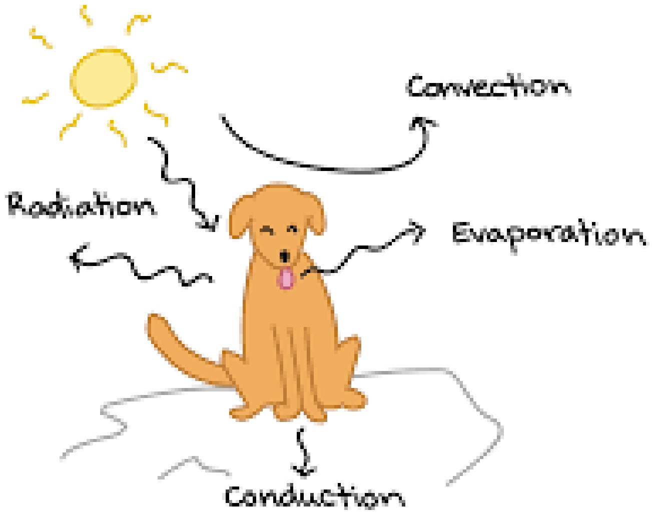
Body Temperature and Its Regulation



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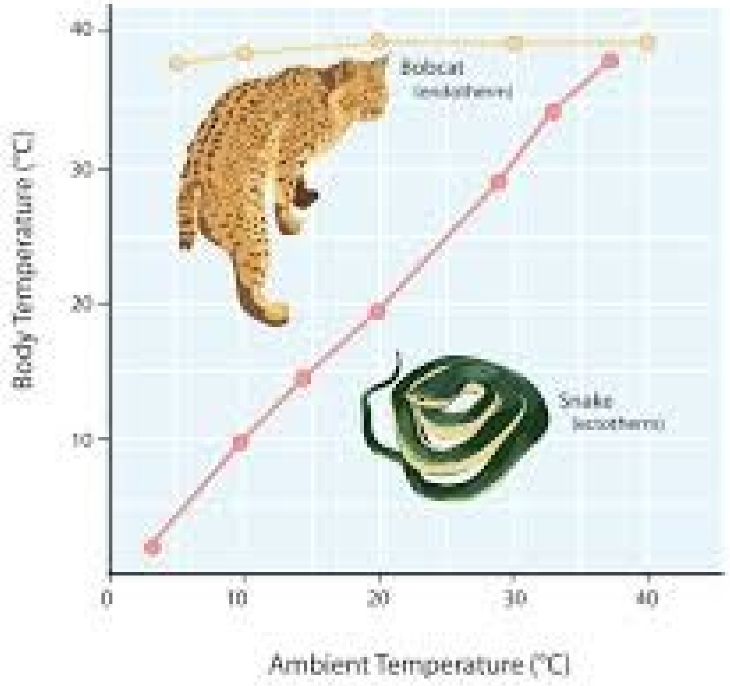
Body Temperature and Its Regulation

- The chemical reactions of the body, and the functions of the body, depend on body temperature.
- An elevation of temperature accelerates the reactions, and a lowering of temperature depresses the reactions.
- To avoid fluctuations in function caused by temperature, mammals and birds have developed a means whereby body temperature is maintained at a relatively constant level regardless of the temperature of the surroundings.
- Mammals and birds are classified as homeotherms, or warm-blooded animals.
- Poikilotherm (cold-blooded) animals have a body temperature that varies with the temperature of the environment.



Body temperature

- An average body temperature is associated with each domestic animal species.
- The temperatures were obtained by rectal insertion of a thermometer in resting animals.
- A number of conditions can influence body temperature, including exercise, time of day, environmental temperature, digestion, and drinking of water.

