38th Lecture
Mon 20 April 2009

Vertebrate Physiology
ECOL 437 (MCB/VetSci 437)
Univ. of Arizona, spring 2009

Kevin Bonine & Kevin Oh

Energetics
Thermal Physiology
Ectothermy
Endothermy

Chapters 7-9

Housekeeping, Mon 20 April 2009

<u>Readings</u>

Mon 20 Apr: Ch 7&8 (Metabolism & Energetics)
Wed 22 April: Ch 9 (Thermal Physiology)
LAB: Nutrition & Metabolism Lab (McWilliams et al. 2004)
Fri 24 April: Ch9 (Thermal Physiology)
Mon 27 April: Exam 3
Wed 29 April: Bird Physiology (Dr. Oh, guest)
LAB: Research Proposal Review Panel

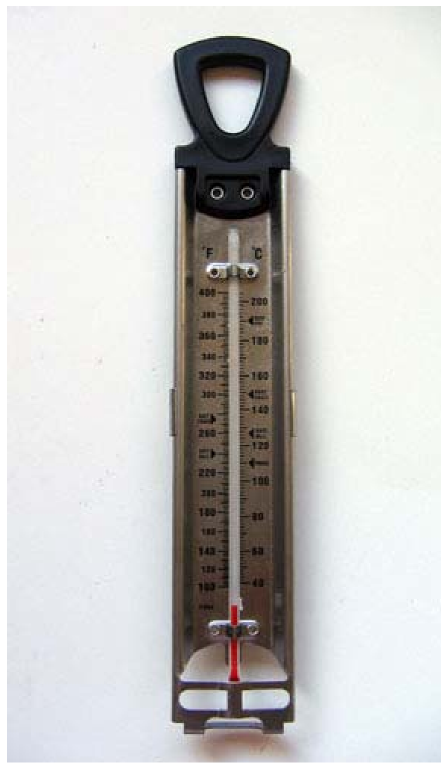
Final research proposal due 10 am Fri 24 April
Third exam: Monday 27 April

Dale Purves, M.D.
Director, Center for Cognitive Neuroscience
George Barth Geller Professor for Research in Neurobiology
Duke University

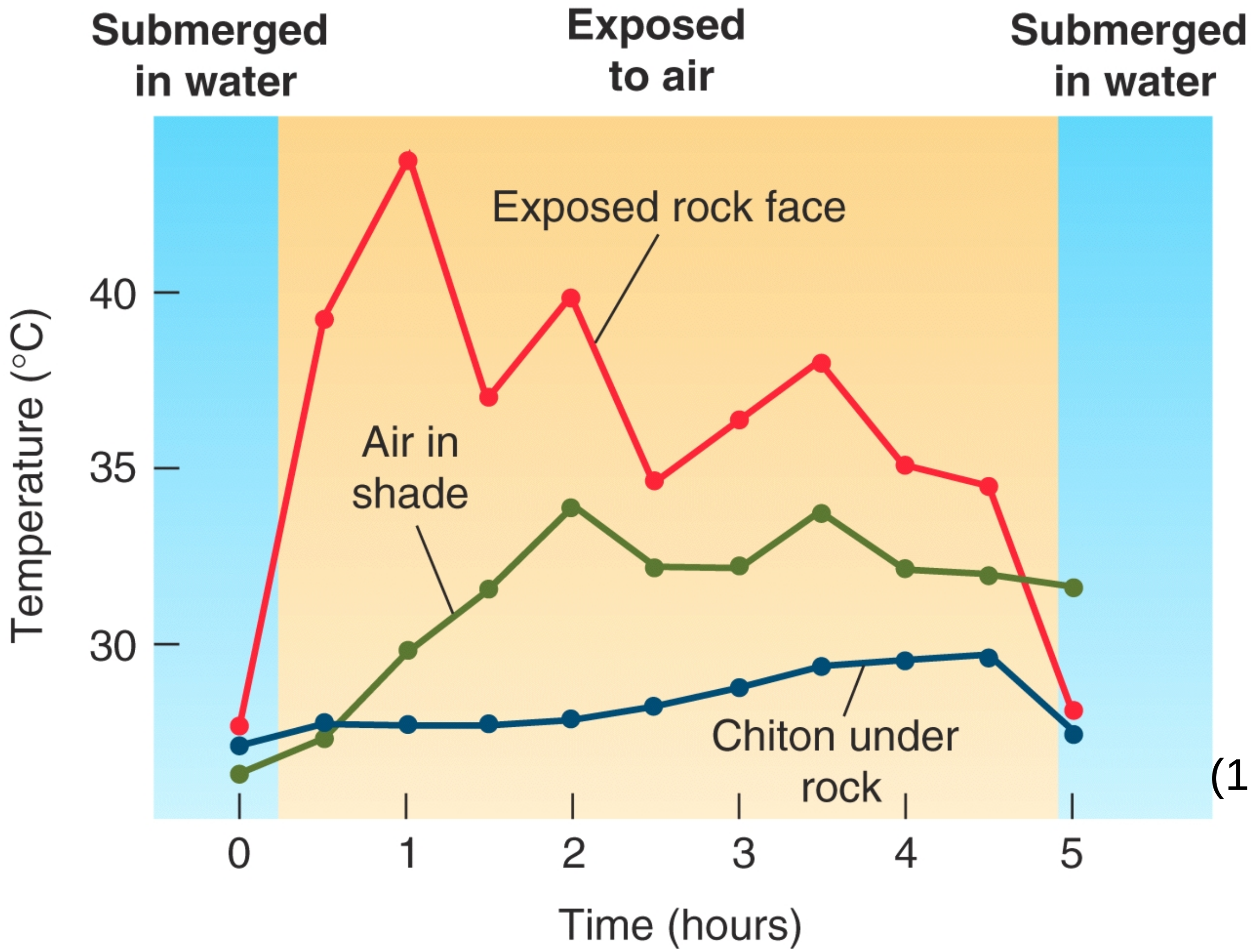
"Why We See What We Do: Exploring Vision in Wholly Empirical Terms"

