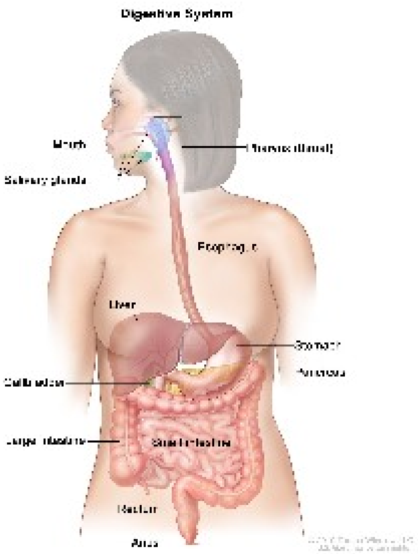
Lecture 1.2: Understanding systems

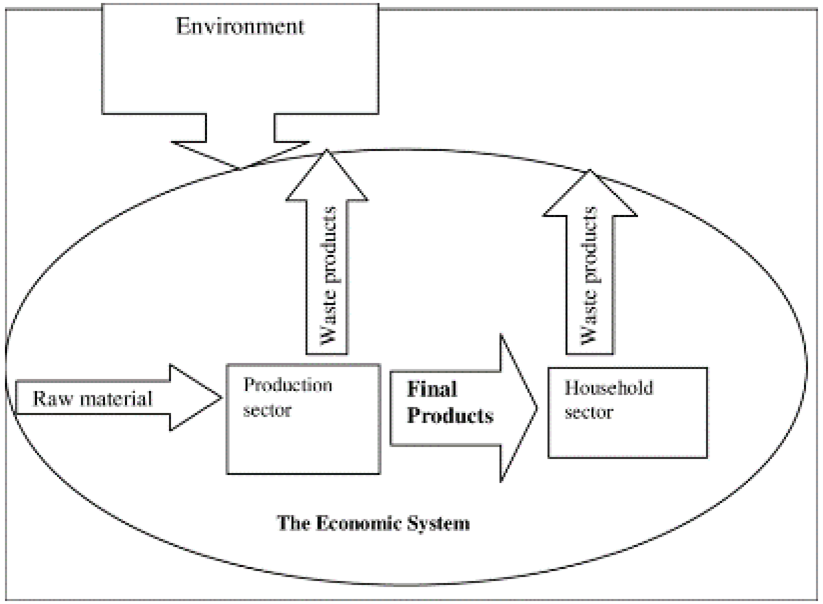
Understanding SYSTEMS!

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



Digestive system

Computer system

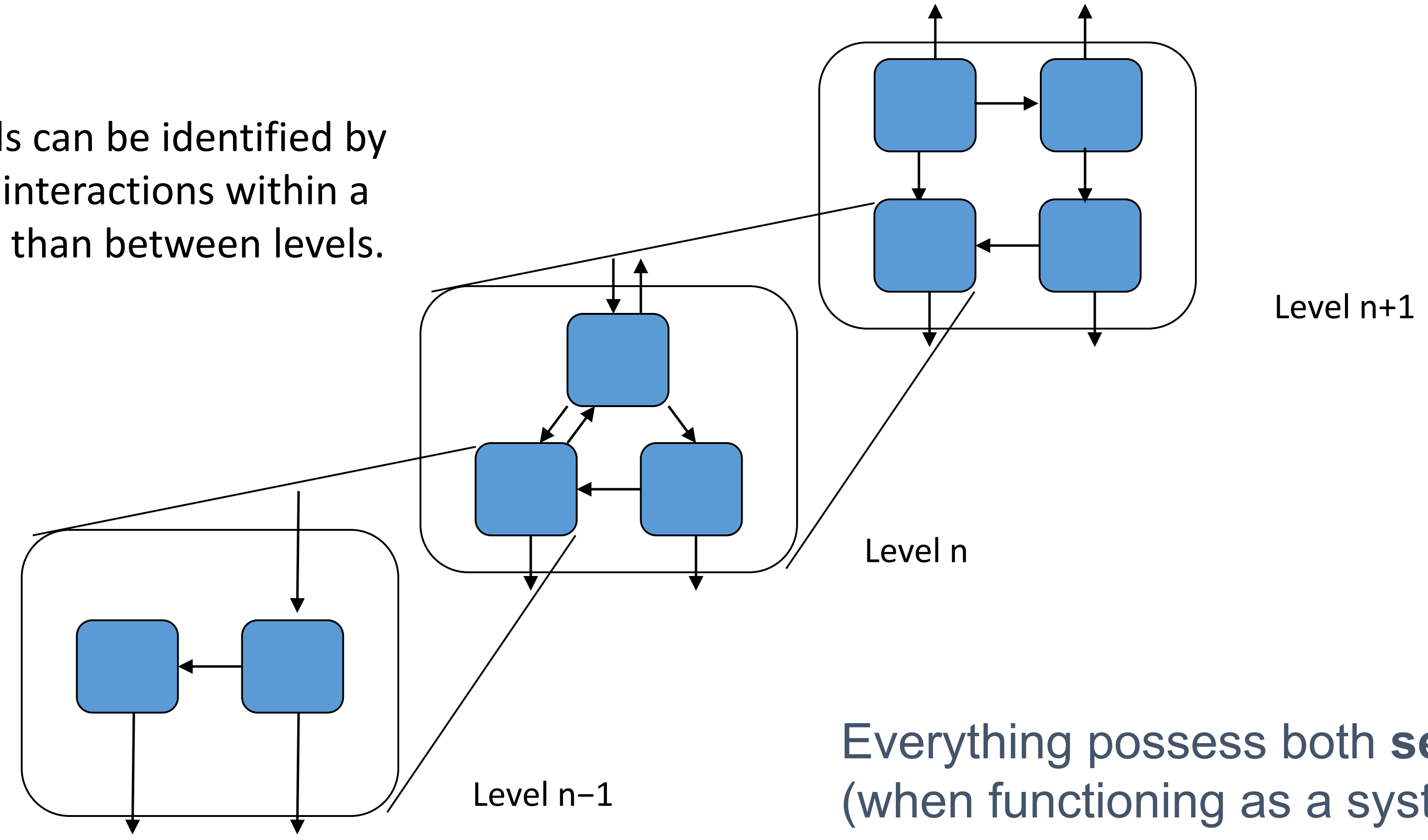


Economic system

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

Hierarchical Representation of Systems

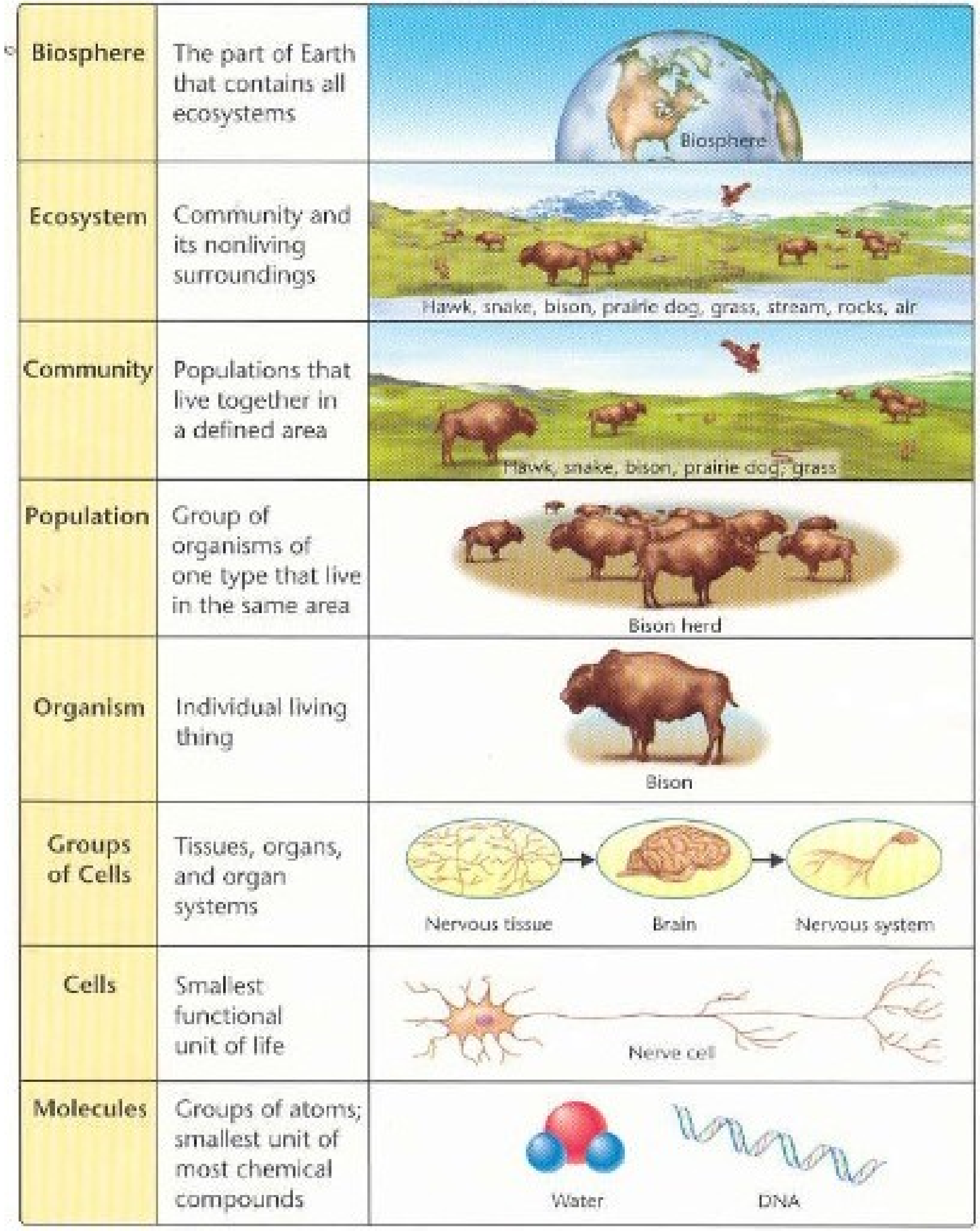
Hierarchical levels can be identified by a stronger set of interactions within a hierarchical level than between levels.