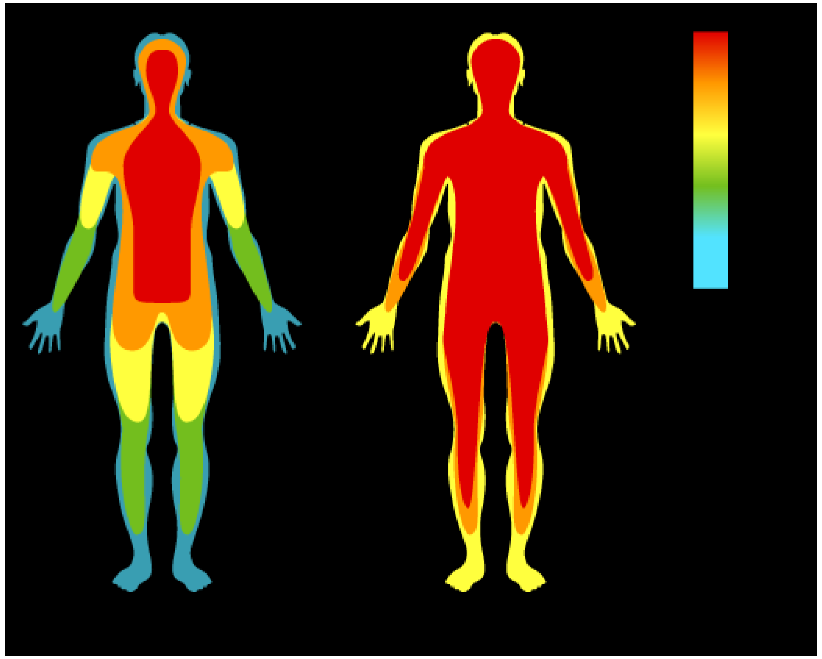
Table 14.1 Average rectal temperatures of various species.

Animal	Average °C	Average °F	Range °C	Range °F
Stallion	37.6	99.7	37.2–38.1	99.0–100.6
Mare	37.8	100	37.3–38.2	99.1–100.8
Donkey	37.4	99.3	36.4–38.4	97.5–101.1
Camel	37.5	99.5	34.2–40.7	93.6–105.3
Beef cow	38.3	101	36.7–39.1	98.0–102.4
Dairy cow	38.6	101.5	38.0–39.3	100.4–102.8
Sheep	39.1	102.3	38.3–39.9	100.9–103.8
Goat	39.1	102.3	38.5–39.7	101.3–103.5
Pig	39.2	102.5	38.7–39.8	101.6–103.6
Dog	38.9	102	37.9–39.9	100.2–103.8
Cat	38.6	101.5	38.1–39.2	100.5–102.5
Rabbit	39.5	103.1	38.6–40.1	101.5–104.2
Chicken (daylight)	41.7	107.1	40.6–43.0	105.0–109.4

Source: Andersson, B.E. and Jonasson, H. (1993) Temperature regulation and environmental physiology. In: *Dukes' Physiology of Domestic Animals*, 11th edn (eds M.J. Swenson and W.O. Reece). Cornell University Press, Ithaca, NY.

