Chapter 3
The Big Picture: Systems of Change

Systems and Feedback

- System:
    - Solutions to many environmental problems involve the study of systems and rates of change.
    - Natural disturbances and changes to systems (like ecosystems) are important to their continued existence.
    - A system can be defined as a group of parts that work together to behave as a whole. There are two types:
        - Open System
        - Closed System

Two Types of Systems

- Open System:
    - Not generally contained within boundaries
    - Some energy or material moves into or out of the system
- Closed System:
    - No material movement into or out of the system

Open & Closed Systems

- Is the Earth an Open or Closed System?
    - Argument 01: The earth is essentially a *closed system* because its materials do not leave, however…
    - Argument 02: with regard to energy, students could also argue it is an *open system* because energy is constantly coming in.
    - Furthermore, one could argue we do get some matter coming in because of space rocks, etc. Lastly, with technology we are also finding ways to remove some matter from the planet.
- Open systems *do not* have boundaries, whereas closed systems *do*.
- All systems respond to *inputs* and have *outputs*.
    - Input = Cause
    - Output = Effect

Systems and Feedback

- Feedback is a special kind of response in a system.
- Occurs when the *output* of the system also serves as an *input*, leading to further changes in the system.
    - Remember, Input = Cause and Output = Effect
- Positive Feedback
- Negative Feedback

Types of Feedback

- Positive Feedback
    - Occurs when an increase in output leads to a further increase in output
    - Has a *destabilizing* effect
    - Sometimes called a “vicious cycle”
    - One example of Positive Feedback loop is exponential growth...

    - *"it keeps going, and going..."*

- Negative Feedback
    - Occurs when the system's response is in the opposite direction of the output
    - Self-regulating
    - Tends to *stabilize* or encourage more constant conditions in a system
    - An increase in output leads to a later decrease.

Which is Worse for the Environment?
- Feedback occurs when the output of a system also acts as an input, those causing increased change within the system.
- *Positive Feedback* will occur when an increase in output causes a further increase in output.
- Conversely, *Negative Feedback* occurs when the initial increase in output causes a later *decrease* in the behavior or output. For this reason it is often referred to as *self-regulating*.

- *Negative* feedback
    - Might occur if the system senses an increase in temperature it would cause the system to react (by sweating for example)... thereby causing the temperature to decreased.
- *Positive* feedback
    - Is seen in the example of a fire. The input of a fire causes wood to burn easily. The fire will then increase causing more wood to dry out and to burn… thus repeating endlessly.
    - It could be argued that positive feedback is worse because it is NOT self-regulating.

Environmental Unity
- Simply stated, "It is impossible to change only one thing; *everything affects everything else*."
- Changes in one part of the system often have a secondary and tertiary effect within the system & the effects on adjacent systems.

Uniformitarianism
- The philosophical principle that processes that operate today operated in the past.
- Observations of processes today can explain events that occurred in the past and leave evidence
- *Normally stated as,"The present is the key to the past."...... But, should be restated as: "The study of the past AND present is the key to the FUTURE"*

Changes and Equilibrium in Systems
- Steady state:
    - A state where the Input = Output
    - Material or energy is entering and leaving the system in equal amounts
    - Opposing processes occur at equal rates
    - Sometimes referred to as the *"Balance of Nature"*
    - However, steady state is rarely obtained or maintained for very long.

Natural Order of Systems
- The environmental lesson is that systems change naturally.
- We need to gain a better understanding of the following to manage systems:
    - Types of disturbances and changes that are likely to occur
    - Time periods over which changes occur
    - Importance of each change to the long-term productivity of the system

Changes and Equilibrium in Systems

- Average Residence Time: (also known as removal time) is the average amount of time that a particle spends in a particular system.
- This measurement varies directly with the amount of substance that is present in the system.

Changes and Equilibrium in Systems

- Average Residence Time (ART):
    - The equation for average residence time is: ART = *S/F*
    - *Where S is size of the reservoir, F is the rate of transfer*

ART

- The main two reasons why ART is important is to understand:
    - How quickly things can affect change &
    - How quickly things can recover from change.
- Inflow and outflow will also have an effect on the residence time of a system.
- If the inflow and outflow are increased, the residence time of the system will be shorter.
- However, if the inflow and the outflow of a system are decreased, the residence time will be longer.
- This is assuming that the concentration of the substance in the system and the size of the system remain constant, and assuming steady-state conditions.
- More specifically it is the time during which water remains within an aquifer, lake, river, or other water body before continuing around the hydrological cycle.
- Residence times of water in rivers are a few days, while in large lakes residence time ranges up to several decades.
- Residence times of continental ice sheets is hundreds of thousands of years, of small glaciers a few decades.
- Understanding the residence time of oceans, lakes and streams is important in order to determine the concentration of pollutants and how this may affect the marine life & local population.
    - A system much like a small lake with an inlet and an outlet and a *high* transfer rate of water has a *short* residence time for water.
    - The small lake is especially vulnerable to change if a pollutant is introduced, but the good news is they can also be cleaned up quickly.
    - *Transfer Rate of Water = Inflow and Outflow*
    - Large systems with a *slow* rate of transfer of water, such as oceans, have a *long* residence time and are much less vulnerable to quick change and are not usually able to be polluted easily.....
    - However, once polluted, large systems with slow transfer rates are a MAJOR problem to clean up.

Earth as a Living System

- <u>Biota</u>:
    - All the organisms of all species living in an area or region up to, and including, the biosphere
- <u>Biosphere</u>:
    - That part of a planet where life exists
    - The system that includes and sustains life

Ecosystem

- A community of organisms and its local nonliving environment in which matter (chemical

elements) cycles and energy flows.
- Sustained life on Earth is a characteristic of ecosystems
- Can be natural or artificial

The Gaia Hypothesis
- Named for Gaia, the Greek goddess Mother Earth
- Devised by James Lovelock
- States that the surface environment of the Earth is actively regulated by the sensing, growth, metabolism and other activities of the biota.
- Simply stated, Life manipulates the environment for the maintenance of Life...., and that the planet Earth is capable of physiological self-regulation.
- James Hutton, (Uniformitarianism author), believed Earth to be a super-organism and compared the cycling of nutrients from soils and rocks in streams and rivers to the circulation of blood in an animal.
- Figuratively, the rivers are the arteries and veins, the forests are the lungs, and the oceans are the heart of Earth.

Exponential Growth
- Growth occurs at a constant rate per time period
- Equation to describe exponential growth is:
- Doubling time: The time necessary for the quantity being measured to double.
    - Approximately equal to 70 divided by the annual percentage growth rate

Why Solving Environmental Problems Is Often Difficult
- Exponential growth
    - The consequences of exponential growth and its accompanying positive feedback can be dramatic
- Lag time
    - The time between a stimulus and the response of a system
    - If there is a long delay between stimulus and response, then the resulting changes are much more difficult to recognize.
- Irreversible consequences
    - Consequences that may not be easily rectified on a human scale of decades or a few hundred years.

Why Solving Environmental Problems Is Often Difficult
- Exponential growth, long lag time, and the possibility of irreversible consequences have special implications for environmental problems and finding solutions to those problems.
- Most changes by human activity involve rather slow processes with cumulative effects
- Example: Global warming can be traced to the Industrial Revolution, when people started burning massive amounts of fossil fuels.