Everything possess both **self-assertive** (when functioning as a system) and **integrative tendencies** (when being a part in a system)

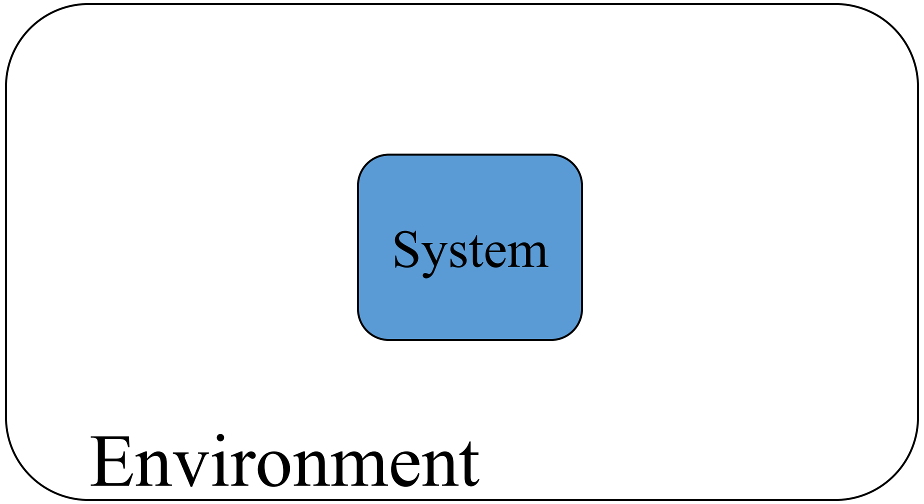
Hierarchy

- 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

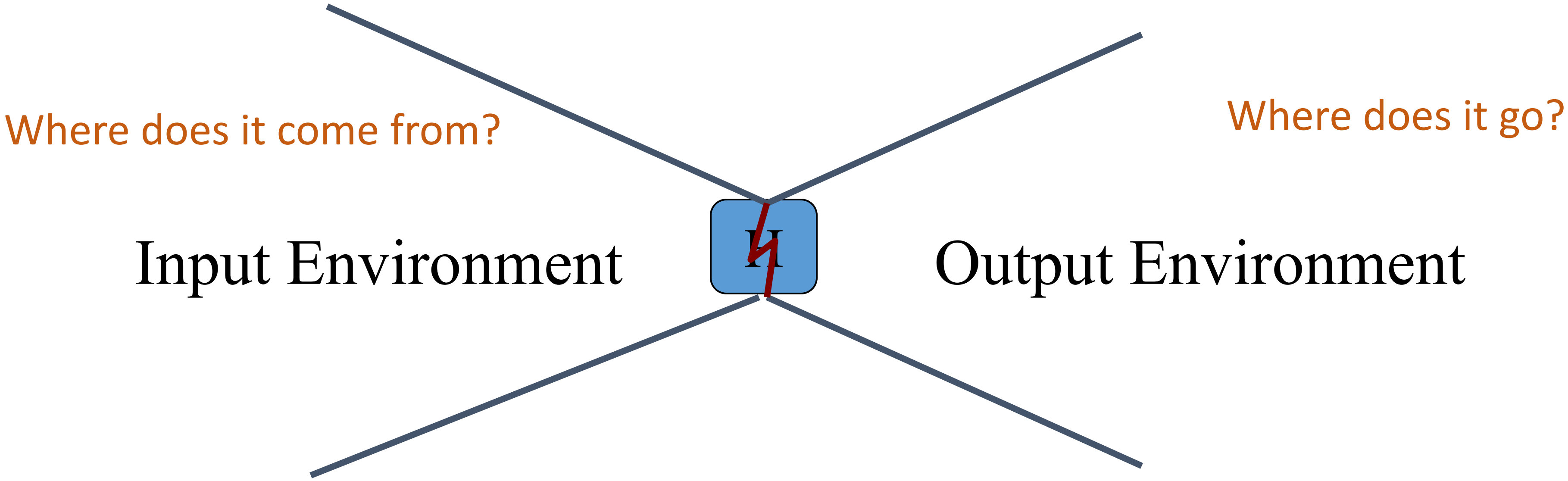


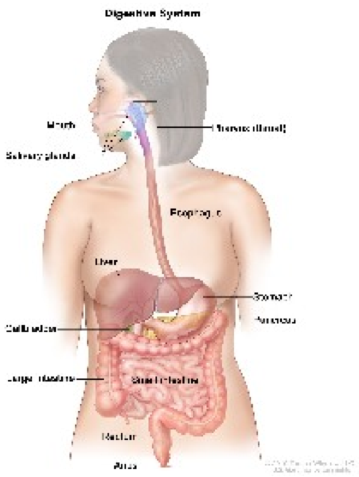
Biosphere	The part of Earth that contains all ecosystems	Biosphere
Ecosystem	Community and its nonliving surroundings	Hawk, snake, bison, prairie dog, grass, stream, rocks, air
Community	Populations that live together in a defined area	Hawk, snake, bison, prairie dog, grass
Population	Group of organisms 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

Old perspective, dichotomy between system and environment



New perspective, system is focus of two environments





Thermodynamic (energy) 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, it’s ability to due work decreases

OPEN SYSTEMS are characterized by the continual input, throughflow, and output of matter and energy

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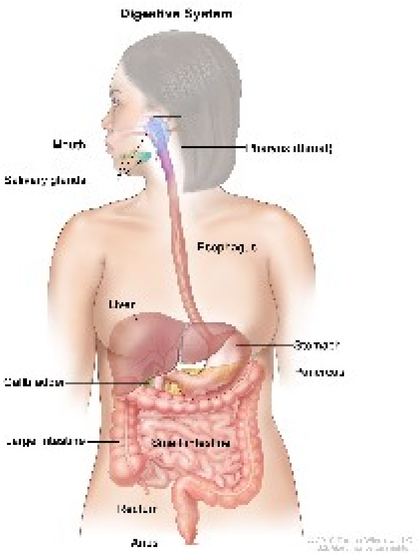
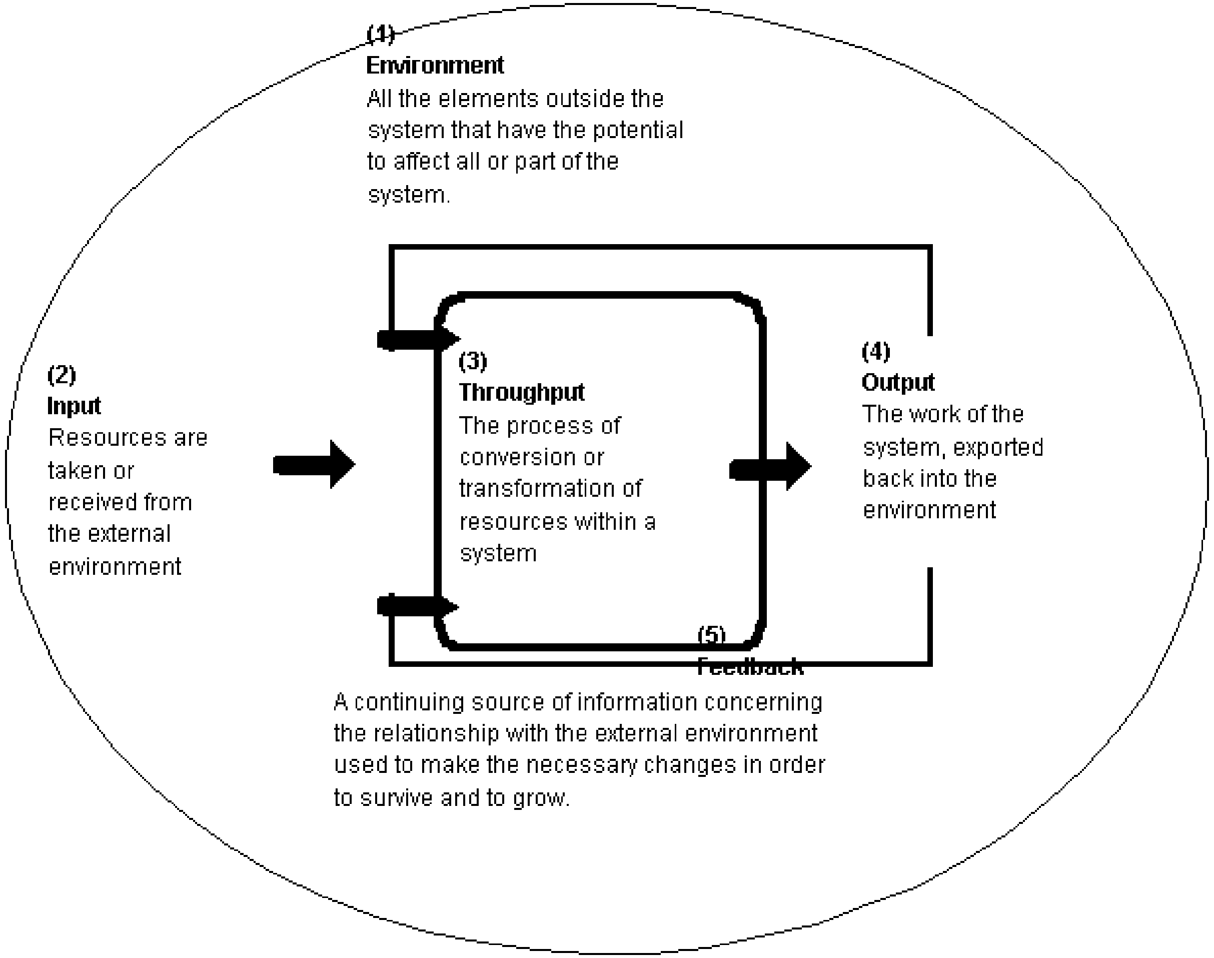
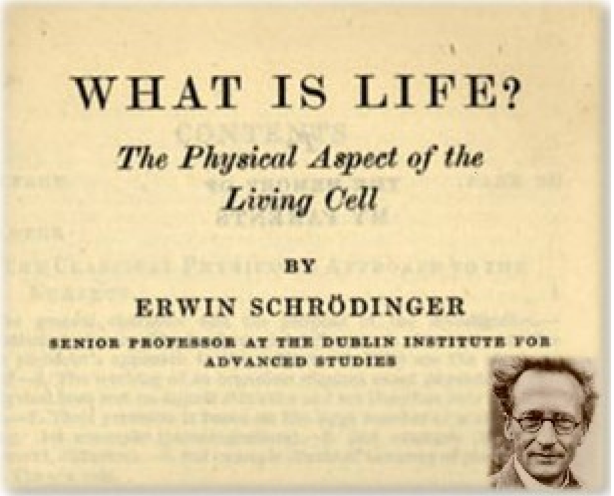
ALL ENVIRONMENTAL SYSTEMS ARE OPEN SYSTEMS





What is life?

