks of extinctions
 - 22% of mammal species
 - 13.1% of bird species
 - 26.8% of amphibian species
- Extinction is only part of the story of biodiversity loss, the larger part of the story is decline in population sizes
- Reasons for biodiversity losses are multifaceted and factors may interact synergistically
- Causes for population decline:
 - Habitat Alteration
 - Invasive Species
 - Pollution

- Overharvesting
- Climate Change

Anthony Barnosky

- Carried out a detailed statistical comparison of the current rate of species extinction with the rates of extinction during the “Big Five” mass extinctions
- Extinctions in the past 500 years do not yet constitute a mass extinction
- Rates of extinction today are much higher than in similar periods during the “Big Five”
- Conservation efforts are urgently needed

Living Planet Index

- Summarizes trends in representative populations of more than 10 000 species of vertebrates

Four primary causes of population decline and species extinction

- Habitat alteration or loss
- Invasive species
- Pollution
- Overharvesting

Habitat Alteration

- Farming replaces diverse natural communities with simplified ones of only one or a few plant species
- Grazing modifies structure and species composition of grasslands. Either type of agriculture can lead to desertification
- Clearing forests removes the food, shelter, and other resources that forest-dwelling organisms need to survive
- Hydroelectric dams turn rivers into reservoirs upstream and affect water conditions and floodplain communities both upstream and downstream
- Urbanization and suburban sprawl supplant diverse natural communities with simplified human-made ones, driving many species from their homes
- Human-induced habitat change benefits *some* species, but very few
- For every species that gains, more lose

- Species that do well in our midst tend to be cosmopolitan generalists that are in little danger of disappearing any time soon
- Greater cause of biodiversity loss today
- Today: habitat is being lost most rapidly in tropical rain and dry forests, and savannahs

Invasive Species

- Introduction of non-native species to new environments, where some may become invasive
- Pushed native species toward extinction.
- Some introductions have been accidental
- Other introductions are intentional
- People have brought food crops, domesticated animals, and other organisms as they colonized new places (generally unaware of the consequences)
- Species native to islands are especially vulnerable to disruption from introduced species because native species have been in isolation for so long with relatively few parasites, predators, and competitors
- Most organisms introduced to new areas perish, but those that survive may do very well
- Invasive species cause billions of dollars in economic damage each year

Pollution

- Air pollution can degrade forest ecosystems
- Water pollution can adversely affect fish and amphibians
- Agricultural runoff (including fertilizers, pesticides, and sediments) can harm many terrestrial and aquatic species
- Exposure to contaminants, mostly transported by atmospheric and oceanic processes from low latitudes, is cited as one of the potential threats to the survival of the polar bear

Overharvesting

- For most species, high intensity of hunting or harvesting by humans will not in itself pose a threat of extinction, but for some species it can
- Ex: polar bear...
- Large in size, few in number, long-lived, and raising few young in its lifetime
- Polar is a classic K-strategist species

- It is the type of animal to be vulnerable to population reduction by hunting
- Past century, hunting has led to steep declines in the population of many other K-selected animals
- Illegal harvesting, poaching, and the sale of contraband wildlife products on the black market contribute to the problem

Climate Change

- Our emissions of carbon dioxide and other “greenhouse gases” that trap heat in the atmosphere are causing average temperatures to warm worldwide
- Modifying global weather patterns and increasing the frequency of extreme weather events
- Global climate change will accelerate and become more severe in the years ahead until we find ways to reduce our emissions from fossil fuels
- Extreme weather events such as droughts put increased stress on populations
- Warming temperatures are forcing species to move toward the poles and to higher altitudes

More people = More Consumption = More Habitat Alteration = More Invasive Species = More Pollution = More Overharvesting = More Climate change

Biodiversity Provides Ecosystem Services

- Intact forests provide clean air and buffer hydrologic systems against flooding and drought
- Native crop varieties provide insurance against disease and drought
- Abundant wildlife can attract tourists and boost the economies of developing nations
- According to UNEP, biodiversity:

- | |
|--|
| <ul style="list-style-type: none"> ■ provides food, fuel, and fibre ■ provides shelter and building materials ■ purifies air and water ■ detoxifies and decomposes wastes ■ stabilizes and moderates Earth’s climate ■ moderates floods, droughts, wind, and temperature extremes ■ generates and renews soil fertility and cycles nutrients ■ pollinates plants, including many crops ■ controls pests and diseases ■ maintains genetic resources as inputs to crop varieties, livestock breeds, and medicines ■ provides cultural and aesthetic benefits ■ gives us the means to adapt to change |
|--|

- Organisms and ecosystems support a vast number of vital processes that humans could not replicate or would need to pay for if nature did not provide them

Biodiversity Helps Maintain Ecosystem Integrity

- High levels of biodiversity tend to increase the stability of communities and ecosystems
- Increase the resilience of ecological systems: their ability to weather disturbance, bounce back from stresses, and adapt to change
- Decrease in biodiversity could diminish a natural system's ability to function and provide services to our society
- Loss of a few endangered species will really make much difference in an ecosystem's ability to function, just depends which species are removed

Keystone Species: one whose removal results in significant changes in an ecological system

- If a keystone species is extirpated or driven extinct, other species may disappear or experience significant population changes as a result
- Top predators are often keystone species
- Removal of a single individual at the top of a food chain can have impacts that multiply as they cascade down the food chain
- Top predators are among the species most vulnerable to human impact
- Large animals are frequently hunted, and also need large areas of habitat, making them susceptible to habitat loss and fragmentation
- They are also vulnerable to the buildup of toxic pollutants in their tissues through the process of biomagnification

Biodiversity Enhances Food Security

- Benefits agriculture
- California's barley crops annually receive \$160 million in disease resistance benefits from Ethiopian strains of barley

Biodiversity Provides Drugs & Medicines

- People have made medicines from plants for centuries, and many of today's widely used drugs were discovered by studying chemical compounds present in wild plants, animals, and microbes

- Rosy Periwinkle (native plant from Madagascar) produces compounds that treat Hodgkin's disease and a particularly deadly form of leukaemia

Biodiversity Boost Economies through Recreation & Tourism

- Direct source of income through tourism
- Particularly for developing countries in the tropics that have impressive species diversity
- Ex: costa rica

Ecotourism: travel whose main purpose is to experience relatively pristine, undisturbed natural areas

People Value Connections with Nature

- Some argue that there is a deeper importance to biodiversity
- **Biophilia:** the connections that human beings subconsciously seek with the rest of life
- Richard Louv: today's children are increasingly deprived of outdoor experiences and direct contact with wild organisms, they suffer from "**nature-deficit disorder**"
- May damage childhood development and lie behind many of the emotional and physical problems young people in developed nations face today
- As our society's sphere of ethical consideration has widened over time, more people have come to believe that other organisms have intrinsic value and an inherent right to exist

Preservation: implies the maintenance of a natural area or species in a pristine or unaltered state

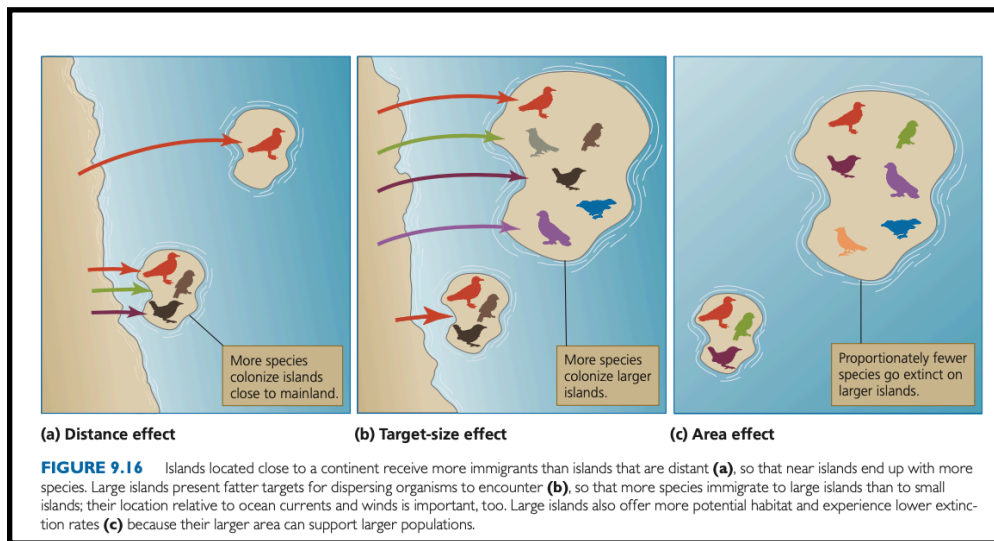
Conservation: implies that natural habitat and species should be cared for and maintained for multiple purposes

Conservation Biology: scientific discipline devoted to understanding the factors, forces, and processes that influence the loss, protection, and restoration of biological diversity

- Conservation biologists choose questions and pursue research with the aim of developing solutions to the problems of habitat degradation and species loss
- They integrate an understanding of evolution and extinction with ecology and the dynamic nature of environmental systems
- Study the impacts of humans on other organisms
- They also attempt to design, test, and implement ways to mitigate human impact
- An applied and goal-oriented science, with implicit values and ethical standards

Equilibrium Model of Island Biogeography (1963)

- E.O. Wilson and Rober MacArthur
- How species came to be distributed among oceanic islands
- Researchers have also applied it to habitat islands
- **Habitat Islands:** patchers of one habitat type isolated within seas of others
- Explains how the number of species on an island results from an equilibrium balance between the number added by immigration and the number lost trough extirpation
- Predicts an islands species richness



- Species-Area Curves: quantify the number of species per area in a particular habitat

Habitat Fragmentation: Forests cut into smaller areas by logging and road building

- Fragmentation of forests and other habitats constitutes one of the prime threats to biodiversity
- Creates a greater proportion of edge habitat relative to core habitat
- Edge and core hold different characters in terms of properties such as light levels, density of vegetation, and moisture
- Greatest impact on large species and migratory species

SLOSS Dilemma (Single Large or Several Small)

- Argument about whether it is better to make wildlife reserves large in size and few in number, or many in number but small in size
- Related Argument: Are corridors of protected land are important for allowing animals to travel between islands of protected habitat
- Connections between fragments provide animals with access to more habitats, and enable gene flow to maintain populations in the long term

Captive Breeding and Cloning are Single-Species Approaches

- Conservation efforts that aim to save species by maintaining their habitat are example of **in situ** conservation
- In Situ: in its natural or original place
- **Ex Situ:** Out of place. (conservation efforts involve the preservation of species in zoos, aquaria, seed banks, arboretums, etc)
- **Captive Breeding:** raising individuals for the purpose of reintroducing them into the wild

Convention on Biological Diversity

- Cornerstone of international efforts to protect biodiversity
- Embodies three goals
 1. To conserve biodiversity
 2. To use biodiversity in a sustainable manner
 3. Ensure the fair distribution of biodiversity's benefits

- | |
|--|
| <ul style="list-style-type: none"> ■ provide incentives for biodiversity conservation ■ manage access to and use of genetic resources ■ transfer technology, including biotechnology ■ promote scientific cooperation ■ assess the effects of human actions on biodiversity ■ promote biodiversity education and awareness ■ provide funding for critical activities ■ encourage every nation to report regularly on their biodiversity conservation efforts |
|--|

Biodiversity Hotspots

- Norman Myers
- Way to prioritize regions that are most important globally for biodiversity conservation
- To qualify:
 1. Must harbour at least 1500 endemic plant species (or 0.5% of the world total)
 2. Must have already lost 70% of its habitat as a result of human impacts and be in danger of losing more (at risk)

Ecoregion: large area of land or water with a geographically distinct assemblage of natural communities that share similar environmental conditions and ecological dynamics, and interact ecologically in ways that are critical for their long term persistence

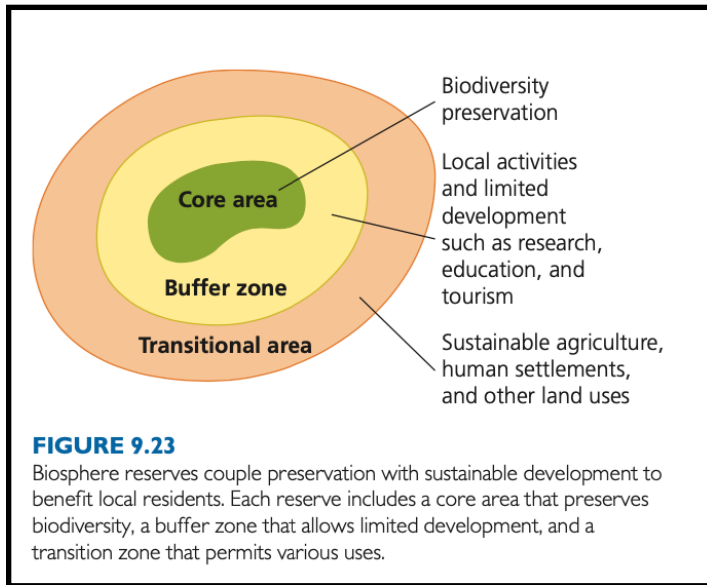
Alfred Runte cited four traditional reasons as to why parks and protected areas have been established:

1. Enormous, beautiful, or unusual features such as the Rocky Mountains and Clayoquot Sound inspire people to protect them—an impulse termed *monumentalism* (**FIGURE 9.22**).
2. Protected areas offer recreational value to tourists, hikers, fishers, hunters, and others.
3. Protected areas offer *utilitarian* benefits and ecosystem services. For example, undeveloped watersheds provide cities with clean drinking water and a buffer against floods.
4. Parks make use of sites lacking economically valuable material resources or that are hard to develop; land that holds little monetary value is easy to set aside.

