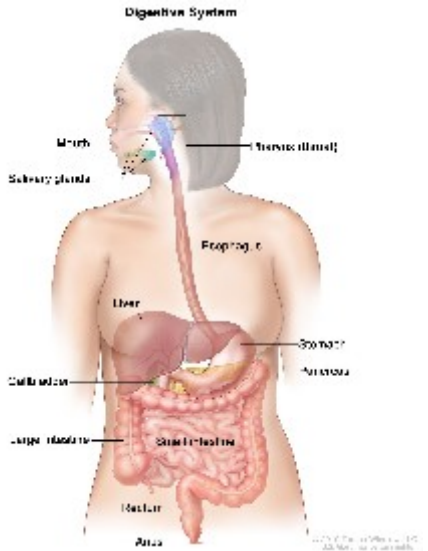
Lecture 1.2: Population and feedback systems

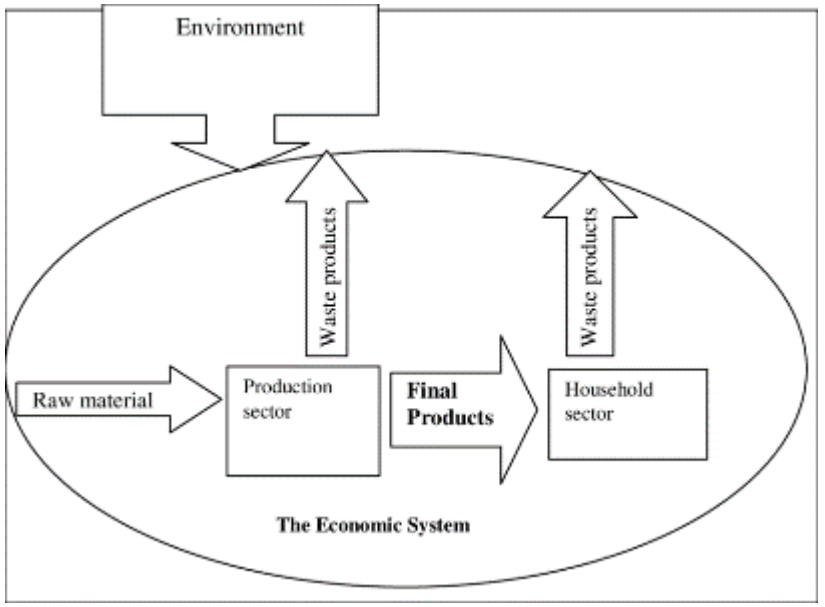
Understanding SYSTEMS!

- A set of inter-relationships between components or parts that function together to act as a whole



Digestive system

Computer system

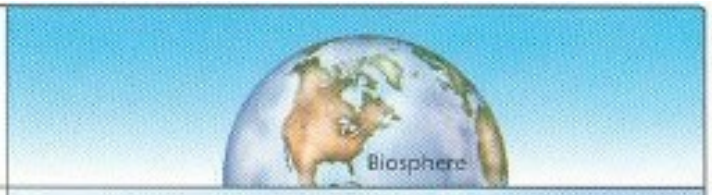
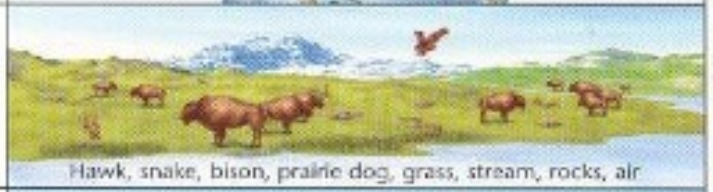
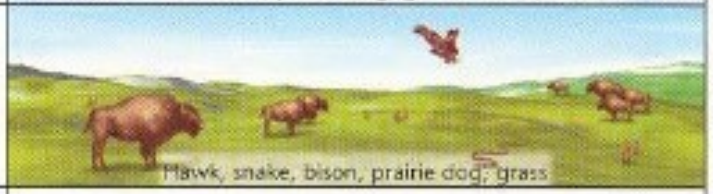


Economic system

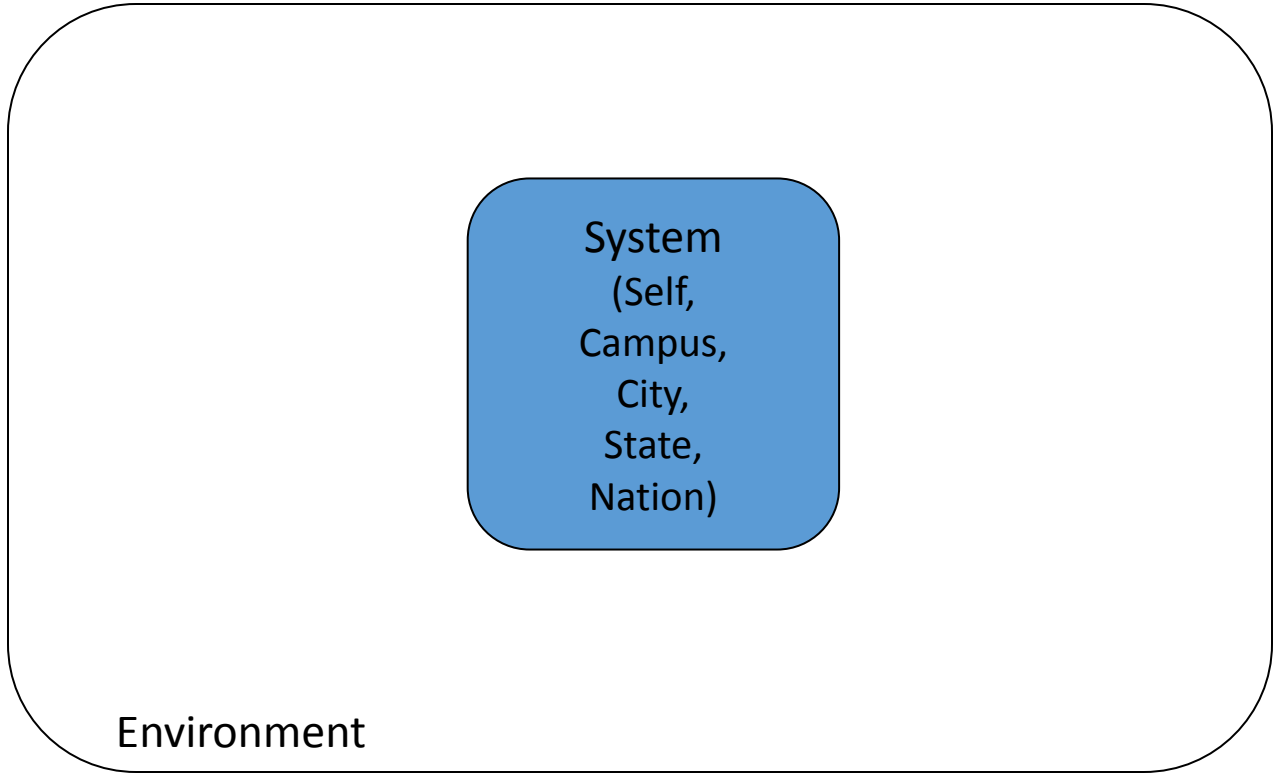
- A system is simultaneously both a system and a part of a larger system

Hierarchy

- A system is simultaneously both a system and a part of a larger system
- Something that is both a part and a whole has been called a “holon”, the basic part—wholes of a hierarchy

