Chapter 2: Science, Matter, Energy, and Systems

Science…

- to discover…by observation, measurement, and experiments
- scientific method? - identify a problem; find out what is known about the problem; ask a question to investigate; collect data to answer the question; propose a hypothesis to explain the data; make testable projections; test projections with more experiments; accept or reject hypothesis

Make Observations

What do I see in nature? This can be from one's own experiences, thoughts, or reading.

Think of Interesting Questions

Why does that pattern occur?

Formulate Hypotheses

What are the general causes of the phenomenon I am wondering about?

Develop Testable Predictions

If my hypotesis is correct, then I expect a, b, c,...

Gather Data to Test Predictions

Relevant data can come from the literature, new observations, or formal experiments. Thorough testing requires replication to verify results.

Refine, Alter, Expand, or Reject Hypotheses

Develop General Theories

General theories must be consistent with most or all available data and with other current theories.

Easter Island - Rapa Nui

- Know the example :-)
- Jared Diamond: Easter Island is an example of ‘ecocide’. Easter Island is the "clearest example of a society that destroyed itself by overexploiting its own resources."
- Terry Hunt and Carl Lipo: not ecocide at all

These moai on Easter Island were so imposing that Europeans couldn't believe they'd been created by just a couple thousand people.

Hundreds of years ago, an advanced, seafaring civilization called Rapa Nui built more than 800 monuments that were so massive and ambiguous that they remain a mystery to this day. The Easter Island statues, or moai, are enormous stone figures placed along the coastline as if surveying the island's interior lands. One of archaeology's greatest mysteries is what happened to the Rapa Nui of Easter Island.

What had decimated the great civilization of Easter Island?
Why were there so few of the Rapa Nui left? What happened?

Diamond: the Rapa Nui had greedily used up all the island's resources. They ate all the food, cut down all the trees, and were left to squabble over the remaining scraps. With no more trees left, they couldn't build boats to leave the island and look for more food. So they fell into war and cannibalism, leaving only a few thousand people left to greet the Europeans. It's a perfect parable for our age of environmental collapse and resource depletion.

Is it accurate? What Questions would you need to ask?
What assumptions do you have?

Citing the evolutionary biologist Peter Turchin, famous for developing a theory of history called "cliodynamics," Lipo believes that the common thread in human history is cooperation rather than war. The fate of the Rapa Nui on Easter Island is often used to illustrate how humans destroy their communities with environmental destruction and warfare. But it might actually provide a good model for sustainable civilizations of the future. Lipo explained:

> Easter Island is a great case of this kind of sociality in which populations seem to have mediated competition over limited resources through the community building of statues. What looks like strange behavior to us is likely central to their success. This is an area we are following up on in our ongoing research. I think we have a lot to learn from Easter Island as to what it takes to survive on an isolated and remote island with limited resources. But rather than being a "scary parable" about the effects of cultural hubris and ultimate collapse, we can learn valuable insights into strategies that lead to cooperation, resilience, and sustainability.

Cliodynamics is a transdisciplinary area of research integrating historical macrosociology, cultural and social evolution, economic history/ cliometrics, mathematical modeling of long-term social processes, and the construction and analysis of historical databases.

Limitations to science

- (1) uncertainty and certainty vs proof
  - IPCC: 2001 - 66 % chance that climate change is anthropogenic ; 2007: 90% certain
  - Virtually certain; extremely likely; high confidence
  - 2007, IPCC report, “very high confidence” that global average temperature increases were due to the increases in greenhouse gas concentrations. i.e. 95% certain

Confidence Terminology	Degree of confidence in being correct
Very high confidence	At least 9 out of 10 chance
High confidence	About 8 out of 10 chance
Medium confidence	About 5 out of 10 chance
Low confidence	About 2 out of 10 chance
Very low confidence	Less than 1 out of 10 chance

The scales of scientific confidence used by the IPCC. http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html

Likelihood Terminology	Likelihood of the occurrence/ outcome
Virtually certain	> 99% probability
Extremely likely	> 95% probability
Very likely	> 90% probability
Likely	> 66% probability
More likely than not	> 50% probability
About as likely as not	33 to 66% probability
Unlikely	< 33% probability
Very unlikely	< 10% probability
Extremely unlikely	< 5% probability
Exceptionally unlikely	< 1% probability

IPCC measures certainty using the likelihood scale. The highest scientific certainty we can convey is virtually certain (99-100% probability). http://www.ipcc.ch/publications_and_data/ar4/wg1/en/ch1s1-6.html

Limitations to science

- (2) People are biased…
- (3) many systems in the natural world involve a huge number of variables with complex interactions [mathematical models; statistical tools]

The Results of Science Can Be Tentative, Reliable, or Unreliable

- Tentative science, frontier science
  - Not yet considered reliable by the scientific community
- Reliable science
  - Widely accepted by experts
- Unreliable science
  - Has not been through peer review or has been discredited

- Note: whether we review the material in the chapter or not, you are still responsible for it.

