8

Plants and animals can exist in physically challenging environments due to a variety of physiological adaptations.

Physical Ecology of the Organism

The environment has two distinct components. The biotic component consists of the living organisms. Much of ecology is devoted to the study of the interactions of coexisting plants and animals. Topics like energy flow, competition, predation, and parasitism are all examples of these types of biological interactions. The abundance and distribution of species must be affected in some way by the numbers and kinds of parasites, predators, and competitors in the local environment. However, these biological interactions cannot tell us the whole story.

Physical aspects of the environment are also important in determining the abundance and distribution of species. Many limitations of the physical environment are obvious; for example, photosynthetic plants need light in order to live. Some places on Earth are simply too cold or too hot for many species to live there. We can learn about adaptation by studying organisms that live in extreme conditions. Even in the harshest environments, we find organisms that have evolved unusual adaptations that permit them to live there. For instance, how is it possible for fish to live in oceans so cold that the temperature is actually below freezing?

The size and shape of an organism also determines the kinds of interactions it will have with its environment. For instance, there is a simple relationship between the surface area of an organism and its size. Because it is in direct contact with the physical environment, usually either air or water, the surface area of an organism is an important location for the exchange of heat and gases. We will see that there are important consequences to organism function that follow as a direct consequence of the surface area to volume relationship.

Temperature and Light

8.1 Animals regulate their temperature in various ways

Some of the most conspicuous adaptations of plants and animals are those that help overcome problems created by the physical environment. Animals have a variety of ways to reduce heat loss in cold environments, for example, fur, feathers, and fat layers. Plants in very warm, dry climates have thick, waxy leaves to help prevent water loss. In this module we will review some of the problems that the physical environment—particularly temperature and light—poses to organisms. We will also look at how various organisms deal with these problems.

Temperature When we consider the possibility of life on other planets, we can immediately eliminate most of them, because we believe they are either too hot or too cold to support life as we know it. Even on Earth there are places where temperatures are too extreme for life. In those places where life can exist, the rate of an organism's chemical reactions—its metabolism—will be affected by its body temperature.

Animals are often classified according to how they maintain their body temperature, but the relevant terminology is often used imprecisely. For example, the terms **cold-blooded** and **warm-blooded** are used to describe animals. These terms refer to how the animal feels when touched. Birds and mammals are considered warm-blooded, and all other animals are called cold-blooded. However, a lizard that has been basking in the sun can feel quite warm to the touch.

Other commonly used terms are *poikilotherm* and *homeotherm*. These refer to whether an animal's body temperature tends to vary (**poikilotherm**) or stay constant (**homeotherm**). However, these terms also tend to be confused, since there are mammals that hibernate, causing their body temperatures to vary significantly. Deep-sea fish show little variation in their body temperatures, because their environmental temperature changes little.

A better set of terms refers to how animals generate body heat. **Ectotherms** require external sources of heat energy, while **endotherms** generate heat internally from their own metabolism. These various definitions, and the animal groups they apply to, are summarized in Figure 8.1A.

If a plant or animal cannot regulate its body temperature, its metabolism will slow down as the temperature cools down. Animals that cannot regulate their body temperature will become less active in cold conditions. Some animals, the endotherms, attempt to avoid these problems by using the chemical energy of metabolism to keep their body temperature constant. As a consequence, endotherms can live and remain active in a far greater range of environments than ectotherms can.

This does not mean that ectotherms are completely at the mercy of the environment. In later modules we will consider the effect of temperature on organismal function in more detail, and we will review some of the short-term responses that ectotherms can make to help them adjust to new environmental conditions.

Light An important issue in contemporary global ecology is the level of ozone in our atmosphere. This level is important because ozone filters out harmful ultraviolet light (UV) energy. However, UV light is not the only part of the light spectrum that is subject to filtration. Both the gaseous atmosphere and water absorb significant portions of the light energy that arrives from the sun. This filtering has a profound impact on the energy available to plants for photosynthesis. Both the type and amounts of light are affected by atmospheric filtering.