Wildlife Refuges: protected or semi-protected havens for the conservation of wildlife and habitat as well as being available for hunting, fishing, wildlife observation, photography, environmental education, etc

- Hunters have long been in the forefront of the conservation movement and have traditionally supplied the bulk of funding for land acquisition and habitat management for refuges

Land Trusts: local or regional organizations that purchase land with the aim of preserving it in its natural condition



Module 5

Chapter 10

Clayoquot Sound

- Vancouver, BC
- 1993 activists opposing clear cutting
- **Clear Cutting:** logging practice that removes all trees from an area
- Among the largest undisturbed stands of temperate rain forest left on the planet
- Timber from old-growth forests had long powered BC's economy
- **Old-growth forests:** complex, primary forests in which the trees are at least 150 years old
- By 1993, the Timber industry was cutting thousands of jobs a year because of mechanization, and the looming depletion of old growth threatened to slow the industry
- 1995: provincial government called for an end to clear-cutting at Clayoquot sound
- Two years later, new premier pronounced forest activists *Enemies of BC*
- Wilderness advocates and MacMillan-Bloedel agreed to log old growth in limited areas, using environmentally friendly practices
- Leaving most of the trees standing accomplished what forest advocates had predicted: People from all over the world are now visiting Clayoquot Sound for its natural beauty and are kayaking and whale-watching in its waters
- Ecotourism has surpassed logging as a driver of local economies

Forest covers roughly 31% of Earth's land surface about 4 billion hectares

Not all forests are dominated by trees

Trees are autotrophs

- For photosynthesis to occur and the tree to survive, there are several fundamental requirements:
 - An amenable temperature (specific temperature range varies by species)
 - Air (with which the tree exchanges carbon, hydrogen, oxygen, and nitrogen)
 - Light (the energy source for photosynthesis)
 - Soil (the source of mineral nutrients)

- Water (needed for a variety of reasons)
- The nutrients required for plant growth are supplied through the tree's roots from the soil, using soil water as the transfer medium
- **Micronutrients:** Nutrients that are required by living organisms only in small amounts
- **Macronutrients:** Nutrients that are required in relatively large amounts

Nitrogen fixation by soil-dwelling bacteria converts atmospheric nitrogen into a form that is usable by plants, including trees

- Lightning is another natural process that leads to the fixation of atmospheric nitrogen in the soil
- Thus trees acquire much of their nitrogen from the atmosphere, by way of the soil
- Nitrogen also can come from the decomposition of organisms, fecal matter from animals, and artificial fertilizers

Water acts as a solvent

- Dissolving mineral constituents from particles in the soil
- These are taken up by the tree's roots, to be used as nutrients

Water transports chemicals

- From one part of the tree to wherever they are needed to carry out the metabolic processes that keep the tree alive

Water provides support for cells

- Plant cells require internal water pressure (turgidity) in their cells, or they will wilt and eventually die
- Turgidity: main way that nonwoody plants stay upright

Transpiration: Trees require water to pass from their roots through their trunks and branches and evaporate from their leaf surfaces

- Cools the plant, as well as assisting in the movement of nutrients
- Helps small openings in the leaves, called stomata, to open allowing for the intake of carbon dioxide during photosynthesis

- Transpiration occurs when solar energy causes water to evaporate from leaf surfaces, resulting in negative internal water pressure

Agroforestry: It is useful to plant trees in close proximity to crops

Water and Nutrient Pumping

- When trees draw mineral nutrients and water from depth through their root systems, they deliver them to near-surface soil layers, where they become available for other plants
- Trees also deliver organic material back to the topsoil in the form of litter, which consists of fallen branches and leaves

Forest: a land area with significant tree cover in which the canopy is largely closed

- **Canopy:** the upper level of leaves and branches defined by the majority of the treetops
- **Closed:** continuous

Woodland: wooded (treed) area in which the canopy is more open

- **Opened:** discontinuous. There are some openings between the trees that allow light to penetrate to the ground (or floor) of the forest

Three major types of biomes...

Boreal Forest

- High latitude forest type (mainly in northern hemisphere)
- Characterized by cold, relatively dry climates with short growing seasons
- Taiga: northernmost part of the boreal forest
- Tundra: more open and northern
- Characterized by evergreen, coniferous trees
- Coniferous: trees whose leaves take the form of needles and that produce seed pods in the form of cones

Temperate Forest

- The second major forest biome type, occurs in midlatitude areas of seasonal climate, which typically experience a distinct winter season and summer growing season
- Temperate forests cover much less area globally than boreal forests, in part because people have already cleared so many temperate forests
- Trees in temperate forests must be adapted to a seasonal climate and wide ranges in temperature and precipitation
- Characterized by deciduous trees
- Deciduous trees: trees whose leaves turn colour (senesce) and drop off in the fall, in preparation for a period of winter dormancy

Tropical Forest

- Host extremely diverse flora and fauna, occur in the wet, tropical climates of equatorial South and Central America, equatorial Africa, and Indonesia and Southeast Asia
- Trees remain green because they have year-round growing conditions

Rain forests: their central characteristic is not high temperature, but high rainfall

Shrublands: wooded areas that are covered by smaller, bushier trees, or shrubs, often interspersed with occasional taller trees

Savannah: is an open woodland area with scattered trees and lots of grass, typically grading into grasslands

- **Grasslands:** large open stretches of land dominated by grasses
- Savannahs and scrublands are not forests, it is common to group these biome types with grasslands under the category of **drylands**

Canada's current 348 million ha of forested and other wooded land represents about 9% of the world's forest cover

- 35% of Canada's total land area
- 25% of the world's natural forest
- 30% of the world's boreal forest
- 20% of the world's temperate rain forest

- 64 countries in the world have either no forest at all, or less than 10% of forested land

Canada's forest biomes include many regional variations

Forests of the north

Forests of the west

Forests of the east

Forests are ecologically valuable

- B/c of their structural complexity and their ability to provide many niches for organisms, forests compose some of the richest ecosystems for biodiversity
- Furnish food and shelter for an immense diversity of vertebrate and invertebrate animals
- Countless insects, birds, mammals, and other organisms subsist not the leaves, fruits, and seeds that trees produce

Some animals are adapted for living in the dense treetop canopy

- Providing food for birds
- Arboreal mammals consume fruit and leaves
- Other animals specialize on the sub canopies of trees, and still others utilize the bark, branches, and trunks
- Dead and dying trees are valuable for many species

Understorey: forest floor and the lowest levels of growth

- Give a forest structural complexity and provide habitat for still more organisms

Core: middle of a large forested area

Edge: edge of the forest

- Even if still forested, can be quite different in character from habitat in the forest core in terms of light levels, density of vegetation, and moisture

Forests with a greater diversity of plants, such as tropical rain forests, host a greater diversity of organisms

Trees and forests provide all manner of vital ecosystem services that are of value to people

- Regulating the hydrologic cycle, trees and other forest plants slow runoff, lessen flooding, and purify water as they take it in from the soil and release it to the atmosphere
- Tree branches and leaves physically block and soften the fall of rain, which further protects the soil from degradation
- Forests also store carbon, release oxygen, and act as a moderating influence on climate
- Forest vegetation also stabilizes soil and prevents erosion
- Many direct socioeconomic benefits from forests - everything from food, shelter, and fuel, to employment and income from the harvesting of forest products, to spiritual fulfillment

1.6 billion people worldwide depend on forests

Softwood: timber harvested from coniferous trees

Hardwood: timber that come from deciduous trees

Forests also supply non-wood products in abundance

- Medicinal and herbal products
- Decorative products
- Edible products

Clear-cutting

- Most cost-efficient method in the short term, but it has the greatest impacts on forest ecosystems
- Best-case scenarios, clear cutting of small areas may mimic natural disturbance events such as fires, tornadoes, or windstorms that knock down trees across large areas
- Worst-case scenarios, entire communities of organisms are destroyed or displaced, soil erodes, and the penetration of sunlight to ground level changes microclimatic conditions such that new types of plants replace those that had composed the native forest

Seed-tree approach

- Small numbers of mature and vigorous seed-producing trees are left standing so that they can reseed the logged area

Shelterwood

- Small numbers of mature trees are left in the place to provide shelter for seedlings as they grow

Selection systems: allow uneven-aged stand management

- Only some trees in a forest are cut at any one time
- Include single-tree selection, in which widely spaced trees are cut one at a time, and group selection, in which small patches of trees are cut
- Not ecologically harmless
- Compacts the soil and disturbs the forest floor
- Opening roadways and fragmenting core habitat
- Unpopular with timber companies because they are too expensive

All methods of logging result in habitat disturbance

- All methods change forest structure and composition, increasing edge and diminishing core habitat
- Cause increased soil erosion, leading to siltation of waterways, which can degrade habitat and affect drinking water quality
- Flooding

Forest plantations make up about 7% of forested land globally

Reforestation: planting of trees after logging

Afforestation: the planting of trees where forested cover has not existed for some time (over 50 years)

All trees in a managed stand are planted at the same time, the stands are **even-aged**

- Stands are cut after a certain number of years (rotation time)

Uneven-aged stands, where a mix of ages (and often mixed species) makes the stand more similar to a natural forest

Maximum sustainable yield (MSY)

- Basic principle of renewable resource management, based on harvesting only as much wood as can be regenerated within a year
- Argues for cutting trees shortly after they have gone through their fastest stage of growth, and trees often grow most quickly at intermediate ages
- Trees may be cut long before they have grown as large as they would in the absence of harvesting
- Maximize timber production and harvests efficiency, can cause drastic changes in the ecology of a forest by eliminating habitat for species that depend on mature trees

Clearing of forested land has been one of the very significant human-generated environmental impacts

- Used as an approach in warfare and to flush out game for hunting purposes
- Deforestation: loss of forested area worldwide

Primary forest: long standing natural forest, uncut by people

- Early twentieth century, little of these were left in the United States

Second-growth trees: trees that have sprouted and grown to partial maturity after old-growth timber has been cut

Deforestation must be considered in terms of the net loss to forested area

- Function of the loss of trees as a result of both natural causes and human activities
- According to Natural Resources Canada it affects less than 0.02% of Canada's forested area annually

39% of Earth's terrestrial surface is devoted to agriculture

- 26% supports rangeland
- 13% consists of cropland

Cattles are raised by grazing on open rangelands

- **Rangelands:** grasslands or wooded areas converted for the purpose of supporting livestock
- Overgrazing damages soils, waterways, and vegetative communities
- Cropland agriculture uses less than half the land taken up by livestock grazing, which covers a quarter of the world's land surface

An increasing cause of forest loss, in Canada and elsewhere, is pest infestations

- They come and go
- Insects that have been problematic in Canadian forests: Emerald ash borer, asian long-horned beetle, spruce budworm, and mountain pine beetle
- Mountain pine beetle: highest profile forestry problems in BC since 1990s
- Killed 50% of the total commercial volume of lodgepole pine in the province
- Two primary reasons for the current extraordinary outbreaks
 - Past forest management has resulted in even-aged forests across large regions, and many trees in these forests are now at a prime age for beetle infestation
 - Plantation forests dominated by single species that the beetles prefer are most at risk
 - Second reason is climate change
 - Milder winters allow beetles to over-winter further north, and warmer summers speed up their consumption and reproduction
 - Droughts in recent years have stressed and weakened trees, making them vulnerable to attack
 - By killing trees, they reduce the amount of carbon dioxide pulled from the air, and thereby intensify climate change

About 13 millions ha are deforested each year

- Average yearly rate of deforestation from 2000 to 2014

Developing nations are often so desperate for economic development they impose few or no restrictions on logging

- Their timber is extracted by foreign multinational corporations
- Concession: right to extract the resource

- Many of the short-term economic benefits are reaped not by local residents but by the corporations that log the timber and export it elsewhere
- Local people may or may not receive temporary employment from the corporation, but once the timber is harvested they no longer have the forest and the ecosystem services it once provided

Clearing for plantations encourages further development and eases access for people to enter the forest and conduct logging illegally

- Many people eager to fight climate change had urged the development of biofuels to replace fossil fuels

Professionals who manage forests through the practice of **forestry** must balance the central importance of forests as ecosystems with civilization's demand for wood products