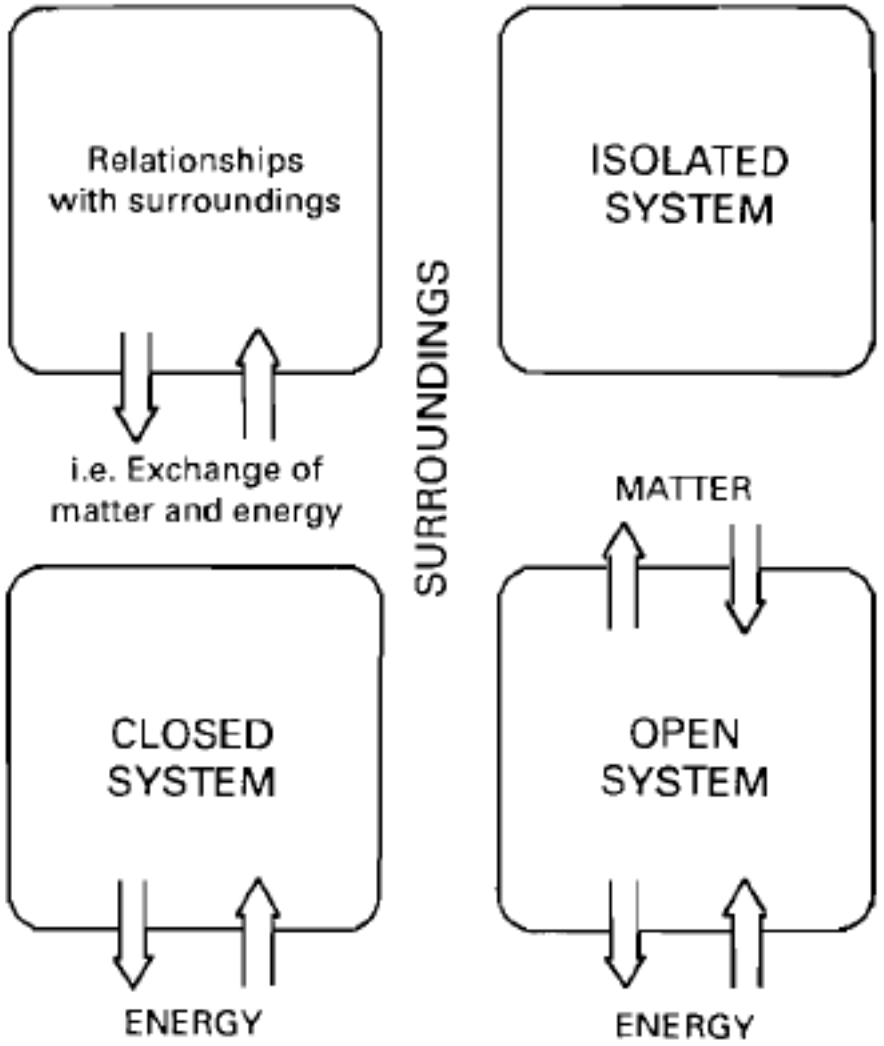
Biosphere	The part of Earth that contains all ecosystems	
Ecosystem	Community and its nonliving surroundings	
Community	Populations that live together in a defined area	
Population	Group of organisms of one type that live in the same area	 Bison herd
Organism	Individual living thing	 Bison
Groups of Cells	Tissues, organs, and organ systems	 Nervous tissue Brain Nervous system
Cells	Smallest functional unit of life	 Nerve cell
Molecules	Groups of atoms; smallest unit of most chemical compounds	 Water DNA

Systems Theory - boundaries

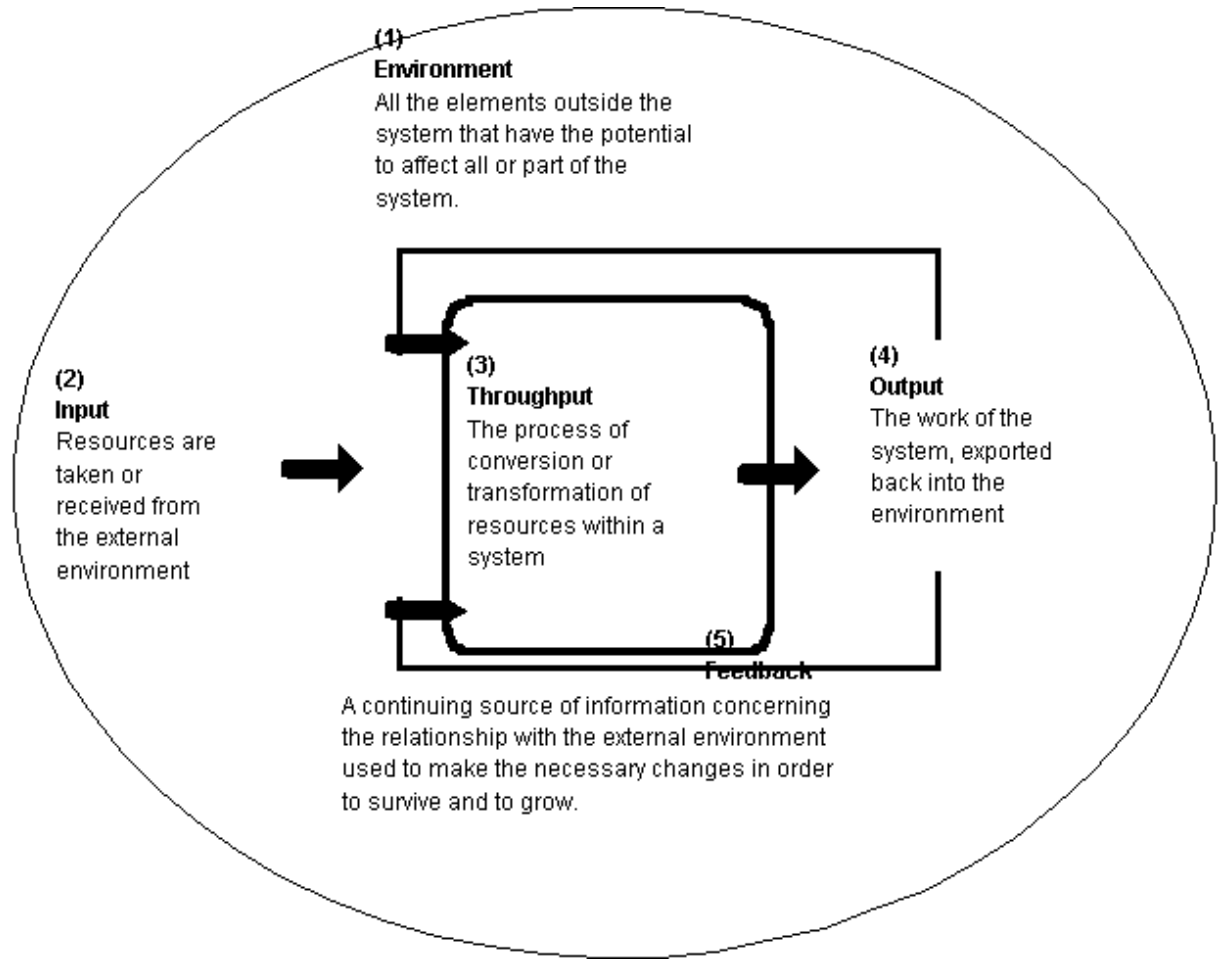


Defining energy systems

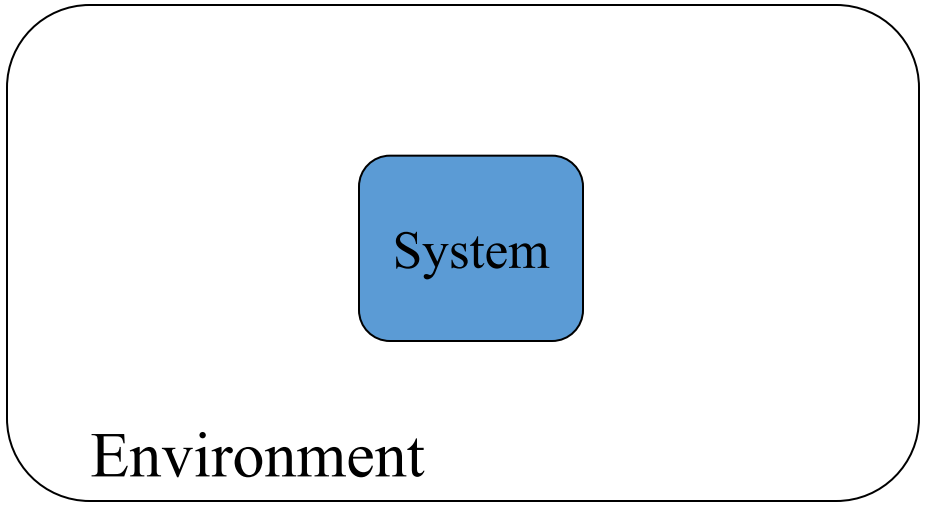
- Isolated systems no exchange with surrounding
  - Unrealistic, for comparison only
- Closed systems exchange energy, not matter
  - Earth can be thought of as a closed system
- Open systems exchange energy and matter
  - All environmental systems are open systems