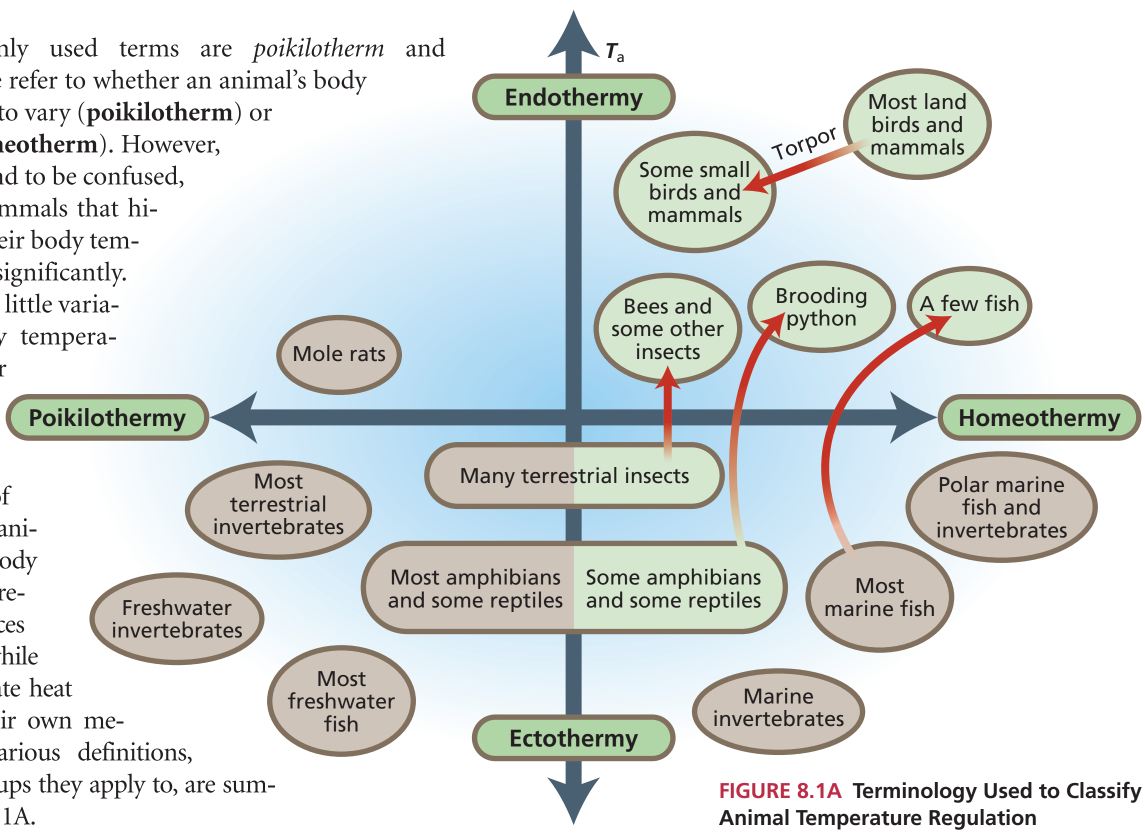


FIGURE 8.1A Terminology Used to Classify Animal Temperature Regulation

Temperature profoundly influences organismal function 8.2

Temperatures on Earth vary over a tremendous range. In Antarctica, low temperatures have been recorded down to −89°C; in other environments, high temperatures range from 80°C in deserts to 100°C in hot springs. In the deep sea, hydrothermal vent temperatures may reach 350°C.

The internal temperatures at which plants and animals can function are much more limited. While some unicellular organisms can live at 90°C, few multicellular organisms can live at temperatures much in excess of 50°C. No organism can function once it is frozen, so the lowest body temperature of functioning organisms is determined by the freezing point of seawater, which is −1.86°C. Some animals can live in environments where the temperature dips to −60°C, but these are birds and mammals that maintain a high internal body temperature by using metabolic energy. Some organisms, like nematodes, tardigrades, and certain insect eggs, can be revived after freezing in liquid helium (−269°C). As Figure 8.2A shows, the bodies of most endotherms operate within a fairly narrow range of temperatures. This range is somewhat higher for ectotherms, but it is still narrow compared to the range of environmental temperatures.