- Sustainable forest management is based on maintaining equilibrium between stocks and flows
- Removal or harvesting of material from the resource by logging should not occur at a rate that exceeds the capability of the resource to replenish or regenerate itself

94% of Canada's forest is publicly owned

- 6% of forested land in Canada is privately owned
- 1.5% by logging companies
- Remainder under federal or territorial control

Multiple use: meaning that forests were to be managed for recreation

Ecosystem-based management: attempts to manage the harvesting of resources in ways that minimize impacts on the ecosystems and ecological processes of the forest

- Aims to preserve forest health, structure, functions, composition, and biodiversity
- Aims to preserve the functional integrity of the forest ecosystem, even while allowing for some resource-extraction activities
- Often come to mean different things to different people

Adaptive Management: systematically testing different management approaches, and learning from approaches that work or don't work

- Monitoring the results and continually adjusting practices as needed, based on what has been learned
- Partnership of science and management
- Can be time-consuming and complicated

Ecological research shows that many ecosystems depend on fire, particularly in the boreal forest

Fire depend on the triad of oxygen, heat, and fuel to progress

- Branches, fallen logs, sticks, and leaf litter accumulate on the forest floor, producing kindling and fuel for future fires
- Overall dry climate or unusually dry weather can cause litter and upper soil layers to be dry, and organic matter to be easily ignited
- **Ground fires:** the litter layer itself burns
- **Crown fires:** upper tree canopy is ignited
- Storms also bring winds that can fan fires
- Lightning is responsible for igniting the majority of naturally induced forest fires
- Other causes of forest fires are volcanic eruptions, and, of course, human carelessness
- Fire suppression leads to a buildup of dead wood, which can fuel catastrophic fires that truly damage forests, destroy human property, and threaten human lives

Global climate change is bringing drier weather to much of the Canadian Prairies, further worsening the wildfire risk

Prescribed burns

- Controlled burns
- To reduce fuel load and improve the health and safety of forests, forest management agencies have in recent years been burning areas of forest under carefully controlled conditions

Salvage logging

- The removal of dead trees, or snags, following a natural disturbance
- Economically: makes good sense. Proponents of salvage logging argue that forests regenerate best after a fire if they are logged and replanted with seedlings

- May reduce future fire risk by removing woody debris that could serve as fuel
- Snags have immense ecological value, the insects that decay them provide food for wildlife, and many birds, mammals, and reptiles depend on snags for nesting and roosting sites
- Removing timber from recently burned land can also cause severe erosion, collapse of stream banks, and soil damage

Past few decades, **fires have burned approximately 2.3 million ha of forest per year in Canada.**

- Year 2014: 4.2 million ha
- Increases in wildfire activity are seen when summers are hotter

Because trees absorb carbon dioxide from the air during photosynthesis and then store carbon in their tissues, forests serve as a major reservoir for carbon

- World's forests store over 280 billion metric tons of carbon in living tissue, more than the atmosphere contains
- Plant matter is burned or when plants die and decompose, carbon dioxide is released and thereafter less vegetation remains to soak it up
- When we cut forests, we worsen climate change

Assisted Migration

- Helping trees and other organisms migrate to more appropriate habitats by purposely introducing them into new locations
- Natural ranges of plant and animal species will shift in response to changes in temperature and precipitation
- Help species adjust by essentially picking them up and moving them to new ranges that suit their needs
- Nina Hewitt from York University's Institute for Research and Innovation in Sustainability
- "Intentional translocation or movement of species outside of their historic ranges in order to mitigate actual or anticipated biodiversity losses caused by anthropogenic climatic change"
- Climate-induced shifts in plant and animal ranges could lead to extinctions in two different ways
- 1st, physiological: an organism simply can't survive in the new temperature and moisture conditions, and can't migrate quickly enough to keep up with the changes, it will die out.

- 2nd: interactions among different species. If climate change causes a prey species to move or become extirpated or extinct, organisms that depend on that species as a food source also will encounter difficulties
- Trees and other forest plants disperse by a wide variety of mechanisms, including seed dispersal by wind, gravity, water, and animals
- Investigating the potential for long-range seed dispersal in trees
- Assisted migration is seen by its supporters as being most appropriate in cases where species are particularly vulnerable to the impacts of climate change, have low dispersal rates, or have habitats that are geographically small, fragmented, or isolated
- We are already seeing impacts of warming in the expansion and northward shifts of range in both native and alien invasive species in the forest ecosystems
- Invasives have socioeconomic impacts: loss of commercially valuable resources, human impacts such as Lyme disease, carried by deer ticks, whose range is expanding northward
- Significant risks and benefits that must be considered before assisted migration is translated into policy
- Benefits: rescuing species from extinction, protecting biodiversity, preserving ecosystems and ecosystem services, and maintaining stocks of commercially valuable resources, including timber
- Risks: significant potential for a translated species to become invasive in its new ecosystem, diversion of funds away from other biodiversity protection measures, such as ecosystem restoration, lack of scientific understanding

Forest loss accounts for as much as 20% of the world's greenhouse gas emissions, as much as all the world's vehicles emit

- International negotiators have outlined a program called *Reducing Emissions from Deforestation and Forest Degradation* (REDD)
- Wealthy industrialized nations provide financial incentives to developing nations to conserve forests

The Canadian Forest Service is preparing for the forest management impacts of climate change by carrying out research to:

- study the influence of Canada's forests on the global carbon balance
- assess the past, present, and future impacts of climate change on Canada's forests
- identify options for using Canada's forests to mitigate climate change
- identify options for helping Canada's forest sector adapt to climate change, including the possibility of assisted migration

Several organizations now examine the practices of timber companies and offer **sustainable forestry certification** to products produced using methods they consider sustainable

- ISO: International Organization for Standardization
- SFI: Sustainable Forestry Initiative
- FSC: Forest Stewardship Council
- Have established standards for the certification of forest management practices
- FSC has the strictest certification standards
- FSC-certified timber harvesting operations are required to protect rare species and sensitive habitats, safeguard water sources, control erosion, minimize pesticide use, and maintain the diversity of the forest and its ability to regenerate after harvesting
- FSC-certification is the best way for consumers of forest products to know what they are supporting sustainable practices that protect forests

Module 3

Chapter 6: Human Population

China: world's most populous nation

- 1.4 billion
- Significant increases in China's population resulted from enhanced agricultural production and a powerful government
- 1970: China's population grew to 800 million people. Average Chinese woman gave birth to 5.8 children
- Government instituted a population control program that prohibited most Chinese couples from having more than one child
- Program began with education and outreach efforts encouraging people to marry later and have fewer children
- Increased accessibility of contraceptives and abortion
- 1975: growth rate dropped from 2.7% to 1.5%
- 1979: instituted a rewards and punishment system to enforce a one-child limit
- Rewards: access to better schools, medical care, housing, government jobs, and longer maternity leaves
- Punishment: social scorn and ridicule, employment discrimination, monetary fines (sometimes half the couple's annual income)
- 2015: policy was terminated
- Quantitative terms: experiment was a major success. Nation's growth rate is now down to less than 0.5%

The rate of global growth is slowing, but we are still **increasing** in absolute numbers, and today more than 7.3 billion of us inhabit the planet.

The world's population has doubled since 1970

- Growing by roughly 80 million people annually
- 2.5 people are added every second
- Nearly all growth has occurred in the last 200 years

Exponential growth: increase in a quantity by a fixed percentage per unit time

- Even if the growth rate remains steady, population size will increase by greater increments with each successive generation
- During much of the 20th century the growth rate actually rose from year to year

Industrial Revolution in England of the 1700s

- Population growth was seen as a good thing
- For parents, more children meant more support for them at an old age
- For society, it meant a greater pool of labour for factory work

Thomas Malthus

- Unless population growth was limited by laws or other social controls, the number of people would outgrow the available food supply until starvation, war, or disease arose and reduced the population
- *An Essay on the Principle of Population*

Paul Ehrlich

- *The Population Bomb*
- Predicted that rapidly increasing human population would unleash widespread famine and conflict that would consume civilization by the end of the 20th century

Sheldon Richman

- There is no population problem
- Overpopulation does not exist, and that the concept of carrying capacity does not apply to people
- "There is no population problem...Human beings create resources. We find potential stuff and human intelligence turns it into resources"

If the human population grows at a rate of 1.2% per year, in 2500 years the people of Earth would weigh as much as Earth itself

- Impossible scenario
- Environmental limitations do exist
- Not all resources can be replaced or reinvented once they have been depleted
- We cannot expand Earth like a balloon to increase its surface area

Many national governments still offer financial and social incentives to encourage their citizens to produce more children

- 3 of every 5 European national governments take the view that their birth rates are now too low, non states that its too high

Environmental degradation and scarcity, particularly in situations of overcrowding in sensitive environments, can lead to migrantism, refugeism, and even armed conflict.

IPAT Model

- Increased population intensifies impact on the environment as more individuals take up space, use natural resources, and generate waste.
- Increased affluence magnifies environmental impact through the greater per capita resource consumption that generally has accompanied enhanced wealth
- Changes in technology may either decrease or increase human impact on the environment
- Sensitivity factor (S) to denote how sensitive a given environment is to human pressures

$$I = P \times A \times T \times S$$

The Science Behind the Story

A Different Population Bomb: The “Household Explosion”

- Increasing tendency to live in smaller and smaller households is putting higher demands on our natural resources
- Connections between households and resource consumption
- Household size has been in decline in some countries for centuries
- Economically developed countries, household size peaked at 5.0 individuals per household in the 1800s
- Decline to about 2.5 individuals per household today
- Sociological factors can lead to proliferation of households: increasing affluence, aging populations, increasing divorce rates, changing preferences for privacy
- Shrinking size of households along with a growing/stable population, means the rate of growth in the number of households has outpaced population growth since 1985
- Consequences of adding households to the planet: require lumber and other building materials, smaller households tend to be less efficient, requires more land, water and energy.
- Require infrastructure such as roads, sewers, and commercial development. All of which increase our ecological footprint

- Dr. Jianguo Jack Liu and his group, suggests that the number of households is a more useful number than population size itself in predicting important environmental variables such as CO₂ emissions, fuelwood consumption, and per capita automobile use
- IPAT model modification: $I = PHoG$
- Impact = (population x personal goods) + (households x household goods)

Four significant periods of societal change appear to have fundamentally altered the human relationship with the environment and increased the carrying capacity, triggering remarkable increases in population size...

Paleolithic Period (Old Stone Age)

- Humans gained control of fire
- Shape and use stones as tools with which to modify their environment
- Made life easier and the environment more manageable
- Population grew substantially
- Little direct evidence about world population dating from that period

Agricultural Revolution (Neolithic - Stone Age Period)

- Transition from a nomadic hunter-gatherer lifestyle to a settled agricultural way of life
- More intensive and manipulative in the production of resources from the land
- Grow their own crops, raise domestic animals, live settled, sedentary lives in villages, they found it easier to meet their nutritional needs
- Began to live longer and to produce more children who survived to adulthood
- Initiated a permanent change in the way humans relate to the natural environment
- Created surplus food
- Agriculture made cities, trades, science, armies possible

Industrial Revolution

- Rural life, animal powered agriculture, and manufacturing by craftsmen, to an urban society powered by fossil fuels
- Improvements in sanitation and medical technology

- Agricultural production enhanced by fossil-fuel-powered equipment, steam engines, and synthetic fertilizers, along with advances in plant and animal breeding

Medical Technological Revolution

- Current major transition
- Globalization of modern medical and technological advancements
- Developments in medicine, sanitation, and pharmaceuticals
- Explosion of communication technologies
- Shift to modern agricultural practices known as the *Green Revolution* that have collectively allowed more people to live longer, healthier lives
- Long-term implications are unknown from this period

Helmut Haberl

- Attempted to measure our consumption of net primary production (NPP)
- NPP: net amount of energy stored in plant and algal biomass as a result of photosynthesis
- Human overuse of NPP diminishes resources available for other species, alters habitats, communities, and ecosystems, and threatens our future ability to derive ecosystem services
- Potential NPP: vegetation that would exist if there were no human influence
- People are harvesting 12.5% of global NPP
- Land use reduces it 9.6% further, and fires another 1.7%
- Makes us responsible for 23.8% of the planet's NPP
- Global map showing human use of NPP reveals that densely populated and heavily farmed regions have the greatest proportional use of NPP
- Map shows heavy appropriation of NPP in areas where population is dense relative to the area's vegetative production

Demography: the study of statistical change in human populations

Demographers study population size, density, distribution, age structure, sex ratio, and rates of birth, death, immigration, and emigration of humans

- Understand population dynamics and the potential environmental impacts of population changes

Population Size

- Population's environmental impact depends on its density, distribution, and composition, as well as on affluence, technology, level of consumption, and other factors