2-2 What Is Matter and What Happens When It Undergoes Change?

- Matter
  - Consists of elements and compounds, which are in turn made up of atoms, ions, or molecules
- The law of conservation of matter
  - Whenever matter undergoes a physical or chemical change, no atoms are created or destroyed

- The law of conversation of matter: whenever matter undergoes a physical or chemical change, no atoms are created or destroyed

- energy: the capacity to do work or to transfer heat [work = force * distance]

    - energy: kinetic energy (matter in motion; heat; electromagnetic radiation) and potential energy

        - energy quality: high-quality energy is concentrated [concentrated sunlight; high-speed wind; burning gasoline or coal]; low-quality energy is dispersed

- 1st law of thermodynamics: law of conservation of energy

- 2nd laws of thermodynamic: law of entropy

2-3 What is Energy and What Happens When It Undergoes Change?

- Whenever energy is converted from one form to another in a physical or chemical change, two changes may happen:
  - No energy is created or destroyed (first law of thermodynamics)
  - We end up with lower quality or less-usable energy than we started with (second law of thermodynamics)

Renewable and Nonrenewable Energy

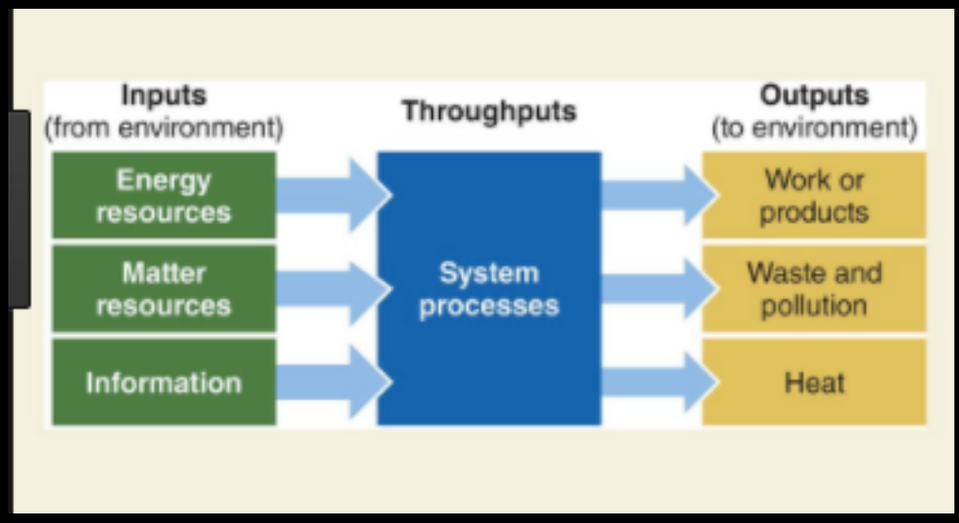
- Renewable energy:
  - Gained from resources that are replenished by natural processes in a relatively short time
- Nonrenewable energy:
  - Resources can be depleted and are not replenished by natural processes within human timescales

Systems

- Systems: inputs —> throughputs —> outputs

- Positive Feedback loops: causes a system to change FURTHER in the same direction

- Negative Feedback Loops: causes a system to change in the OPPOSITE direction from which it is moving



