3 SYSTEMS

Why are Environmental Problems so Difficult to Solve?

PowerPoint® Lecture prepared by Gary A. Beluzo

STUDENT LEARNING OUTCOMES

After reading this chapter, students will be able to

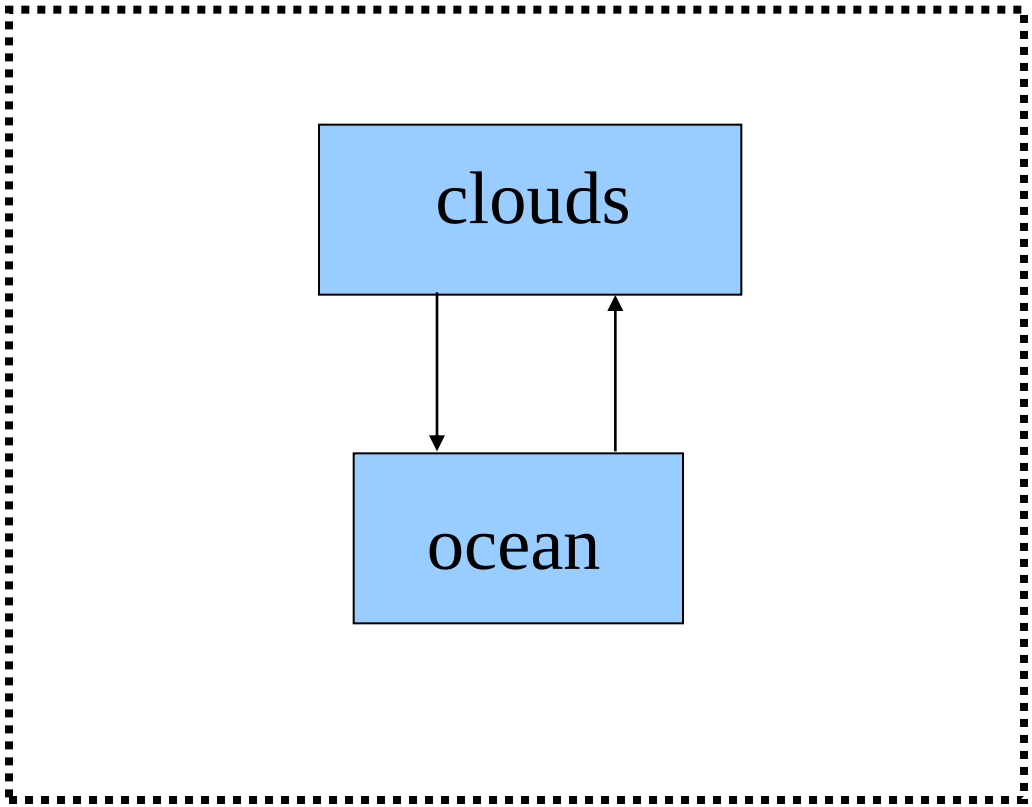
- Explain how systems are able to generate predictable behaviors and are able to display homeostasis.
- Explain how natural selection traits allow organisms to thrive in particular environments.
- Compare and contrast linear and non-linear growth and their effects on society's ability to manage the environment.
- Identify the characteristics of systems that make it difficult to solve environmental challenges and why potential solutions sometimes make the problem worse.
- Explain how the scientific method is able to evaluate competing explanations for observable phenomena.

The Last Tree on Easter Island and the Lorax

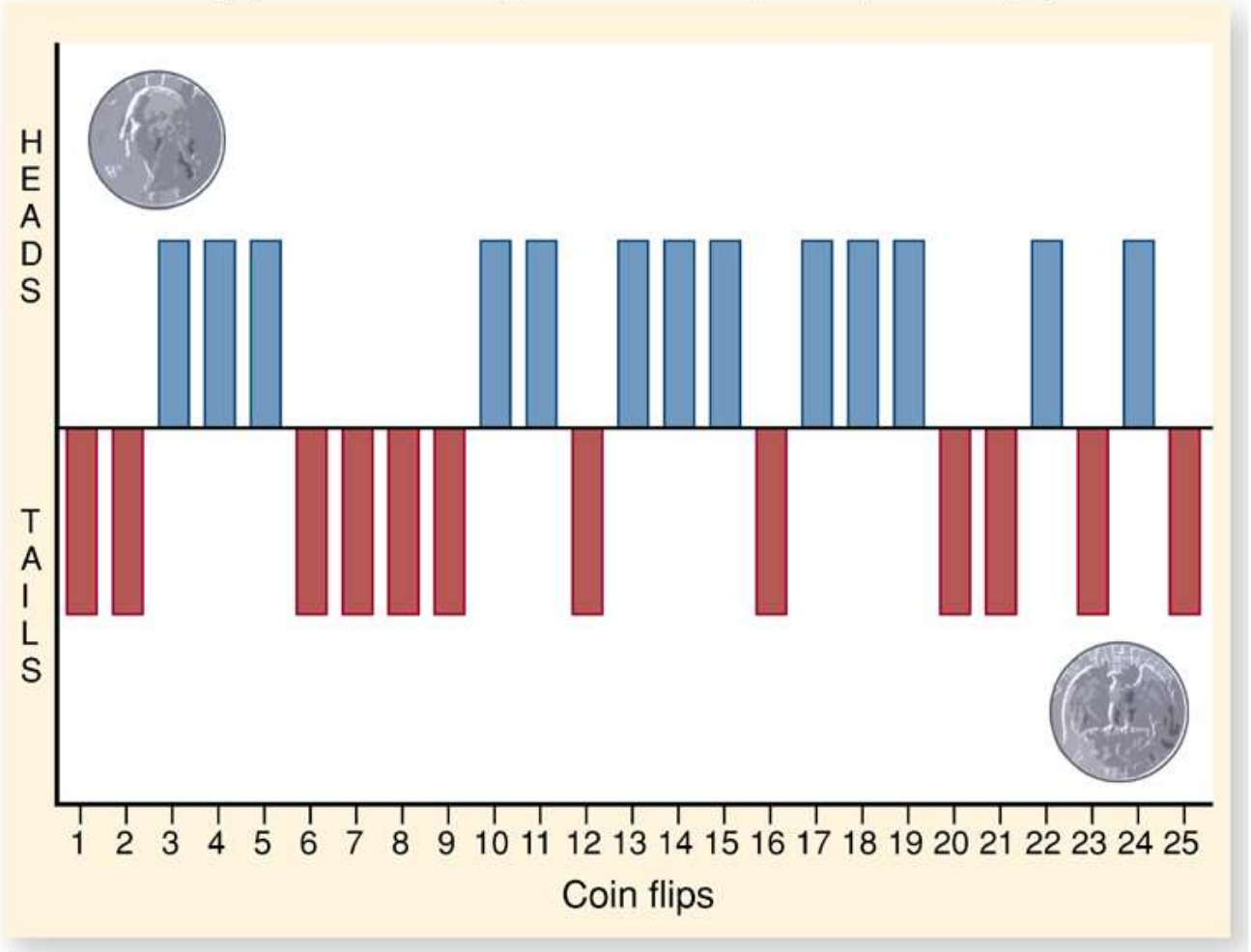
- Roggeen arrived on Easter Island in 1722, no trees or bushes higher than 3 meters present
- Analysis of charcoal and pollen in mud cores indicated up to 21 species of trees were originally present.
- Forest largely eliminated between 1400s and 1600s
- How could the Easter Islanders have cut down the last of their trees?
- **Who Is the Lorax?**