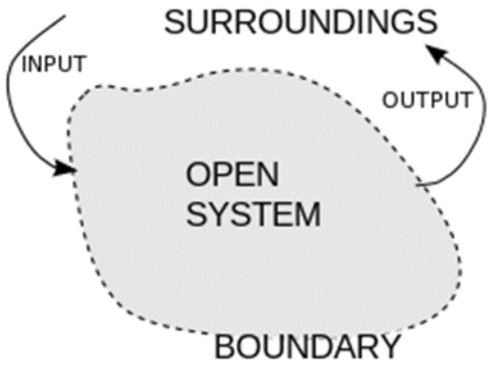


- Biological systems build structure (they grow) and maintain (metabolize) complex structures within their boundaries by diverting high-quality energy and exporting low-quality.

- “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.

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)

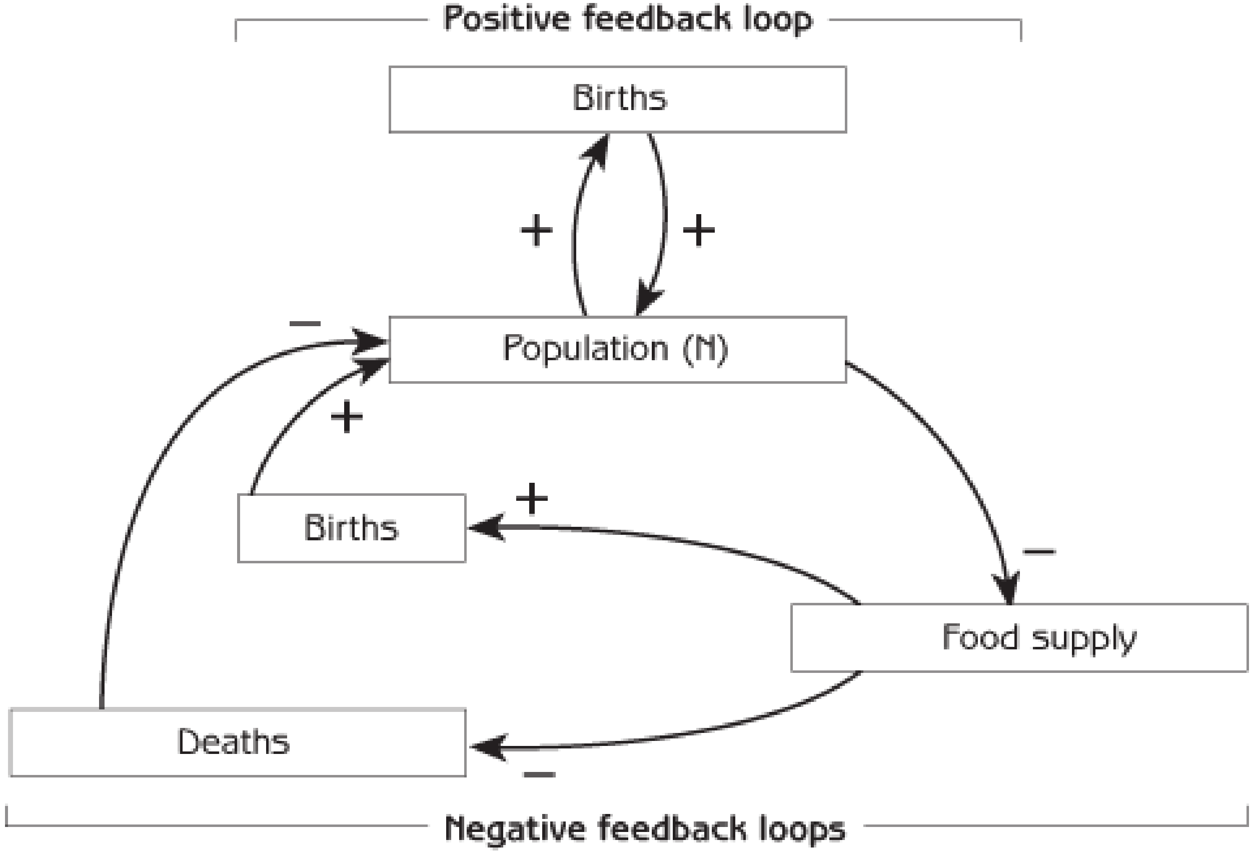


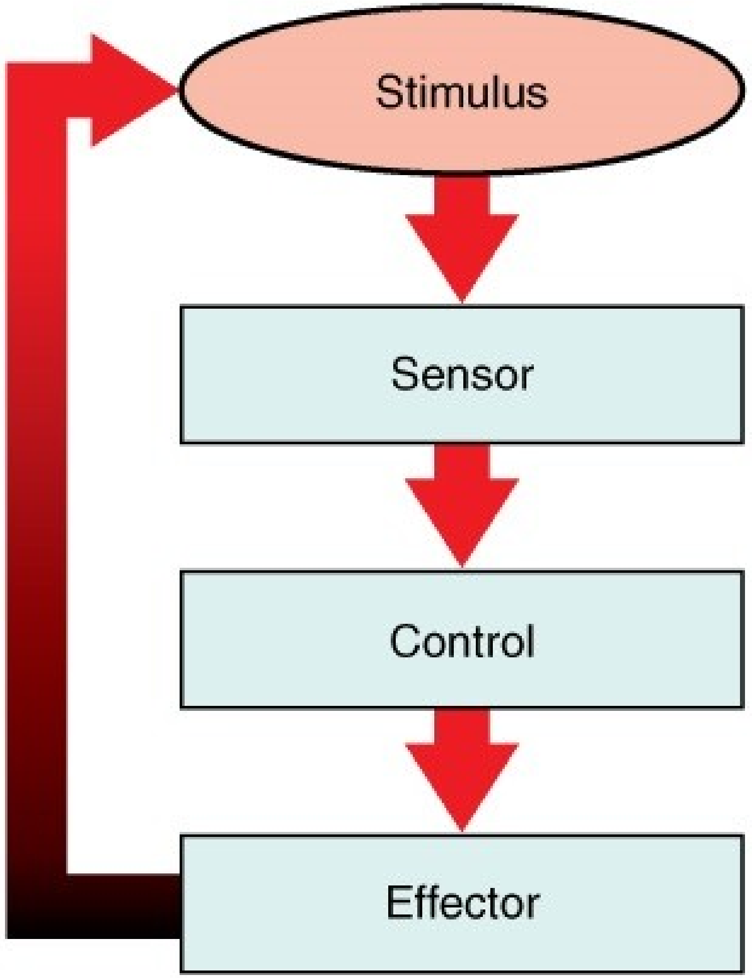
FEEDBACK as a consequence of interconnections

Ecological Systems possess capacity for

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

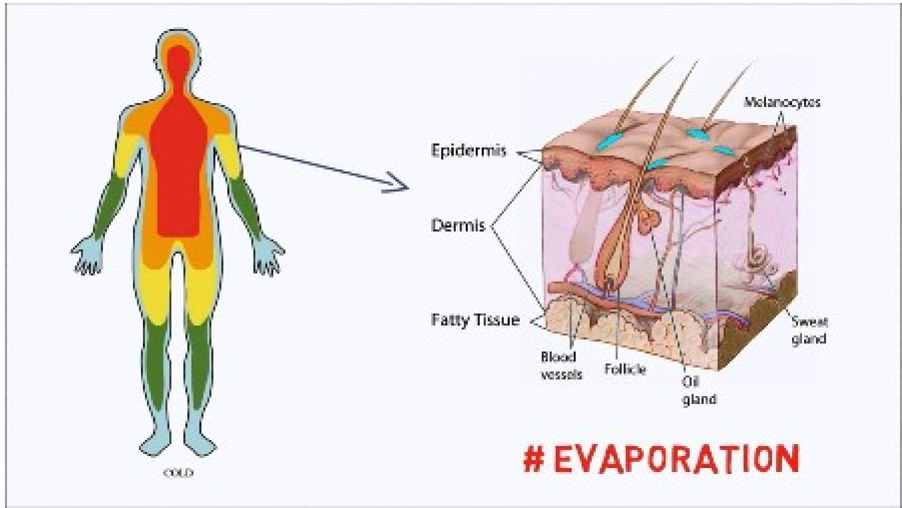
(b) self-adaptation: positive feedback - deviation-amplifying, destabilizing





