Environmental Science, 15e

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3

Ecosystems: What Are They and How Do They Work?

Core Case Study: Tropical Rainforests are Disappearing

- Cover only 2% of the earth's surface, but can contain up to half of the world's terrestrial plant and animal species
  - Destroyed by logging, crop development, cattle grazing and encroaching civilization
- Why should you be concerned about the disappearance of tropical rainforests?
- Can you identify the ecosystem in which you live?

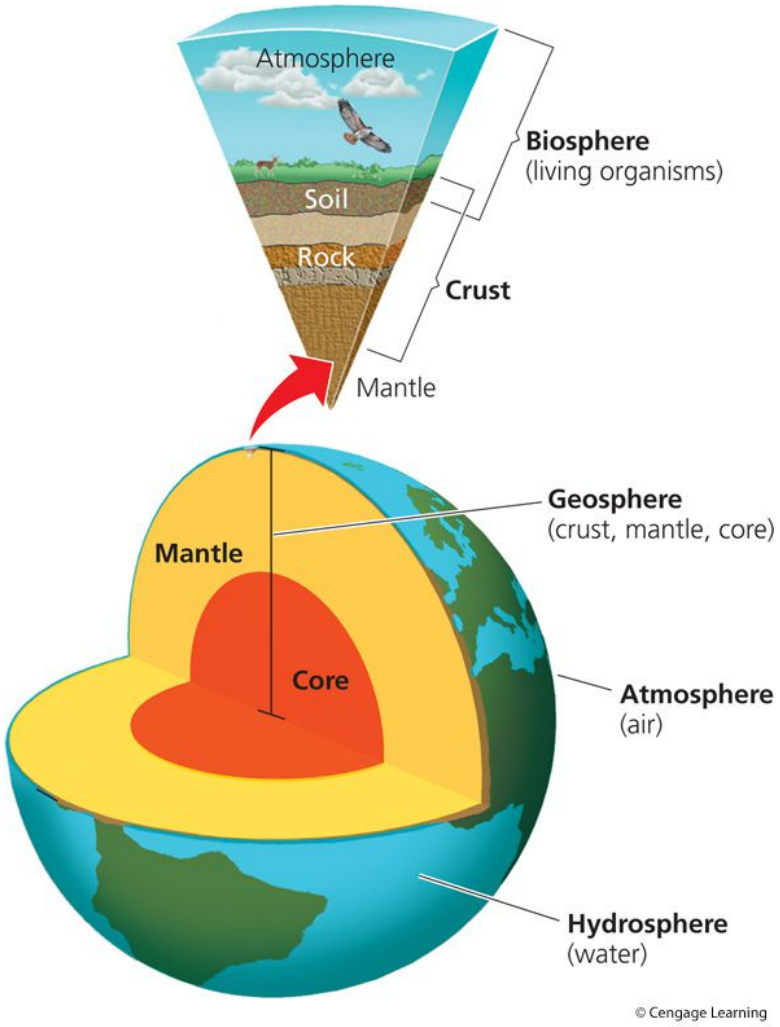
3.1 How Does the Earth's Life-Support System Work?

- Earth's life-support system has four spherical components that interact with each other
- Life is sustained by the cycling of nutrients and energy between and through these systems

Earth's Life-Support System Has Four Major Components

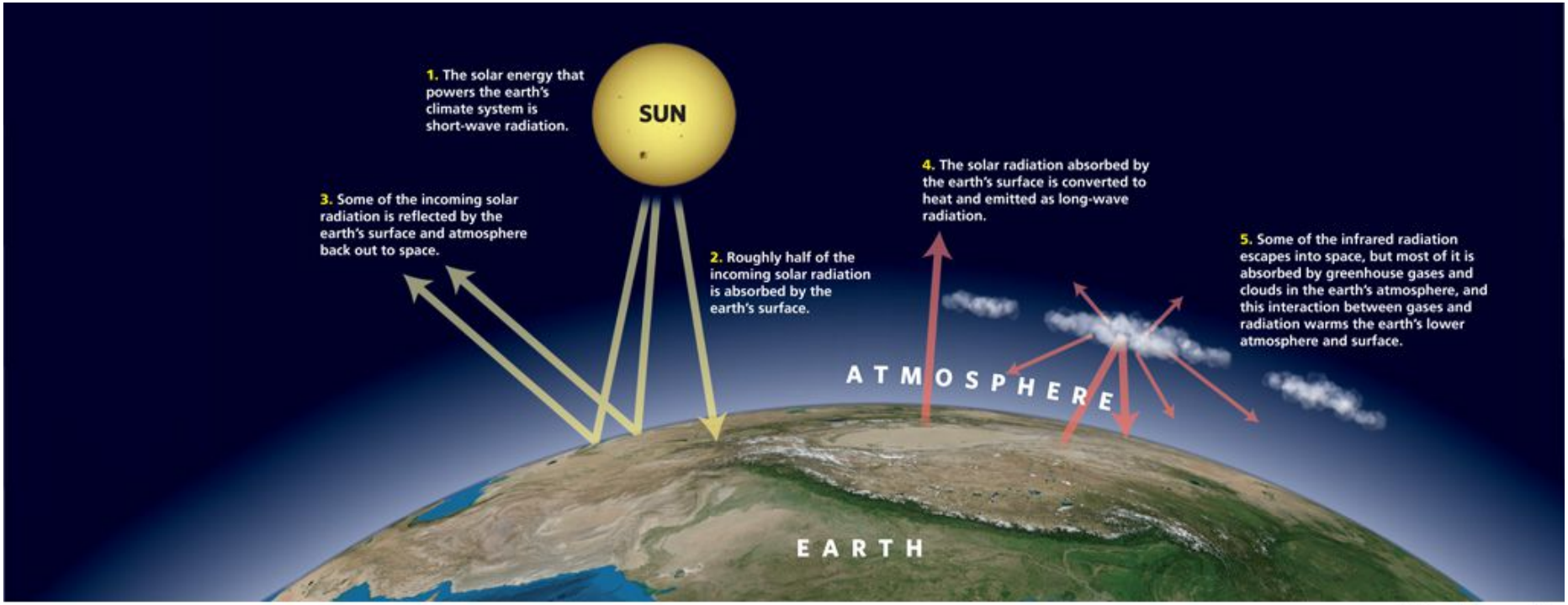
- Atmosphere – composed of the troposphere and the stratosphere
- Hydrosphere – water at or near the earth's surface (ice, water, and water vapor)
- Geosphere – composed of a hot core, a thick, mostly rocky mantle and a thin outer crust
- Biosphere – wherever life is found within the other three spheres

