

Winter Ecology – Mammalian Adaptations to Winter Study Worksheet – KEY and Fun Facts

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I. Concepts

1. **Energy Balance:** Purpose is maintenance of **euthermy**: To do this, Metabolism and Thermal Conductance must be adjusted as temperatures decrease.

How is this done, that is, through what 3 categories of adaptations?

Morphological, Physiological and Behavioral mechanisms.

2. **Survival Mechanisms** in winter (after Feldhammer, et. al, 2004, Table 8.1, p.117):

Avoidance: define as many of the (nine) mechanisms as you can -

1. Body size: Larger further north (coyotes, foxes, deer, elk) – see Bergmann’s rule
2. Appendages: smaller ears (rabbits, hares, foxes); shorter legs (foxes) – see Allen’s rule
3. Insulation: grow undercoat (deer, goats), aquatic mammals – double problem - undercoat traps air bubbles (beaver, muskrat, water shrews, otter); blubber (marine mammals)
4. Coloration: molt to white in winter (snowshoe hare, long tailed weasel, arctic fox, collared lemming) or always white or lighter (polar bears, caribou, wolves, arctic hare) see Gloger’s rule
5. Food Hoarding: pika haystacks, squirrels, weasels, (reported for 6 orders, 30 families)
6. Reduction of Level of Activity: shrews, *Peromyscus spp*, voles
7. Reduction in Body Mass: voles, shrews
8. Dormancy, or adaptive hypothermia: Hibernation (marmots, arctic ground squirrels); torpor (marsupials, bats, insectivores, mice), lethargy (bears). Torpor not known in most shrews and voles.
9. Modification of microclimatic regime
 - a. Communal nesting (voles, squirrels, raccoons)
 - b. Construction, maintenance of elaborate nests (furlined – weasels)
 - c. Foraging zones: facultative migration (deer, elk)

Resistance: by increase thermogenic capacity. Give examples of the different ways this can be done –

Overall, by increasing BMR (basal metabolic rate) through:

- a. Increased activity & exercise (weasels)
- b. Shivering (all mammals)
- c. NST – non-shivering thermogenesis accomplished with brown adipose tissue – an interscapular patch in bats, shrews.

3. **Countercurrent heat exchange (peripheral heterothermy) and rete mirabile:** As warm arterial blood passes into an appendage, heat is shunted from the artery to veins, which carry the colder blood back to the body’s core. **example given:** Beaver’s tail.
4. **Bergmann’s Rule:** “Races from cooler climates in species of warm-blooded vertebrates tend to be larger than races of the same species from warmer climates” (Mayr 1970:197) **example given:** deer
5. **Allen’s Rule:** Appendages of endothermic animals are shorter in cold climates than those of animals of the same species found in warmer climates. **example given:** foxes ears (arctic, desert kit)

6. **Gloger's Rule:** "Races in warm and humid areas are more heavily pigmented than those in cool and dry areas." (Mayr 1970:200). **example given:** caribou
7. **Rapoport's Rule:** Species ranges are in general smaller in the tropics than in the temperate regions, the species richness is higher, complexity of the biotic interactions is both higher and more species-specific.

II. Terminology

- BMR: Basal Metabolic Rate: Volume of oxygen consumed per unit of time at a standard temp and pressure.
- Endothermy – maintenance of a relatively constant body temperature by means of heat produced from inside (*endo*) the body.
- Homeothermy – more precise than endothermy, the physiological regulation of a constant body temperature.
- Ectothermy – determination of body temperature primarily by sources outside (*ecto*) the body.
- Poikilothermic – variation in body temperature under environmental conditions.
- Heterothermic – mammals & birds capable of dormancy (hibernation, estivation and daily torpor)
 - Regional heterothermy – body temperature regulated on different parts of the body (beaver's tail)
 - Temporal heterothermy - body temperature regulated at different times (bats)
- Set Point – comfort zone set at the hypothalamus, unique to each species
- Shivering – Muscle contraction to generate heat, primary means of heat production in prototherians (marsupials and monotremes).
- Interscapular brown adipose tissue – produces heat through **Non-shivering thermogenesis (NST)**.
- Thermoneutral Zone – Metabolic rate (MR) is minimal, unchanging as ambient temp changes.
- Lower critical temperatures – ambient temp at which an animal must increase its MR to balance heat loss.
- Upper critical temperatures – ambient temp at which an animal must dissipate heat by evaporative cooling or modifying behavior.
- Torpor – a type of dormancy. Heart rate, body temp., respiration lowers but not as much as hibernation.
- Hibernation – profound dormancy. Animal's body temp remains at 2° to 5° C for weeks.
- Winter lethargy – exhibited by bears; body temp only reduced to about 31° C (down 6° -7° C)
- Estivation – a period of dormancy in reaction to dry or hot conditions, occurring at high body temperatures.
- Radiation – heat lost from animal to the environment or absorbed from the environment (solar radiation)
- Convection – air movement
- Evaporation – cause of heat loss by the loss of water from lungs, or from sweat glands to the air.
- Thermal Conduction – Rate at which heat is lost from skin to outside environment. Expressed as

$$C = \frac{MR}{T_b - T_a}$$
 where MR is metabolic cost (ml O₂/gram body mass for a given time interval);
 T_b = body temp and T_a = environmental temp
- Subnivean – Environment beneath snow cover – also called microhabitat or foraging zone.

- Heimal threshold – the presence of a sufficient depth of snow to insulate the subnivean environment.