What are Systems?

- A system is a collection of parts, which are known as ***storages and flows***, that interact with each other to generate regular or ***predictable*** patterns or behaviors.



Random versus Predictable

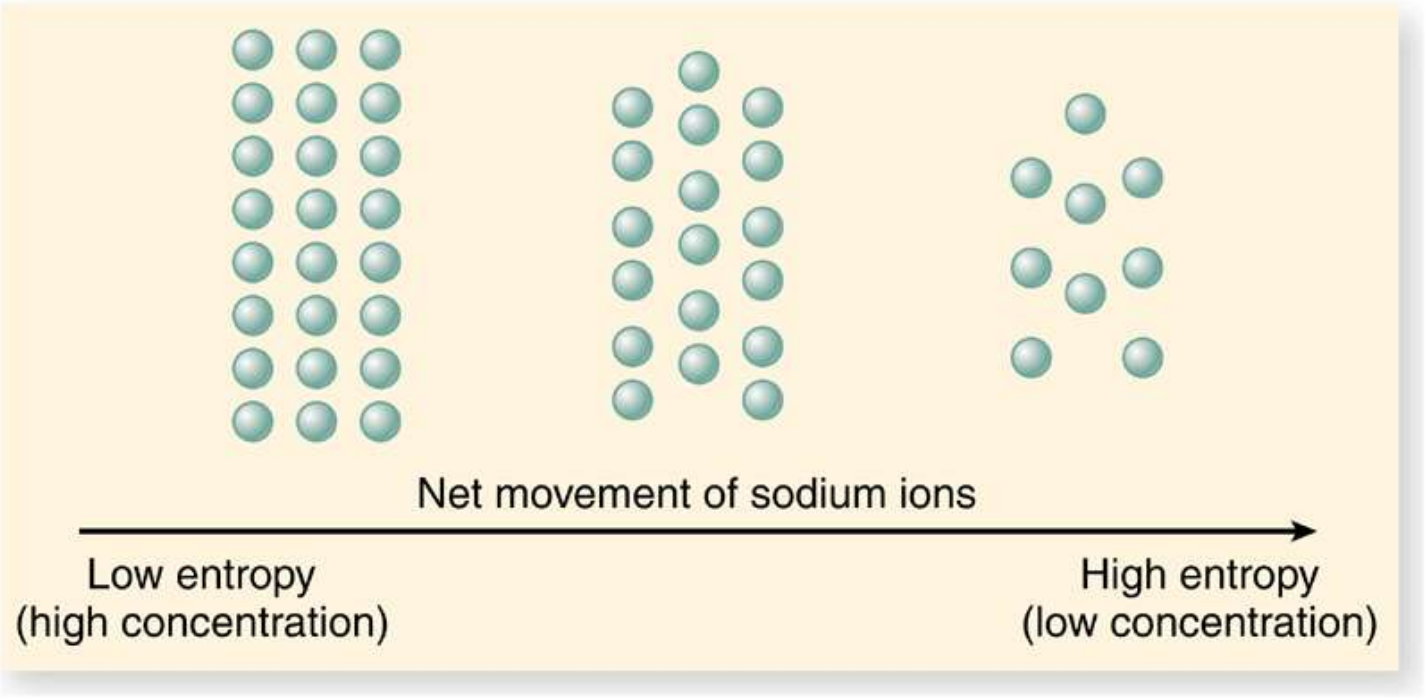


Do Systems Have Goals?

- Defining characteristic of a system is its regularity or predictability
- Environmental impacts are often determined by economic systems
- The PURPOSE of an economic system is to produce and distribute goods and services that people associated with material well-being.
- Economic behaviors are judged by efficiency, which refers to getting the most out of the resources used
- Economic efficiency not equated with fairness
- **Economic changes produce winners and losers but that does not indicate whether the changes are economically good or bad**.

Using Energy to Generate Order

- Materials flow spontaneously from low entropy to high entropy resulting in **gradients**.