Natural Capital: Earth's Four Life-Support Systems



Three Factors Sustain the Earth's Life

- The one-way flow of high-quality energy
  - Solar energy principle of sustainability
  - Greenhouse effect
- The cycling of nutrients
  - Chemical cycling principle of sustainability
- Gravity



National Geographic

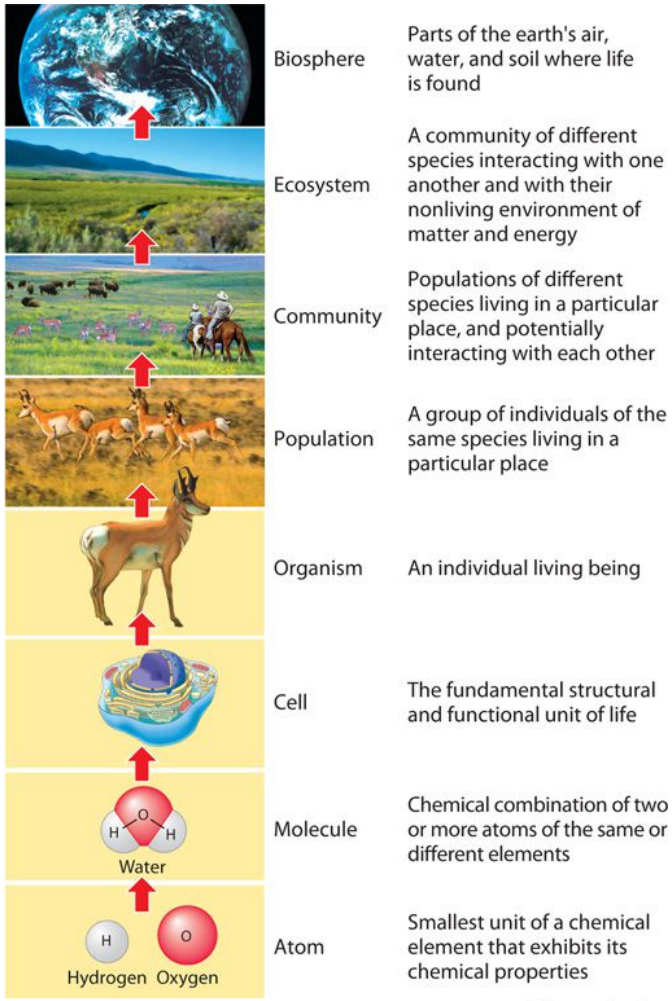
3.2 What Are the Major Components of an Ecosystem?

- Organisms that:
  - Produce their own nutrition
  - Satisfy nutritional requirements by consuming other organisms
  - Decompose waste and remains of organisms thereby recycling nutrients

Ecosystems Have Several Important Components

- Ecology: organisms interact with each other and with their non-living environment
- Biotic (living) and abiotic (non-living) parts of the environment exhibit sequential levels of organization
  - Five of these levels: organisms, populations, communities, ecosystems, and the biosphere

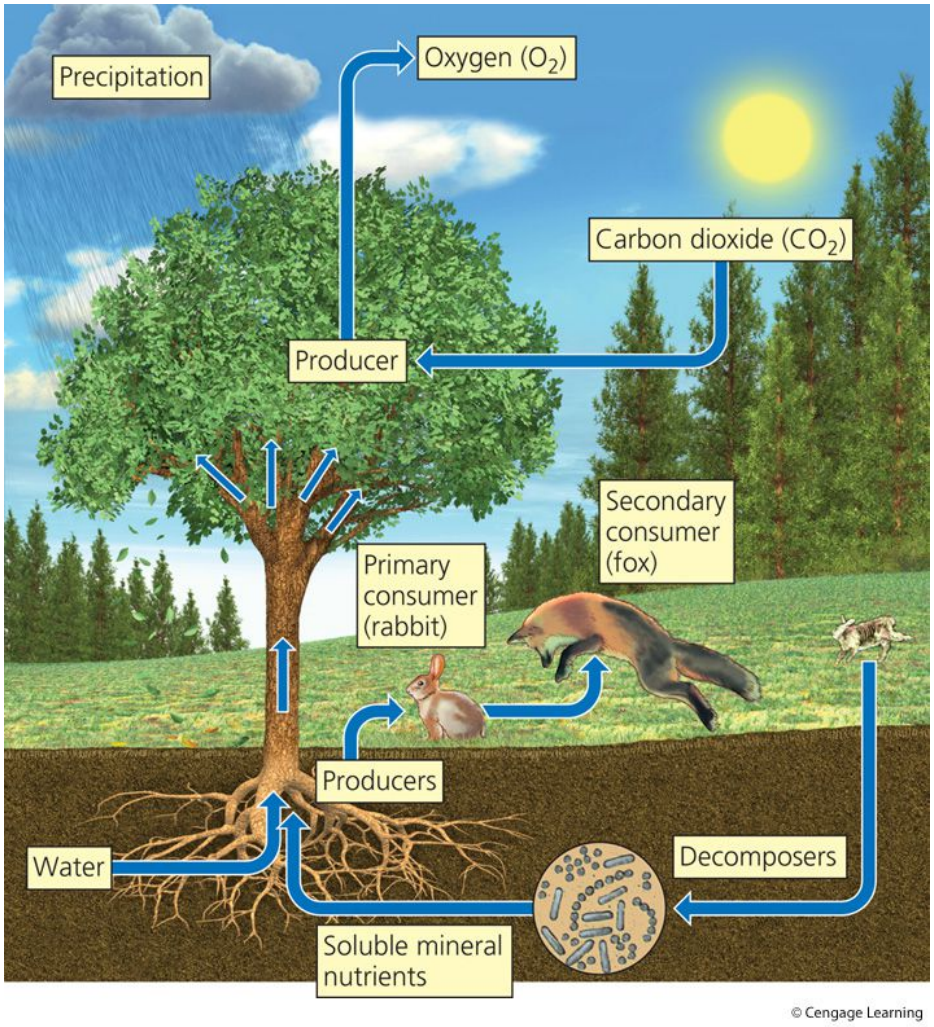
Levels of the Organization of Matter in Nature