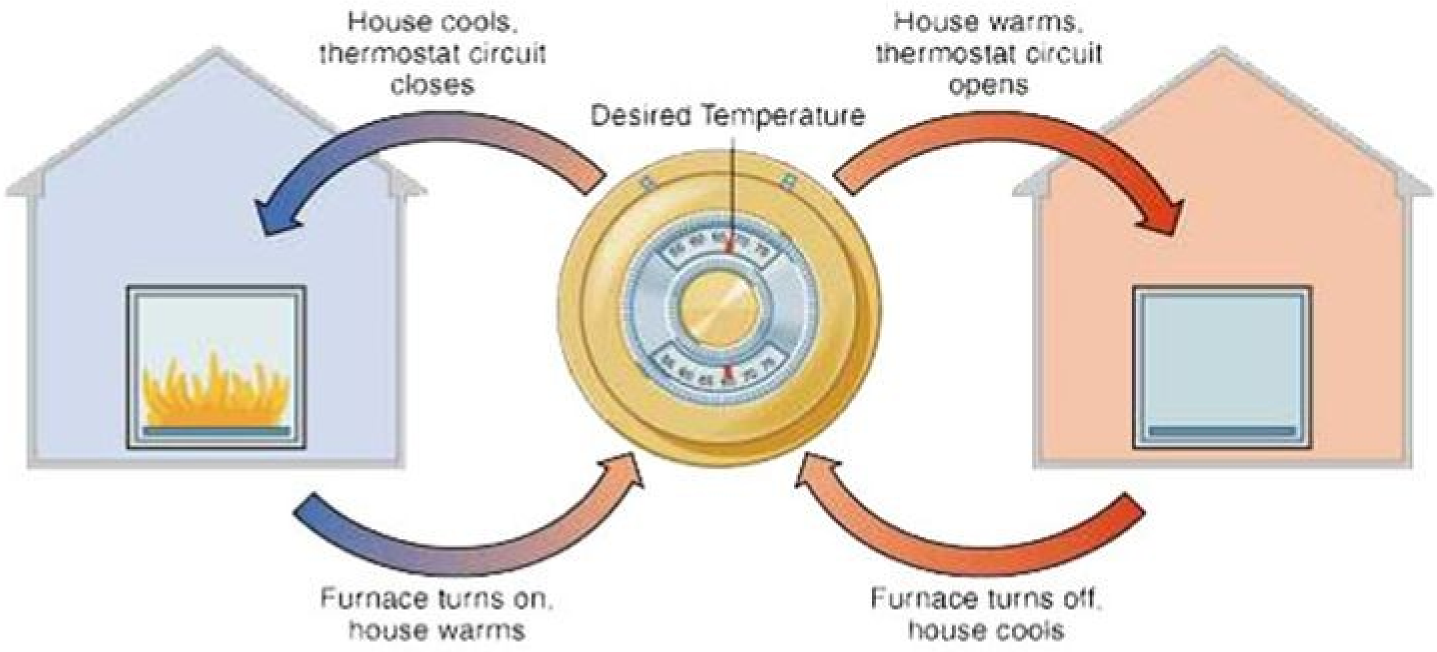
(a) Negative feedback loop

Stabilizes body temperature

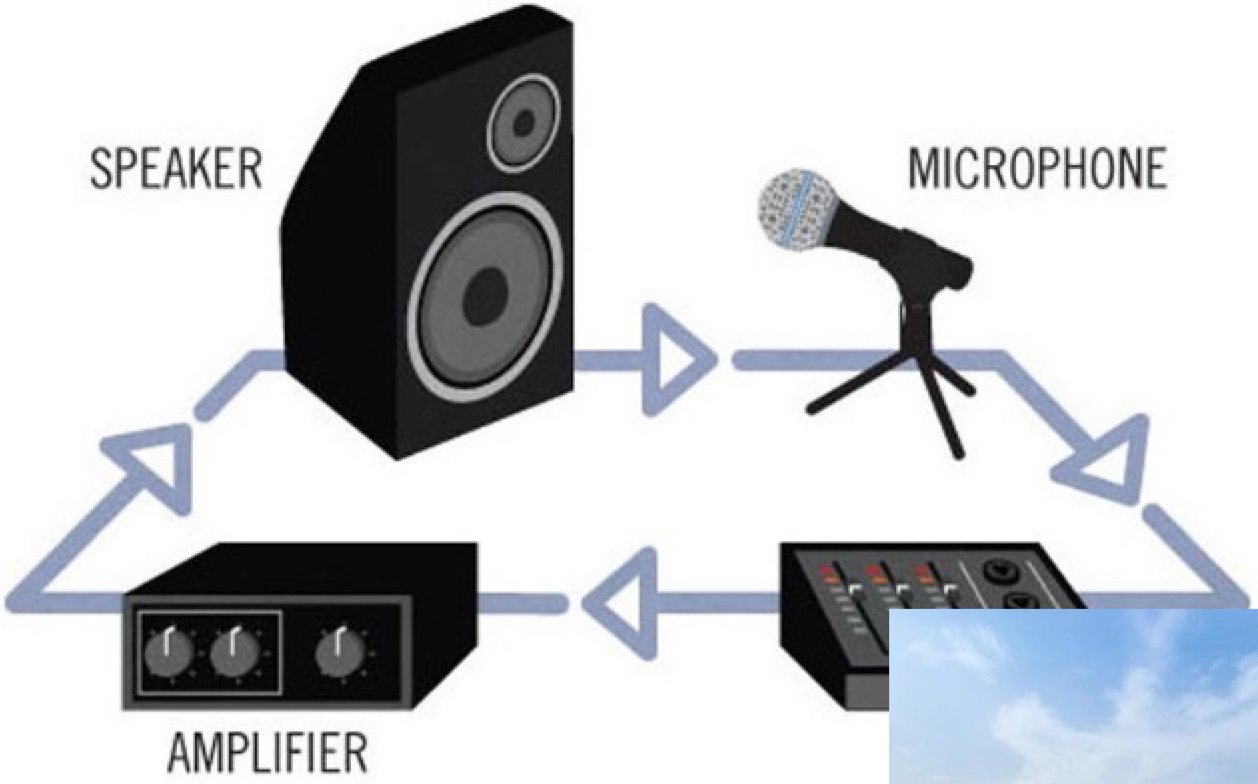


Negative feedback

- 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

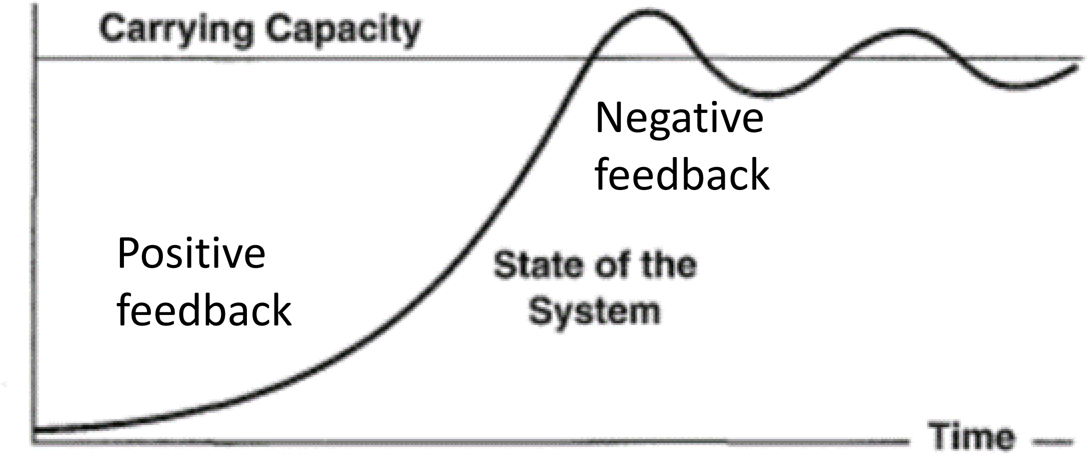


Sound system

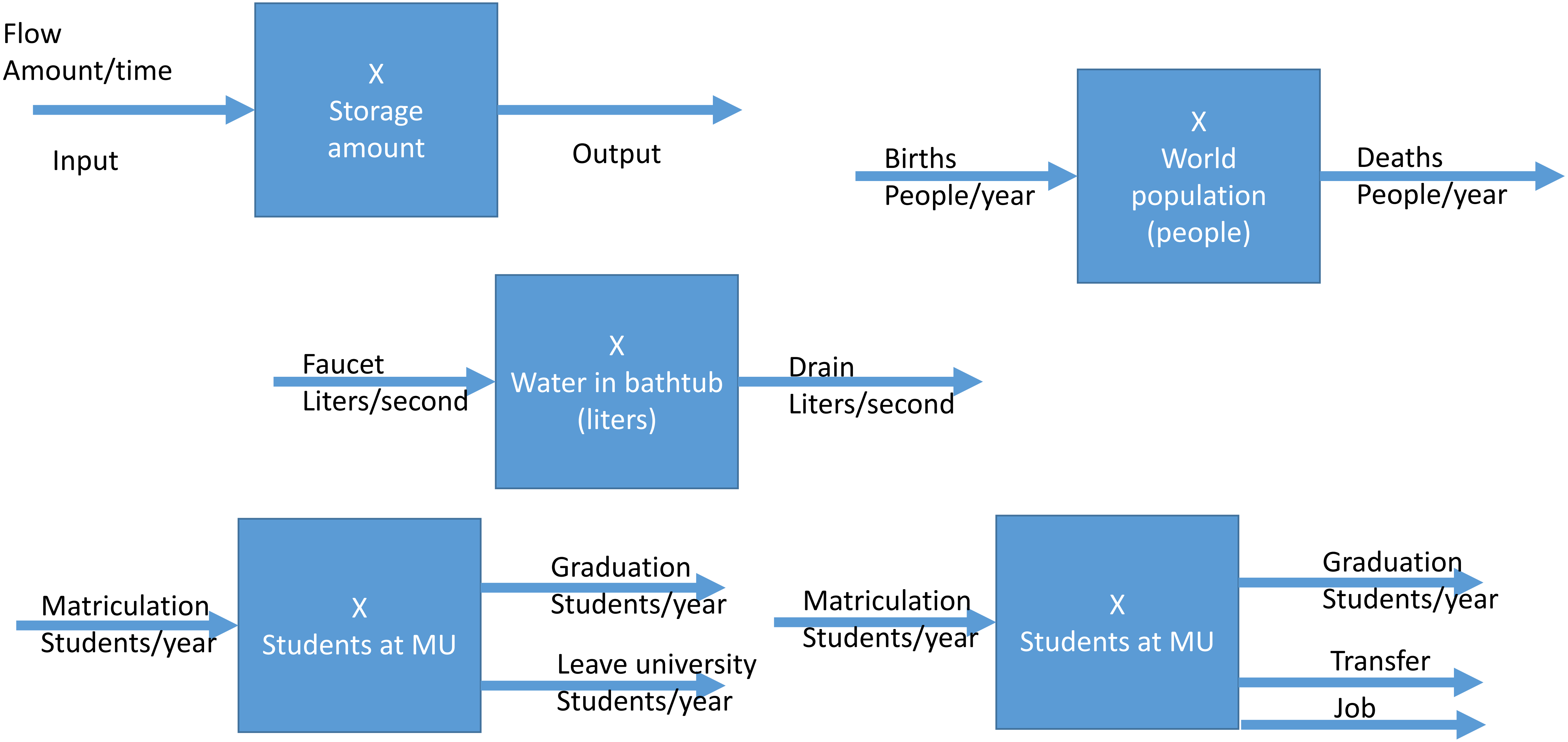
Biological growth is a positive feedback