Types of Flow

Spontaneous Flow

- Occurs without energy input
- From high concentration to low

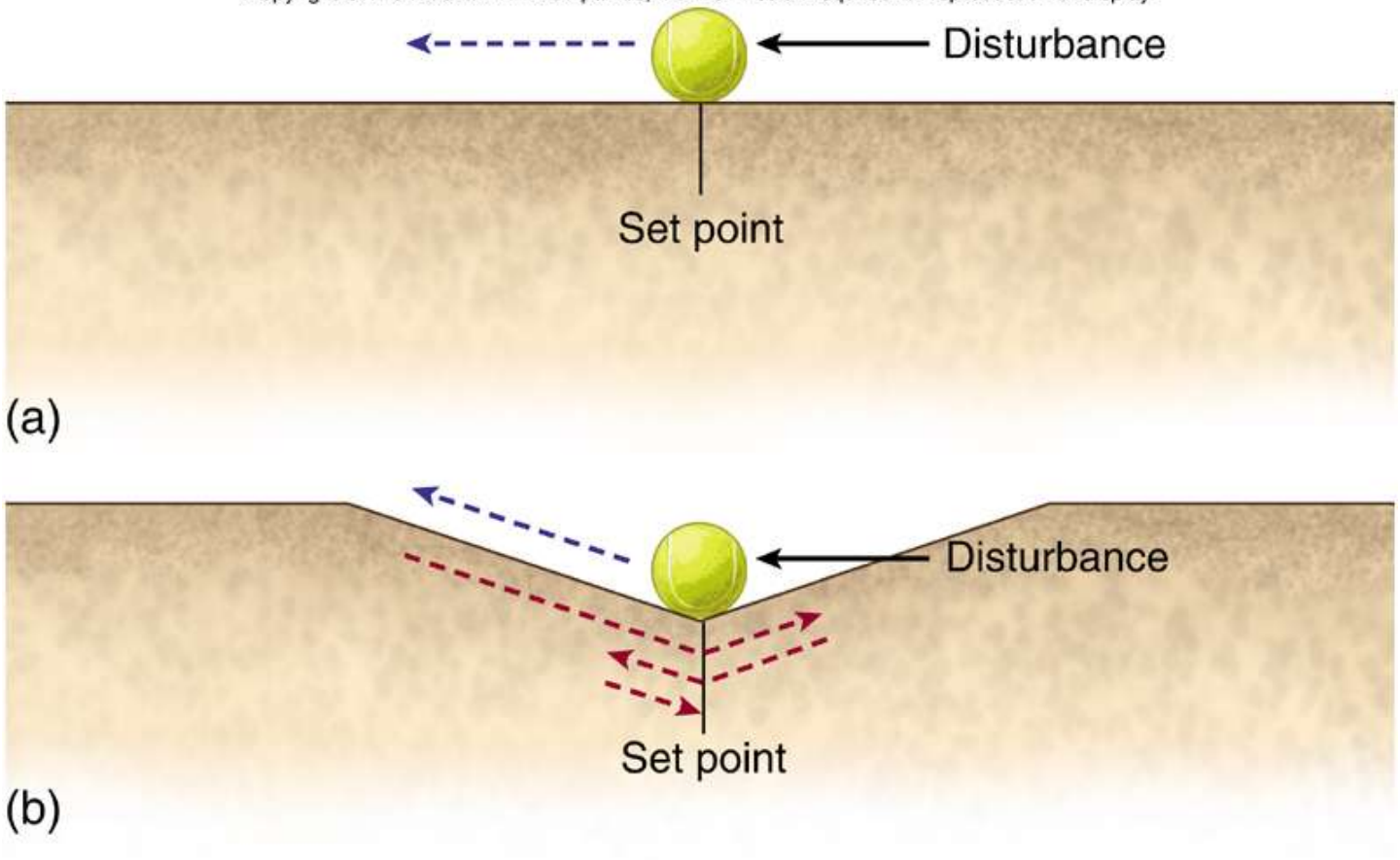
Non-Spontaneous Flow

- Requires energy input
- From low concentration to high
- At least one of these required in biogeochemical cycles

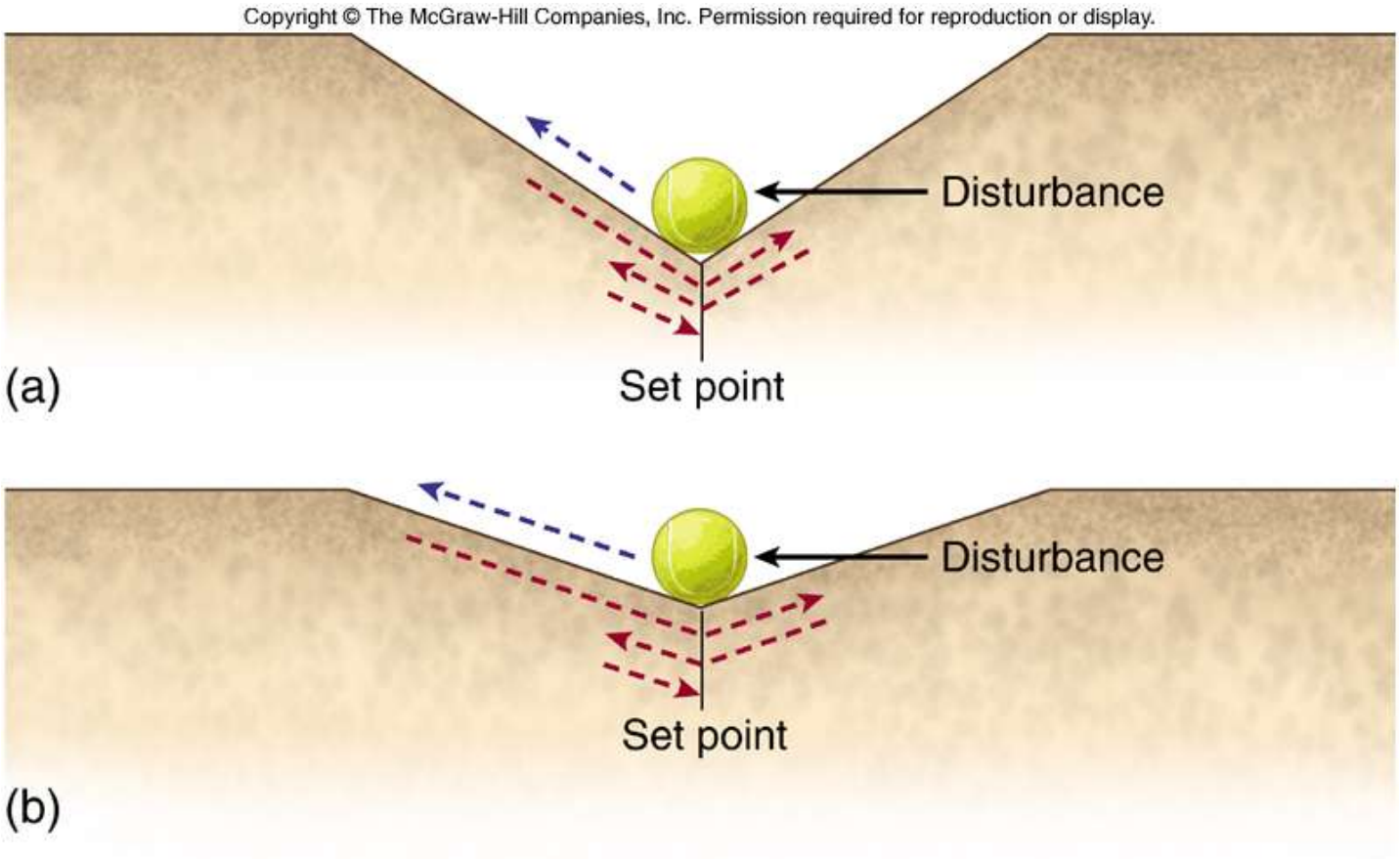
Homeostasis

- The ability to maintain the behavior of a system when disturbed.
- Measured by system's ability to maintain a certain storage or flow, termed the **set point**.
- For example, the **temperature set point** for the human body is 37 degrees Celsius.