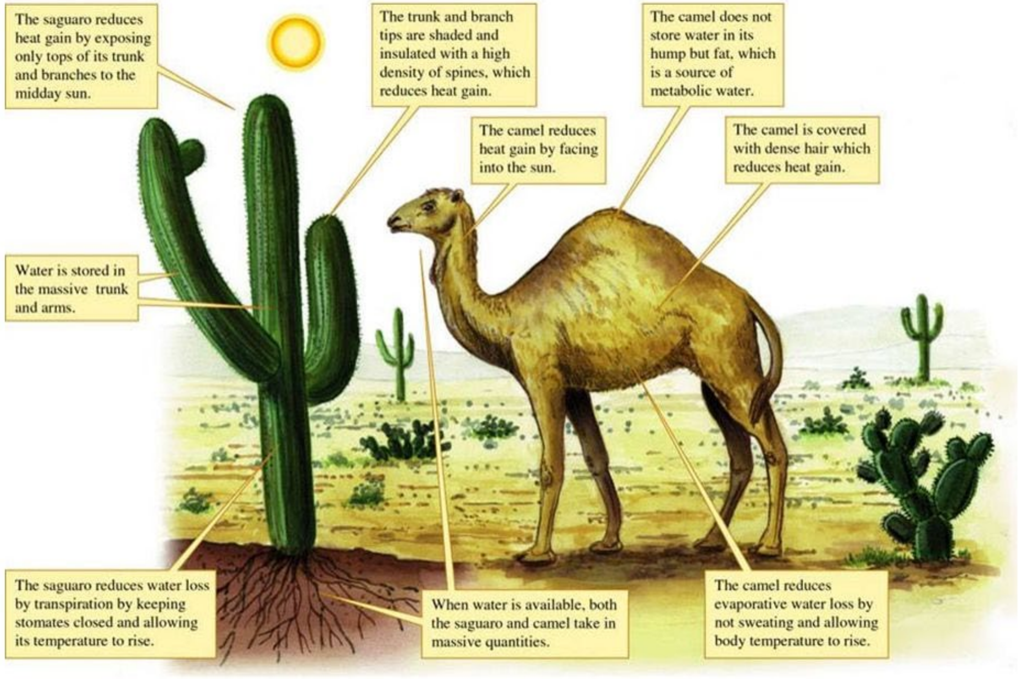
Gradients of temperature

- Different parts of the body can differ in temperature because of differences in metabolic rate, blood flow, or distance from the surface.
- For example, the liver and the brain can have a temperature that is higher than that of blood, and they are therefore cooled by blood circulation.
- The deep body temperature, or core temperature, is higher than the temperature of the limbs or even higher than the temperature observed rectally.
- However, rectal temperature represents a true steady state of temperature because it reaches equilibrium more slowly.



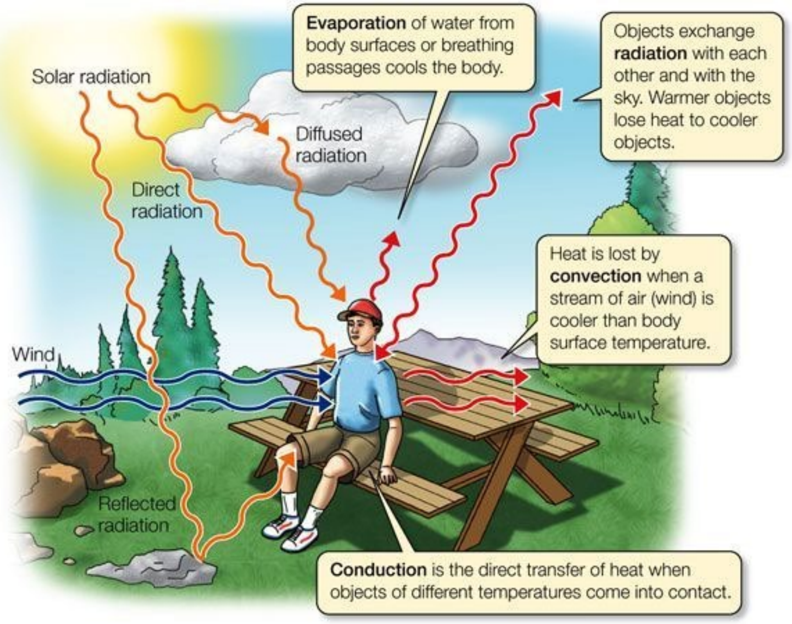
Diurnal temperature

- Variations in temperature related to the time of day are designated as diurnal temperatures.
- Animals that are active during the day and sleep at night have body temperatures that are lower in the morning than in the afternoon.
- The opposite is true for nocturnal (night-active) animals.
- Also, as a water conservation measure, the body temperature of the camel is permitted to increase during the day so that the excess heat can be dissipated at night when the desert air is cool; this is known as heat storage.
- The temperature of a normal camel, watered every day and fully hydrated, varies by less than 2 °C, between about 36 and 38 °C (more water available for evaporation and less need for heat storage).
- When the camel is deprived of drinking water, however, its morning temperature can be as low as 34 °C and its highest temperature, in the late afternoon, can be nearly 41 °C



Physiologic responses to heat

- Heat is produced constantly in the body as a result of metabolism.
- If there were not provisions for losing heat, the temperature of the body would increase to intolerable levels.
- Two principal means for losing heat are (i) radiation, conduction, and convection, and (ii) evaporation of water from the skin and respiratory passages.
- A third way considers the excretion of feces and urine that leave the animal at body temperature.
- Heat lost by excretion of feces and urine is small and is considered negligible.
- Under ordinary conditions, about 75% of the heat lost from the body is dissipated by radiation, conduction, and convection and is controlled mostly by vasomotor activity.