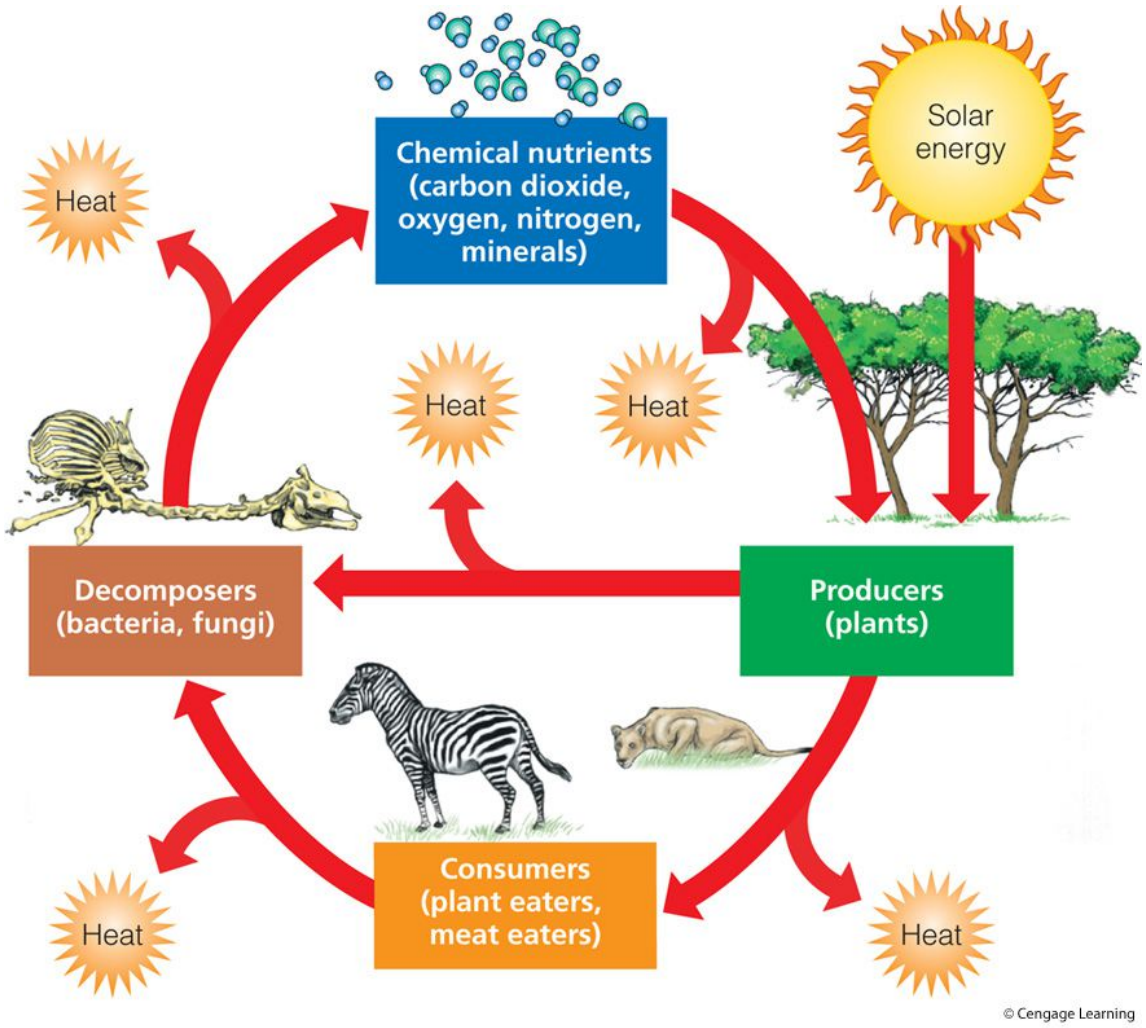
Producers and Consumers

- Organisms belong to feeding/tropic levels depending on their source of nutrients
- Producers (autotrophs – plants) use photosynthesis to make nutrients
- Consumers (heterotrophs) feed on other organisms or their remains
  - Can be herbivores (plant eaters), carnivores (meat eaters) or omnivores (eat both plants and meat)