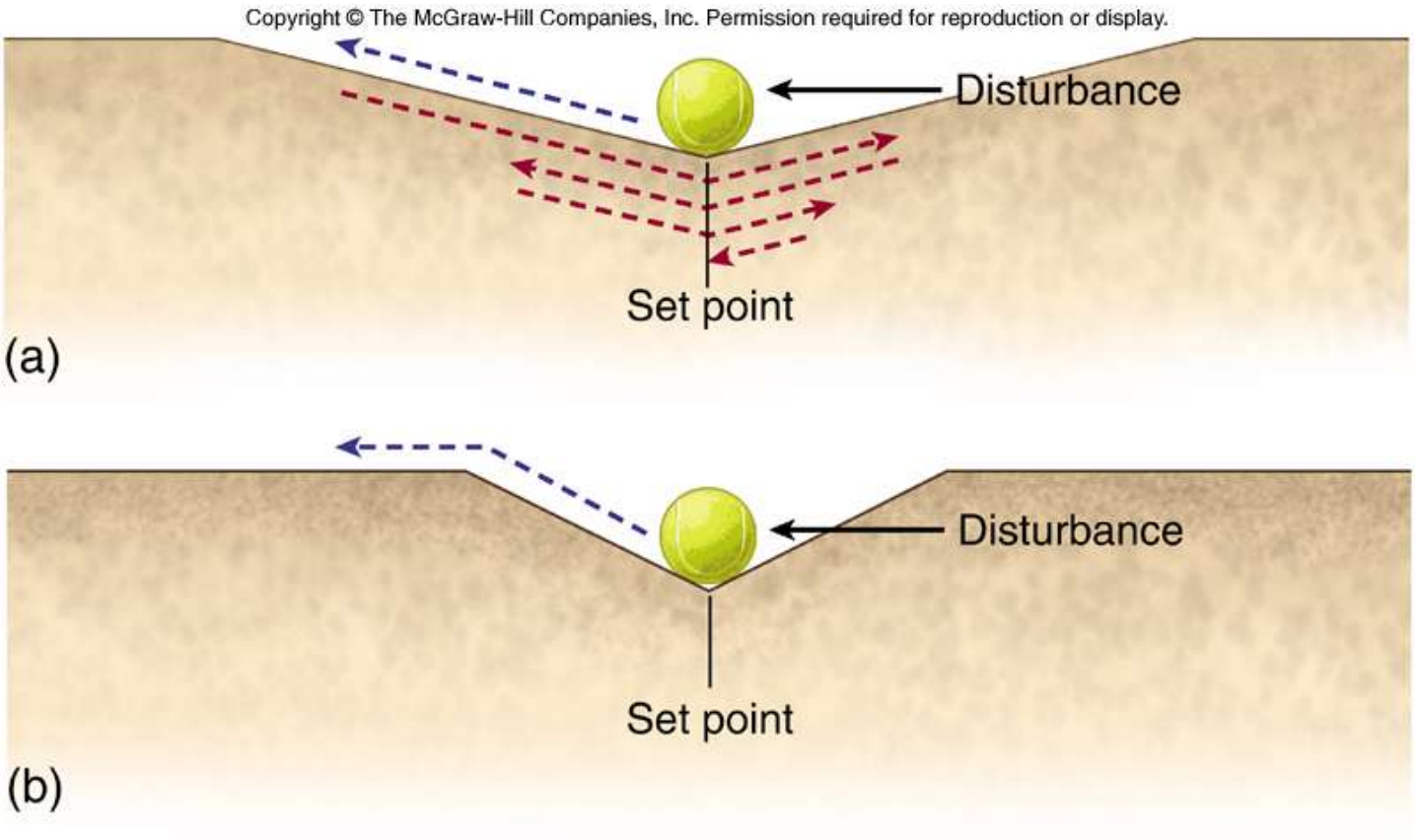
System Stability



System Resistance



System Resilience



System Structure

- Positive Relationship between system parts
- Increase in one part means increase in another
- Decrease in one part means decrease in another
- Symbolized with a +
- Amplifies behavior
- GUITAR AMPLIFIER
- GLOBAL WARMING?

- Negative Relationship between system parts
- Increase in one part means a decrease in another
- Decrease in one part means increase in another
- Symbolized with a -
- Balances behavior
- THERMOSTAT/FURNACE
- HUMAN BODY TEMP

A **complex, dynamic system** (e.g. a living organism) consists of **many** positive and negative relationships

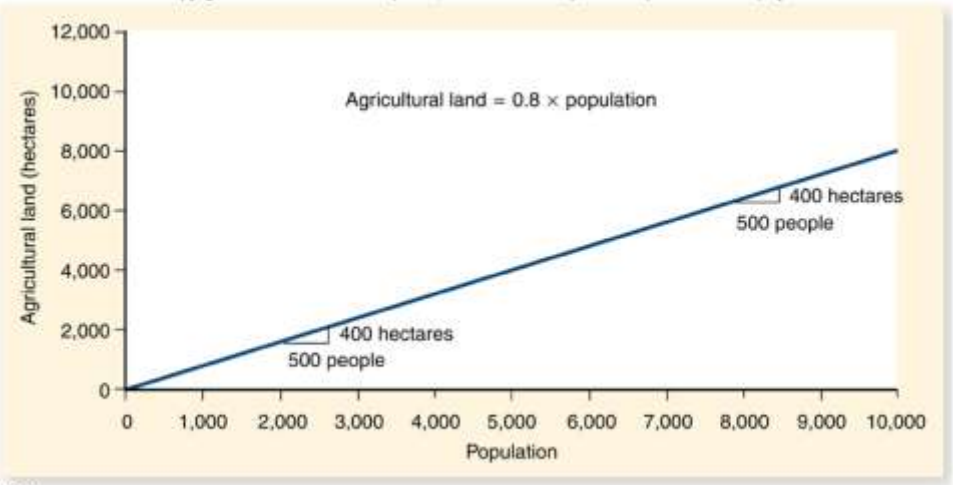
Analyzing Relationships

- **Function** is a mathematical formula that relates one variable (dependent) to another variable (independent)
- **Independent variable** is on the right hand side of the equal sign in a function and is represented by X-axis (horizontal)
- **Dependent variable** is on the left hand side of the equal sign in a function and is represented by Y-axis (vertical)