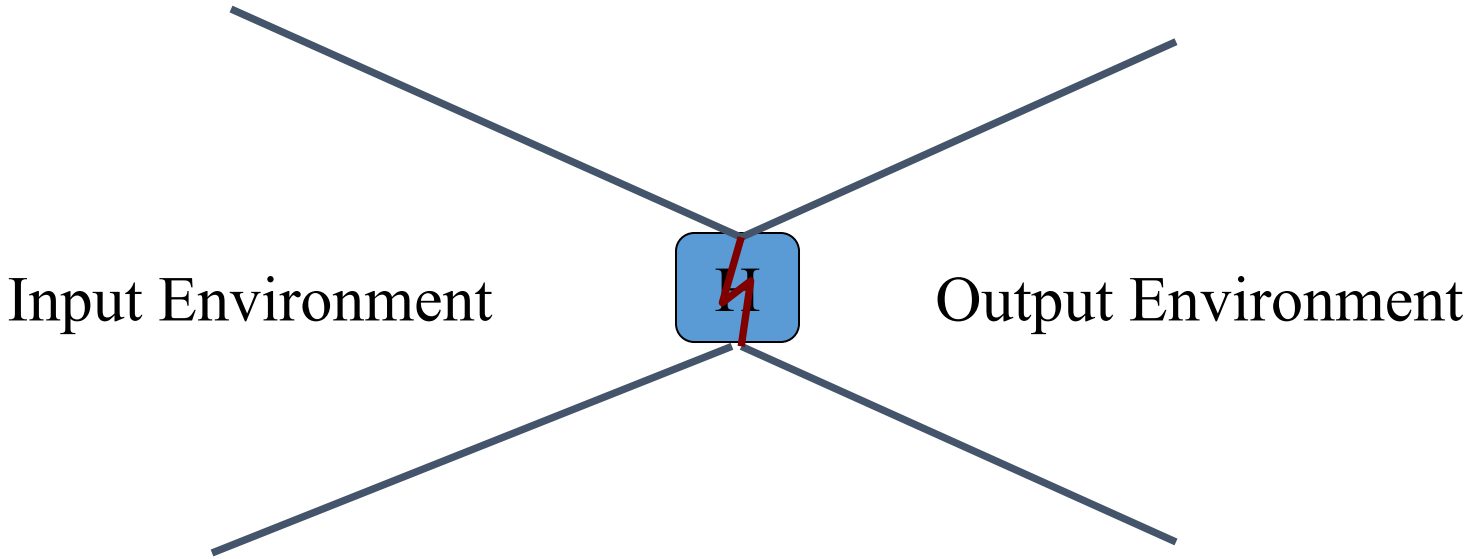
OPEN SYSTEMS are characterized by the continual input, throughflow, and output of matter and energy – ALL ENVIRONMENTAL SYSTEMS ARE OPEN SYSTEMS



Old perspective, dichotomy between system and environment

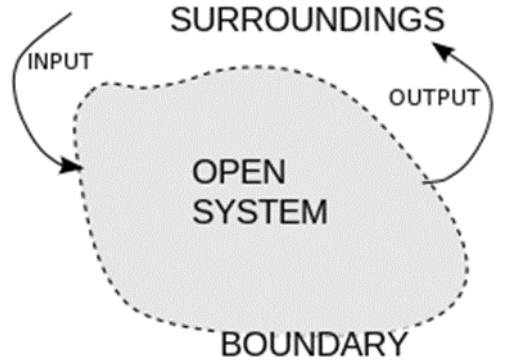


New perspective, system is focus of two environments



A system is an assemblage of parts that function in some way as a whole

- Establish a system boundary
- What are the parts inside the system?
- How are they connected?
- Receives inputs
- Generates outputs
- When outputs become inputs that is feedback –
  - posses capacity for self-organization (growth) and self-regulation (stability)



Thermodynamic systems-

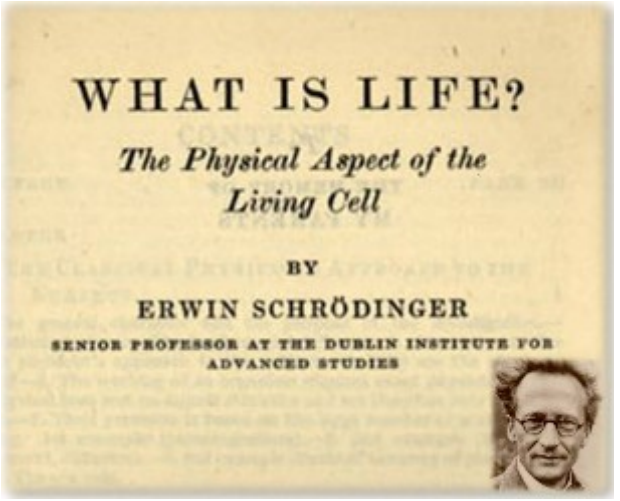
Energy is the ability to do work

Forms of energy: potential, kinetic, thermal, chemical, electrical, etc.

1st Law of Thermodynamics:
energy cannot be created or destroyed

2nd Law of Thermodynamics:
energy goes from a high quality to a lower
quality during each energy transformation; while energy is conserved,
its ability to due work decreases

What is life?



- Biological systems build structure (they grow) and maintain (metabolize) complex structures within their boundaries by diverting high-quality energy and exporting low-quality.

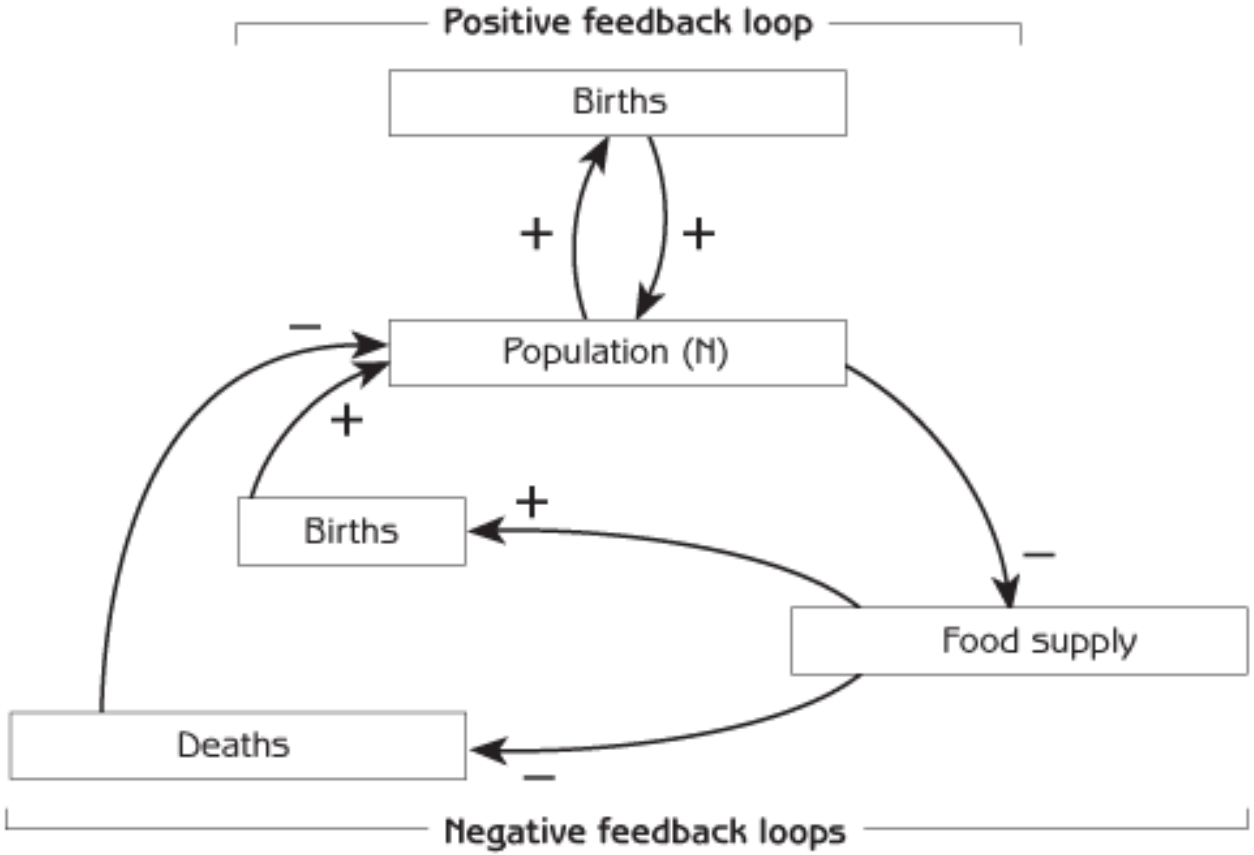
- “The device by which an organism maintains itself at a fairly high level of orderliness consists in continually sucking orderliness from its environment” – Schrödinger. 1944. What is life? p.73.