Living (Biotic) and Non-Living (Abiotic) Components



Natural Capital: The Main Components of a Ecosystem

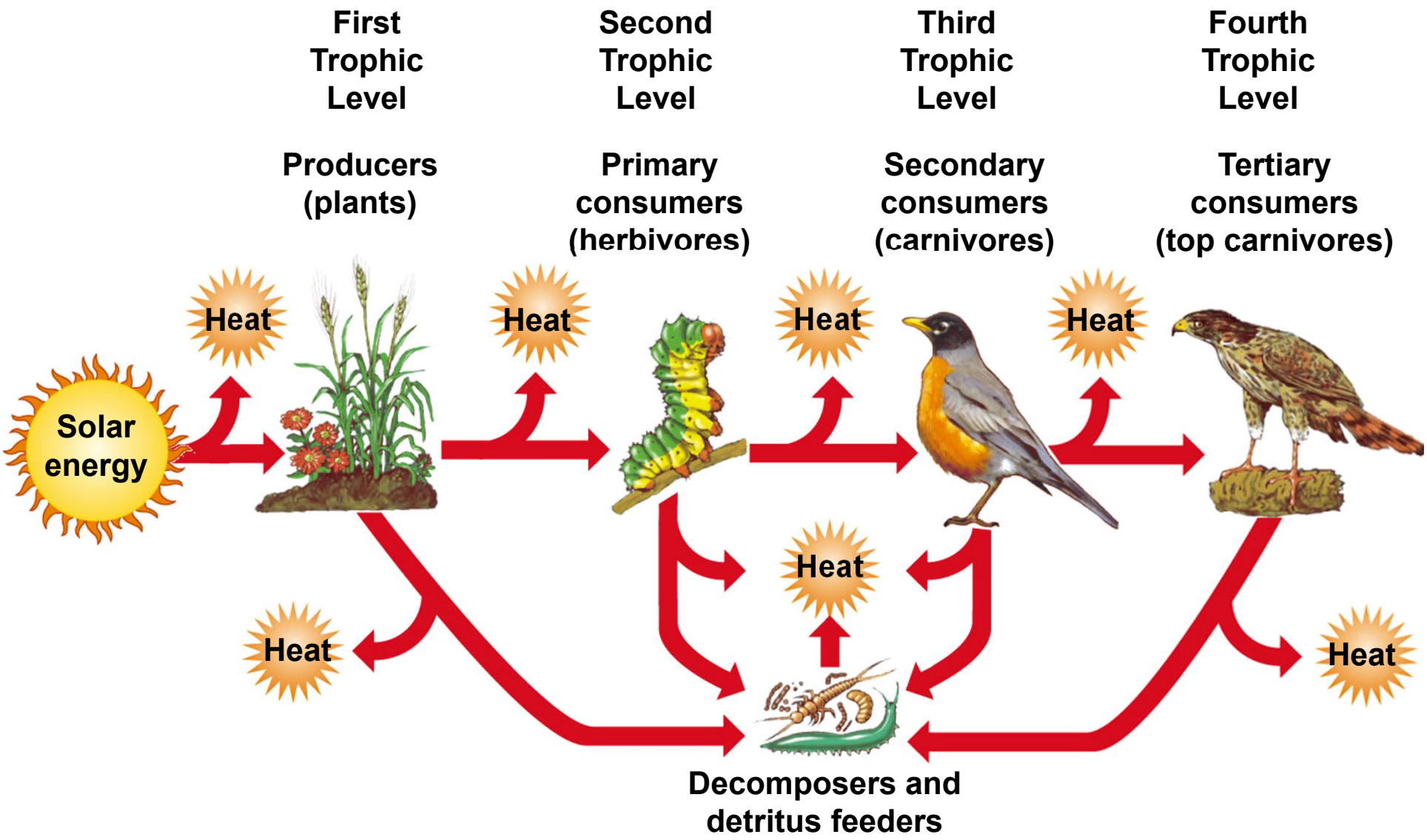


3.3 What Happens To Energy in an Ecosystem?

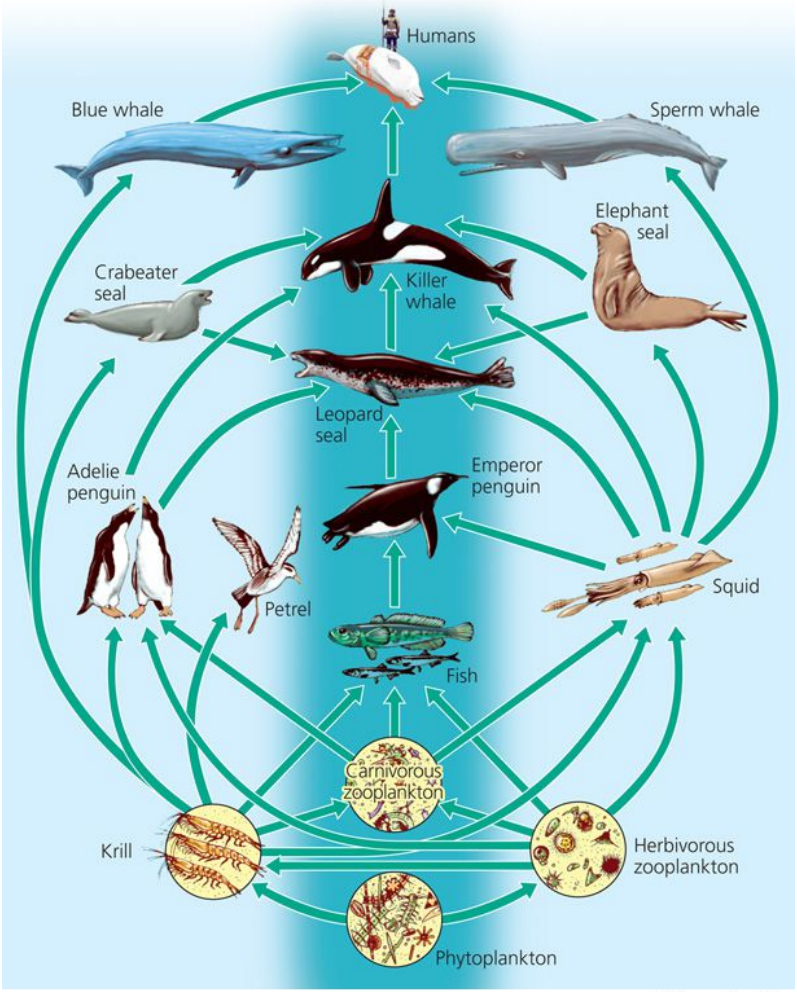
- Energy flows through ecosystems via movement between trophic levels through food chains and food webs
  - The quality of energy available to organisms decreases as each successive trophic level is reached, because so much energy (heat) is lost moving from one level to the next

Energy Flows Through Ecosystems in Food Chains and Food Webs

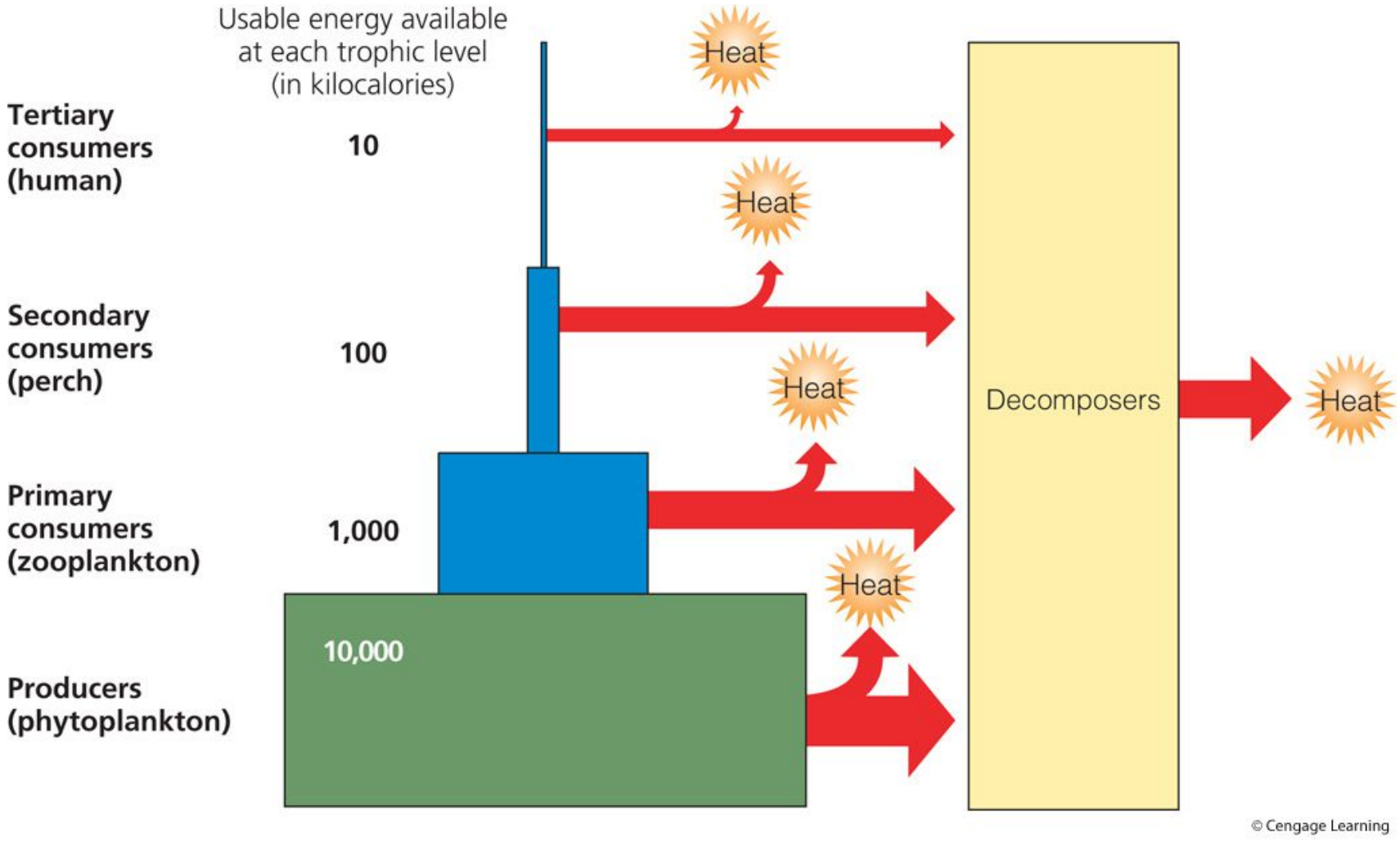
- Food chains
  - A sequence of organisms, each of which serves as a nutritional source for the next (big fish eat little fish)
- Food webs
  - A complex network of interconnected food chains
- Pyramid of energy flow
  - Energy flow through various trophic levels



