1.3 Energy & Equilibrium

IB ESS
Read pages 27 - 40

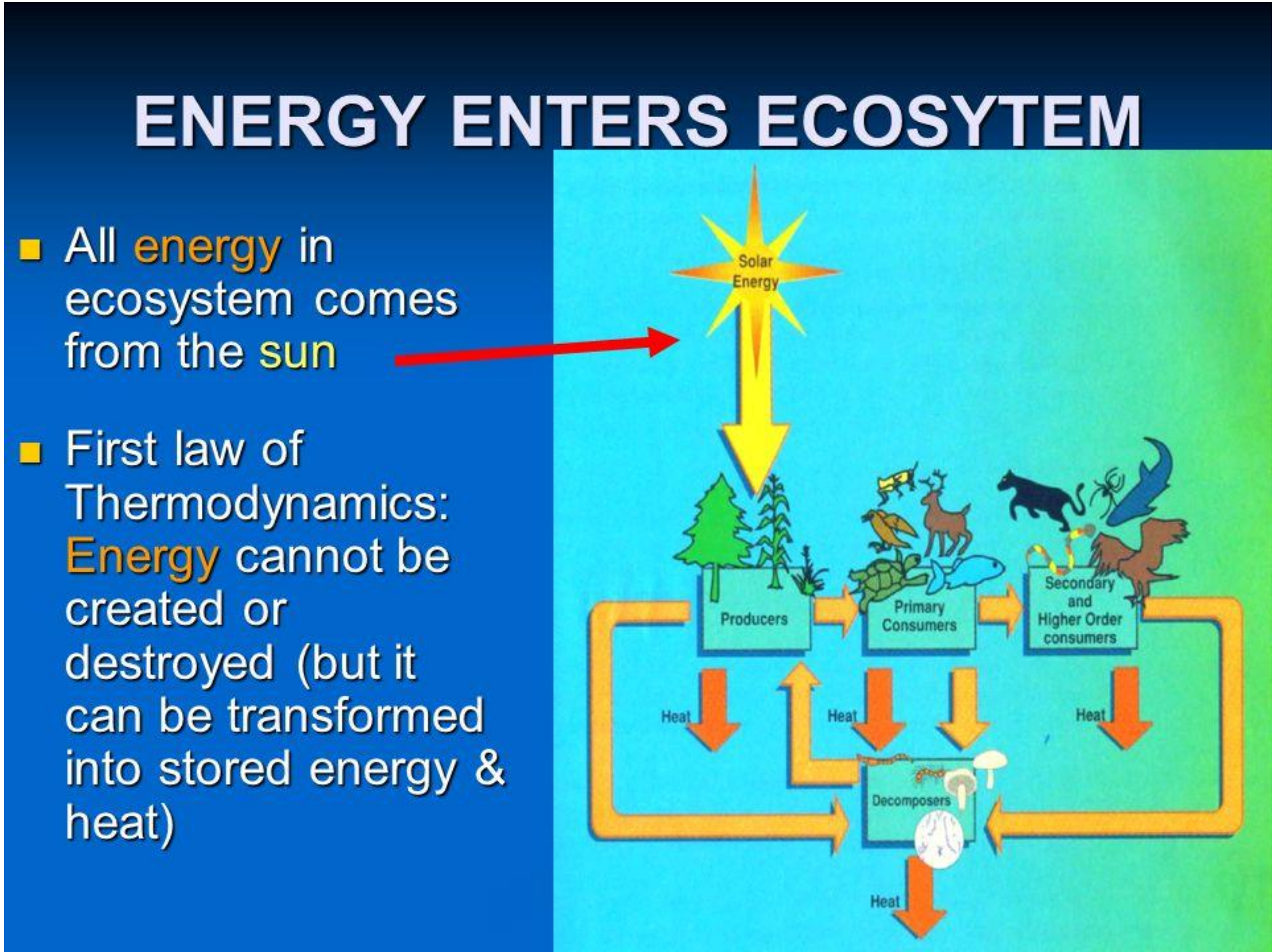
Learning Objectives

- Outline the laws of thermodynamics
- Explain how laws of thermodynamics relate to environment systems and govern flow of energy in a system
- Describe how a system can exist in alternative states of equilibrium
- Describe how positive destabilizing feedback mechanisms can drive a system to a tipping point
- Describe how negative feedback can stabilize a system