Agriculture Land = 0.8 * Population

Dependent variable coefficient Dependent variable

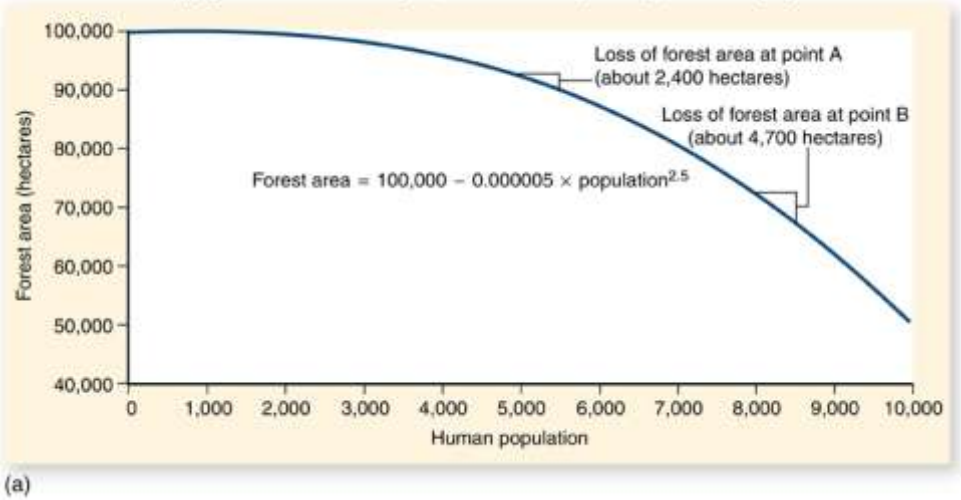
Agriculture Responds to Population +



(a)

(b)

Forest Responds to Population -

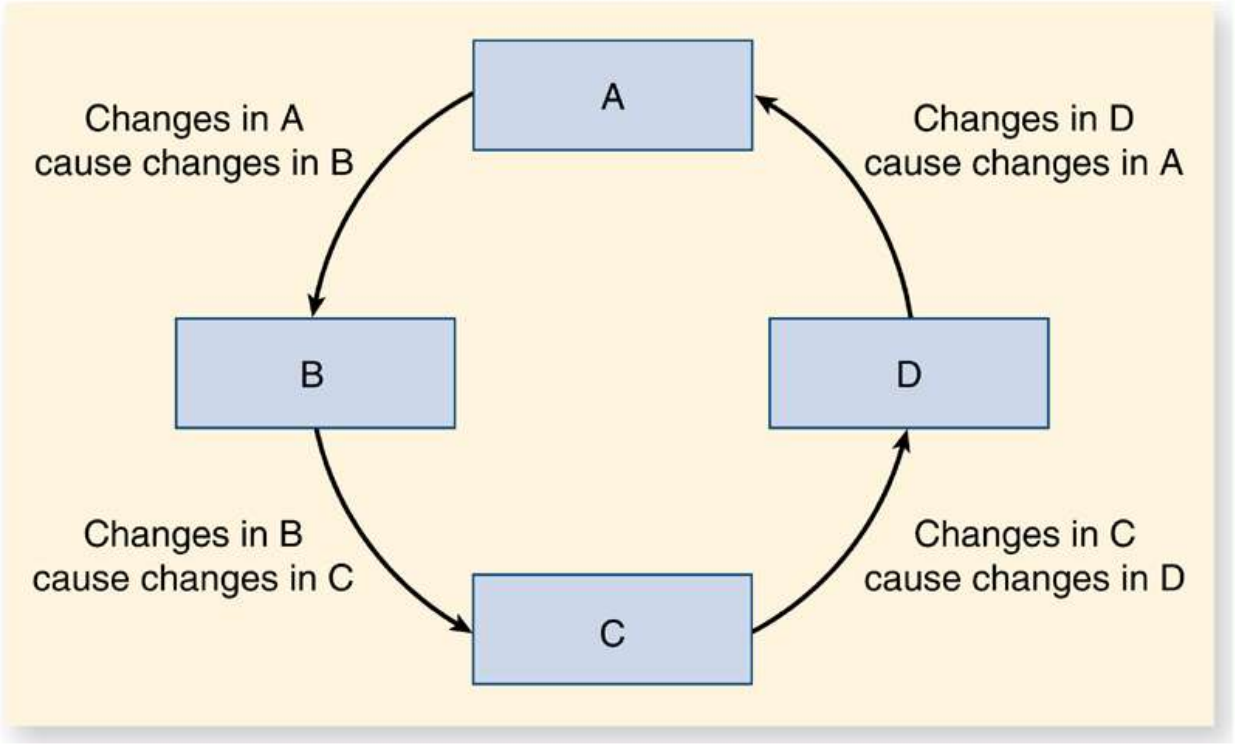


(a)