LIFE 8e, Figure 40.11

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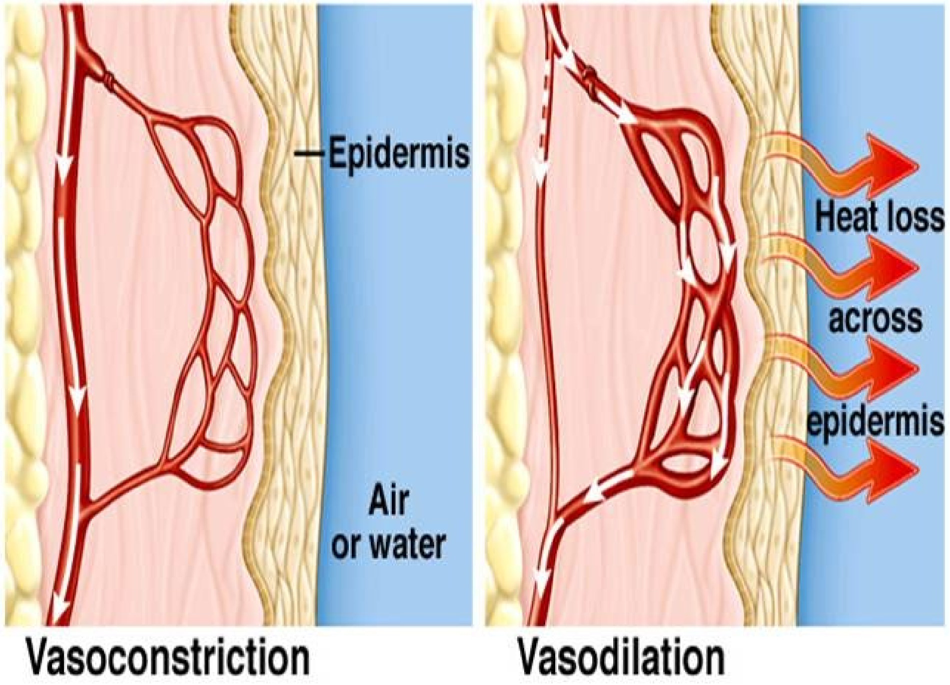
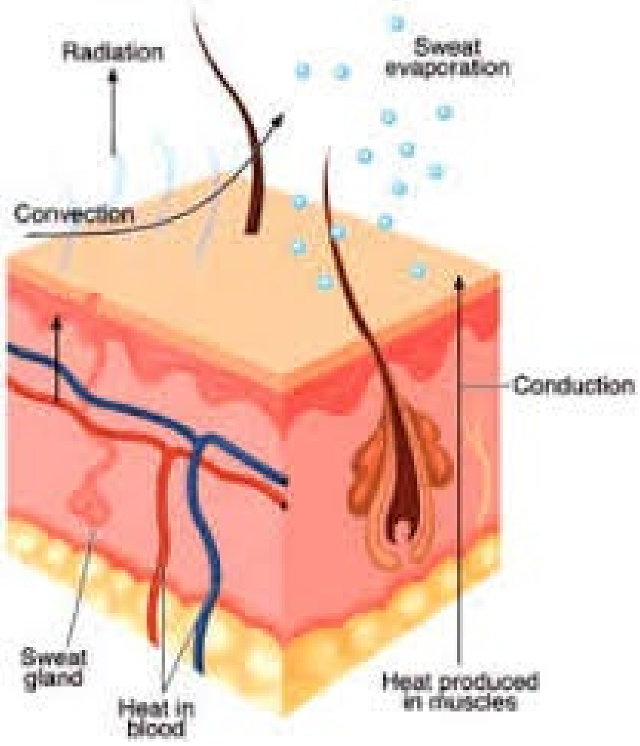
Circulatory adjustments

- Heat can be lost from the blood if blood is brought to the skin surface and exposed to a gradient for loss to the environment.
- The volume of blood circulating to the skin is controlled by sympathetic vasoconstrictor fibers to the blood vessels.
- An increase in tone results in constriction of blood vessels and diversion of blood from the surface, thereby conserving heat.
- A decrease in tone allows more blood to the surface.
- A stimulus for a decrease in tone, so that more heat can be lost from the body, is the temperature of the blood circulated to the brain.
- Thermosensitive cells in the rostral hypothalamus respond to warming by activating physiologic and behavioral heat loss mechanisms.
- Similarly, cooling of the same region stimulates other thermosensitive cells to evoke thermoregulatory responses for heat gain.
- Reflexes to inhibit vasoconstrictor tone also arise from thermoreceptors in the skin and other parts of the body.