Stepped Art



A Generalized Pyramid of Energy Flow



Some Ecosystems Produce Plant Matter Faster than Others Do

- GPP (gross primary productivity)
  - The rate that an ecosystem's producers convert energy into biomass
- NPP (net primary productivity)
  - The rate that producers use photosynthesis to produce and store chemical energy minus the rate at which they use energy for aerobic respiration

Some Ecosystems Produce Plant Matter Faster Than Others Do

- Terrestrial and aquatic ecosystems differ in their NPP (net primary productivity)
  - Despite low NNP, oceans produce most of the world's biomass because of their vast size
  - Tropical rainforests have high NPP – much is lost through natural capital degradation
- Only plant matter represented by NPP is available as nutrients for consumers

3.4 What Happens To Matter in an Ecosystem?

- Matter in the form of nutrients and energy are naturally cycled and recycled through ecosystems and the biosphere
  - However, these chemical cycles are being altered by human activities

Nutrients Cycle Within and Among Ecosystems

- Biogeochemical cycling, driven by incoming solar radiation and earth's gravity continually, moves nutrients and energy through air, water, soils, rocks, and living organisms
  - Supports the chemical cycling principle of sustainability

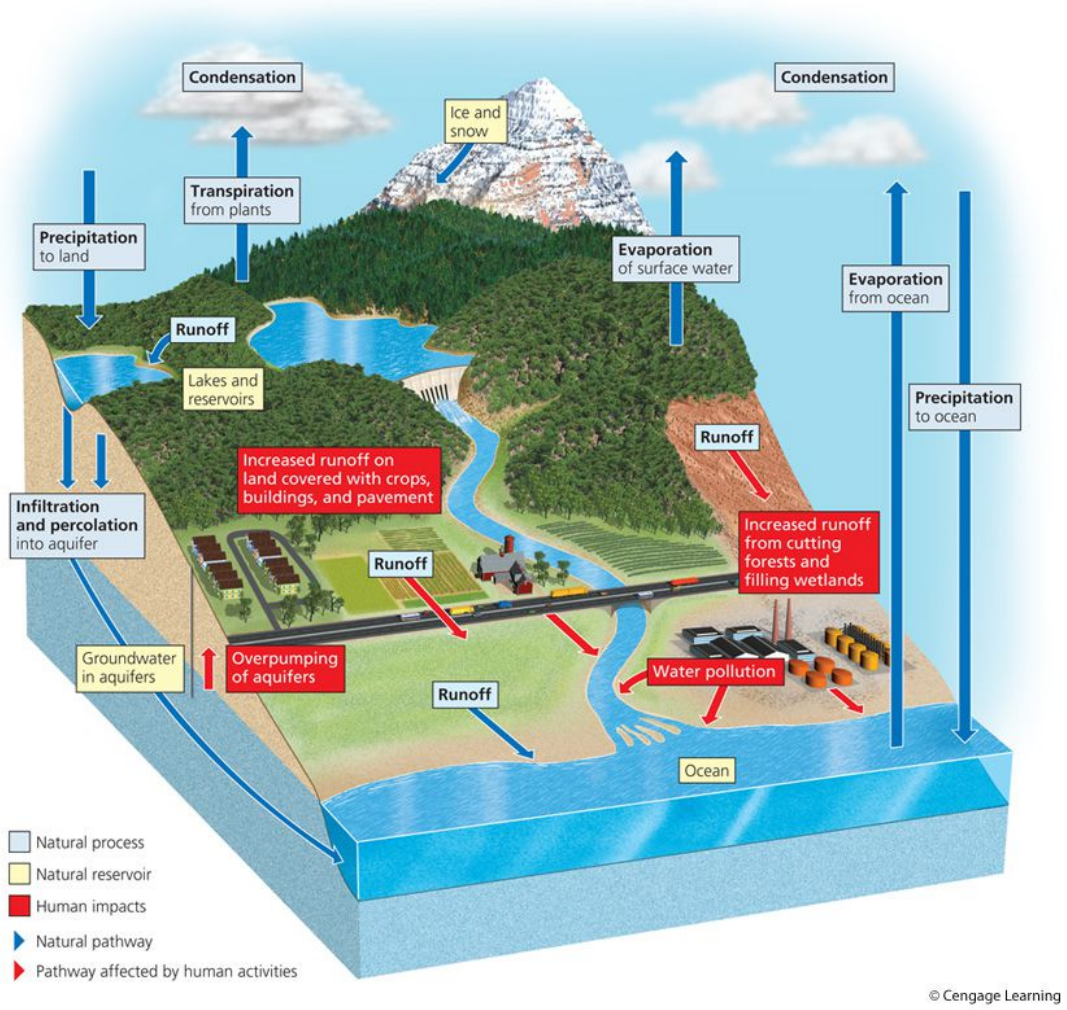
The Water Cycle – Evaporation and Transpiration

- The hydrologic cycle or water cycle collects, purifies, and distributes the earth's fixed supply of water
  - The cycle of natural water quality renewal
- Incoming solar radiation moves water at the surface into the atmosphere through evaporation
  - Mainly via transpiration (evaporation from the surface of plants)

The Water Cycle – Precipitation and Surface Runoff

- Condensation in the atmosphere and effects of gravity create precipitation which returns water to the earth's surface
  - Surface runoff
  - Aquifers and ground water
- Only a very small portion of earth's water is fresh water
  - The rest is in oceans, stored as ice or is too deep to access