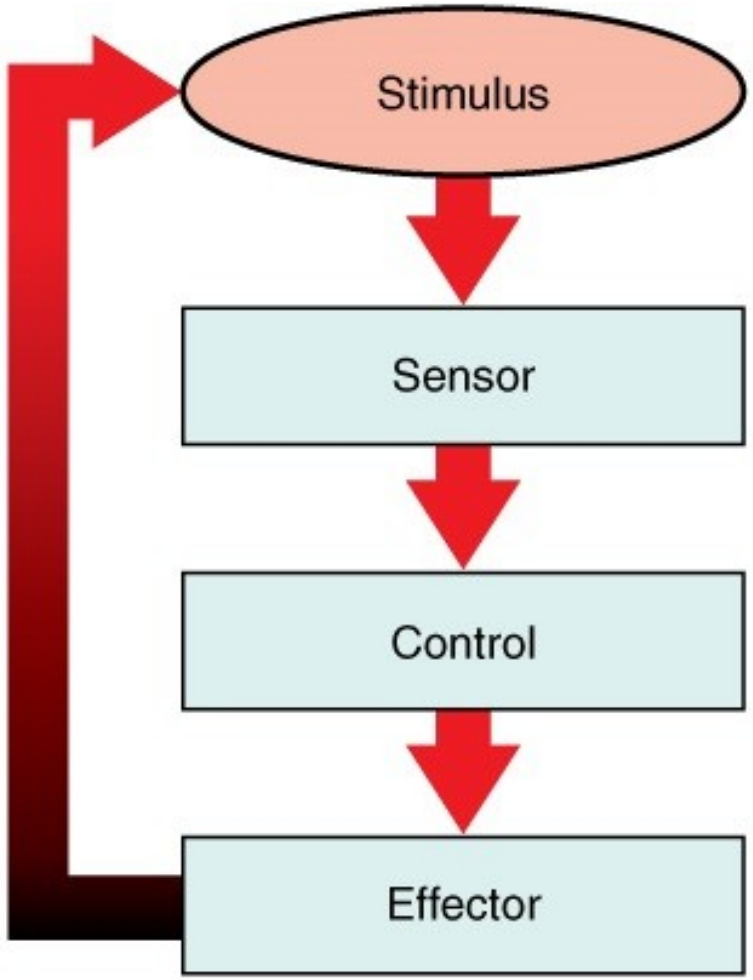
FEEDBACK as a consequence of interconnections

Ecological Systems possess capacity for

(a) self-regulation: negative feedback - deviation damping, stabilizing

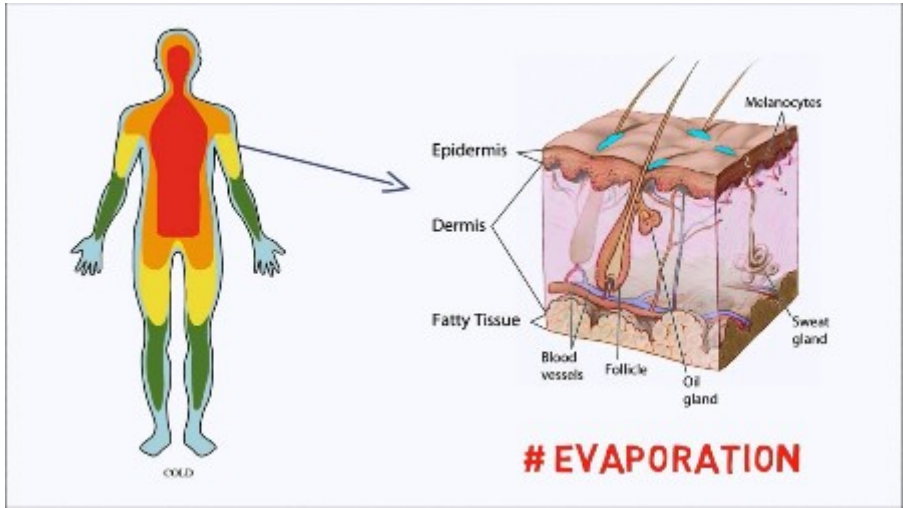
(b) self-adaptation: positive feedback - deviation-amplifying, destabilizing





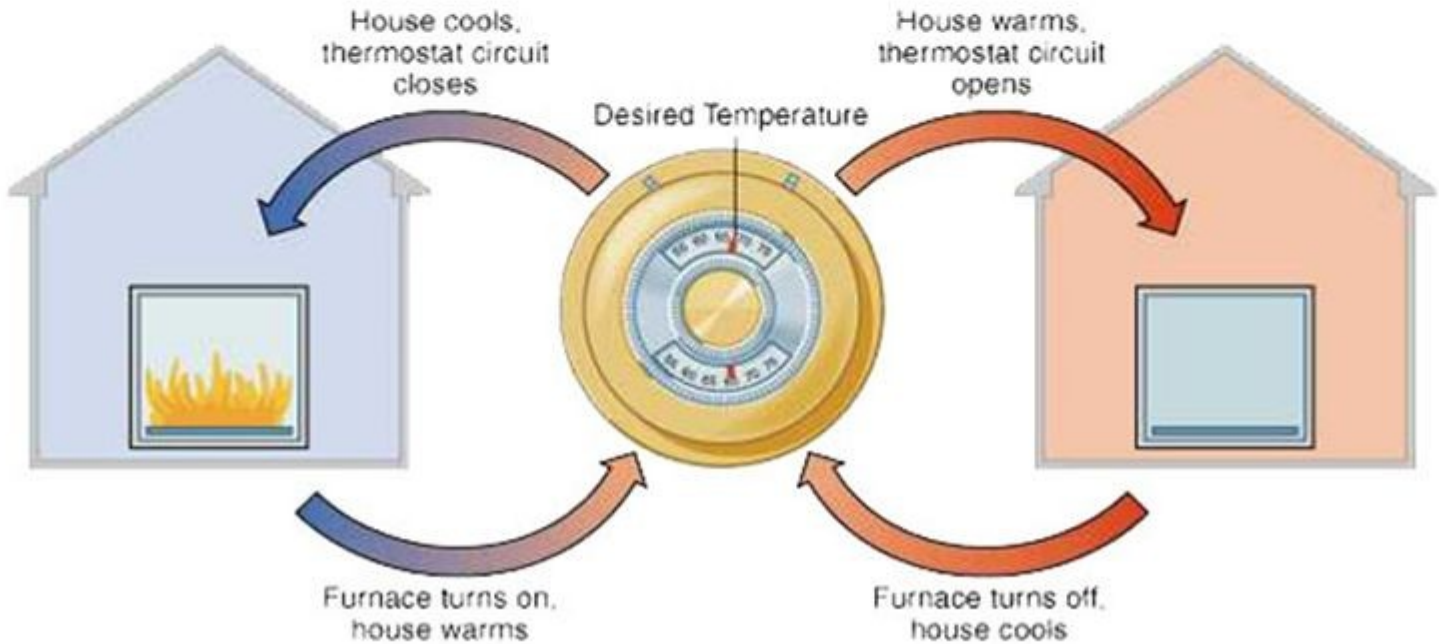
(a) Negative feedback loop

Stabilizes body temperature

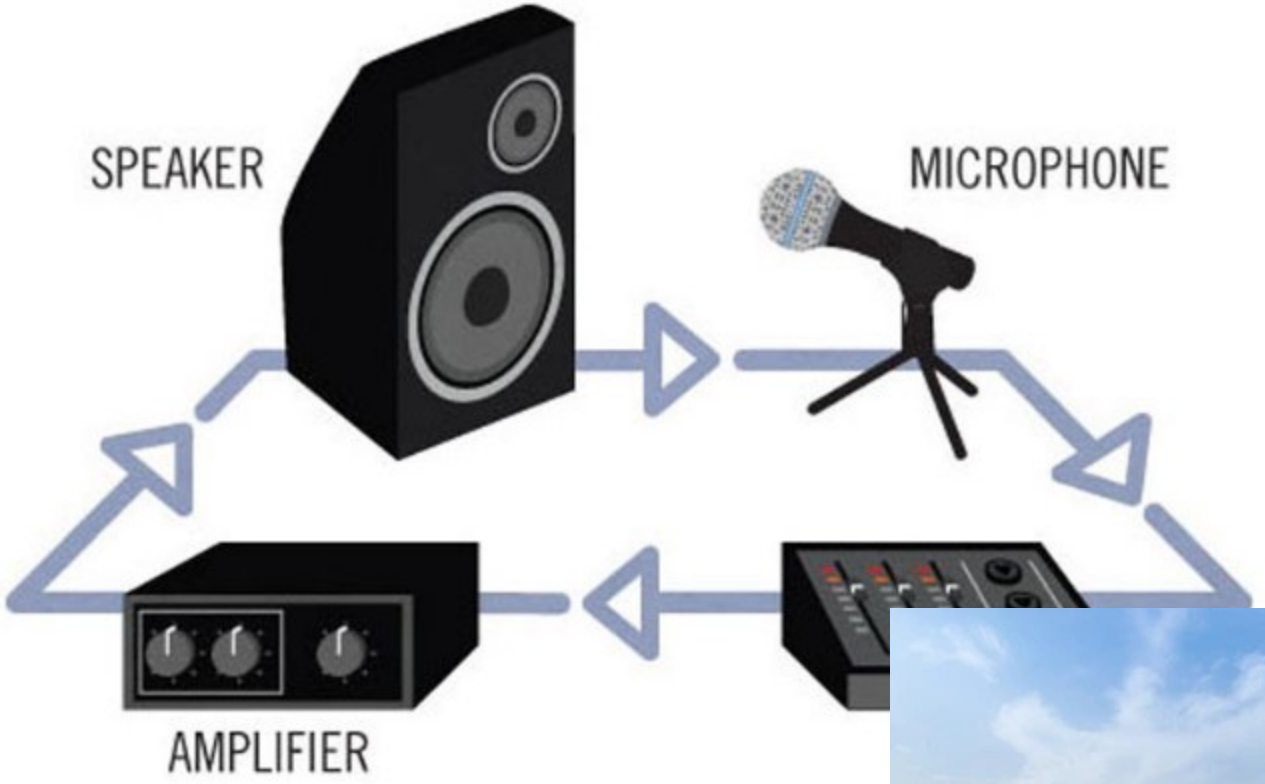


Negative feedback

- Process by which a mechanism is activated to restore conditions to their original state
- It ensures that small changes don't become too large.
- Why is a thermostat a negative feedback system?