Evaporative heat loss

- Evaporation of water results in cooling.
- Loss of water by evaporation is referred to as insensible water loss; this includes water lost from the skin surfaces and water lost in the heated exhaled air.
- Normally about 25% of the heat produced in an animal at rest is lost when water is removed by insensible means. Evaporative heat losses are increased by sweating and panting.
- The relative importance of sweating as a heat loss mechanism varies among species.
- **There are two types of sweat glands: apocrine and eccrine.** Eccrine sweat glands are those typically found in humans, but are sparse among domestic animals.
- In the dog and cat they occupy only the foot pad location. This area does not subserve thermoregulation, but provides a moist surface and subsequent improved traction. Horses, cattle, sheep, dogs, and cats have apocrine sweat glands disseminated over the body surface
- In the dog, and perhaps in other species, apocrine sweat is a proteinaceous, white, odorless, milky fluid that is formed slowly and continuously. On the skin surface, it mixes with sebum from the sebaceous glands to form a protective emulsion that acts as a physical and chemical barrier.
- Characteristic animal odors arise from the action of bacterial flora on apocrine secretions. Heat loss from sweating (thermoregulatory function) is probably greatest in the horse, followed (in order) by cattle, sheep, dogs, cats, and swine.



Evaporative heat loss

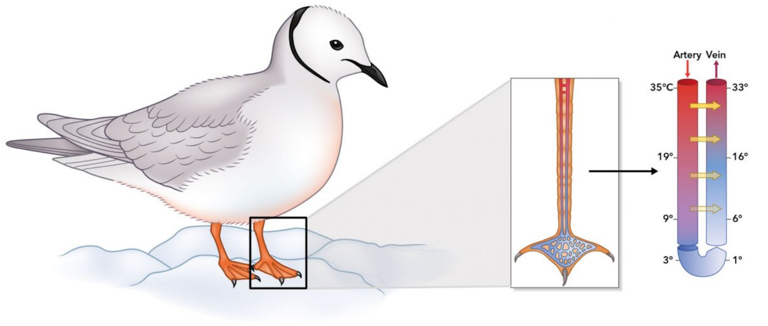
- The panting mechanism is effective in dissipating the heat load because greater amounts of air are forced over moist surfaces.
- Panting is most effective in the dog, but is also observed in the other domestic animals.
- Essentially, panting is an increase in dead space ventilation without change in respiratory alveolar ventilation.
- A decreased tidal volume is associated with the increased respiratory frequency of panting; in this way, hyperventilation of the alveoli is prevented.
- In cattle, panting is accompanied by increased salivation, and the salivary secretion promotes cooling by evaporation.
- Salivary secretion loss by evaporation and drooling (physical loss to the exterior of the body) can result in metabolic acidosis because of loss of bicarbonate and phosphate buffers contained in ruminant saliva.
- Increases in sweating and panting are brought about by increased blood temperature, subsequent adjustments by the hypothalamus, and reflexes produced by local heating of the skin.

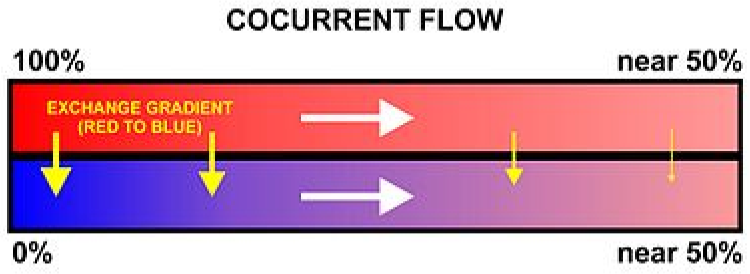
Responses to extremes of heat

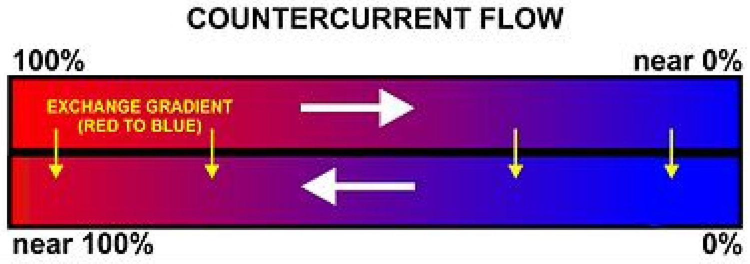
- The humidity of the air becomes a factor: as humidity increases, evaporation from insensible losses is reduced and less cooling occurs.
- Of all domestic animals, cattle and sheep seem to be the most able to withstand extremes of heat. Open-mouth panting and sweating occur as the temperature increases, and these animals can withstand temperatures as high as 43 °C (109 °F) with humidity above 65%.
- The pig cannot tolerate a temperature above 35 °C (95 °F) with humidity above 65%.
- The intolerance of pigs to heat is recognized by transporters of livestock. During periods of heat, the transport of pigs is usually delayed until night, and they often are hosed with water.
- Pigs do not sweat copiously, and their small mouth makes them ineffective at panting. In addition, they often have substantial subcutaneous fat.
- When the relative humidity is above 65%, the cat cannot withstand prolonged exposure to an environmental temperature of 40 °C (104 °F) or higher.
- In addition to panting, the cat can increase evaporative losses by spreading saliva over its hair coat.
- Because the dog is effective at panting, it can withstand extreme environmental temperatures better than the cat, but it is in danger of collapse when its rectal temperature reaches 41 °C (106 °F).
- In birds, the air sacs are extensions of the lungs that extend into the body cavities.
- The body temperature of birds is about 41 °C (106 °F). Pulmonary ventilation air is more likely to cool the body of birds than that of mammals .because of the larger gradient and because of the closeness of the air to the body organs.
- It seems that prolonged exposure of a hen to an air temperature of 38 °C (100 °F) is unsafe if the relative humidity is above 75%. A rectal temperature of 45 °C (113 °F) is the upper limit of safety in the chicken.