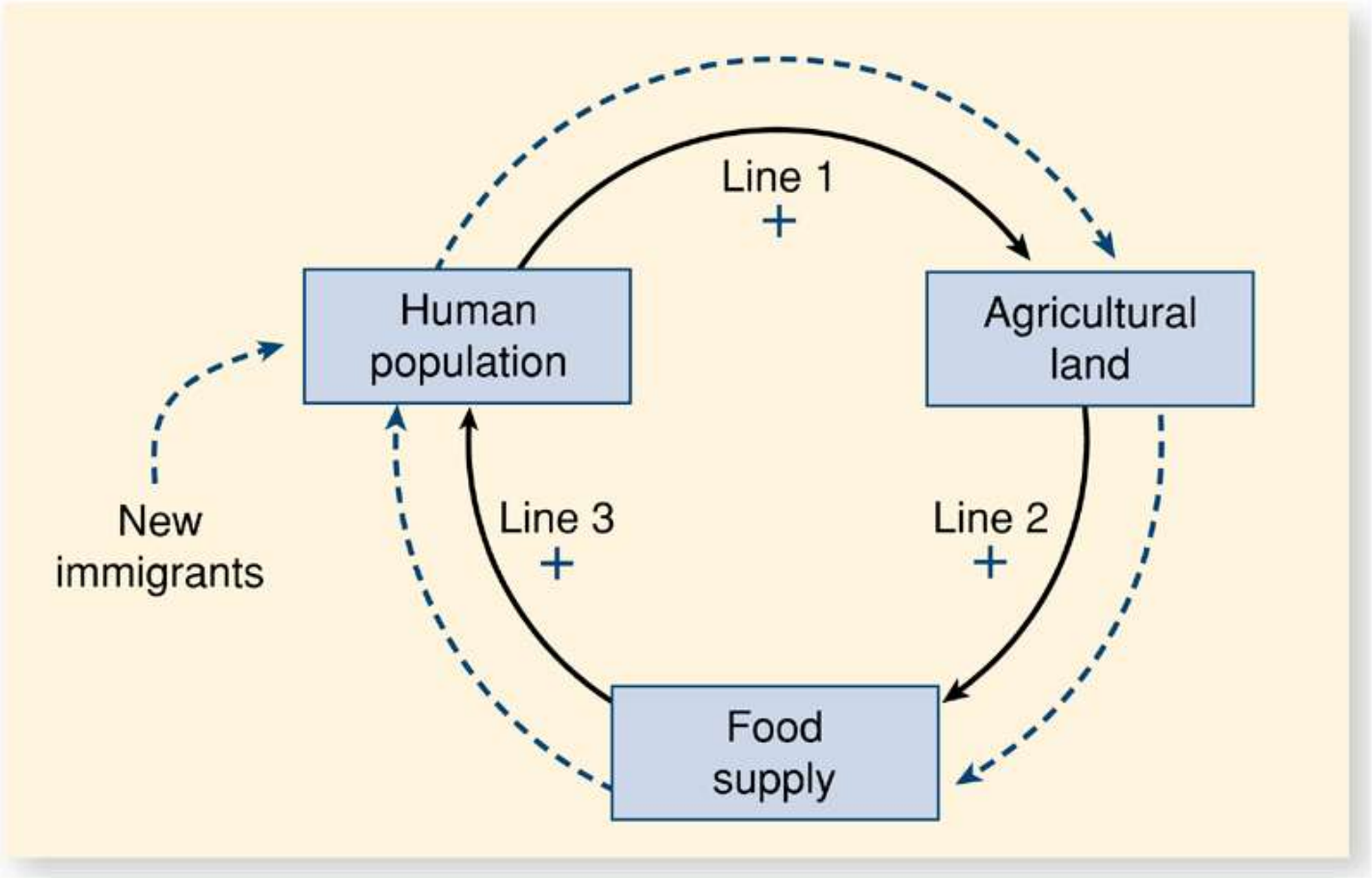
(b)

Feedback Loops

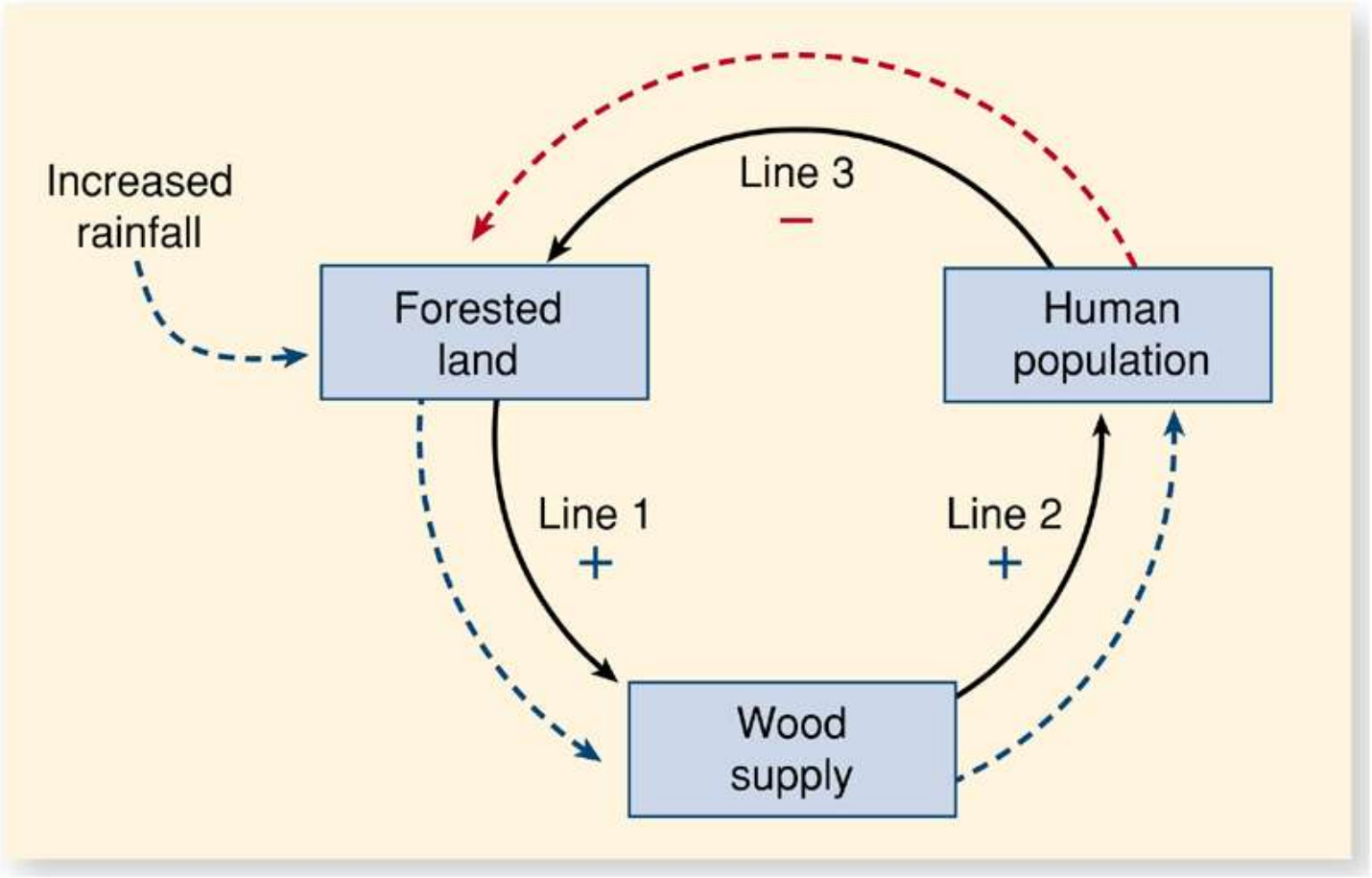
The effects of a disturbance on a system can be evaluated using the notion of a feedback loop.