First Law of Thermodynamics

- Energy cannot be created nor destroyed, only converted from one form to another
- Energy exists in many forms
  - Light, heat, chemical, electrical, sound & kinetic
  - In LIVING systems:
    - HEAT cannot be converted to other forms
    - No new energy is created….but input energy is converted from one form to another
    - Total amount of energy ecosystems DOES NOT CHANGE
    - Amount available to living things gradually reduces
      - Energy is used for growth, movement, reproduction & other processes
    - Energy transfer & transformations are not efficient in living systems
      - Ex. less than 10% usable energy is passed from one organism to the next in a food chain

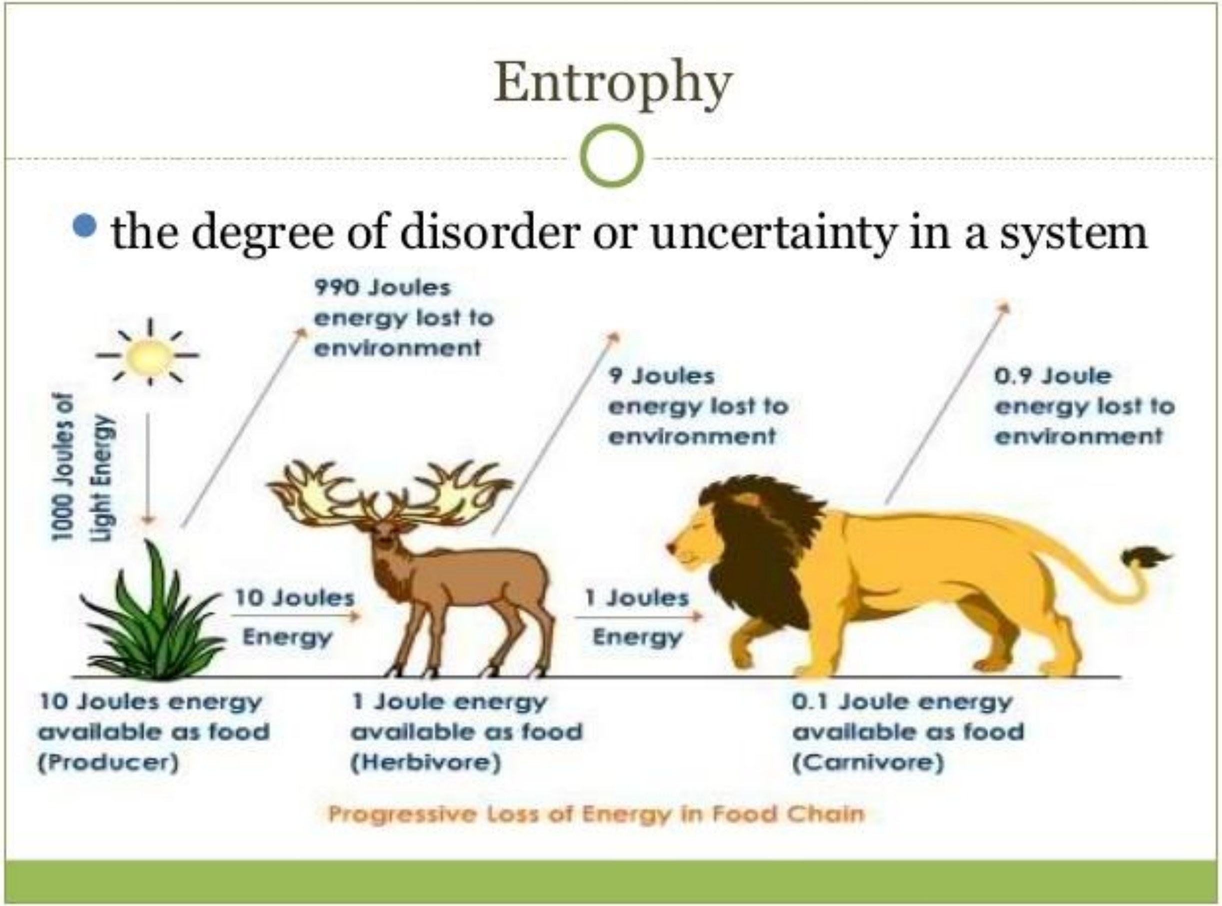
First Law of Thermodynamics



Second Law of Thermodynamics

- In isolated systems, entropy (disorder) tends to increase with time because the system becomes disorganized
- Entropy, in terms of evenness of energy distribution in a system
  - Energy used to create order & hold molecules together
  - Entropy increases if less energy is available
  - Entropy increases → energy & matter change from concentrated to more dispersed
  - Availability of energy to carry out processes lessens
- Most concentrated form of energy = sun
- Most dispersed form of energy = heat
- Living systems require constant input of energy (sun) to replenish what is lost as heat in order to maintain order & structure

