5 THE FLOW OF ENERGY IN BIOLOGICAL SYSTEMS

Why Does It Matter?

PowerPoint® Lecture prepared by Gary A. Beluzo

STUDENT LEARNING OUTCOMES

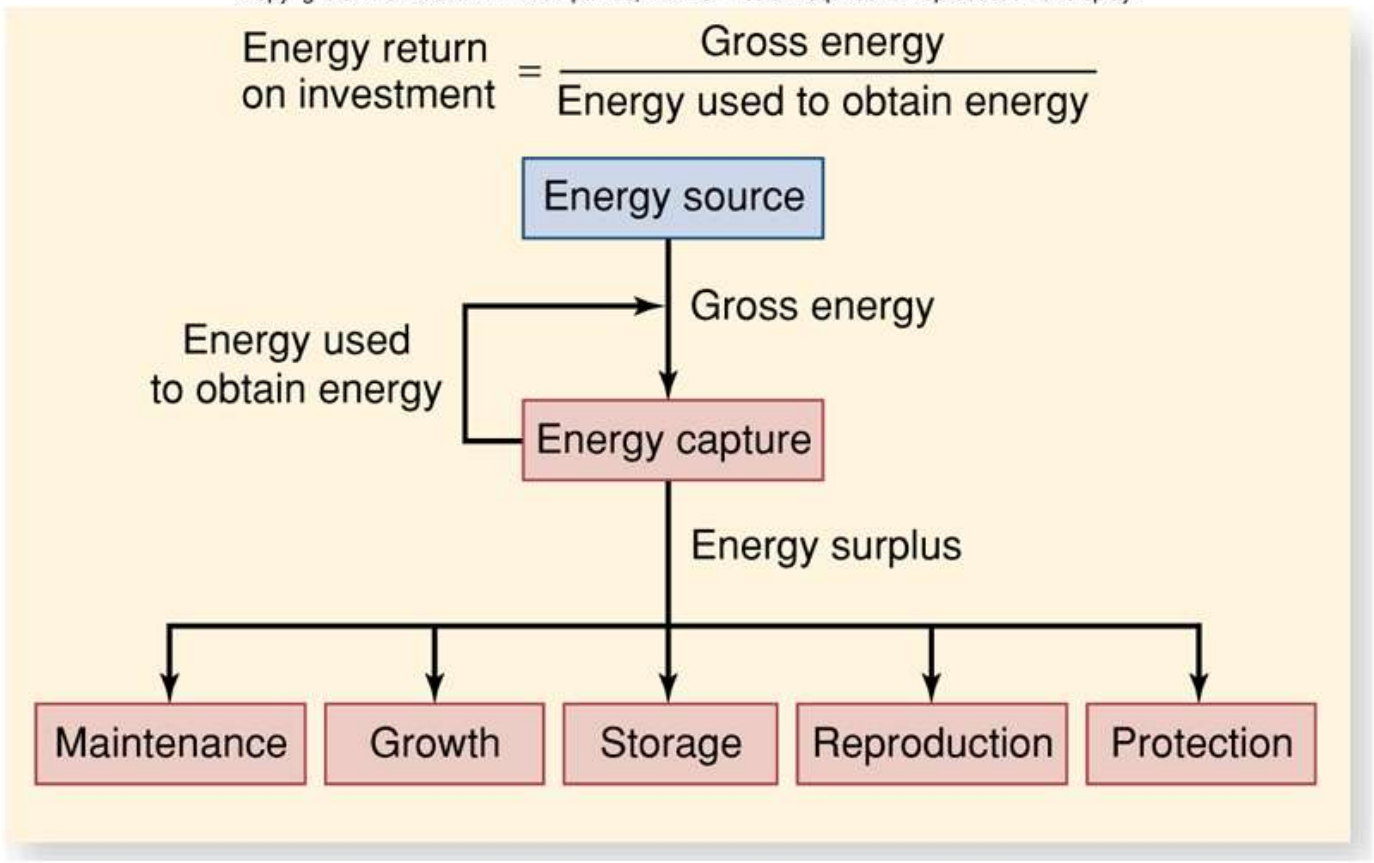
After reading this chapter, students will be able to

- Explain how evolutionary strategies can be described in relation to the allocation of energy among six uses.
- Compare and contrast the costs and benefits of endothermy versus ectothermy.
- Compare and contrast the alternative strategies for the timing and the quantity of energy allocated towards reproduction.
- Explain what determines the total biomass of organisms living in a given area and the number of trophic positions present.
- Explain why the concentration of toxic materials in living organisms is many times greater than the concentration of those materials in the physical environment.