Population Density and Distribution

- Our distribution is clumped at all spatial scales
- Population density is particularly high in regions with temperate, subtropical, and tropical climates (China, Europe, Mexico, southern Africa, India)
- Population density is low in regions with extreme-climate biomes, such as desert, deep rain forest, and tundra
- Human population is less dense at locations far from water
- Uneven distribution means that certain areas bear far more environmental impact than others
- 36 cities are mega cities and the number increases every year
- **Mega Cities:** home to more than 10 million residents
- Growing cities are in developing world, due to wars, conflict, and environmental degradation are driving millions of people out of the countryside and into cities
- Many cities in the developing world are growing at rates of 3 to 5% per year and even higher
- Deserts are easily affected by development that commandeers a substantial share of available water
- Grasslands can be turned to deserts if they are farmed too intensively
- Arctic tundra that is sensitive to disturbance of vegetation, can cause deep melting of permafrost and collapse of soil the scars of which may last for years or even decades

Age Structure

- Population Pyramids: visual tools scientists use to illustrate age structure
- Pyramid with a wide base denotes a large proportion of people who have not yet reached reproductive age, indicates a population soon capable of rapid growth
- Older populations will present new challenges for many nations, as increasing numbers of older people require the care and financial assistance of relatively fewer working-age citizens

Sex Ratios

- For every 100 female infants born, 105 to 106 male infants are born
- Males are slightly more prone to death during any given year of life
- China has a strong traditional preference for boys
- 2010: 118 boys were reported born for every 100 girls
- Overall ratio of males per 100 females for the Chinese population as a whole is currently around 107
- May change where young single men will outnumber young single women by 50 to 60%
- Leading hypothesis for unusual sex ratios is that parents are selectively aborting female fetuses: prenatal sex selection
- Traditionally, Chinese culture has valued sons because they can carry on the family name, assist with farm labour in rural areas, and care for aging parents.
- Daughters, will most likely marry and leave their parents as the culture dictates
- UAE and Qatar: 2 boys survive to adulthood for every one girl
- Undesirable social consequence of leaving many Chinese men single
- Parts of rural China, teenaged girls are being kidnapped and sold to families in other parts of the country as brides for single men

Total Fertility Rate (TFR)

- Average number of children born per female member of a population during her lifetime
- Key statistic demographers calculate to examine a population's potential for growth

Replacement Fertility

- The TFR that keeps the size of a population stable
- For humans, replacement fertility is equal to a TFR of 2.1
- TFR drops below 2.1, the population size (absence of immigration) will shrink

Factors that drive TFR downward

- Increasing urbanization: rural families need children to contribute to farm labour
- If a government provides some form of social security, parents need fewer children to support them in their old age

- Greater education and changing roles in society, women tend to shift into the labour force, putting less emphasis on child rearing
- All these factors come together in Europe where TFR has dropped from 2.6 to 1.5
- Every European nation now has a fertility rate below the replacement level

Birth and immigration add individuals to a population, whereas death and emigration remove individuals

- Birth and death rates as number of births and deaths per 1000 individuals for a given period
- Crude birth rate (nativity or natality) and crude death rate (mortality)
- Subtracting crude death rate from crude birth rate: rate of natural increase. Net increase from births alone
- Technological advances have led to dramatic decline in human death rates, widening the gap between crude birth rates and crude death rates and resulting in the global human population expansion

Refugees: people forced to flee their home country or region

- More numerous in recent decades due to war, civil strife, and environmental degradation
- UN states the number of refugees who flee to escape poor environmental conditions is in the millions per year
- Rwanda: destroyed large areas of forest while trying to obtain fuelwood, food, and shelter to stay alive once they reached Congo

Growth Rates

- Economically developed, industrialized nations have fallen since 1950s
- Developing nations have fallen since late 1960s
- World's least-developed nations, growth rates fall in 1990s
- Rate of growth rate slowing, while absolute size of population continues to increase

Countries with good sanitation, good health care, and reliable food supplies, more people than ever before are living long lives

- Life expectancy for the average person has increased from 46 to 68 years as the global crude death rate has dropped from 20 deaths per 1000 people to 8 deaths per 1000 people

- **Life expectancy:** average number of years that an individual in a particular age group is like to continue to live
- Increase in life expectancy is due to reduced rates of infant mortality
- Urbanization and industrialization have been able to generate personal wealth for their citizens

Demographic Transition: model of economic and cultural change proposed

- Frank Notestein
- Explaining the declining death rates and birth rates that have occurred in Western nations as they became industrialized
- Nations tend to move from a stable pre-industrial state of high birth and high death rates to a stable post-industrial state of low birth and low death rates
- Industrialization, caused rates to fall naturally by first decreasing mortality and then lessening the need for large families
- Death rates fall before birth rates fall
- Population growth is a temporary phenomenon which occurs as societies move from one stage of development to another
- Useful way to understand the interrelationships among birth rate, death rate, and population size, and various social and economic factors that influence them
- Projecting future population
- Demographic transition model has 4 states

Pre-Industrial Stage

- Death rates are high: disease is widespread, medical care rudimentary, and food supplies unreliable and difficult to obtain
- Birth rates are high: people must compensate for high mortality rates in infants and young children by having several children
- Children are valuable as additional workers
- Populations are not likely to experience much growth, which is why the human population was relatively stable

Industrialization and Falling Death Rates

- Transitional stage
- Transition from the pre-industrial stage to the industrial stage
- Declining death rates due to increased food production and improved medical care

- Birth rates remain high because people have not yet grown used to the new economic and social conditions
- Population growth surges

The Industrial Stage and Falling Birth Rates

- Increases opportunities for employment outside the home, particularly for women
- Children become less valuable as they do not help meet family food needs as they did in the pre-industrial stage
- Birth rates fall, closing the gap with death rates and reducing the rate of population growth

Post-Industrial Stage

- Birth and death rates have fallen to low levels
- Population sizes stabilize or decline slightly
- Population dynamics may be different for developing nations that adopt the Western world's industrial model rather than devising their own
- Transition will fail in cultures that place greater value on childbirth or grant women fewer freedoms

Status of Women greatly affects population growth rates

- Affluence alone doesn't determine the total fertility rate
- Drops in TFR have been most noticeable in countries where women have gained access to contraceptives and education, particularly family planning education
- Data clearly demonstrate that in societies where women have little power, substantial numbers of pregnancies are unintended
- 2010: unmet need for worldwide contraception was over 12%
- Amounts to almost 150 million women in marriages or civil unions with an unmet need for contraception
- Worldwide (2015) only 22% of elected government officials in national legislatures are women

Population Control

- Unless India strengthens its efforts to slow population growth, it seems set to overtake China and become the world's most populous nation by 2030
- Government of Thailand relies on an education based approach to family planning that has reduced birth rates and slowed population growth

- 1960s, Thailand's growth rate was 2.3% but today (2014) 0.32%
- Government-sponsored programs devoted to family planning education and increased availability of contraceptives

Poorer societies tend to show higher population growth rates than do wealthier societies

- Poorer nations tend to have higher fertility rates
- Higher overall growth rates, higher birth and infant mortality rates, and lower rates of contraceptive use
- UN estimates 90% probability that 1 billion people will be added to the current population of 1.1 billion in Africa by 2045
- So many people will be added to countries that are poorly equipped to provide for them
- Poverty often results in environmental degradation

Individuals from affluent societies leave a considerably larger per capita ecological footprint

- Addition of 1 Canadian to the world has about as much environmental impact as the addition of 6 Chinese, 12 Indians or Ethiopians, or 40 Somalians
- Recently analysis concluded that humanity's global ecological footprint surpassed Earth's capacity to support us in early 1970s and that our species is now living as much as 50% beyond its means
- Contrast between affluent and poorer societies in today's world is the cause of social as well as environmental stress
- A billion people are currently living on less than \$1.25 per day

Of the 35 million people in the world infected with HIV/AIDS as of 2014, two-thirds live in the nations of sub-Saharan Africa

- One in every 20 adults in sub-Saharan Africa is infected with HIV
- Southern African nations, the figure is more than one in five
- Valuable environmental and farming knowledge is being lost as an entire generation of Africans is decimated
- Demographically fatigued governments face overwhelming challenges related to population growth, including educating and finding jobs for their swelling ranks of young people

World Health Organization & UNAIDS

- Set a 90-90-90 target for 2020
- 90% of people living with HIV would know their HIV status
- 90% of those who know their status would be able to access HIV treatment
- 90% of people on treatment would achieve viral suppression

Millennium Declaration

- Set out a framework of basic goals for humanity over the next decade and a half
- Millennium Development Goals (MDG)
- Both population growth and resource consumption levels will need to be addressed
- New goals for the Post-2015 Development Agenda are being called **Sustainable Development Goals (SDGs)**

90% of children born today are likely to live their lives in conditions far less healthy and prosperous than most of us in the industrialized world are accustomed to

- Although global population is still rising, rate of growth has decreased nearly everywhere
- Most developed nations have passed through the demographic transition, showing that it is possible to stabilize population while still lowering death rates and creating more prosperous societies
- Women are slowly being treated more equitably, receiving better education, obtaining more economic independence, and gaining more ability to control their reproductive decisions

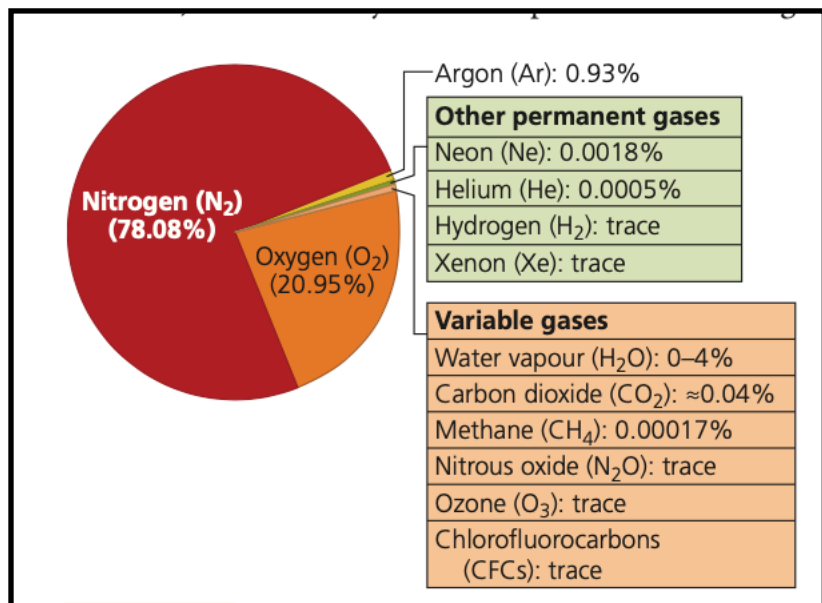
- eradicate extreme poverty and hunger
- achieve universal primary education
- promote gender equality and empower women
- reduce child mortality
- improve maternal health
- combat HIV/AIDS, malaria, and other diseases
- ensure environmental sustainability
- develop a global partnership for development

“Airpocalypse” in Beijing

- Poor air quality became a serious concern for the health and performance of athletes during the Beijing Olympics of 2008
- Pollution levels soared 30x past the World Health Organization (WHO) safe limits
- Beijing: 1500 new cars hit the streets each day
- Blamed outdoor air pollution for 1.2 million premature deaths in China each year
- Minhong Tan found that dust storm activity was stable for many years but has been highly variable since 2000
- Climatic conditions and land use changes are the most important factors in recent dust storm activity

Atmosphere

- Thin layer of gases that surrounds Earth
- We live at the bottom of this layer
- provides us with oxygen, absorbs hazardous solar radiation, burns up incoming meteors, transports and recycles water and nutrients, moderates climate
- Consists of 78% nitrogen gas and 21% oxygen gas
- Remaining 1% is composed of argon gas and minute concentrations of several other gases
- Human activity is altering the quantities of some atmospheric gases, such as CO₂, methane (CH₄), and ozone (O₃)
- Minute concentrations of permanent (remain at stable concentrations) and variable gases (varying concentrations)



Troposphere

- Bottommost layer of the atmosphere
- Provides us with the air we need to live
- Movement of air within it is responsible for the planet's weather
- Contains 3/4 of the mass of the atmosphere, because air is denser near Earth's surface
- Warmest near the surface, because it is heated from below by surface materials that absorb and reradiate solar energy
- -57°C at its highest point
- **Environmental Lapse Rate:** rate at which temperature decreases with height in the troposphere
- **Tropopause:** boundary at the top of the troposphere where temperatures cease to decline with altitude
- Tropopause acts like a cap, limiting mixing between the troposphere and the layer above it, stratosphere

Stratosphere

- 11km to 50km above sea level
- Similar in composition to the troposphere, but 1000x as dry and much less dense
- Attains a maximum temperature of -3°C at its highest altitude but is colder in its lower reaches
- Ozone and oxygen absorb and scatter the Sun's UV radiation, so that much of the UV radiation penetrating the upper stratosphere fails to reach the lower stratosphere
- **Ozone Layer:** amount of ozone is concentrated in a portion of the stratosphere roughly from 17km to 30km above sea level
- Ozone layer reduces the amount of UV radiation that reaches Earth's surface
- UV light can damage living tissue and induce mutations in DNA