Second Law of Thermodynamics



Equilibrium

- State of balance that exists between the different parts of any system
  - Natural systems are open & in a steady-state equilibrium
  - Steady-state equilibrium - (dynamic equilibrium) a stable form of equilibrium that allows a system to return to its steady state after a disturbance (EX. homeostasis)
  - Example:
    - Regulation of body temperature in mammals (sweating & shivering)
    - Population of animals that remains the same size (birth & death)
    - Woodland recovers after heavy rainfall
    - Forest re-grows fallen trees

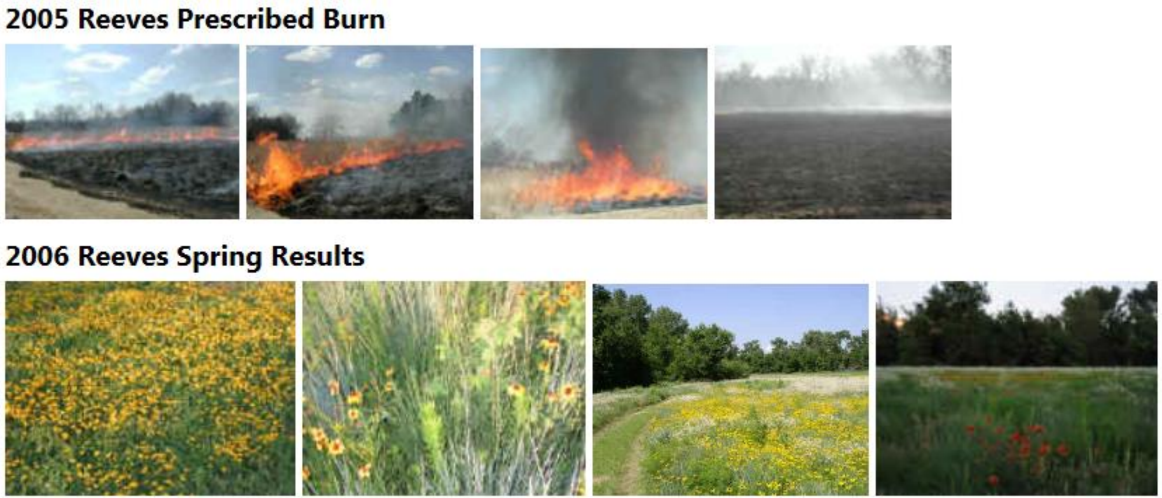
“The more things change, the more they stay the same”

Static equilibrium

- NOT living.
- Remain unchanged for long periods of time
- Example:
    - Rock formation, bottle sitting on a table