Smart, Fast Dinosaurs?

- The three ***Jurassic Park*** movies portray dinosaurs as quick and clever
- How did dinosaurs use energy?
- Many scientists now think dinosaurs used energy rapidly, even at rest.
- May have been more like present-day mammals than present-day reptiles.
- Much indirect evidence from fossil records, e.g. the ratio of herbivores to carnivores.
- Energy flows play critical role in biological systems

How Living Organisms Use Energy



Photosynthesis

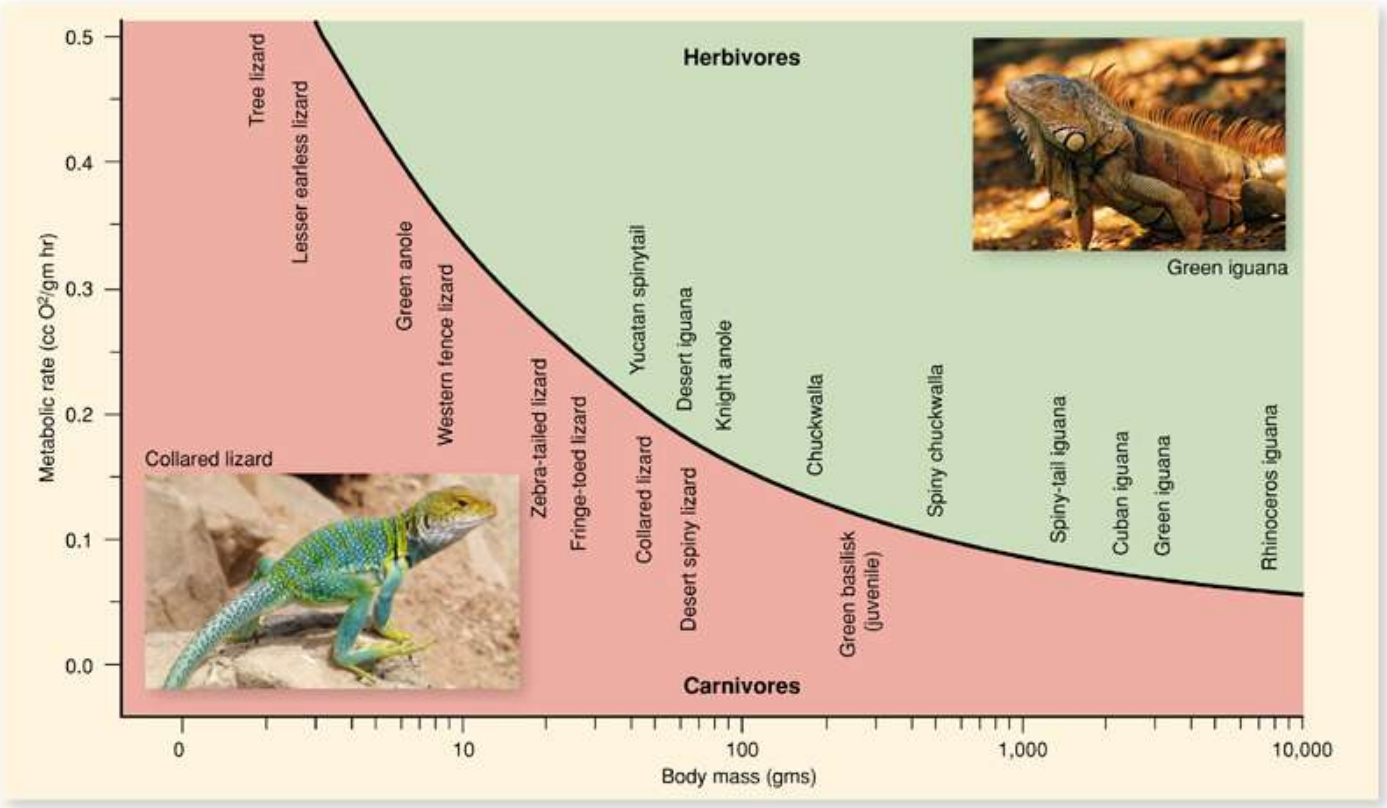
- Autotrophs convert inorganic forms of energy to organic forms of energy

$$6\,CO_2 + 6\,H_2O \xrightarrow{\text{solar energy}} C_6H_{12}O_6 + 6\,O_2$$

carbon dioxide water glucose oxygen

- There is conservation of matter and energy is associated with the chemical bonds in the glucose molecule (food).
- Photosynthesis is only **1.0% efficient**.