Tuesday, April 21, 2009
Harvill Room 150 4:00 PM

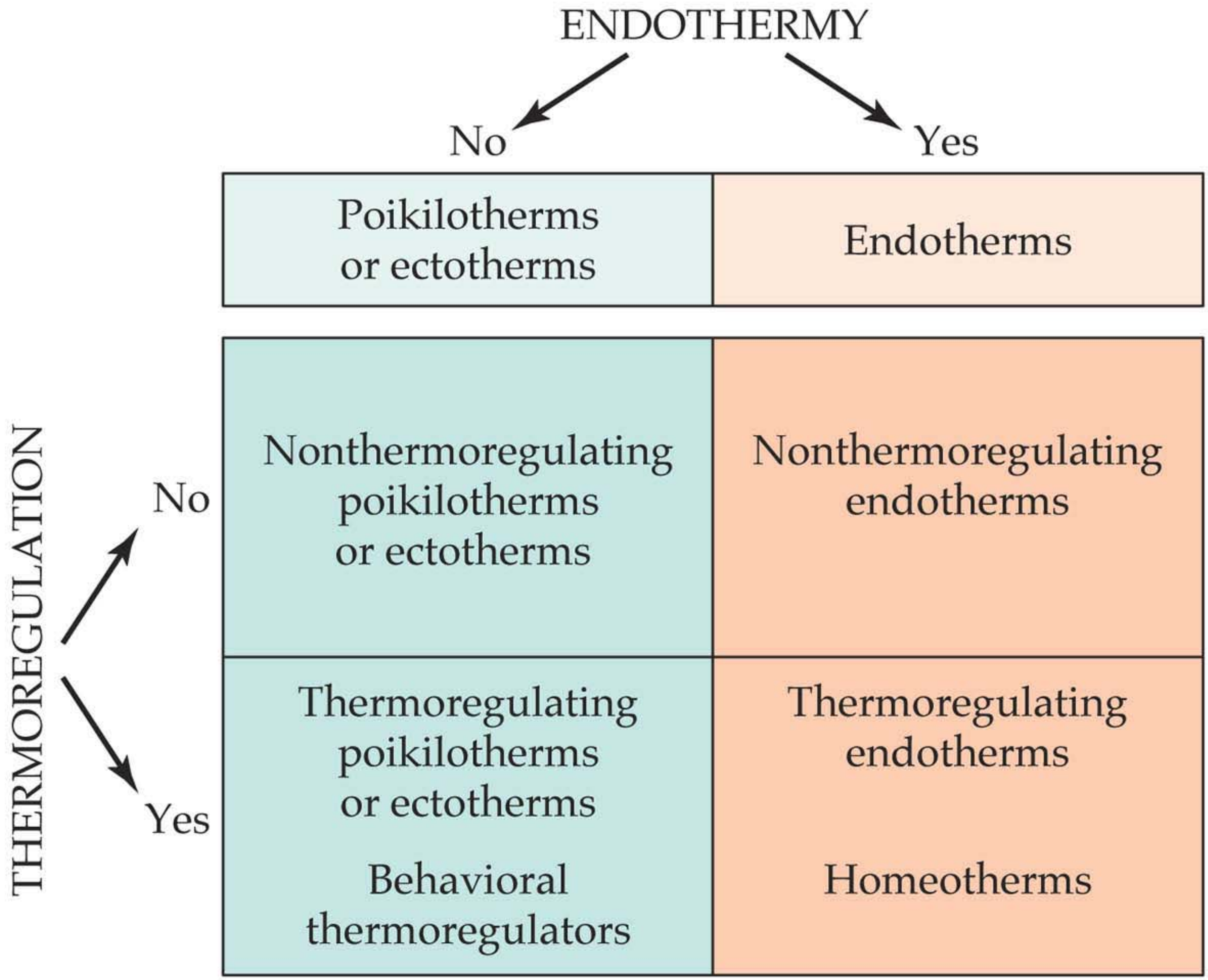
Thermal Physiology



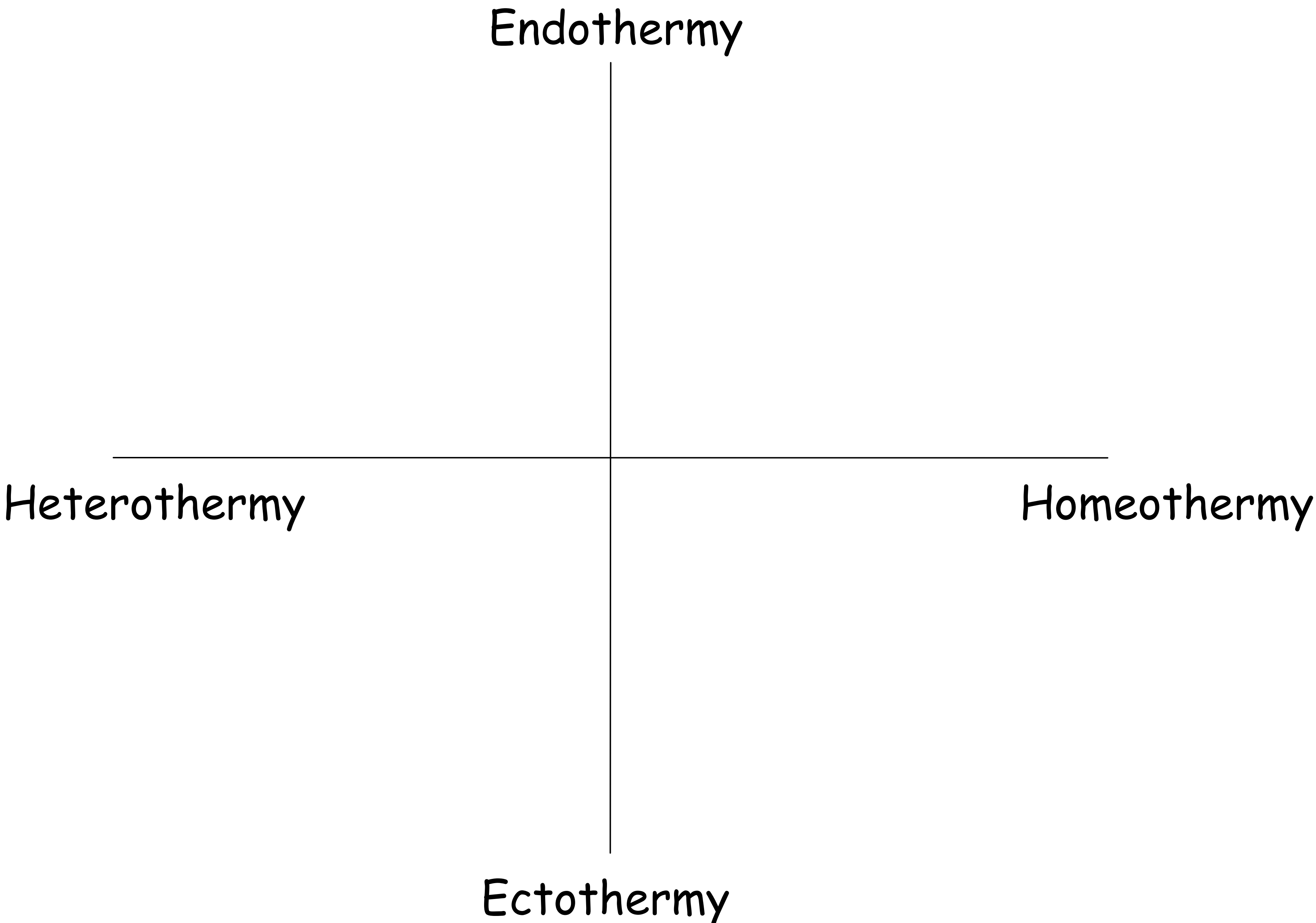
Microhabitat

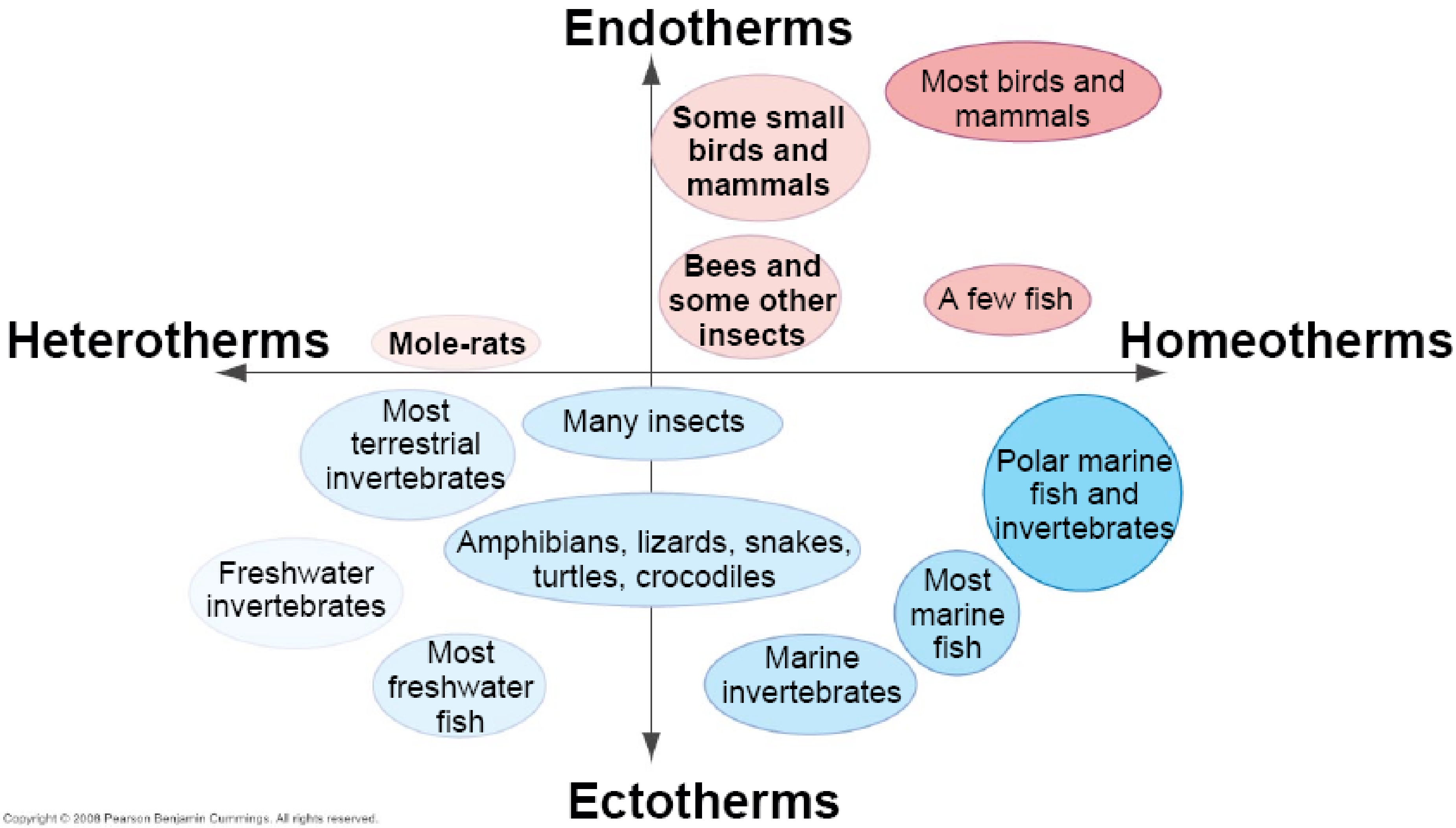


(17-10)