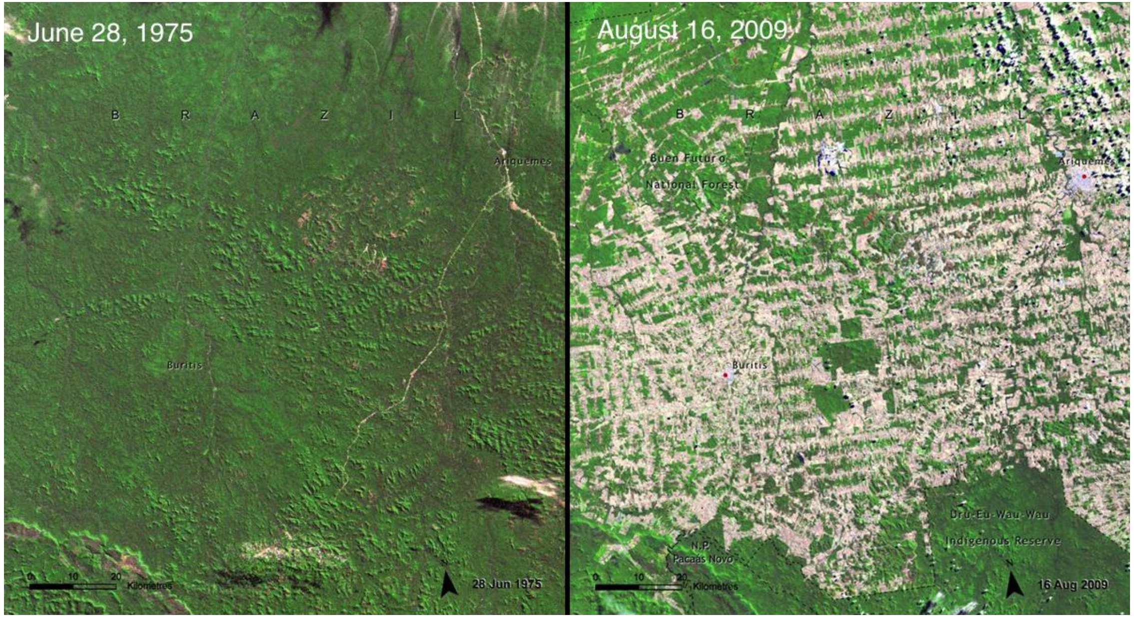
Stable equilibrium

- System tends to return to the same equilibrium after a disturbance
  - Swinging pendulum
  - Natural, open ecosystems
    - May be steady-state equilibrium (climax community) OR developing steady-state equilibrium (develops over time, like a changing ecosystem or succession)



Unstable Equilibrium

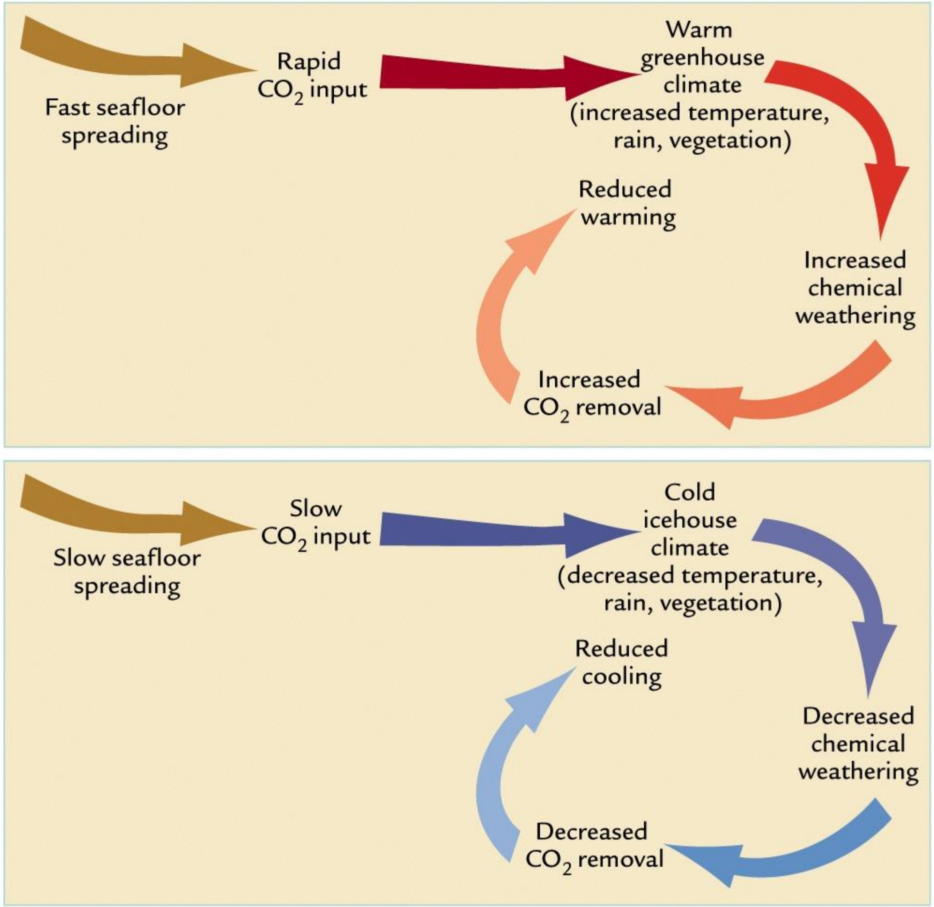
- A new equilibrium is formed after the disturbance
  - A ruler balanced vertically on a finger (if disturbed it will fall & continue to fall until it hits the ground, creating a new & different equilibrium)