Heterotrophy Efficiency



© (left): Courtesy Donald Blanchard, Colorado Herpetological Society; (right): © Creatas/PunchStock

Ectothermy versus Endothermy

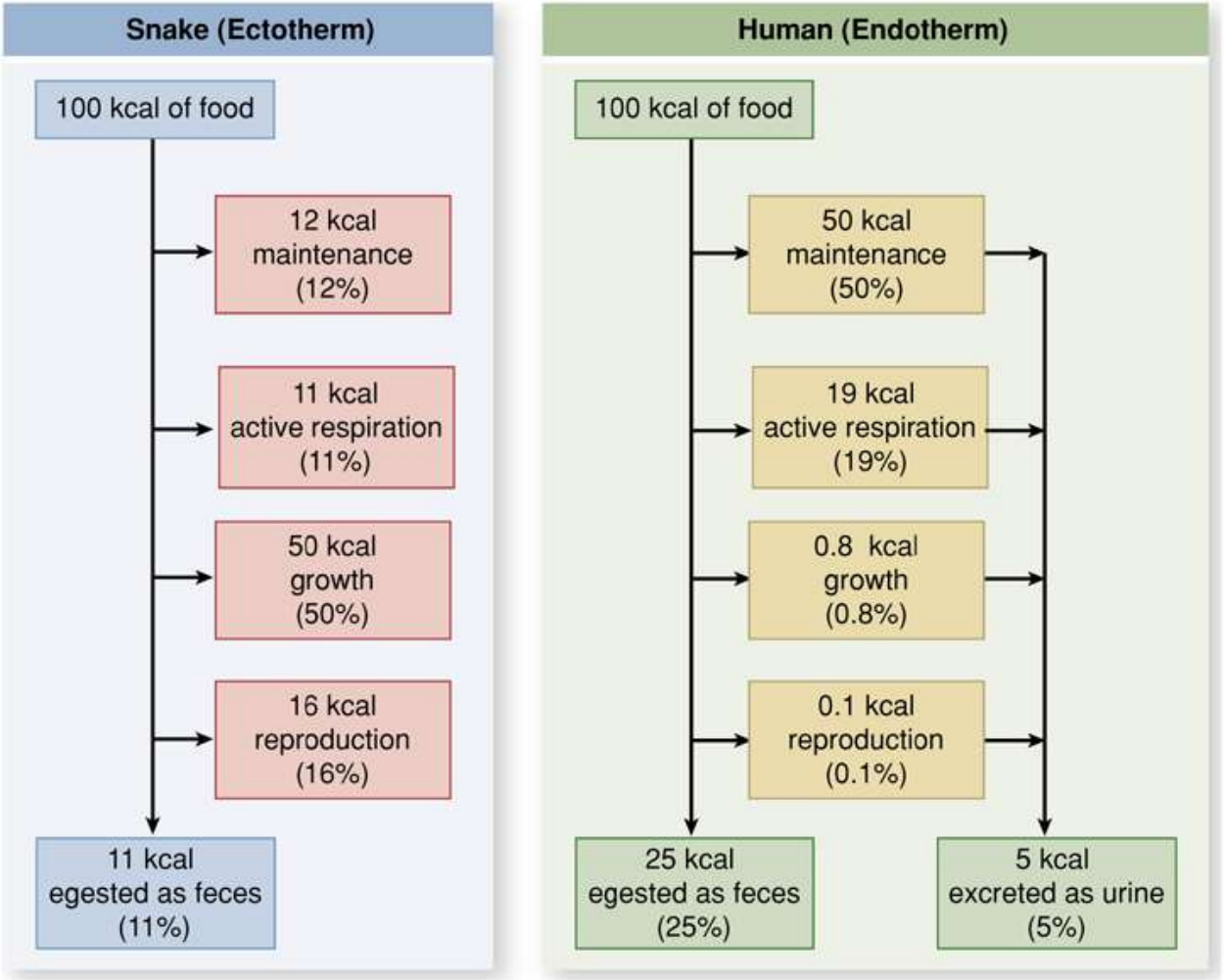
Ectothermy

- Low basal metabolism
- Small fraction of energy budget for maintenance respiration
- Use energy slowly
- Gain heat from the environment
- Active only small periods
- Long dormancy periods possible