Natural Capital – The Hydrologic Cycle



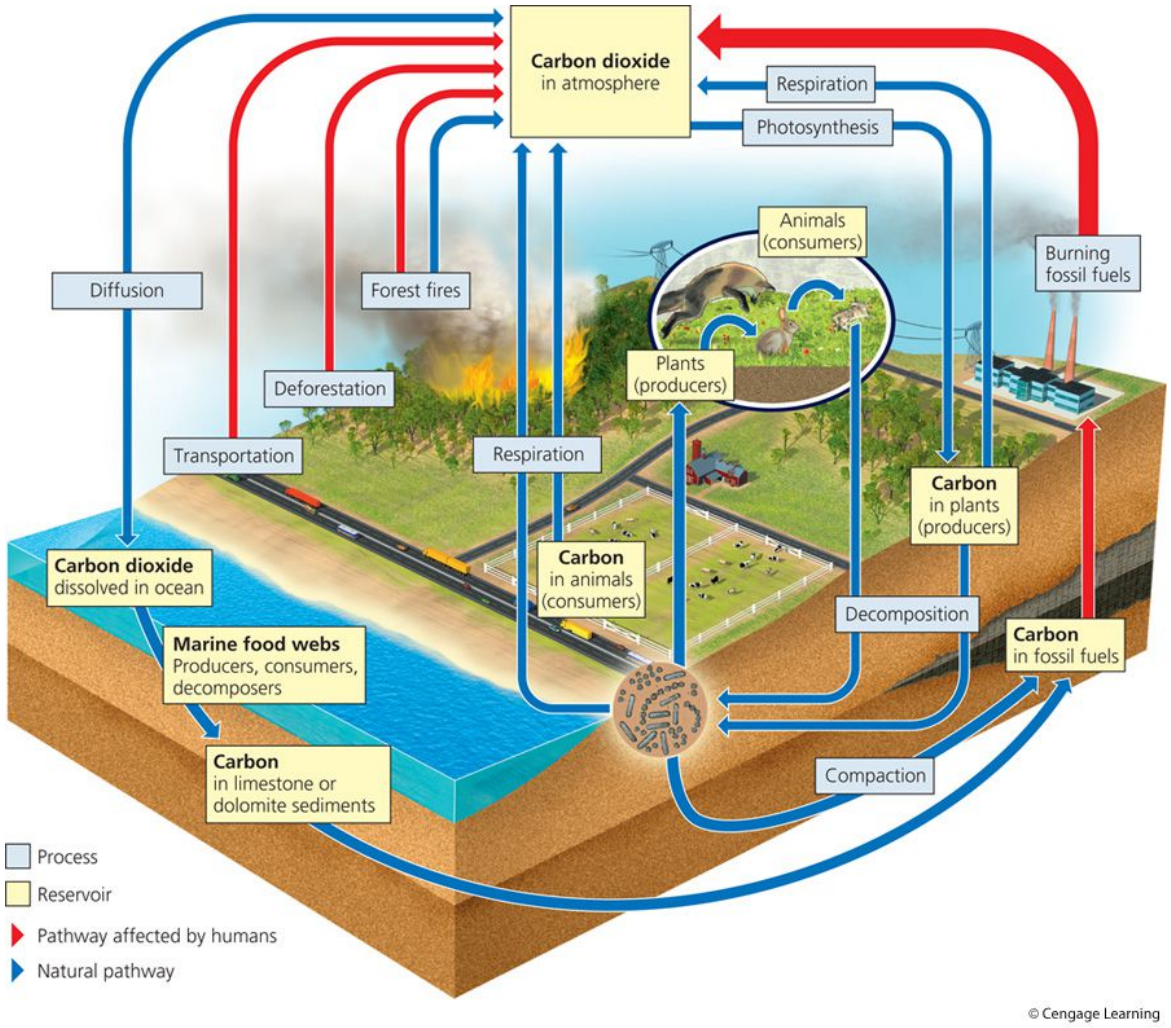
How Do Humans Alter the Water Cycle?

- By withdrawing fresh water resources faster than natural processes replenish it
- By replacing forests/vegetation with urban development – reducing transpiration and increasing runoff
- By draining and filling in wetlands, which disturbs the renewal abilities of the hydrologic cycle

The Carbon Cycle

- Atmospheric carbon dioxide, a key component of the carbon cycle, has a significant temperature effect (greenhouse effect)
- How does carbon cycle through the biosphere?
  - Photosynthesis by producers
  - Aerobic respiration by producers, consumers and decomposers

Natural Capital: The Global Carbon Cycle



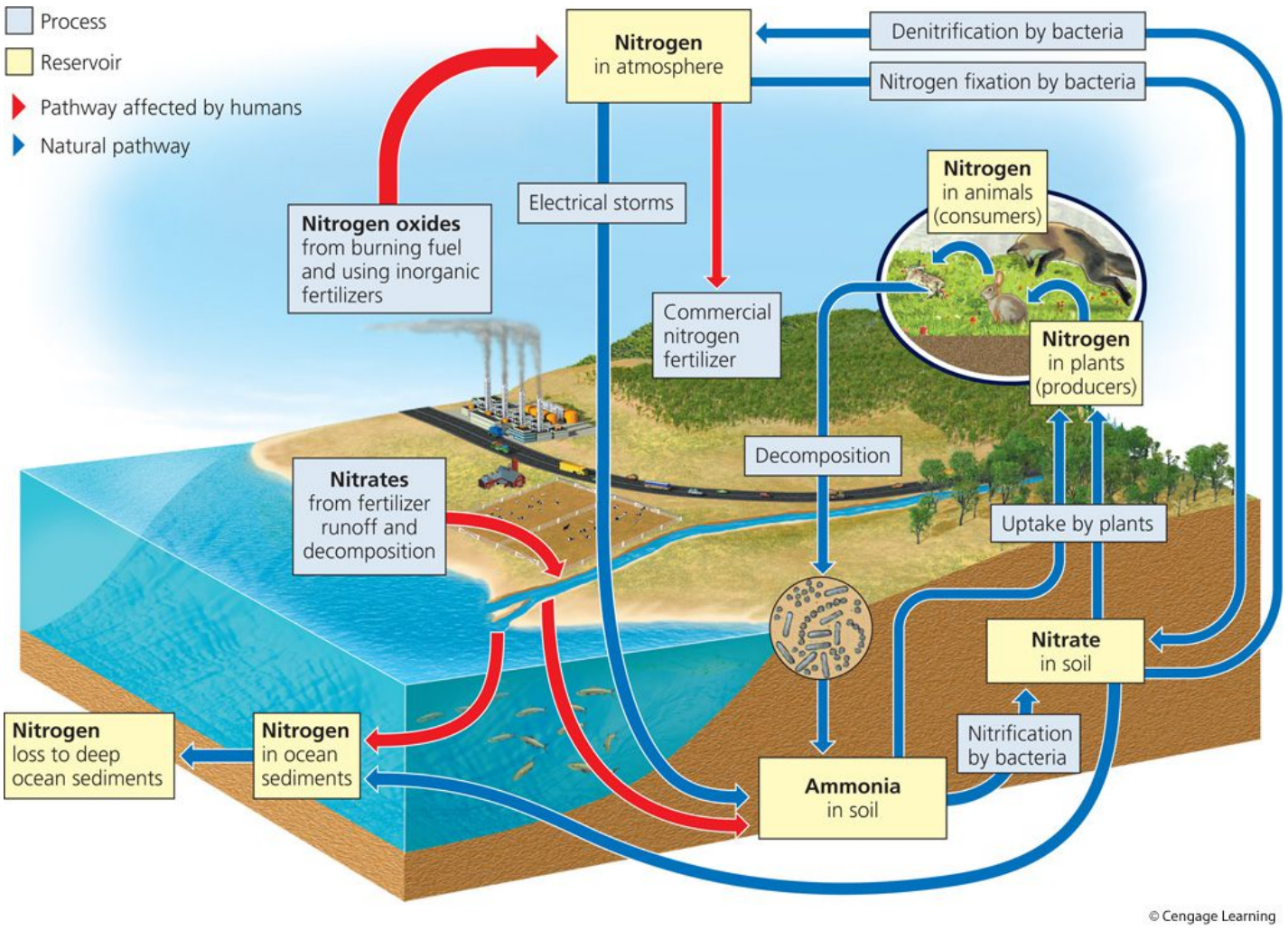
How Do Humans Alter the Carbon Cycle?

