Ectotherms and Endotherms

Animal Physiology: BIOS 6130

In the process of creating energy for an animal, heat is generated.

Why and How????

Second Law of Thermodynamics

The entropy of a system plus its surroundings increases over time as the energy content degrades to unusable heat.

Entropy is the quantitative measure of disorder in a system.
75% of the total potential energy derived from breaking covalent bonds in molecules is ultimately lost as heat.

Two categories describe how animals use heat in their bodies

- Ectotherms: depend on external heat for their body temperatures
- Endotherms: use internal heat to regulate body temperatures

Energy input and output

The internal body temperatures of both ectotherms and endotherms depend simply on the difference between heat input and heat output.
Endotherms and ectotherms are influenced by heat exchanges within their environments.

Heat gain versus heat loss will ultimately decide and determine the core body temperature.

Two types of ectotherms

**Poikilothermy ectotherms:**
Live in thermally variable environments and their body temperatures vary as well. Metabolic rates in these animals decrease in the cold to save energy and speed up in warmer environments.

**Ectothermic Regulators:**
Some ectotherms that depend on external heat for their body temperatures cannot cope with any significant change in temperature changes. These animals have to regulate heat exchange from the environment.
Strategies to regulate heat in ectotherms

- Gain external heat to avoid loss of heat to cold environments.
- Generate internal heat by using locomotory muscles more.
- Dilate blood vessels in skin to increase heat loss.
- Behavioral strategies to avoid extreme conditions.

Some ectotherms can metabolically compensate for changes in body temperatures

- Homeoviscous membrane adaptation
- pH regulation
- Enzyme concentration changes
- Isoform regulation
How do ectotherms survive extreme cold?

- dormancy
- freeze avoidance or freeze tolerance

Details of Freeze Tolerance

1) When water freezes on the peeper frog's outer skin, a signal is sent to the liver to trigger a massive breakdown of glycogen in the liver.
2) As a result, a flood of glucose molecules enter the circulatory system raising blood sugar over 450 fold above normal.
3) The increase of blood sugar acts as an antifreeze by lowering the freezing point due to simple colligative properties.
4) Glucose molecules are transported into cells and act as a cryoprotectant to help keep the cells in osmotic balance with the increasing osmotic pressure in the ECF caused by ice crystals.
5) When the animal finally thaws, it has lots of glucose to generate lots of ATP.

Mechanism of Freeze Avoidance

- 1) Animals use different compatible cryoprotectants, such as sorbitol and glycerol in both the ECF and the ICF. As a result, the ECF is protected from freezing.
- 2) Special antifreeze proteins can be made that contain hydrophilic amino acids and sugar side chains that bind to growing ice crystals and prevent their growth.
- 3) Supercooling. This is a state of water in which the temperature is well below the freezing point, but there is no trigger or nucleation site to begin ice formation. No ice forms.
How do ectotherms deal with extreme heat?

Heat shock proteins:

Small, thermostable, hydrophobic proteins that bind to larger, unfolded proteins and assist their folding into functional conformations.

Characteristics of Endothermy

- There is a large metabolic cost to maintain a constant internal temperature so endotherms need to consume 5-20 times more food than ectotherms of the same mass.
- Because of the extra energy endotherms have to bring in, they also have to remove excessive heat more effectively than ectotherms.
- Endothermic animals rely on high levels of aerobic metabolism for sustainable heat production. In animals that contain locomotory muscles, it is aerobic locomotory muscles that provide extra heat.
- To maintain a stable core temperature, heat gain must balance heat loss.
Mechanisms used by endotherms to maintain a stable core temperature

- Gaining external heat/avoiding loss to cold environments
- Retaining Internal heat
- Generating more internal heat
- Losing Excess heat/avoiding gains from hot environments

Gaining external heat/avoiding loss to cold environments

- Ectothermic behavior
- Anatomic features to help absorb solar radiation

Retaining Internal Heat

a) Vasoconstriction in the blood vessels to the skin to reduce heat loss.

b) Anatomic insulation

c) Behavioral insulation

d) Larger body size in colder climates will generate more heat than smaller bodies.

e) Countercurrent exchangers: Blood flow can be used to retain core heat using a countercurrent exchanger. Typically found between the core body and exposed peripheral organs that could lose heat rapidly
Rete Mirabile

The exchanger consists of a set of veins and arteries placed closely together in a dense array known as a rete mirabile.
How does a rete work?

- Warm core blood moves out the arteries toward the cold peripheral tissue.
- In the rete, it encounters cold blood returning from that periphery.
- By conduction, the heat moves into the cold vein and is warmed before returning to the core.
- As a result, the venous blood leaving the rete is nearly as warm as the blood coming from the core.
- Little core heat is lost.

Generating more internal heat

Endotherms generate more internal heat than ectotherms due to:

- Increased consumption of oxygen
- The Na/K ATPase pump uses ATP 3-6 times faster than the ATPase pump in ectotherms
- Muscle activity generates the most heat in endotherms

Losing Excess heat/ avoiding gains from hot environments

- Reduced insulation.
- Vasodilation. When blood vessels to the skin are dilated, more heat will be released to the environment.
- Enhanced evaporation.
- Countercurrent exchangers can also be used to loss heat.
- Avoidance behavior to stay out of areas too hot
- Anatomic reduction of heat gain.
What coordinates all the behaviors and physiological responses to heat or cold?

Characteristics of hypothalamus as a thermoregulator

- The hypothalamus integrates a multitude of thermosensory inputs from both the core and the surface of the body.
- Works in a negative feedback manner.
- Acts as the primary thermostat for the body.
- It gets input from central and peripheral thermoreceptors that are located throughout an animal.

Function of Hypothalamus in Thermoregulation

- The hypothalamus receives afferent information about body temperature from various regions of the body and initiates coordinated adjustments in heat gain and heat loss mechanism as necessary to correct any deviations in core temperature from the set point.