Positive feedback – when the signal is amplified and moves the system further from its original condition

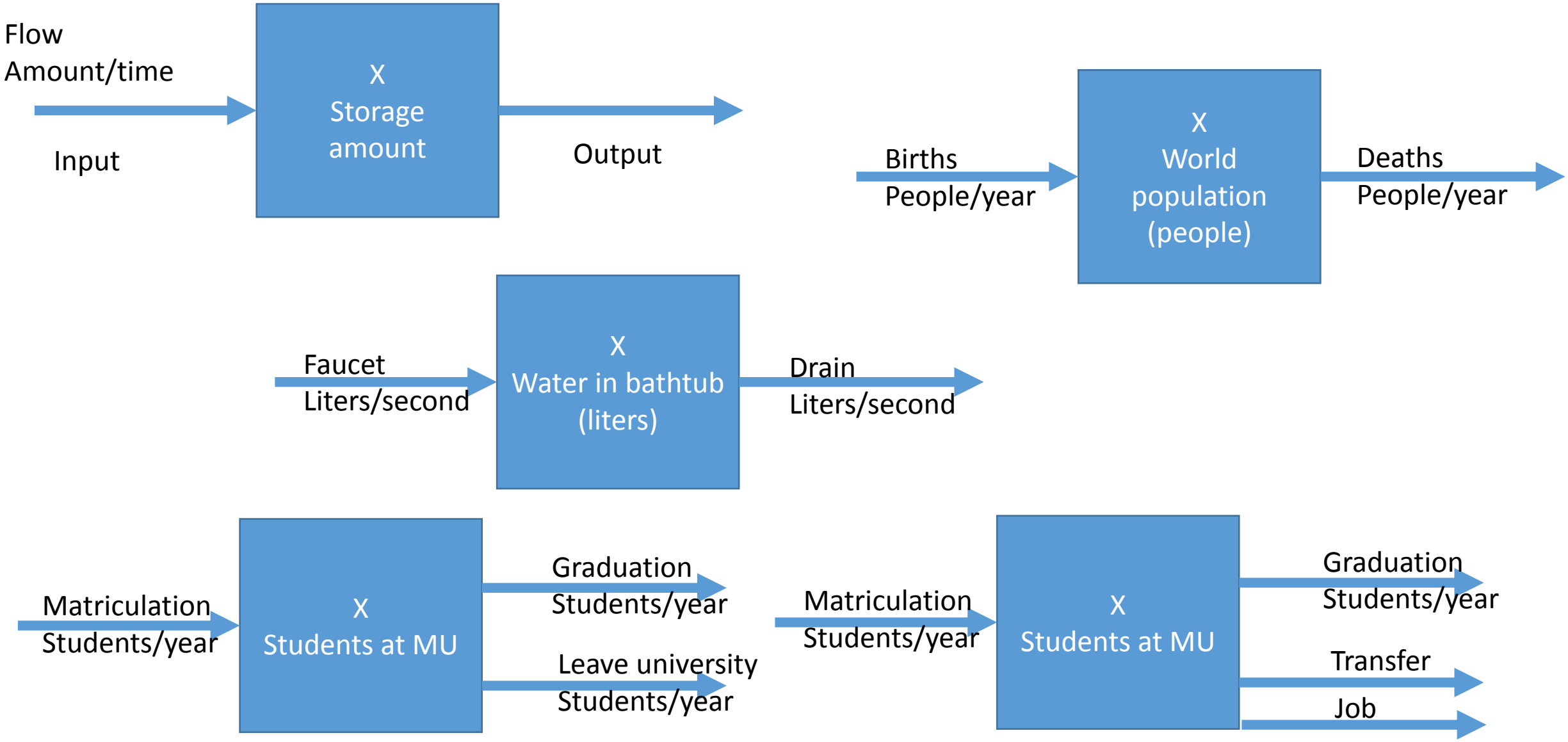


Sound system

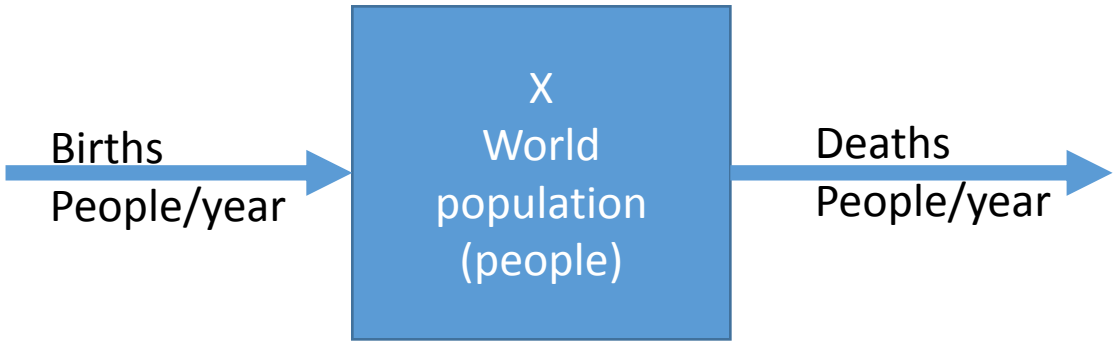
→

Biological growth is a positive feedback

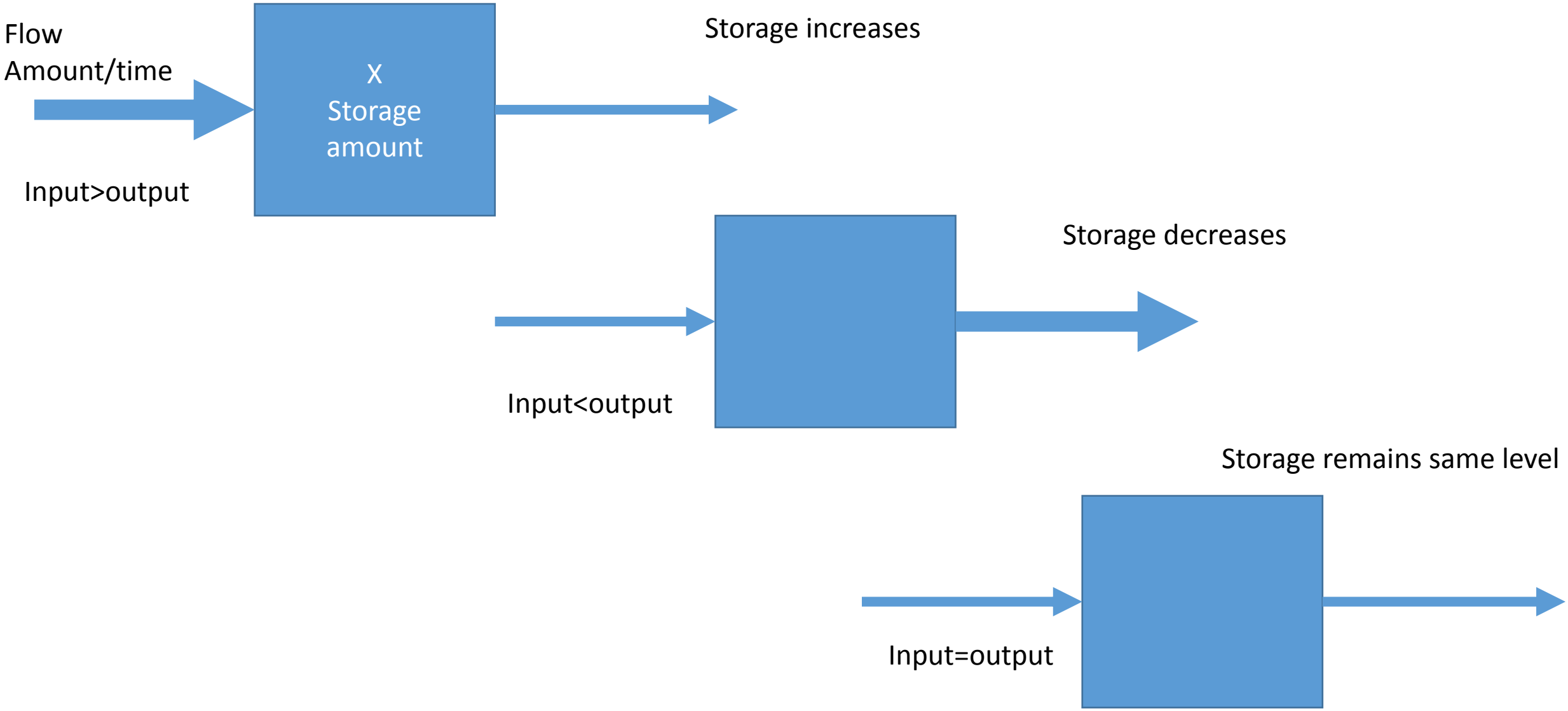
Input-Output models – Box and arrow models