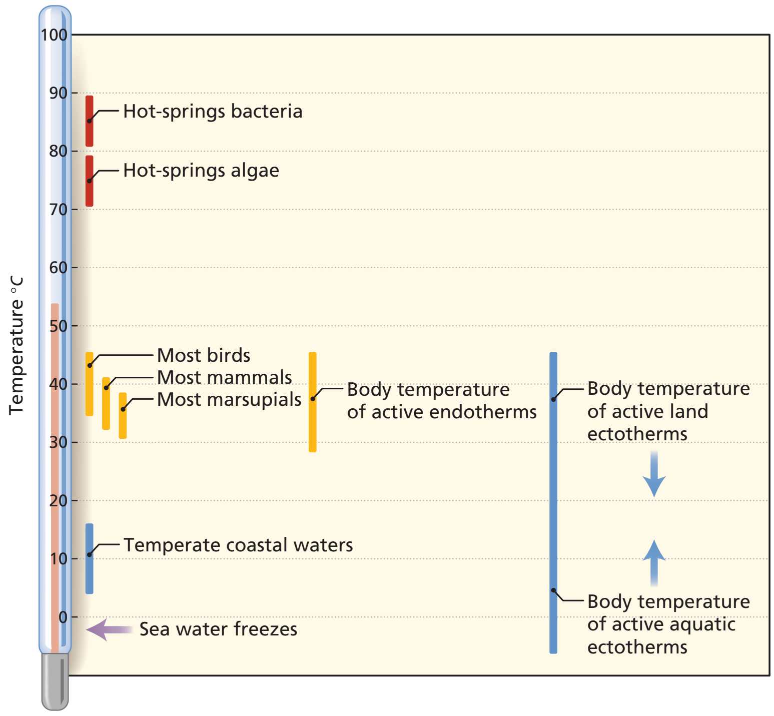


FIGURE 8.2A The Temperature Range Tolerated by Different Plants and Animals

Animals and plants lose and gain heat energy in different ways. The flow of energy shown in Figure 8.2B is typical of animals, but many of these energy flows also occur in plants.

Conduction is the flow of heat energy that occurs when two bodies at different temperatures come into direct contact. Heat energy flows from the warmer to the colder object. On the outside surfaces of animals, fur and feathers provide insulating surfaces that reduce heat loss through conduction. Some ectotherms use conduction to warm their bodies. For instance, lizards lie on rock surfaces that have been heated by the sun in order to warm their bodies.

Heat may be transferred between two bodies at different temperatures via a third moving or fluid layer of either gas or liquid. This process is called **convection.** Many animals have a small layer of air, surrounding their bodies, that is warmed by the animal. Convection mediates the transfer of heat from the organism through the boundary layer and into the surrounding environment. Heat loss by convection is typically much quicker than by conduction.

Objects that have heat energy also emit **radiation**. The type and amount of radiation depend on the temperature of the object and other properties that are related to its color and reflective surface. Living organisms emit energy in the infrared wavelength range. The amount of energy lost is about 300–500 watts per square meter. A resting mammal with 1 square meter of radiating surface may only produce 20 watts from their own metabolism. However, most of the energy lost from radiation is gained through the absorption of radiant energy from the surrounding environment.

As water changes state from liquid to gas, it absorbs considerable energy. Such **evaporation** is an important means of dissipating heat on the surface of an organism. The rate of evaporation will be a function of the surface temperature of the organism, the relative humidity of the air, and convective processes. Some larger land animals use evaporation as a means of cooling. However, since evaporation entails water loss, it is usually not an efficient method for cooling very small organisms or for cooling in very dry environments.