Endothermy

- Basal metabolic rate 10x
- Large fraction of energy budget for maintenance respiration
- Use energy quickly
- Waste heat used to heat body
- Can be active anytime
- More speed and endurance while moving

Energy Allocation Strategies



Growth

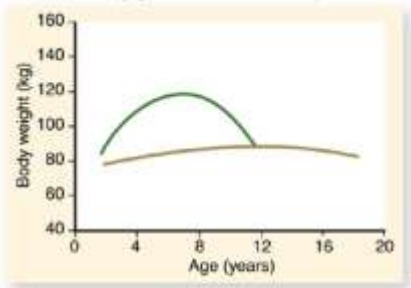
- Maturation
- Metamorphosis (take advantage of temporary foods)
  - Complete
  - incomplete

Storage

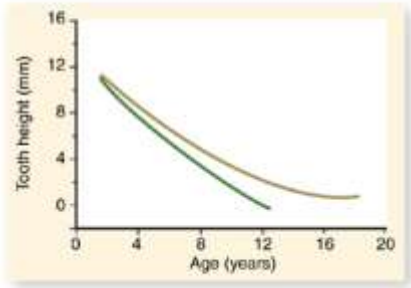
- Energy storage for periods when food less available
- Hibernation (metabolic rate may drop 99%)
- Aestivation (summertime- drought conditions)
- Plants store excess energy as starch in roots
- Animals store energy as fat; plants store excess energy in carbohydrates

Reproduction

- Allocating energy to produce and care for offspring
- Reproduction requires energy resources
- **Senescence** (planned obsolescence)



(a)



(b)

Male red deer
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Female red deer
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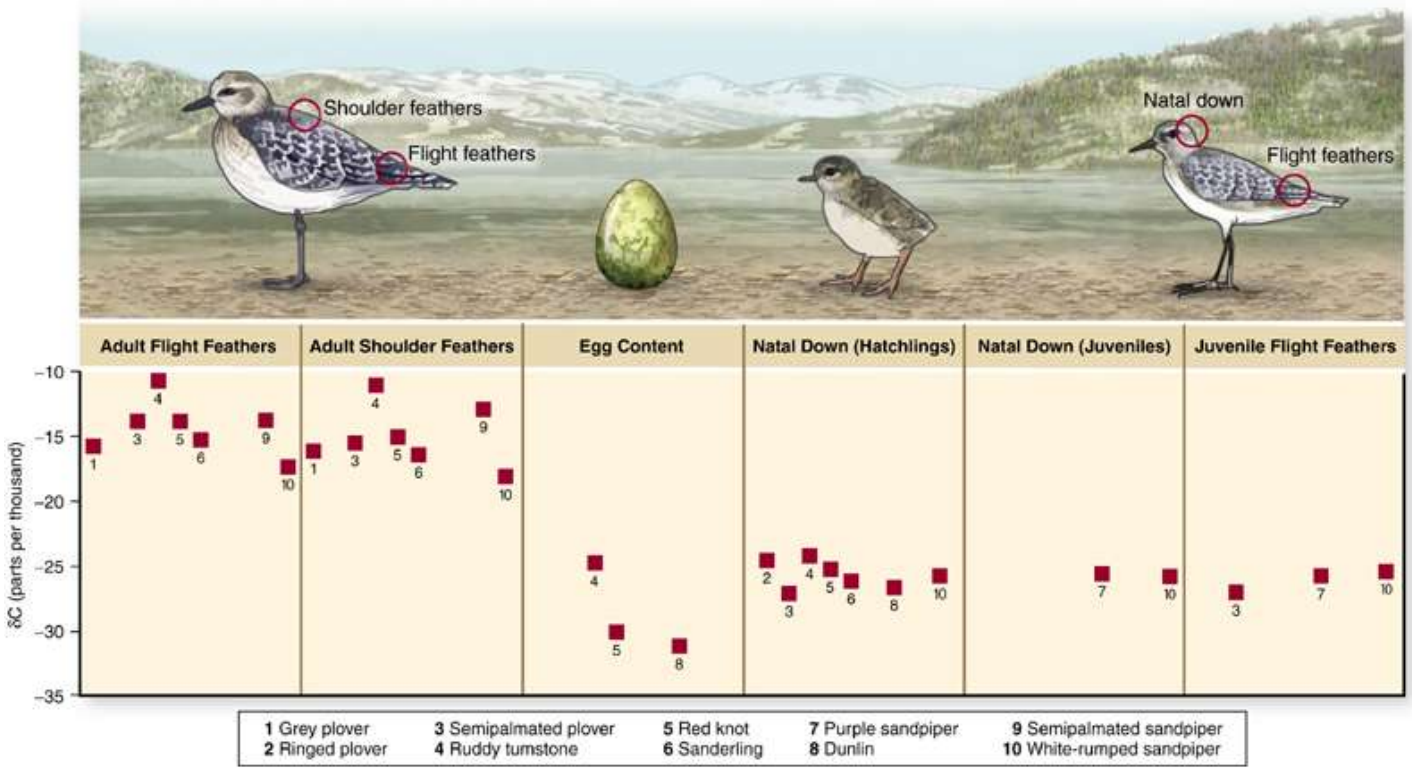
Energy Investment in Reproduction