Positive Feedback Loop

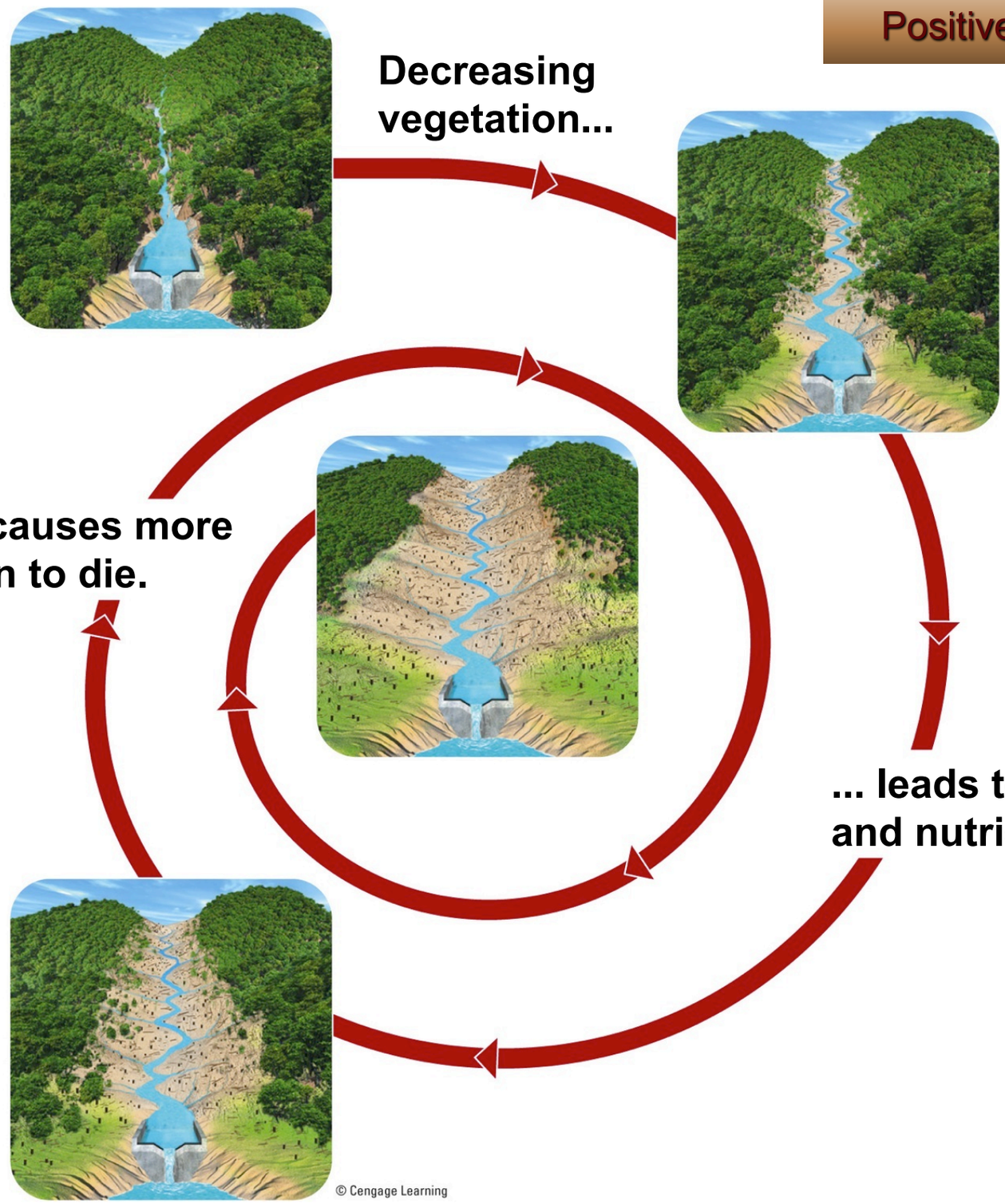


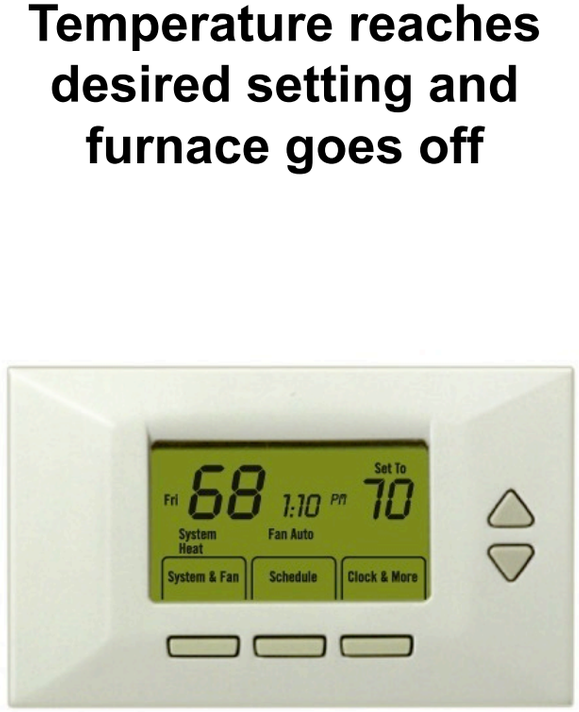
Fig. 2-16, p. 45

Negative Feedback Loop

House warms