- By extracting and burning fossil fuels at a much higher rate than they are naturally formed
  - This adds carbon dioxide to the atmosphere
- By clear cutting forests faster than they re-grow
  - This destroys carbon-absorbing vegetation

The Nitrogen Cycle: Bacteria in Action

- How does nitrogen cycle through the biosphere?
  - Atmospheric nitrogen cannot be absorbed or used directly by most organisms
  - Bacteria convert the nitrogen into a usable form so it becomes a useful plant nutrient
  - Consumers (herbivores) and decomposers convert the nitrogen back into nitrogen gas which is then released into the atmosphere

Natural Capital: The Nitrogen Cycle



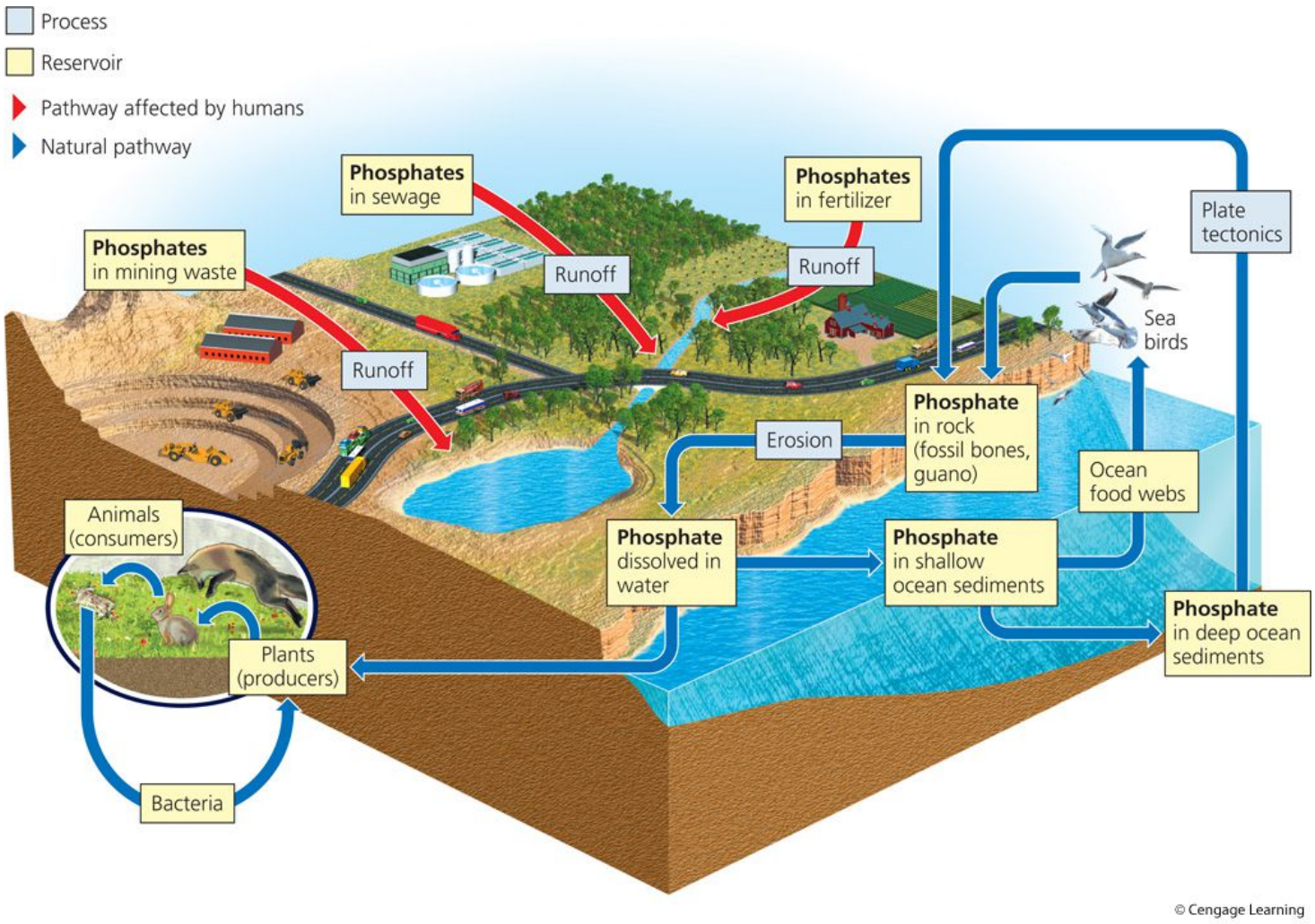
How Do Humans Alter the Nitrogen Cycle?