Reproductive Strategies

R- selected

- Large fraction of energy for eggs
- Relatively early in life cycle
- Produce many small off spring
- Little or no parental care

K- selected

- Large number of predators
- Small fraction of energy used for eggs
- Relatively late in life cycle
- Produce few large offspring
- Parental care

Protection

Animals

- Sharp teeth
- Horns
- Claws
- Speed to escape
- Camouflage
- Mimicry

Plants

- Protective chemicals

© U.S.Fish and Wildlife Service

Respiration (Organic vs. Inorganic)

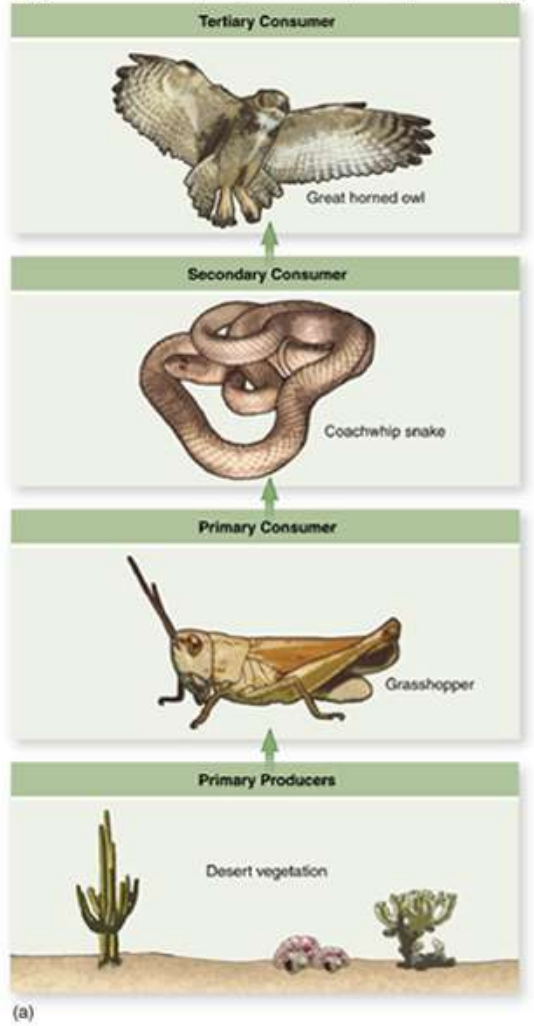
$$C_6H_{12}O_6 \longrightarrow 2C_3H_6O_3 + \text{Energy}$$