Temperature reaches desired setting and furnace goes off

Furnace on



Temperature drops below desired setting and furnace goes on

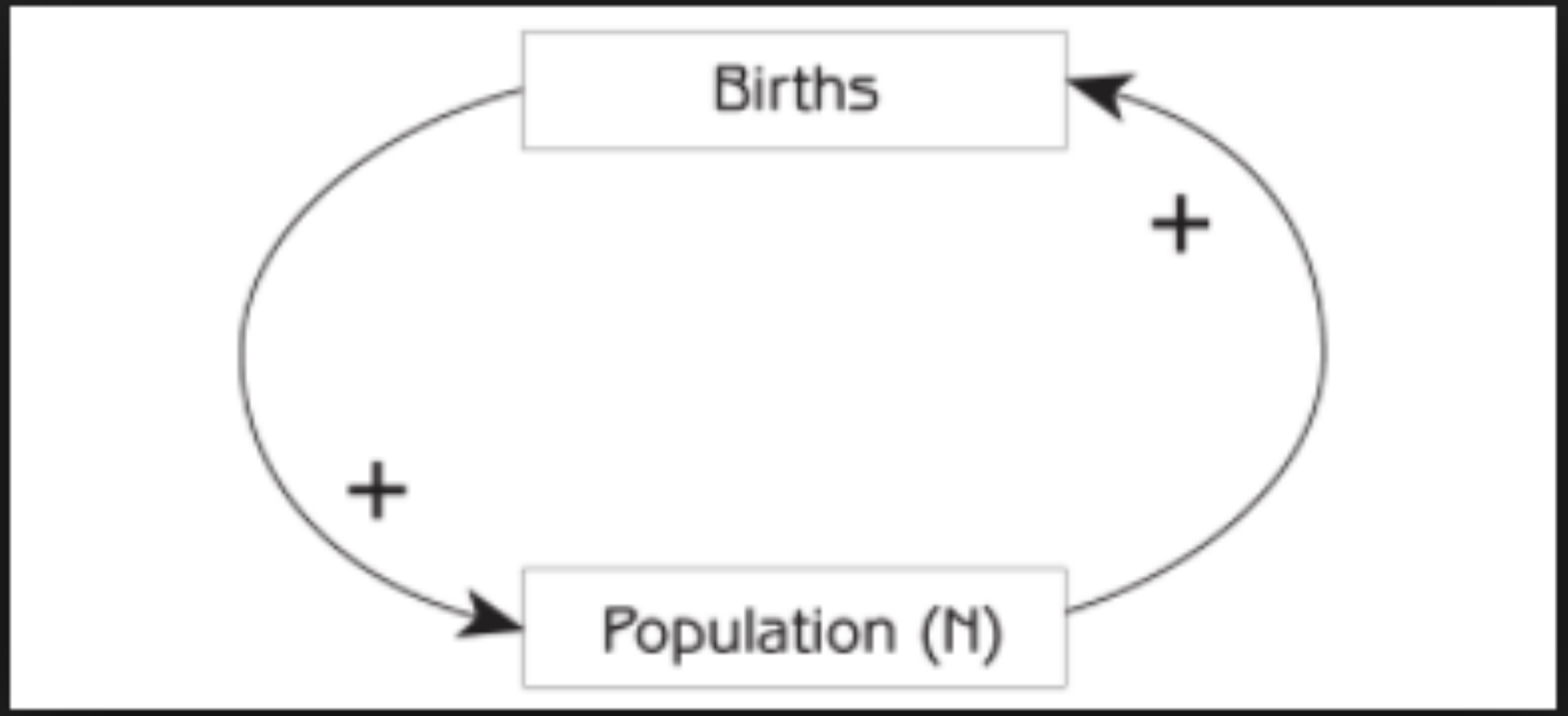
Furnace off