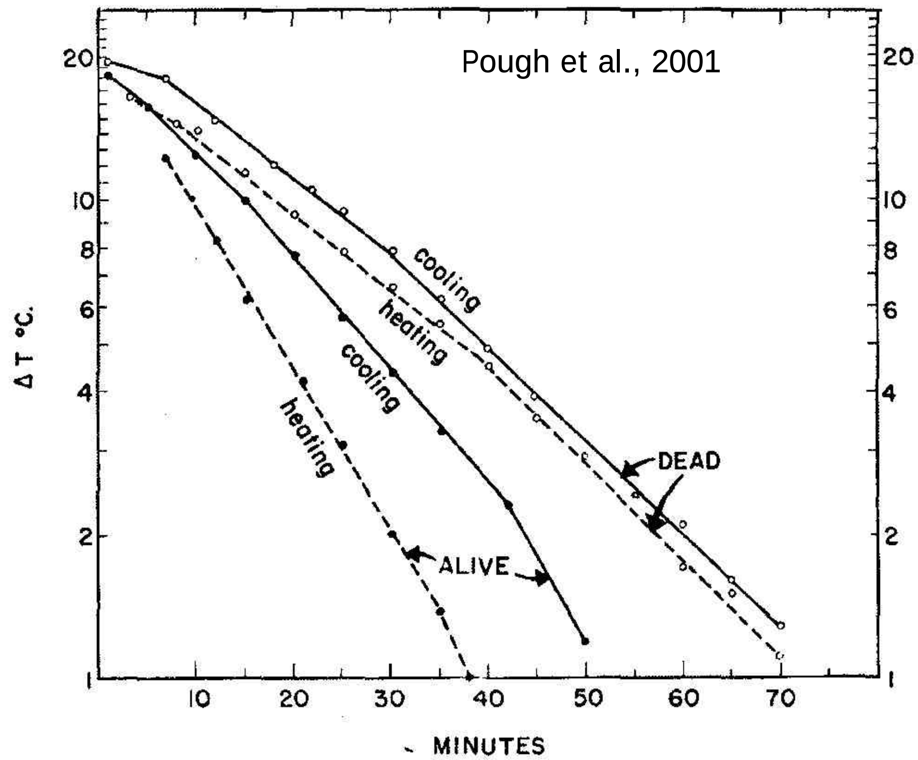
ANIMAL PHYSIOLOGY, Figure 8.1


Endothermy
Heterothermy
Homeothermy
Ectothermy

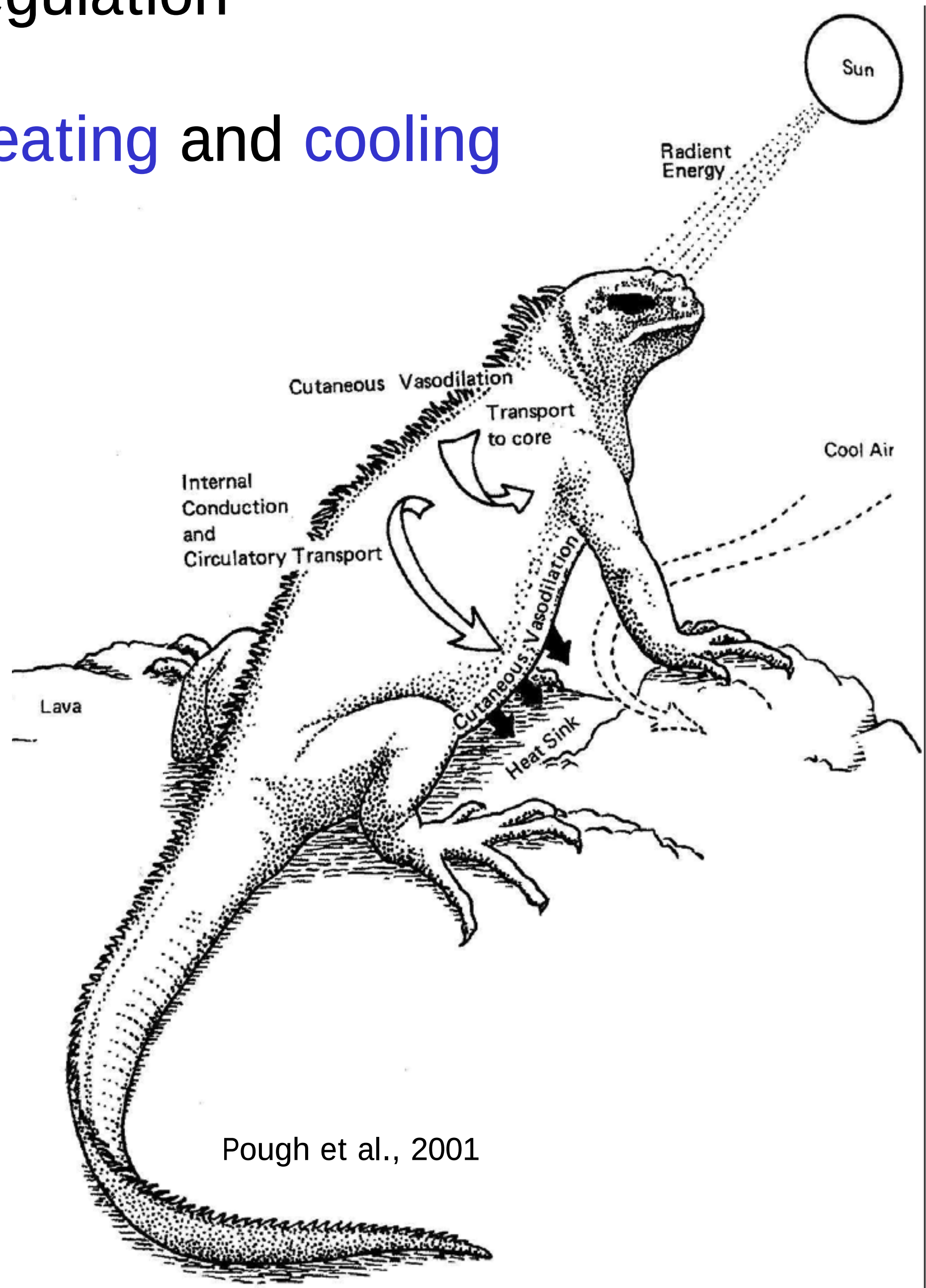

Endotherms
Some small birds and mammals
Most birds and mammals
Bees and some other insects
A few fish
Heterotherms
Mole-rats
Homeotherms
Most terrestrial invertebrates
Many insects
Polar marine fish and invertebrates
Amphibians, lizards, snakes, turtles, crocodiles
Freshwater invertebrates
Most marine fish
Most freshwater fish
Marine invertebrates
Ectotherms

Thermoregulation

Cardiovascular control of heating and cooling



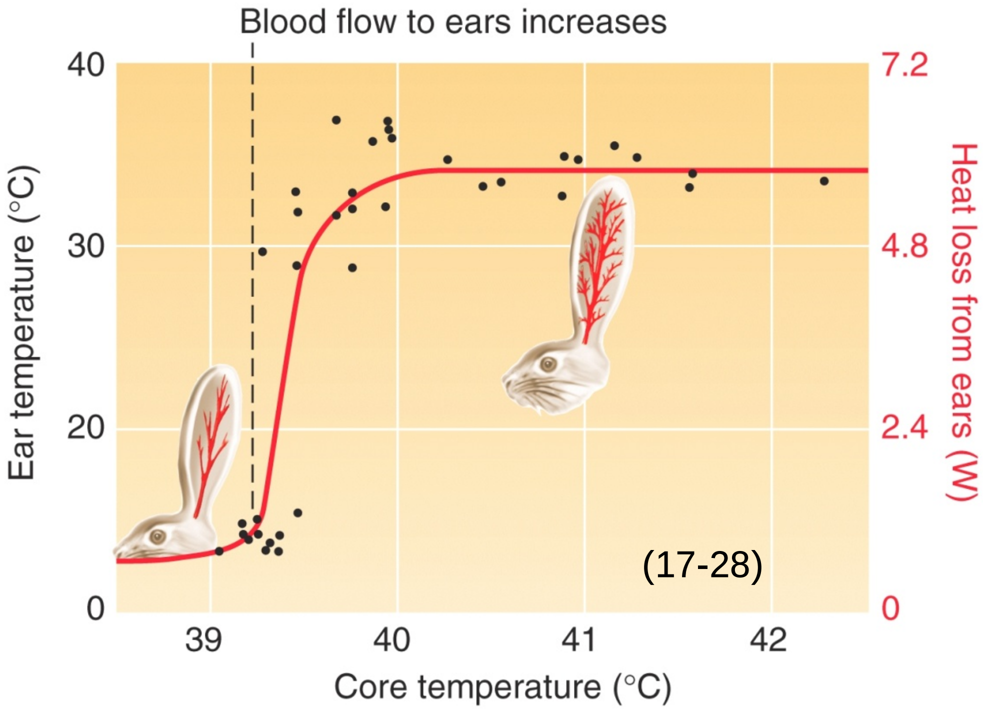
- Cardiac Shunts
- Peripheral Vasodilation