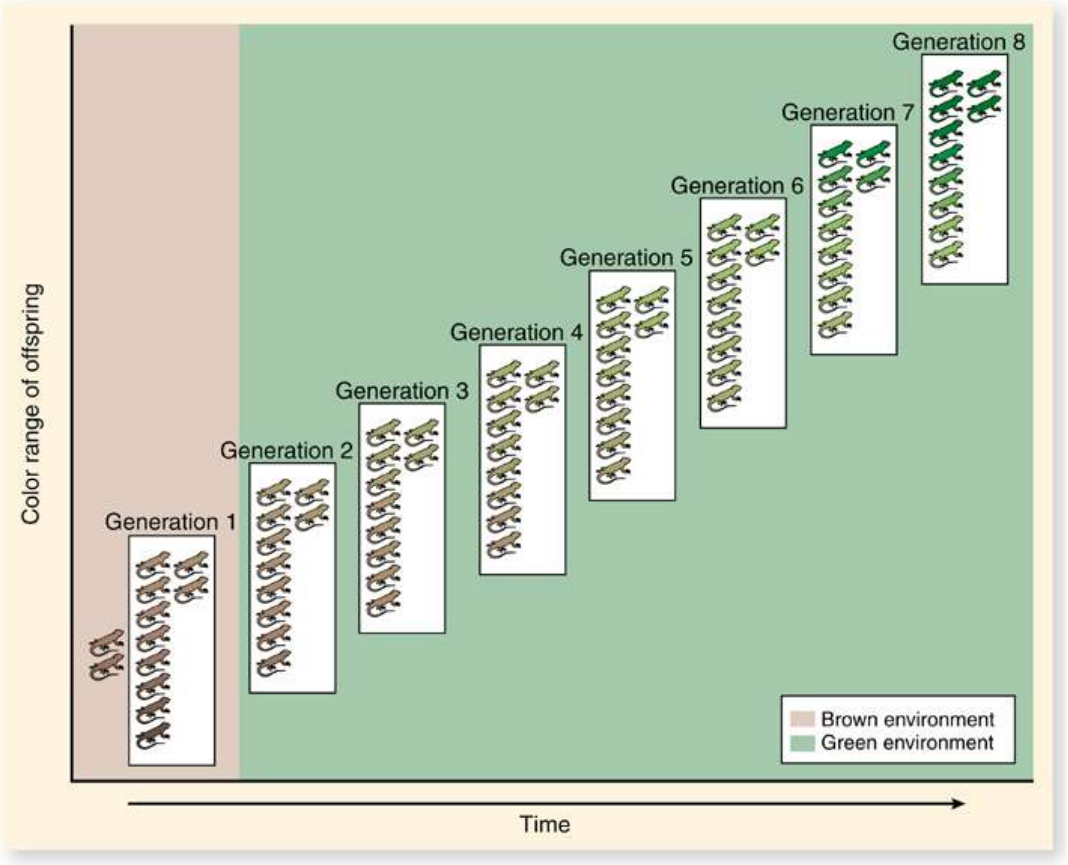
Positive Feedback Loop +



Negative Feedback Loop -



Natural Selection

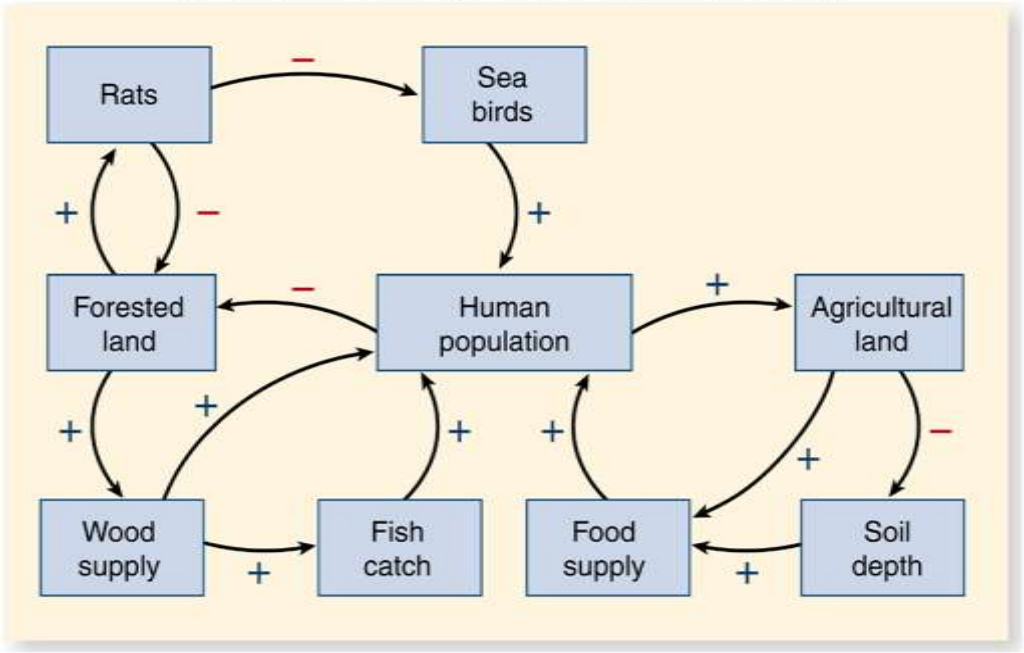


Why are Systems Difficult to Manage?

