Thermal Pathways:

- Heat gain
  - Direct Solar Energy
  - Infrared Radiation
  - Conduction

- Heat loss
  - Convection
  - Evaporation
Physical Laws of Heat Exchange:

1. Conduction rate dependent on substrate
2. Conduction rate varies by area
3. Heat exchange faster with higher gradient
4. Greater distance apart, lower heat exchange
Physiological ecologists study how species are adapted to their environment

-- use metabolic rate to measure energy use, or kcal burned per gram body tissue

-- basal metabolic rate = when animal is at rest

-- use $O_2$ consumption as a proxy for kcal burned,

-- 4.8 kcal burned per liter $O_2$, average for metabolism of fats, carbohydrates, or protein
Young shrews (*Crocidura leucodon*): A. Holding on to their mother and each other in their early explorations; B. Holding on to each other even when lifted; C. Attempting to hold on to a mouse; D. Effect of introducing a white mouse. Photos from *Handbuch der Zoologie*, “Das Verhalten der Insektivoren,” K. Herter.
Counter-current heat exchange

Figure 8.15 (EFB)
Figure 7.16
In terms of physiological adaptations, the most amazing of all mammals is....
The Arctic Ground Squirrel!!

Hibernates from 8-9 months per yr

Can lower $T_B$ to -2.9 °C for up to 2 weeks in Arctic winter

10X energy savings when $T_B$ below 0 °C

Science magazine
Quiz

1. What thermal pathways allow for both heat loss and gain?

2. Graph and explain metabolic rate with ambient temperature in an ectotherm.

3. Why do endotherms reach hyperthermia more quickly than hypothermia?

4. Explain countercurrent heat exchange.

5. Explain Bergmann’s Rule.
Heterotrophs

--can’t covert light energy to chemical energy

--must obtain their energy from autotrophs or other heterotrophs

--can use light energy to obtain heat and save on metabolic heat production

--similar to autotrophs in that they are
  (1) affected by the same limiting factors
  (2) use ATP as primary energy molecule in respiration
  (3) use both anaerobic and aerobic pathways
Two major categories of heterotrophs based on heat exchange with the environment

1. Ectotherms: “outside heat”, also known as poikilotherms

2. Endotherms: “within heat”, also known as homeotherms

These categories are not mutually exclusive! e.g., newly hatched birds, some insects, camel
Physiological Ecology

--study of how physiological mechanisms allow for survival at different $T_A$

--overlap physiological adaptations with behavior and morphology

--use metabolic rate as standard measurement of energy use, or kcal burned per gram body tissue

--basal metabolic rate = when animal is at rest

--kcal hard to measure, use $O_2$ consumption as a proxy, e.g., $O_2$ used per gram per minute

--4.8 kcal per liter $O_2$, average for metabolism of fats, carbohydrates, or protein
In seasonal climates, ectotherms and endotherms have three choices as winter approaches:

1. Stay and cope with the new conditions
2. Leave the area: migration
3. Stay, but go into an inactive state

Hibernation: gradual physiological changes in response to decrease in photoperiod, changing seasons

--involves large drop in $T_B$
--long period of inactivity, no arousal until end
--usually only small mammals are true hibernators
**Torpor: brief period of inactivity**

--not under control of changing photoperiod, but induced by sudden change in temperature, loss of food, etc.

--little physiological preparation

--energy savings can be considerable

e.g., mouse with $T_B = 38 \, ^\circ C$ uses 11.9 ml O$_2$/g/2 hr

lower $T_B$ to 15 $^\circ C$ for 2 hr, uses only 0.7 ml O$_2$/g, plus 5.8 ml to return to 38 $^\circ C$

Total use with torpor is 6.5 ml O$_2$/g/2 hr, or a 45% savings