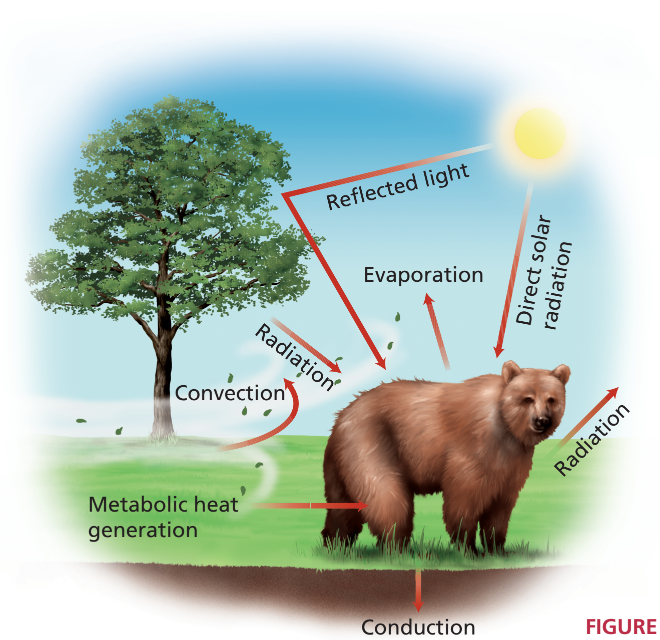


FIGURE 8.2B Thermal Exchanges between an Animal and the Environment

8.3 The temperature coefficient, Q_{10}, expresses the effect of temperature on organismal function

The kinetic energy of molecules increases with temperature, which also increases the rate of most chemical reactions. There are some limits to this effect in living things. For instance, temperatures may get so high that the folding of protein enzymes is disrupted, and the reactions dependent on these enzymes then cease altogether.

Over normal metabolic temperatures, there is a simple relationship between temperature and chemical reaction rates. The rate at which chemical reactions accelerate due to temperature is called the **temperature coefficient**, or $\boldsymbol{Q_{10}}$. As shown in Figure 8.3A, the log of the reaction rates at elevated temperatures increases with temperature in a linear fashion.

Q_{10} is used to express the effect of temperature on organismal function. The temperature coefficients for many biological processes are in the range of 2–3. A Q_{10} of 2 means that the rate of the metabolic process doubles for each increase of 10°C. Thus an increase of 20°C will quadruple the rate of the reaction with a Q_{10} of 2.

For organisms that cannot regulate temperature, like plants and ectothermic animals, most of their metabolic processes will increase as they warm up. If we take a typical insect—like the Colorado potato beetle—that has been raised at