III. Review Questions

1. Define and explain the differences between: homeothermy, ectothermy, poikiothermy, and heterothermy.

[Integrate from definitions given above]

2. Label the arrows in the diagram with appropriate radiation (thermal, reflected), conduction, convection, and evaporation. [as now included in the figure]

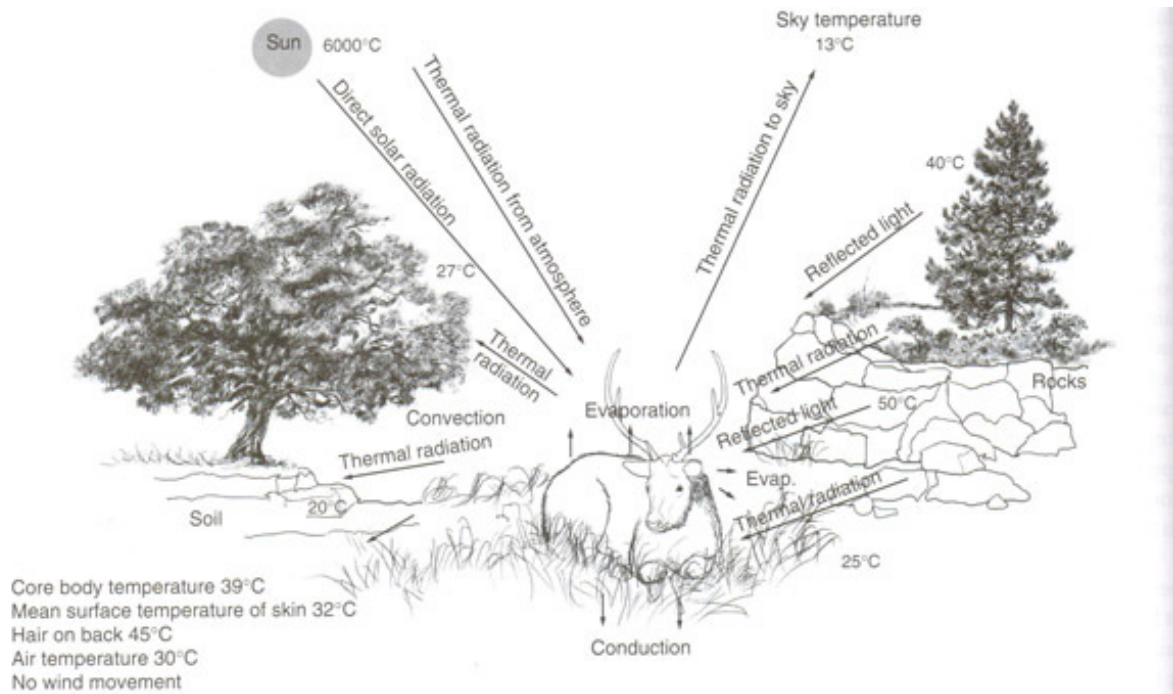


Figure 8.1 Energy exchange. Illustration of the energy exchanges between an animal and its environment under warm conditions. Adapted from M. S. Gordon, 1982, *Animal Physiology: Principles and Adaptations*, 4th edition, Macmillan Publishing Company.

3. What factors do mammals use to maintain their body temperature around a set point?
 - a. Insulation
 - b. Activity levels (hibernation, daily torpor, estivation)
 - c. Behavioral choices (postures, denning, social huddling, facultative migration)
 - d. Microclimatical regimes and microhabitat choices (subnivean, rock outcrops – gray fox, mountain lion, coyote)

IV. Why is there debate about Bergmann's, Gloger's and Allen's rules?

There are notable exceptions to the rules.

- McNab (1971) found only 32% of 47 species followed Bergmann's Rule. Also, Geist (1987) noted small body size occurs at lowest and highest latitudes.
- Bush dogs in S. America are short legged (vs. Allen's Rule).
- Fisher, mink, and the blue form of the arctic fox are dark even at high latitudes (vs. Gloger's Rule).

Fun Facts:

- Evolutionarily, endothermy thought to have evolved from ectothermy 2-3 times during the late Triassic in response to selection requiring sustained activity and temperature regulation.
- Weasels. Cold-stressed weasels have metabolic rates 50% to 100% greater than a less slender mammal of similar size to compensate for heat loss, due to a 15% higher surface-area-to-mass ratio than the comparably sized woodrat.
- Lower critical temperature of the arctic fox is -4°C . At -70°C the arctic fox only elevates its metabolic rate 50% above resting MR.
- Pelage. In Families Muridae (new and old world rats, mice, voles, others) and Soricidae (shrews), pelage insulation can increase 11-19%. Other mammals may increase fur thickness up to 50% in winter.
- Brown fat. Reported in eight orders of mammals, unique to eutherian (placental) mammals, brown fat cells have more mitochondria than white fat cells. Brown adipose tissue cells have a protein, **thermogenin**, that uncouples mitochondrial respiration from ATP synthesis so that the oxidation energy of fatty acids is dissipated as heat. When bats arouse from hibernation the brown fat pad is much warmer than the rest of the body.
- Blubber. In winter, blubber in the ringed seal (*Phoca hispida*) may account for 40% of its mass.
- Beaver's Tails can reduce heat loss to just 2% of resting MR in winter due to countercurrent heat exchange.
- Caribou and other large mammals have a flap of skin to close their nostrils, reducing heat loss from the lungs.
- Loss of body mass. *Sorex cinereus* can lose 53% body mass between early summer and winter (Merritt 1995).
- Northern forms of *Peromyscus* use more nesting material than southern forms, even when the temperature is constant.

Sources:

- Feldhamer, George A., Lee C. Drickamer, Stephen H. Vessey, Joseph F. Merritt, editors. 2004. Mammalogy: adaptation, diversity, ecology. McGraw Hill, New York, New York. 550 pages.
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