Effect of cold and hot temperature on organisms

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- Temperature is perhaps the most important factor in the distribution and abundance of organisms because of its effect on biological processes, such as metabolic rates, and because of the inability of most organisms to regulate their body temperature precisely.
- For example, the organisms that form coral reefs secrete a calcium carbonate shell.
- Shell formation and coral deposition are accelerated at high temperatures but are suppressed in cold water

- Coral reefs are therefore abundant only in warm water, and a close correspondence is observed between the 20°C isotherm for the coldest month of the year and the limits of the distribution of coral reefs
- An isotherm is a line on a map connecting points of equal temperature.
- Coral reefs are located between the two 20ºC isotherm lines that are formed above and below the equator.

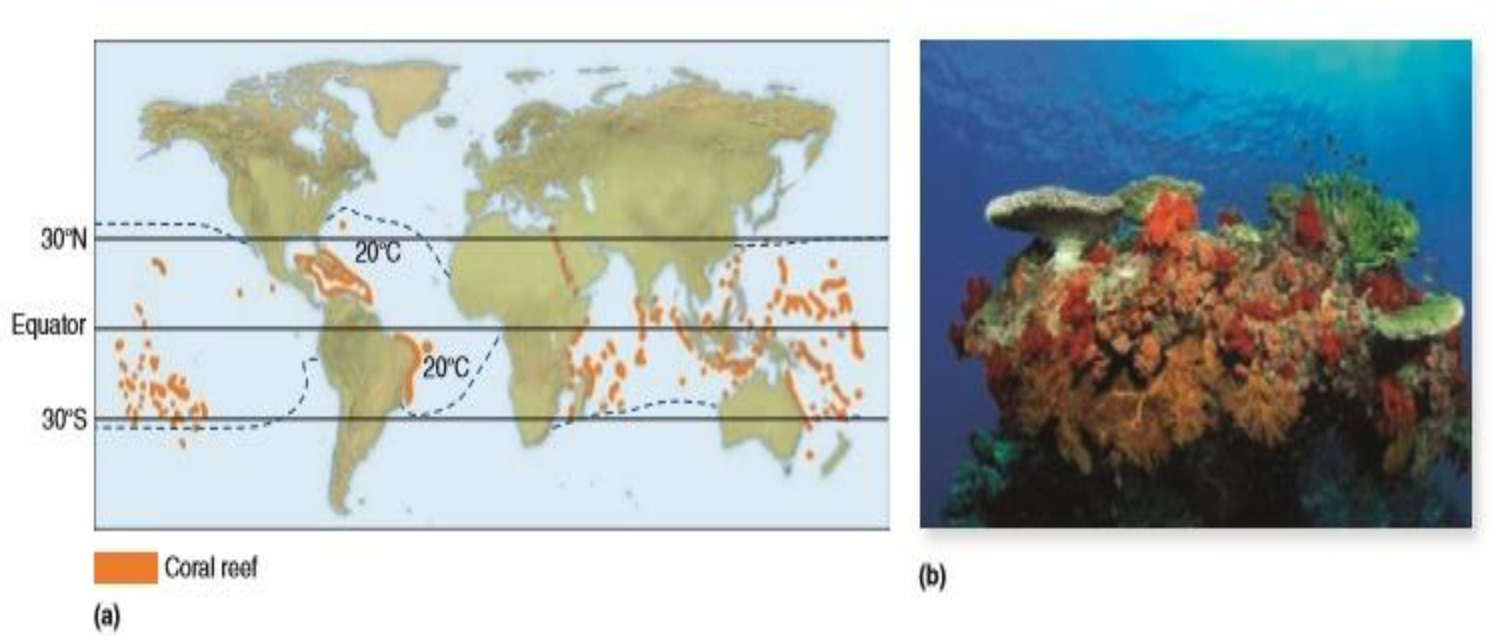

Figure 5.1 **Coral reefs occur only in warm water.** **(a)** Coral reef formation is limited to waters bounded by the 20°C isotherm (dashed line), a line where the average daily temperature is 20°C during the coldest month of the year. **(b)** Coral reef from the Pacific Ocean.