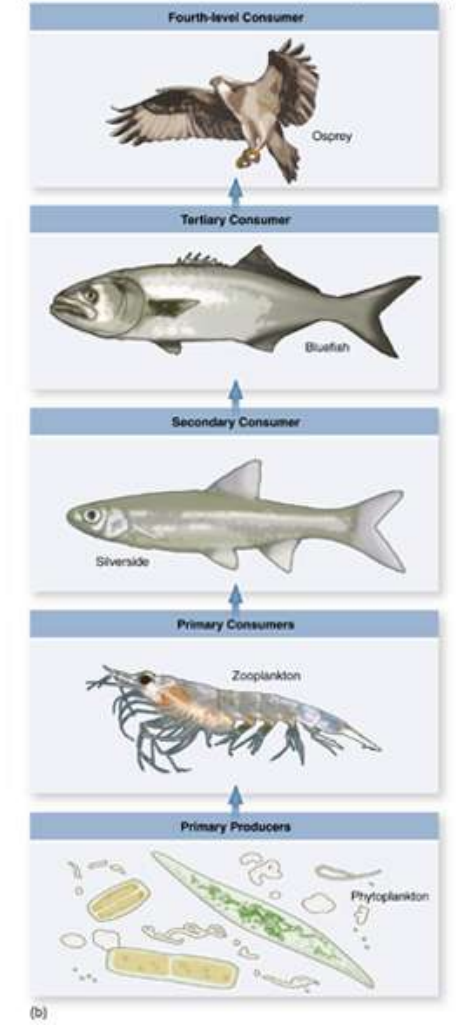
glucose — lactate — 47 units

$$C_6H_{12}O_6 + 6O_2 \longrightarrow 6\,CO_2 + 6\,H_2O + \text{Energy}$$

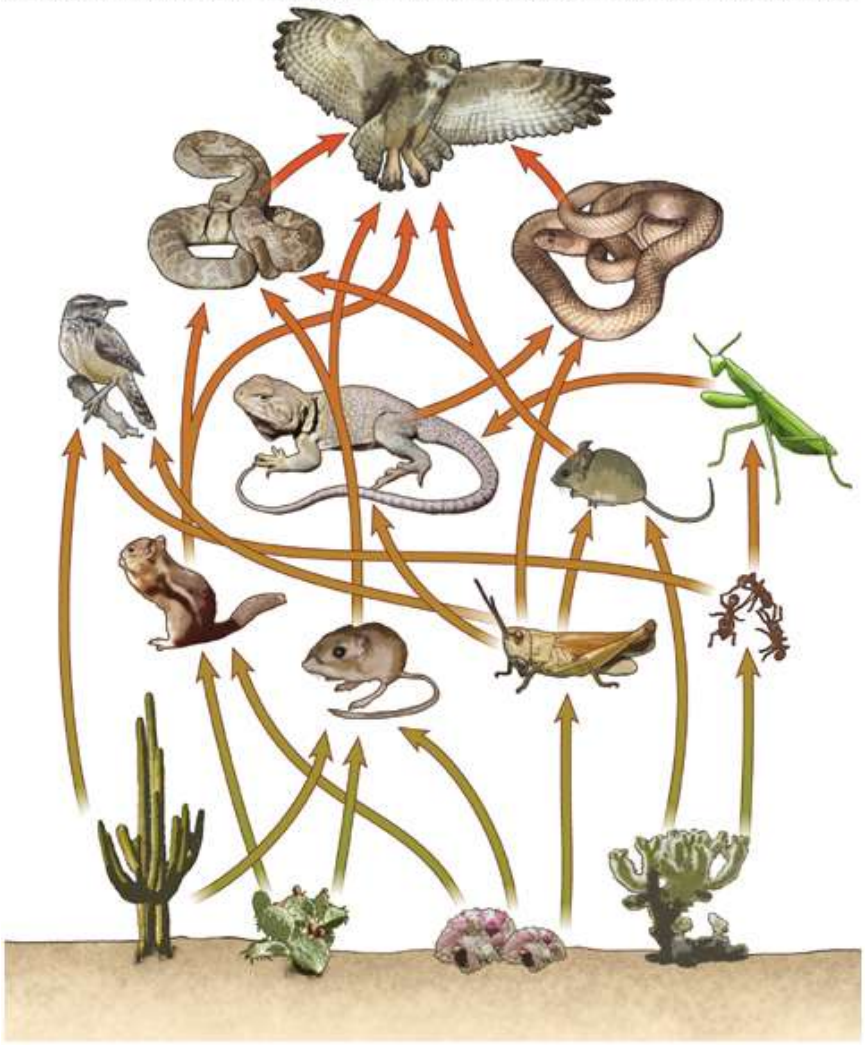
glucose — oxygen — carbon dioxide — water — 686 units