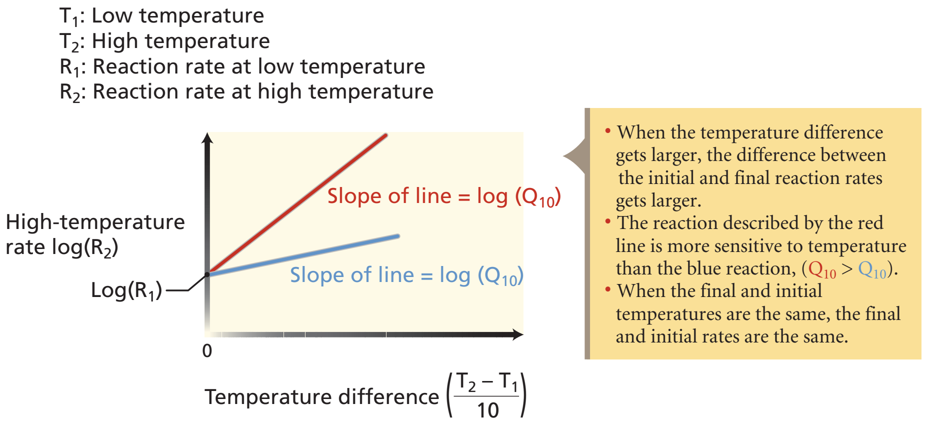


FIGURE 8.3A Increasing Temperature Accelerates Chemical Reactions

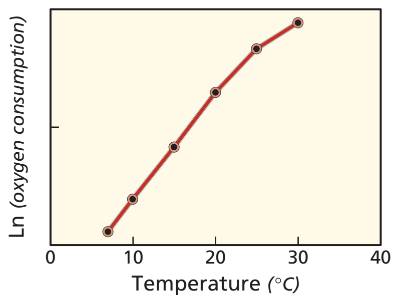


FIGURE 8.3B Oxygen Consumption of the Colorado Potato Beetle

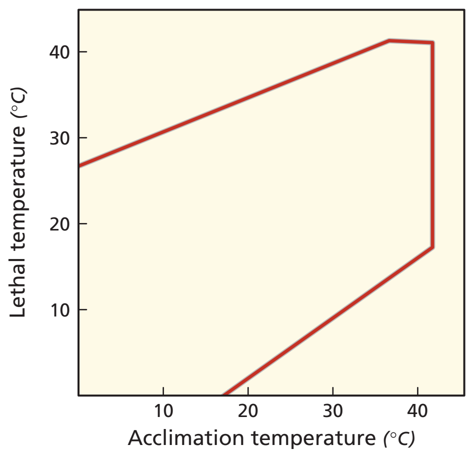


FIGURE 8.3C Acclimation and Lethal Temperatures for Goldfish

8°C, and increase the ambient temperature, the insect's oxygen consumption predictably increases (Figure 8.3B). The elevated oxygen consumption reflects the beetle's increased need for energy to fuel the accelerated metabolism rates brought on by high temperatures.

Often the metabolic performance of an organism is less efficient when its body temperature has just been significantly increased or decreased. Most organisms go through a process called **acclimation** if left in these new conditions. Acclimation may take from days to weeks and involve physiological and biochemical changes that allow the organisms to perform better in the new environment. These changes may include the increased or decreased production of different enzymes, or changes in the molecular components of cell membranes. Sometimes this acclimation process is called *adaptation*; however, this term can be confused with the evolutionary concept of adaptation by natural selection. We will avoid using the word *adaptation* to describe individual physiological responses to the environment.

We can follow the process of acclimation to different temperature regimes in fish by determining the low and high temperatures at which adults can survive. In Figure 8.3C we see that adult goldfish increase both their lower and upper tolerance zones as they become acclimated to higher temperatures.

8.4 Life at extreme temperatures reveals how organisms adapt to environmental stress

FIGURE 8.4A The Antarctic fish *Trematomus borchgrevinki*

Very high and very low temperatures present different types of problems for living organisms. At high temperatures, proteins that are essential for life may become unfolded, or *denatured*, and so are unable to perform their structural or enzymatic functions. At very low temperatures, water within the cells begins to freeze. The solid ice crystals that then form may cause irreversible damage to the cells, killing the organism. Yet some fish live in the polar oceans at temperatures of about −1.8°C (Figure 8.4A). Due to the high salt content of seawater, its freezing point is depressed below the value for pure water (0°C) to −1.86°C. The ocean water around the poles has a fairly consistent temperature of about −1.8°C. We would expect ice to form in fish at this temperature. How do fish such as the one in Figure 8.4A avoid this problem?

Some species, characterized as **freeze-intolerant**, die if frozen but can live in very cold environments by preventing ice formation. Living organisms accomplish this in the same way people prevent water in their car radiators from freezing: with antifreeze. Adding antifreeze solutes to water depresses the freezing point. Certain compounds do this quite effectively. One compound used by a number of insects is glycerol. For instance, the winter gallfly survives winters in Alaska by increasing glycerol concentration to almost 50 percent. The overwintering immature gallflies can survive temperatures down to −60°C.

Fish also use antifreeze, but a different type. Antarctic fish have compounds called **glycoproteins**, composed of protein and sugar molecules, that effectively inhibit ice crystal formation, as shown in Figure 8.4B. Antifreezes have been found in fish from 11 different families, and the chemical structures of these antifreeze molecules are quite different from each other. This information suggests that the use of antifreeze compounds has evolved independently several times.

Other groups, labeled **freeze-tolerant**, can survive periods of freezing. These organisms typically employ two methods of coping with freezing. The first is to maintain high levels of glycerol in their cells; this reduces the temperature required for freezing. Glycerol also can reduce cell damage once freezing has occurred. Secondly, when ice does form in a freeze-tolerant organism, it often occurs in the intercellular spaces, thus reducing damage to cell contents. Ice formation requires a seed or nucleating agent. The nucleating agent can be an ice crystal, or it may be some other compound. Many freeze-tolerant species have high-molecular-weight proteins in their intercellular spaces that act as nucleating agents and thus encourage ice formation outside of the cell.