- Why do societies behave unsustainably?
- **Unpredictability** (stochastic behavior)
- **Variance** is the degree or dispersion or scatter in a variable (large variance means low predictability)
- **Unpredictability and extreme events** make it difficult to manage environmental systems
- Risk Management (used without knowing all!)
- **Complexity**
  - The number of storages, flows, and the number and strength of feedback loops in a system

Complexity in Easter Island System

- **Positive feedback loop** that included human population, agricultural land, and food supply.
- **Negative feedback loop** that included population, agricultural land, forest area, and supply. Not possible to know which of these loops predominates.



Hierarchy

- Systems often are part of a larger system.
- Subsystems arranged like a ladder according to function
- Organization of natural world viewed as hierarchy of systems

Time Lags

- Time lag refers to the period that lapses between a **cause and an effect.**
- **Long lag times make it difficult to establish cause and effect**
- Long lag times also diminish effectiveness of environmental policy

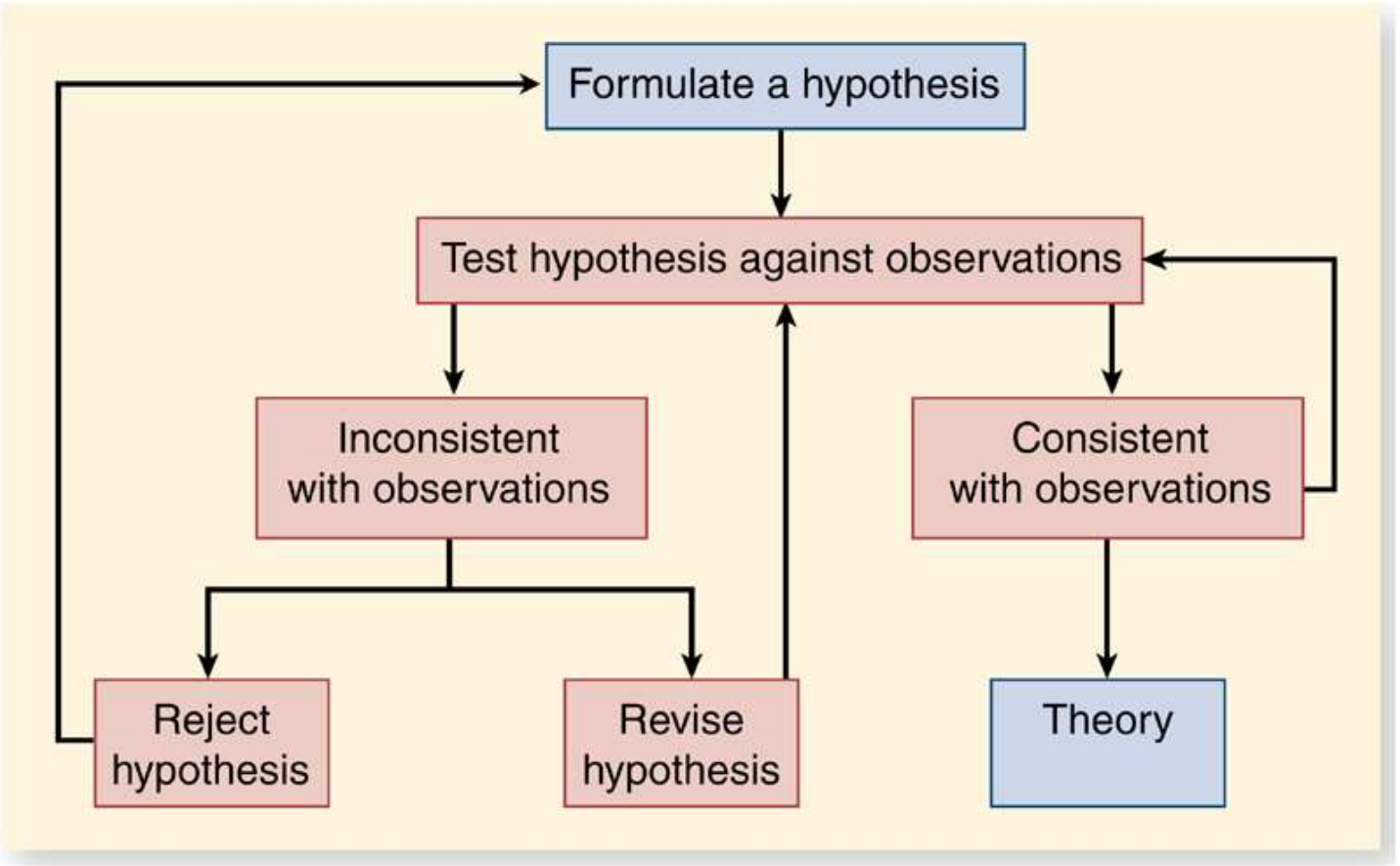
Distance Effects

- Distance refers to the separation in **space between a cause and an effect**.
- Effects of Acid Rain in the Appalachian Mountains and the tall stacks in the Mid-West.

Linear versus Non-Linear Relationships

- Linear functions are represented with a straight line
- Constancy disappears in nonlinear relationships, which are represented with a function other than a straight line.
- Most of us tend to see the world through “linear glasses”
- Nonlinear implies that the severity of an environmental problem can increase **suddenly even if the cause of the problem increases gradually**.

The Scientific Method



Reductionistic versus Systems

- A Reductionist Approach is based on a premise that the best way to learn about something is to break it into its **parts and study parts separately.**
- **This approach has been quite successful in the natural sciences (biology, chemistry, physics)**
- Limits of the reductionist approach were first recognized by Frederick von Bertlanfy
- **General Systems Theory-** concerned with problems of relationships, structures, and interdependence, rather than constant attributes of object.
- **Integrated Systems Approach**

Simulation Models

- Mathematical representations that simulate behavior of systems from insights gained from many disciplines
- First, choose which storages and flows to include
- Quantify the nature (positive or negative) and the strength (weak or strong) of the **relationships**.
- Calibrate or validate the Model using real-world observations.
- **Scenario Analysis (“What if?”)**
- Use an existing such as SimCity, SimEarth, or build your own: **STELLA**