→

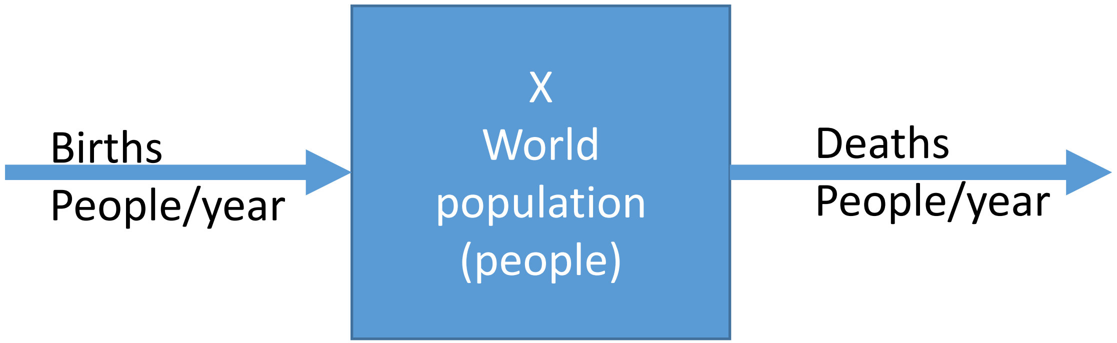
All system dynamics are an interplay of positive feedbacks that grow and change the system and negative feedbacks that stabilize and maintain the system
For example:

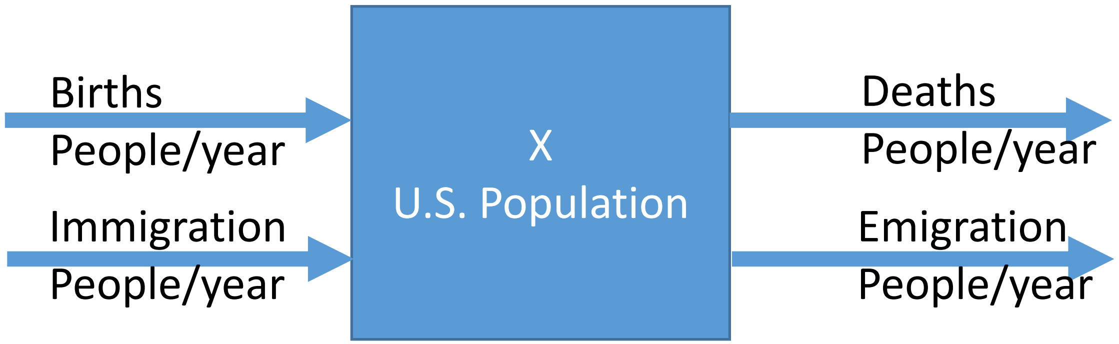


Input-Output models – Box and arrow models

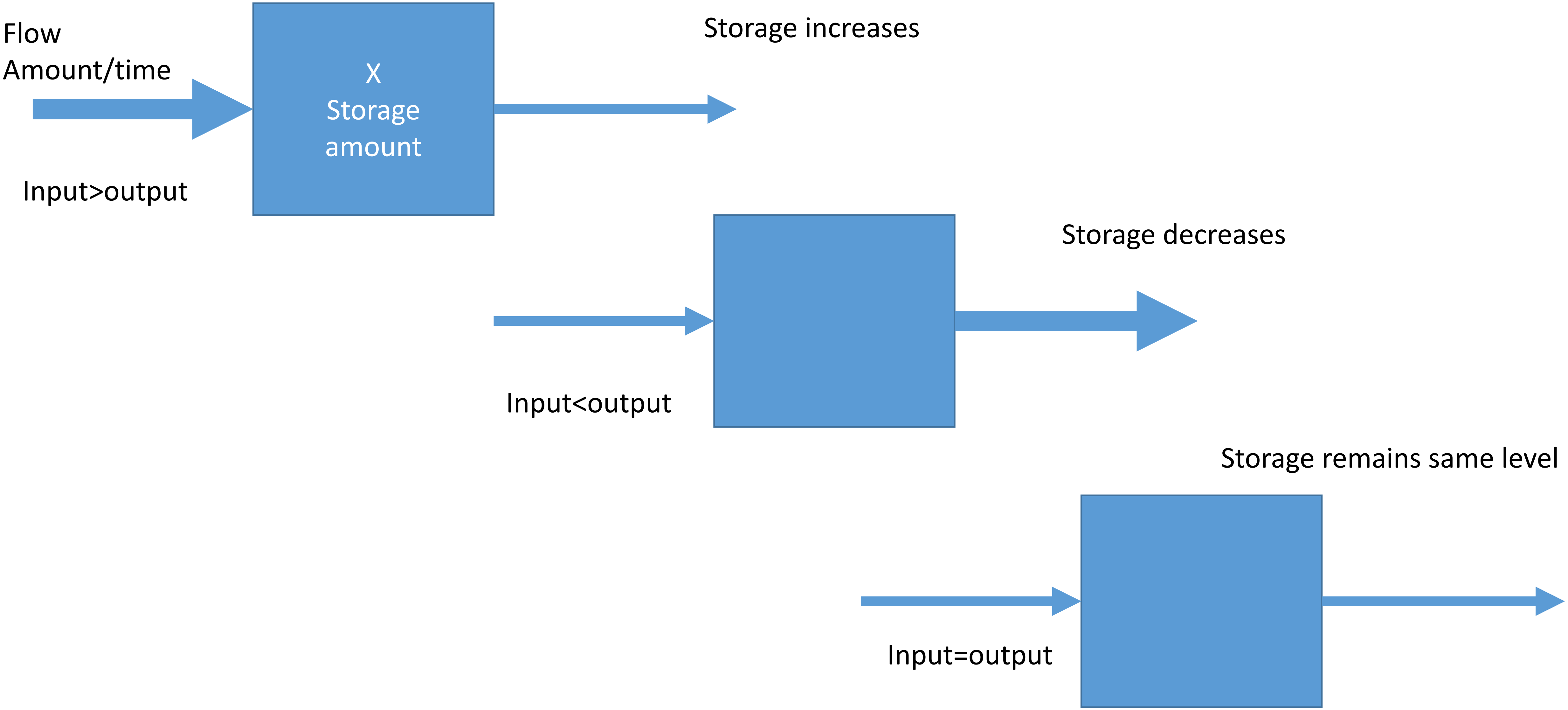


Input Output models

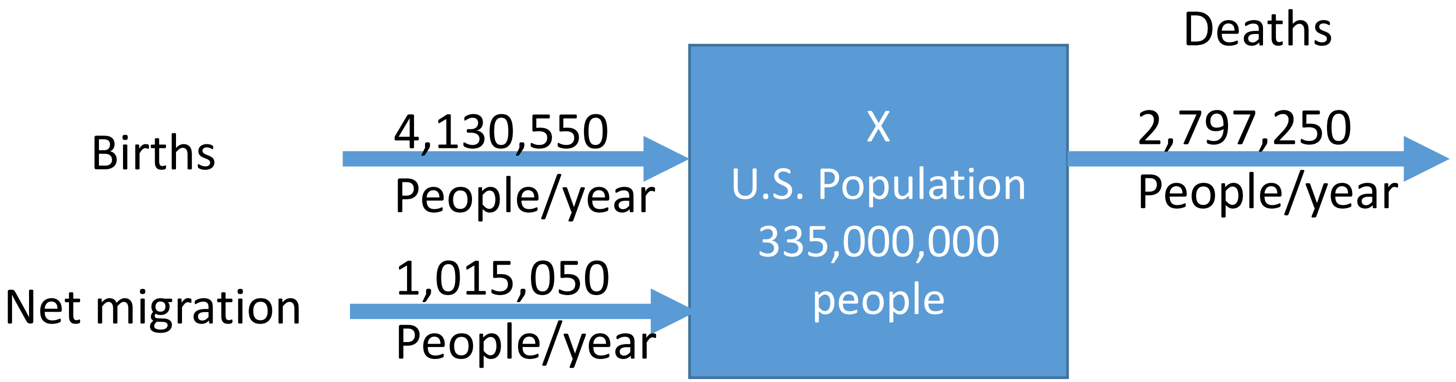




Input Output relations



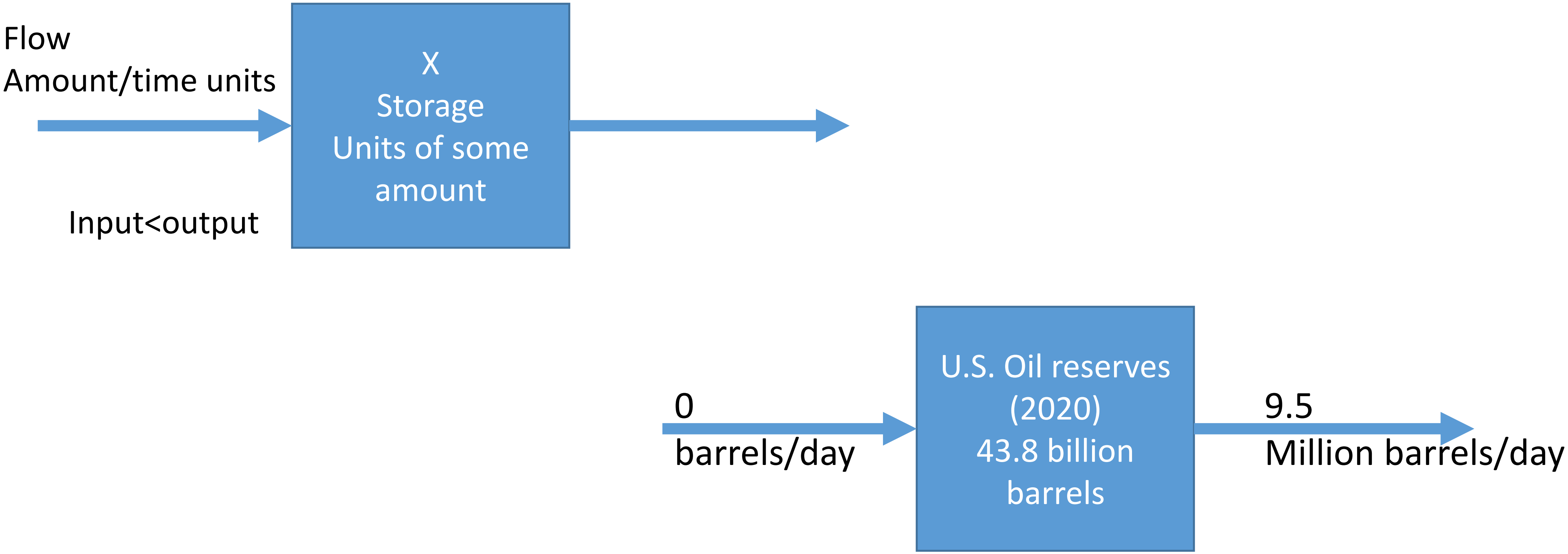
Input Output relations



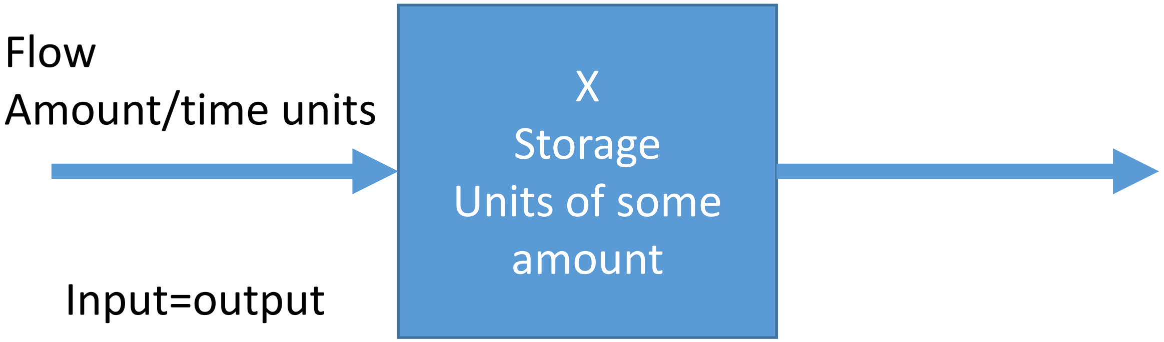
Change in population = Births + Net migration – deaths
4,130,550 people/year +1,015,050 people/year – 2,797,250 people/year = 2,348,350 people/year

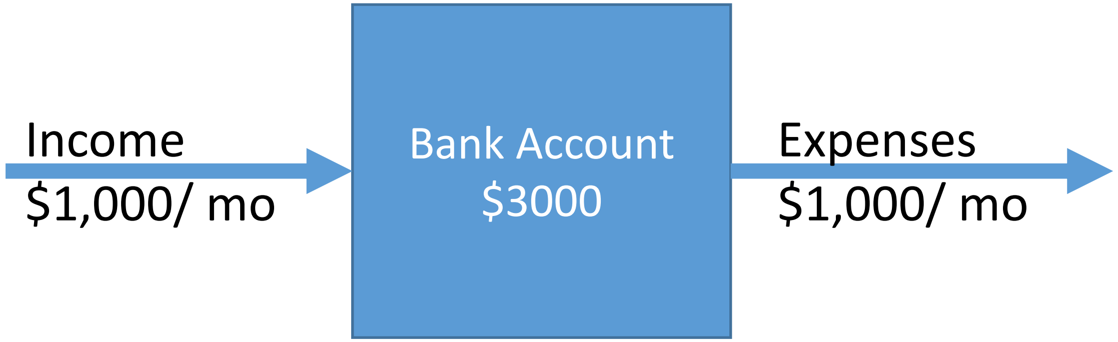
New population at time t = initial population + change in population * years (t)
335,000,000 people + 2,348,350 people/year * 1 year = 337,348,350 people

Input Output relations



Input Output relations





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

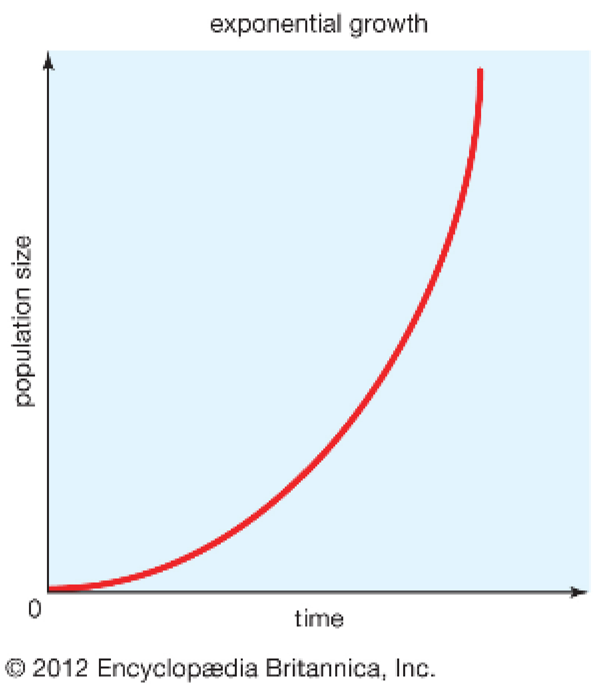
Practice making some input-output models of systems of your choice

- 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

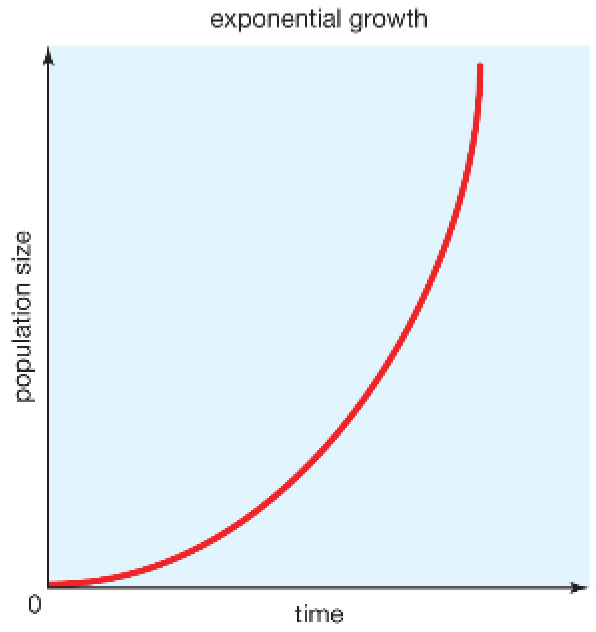
Exponential growth

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

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 number = 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

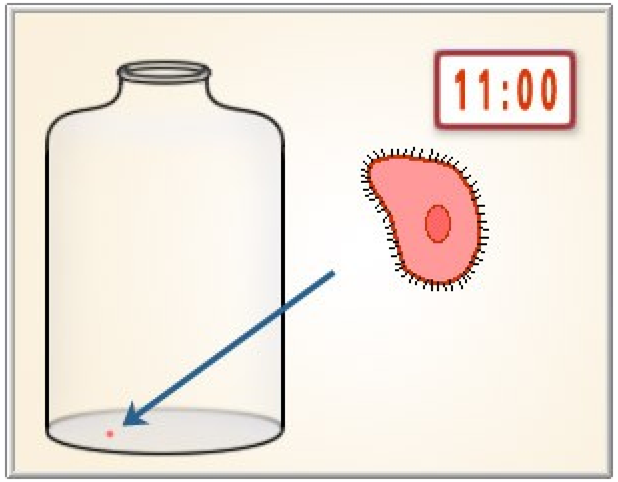
Step 2: take $e^{(rt)}$

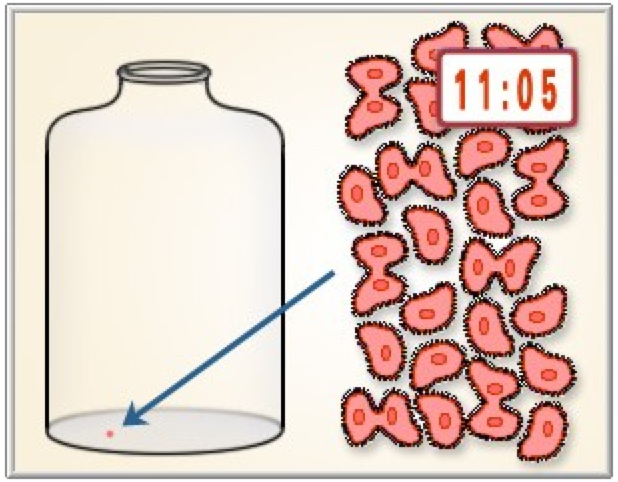
Step 3: multiply by N_0 Nt = 276,994,516,015,121,465 people