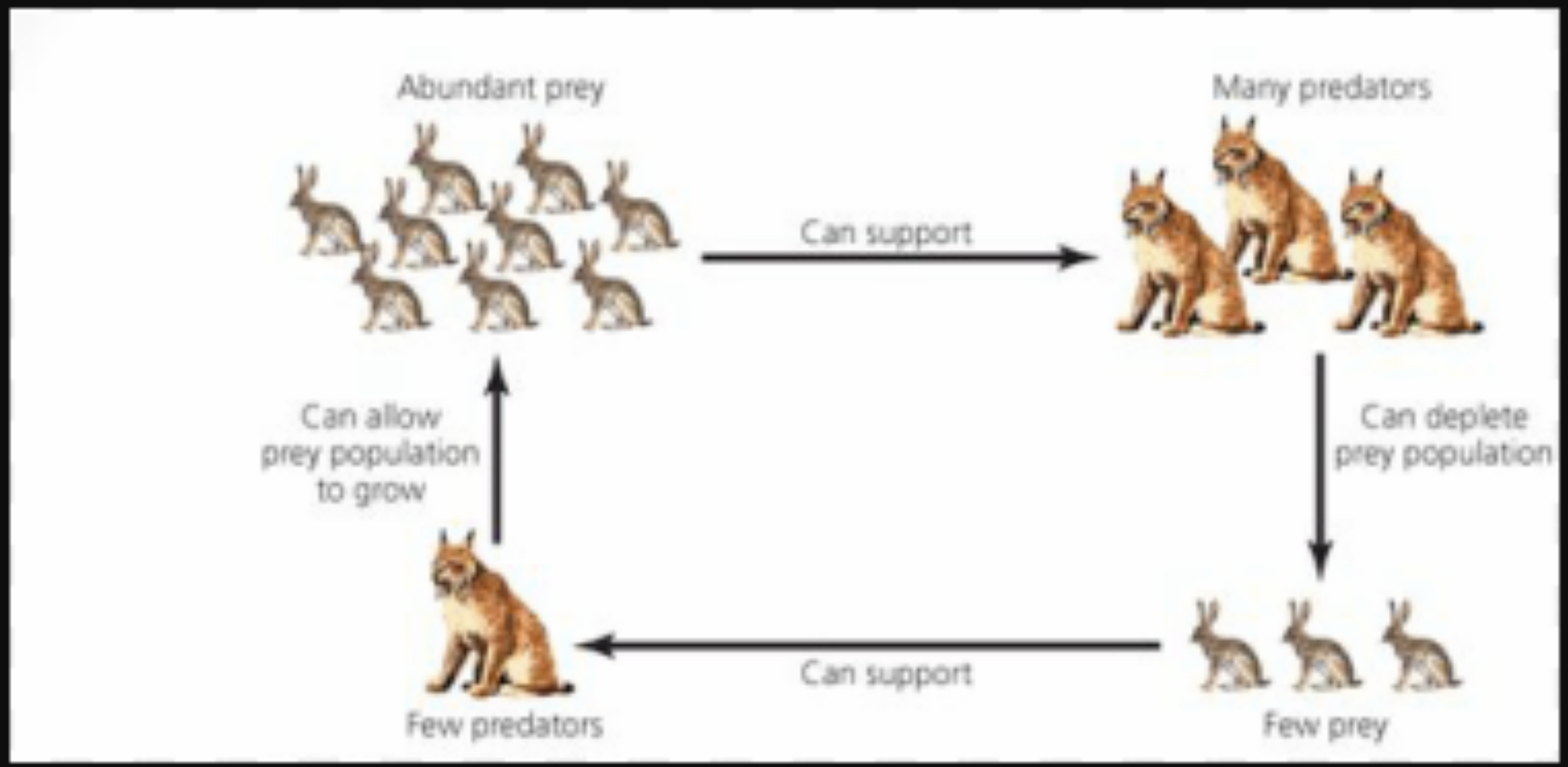
House cools

Fig. 2-17, p. 46

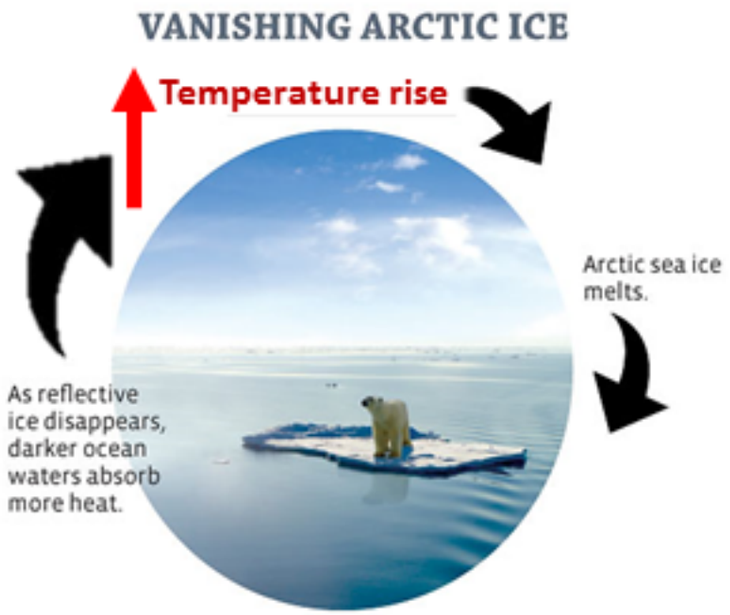
It Can Take a Long Time for a System to Respond to Feedback