Pough et al., 2001

Heat Windows

Rabbit Ears



Guanaco

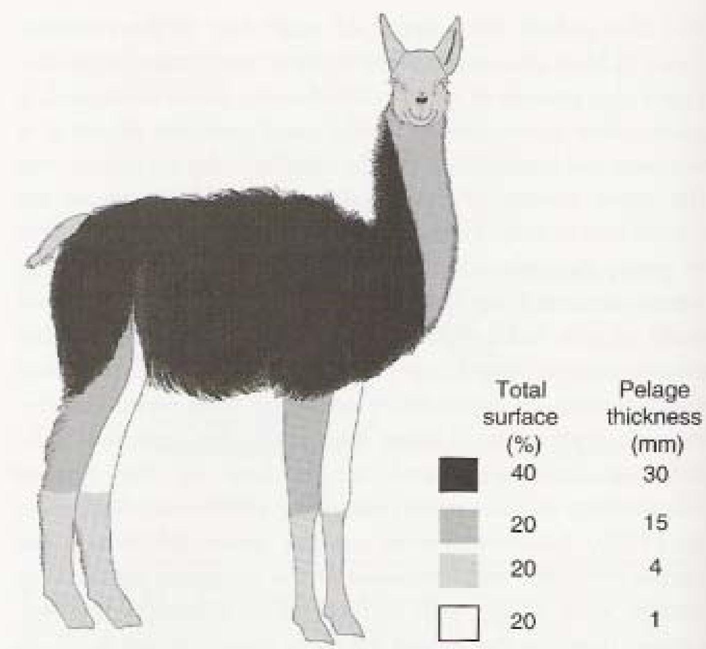
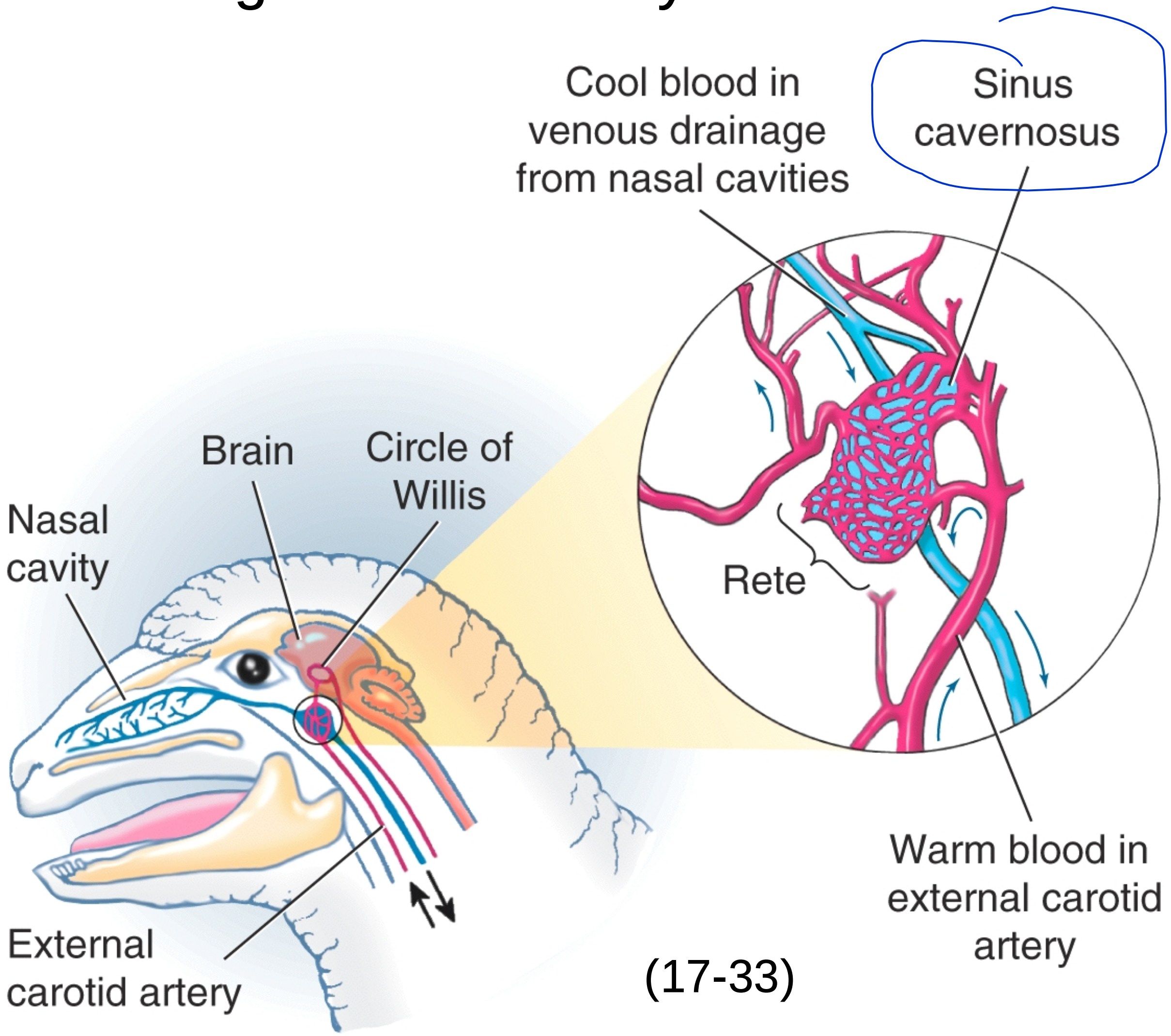


Figure 8.24 Thermal windows. Schematic representation of the distribution of wool of differing thickness in the guanaco, a South American member of the Family Camelidae. The white areas are thermal windows of almost bare skin.

Source: Data from P.R. Morrison, "Insulative Flexibility in Guanaco" in Journal of Mammalogy, *47:18–23, 1966.*

Hot Body, Cool Brain

Keep brain cool during prolonged increased organismal activity:



(17-33)