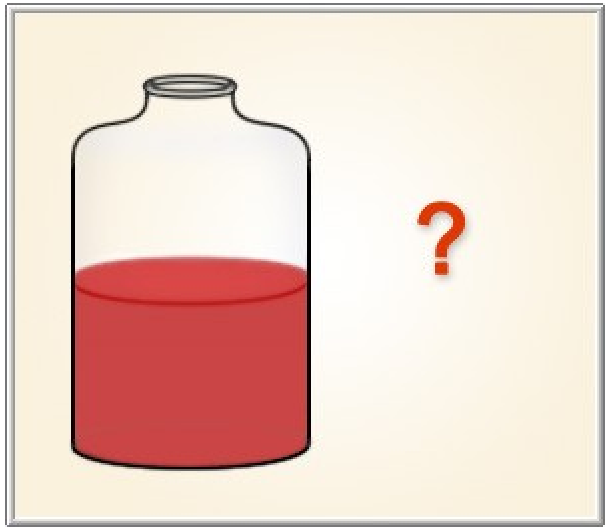
More practice problems – calculate the following:

1. e^2
2. $e^{0.25}$
3. $e^{3.75}$
4. e^{rt}, where r=0.1/day & t=10 days
5. e^{rt}, where r=0.05/day & t=50 days
6. e^{rt}, where r=5%/month & t=50 months
7. e^{rt}, where r=7%/year & t=25 years
8. e^{rt}, where r=0.0375/hour & t=1 day
9. $N_t = N_0 e^{rt}$, where N_0= 50 mice, r=1%/year & t=10 years
10. $N_t = N_0 e^{rt}$, where N_0= 200 bacteria, r=0.002/second & t=2000 seconds
11. t, where N_0= 1,000,000,000 humans, r=0.01/year & N_t= 2,000,000,000 humans