Food Chains





Food Web

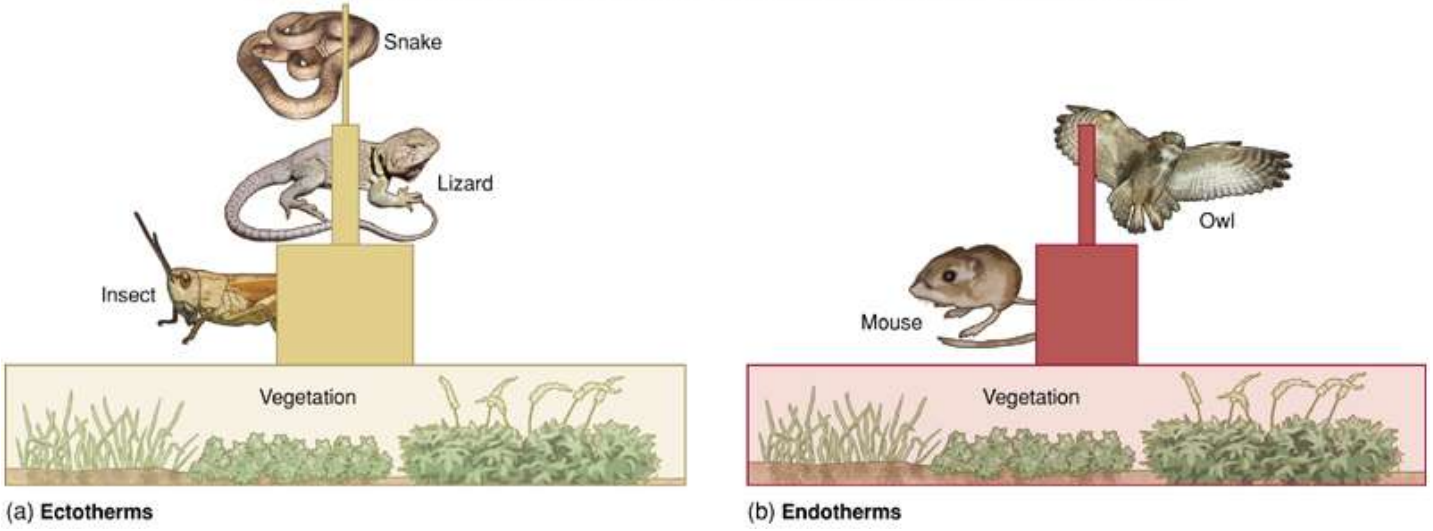


Ecological Efficiency

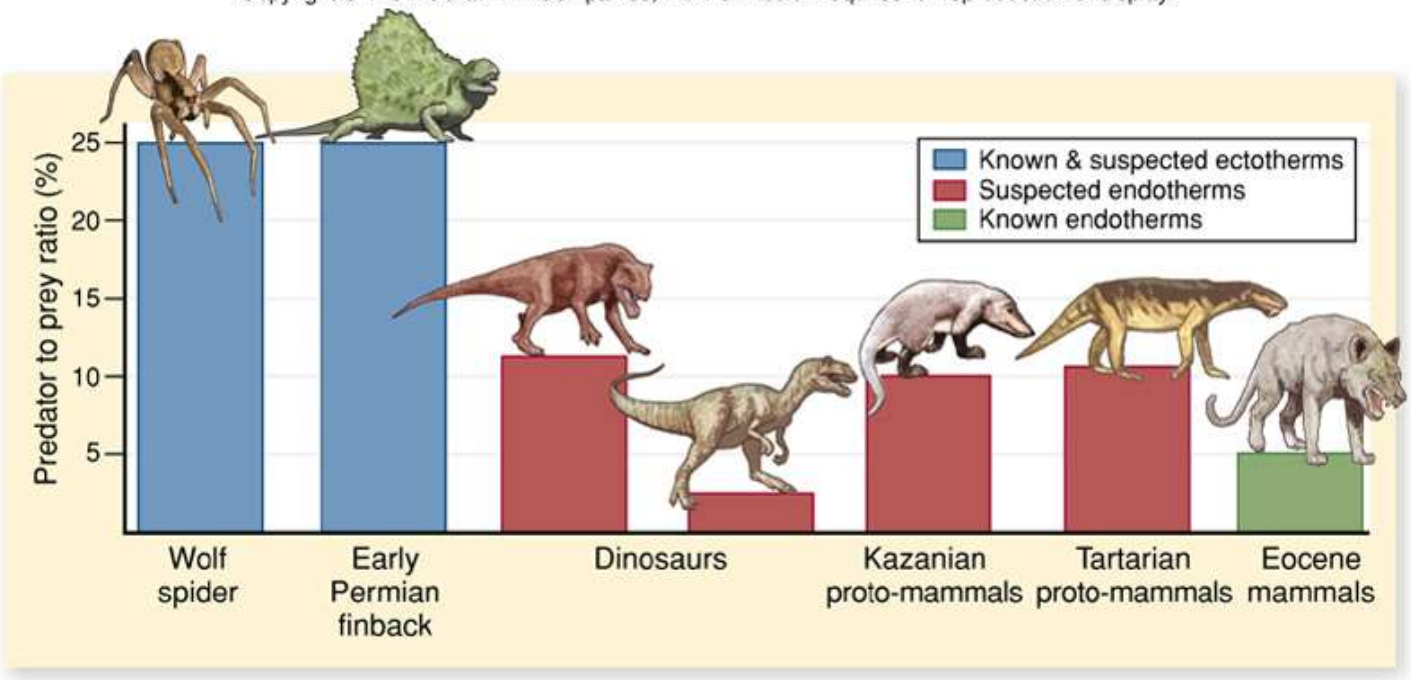
- Shape and length of food chain determined by **NPP** and **Ecological Efficiency**.
- The percentage of energy from one trophic level that is incorporated into the next.
- Generally ranges from **1-10%**
- Secondary Productivity
- Energy Pyramid

Energy Pyramid for Endotherms vs. Ecotherms