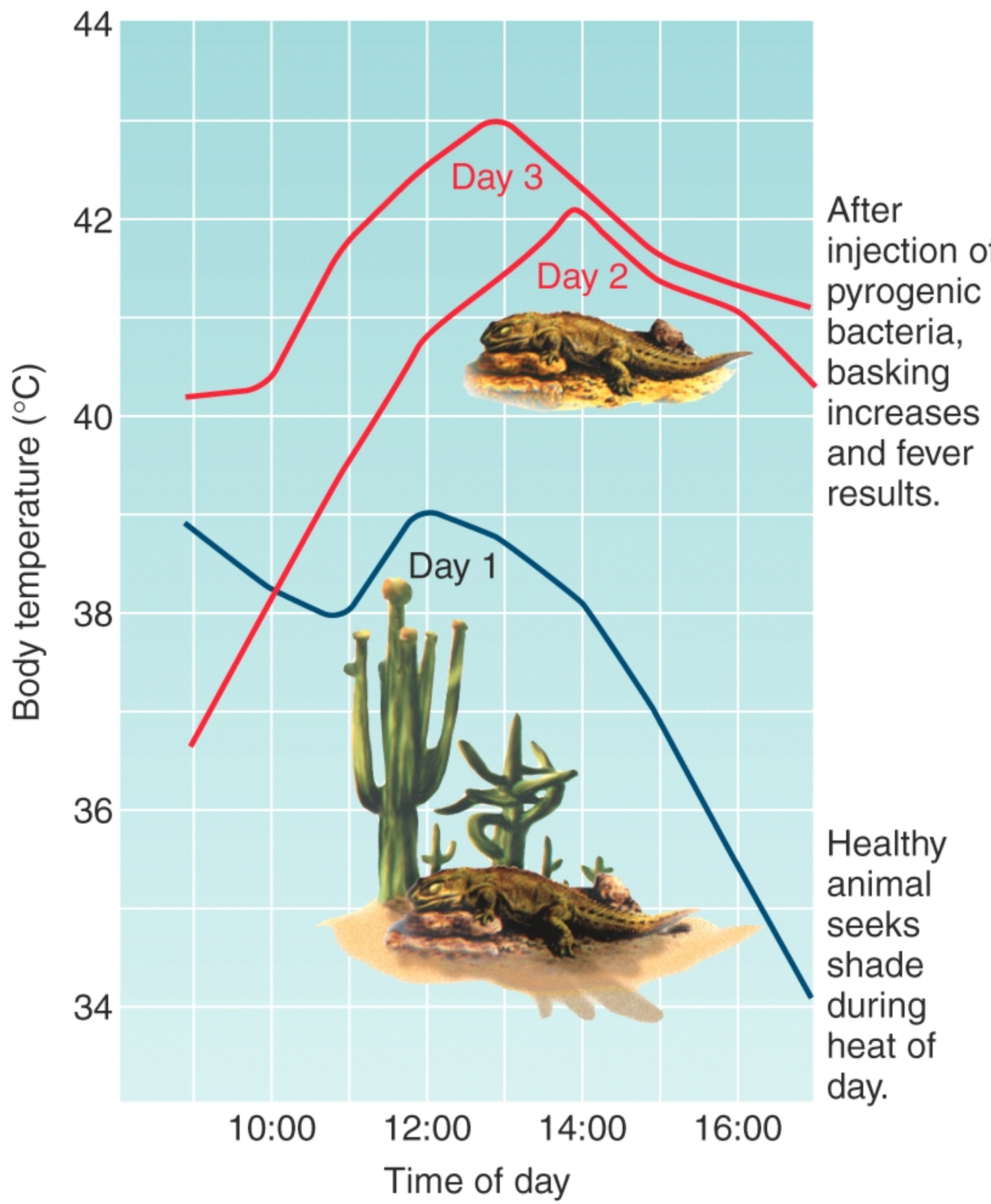
-Countercurrent

-Carotid Rete

Pyrogens

Fever

Dipsosaurus dorsalis



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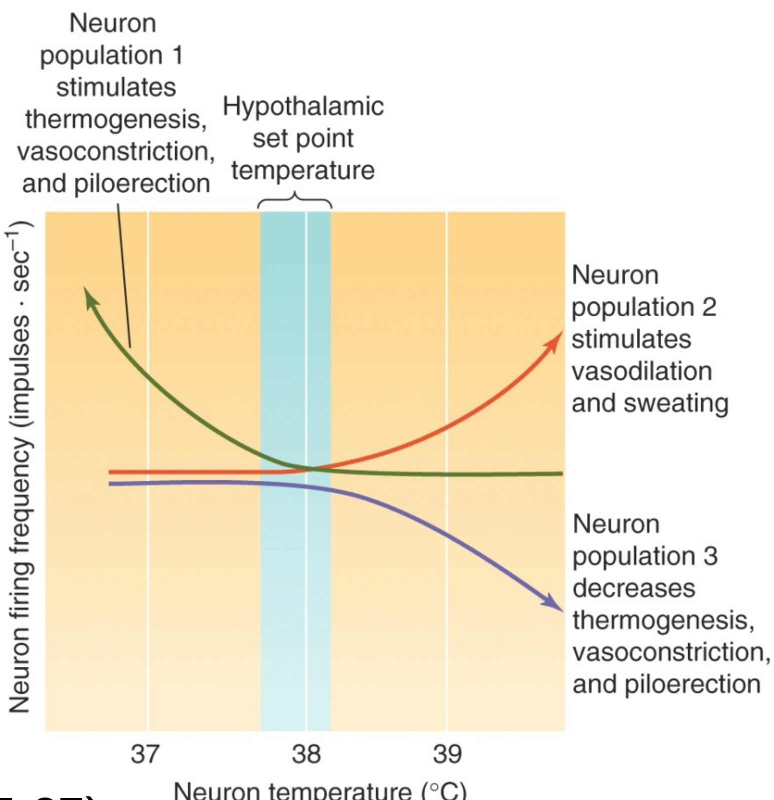
Neuronal Control of Thermoregulation

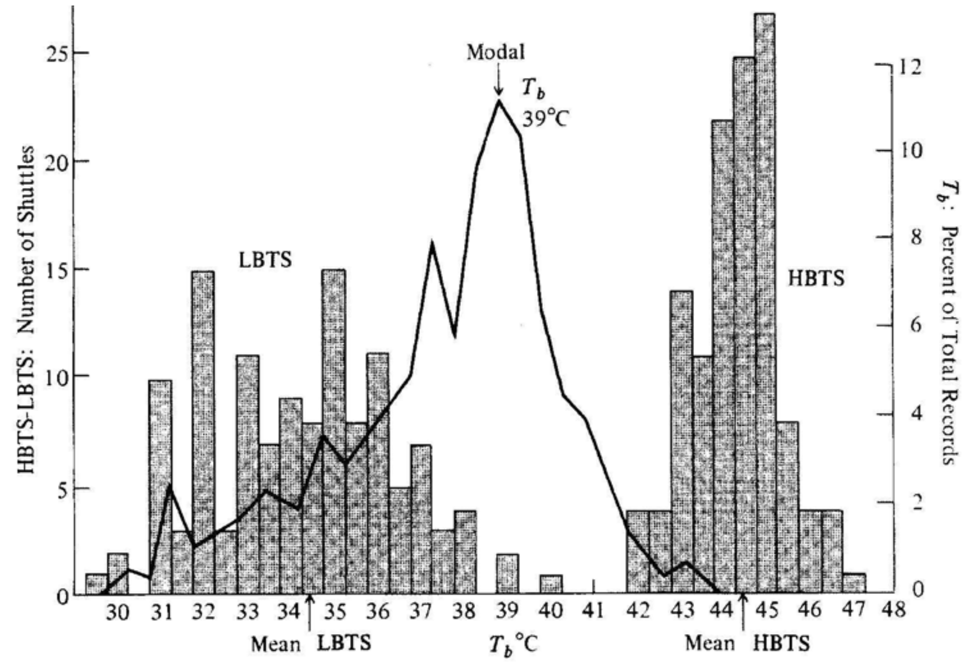
Temperature Set Point

(season, reproductive state, infection)

Hypothalamus functions as thermostat



(17-27)



Pough et al., 2001

Physiology and Behavior

Endotherms in the COLD…

Countercurrent Heat Exchange

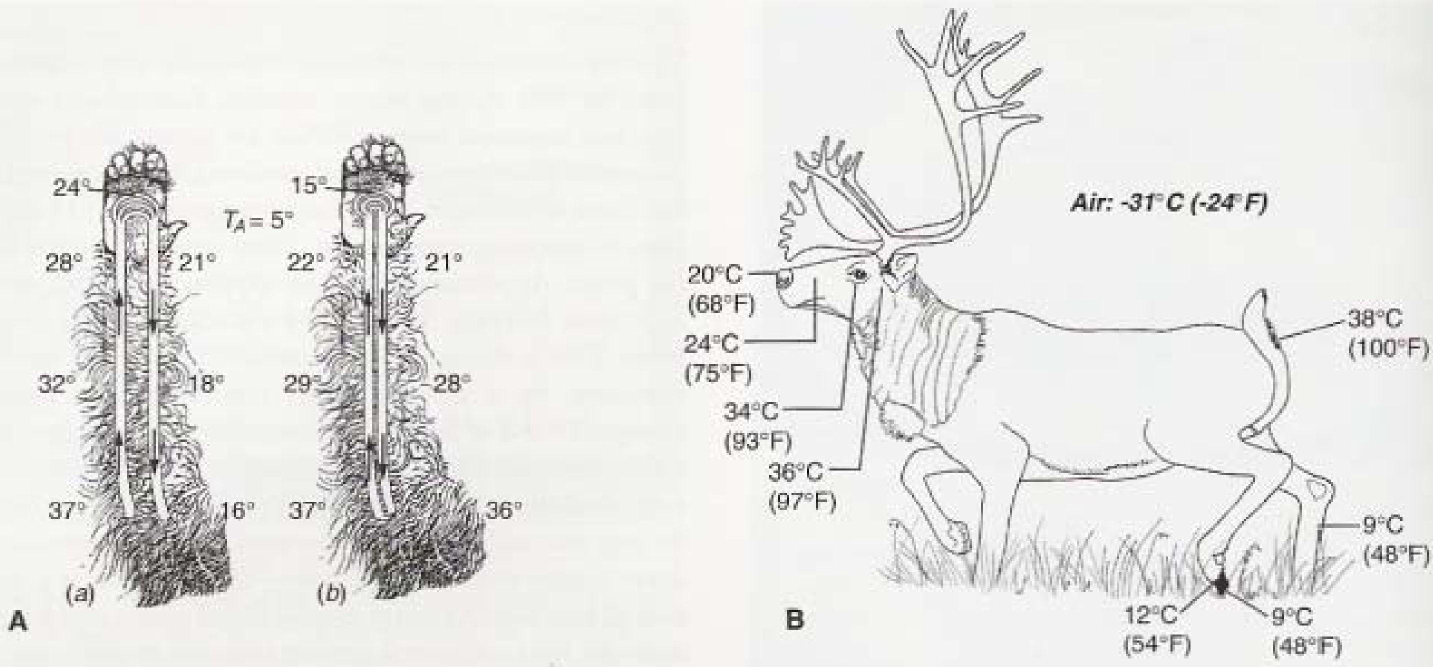
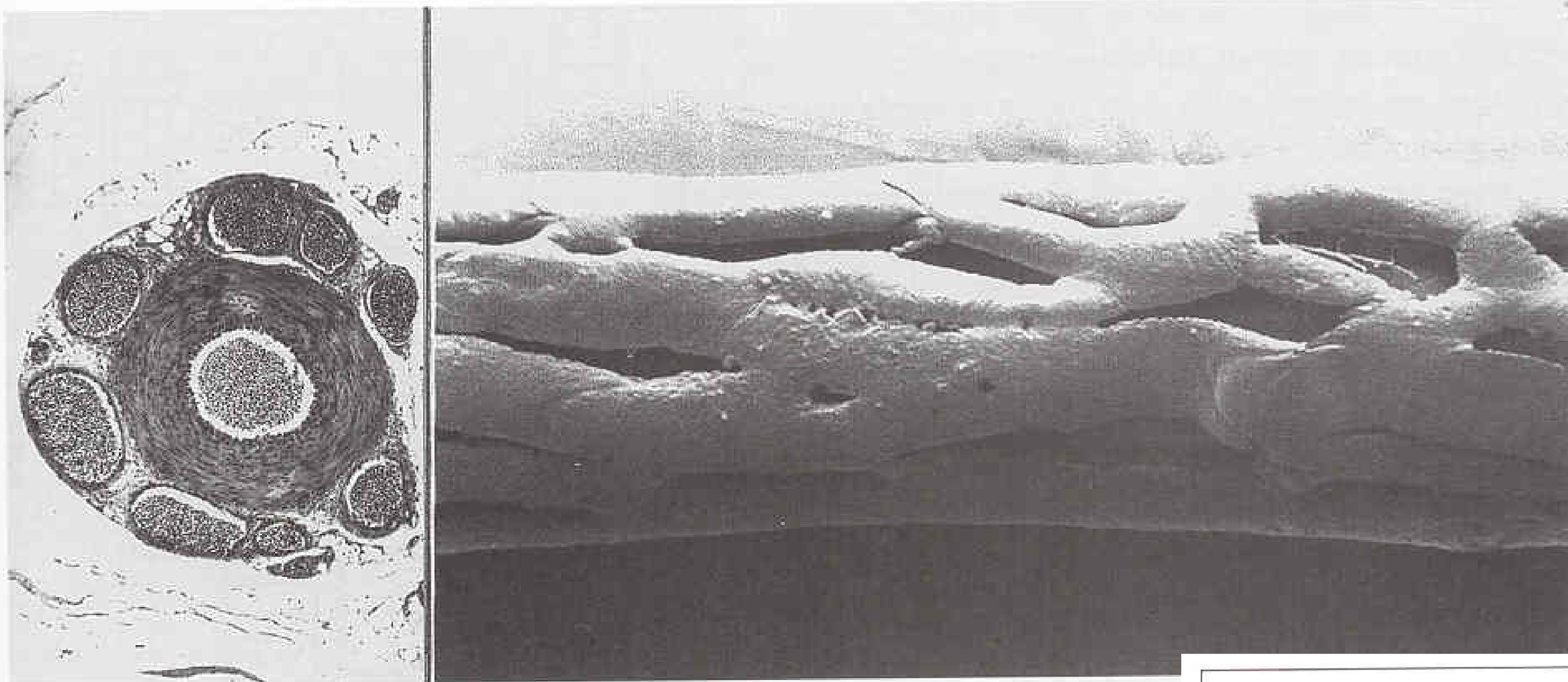