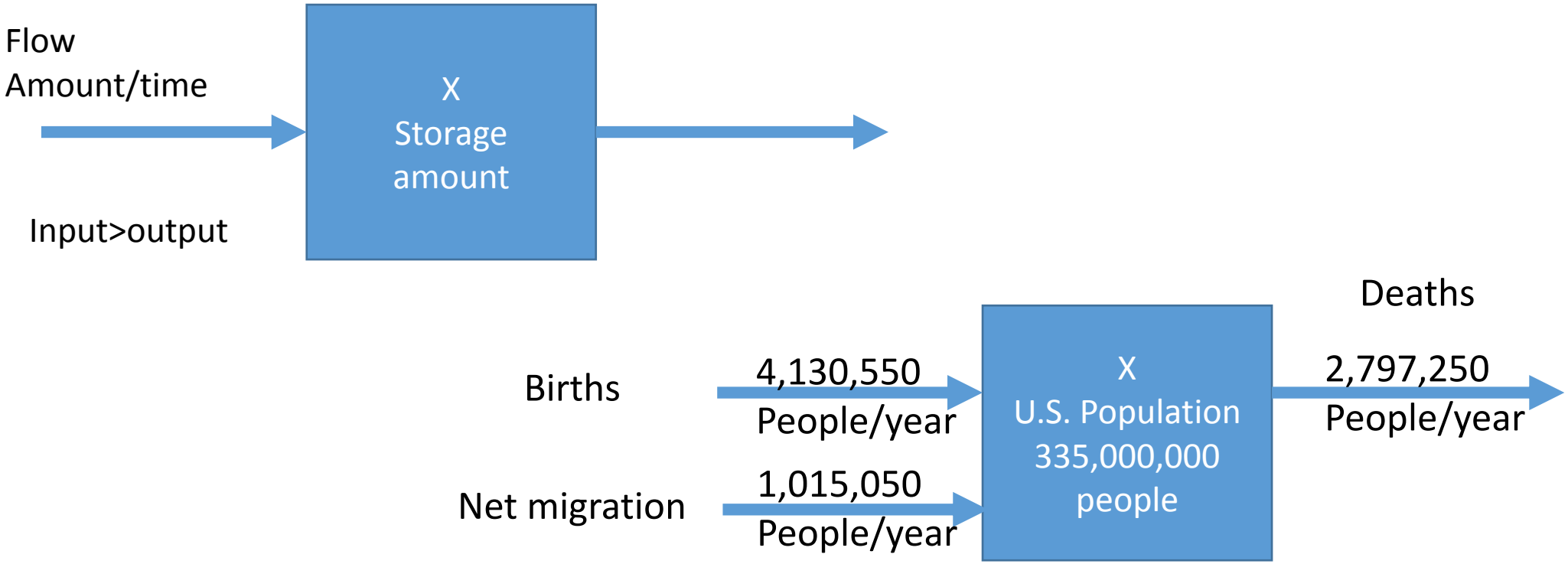
Input Output models



Input Output relations



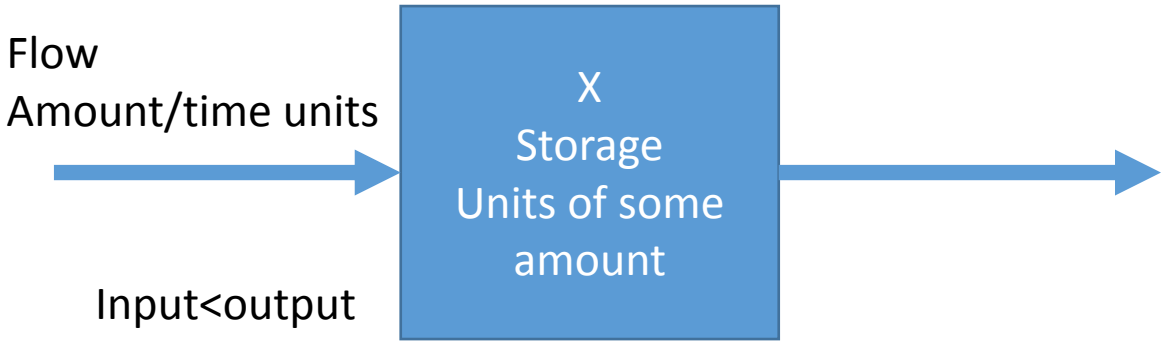
Input Output relations

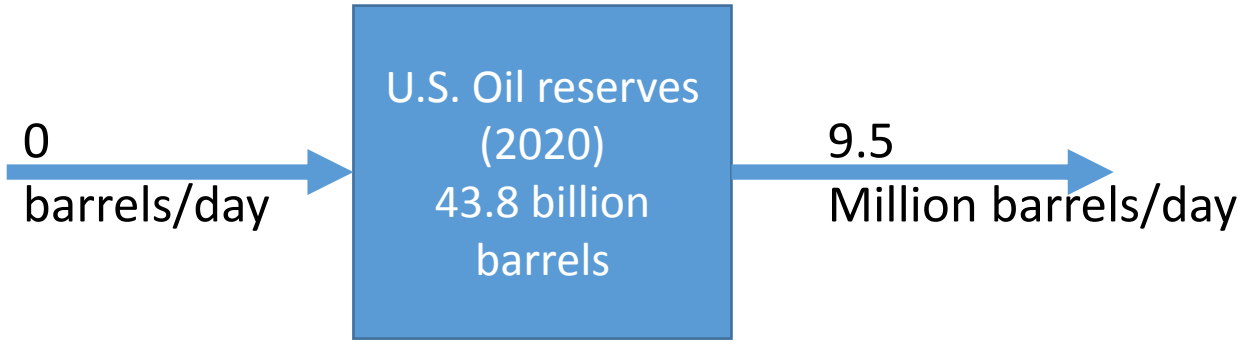


Change in population = Births + Net migration – deaths
4,130,550 people/year +1,015,050 people/year – 2,797,250 people/year = 2,348,350 people/year

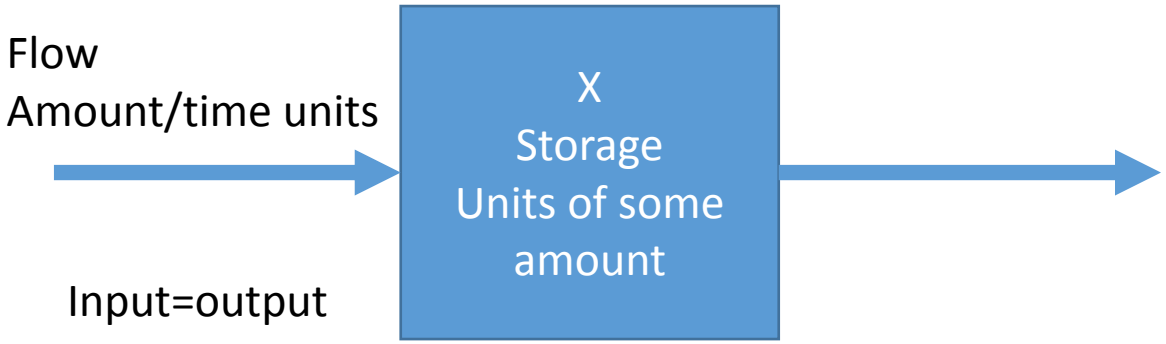
New population at time t = initial population + change in population * years (t)
335,000,000 people + 2,348,350 people/year * 1 year = 337,348,350 people

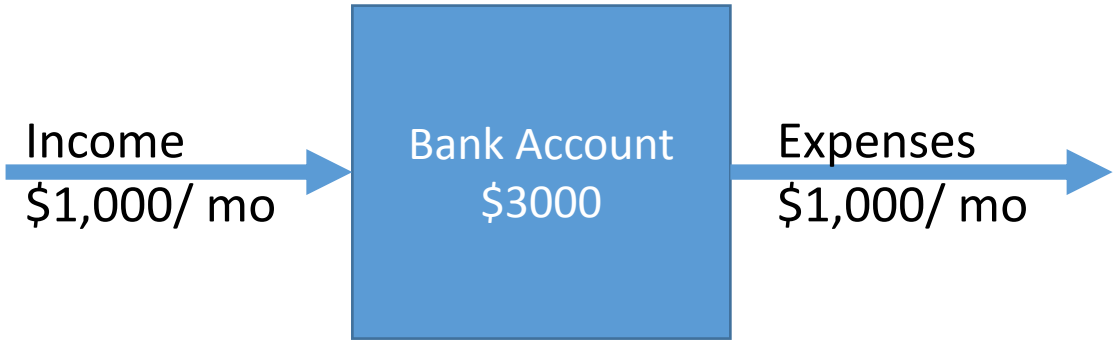
Input Output relations





Input Output relations





When input = output, this is called steady state system
The system is changing but balanced