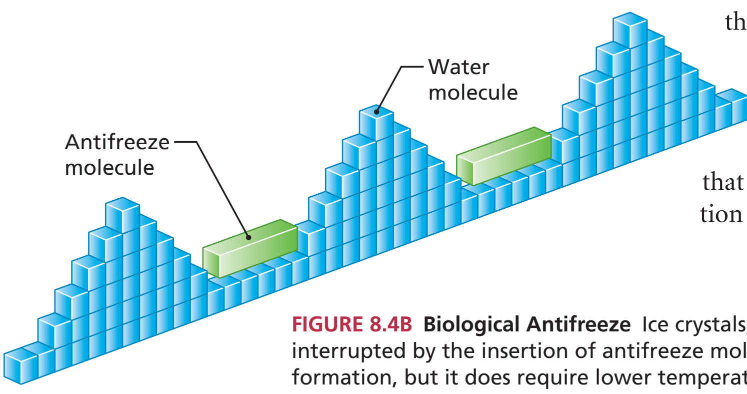


FIGURE 8.4B **Biological Antifreeze** Ice crystals, represented as cubes, have their growth interrupted by the insertion of antifreeze molecules. The antifreeze does not prevent ice formation, but it does require lower temperatures for ice to form.

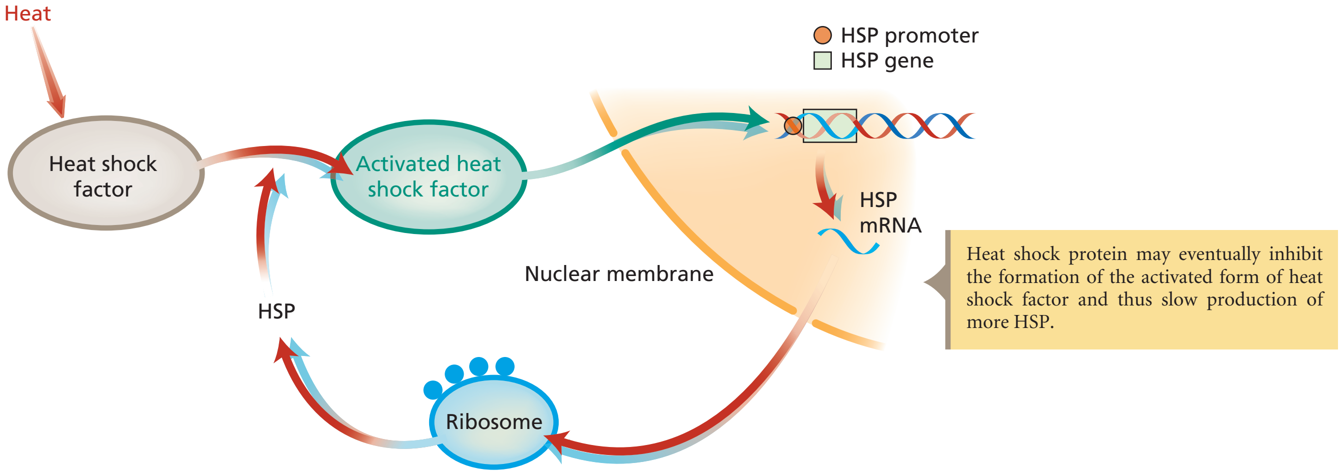


FIGURE 8.4C **The Regulation of Heat Shock Proteins**

High temperatures are also stressful and potentially deadly. Many organisms show a similar response to a sudden increase in temperature, called the **heat shock response**. The heat shock response is rapid, happening in a matter of minutes to hours. It involves the production of several types of proteins called **heat shock proteins** or **HSPs**. The HSPs act as molecular chaperones for proteins that have become unfolded. A molecular chaperone stabilizes protein structure and aids the protein in resuming its correct three-dimensional structure so that it can function properly.

How does the heat shock response work? The sudden increase in temperature causes a monomeric molecule called the *heat shock factor* to become a trimer. In this activated form, the heat shock factor interacts with the cell's nuclear DNA to initiate the transcription of HSP RNA, which is then translated into functional HSP (Figure 8.4C).

Several other stress conditions can trigger the heat shock response. It is a general physiological mechanism for coping with environmental stress.

8.5 The physical properties of light striking the Earth constitute a key environmental factor mediating the physiology, distribution, and abundance of organisms

Almost all biological systems ultimately depend on sunlight for their energy. The properties of light thus influence many features of biological systems, such as where life can exist.