Physiologic responses to cold

- Cold activates body heating mechanisms, just as excess heat activates body cooling mechanisms.
- With excess cooling, heat is either conserved by reducing heat loss or is generated to compensate for that which is lost. The physiologic responses to cold are activated by blood temperature and local reflexes, as are the responses to heat.
- **Reduction of heat loss**
- In an attempt to reduce heat loss, animals instinctively curl up when they lie down.
- This behavioral response reduces the surface area exposed to the cold.
- To increase the insulation value of their hair or fur, piloerection occurs.
- In this process the hair is made to become more erect by the arrector pili muscle of the hair follicle.
- With sustained exposure to cold, the hair coat thickens and the amount of subcutaneous fat increases.
- In contrast to vasodilation, which occurs to accommodate heat loss, the peripheral vessels are constricted by an increase in vasoconstrictor tone.
- Heat is also conserved by the arrangement of the deep blood vessels that supply the legs of animals.
- Blood returning in the veins from the colder legs is close to the warmer blood in the arteries directed to the legs.
- Because of the temperature differences, heat is transferred from the arteries to the veins; this decreases the gradient for heat loss from the arterial blood to the environment. This arrangement of blood vessels is known as a **countercurrent system.**

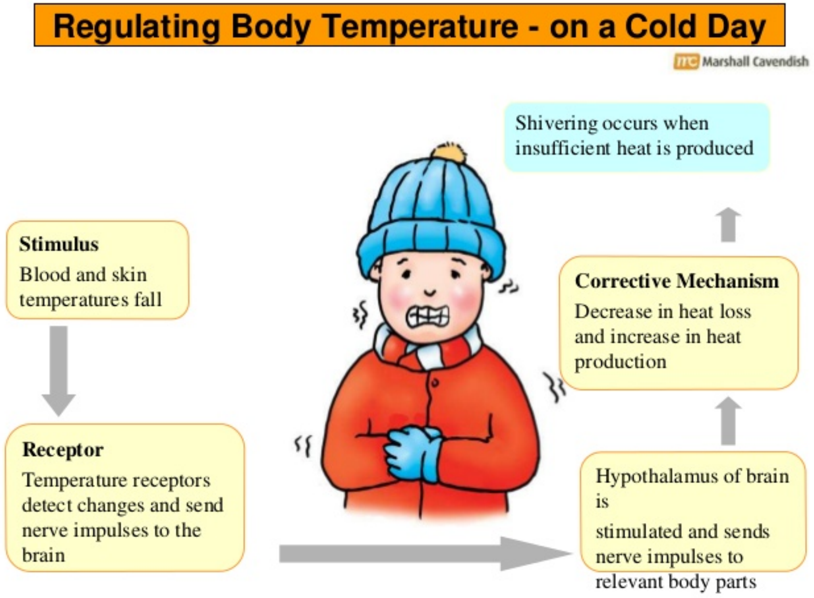






Physiologic responses to cold

- **Increase in heat production**
- When the ability to reduce heat loss is not adequate to maintain a normal body temperature, heat must be produced.
- The temperature to which body temperature decreases before heat generation begins is known as the critical temperature.
- Among farm animals, cattle and sheep have the lowest critical temperature, which means that they are better suited to withstand cold.
- Shivering is one means by which heat is generated.
- Shivering is a generalized rhythmic contraction of muscles.
- Because 30–50% of the energy of muscle contraction is converted to heat, the seemingly spasmodic contraction of muscle serves a useful purpose.
- Other methods are used to generate heat in addition to shivering.
- Epinephrine and norepinephrine are both released in increased amounts in the cold. Brown fat is an important source of thermogenesis.
- Epinephrine and norepinephrine are the stimuli for increased metabolism of brown fat. In addition to hibernating animals, brown fat is also found in newborn mammals.
- Epinephrine and norepinephrine have calorigenic effects on other cells as well, and the calorigenic effects are potentiated by thyroid hormone. Thyroid hormone is secreted in increased amounts during periods of cold.