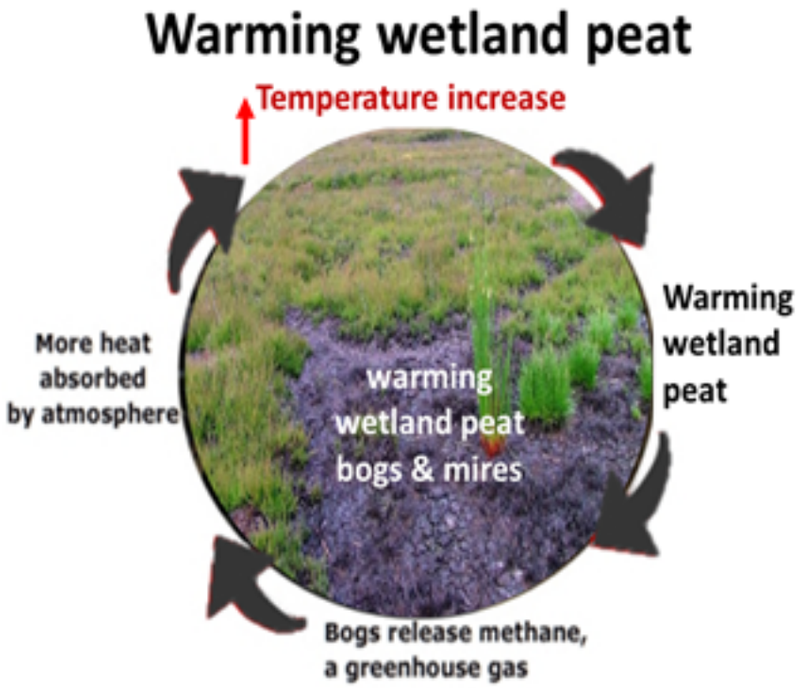
- Time delay
  - Amount of time between the input of a feedback stimulus and the response to it
- Tipping point, threshold level
  - Fundamental shift in the behavior of the system

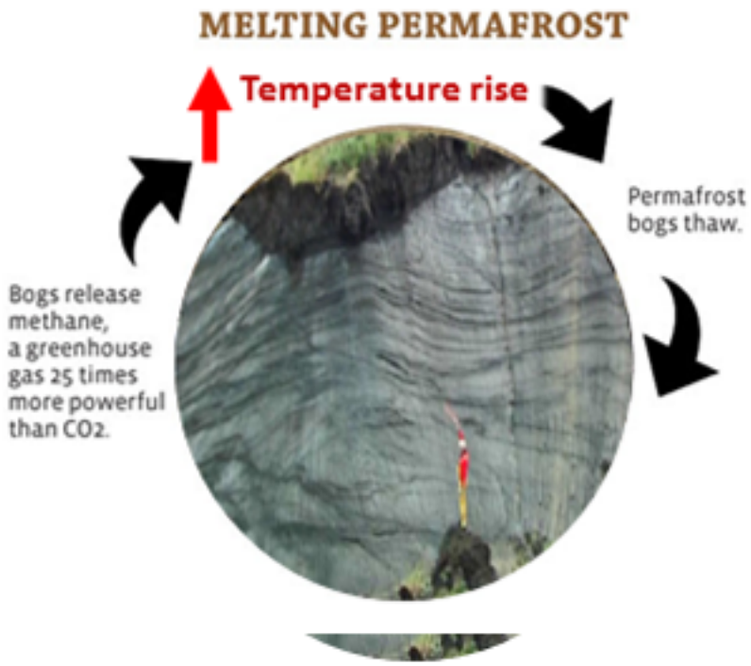

Births
+
+
Population (N)

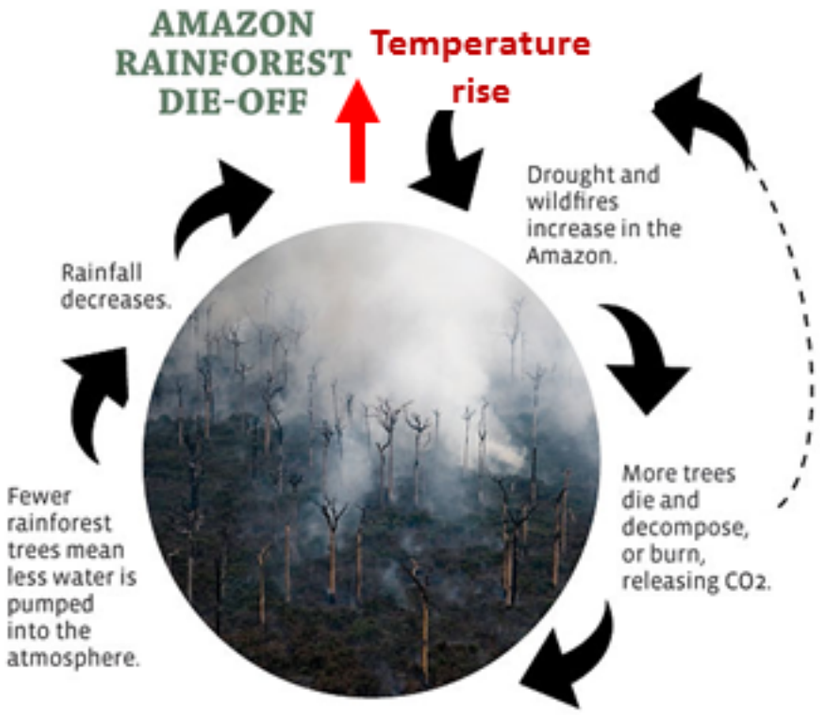

Abundant prey
Can support
Many predators
Can allow prey population to grow
Can deplete prey population
Few predators
Can support
Few prey