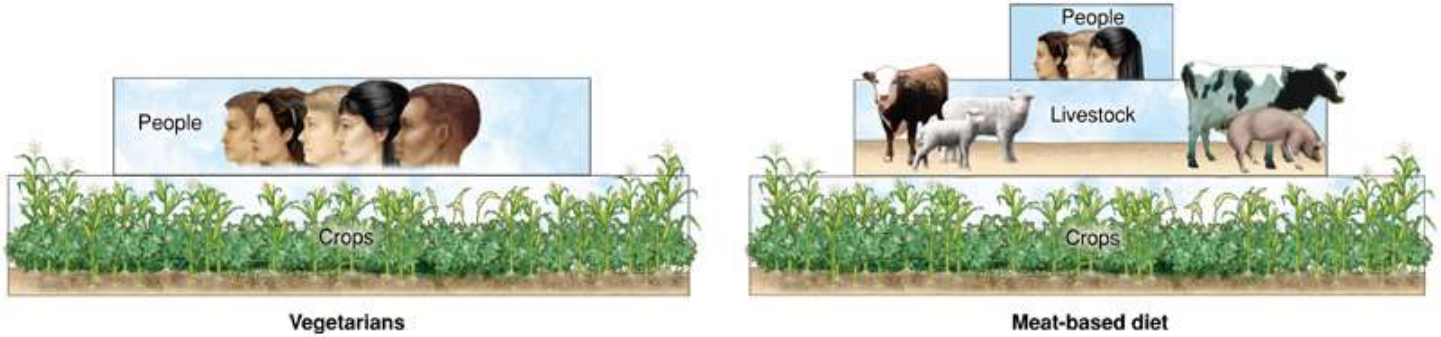
- The rate at which pyramid narrows depends on secondary productivity
- Endotherms narrow more rapidly than Ectotherms



How Did Dinosaurs use Energy?



Vegetarianism?



Biomagnification

- Pesticide or toxin increases in concentration at higher trophic levels
- Amplified by flow of energy between trophic levels
- Organism eats food (lower trophic level) that has concentrated the toxin over its lifetime