- Ecologists classify animals according to their source of heat and their ability to maintain their body temperature.
- Ectotherms rely on external heat sources to warm themselves, while endotherms generate their own internal heat.
- Homeotherms maintain an internal temperature within a narrow range.
- While the body temperature of heterotherms varies widely with environmental conditions

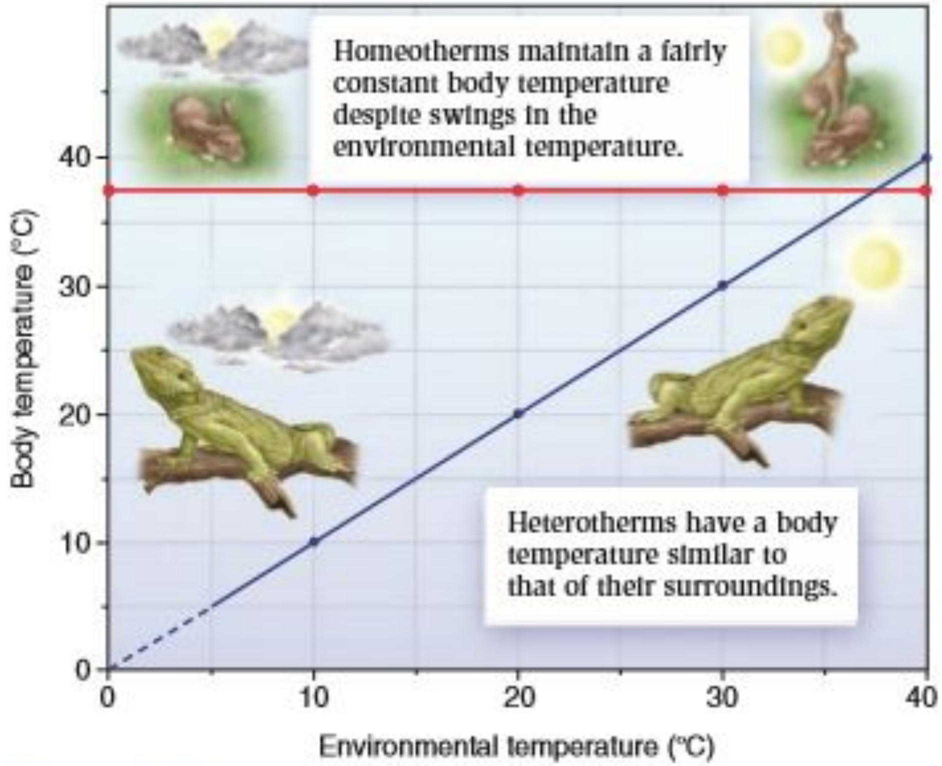

Figure 5.2 Body temperature of homeotherms and heterotherms in different environmental conditions. Homeotherms maintain stable body temperatures across a range of environmental temperatures, whereas the body temperature of heterotherms varies with the external temperature.

- Most animals fall into two categories.
- Birds and mammals are generally endothermic and homeothermic; other vertebrates and invertebrates are ectothermic and heterothermic.
- During the winter, the body temperature of hibernating mammals drops as their metabolism slows
- In effect, they are heterothermic at the transition period from fall to winter, and again from winter to spring, as they let their body temperature approach that of the ambient temperature

- Deep-water fish behave like homeotherms, because the temperature of water, and therefore their body, is essentially constant.
- The Effects of Cold Temperatures, Especially Freezing, Are Severe
- Animals use a variety of techniques to survive in cold temperatures.
- Some organisms change their behavior, curling up into a ball to reduce the exposed surface area.
- Others, such as penguins, may huddle together to conserve heat.

