Thermoregulation

1. Mammals and birds generally maintain body temperature within a narrow range (36-38°C for most mammals and 39-42°C for most birds) that is usually considerably warmer than the environment. Because heat always flows from a warm object to cooler surroundings, birds and mammals must counteract the constant heat loss. This maintenance of warm body temperature depends on several key adaptations. The most basic mechanism is the high metabolic rate of endothermy itself. Endotherms can produce large amounts of metabolic heat that replace the flow of heat to the environment, and they can vary heat production to match changing rates of heat loss. Heat production is increased by such muscle activity as moving or shivering. In some mammals, certain hormones can cause mitochondria to increase their metabolic activity and produce heat instead of ATP. This non-shivering thermogenesis (NST) takes place throughout the body, but some mammals also have a tissue called brown fat in the neck and between the shoulders that is specialized for rapid heat production. Through shivering and NST, mammals and birds in cold environments can increase their metabolic heat production by as much as 5 to 10 times above the minimal levels that occur in warm conditions.

2. Another major thermoregulatory adaptation that evolved in mammals and birds is insulation (hair, feathers, and fat layers), which reduces the flow of heat and lowers the energy cost of keeping warm. Most land mammals and birds react to cold by raising their fur or feathers, thereby trapping a thicker layer of air. ■(A) Humans rely more on a layer of fat just beneath the skin as insulation; goose bumps are a vestige of hair-raising left over from our furry ancestors. ■(B) Vasodilation and vasoconstriction also regulate heat exchange and may contribute to regional temperature differences within the animal. ■(C) For example, heat loss from a human is reduced when arms and legs cool to several degrees below the temperature of the body core, where most vital organs are located. ■(D)

3. Hair loses most of its insulating power when wet. Marine mammals such as whales and seals have a very thick layer of insulation fat called blubber, just under the skin. Marine mammals swim in water colder than their body core temperature, and many species spend at least part of the year in nearly freezing polar seas. The loss of heat to water occurs 50 to 100 times more rapidly than heat loss to air, and the skin temperature of a marine mammal is close to water temperature. Even so, the blubber insulation is so effective that marine mammals maintain body core temperatures of about 36-38°C with metabolic rates about the same as those of land mammals of similar size. The flippers or tail of a whale or seal lack insulating blubber, but counter-current heat exchangers greatly reduce heat loss in these extremities, as they do in the legs of many birds.

4. Through metabolic heat production, insulation, and vascular adjustments, birds and mammals are capable of astonishing feats of thermoregulation. For example, small birds called chickadees, which weigh only 20 grams, can remain active and hold body temperature nearly constant at 40°C in environmental temperatures as low as -40ºC—as long as they have enough food to supply the large amount of energy necessary for heat production.

5. Many mammals and birds live in places where thermoregulation requires cooling off as well as warming. For example, when a marine mammal moves into warm seas, as many whales do when they reproduce, excess metabolic heat is removed by vasodilation of numerous blood vessels in the outer layer of the skin. In hot climates or when vigorous exercise adds large amounts of metabolic heat to the body, many terrestrial mammals and birds may allow body temperature to rise by several degrees, which enhances heat loss by increasing the temperature gradient between the body and a warm environment.

6. Evaporative cooling often plays a key role in dissipating the body heat. If environmental temperature is above body temperature, animals gain heat from the environment as well as from metabolism, and

evaporation is the only way to keep body temperature from rising rapidly. Panting is important in birds and many mammals. Some birds have a pouch richly supplied with blood vessels in the floor of the mouth; fluttering the pouch increases evaporation. Pigeons can use evaporative cooling to keep body temperature close to 40°C in air temperatures as high as 60°C, as long as they have sufficient water. Many terrestrial mammals have sweat glands controlled by the nervous system. Other mechanisms that promote evaporative cooling include spreading saliva on body surfaces, an adaptation of some kangaroos and rodents for combating severe heat stress. Some bats use both saliva and urine to enhance evaporative cooling.

Glossary
ATP: energy that drives certain reactions in cells
mitochondria: a membrane of ATP

1. According to paragraph 1, the most fundamental adaptation to maintain body temperature is
(A) the heat generated by the metabolism
(B) a shivering reflex in the muscles
(C) migration to a warmer environment
(D) higher caloric intake to match heat loss

2. Based on information in paragraph 1, which of the following best explains the term "thermogenesis "?
(A) Heat loss that must be reversed
(B) The adaptation of brown fat tissue in the neck
(C) The maintenance of healthy environmental conditions
(D) Conditions that affect the metabolism

3. Which of the sentences below best expresses the information in the underlined statement in the passage? The other choices change the meaning or leave out important information.
(A) An increase in heat production causes muscle activity such as moving or shivering.
(B) Muscle activity like moving and shivering will increase heat production.
(C) Moving and shivering are muscle activities that increase with heat.
(D) When heat increases, the production of muscle activity also increases

4. The word ‘minimal’ in the passage is closest in meaning to
(A) most recent
(B) most active
(C) newest
(D) smallest

5. In paragraph 2, the author explains the concept of vasodilation and vasoconstriction by
(A) describing the evolution in our ancestors
(B) giving an example of heat loss in the extremities
(c) comparing the process in humans and animals
(D) identifying various types of insulation

6. The word ‘regulate’ in the passage is closest in meaning to
(A) protect
(B) create
(C) reduce
(D) control

7. According to paragraph 3, why do many marine animals require a layer of blubber?
(A) Because marine animals have lost their hair during evolution
(B) Because heat is lost in water twice as fast as it is in air
(C) Because dry hair does not insulate marine animals
(D) Because they are so large that they require more insulation

8. Why does the author mention chickadees in paragraph 4?
(A) To discuss an animal that regulates heat very well
(B) To demonstrate why chickadees have to eat so much
(C) To mention an exception to the rules of thermoregulation
(D) To give a reason for heat production in small animals

9. In paragraph 6, the author states that evaporative cooling is often accomplished by all of the following methods EXCEPT
(A) by spreading saliva over the area
(B) by urinating on the body
(C) by panting or fluttering a pouch
(D) by immersing themselves in water

10. Look at the four squares [■] that show where the following sentence could be inserted in the passage.

The insulating power of a layer of fur or feathers mainly depends on how much still air the layer traps.

Where could the sentence best be added? Click on a square [■] to insert the sentence in the passage
(A)
(B)
(C)
(D)