- By burning fossil fuels that adds nitric oxide to the atmosphere
  - Nitrogen dioxide gas/nitric acid vapor causes acid rain
- By removing atmospheric nitrogen to make fertilizer
  - Agricultural runoff from fields into the water supply leads to algal overgrowth that disrupts the oxygen balance in aquatic systems

The Phosphorus Cycle

- How does phosphorus cycle through the biosphere?
  - Cycles through soils, rocks, water and plants, but not through the atmosphere
  - Can be temporarily removed from natural cycling when washed into oceans and trapped in marine sediments
  - As with nitrogen, contributes to agricultural runoff

Natural Capital: The Phosphorus Cycle



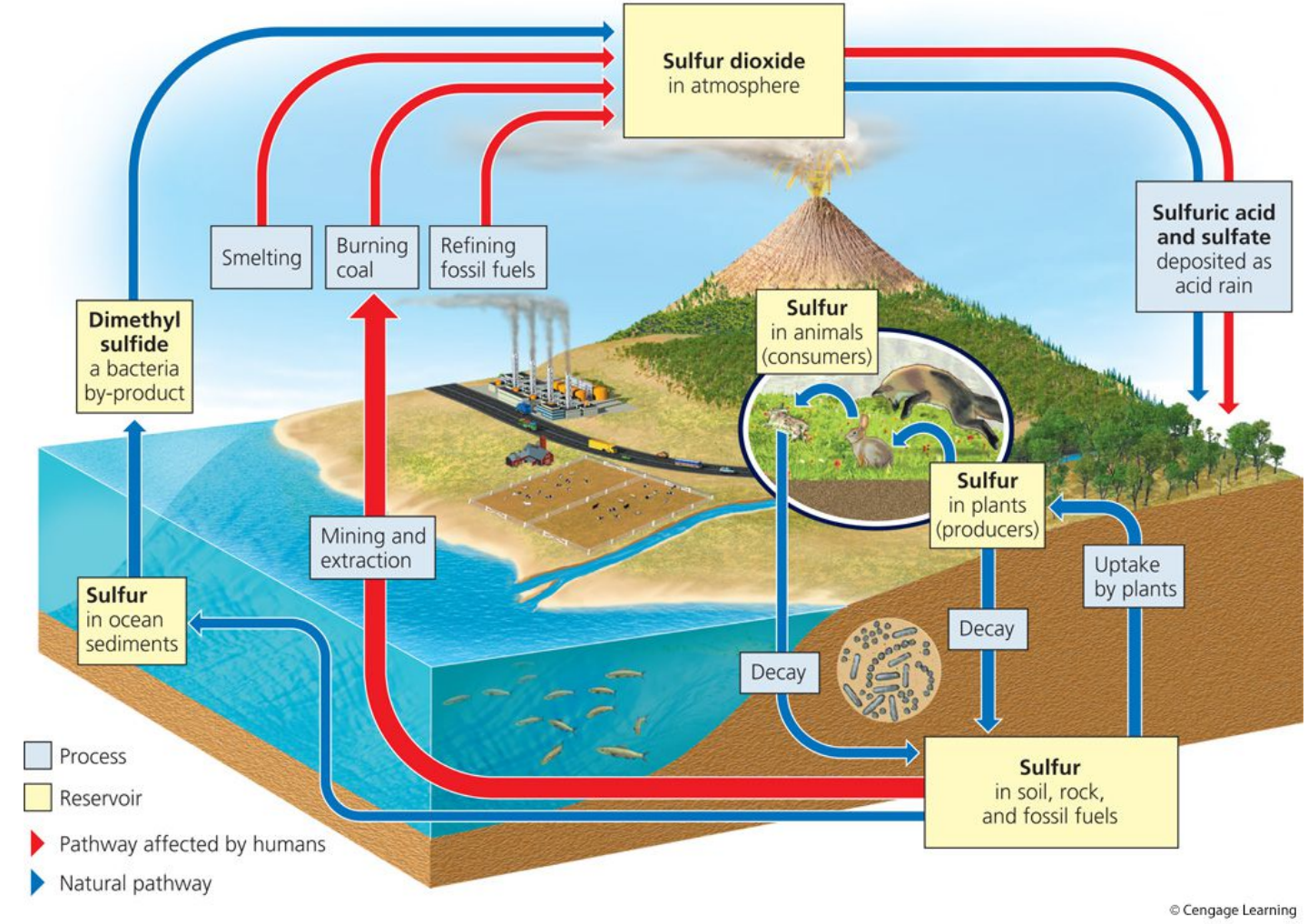
How Do Humans Alter the Phosphorus Cycle?

- By mining phosphorus deposits to make fertilizer
- Through clearing of tropical forests, which reduces phosphorus in the topsoil
- Through agricultural runoff and topsoil erosion, which disturbs biogeochemical cycling

The Sulfur Cycle

- How does sulfur cycle through the biosphere?
  - Via mining of ore deposits/ocean sediments
  - From active volcanoes – as poisonous hydrogen sulfide and sulfur dioxide gases
  - Through decomposition of organic matter in wetlands
  - From sea spray, dust storms, and forest fires
  - Absorption by plant roots

Natural Capital: The Sulfur Cycle



How Do Humans Alter the Sulfur Cycle?

- By releasing sulfur dioxide into the atmosphere
  - Burning sulfur containing coal and oil in power plants to generate electricity
  - Refining sulfur containing oil to make gasoline
  - Mining and smelting metals from sulfur deposits
- The key components of acid rain are nitrogen dioxide and sulfuric acid

3.5 How Do Scientists Study Ecosystems?

- Scientists learn about ecosystems by:
  - Using field and laboratory research
  - Designing controlled experiments
  - Developing mathematical and statistical models

Some Scientists Study Nature Directly

- Make direct observations and take measurements of ecosystems in the field
- Fly over ecosystems to photograph them
- Carry out controlled experiments
- Use radio transmitters and remote sensing to track organisms
- Run mathematical models for issues that cannot be studied in the lab or field

Some Ecologists Use Laboratory Experiments or Modeling

- How do scientists model ecosystems in the lab?
  - With culture tubes, aquariums, greenhouses, and in indoor/outdoor chambers with controlled variables (light, temperature, etc.)
- Pros: small, controlled lab experiments save money and are faster to carry out
- Con: these experiments may not reflect reality well enough

We Need To Learn More About the Health of the World's Ecosystems

- The 2005 ecosystem assessment shows that more baseline ecologic data is needed to:
  - Evaluate the status of the world's ecosystems
  - Develop effective strategies for preventing and slowing ecosystem degradation
  - Identify planetary boundaries that lead to irreversible changes if passed – and help us to avoid reaching or passing them

Additional Case Study: Ecosystems – An Overview

- Ecosystems – watch the video and learn how scientists study ecosystems to understand them and predict how they change over time
  - Choose an ecosystem from the video and describe its components and structure
  - How did the scientists study the ecosystem you chose?

Ecosystems and Three Big Ideas

- Life is sustained by the flow of energy and nutrients through ecosystems which are continually recycled
- Ecosystems are characterized by producers, consumers, and decomposers – All aid in the cycling process
- Human activities impact ecosystem cycling, sometimes negatively, sometimes positively (e.g., Yellowstone)