- Some species, notably bears, hibernate, spending the winter in a deep sleep in a secluded den where their pulse rate, breathing rate, and temperature are all reduced
- In many endotherms, shivering occurs in cold conditions whereby the body undergoes rapid muscle contractions without any locomotion.
- Virtually all of the energy liberated by the contracting muscles is used to produce internal heat.
- Many birds that remain in cold climates over winter shiver repeatedly.

- Arctic bees can raise their body temperatures by up to 15°C by shivering.
- Many small mammals of cold climates, such as hibernating bats or rodents, possess brown fat, a specialized heat-producing tissue.
- When the body temperature falls, brown fat cells increase their metabolic rate, and hence heat production.
- Many organisms minimize heat loss to the environment via countercurrent heat exchange, a mechanism that conserves body heat by minimizing heat loss in the extremities and returning heat to the body core

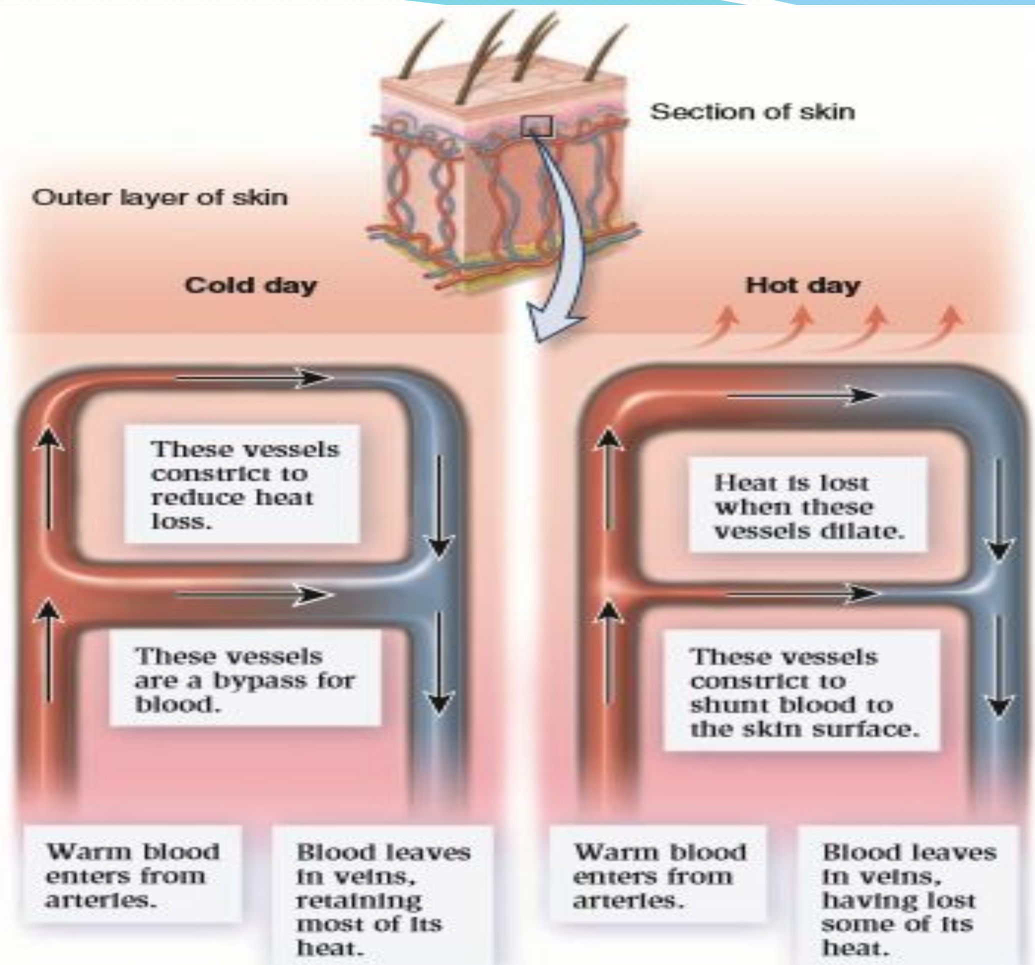

Figure 5.3 **Countercurrent heat exchange.** Near the surface of some animals' skin the surface blood vessels constrict in cold temperatures, restricting blood flow and heat loss. These vessels dilate on hot days, increasing blood flow and heat loss. Arrows indicate the direction of blood flow.