Mesosphere

- 50km to 85km above sea level
- Air pressure is extremely low
- Temperatures decrease with altitude

Thermosphere

- Atmosphere's top layer

- Extends to an altitude of 500km
- Heated from above by direct exposure to sunlight
- Fades gradually away
- Karman Line: altitude of 100 km, boundary between the atmosphere and outer space

Air movement in the troposphere is caused by differences in the physical properties of air masses

- Pressure
- Density
- Relative Humidity
- Temperature

Temperature Variations

- Global scale: varies over Earth's surface because the Sun's rays strike some areas more directly than other
- Local scales: varies because of topography, plant cover, proximity of land to water, and many other factors
- Temperature distinguishes one air mass from another

Microclimate: weather pattern

Atmospheric Pressure: force per unit of area produced by a column of air, also decreases with altitude in the troposphere

- Gravity pulls gas molecules toward Earth's surface, causing air to be most dense near the surface, and less dense at higher altitudes

Relative Humidity: ratio of water vapour in a volume of air to the maximum amount it could potentially contain at a given temperature

- Average daytime relative humidity in a desert is 25-30%. Air contains only 1/4 to 1/3 of the water vapour it possibly could at that temperature
- Rain forests, rarely drops below 80%.
- People are sensitive to changes in relative humidity because we perspire to cool our bodies

Air mass: large volume of air that is fairly uniform internally, in temperature, relative humidity, and air pressure, is called an air mass

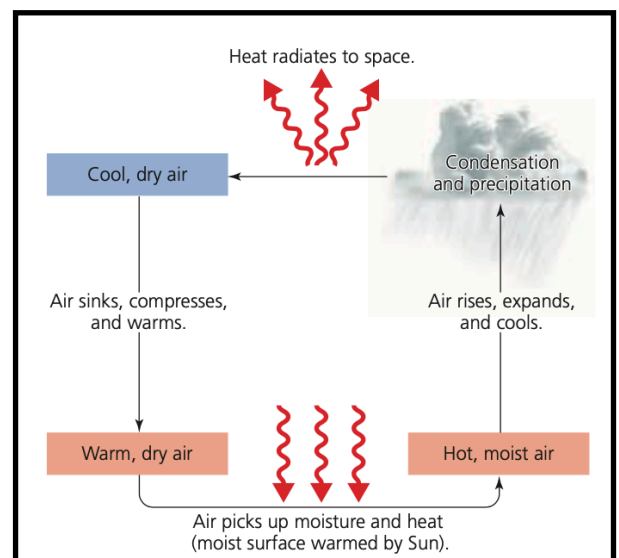
An enormous amount of solar energy continuously bombards the upper atmosphere.

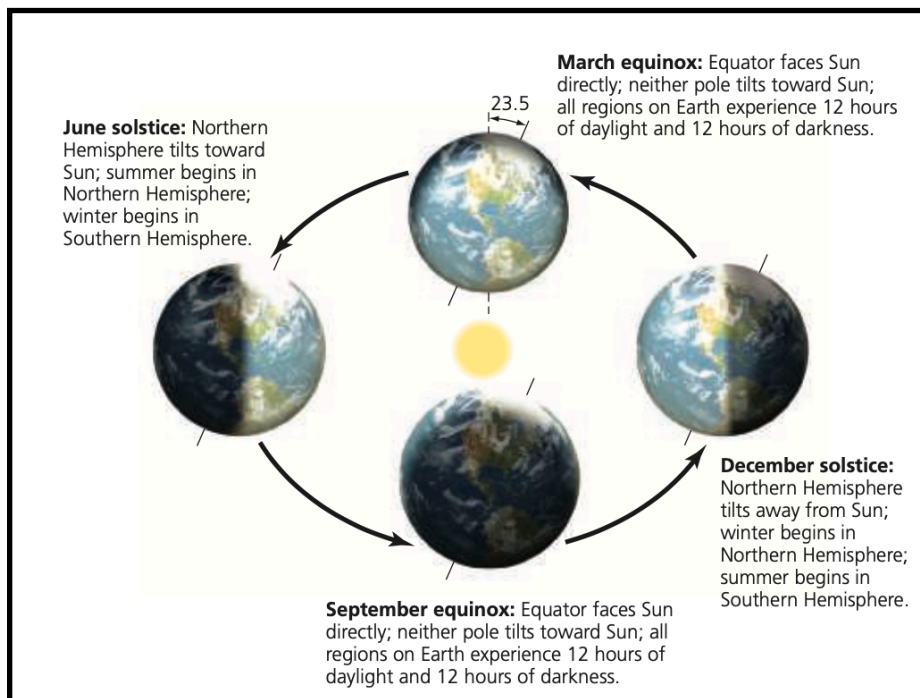
- 70% is absorbed by the atmosphere and planetary surface, while the rest is reflected back into space
- Sunlight that comes into the Earth system heats air in the atmosphere, drives air movement, helps create seasons, and influences weather and climate, in addition to heating surface materials and driving photosynthesis
- Sunlight is most intense when it shines directly overhead and meets the planet's surface at a perpendicular angle. It passes through a minimum of energy-absorbing atmosphere, and Earth's surface receives a maximum of solar energy per unit of surface area
- Solar energy that approaches Earth's surface at an oblique angle loses intensity as it traverses a longer distance through the atmosphere, and it is less intense when it reaches the surface.
- Solar radiation intensity is highest near the equator and weakest near the poles

Earth is tilted on its axis

- 23.5°
- Northern and Southern Hemispheres each tilt toward the Sun for half the year, resulting in the change in seasons
- Near the equator, they experience about 12 hours each of sunlight and darkness every day throughout the year
- Near the poles, the effect is strong, and seasonality is pronounced
- Land, water, and all materials on Earth's surface absorb solar energy
- Air near Earth's surface therefore tends to be warmer and moister than air at higher altitudes

Weather: refers to atmospheric conditions over short





time periods

Climate: describes the pattern of atmospheric conditions found across large geographical regions over long periods

Front: the boundary between air masses that differ in moisture content and temperature (and density)

- Where we typically experience the most active weather

Warm Front: the boundary along which a mass of warmer, moister air replaces a mass of colder, drier air

- Warm, moist air behind a warm front rises over the cold air mass and then cools and condenses to form clouds that may produce light rain

Cold Front: boundary along which a colder, drier air mass displaces a warmer, moister air mass

- The colder air, being denser, tends to wedge beneath the warmer air
- The warmer air rises, expands, and then cools to form clouds that can produce thunderstorms and even tornadoes

High-pressure System: contains air that moves outward away from a centre of high pressure as it descends

- Brings fair weather

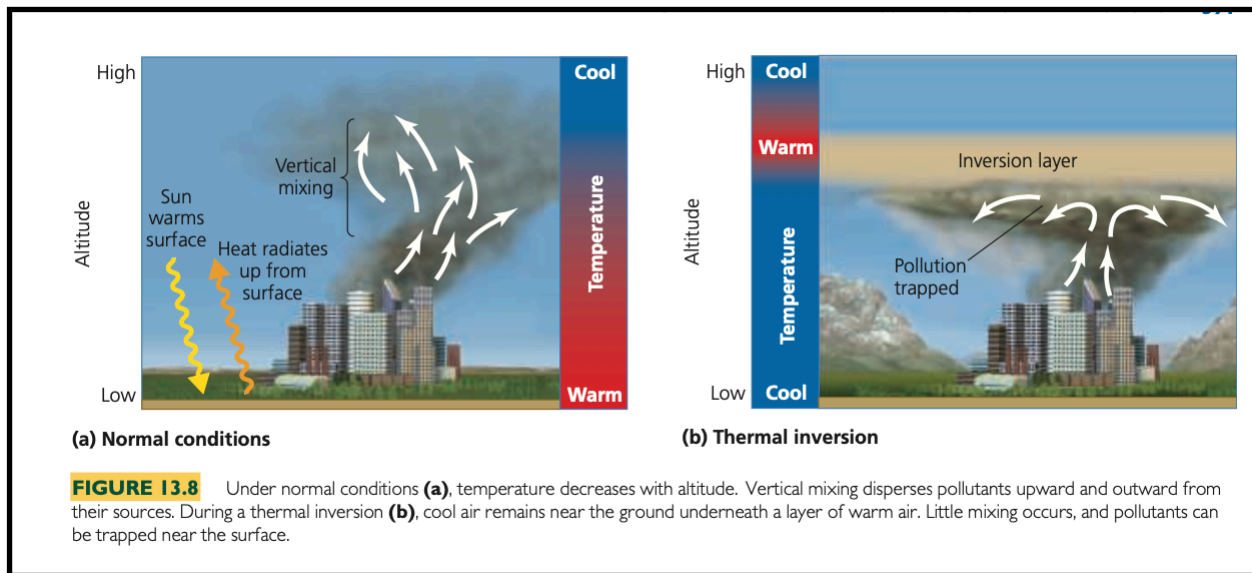
Low-pressure System: air moves toward the low atmospheric pressure at the centre of the system and spirals upward

- The air expands and cools, and clouds and precipitation often result

Urban Heat Island Effect: cities often have ambient temperatures that are several degrees higher than the surrounding suburbs and rural areas

- Results from the concentration of heat-generating buildings, cars, and factories, and people in the city centre

Normal Conditions & Thermal Inversion



Dust Dome: when heated air becomes trapped over cities, the smog and particulate air pollution it carries become trapped as well

Convective air currents contribute to broad climatic patterns

- Near the equator, solar radiation sets in motion a pair of convective cells known as **Hadley cells**
- Here sunlight is most intense, surface air warms, rises, and expands
- It releases moisture, producing the heavy rainfall that gives rise to tropical rain forests near the equator
- After releasing much of its moisture, air diverges and moves in currents
- Cools and descends back to Earth at about 30° latitude north and south
- The descending air has low relative humidity, the regions around 30° latitude are quite arid, giving rise to deserts

Ferrel Cells and Polar Cells

- Lift air and create precipitation around 60° latitude north and south and cause air to descend at around 30° latitude and in the polar regions

Ferrel, Polar, and Hadley cells account for most of the latitudinal distribution of moisture across Earth's surface:

- warm, wet climates near the equator
- arid climates and major deserts near 30° latitude
- moist, temperate regions near 60° latitude
- dry, cold conditions near the poles
- They interact with Earth's rotation to produce the global wind patterns

Locations on the equator spin faster than locations near the poles

- North-south air currents of the convective cells are deflected from a straight path as some portions of the globe move beneath them more quickly than others
- Deflection is called **Coriolis effect**, results in the curving global wind patterns
- It influences the circulation of any freely moving fluid on Earth's surface, but its influence is not noticeable unless the scale of the circulation is quite large

Where **trade winds** meet and are deflected toward the west lies a region with little wind known as doldrums

- Zone where winds from the north and south come together is called **intertropical convergence zone**
- People used these global circulation patterns for centuries to facilitate ocean travel by wind-powered sailing ships

Air pollution: release of harmful substances into the air

Natural sources can pollute

- Winds sweeping over bare, arid terrain can send huge amounts of dust aloft
- Volcanic eruptions release large quantities of particulate matter, as well as sulphur dioxide and other gases, into the troposphere

- Sulphur dioxide reacts with water and oxygen, and then condenses into aerosols, which reflect sunlight back into space and thereby cool the atmosphere and surface
- Burning vegetation also pollutes the atmosphere with soot and gases
- More than 60 mil hectares of forest and grassland burn in a typical year
- Fires occur naturally, but many are made more severe by human action

Air pollution can emanate from mobile or stationary sources, and from point sources or non point sources

Point source: describes a specific spot where large quantities of pollutants are discharged

Non-point source: diffuse, often consisting of many small sources

In rural areas, people may suffer from drift of airborne pesticides from farms, as well as from industrial pollutants transported from cities, factories, and power plants

- Huge numbers of animals at feedlots produce dust as well as methane, hydrogen sulphide, and ammonia
- These gases create objectionable odours and can lead to respiratory health problems

Primary Pollutants: pollutants emitted into the troposphere in a form that can be directly harmful or that can react to form harmful substances

Secondary Pollutants: Harmful substances produced when primary pollutants interact or react with constituents of the atmosphere

Canadian Environmental Protection Act (**CEPA**): provides a list of air pollutants that are subject to legislative control and management.