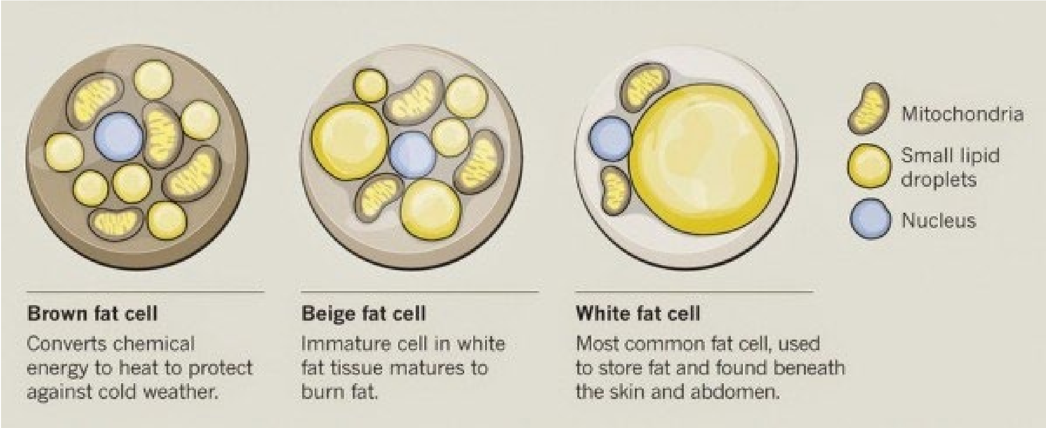


Hibernation

- Hibernation is the act of resting in a dormant state in a protected burrow.
- This definition has recently returned to favor.
- Formerly, it was proposed that Hibernation is the assumption of a state of greatly reduced core temperature by a mammal or a bird which has its active body temperature near 37 °C, meanwhile retaining the capability of spontaneously rewarming back to the normal homeothermic level without absorbing heat from its environment (Menaker, 1962).
- According to the former definition, bears were not considered to be true hibernators because their core body temperature was not greatly reduced.
- The core body temperature of bears is reduced by only 6.8 °C during their dormancy, as opposed to a reduction of 20–30 °C by animals that were considered to be true hibernators.
- The lesser reduction in body temperature of the bear is now believed to be a biologic protection for hibernating bears; accordingly, they are considered true hibernators.
- Because of their large body mass, it is thought that too much time would be involved in their revival to activity if their body temperature were lowered by 20–30 °C.
- The longer revival time would make them easy victim to another cannibalistic bear that had revived.
- **The characteristics of hibernation are as follows:**
  - **1 Hibernation is a process involving warm-blooded animals.**
  - **2 The process is autonomous: the animal induces and reverses it by some self-contained mechanism.**
  - **3 The process is radical: changes involve not only overt physiologic functioning, but also cellular and subcellular changes.**
  - **4 All physiologic functions continue, but at a reduced rate.**
  - **5 During the process, body temperature is lowered significantly to a level compatible with survival for the species.**