- Countercurrent heat exchange occurs primarily in the extremities such as in dolphin flippers or bird legs.
- In cold temperatures, venal blood returning from the extremities is cool while arterial blood is warmer.
- By positioning both artery and vein close together, in countercurrent heat exchange, heat moves by conduction from the artery to the adjacent vein.
- The temperature of arterial blood drops considerably, so that by the time it reaches the body surface, it has cooled, reducing heat loss to the environment and returning heat to the body's core.

- Many ectotherms, such as fi sh, use countercurrent heat exchange to warm their muscles.
- Swimming muscles generate heat, which warms the blood in the veins leaving the muscles.
- Without a countercurrent system, this heat would be lost as the warm blood enters the gills and is cooled by the adjacent water.
- However, heat from the warm veins is conducted into nearby arteries and returned to muscles rather than being lost from the gills.

- By positioning the muscle arteries close to the veins, heat is conducted to the arteries and heat loss is minimized.
- Warm temperatures increase muscle efficiency
- Some insects and a few species of amphibians release large amounts of glucose into the blood, which lowers the freezing point in much the same way as adding antifreeze lowers the freezing temperature of water in your car radiator.
- This ability to withstand freezing is called supercooling.

- Other species combine carbohydrates with proteins to produce glycoproteins.
- Glycoproteins can permit some invertebrates to withstand temperatures as low as –18°C without freezing.
- Cold temperatures mean higher metabolic costs, which in turn are dependent on high feeding rates.
- Below –4°C, the Eastern phoebe cannot feed fast enough or, more likely, find enough food to keep warm.
- Other small endotherms with high basal metabolic rates, such as shrews, must eat almost continuously and will die if deprived of food for as little as a day.

- In plants, cold temperature can be lethal because cell membranes may start to leak.
- Even immediate chilling to 10°C injures tropical plants because ions leak out of the cells and the photosynthetic and respiratory systems become inefficient.

Freezing temperatures are lethal for many plant species

- Freezing temperatures are probably the single most important factor limiting the geographic distribution of tropical and subtropical plants

- Only low-elevation tropical areas are frost free
- First, cells may rupture if the water they contain freezes.
- Second, water availability is lessened, especially during freezes.
- At –4°C and below, the ground freezes solid, effectively stopping water uptake.
- Cell dehydration can occur, similar to what happens in a drought.

- Freeze-tolerant plants may also add molecules to their cell water that lower the freezing temperature, which is another example of super cooling.
- An example of such a chemical is glycerol.
- In other freeze-tolerant plants, ice formation occurs in the extracellular space and water is drawn out of the cells.
- The dehydrated cells can withstand temperatures down to −38°C.

Animal body size changes in different temperatures

- A number of patterns relate changes in animal body size and extremity length over different geographic areas to different temperature regimes.
- The best known patterns are Bergmann’s rule and Allen’s rule.
- In 1847, Carl Bergmann noted that among closely related mammals or birds, the largest species occurred at higher latitudes, where it is colder.
- This is known as Bergmann’s rule.

- The logic behind this rule is that individuals with greater mass have a smaller surface area to volume ratio, which helps to conserve heat.
- Another pattern relating to cold temperature adaptation was proposed by J. C. Allen in 1878.
- Allen's rule states that among closely related endothermic (warm-blooded) vertebrates, those living in colder environments tend to have shorter appendages than those living in warmer environments.

- A classic example is the ear size of hares and foxes. Those species in colder, arctic environments have shorter ears than those in temperate or hot desert environments .
- The greater the surface area, the greater the heat loss.
- Hot Temperatures Limit Many Species' Distributions
- High temperatures are also limiting for many plants and animals because relatively few species can survive internal temperatures more than a few degrees above their metabolic optimum.