Figure 8.9 Countercurrent heat exchange. (A) A diagram representing the circulation in a limb of a mammal showing hypothetical temperature changes of the blood in the absence (a) and presence (b) of countercurrent heat exchange. Arrows indicate direction of blood flow. In (b), the venous blood takes up heat (thus cooling the arterial blood) all along its path of return because even as it becomes warmer and warmer, it steadily encounter arterial blood that is warmer yet. (B) Regulation of external body temperature in the caribou. Temperature regulation is accomplished in part by countercurrent heat exchange. An intricate meshwork of veins and arteries acts to keep the temperature of the legs near that of the environment so heat is not lost from the body.

(A) Source: Data from R.W. Hill and G.A. Wyse, Animal Physiology, *2nd edition, 1989, Harper & Row, New York. (B) Data from J.F. Merritt, "Animals of the Arctic" in* Arctic Life: Challenge to Survive, *(M.M. Jacobs & J.B. Richardson III, eds.), 1983, The Board of Trustees, Carnegie Institute, Pittsburgh, Pennsylvania.*



BLOOD VESSELS IN A BIRD LEG Cross section (left) and surface view of the blood vessels in the leg of a European rook (*Corvus frugilegus*), a crow-like bird. The thick-walled artery runs in the center and is surrounded by several thin-walled veins that branch and anastomose so that they virtually cover the a
the structure is 2 mm. [Cour
University of Copenhagen]

Knut Schmidt_Nielsen 1997

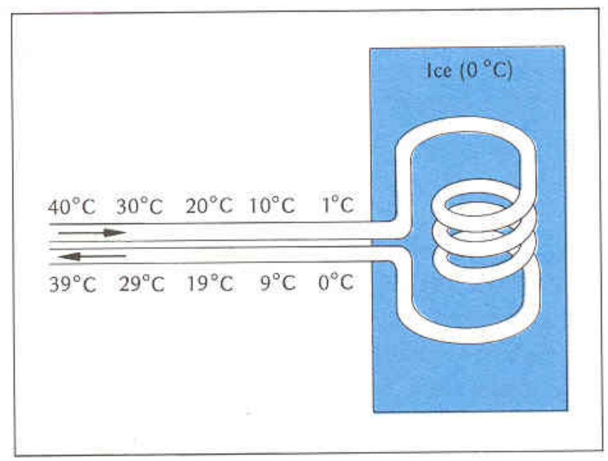


Figure 7.17 Model of a countercurrent heat exchanger. In this case heat is conducted from the incoming water to the outflowing water so that in the steady-state condition the outflowing water is pre-warmed to within 1 °C of the incoming water. For explanation, see text.

Thermogenesis

Endotherms in the COLD...

Shivering (or locomotion)

antagonistic muscle contractions

heat byproduct

Non-shivering

fats metabolized,

but produce heat instead of ATP

brown fat specialized

sympathetic stimulation:

1. ATP hydrolysis used to pump ions needlessly
2. Proton leakage in mitochondria,

rather than production of ATP

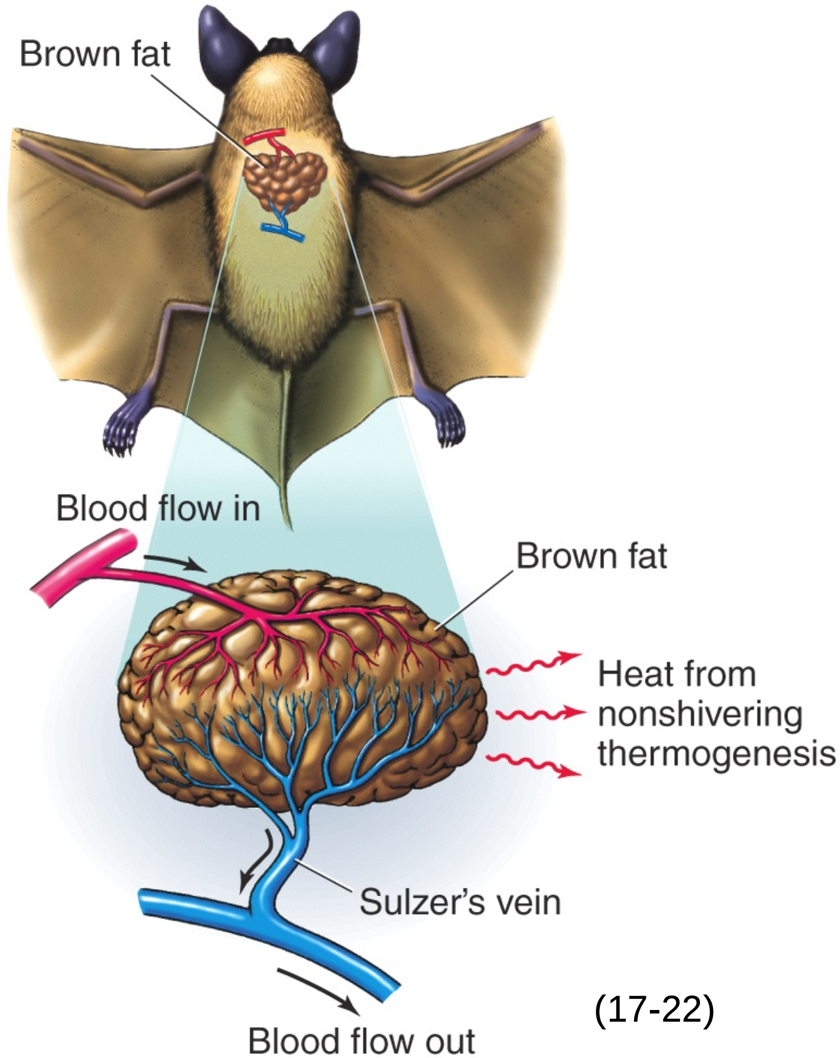
in presence of thermogenin

Endotherms in the COLD…

Thermogenesis

Shivering (or locomotion)
-antagonistic muscle contractions
heat byproduct

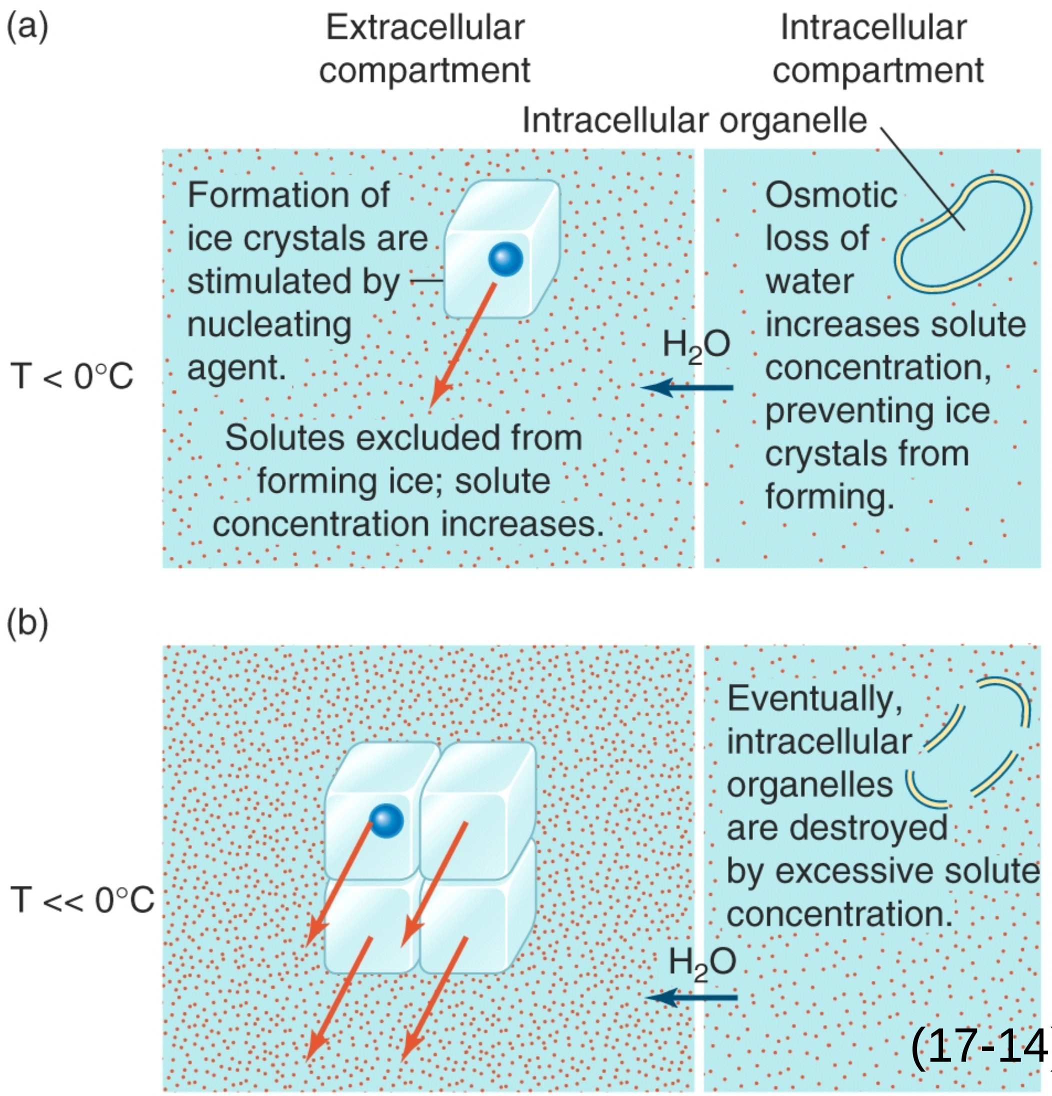
Non-shivering
fats metabolized, but produce
heat instead of ATP
- brown fat specialized



(17-22)

Ectotherms in the COLD

Freeze Tolerance vs. Supercooling/Antifreeze



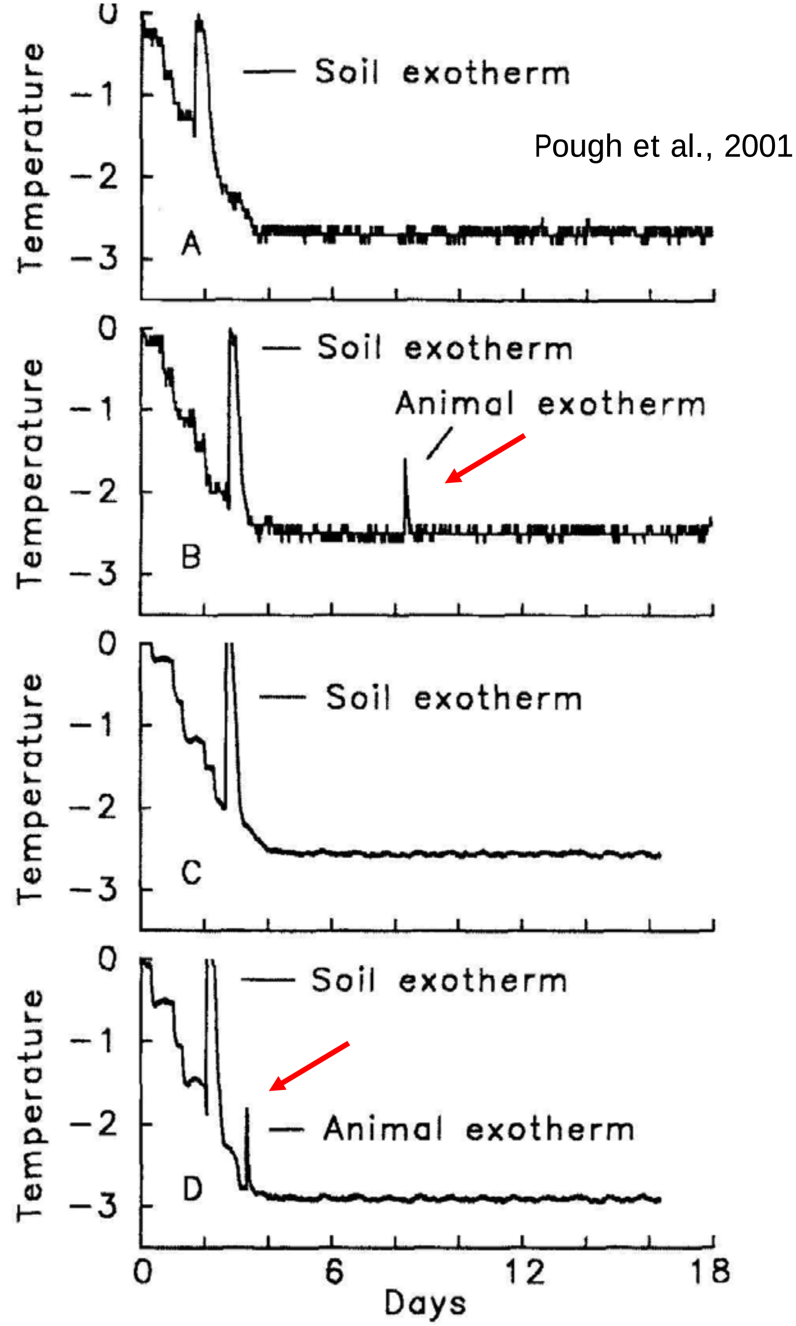
(17-14)

- Extracellular Nucleation
- [Solute]
- Rate

Thermoregulation

Freezing - ice crystal formation
-alter osmolality
-physical destruction

Freeze Resistance
supercool
prevent ice crystals
(Sceloporus jarrovii)
(Chrysemys picta)

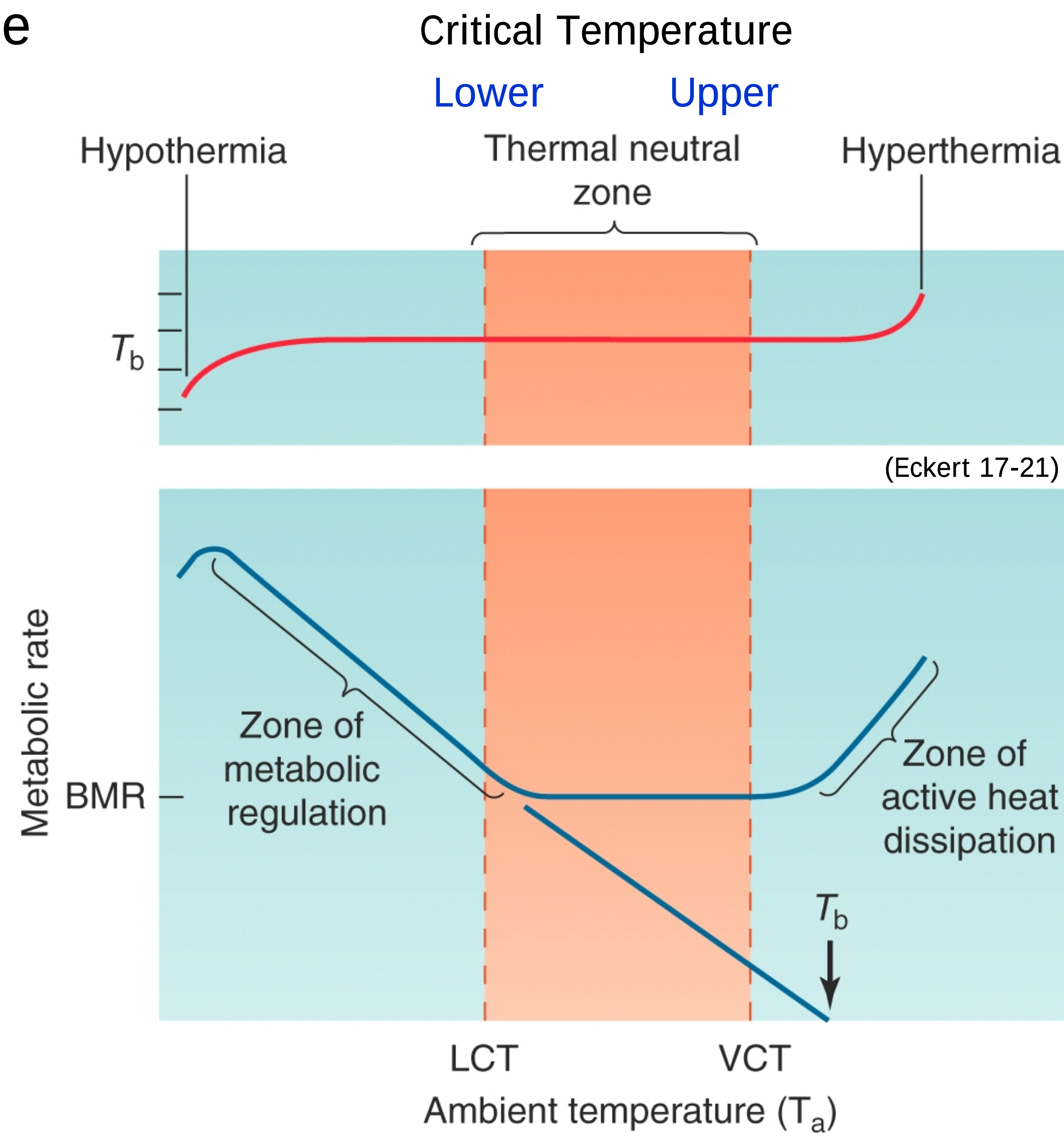


Thermal Neutral Zone

Within TNZ:
- -Vasomotor
- -Posture
- -Insulation
  fluff fur/feathers

Below TNZ:
- -Increase metabolism
  above basal

Above TNZ:
- -Cool via evaporation



(Eckert 17-21)