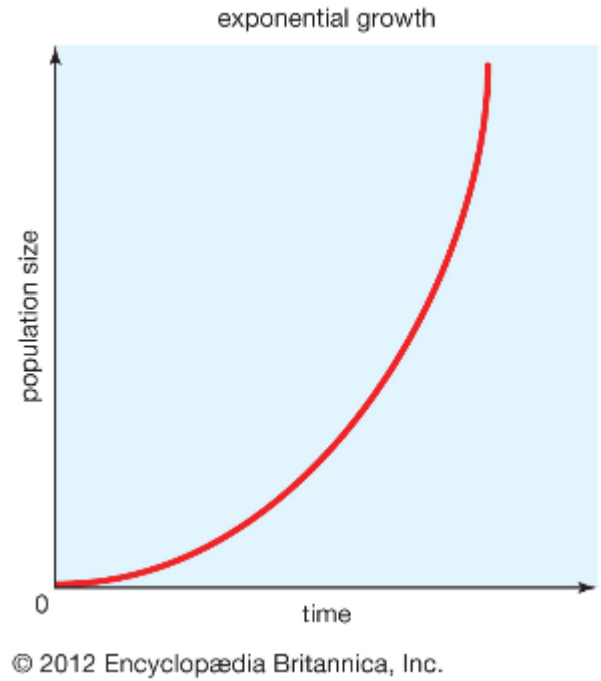
Practice making some input-output models of systems of your choice

- Can you quantify the flows and compare input and output?

Exponential growth

- **Growth at a constant rate**

$$\frac{dN}{dt} = rN$$



Where N is the population size, dN/dt is the change in population over time, r is the constant rate of growth

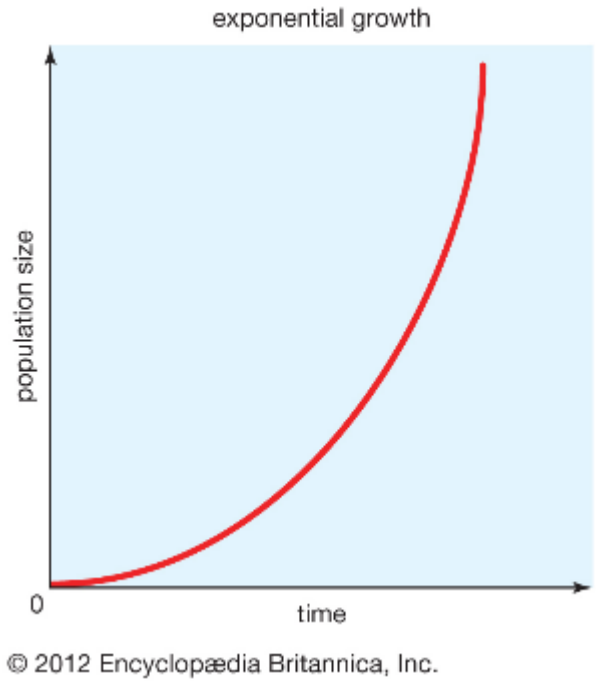
Exponential growth grows unbound

Exponential growth

$$\frac{dN}{dt} = rN$$

Solving for N gives the following:

$$N_t = N_0 e^{rt}$$



Where N_t is the population size at time t, and N_0 is the initial population size (at time zero), and e is the exponential. e is a constant = 2.71828…

Exponential growth

$$N_t = N_0 e^{rt}$$

Example:

N_0 = \$1,000

r = 3%/year = 0.03/year

t = 30 years

Step 1: multiply r*t = 0.9

Step 2: take $e^{(rt)}$ = 2.4596

Step 3: multiply by N_0

N_t = \$2,459.6

What if you wait 40 years? N_t=\$3,320.1

Exponential growth

$$N_t = N_0 e^{rt}$$

Example:

N_0 = 7,800,000,000 people

r = 1.03%/year = 0.0103/year

t = 80 years

Step 1: multiply r*t

Step 2: take $e^{(rt)}$

Step 3: multiply by N_0 = 17,780,880,195 people

Exponential growth

$$N_t = N_0 e^{rt}$$

Example:

N_0 = 255,000,000 people

r = 1.03%/year = 0.0103/year

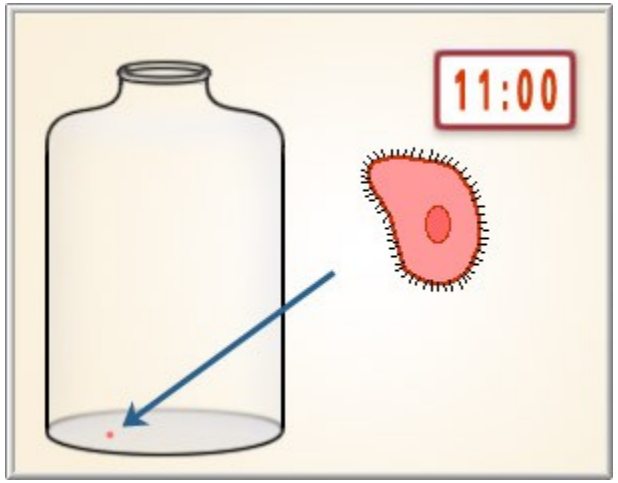
t = 2020 years

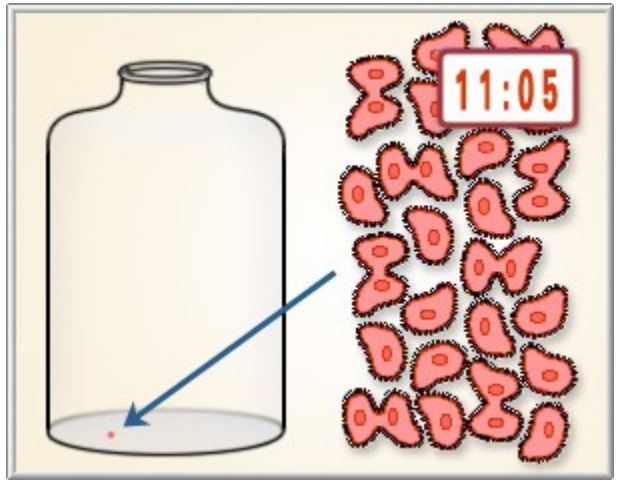
Step 1: multiply r*t

Step 2: take $e^{(rt)}$

Step 3: multiply by N_0 Nt = 276,994,516,015,121,465 people

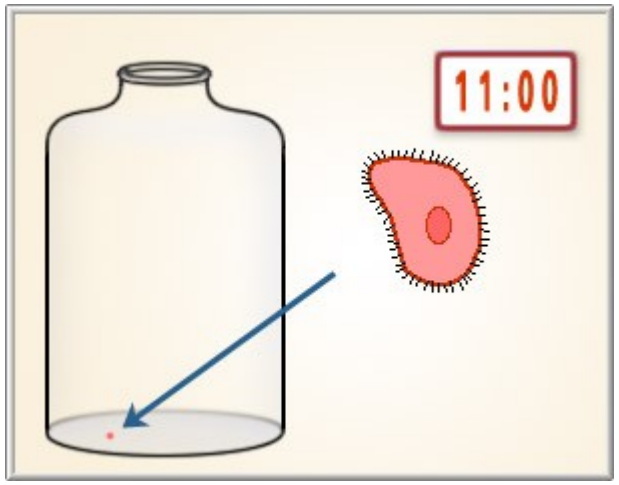
Exponential growth – unbound growth in the context of resource constraints