Environment Canada groups the pollutants of greatest concern into four categories:

Criteria Air Contaminants

- Sulphur dioxide (SO₂): colourless gas with a strong odour
- Sulphur Oxides (SO_x or SOX)
- Nitrogen dioxide (NO₂): highly reactive, foul-smelling reddish brown gas that contributes to smog and acid precipitation
- Nitrous Oxides (NO_x or NOX)

- Particulate matter: composed of solid or liquid particles small enough to be suspended in the atmosphere
- Volatile organic compounds (VOCs or NOX): carbon containing chemicals used in and emitted by vehicle engines and a wide variety of solvents and industrial processes, as well as many household chemicals and consumer items
- Carbon monoxide (CO): colourless, odourless gas produced by the incomplete combustion of fuel
- Ammonia (NH₃): colourless gas with a pungent odour, smell associated with urine
- Tropospheric Ozone: ground-level ozone, shields us from the dangers of UV radiation

Persistent Organic Pollutants

- Can last in the environment for long periods of time
- Are capable of travelling great distances of air because they are volatile (evaporate readily)
- Persistent refers to substances that have long residence times because they remain in environmental reservoirs for a long time, or because they take a long time to degrade or break down, or both
- Can enter the food supply, bioaccumulate in body tissues, and have significant impacts on human health and the environment
- Include industrial chemicals (PCBs, DDT, contaminants from incomplete combustion processes)

Heavy Metals

- Can be transported by the air, enter our water and food supply, and reside for long periods in sediment
- Metals tend to be associated with particulate matter, either occurring in particulate form or attaching to small particles that can then be transported atmospherically
- Poisonous, can bioaccumulate in body tissues
- Mercury and lead

Toxic Air Pollutants

- Constitute a broad category of other pollutants identified as being harmful or toxic
- Subject to regulation, control, and monitoring
- Substances known to cause cancer, reproductive defects, or neurological, developmental, immune system, or respiratory problems

Government agencies share responsibility for air pollution

Federal

- Principal federal legislation under which air quality is regulated is CEPA (1999)
- CEPA is the act respecting pollution prevention and the protection of the environment and human health in order to contribute to sustainable development
- Responsible for entering Canada into international agreements concerning air quality
- **Transboundary Pollution:** pollution that crosses political borders
- **Canada-United States Air Quality Agreement:** Present bilateral international agreement on transboundary air pollution
- The agreement deals with acid rain precursors, coordination of international scientific research, and ground-level ozone
- Montreal Protocol and Kyoto Protocol: examples of multilateral international agreements signed by Canada that are intended to address air pollution issues of global concern
- WHO sets minimum standards for safe air quality in consultation with governments around the world, and participates in monitoring and evaluating air quality

Provincial/Territorial

- Each provincial and territorial government approaches air quality issues with its own agenda and set of rules, through its environment ministry
- Issues vary dramatically from one region to another

Municipal

- Two municipalities in Canada (Montreal and Greater Vancouver) have been given direct regulatory authority over sources of air pollution by their respective provincial governments
- Most countries have implemented reporting processes in which the scientific results of monitoring are combined and translated into a scale that is simpler and more straightforward to interpret: **Air Quality Index**
- Represent good or safe air quality as a low number, with poor air quality increasing as the scale goes up
- Various standards and protocols for monitoring and reporting of air pollutants were brought into alignment across the country, through **Air Quality Health Index (AQHI)**
- Focuses on pollutants that are known to cause problems for human health
- Targets are called Canada-Wide Standards (CWS)

CEPA not only lists the pollutants of interest but also requires that any releases of these pollutants be reported to the **National Pollutant Release Inventory (NPRI)**

Cleaner-burning motor vehicle engines, unleaded gasoline, and automotive technologies such as catalytic converters have played a large part in decreasing emissions of lead, carbon monoxide, and several other pollutants

- **Scrubbers:** chemically convert or physically remove airborne pollutants before they are emitted from smokestacks

Smog: fogs polluted by the smoke of Britain's Industrial Revolution

- Coined by early British scientist
- Today it is used worldwide to describe unhealthy mixtures of air pollutants that often form over urban areas

Industrial Smog: the deadly smog that enveloped London in 1952

- When coal or oil burned, some portion is completely combusted, forming CO₂
- Some is partially combusted, producing CO
- Some remains unburned and is released as soot, or particles of carbon
- Coal contains mercury and sulphur
- Sulphur reacts with oxygen to form sulphur dioxide, which undergoes a series of reactions to form sulphuric acid and ammonium sulphate

Photochemical Smog: smog formed by photochemical processes, activated by sunlight

- Formed through light-driven chemical reactions between primary pollutants and natural atmospheric compounds
- Produce a mix of more than 100 different chemicals

Airshed: geographical area associated with a particular air mass

- People who live within the same airshed tend to experience similar weather and "bad air" days

Acid Decomposition

- **Acidic Deposition:** settling of acidic or acid-forming pollutants from the atmosphere onto the surface. Can take place by acidic precipitation (acid rain)
- **Atmospheric deposition:** refers more broadly to the wet or dry deposition on land of a wide variety of pollutants

- Originates from burning fossil fuels. Releases sulphur dioxide and nitrogen oxides. React with water to form sulphuric and nitric acids

Natural rain water is not neutral, it is slightly acidic, with a typical pH of 5.6

- Rain water reacts with naturally occurring carbon dioxide in the air, forming carbonic acid

TABLE 13.1 Effects of Acidic Deposition on Ecosystems in Northeastern North America	
Acidic deposition in northeastern forests has	
■	accelerated leaching of base cations (ions that counteract acidic deposition) from soil
■	allowed sulphur and nitrogen to accumulate in soil
■	increased dissolved inorganic aluminum in soil, hindering plant uptake of water and nutrients
■	caused calcium to leach from needles of red spruce, leading to tree mortality from wintertime freezing
■	increased mortality of sugar maples because of leaching of base cations from soil and leaves
■	acidified many lakes, especially those situated on non-calcareous soils and bedrock of granitic composition
■	lowered lakes' capacity to neutralize acids
■	elevated aluminum levels in surface waters
■	reduced species diversity and abundance of aquatic life, and negatively affected entire food webs

Source: Adapted from Driscoll, C.T., et al. (2001). *Acid Rain Revisited*. Hubbard Brook Research Foundation.

- Rain and other forms of precipitation with pH of less than 5.1 are considered acidified

-

Hubbard Brook Experimental Forest

- 1963, Hubbard Brook researchers broadened their focus to include a long-term study of nutrient cycling in forest ecosystems
- Collected and analyzed weekly samples of precipitations
- Late 1960s, found that precipitation at Hubbard Brook was several hundred times as acidic as natural rain water
- Precipitation had pH values averaging around 4 and that individual rainstorms showed values as low as 2.1 - almost 10 000 times as acidic as ordinary rain water
- Studies of soil nutrients showed that up to 50% of the calcium and magnesium in the soils had leached out
- Acidification of soil does not directly kill trees, but it affects the availability of nutrients and the ability of trees to access them

Ozone Depletion

- In troposphere, ozone (O₃) is a respiratory irritant and a component of smog
- In the stratosphere, it performs a crucial role for life on this planet
- Ozone molecules are so effective at absorbing incoming sunlight that even this low concentration helps protect Earth's surface from the damaging effects of ultraviolet (UV) radiation
- Atmospheric scientists began wondering why their measurement of stratospheric ozone were lower than theoretical models predicted
- Hypothesized that natural or artificial chemicals were depleting the ozone
- Chlorofluorocarbons (CFCs) were being mass-produced by industry at a rate of 1 million metric tons per year in the early 1970s, growing by 20% a year
- CFCs could deplete stratospheric ozone by releasing chlorine atoms that split ozone molecules, creating from each of them an O₂ molecule and a ClO molecule
- 1985, scientists announced that stratospheric ozone levels over Antarctica had declines by 40-60% in the previous decade, leaving a thinned ozone concentration (**ozone hole**)
- Global ozone depletion causes skin cancer, harms crops and decreases ocean productivity
- Scientists now believe that the ozone-depleting chemical reactions may find ideal sites on tiny ice crystals that are found only where the air is extremely cold
- These conditions are optimal over Antarctica, where a circular wind pattern called the polar vortex traps extremely cold air over the pole

Montreal Protocol

- 197 nations agreed to cut CFC production in half
- Today the production and use of ozone-depleting compounds have fallen by 95% since the late 1980s, and scientists can discern the beginnings of long-term recovery of the stratospheric ozone layer
- 5 billion kilograms of CFCs emitted into the troposphere yet to diffuse up into the stratosphere, and CFCs are slow to dissipate or break down
- Biggest success story:

1. Policymakers engaged industry in helping to solve the problem, and government and industry worked together on developing replacement chemicals. This cooperation reduced the battles that typically erupt between environmentalists and industry.
2. Implementation of the Montreal Protocol followed an adaptive management approach, altering strategies midstream in response to new scientific data, technological advances, or economic figures.

- CFCs will remain in the stratosphere for a long time
- Nations can ask for exemptions to the ban. (Ex: US to use methyl bromide to control pests on strawberries)

Indoor Air Pollution

- Indoor air generally contains higher concentrations of pollutants than does outdoor
- Indoor air pollution alone takes roughly 11 000 lives each day
- The average person in North America is indoors at least 90% of the time
- Products as diverse as insecticides, cleaning fluids, plastics, and chemically treated wood can all exude volatile chemicals into the air
- To reduce heat loss and improve energy efficiency, building managers sealed off most ventilation in existing buildings, and building designers constructed new buildings with limited ventilation and with windows that did not open
- Saved energy, but also worsened indoor air pollution by trapping stale, unmixed air - and its pollutants - inside

Developing Nations

- Millions of people in developing nations burn wood, charcoal, animal dung, or crop waste inside their homes for cooking and heating with little or no ventilation
- Inhale dangerous amounts of soot and carbon monoxide

Tobacco Smoke & Radon

- Tobacco smoke consists of a brew of more than 4000 chemical compounds, many of which are known or suspected to be toxic or carcinogenic
- After cigarette smoke, radon is the second-leading cause of lung cancer in the industrialized world, responsible for 15% of lung cancer cases worldwide
- Radon is radioactive gas that occurs naturally and results from the decay of uranium and thorium in soil, rock, or water
- Gas seeps up from the ground and can infiltrate the basements of buildings through pipes and cracks in the foundation. Colourless and odourless
- EPA has estimated that 6% of US homes exceed the maximum recommended level
- Maximum acceptable level for indoor radon in homes and other non-occupational settings recommended by Health Canada is 0.02 WL
- Actionable level defined by the US EPA is equivalent to 0.016 WL

VOCs Pollute Indoor Air

- Most diverse indoor pollutants are volatile organic compounds (VOCs)
- Airborne carbon-containing compounds that are released by everything from plastics to oils to perfumes to paints to cleaning fluids to adhesives to pesticides
- Surrounded by products that emit VOCs, but they are released in small amounts

Living Organisms can Pollute Indoor Spaces

- Tiny living organisms constitute one of the most widespread sources of indoor air pollution
- Dust mites and animal dander can worsen asthma in children
- Some fungi, mould, and mildew can cause severe health problems, including allergies, asthma, and other respiratory ailments
- Some airborne bacteria can cause infectious disease
- **Sick-Building Syndrome:** When the cause of such an illness is a mystery, and when symptoms are general and nonspecific

Chapter 14: Global Climate Change (P.446-485)

The Athabasca Glacier

- 6km long and between 90 and 300 m in thickness
- Glaciers flow (very slowly) under the influence of gravity
- Two main mechanisms for glacial flow
- Internal deformation: ice crystals in the glacier slide translationally along internal planes of weakness
- Basal Sliding: when a layer of melt water lubricates the contact between the glacial ice and the underlying rock
- Moving downslope at a rate of a few centimetres per day
- Accumulation: mechanism by which glaciers grow in both volume and extent
- Has been retreating since 1844
- Glacier has lost half of its volume and has retreated more than 1.5km
- The glacier is currently retreating at a rate of about 2 to 3 metres per year

Fourth Assessment Report

- 2007
- Intergovernmental Panel on Climate Change (IPCC)
- Consensus that climate is changing, that we are the main cause, and that climate change is already exerting impacts that will become increasingly severe if we do not take action

Climate: area's long-term atmospheric conditions, including temperature, moisture content, wind, precipitation, barometric pressure, solar radiation, and other characteristics

- Describes conditions across broader regions over seasons, years, or millennia

Global Climate Change: describes trends and variations in Earth's climate, involving such aspects as temperature, precipitation, and storm frequency and intensity

Global Warming: refers specifically to an increase in Earth's average surface temperature

- Only one aspect of global climate change

Three factors exert more influence on Earth's climate than all others combined

1. Sun: without it, earth would be dark and frozen
2. Atmosphere: without it, earth would be as much as 33°C colder on average, and temperature differences between night and day would be far greater than they are
3. Ocean: shapes climate by storing and transporting heat and moisture
 - Earth's atmosphere, clouds, land, ice, and water together absorb about 70% of incoming solar radiation and reflect the remaining 30% back into space
 - Reflectivity of a surface is called albedo
 - The 70% powers a wide variety of Earth's processes: photosynthesis, winds, waves, and evaporation

Infrared Radiation: radiation with longer wavelengths than visible light

- Radiation emitted by Earth's surface begins to make its way back to outer space
- Some gases that are naturally present in the troposphere absorb this infrared radiation very effectively (GHGs)
- Ozone, carbon dioxide, nitrous oxide, methane, halocarbons, chlorofluorocarbons
- These are known as **greenhouse gases (GHGs)** or radiatively active gases
- GHGs re-emit infrared energy of slightly longer (lower-energy) wavelengths
- Some travels back downward, warming the troposphere and the planet's surface in a phenomenon known as the **greenhouse effect**
- Without the natural greenhouse effect, our planet would have a much colder temperature (avg. of -18°C)