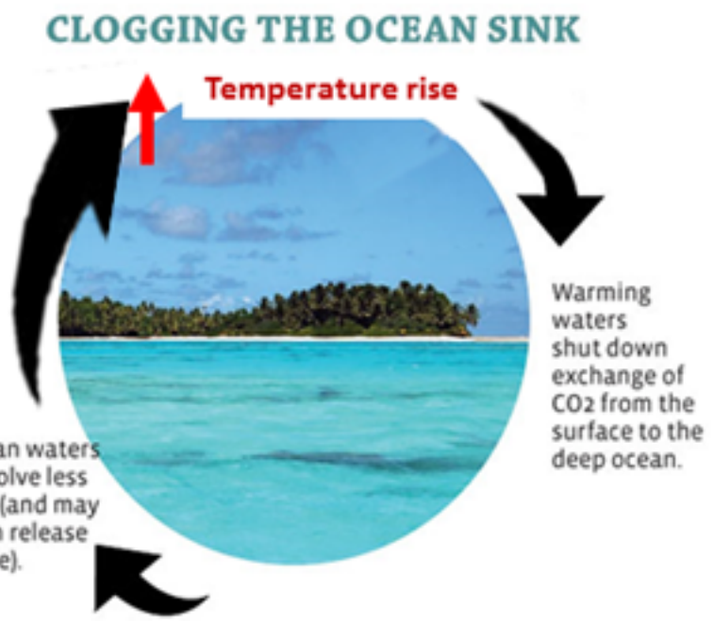
Some large +ve amplifying feedbacks











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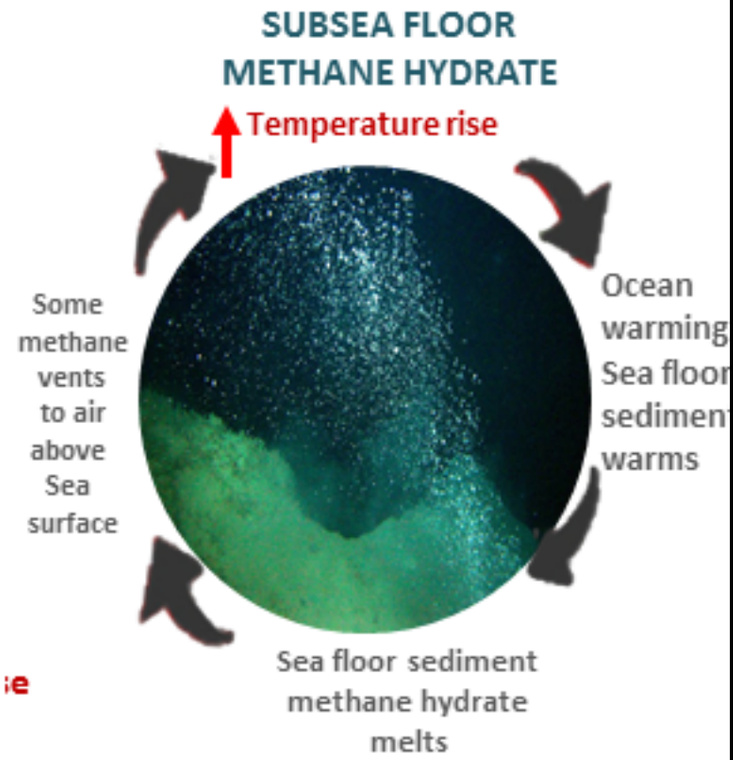


Three Big Ideas

- You cannot really throw anything away
  - According to the law of conservation of matter, no atoms are created or destroyed whenever matter undergoes a physical or chemical change
  - Thus, we cannot do away with matter; we can only change it from one physical state or chemical form to another

Three Big Ideas (cont'd.)

- You cannot get something for nothing
  - According to the first law of thermodynamics, or the law of conservation of energy, whenever energy is converted from one form to another in a physical or chemical change, no energy is created or destroyed
  - This means that in causing such changes, we cannot get more energy out than we put in

Three Big Ideas (cont'd.)