- Corals also sensitive to high temperatures
- When temperatures are too high, the symbiotic dinofl agellates that live within coral and contribute to its coloration die and are expelled.
- The coral tissue loses its color and turns a pale white, a phenomenon known as coral bleaching.
- Many organisms cope with heat stress by producing increased amounts of heat shock proteins (HSPs).
- At high temperatures, proteins may either unfold or bind to other proteins to form misfolded protein aggregations.
- HSPs act to prevent these types of events from taking place.

- HSPs are extremely common and are found in the genomes of all organisms, from bacteria to plants and animals
- In the Tropics, high temperatures can substantially decrease the growth rates and productivity of many crop species.
- There is now substantial interest in identifying crop strains with naturally high HSP levels and identifying thermally tolerant varieties for use in crop-breeding programs.

- Some of the life history stages most resistant to heat are the resting spores of fungi, cysts of nematodes, and seeds of plants.
- High temperatures are particularly stressful when accompanied by lack of water, as in hot deserts.
- Plants have evolved several mechanisms to live in such environments.
- Xerophytes such as cacti are able to survive in environments with little or no water.
- They have few or no leaves and a large stem that can store water

- Phreatophytes are plants that have adapted to arid environments by growing very long roots, enabling them to acquire water at great depths.
- Annual plants grow quickly when the rains come, produce seeds, and die.
- The heat-resistant seeds remain dormant until the next season.
- Animals possess many adaptations to avoid heat stress, including radiation, conduction, convection, and evaporation

- Radiation is the emission of electromagnetic waves by the surface of objects.
- The rate of emission is governed by the relative differences of the radiating body surface and the environment.
- A positive difference results in heat loss, while a negative difference, in which the outside temperature is warmer than the body, results in heat gain.
- Thermal imaging cameras show radiated heat eminating from ectotherms as orange and red colors.

- In conduction, the body surface loses or gains heat through direct contact with cooler or warmer substances such as air or water.
- The greater the temperature difference, the faster the rate of conduction.
- Some animals, such as elephants, have enlarged ears to accelerate the rate of heat loss via conduction.
- Convection is the transfer of heat by the movement of air or water next to the body.
- Convection is aided by air or water currents.
- When elephants flap their ears they create wind currents which help them cool down even more

- Evaporation occurs when organisms lose water from their surfaces and heat from a plant's leaves or an animal's body is used to drive this process.
- Many animals are able to regulate heat loss via evaporation.
- Nerves to the sweat glands stimulate the production of sweat, a dilute aqueous solution containing sodium chloride.
- In endotherms that lack sweat glands, panting helps evaporate water from the tongue surface.