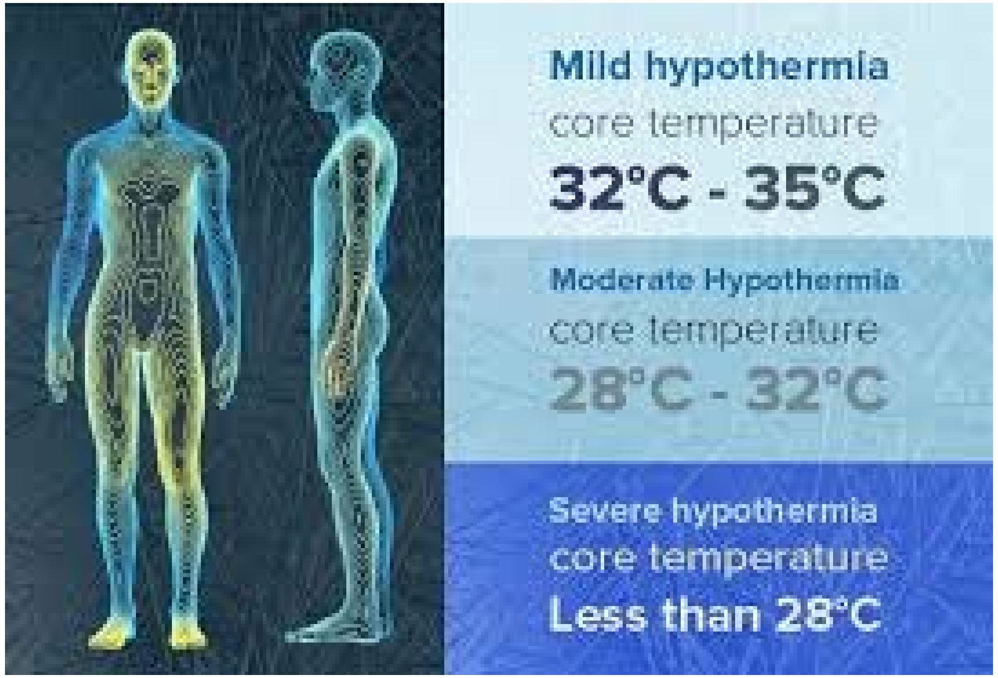
Awakening from hibernation

- Hibernating animals awake from their dormant state periodically.
- For example, the kidneys continue to form urine and the animal has a need to urinate.
- A protective mechanism against profound cooling also exists in winter hibernators.
- If the body temperature declines to levels near freezing, the animal awakes and rapidly rewarms.
- **Brown fat versus white fat**
- *Brown fat is a connective tissue with a color that results from cytochrome pigments and a high density of mitochondria. It is typically found in hibernating animals and in smaller species. It is also present in the newborn of many species and disappears within the first few months of life. Its usual location is in the subcutaneous region between the scapulae (shoulder blades) and in the region of the kidneys as well as within the myocardium. The ability of hibernators to elevate their body temperature from reduced levels to the temperature necessary for arousal (nonshivering thermogenesis) is facilitated by their depots of brown fat. Brown fat differs from white fat not only in color, but also in metabolic characteristics. When brown fat cells are stimulated, they consume oxygen and produce heat at a high rate.*



Hypothermia

- Hypothermia can readily occur during central nervous system anesthesia because the hypothalamic response to cold blood is depressed.
- It normally occurs as a result of prolonged exposure to cold, coupled with an inability of the heat-conserving and heat-generating mechanisms to keep pace. T
- Tolerance to lowered body temperatures varies among species.
- In dogs, death can occur when the rectal temperature approximates 25 °C (77 °F).
- Hypothermia in any animal can become lifethreatening unless environmental conditions improve or external heat is provided.
- It is important to monitor body temperature during and after procedures requiring anesthesia because of the depressed hypothalamic response.
- External heat sources are often fitted to surgical tables for the maintenance of body temperature.
- When these are used, there must be assurance that local injury to skin does not occur.
- When animals do not recover quickly after anesthesia (e.g., pentobarbital anesthesia), monitoring body temperature and provision of external heat is extremely important.



Fever

- Fever is an elevation of deep body temperature that is brought on by microorganism-caused disease.
- Fever is usually beneficial because immunologic mechanisms are accelerated and the high temperature induced is detrimental to the microorganisms, but it can be damaging if allowed to become excessive.
- In fever, the set point of the hypothalamus is elevated and the body senses that the blood is too cold, so heat-conserving and heat-generating mechanisms are recruited.
- Shivering and a feeling of coolness are characteristics of the beginning of fever.
- Fever is generally self-limiting; maximum temperatures of 41 °C (106 °F) can be approached.

Heat stroke and impaired evaporation

- Hyperthermia exclusive of fever can be associated with heat stroke. In this condition, heat production exceeds the evaporative capacity of the environment and occurs when the humidity is high.
- Hyperthermia can also develop when the evaporative mechanisms become impaired as a result of loss of body fluid or reduced blood volume.
- Antipyretic drugs (effective against fever) are ineffective in reducing body temperature in heat stroke and impaired evaporation conditions, and relief is obtained only by whole-body cooling.

TEŞEKKÜRLER