Rainforest area in Brazil
Transformed into farms

Feedback systems

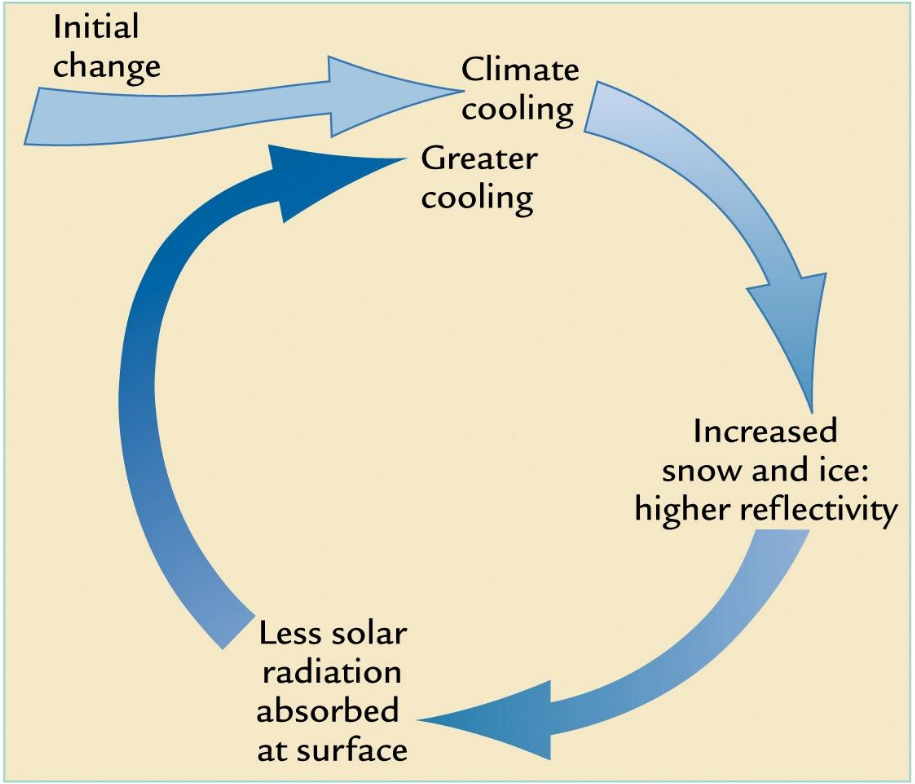
- Return of part of the output from a system as input, so as to affect succeeding outputs
- Information (from inside or outside the system) starts a reaction that affects the processes of the system
  - Changes in these processes lead to changes in the output...in turn affect (feed back to) the level of input
  - Change a system to a new state (positive) or maintain a system at a steady state (negative)



<u>Positive Feedback</u>

- Destabilizing
- Allows a system to change rapidly
- <u>Leads to more & greater change</u>
- Leads to exponential deviation away from an equilibrium (upward or downward, but not both)
    - must eventually come to an end
    - Resources allowing rapid change will come to an end
    - Leads to a vicious cycle of events

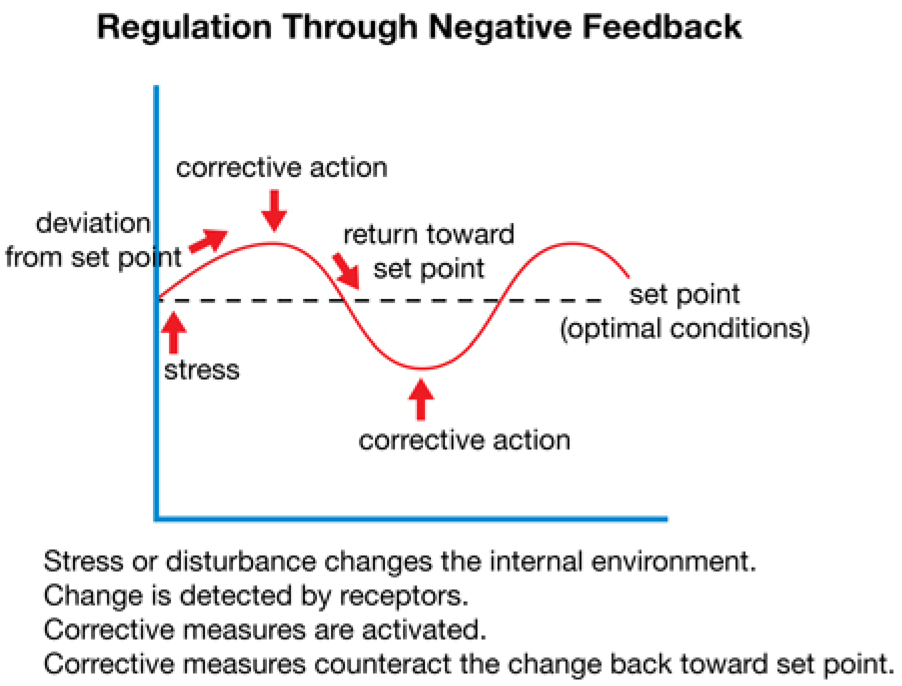
Can you think of an example the model represents?