Exponential growth – unbound growth in the context of resource constraints

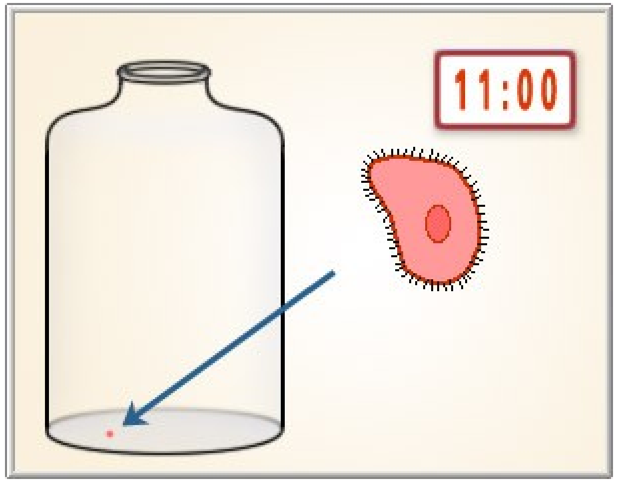


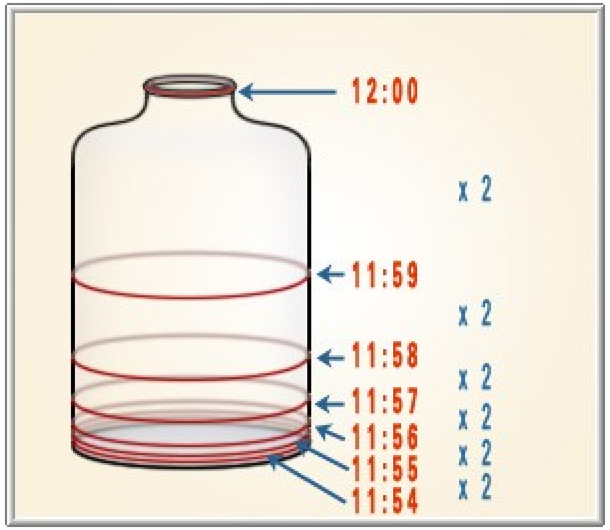


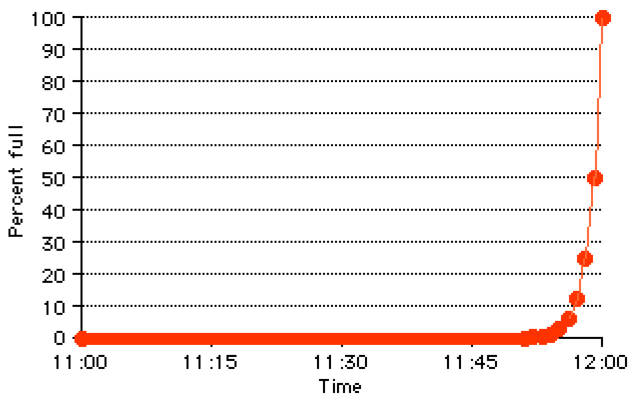


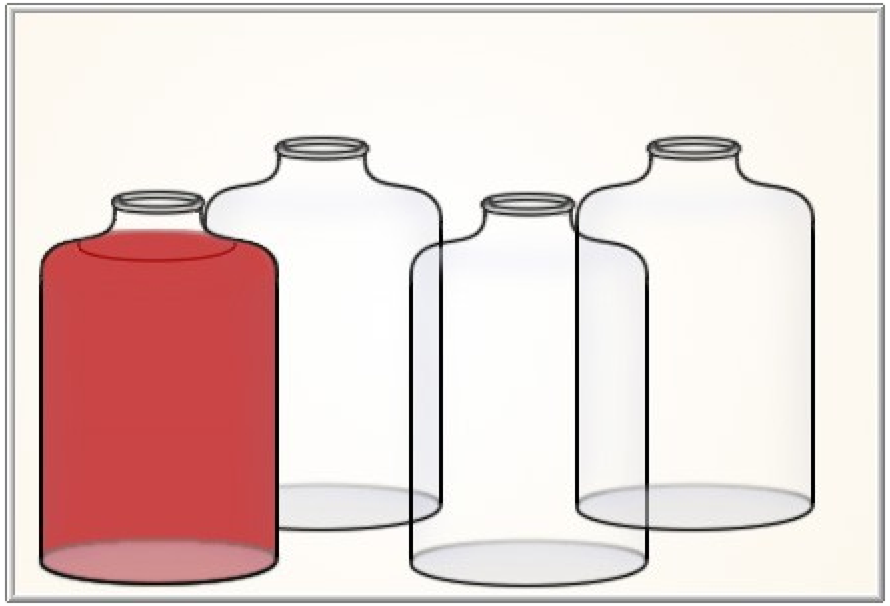
Jar is half-full at 11:59

Exponential growth

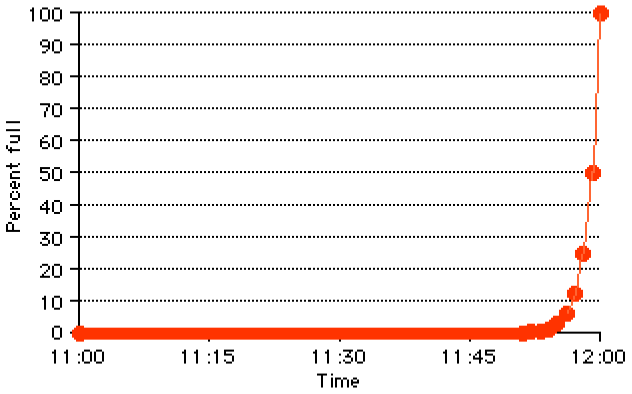


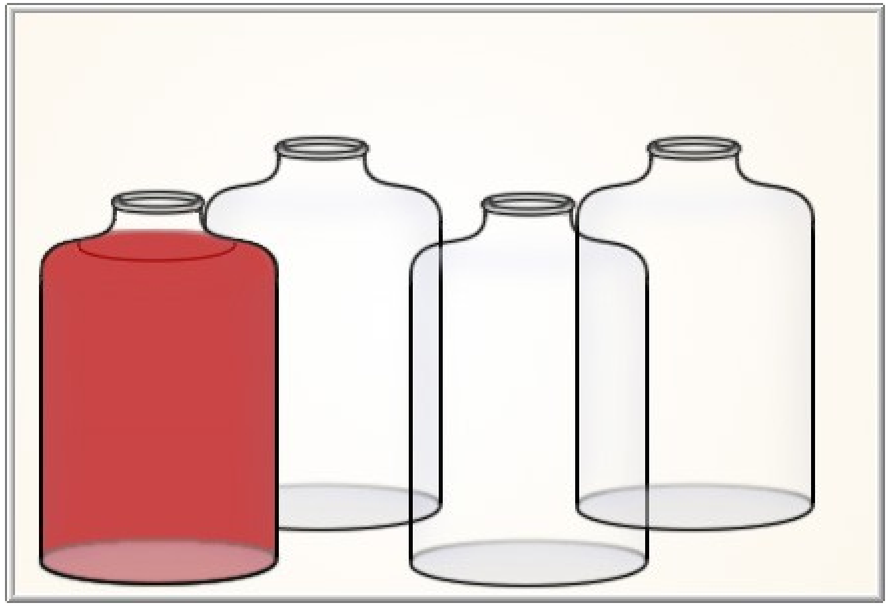


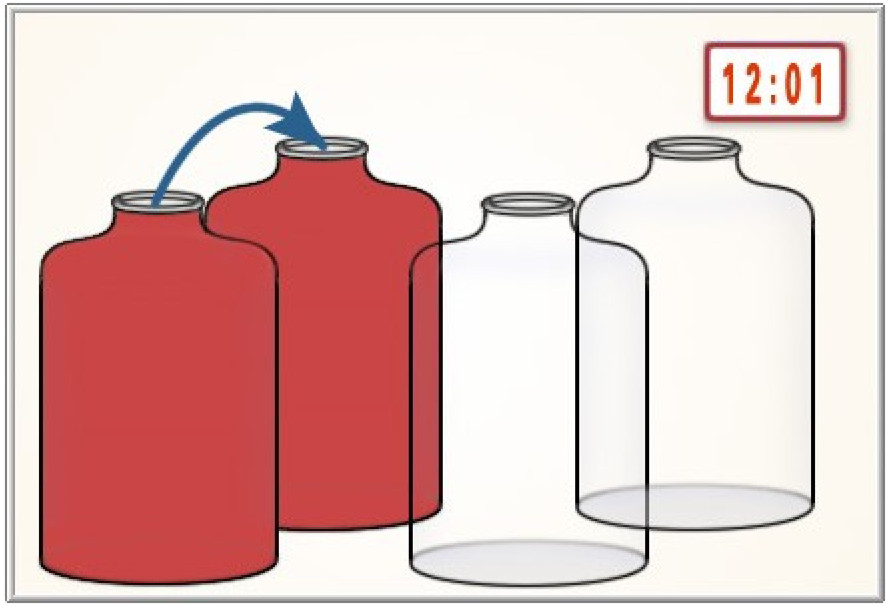


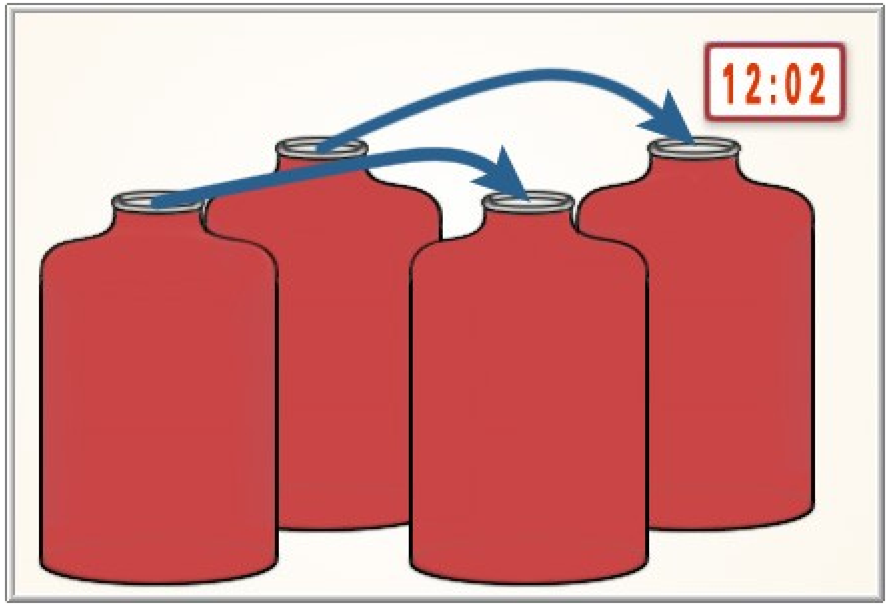


Exponential growth









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**

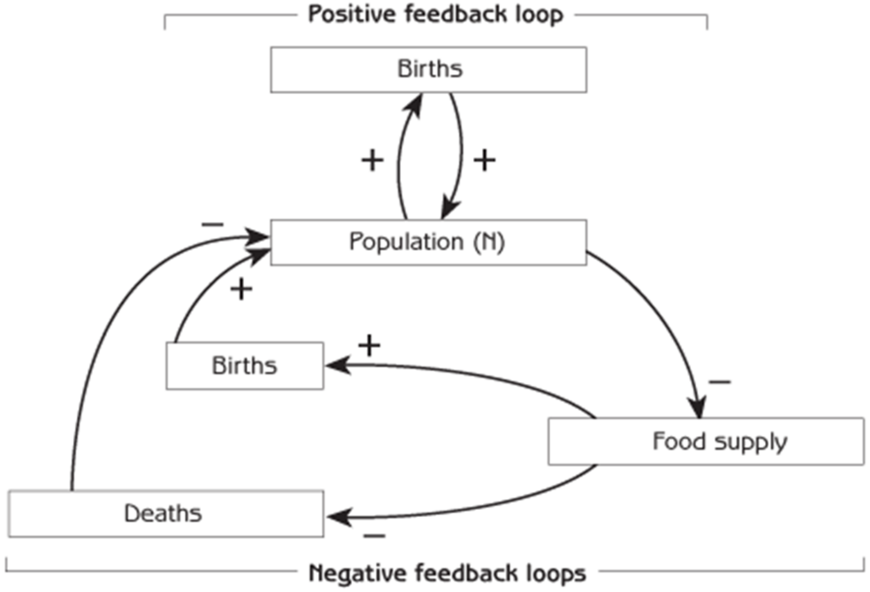
Population Regulation

When population increases, food supply (per individual) decreases

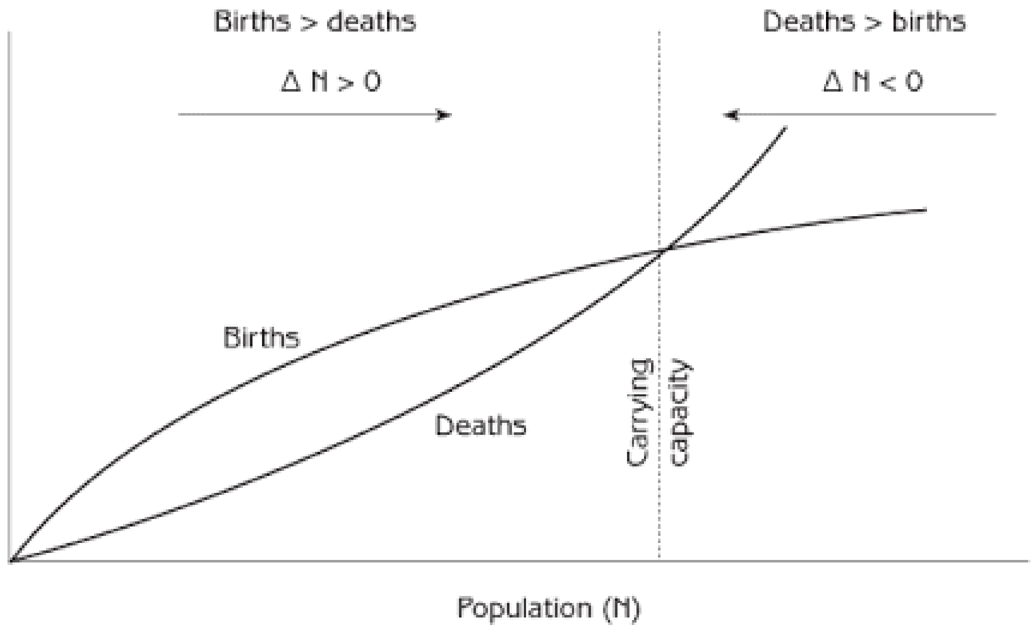
When population decreases, food supply (per individual) increases

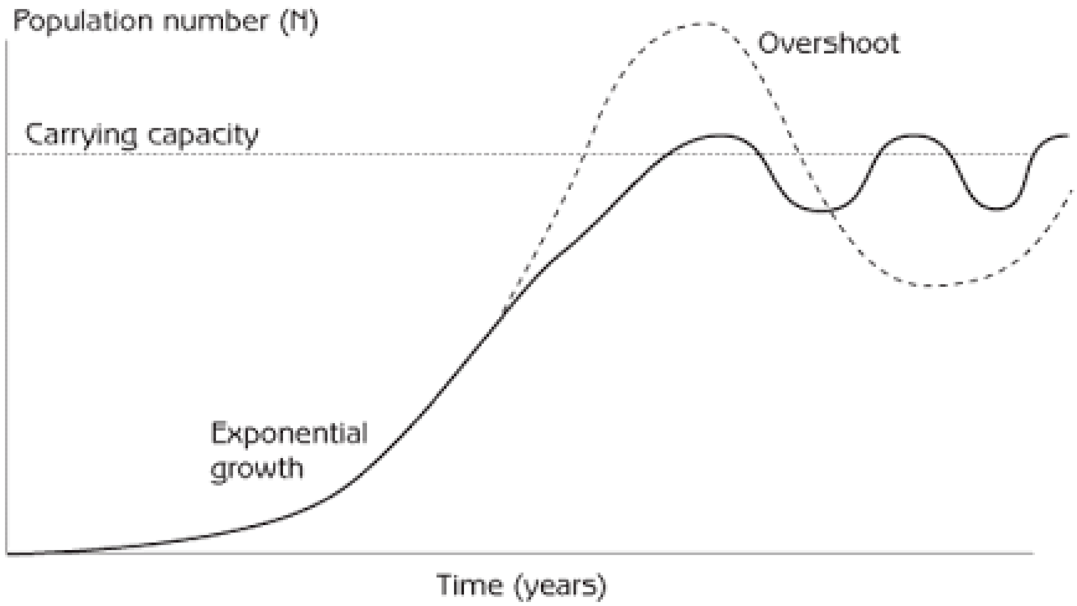
When food supply increases, births increase and deaths decrease

When food supply decreases, births decrease and deaths increase



Population change to carrying capacity





Things to think about

- Think of examples of positive feedback at different levels of social organization in your social system. Draw diagrams to show circular chains of effects.
- Think of examples of negative feedback at different levels of social organization in your social system. Draw diagrams to show circular chains of effects.
- Think of examples in your nation or community that illustrates:
  - Using positive feedbacks to make desired changes
  - Positive feedback that generates undesired changes
  - Negative feedbacks that keeps things the way people want them to be
  - Negative feedbacks that obstructs efforts to change things people consider undesirable

Things to think about

- Habits of a systems thinker

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