birds

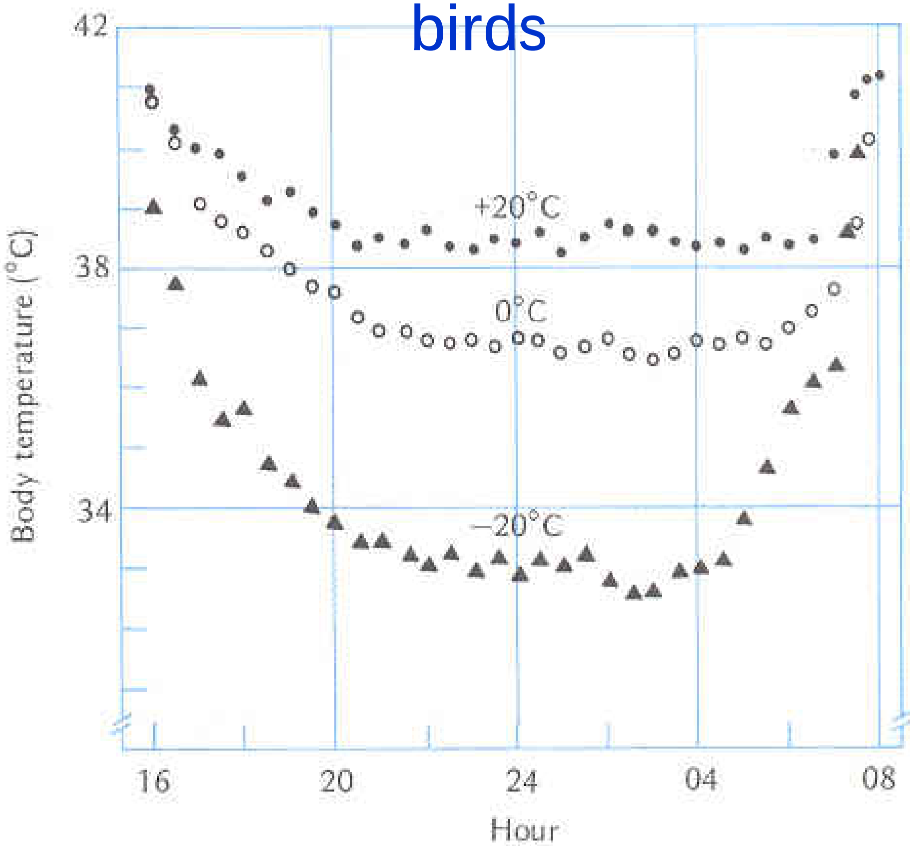
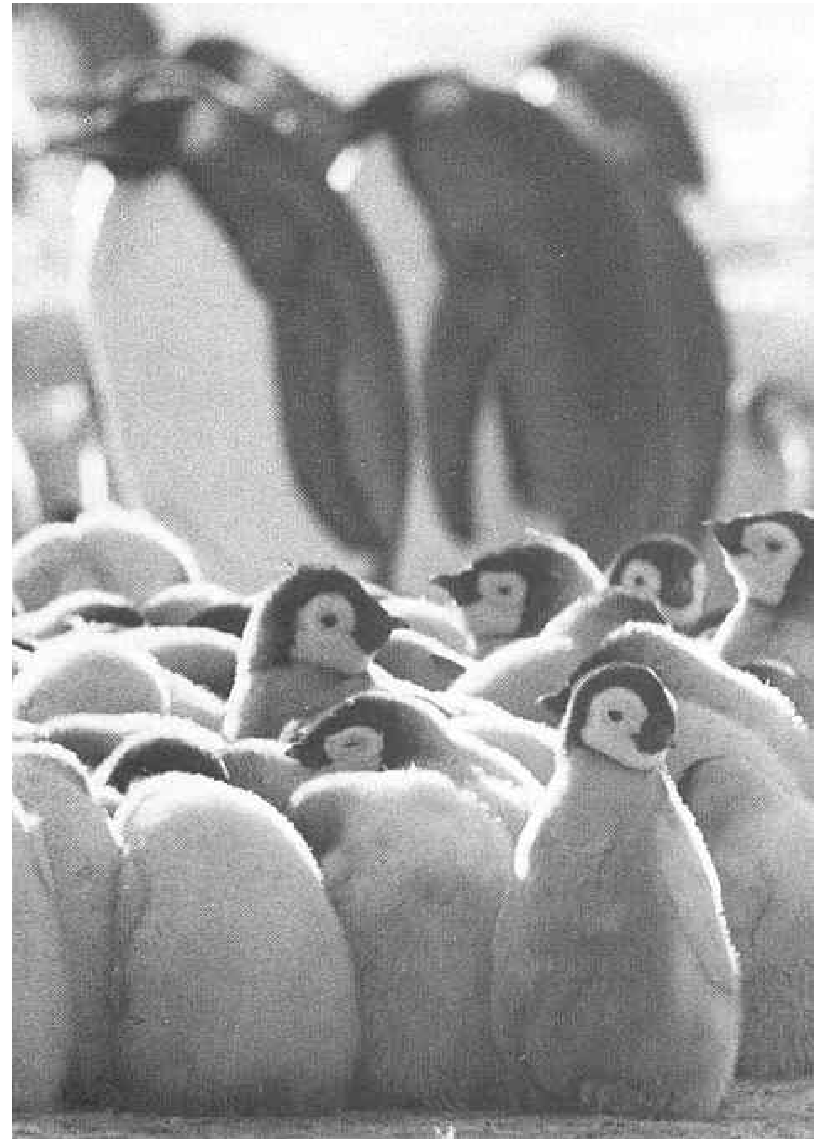


Figure 7.11 Body temperature of a willow tit (*Parus montanus*) during the night hours at three different ambient temperatures. The records are from midafternoon one day to the following morning. [Reinertsen and Haftorn 1986]

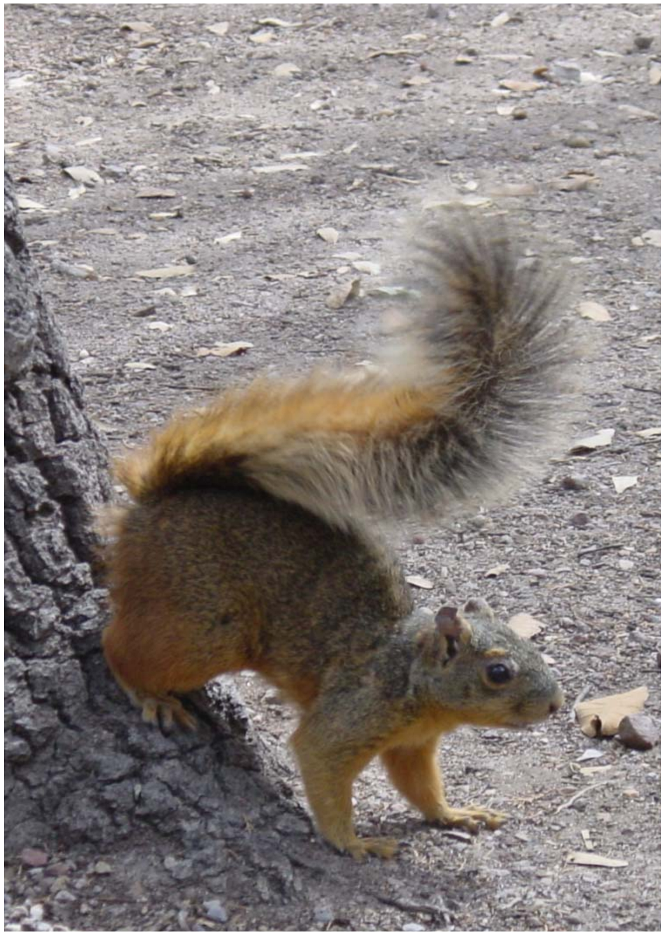
Knut Schmidt_Nielsen 1997



Knut Schmidt_Nielsen 1997

COST/BENEFIT ANALYSIS

Would you rather be an ectotherm or an endotherm?



Ectothermy vs. Endothermy

1. Ectotherms
   - -lower metabolic rate
   - -require less water
   - -require less food (foraging time)
   - -greater proportion energy into growth and repro

   - -small body size works (different shapes)

   - -reliant on environmental heat sources
   - -seasonal and daily limits on activity
   - -low aerobic capacities

2. Endotherms with ‘opposite’ costs and benefits

Small Group Discussion

In the context of environmental physiology:

What are the three biggest environmental challenges (broadly defined) that vertebrates face?

What are the three most important (common?) cellular-level physiological processes that you have encountered this semester?