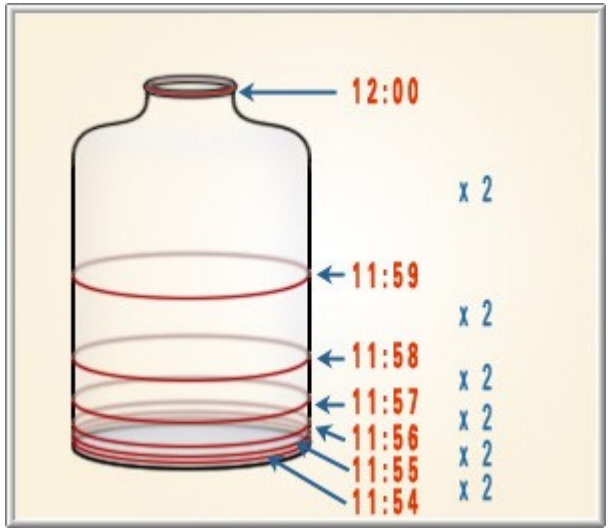


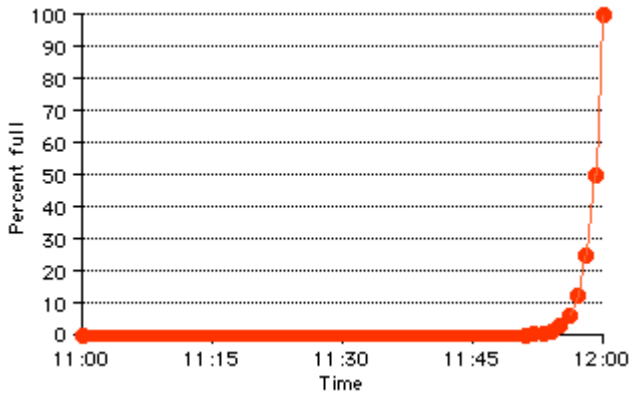


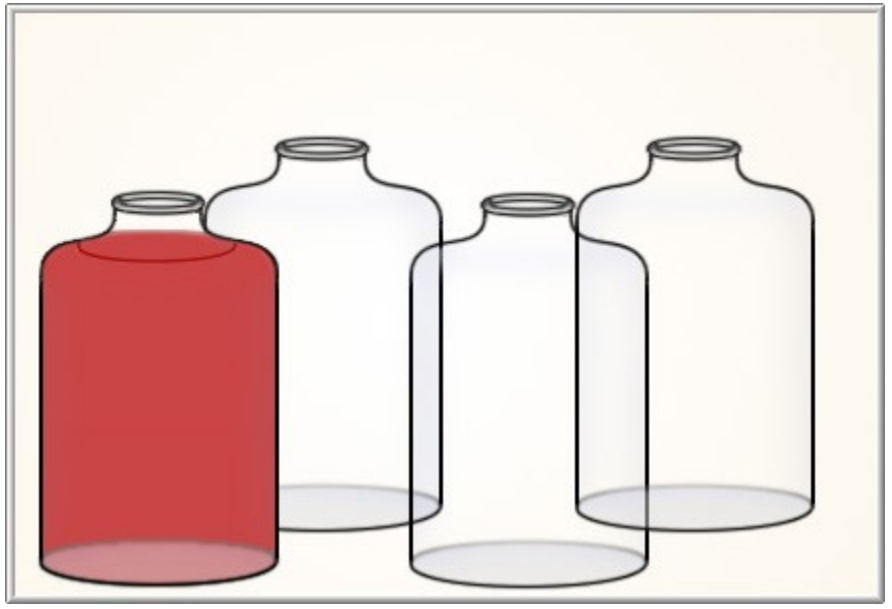
Jar is half-full at 11:59

Exponential growth

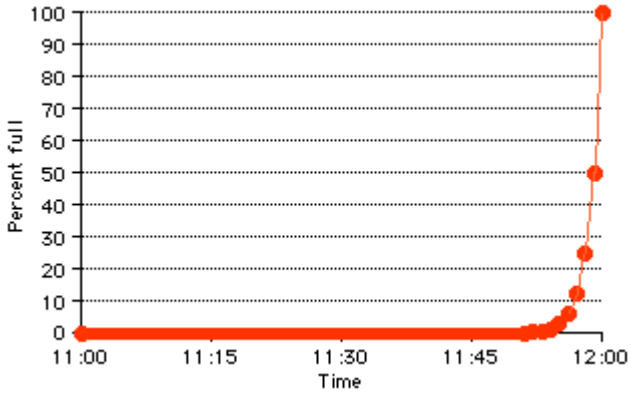


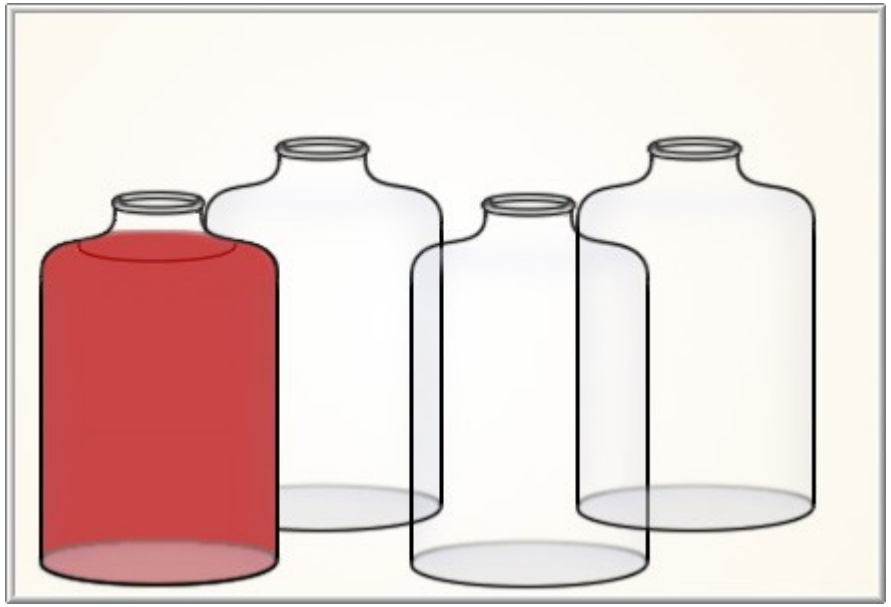


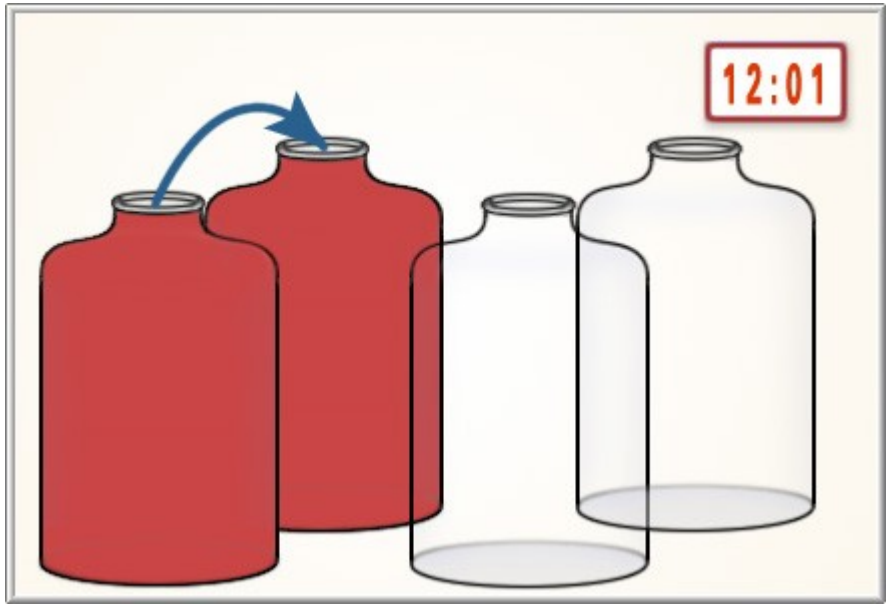


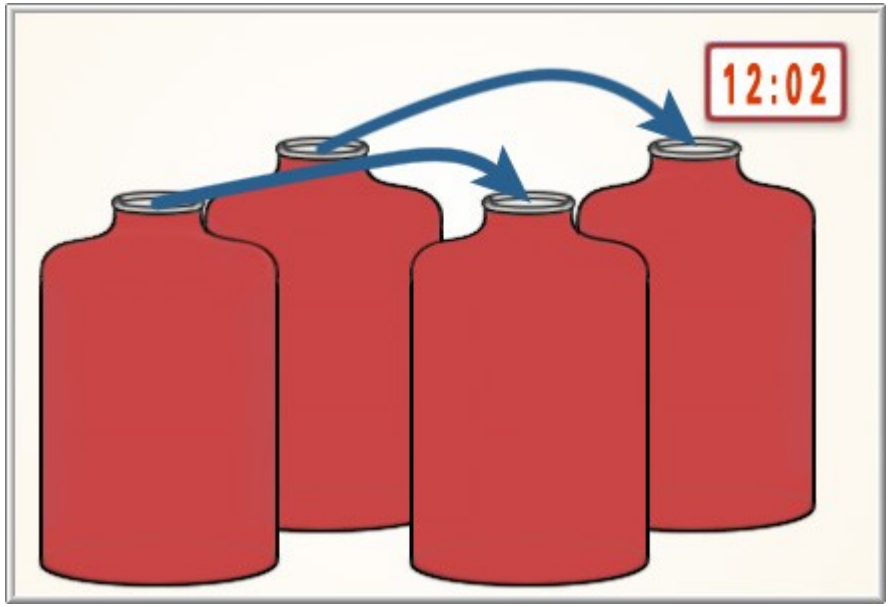


Exponential growth









Exponential Growth quotes

- The greatest shortcoming of the human race is our inability to understand the exponential function.
  - **Albert A. Bartlett**
- Our principal constraints are cultural. During the last two centuries we have known nothing but exponential growth and in parallel we have evolved what amounts to an exponential-growth culture, a culture so heavily dependent upon the continuance of exponential growth for its stability that it is incapable of reckoning with problems of non-growth.
  - **M. King Hubbert**
- Anyone who believes exponential growth can go on forever in a finite world is either a madman or an economist.
  - **Kenneth E. Boulding**

Things to think about

- Habits of a systems thinker

https://waterscenterst.org/systems-thinking-tools-and-strategies/habits-of-a-systems-thinker/