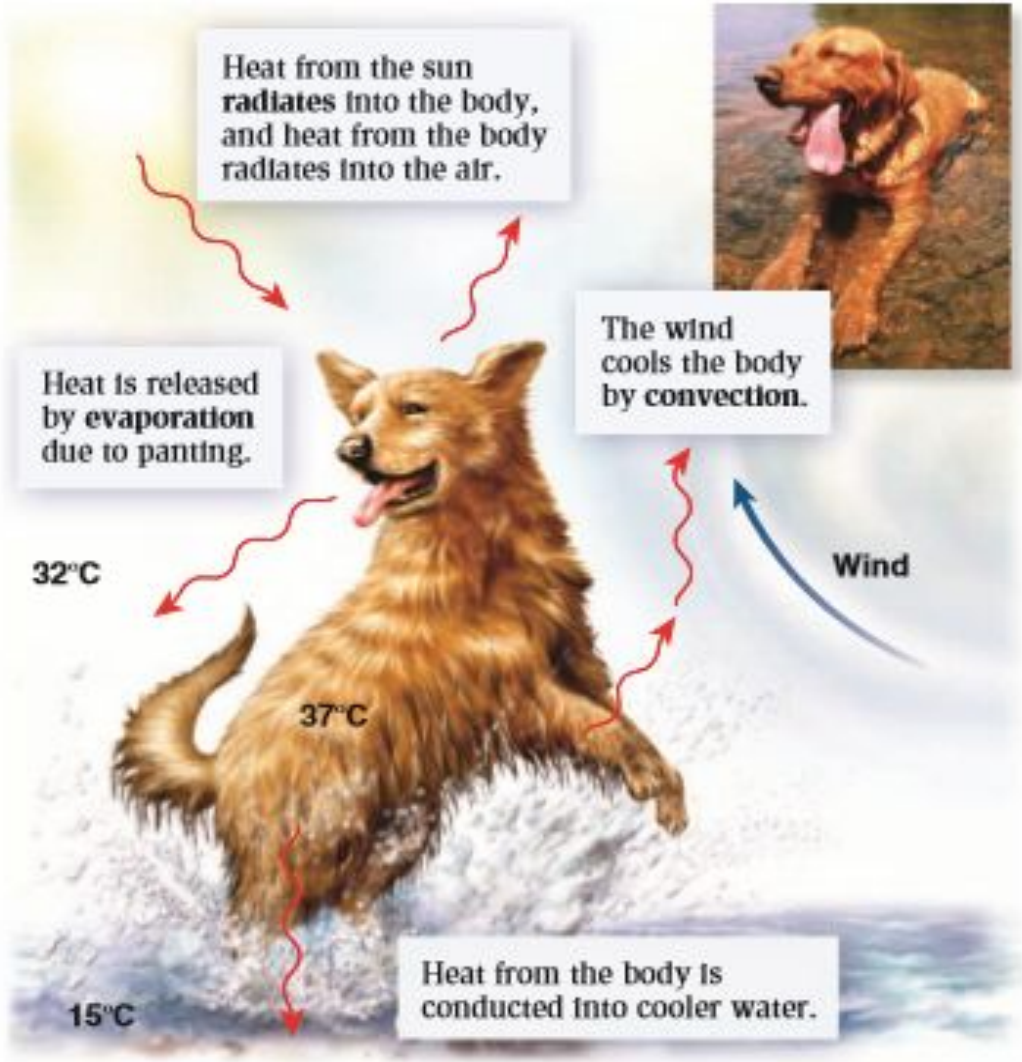

Figure 5.13 Heat exchange. The four methods of heat exchange in animals: radiation, conduction, convection, and evaporation.

- Some species depend on fi re for their existence
- Long-leaf pines therefore depend directly on fi re for their reproductive success.
- The trees also depend on fi res to thin out competing species that would otherwise eventually take over.
- Temperature extremes may be more critical than temperature averages
- Mean average temperatures do not usually limit the range of species but rather the frequency of occasional extremes, such as freezes

- Physical extremes, such as fi res or severe freezes, may be apparent only in isolated years, so ecologists often have to wait many years to determine whether extremes are limiting the distribution and abundance of plants and animals in the fi eld.

- local variations of the climate within a given area, or microclimate, can be important for a particular species.
- Because so many species are limited in their distribution patterns by global temperatures, ecologists are concerned that if global temperatures rise, many species will be driven to extinction or that their geographic ranges will shrink and the location of agricultural areas and forests will be altered.

- Wind can amplify the effects of temperature
- As air heats up, it becomes less dense and rises.
- As hot air rises, cooler air rushes in to take its place.
- Wind amplifi es the effects of temperature.
- It increases heat loss by evaporation and convection (the wind-chill factor).
- Wind also affects living organisms directly in a variety of ways.

- It contributes to water loss in organisms by increasing the rate of evaporation in animals and transpiration in plants.
- Winds can also intensify oceanic wave action, with resulting effects for organisms.
- On the ocean’s rocky shore, seaweeds survive heavy surf by a combination of holdfasts and fl exible structures.
- Wind can also be an important mortality factor in terrestrial systems.
- Hurricanes or gale force winds can kill trees, breaking trunks or completely uprooting individuals

THANK YOU