- You cannot break even
  - According to the second law of thermodynamics, whenever energy is converted from one form to another in a physical or chemical change, we always end up with lower-quality or less usable energy than we started with

Tying It All Together

- The Hubbard Brook Forest Experiment and Sustainability
  - Revealed that clearing a mature forest degrades natural capital
  - How far can we go expanding our ecological footprints without threatening our own quality of life?
  - We need to maintain balance

Core Case Study: A Story About a Forest

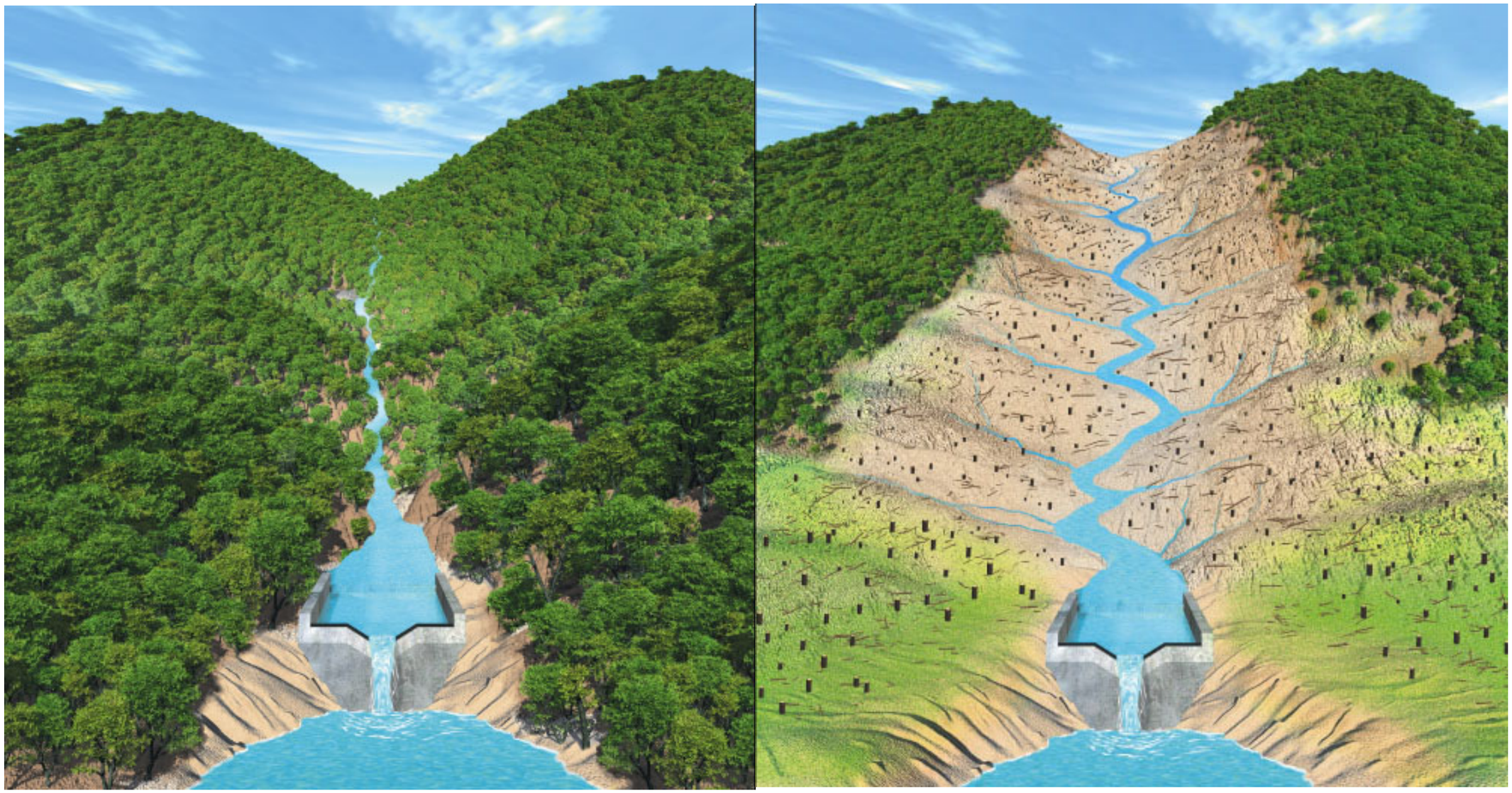
- Hubbard Brook Experimental Forest in New Hampshire
  - Compared the loss of water and nutrients from an uncut forest (control site) with one that had been stripped (experimental site)
- Stripped site
  - 30-40% more runoff
  - More dissolved nutrients
  - More soil erosion

Homework assignment (2) - due Thursday by midnight

- The Hubbard Brook Experimental Forest and Sustainability (Chapter 2, Core Case Study): Humans clear forests to grow crops, build settlements and expand cities. How far can we go in expanding our ecological footprints without threatening the quality of life for our species and other species?

- Answer the three questions (page 52)

The Effects of Deforestation on the Loss of Water and Soil Nutrients



Stepped Art

Fig. 2-1, p. 31