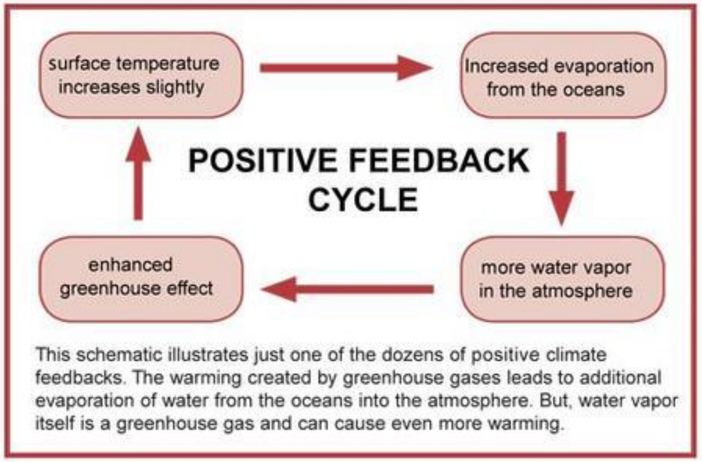


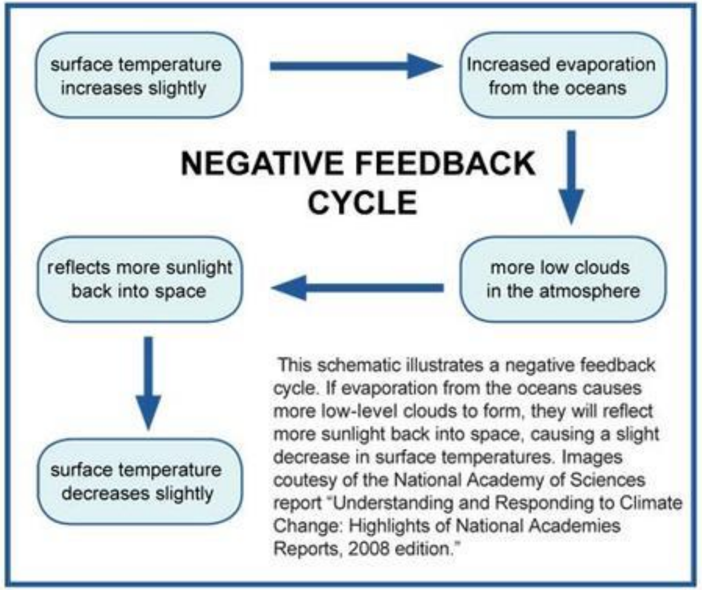
Negative Feedback

- Dampen down or counteract any deviation from an equilibrium
- Promotes stability...steady-state equilibrium
- Allows system to regulate itself
- Stabilizes system to eliminate any stray from the preferred conditions
  - Examples: governor on a steam engine, thermostat, homeostasis in your body, predator-prey population regulation
  - Maintenance of a steady-state equilibrium relies on negative feedbacks
    - Body regulation of temp, blood sugar
    - Sustainable numbers of individuals of a species in an ecosystem
    - CO2 levels & plants

Negative Feedback







Resilience

- Of a system is the tendency of a system to maintain stability and resist tipping points.

Tipping point- minimum amount of change within a system that will destabilize it & cause it to reach a new equilibrium or stable state

- What can test this? (push to tipping point)
  - Exponential growth of a population (invasive species like water hyacinths or humans)
  - Exponential growth in our use of natural resources
  - Exponential growth in production of pollution
- How can tipping points be avoided?
  - Diversity present in system (wide diversity BEST)
  - Size of storages in system (large storages BEST)

Human society can negatively impact resilience of systems

- Reducing diversity…
  - Growing monoculture crops (fewer species)
  - Unable to resist change like drought or pests
  - Replacing ecosystems with development
- Reducing storages…
  - Example - excessive removal of trees or overfishing the ocean
  - Unable to recover

New equilibrium (without the overexploited resource) results