lecture 26
thursday 04 dec. 2003

vertebrate physiology
ecol 437
university of arizona
fall 2003

instructor: kevin bonine
t.a.: bret pasch
kevin bonine

full bio:
• married with dog

interests:
• vertebrate physiology
• conservation biology
• lizards
• frisbee
• bad jokes
• treadmills
happy halloween 2003
chapter 17:
energetic costs of meeting environmental challenges
The World's Tallest Thermometer in Baker, CA.
Outline

• Temperature Dependence of Metabolic Rate
• Determinants of Body Heat & Temperature
• Physiological Classification
• Thermal Biology of Ectotherms
• Thermal Biology of Endotherms
• Neuronal Mechanisms of Temperature Control
Temperature Dependence of Metabolic Rate

Increased temperature →
increased rate of chemical reactions →
increased rate of metabolism

$Q_{10}$ effects:

$Q_{10} = \frac{MR_{(t+10)}}{MR_t}$

$Q_{10}$ often = 2 to 3, depends on the two temps used
snake example

*Figure 1-8*  **Body temperature affects virtually everything an ectotherm does.** This example shows that the snake *Natrix maura* can crawl faster and farther as body temperature increases. Its resting metabolic rate increases with temperature, as does its capacity to increase oxygen consumption (aerobic scope). The rate and efficiency of digestion also increase with increasing temperature. *(Source: Hailey and Davies 1988.)*
Thermal Acclimation & Recent History of Individual

(a)

Frogs acclimated to 5°C

Frogs acclimated to 25°C

Effect of acclimation

O₂ consumption (μL · g⁻¹ · h⁻¹)

Measurement temperature (°C)
Membrane Acclimatization

- Temperature
- Lipid Saturation increases with temp. to decrease fluidity
- Cholesterol adds rigidity
Heat Shock Proteins
- molecular chaperones

Marine snails

![Bar chart showing relative increase of HSPs in T. funebralis and T. brunnea](image)

Intertidal adaptations

(17-5)
Determinants of Body Heat & Temperature

body heat = heat produced + (heat gained - heat losted)

H total = Hv + Hc + Hr + He + Hs

Hv = metabolic heat production
Hc = conduction & convection
Hr = radiation
He = evaporation
Hs = heat storage
Hc = conduction & convection

conduction - transfer of heat between objects in contact with one another (e.g. group thermoregulation)

convection - transfer of heat contained in a mass of gas/liquid by movement of that mass (e.g. wind & water)
Hr = solar radiation absorbed by surface of animal

location - shade or sun

posture - exposure changes

color - melanin in melanophores of dermis

Figure 5–8 The effect of posture on the amount of solar energy a lizard intercepts. The diagrams show the area of the shadow cast by a horned lizard (*Phrynosoma cornutum*) in three postures. (a) Not oriented: The ribs are relaxed; the sun is overhead. (b) Positive orientation: The ribs are spread to make the body nearly circular, and the long axis of the body is perpendicular to the sun’s rays. (c) Negative orientation: Ribs are compressed to make the body narrow, and the long axis of the body is parallel to the sun’s rays. (Source: Modified from Heath 1965.)
Hs = heat storage

Large animals (small SA : mass) heat up more slowly

He = evaporation
(or condensation)

Evaporative cooling via panting or sweating

vs.
Specific Heat Conductance

Surface properties determine

-Ectotherms generally with **high** conductance

-Endotherms generally **low** (feathers, fur, blubber) fur and feathers trap **air** (low conductance)
Regulating Heat Transfer

**Behavioral**
- posture, location, migration

**Physiological Adjustments**
- blood flow
- piloerection
- sweating etc.

**Acclimatization**
- fur, fat, metabolic rate, sweating

**Ontogeny**
- pigs in different environments (SA / V)
Physiological Classification
(generalized categories)

Temperature Stability:
- Homeothermy
- Poikilothermy

Source of Heat:
- Endothermy
- Ectothermy

- Heterothermy
  - regional vs. temporal
POIKILOTHERMY
Body temperature fluctuates with environment

Crab, whose body heat derives from and reflects environment

Benthic fish, in thermally stable environment

Hummingbird, showing night-time torpor

ECTOTHERMY
Body heat derived from environment

Kangaroo rat, whose body heat derives from both metabolism and environment

Human, using metabolic heat to maintain constant body temperature

HOMEOTHERMY
Body temperature remains constant

ENDOTHERMY
Body heat derived from metabolism

HETEROThERMY
Thermal Biology of Ectotherms

...in the **COLD**

![Graph showing the thermal biology of different species of Barracuda congeneres.](image)
...Ectotherms in the COLD

Freeze Tolerance

(a) Extracellular compartment

 Formation of ice crystals are stimulated by nucleating agent.

 Solutes excluded from forming ice; solute concentration increases.

 Intracellular compartment

 Formation of ice crystals is prevented.

(b) T < 0°C

 Intracellular organelle

 Osmotic loss of water increases solute concentration, preventing ice crystals from forming.

 T << 0°C

 Eventually, intracellular organelles are destroyed by excessive solute concentration.

 \(-\uparrow [\text{Solute}]\)

 leads to osmosis

 \(-\downarrow \text{freezing point}\)
Ectotherms in the COLD

**Supercooling/Antifreeze**

- **Supercool** by preventing ice crystal formation (supercooled fishes)

- **Lower Freezing Point**
  Glycerol, Glycoproteins
  \(-17^\circ C, -47^\circ C\)!
Thermal Biology of Endotherms

BMR 7-20 X’s greater than ~ sized ectotherm

mammals: 37-38 °C
birds: 40 °C

polar bears > 70 °C
above ambient temperatures!!
Thermal Neutral Zone

...please