Anthropogenic: human generated

There are both natural and anthropogenic sources for almost all greenhouse gases

- Human activities have increased the concentrations of many GHGs in the past 250 - 300 years, enhancing the greenhouse effect

Global Warming Potential: refers to the relative ability of one molecule of a given greenhouse gas to contribute to warming

Carbon Dioxide

- More abundant in the atmosphere than other GHGs
- Estimated that anthropogenic carbon dioxide is causing nearly 6x more warming than methane, nitrous oxide, and wholly anthropogenic chemicals such as CFCs, combined

TABLE 14.1 Global Warming Potentials of Four Greenhouse Gases

Greenhouse gas	Relative heat-trapping ability (in CO ₂ equivalents)
Carbon dioxide	1
Methane	28
Nitrous oxide	265
CFC-1	4660

- Main natural source of carbon dioxide moving into the atmosphere is the decay of organic material
- Volcanoes also emit a lot of CO₂
- Human activities have boosted the atmospheric concentration of carbon dioxide from 280 ppm to 400 ppm
- When atmospheric GHGs are high, so is temperature

Natural Fluxes (inputs and outputs) cancel each other out

- This is why atmospheric CO₂ has increased, although there are more natural sources than human sources,
- Human sources do not cancel out so they shift the overall balance of fluxes in the carbon cycle
- Over the past 200 years, we have extracted fossil fuels and burned them in our homes, factories, and automobiles, transferring large amounts of carbon from one reservoir (long-term underground deposits) to another (atmosphere)
- Human modified flux of carbon from lithospheric reservoirs into the atmosphere is much faster than the natural flux

- Release of carbon from long-term reservoirs and the acceleration of the carbon flux from the lithospheric reservoir to the atmospheric reservoir are the main reasons atmospheric carbon dioxide concentrations have increased so dramatically since the industrial revolution

Methane (CH₄)

- Tapping into fossil fuel deposits, by raising livestock that emit methane as a metabolic waste product, disposing of organic matter in landfills, growing certain crops like rice
- 1750, atmospheric methane concentration went from 700 to 1800 ppm

Nitrous Oxides

- Atmosphere is the largest nitrogen reservoir, but soils and soil-forming processes are the principal drivers of the nitrogen biogeochemical cycle

Ozone

- Radiatively active gas
- Contributes to warming both near the surface and up in the stratosphere
- Concentration of ozone in the stratosphere has risen about 36% since 1750

Water Vapour

- Most abundant naturally occurring greenhouse gas in our atmosphere, and contributes most to the natural greenhouse effect
- Global concentration has not changed much over recent centuries, so it is not viewed as having driven industrial-age climate change
- Concentration of water in the atmosphere is connected to temperature, as tropospheric temperatures continue to rise
- Means that the effects of other greenhouse gases are amplified by the influence of added water vapour, contributing to further greenhouse warming

Positive Feedback Loop

- EXAMPLE: Global warming increases the concentration of water vapour in the atmosphere, which causes further warming because water is a radiatively active gas
- This additional warming causes more evaporation, increasing further the water vapour in the atmosphere and so on

Negative Feedback Loop

- Self-regulating or self-limiting feedbacks

Radiative Forcing

- Amount of energy that a given factor causes
- Positive forcing warms the surface
- Negative forcing cools the surface
- Earth today is experiencing overall net positive (warming) radiative forcing of about 2.29 watts/m²

FACTORS THAT INFLUENCE CLIMATE

Orbital Factors

- 1920s, Milutin Milankovitch
- Influence of periodic changes in Earth's rotation and orbit around the Sun on insolation
- **Insolation**: amount of solar energy that reaches Earth's surface per unit area in a given period
- **Precession**: wobbling of Earth's rotational axis
- **Obliquity**: tilt of the axis
- **Eccentricity**: change in the shape of Earth's orbit around the sun
- These alter the way solar radiation is distributed over Earth's surface
- **Milankovitch Cycles**, lead to variations that are sufficient to trigger climatic changes such as period episode of glaciation
- During glaciation, global surface temperatures drop and ice sheets advance from the poles toward the mid-latitudes, and the intervening warm interglaciations

Solar Output

- Sun varies in the amount of radiation it emits (luminosity), over both short and long timescales
- Variation in solar energy reaching our planet in recent centuries has not been great enough to drive significant temperature change on Earth's surface

Ocean Absorption

- Ocean acts as a sink
- holds 50x as much carbon as the atmosphere holds
- Absorbs CO₂ from the atmosphere through direct solubility of gas in water, uptake by marine phytoplankton for photosynthesis...
- Rate of absorption increases more slowly than does the concentration in the atmosphere
- Carbon absorption by the ocean is slowing global warming but not preventing it
- Ocean water warms, it absorbs less CO₂ because gases are less soluble in warmer water
- Causes acidification of ocean water, causing calcareous shells and skeletons to dissolve, releasing more CO₂ (positive feedback)

Ocean Circulation

- Ocean water exchanges tremendous amounts of heat with the atmosphere, and ocean currents move energy from place to place
- Because cooler water is denser than warmer water, the cooler water at the poles tends to sink, and the warmer surface water from the equator moves poleward to take its place
- One of the principles underlying global ocean circulation patterns
- **Thermohaline Circulation:** worldwide current system in which warmer, fresher water moves along the surface and colder, saltier water (which is more dense) moves deep beneath the surface
- Interruptions in this circulation could trigger rapid climate change

Paleoclimate: evidence about climate in the geological past

Proxy Indicators: types of indirect evidence that serve as proxies, or substitutes, for direct measurement and that shed light on past climate.

- Growth rings in trees can give information about conditions of temperature and precipitation. They act as a proxy, or a stand-in, for actual measurements
- Researchers can gather data on past ocean conditions from fossils of marine microorganisms in layered sediments, and from corals, which also accumulate material in annual growth rings
- Researchers can also remove core samples from sediments that lie beneath bodies of water
- Earth's icecaps, ice sheets, glaciers, and sediments hold clues to the much longer-term climate history

The Science Behind the Story

- P.430 of the textbook
- Antarctica
- Dome C
- Extracting cores from Greenland and Antarctica, scientists have been able to go back in time 800 000 years, reading Earth's global climatic history across eight glacial cycles

Stable Isotope Geochemistry: clues about paleo climates can be partly uncovered through this study

- Fractionation: separation and differential concentration of isotopes of slightly different mass
- Natural fractionation processes are controlled by variations in temperature

Direct Atmospheric Sampling

- Atmospheric CO₂ concentrations have increased from 315 ppm in 1958 to 392 ppm in 2011
- Seasonal variations in levels due to photosynthetic uptake. More CO₂ absorbed during northern summer

Climate Models

- Couple or combine, the climate influences of the atmosphere and oceans into a single simulation
- Use information about atmospheric circulation, ocean circulation, interactions, and feedback mechanisms
- Global climate models (GCMs)

Intergovernmental Panel on Climate Change (IPCC)

- Established in 1988
- Summarizes evidence of climate change and predicts future impacts
- Fifth Assessment report: represents the consensus of scientific climate research from around the world. Trends in surface temperature, precipitation patterns, snow and ice cover, sea levels, storm intensity, and other factors
- Very likely: carries the specific connotation of a 90-100% probability

- IPCC report concludes that average surface temperatures on Earth increased by 0.85°C in the period from 1880 to 2012
- In the future, we can expect average surface temperatures on Earth to rise by roughly 0.3°C to 0.7°C more over the period 2016 to 2035
- Sea surface temperatures also are increasing as the oceans absorb heat - causing evaporation and adding heat energy and water vapour to the atmosphere
- Pumped-up greenhouse gases in our atmosphere do not on their own produce superstorms, but they create conditions that are conducive to the occurrence of more frequent and stronger storms
- Period from 1983 to 2012 among the 30 warmest years on record for past 1400 years
- IPCC predicts avg surface temp will be 1.5 to 3 °C

Permafrost: perennially frozen ground

- Most characteristic feature of Arctic soils
- Foundations of roads and buildings in the north would be at risk if permafrost undergoes major changes as a result of warming
- Plays a major role in slope stability, with greatly increased chances for landslides as permafrost begins to melt
- Concerns that the warming of permanently frozen soils would lead to the accelerated release of soil gases, such as methane, which could contribute to a positive feedback cycle in the climate system, leading to further warming The resulting rapid downslope movement of the glacier is called a

Surge: The resulting rapid downslope movement of the glacier is called

- Melt water weakens ice on its way down and warms the base of the glacier, melting some of it to create more water
- Warming ocean water also melts ice shelves along the coast, depriving outlet glaciers of the supports that hold them in place
- Without a floating ice tongue at its terminus, a glacier slides into the ocean more readily
- These physical dynamics represent positive feedbacks; once global warming initiates these processes, they encourage further melting

Dr. Luke Copland

- University of Ottawa
- Area of Canada's ice shelves has shrunk by approximately 90% over the past 100 years

- One reason warming is accelerating in the Arctic is that as now and ice cover are melted, darker, less-reflective surfaces are exposed
- Earth's albedo (capacity to reflect light) decreases
- As a result, more of the Sun's rays are absorbed at the surface, fewer reflect back into space, and the surface warms
- In a positive feedback, this warming causes more ice and snow to melt, which in turn causes more absorption of radiation and more warming

Atmospheric Blocking Pattern: loops of polar jet stream get block into one position for a long period

- Can cause droughts and flooding

Melting Ice and Snow

- Mountaintop glaciers are disappearing. They have lost an average of 20 m in vertical thickness since 1945.
- Risks of sudden floods as ice dams burst
- Reducing summertime water supplies
- As ice melts, darker, less-reflective surfaces are exposed and absorb more sunlight, causing more melting
- Melting permafrost makes slopes unstable and could release soil gases leading to further warming

Rising Sea Levels

- As glaciers and ice sheets melt, increased runoff into the oceans causes sea levels to rise
- Sea levels also are rising because ocean water is warming; liquid water expands in volume as its temperature increases
- Average sea levels rose at least 19cm from 1901 to 2010
- Although the extent and mass of floating sea ice are strongly affected by the warming of ocean water, when sea ice melts it makes almost no contribution to sea-level rise
- Sea ice is like an ice cube that is already floating in a glass of water - if it melts, it won't cause the glass to overflow
- Land ice is like water that you pour into the glass from a pitcher, which adds mass and can make the water level rise and cause the glass to overflow

- Higher sea levels lead to beach erosion, coastal flooding, intrusion of salt water into aquifers, and other impacts
- Storm surge is a temporary and localized rise in sea level brought on by the low atmospheric pressure and winds associated with storms
- The higher sea level is to begin with, the farther inland a destructive storm surge can reach
- Rising sea levels will force hundreds of millions of people to choose between moving upland or investing in costly protections against high tides and storm surges

IPCC Fifth Assessment Report

- Seven major indicators that scientists would expect to be increasing, if the global climate is warming. These are increasing
 - Air temperature in the lower part of the troposphere
 - Water vapour in the atmosphere
 - Temperature over land
 - Marine air temperature
 - Sea-surface temperature
 - Ocean heat content
 - Sea level
- Three major indicators that scientists would expect to be decreasing, if the global climate is warming
 - Snow cover
 - Glacier volume
 - Sea ice area

As global warming proceeds, it modifies temperature-dependent biological phenomena

- In the spring, birds are migrating earlier, insects are hatching earlier, and animals are breeding earlier
- Plants are leafing out earlier
- European birds (great tits) vs caterpillars. Changes in seasonal timing, research so far shows that in most cases mismatches occur
- 20-30% of all plant and animal species could be threatened with extinction, IPCC estimates

American Pika (*Ochotona Princeps*)

- Extremely sensitive to environmental conditions, especially temperature, and cannot survive if temperatures are too high
- Their favoured habitat, in the vicinity of glaciers, is threatened as a result of rapidly changing conditions in glacial environments

By drawing in CO₂ for photosynthesis, plants act as sinks for carbon

- If climate change increases vegetative growth, this could help mitigate carbon emissions, in a process of negative feedback
- If climate change decreases plant growth (drought, fire) then positive feedback could increase the carbon flux to the atmosphere

Coral reefs provide habitat for important food fish that are consumed locally and exported

- Offer snorkelling and scuba diving sites for tourism
- Reduce wave intensity
- Protecting coastlines from erosion
- Around the world, rising seas will eat away at the coral reefs, mangrove forests, and salt marshes that serve as barriers protecting our coasts
- Climate change poses two additional threats to coral reefs: warmer waters are causing coral bleaching, and enhanced CO₂ concentrations in the atmosphere are changing ocean chemistry

Climate change will have additional consequences for humans:

Agriculture

- Farmers: earlier springs require earlier crop planting
- Growing seasons become longer and because more carbon dioxide is available to plants for photosynthesis
- Rainfall will shift in space and time, and in areas where droughts and floods become more severe, these will cut into agricultural productivity
- Beyond a rise of 3°C, IPCC expects crop yields to decline
- Seasonally dry tropical and subtropical regions, growing seasons may be shortened, and harvests may be more susceptible to drought and crop failure
- Scientists predict that crop production will fall in these regions even with minor warming

- This would worsen hunger in many of the world's developing nations
- The prairies will still have good soils but will become too hot and dry for successful farming
- Canada's North, although warmer and wetter, won't have the soil to take advantage of the better climatic conditions

Forestry

- Forest managers increasingly find themselves having to battle insect and disease outbreaks, invasive species, and catastrophic fires, which are promoted by longer, warmer, drier fire seasons
- For timber and forest products, enriched atmospheric CO₂ may spur greater growth in the near term, but this will vary substantially from region to region
- Drought, may eliminate these gains

Health

- Face more heat waves - and heat stress can cause death, especially among older adults
- Warmer climate exposes us to health problems

- respiratory ailments that result from air pollution, as hotter temperatures promote formation of photo-chemical smog
- expansion of tropical diseases, such as dengue fever, into temperate regions as vectors of infectious disease (such as mosquitoes) move toward the poles; the advent of mosquito-borne West Nile Virus in southern Canada may be a preview of this scenario
- disease and sanitation problems that occur when floods overcome sewage treatment systems
- injuries and drownings that will likely increase if storms become more frequent or intense
- hunger-related ailments that will worsen as the human population grows and climate-related stresses on agricultural systems increase
- health hazards from cold weather will likely decrease, but researchers feel that the increase from warm-weather hazards will more than offset these gains

Economics

- Researchers predict that costs will outweigh benefits and that this gap will widen as climate change grows more severe
- Gap between rich and poor will widen, both within and among nations

- Poorer people have less wealth and technology with which to adapt to climate change, and poorer people rely more on resources that are particularly sensitive to climatic conditions
- Poor often have the fewest livelihood options
- IPCC has estimated that climate change will cost 1-5% of GDP on average globally, although poor nations would lose proportionally more than rich nations
- Stern Review (British Government): cost roughly 5-20% of world GDP by the year 2200
- Investing just 1% of GDP starting now could enable us to avoid these future costs

IPCC's 2007 Fourth Assessment Report

- More than 90% likely that most of the global warming recorded over the past half-century is due to the well-documented increase in greenhouse gas concentrations in our atmosphere

TABLE 14.2 Global Warming Projections (°C) for IPCC Scenarios Relative to the 1986–2005 Average Temperature

	2046–2065	2081–2100
Scenario	Mean and <i>likely</i> * range	Mean and <i>likely</i> * range
RCP 2.6	+1.0 (0.4 to 1.6)	+1.0 (0.3 to 1.7)
RCP 4.5	+1.4 (0.9 to 2.0)	+1.8 (1.1 to 2.6)
RCP 6.0	+1.3 (0.8 to 1.8)	+2.2 (1.4 to 3.1)
RCP 8.5	+2.0 (1.4 to 2.6)	+3.7 (2.6 to 4.8)

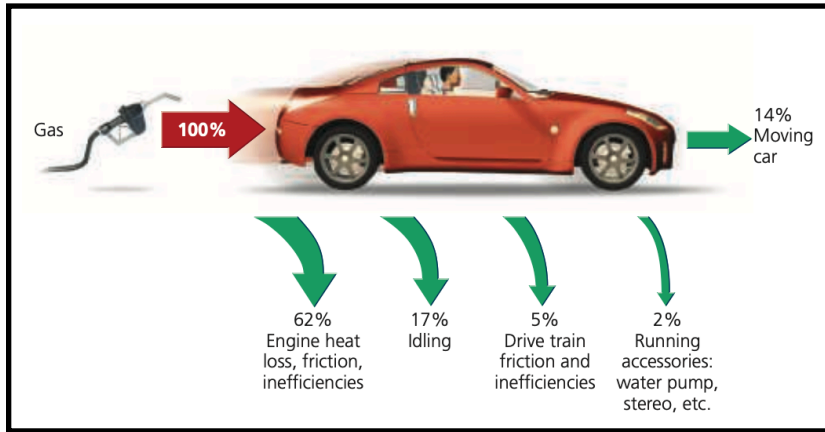
*The term *likely* carries a defined probability of >66%.
 Source: From IPCC (2013). *Fifth Assessment Report, Working Group I: Summary for Policymakers*, Table SPM-2. Copyright © 2013 by IPCC Secretariat. Reprinted by permission.

Mitigation

- Aim is to mitigate, or alleviate, the problem
- Choose to pursue actions that reduce greenhouse gas emissions in order to lessen the severity of future climate change
- As a global community we have failed to meet the challenge of mitigation

Adaptation

- Accept that climate change is happening and to pursue strategies to minimize its impacts on us
- Goal is to adapt to change by finding ways to cushion oneself from its blows



Intervention

- Set of possible large-scale technological modifications to the global climate system
- Makes climate scientists extremely nervous
- Interfering with global-scale Earth systems could lead to all sorts of unanticipated and

unwanted side effects

- Cause people to abandon efforts at mitigation (even the talk of intervention)
- Grand-scale intervention strategies: **Geoengineering**
- Two categories of geoengineering:
 1. Strategies that aim to increase fluxes of greenhouse gases out of the atmosphere
 2. Strategies that aim to reduce the incoming solar radiation
- Many environmental advocates have criticized intervention and even adaptation, because they view them as escapist

Canada's electricity comes mainly from hydroelectric sources (58%), 23% still comes from fossil-fuel-related processes

Carbon Capture and Storage

- Refers to technologies or approaches that remove carbon dioxide from power plant emissions
- Would allow power plants to continue using fossil fuels while curing greenhouse gas pollution

Close to 85% of the fuel you pump into your gas tank does something other than move your car down the road

Canadians use public transportation for approximately 7% of daily transportation needs

Kyoto Protocol

- Outgrowth of the FCCC that required signatory nations, by 2012, to reduce emissions of 6 greenhouse gases to levels below those of 1990

- Took effect in 2005
- Average Canadian or American today still generate 3x the GHG emissions of the average Chinese, and 14x that of the average Indian
- Relied upon the *principle of common but differentiated responsibility*, stating that all nations fo the world have a responsibility to address issues related to climate change, but not all nations have the same capacity to do this, whether financially, politically, or technologically

Paris Agreement

- 195 nations
- Cites the nations' collaborative intention to maintain an increase in global average surface temperature of less than 2°C above pre-industrial levels
- To reach a peak in GHG emissions "ASAP"
- To foster climate resilience and prioritize food security
- To work toward effective financing mechanisms for all of these goals
- It is not legally binding

Carbon Neutrality

- State in which no net carbon is emitted
- Carbon offsets are becoming popular among utilities, businesses, universities, governments, and individuals

Carbon Footprint

- Expresses the amount of carbon we are responsible for emitting

Module 8

Chapter 15: Fossil Fuels: Energy Use & Impacts (489-522)

Tuesday: 11 pages + Notes

Wednesday: 11 pages + Notes

Thursday: 11 pages + Notes

Mackenzie Valley Natural Gas Pipeline

- Proposal to develop three major natural gas fields located in the Mackenzie Delta, Northwest Territories
- The natural gas would be delivered to southern markets via a 1196 km pipeline system, to be constructed along the Mackenzie Valley from Inuvik, NWT, to Alberta border, where it would connect with the TransCanada pipeline system
- Among the main concerns were the potential impacts on people and animals that would result from the infrastructure (roads, airports, towns) likely to accompany the construction of the pipeline
- Native leaders eventually became supporters, realizing that it would bring much needed jobs and revenue to the North

Fossil Fuels

- Highly combustible substances formed from the remains of organisms from past geological ages
- When organisms die and are preserved in sediment under particular conditions, the chemical energy stored in their tissues may be transferred into the form of fossil fuels
- Oil, coal, and natural gas
- Since the Industrial revolution, fossil fuels have replaced traditional biomass (like fuelwood) as our society's dominant source of energy

Renewable

- Energy sources such as sunlight, geothermal energy, and tidal energy
- Inexhaustible, because their supplies are not depleted by our use

Nonrenewable

- Oil, Coal, and natural gas
- Cannot be regenerated quickly enough to offset depletion
- Nuclear power as currently harnessed through the *fission* (splitting) of uranium
- Uranium is a mineral resource, and fission is an irreversible process

It takes about a thousand years for the biosphere to generate the amount of organic matter that must be buried to produce a single day's worth of fossil fuels for our society

- To turn that material into fossil fuel by natural processes takes at least a million years

US (4.4% of world's population) accounts for 18% of the world's energy use

Canada (0.5% of the world's population) accounts for 2.6% of the world's private energy use

Developing nations devote a greater proportion of their energy to subsistence activities

- Agriculture
- Food preparation
- Home heating
- Less on transportation

In Canada, where hydroelectric resources are particularly abundant, oil, coal and natural gas still supply 65% of energy needs

EROI - Energy Return on Investment

- $EROI = \text{Usable Energy Returned} / \text{Energy Invested}$
- Higher ratios mean that we acquire more usable energy from each unit of energy that we invest
- Oil and natural gas combined declined from more than 50:1 in the 1950s to about 30:1 in the 1970s, today they are about 15:1 less
- We are only getting back about half as much useful energy now for our energy investment in oil and natural gas, compared to 45 years ago

The fossil fuels we burn today in our vehicles, homes, industries, and power plants were formed from the tissues of organisms that lived 100 million to 500 million years ago

- The energy these fuels contain came originally from the Sun and was converted to chemical-bond energy as a result of photosynthesis

Aerobic Decomposition: in the presence of air, bacteria, and other organisms that use oxygen break down plant and animal remains into simpler carbon-based molecules that are recycled through the ecosystem as part of the short-term carbon cycle

Anaerobic environment: one that has little or not oxygen

- Bottoms of shallow seas, deep lakes, and swamps

Over millions of years, organic matter that accumulates at the bottoms of such water bodies undergoes decomposition and deep burial by sediment, eventually resulting in an oil called **kerogen**

Coal

- Organic matter that was compressed under very high pressure to form a dense, combustible, carbon-rich solid material
- People have used coal longer than any other fossil fuel
- Coal provides more than 20% of the electrical-generating capacity in Canada
- Canada is both an importer and an exporter of coal
- China and US are the primary producers and consumers of coal

TABLE 15.2 Top Five Producers and Consumers of Coal

Production (% world production)	Consumption (% world consumption)
China, 47.4	China, 50.3
United States, 12.9	United States, 11.9
Australia, 6.9	India, 8.5
Indonesia, 6.7	Japan, 3.4
India, 5.9	Russian Federation, 2.4

Source: Data from British Petroleum (2014). *Statistical Review of World Energy 2014*, statistical tables.

Peat

- The precursor to coal
- A moist soil composed of compressed organic matter
- Scientists categorize coal into several main classes, called *grades*
 - Lignite: brown coal. lowest and softest grade. Least compressed.
 - Bituminous: used to produce steam for electricity generation
 - Anthracite: hard, shiny, black metamorphic rock that is the highest grade. Most compressed

Currently 25 active coal mines in Canada

Subsurface Mining

- For deep deposits
- Risk of injury or death from collapsing shafts and tunnels and from dynamite blasts and coal dust or methane explosions
- Inhale coal dust = respiratory problems like black lung disease
- Less than 2% of Canada's coal is extracted by underground mining

Surface Mining

- For shallower deposits

Open-Pit Mining

- When coal deposits are at or near the surface
- Involves large excavations, which are deepened and widened as mining proceeds

Strip Mining

- When coal deposits are at or near the surface
- Heavy machinery removes earth in long, horizontal strips to expose the seams and extract the coal
- Pits are subsequently refilled with the soil that had been removed

- Destroys large swaths of habitat and cause extensive soil erosion
- Can cause chemical runoff into waterways through the process of acid drainage

Acid Drainage

- When sulphide minerals in newly exposed rock surfaces react with oxygen and rain water to produce sulphuric acid

Coal contains impurities, which can include sulphur, mercury, arsenic, and other trace metals, which vary from deposit to deposit

- When coal is burned, pollutants are released
- Burning high-sulphur coal produces sulphates, which contribute to industrial smog and acidic deposition
- Combustion of coal also can emit mercury, which bioaccumulates in organisms and bioconcentrates at high trophic levels in food chains
- Clean coal technologies focus on approaches to rid toxic chemicals before, during, or after the burning of the coal
- Combustion focused technologies start with the pulverized-coal process and apply improvements aimed at making combustion more efficient and more complete (cleaner)

Fluidized Bed technologies: bathe the finely pulverized coal in jets of air during combustion

Gasification and liquefaction technologies involve creating clean synthetic fuels, called *syngas*, from mixtures of pulverized coal, methane, water vapour, and other components