An important physical property of light is its wavelengths. Light from the sun is composed of multiple wavelengths, some visible to the human eye and others not (Figure 8.5A). Energy in the ultraviolet range (not visible to the human eye) is further divided into ultraviolet A (315 nm to 380 nm) and ultraviolet B (280 nm to 315 nm). This high-energy light can damage biological tissues, but fortunately much of it is absorbed by the ozone in our atmosphere (Figure 8.5B). The other wavelengths of light are also reduced in intensity as they pass through the Earth's atmosphere, but the blue and ultraviolet are the most attenuated. Much of the blue light is scattered (reflected) in the atmosphere, giving rise to the blue color of the sky. Most of the sun's energy reaches the Earth's surface in the range of visible light. It is these wavelengths that plants use for photosynthesis.

Light from the sun is composed of multiple wavelengths, some visible to the human eye and others not.

Plant chlorophyll absorbs light in the blue and red wavelengths and reflects green light, giving leaves their usual green color. Light is attenuated very rapidly in water (Figure 8.5C). As a consequence, most water plants are found close to the surface of the water column. The light-limited distribution of plants is determined by the **compensation point:** the intensity of light at which the production of energy by photosynthesis just equals its consumption by respiration. At light intensities below the compensation point, a plant suffers a net loss in energy.

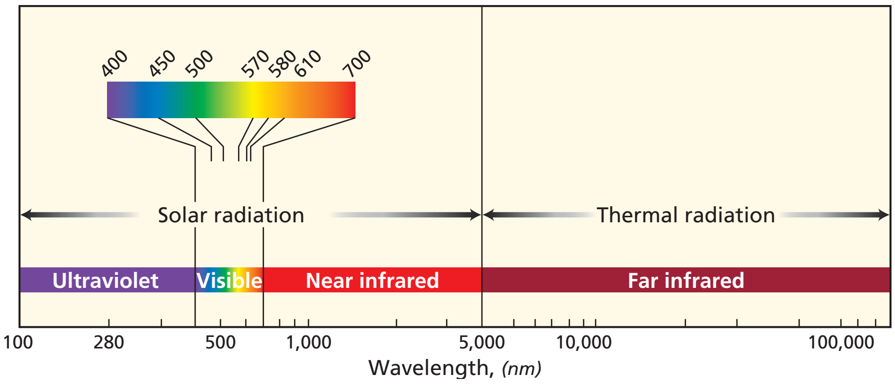


FIGURE 8.5A Properties of Light That Reaches the Earth's Surface Visible light is a small portion of the electromagnetic spectrum.

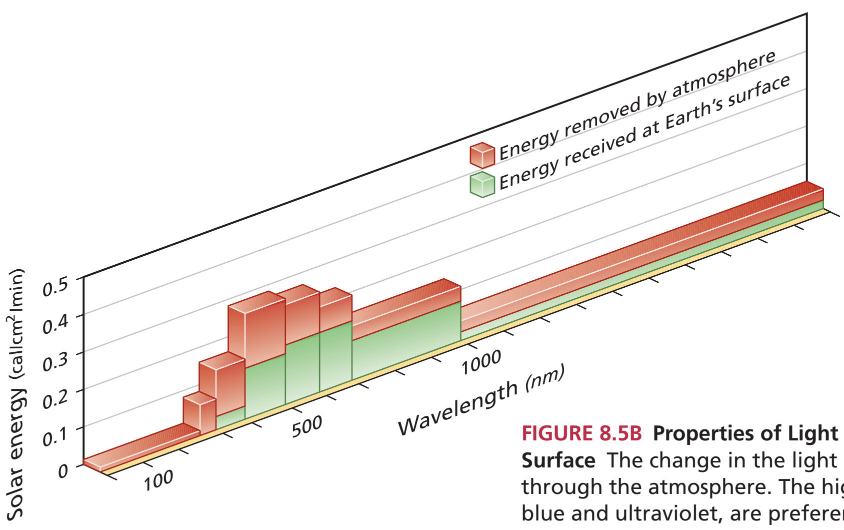


FIGURE 8.5B Properties of Light That Reaches the Earth's Surface The change in the light spectrum after it passes through the atmosphere. The higher-energy wavelengths, blue and ultraviolet, are preferentially removed.

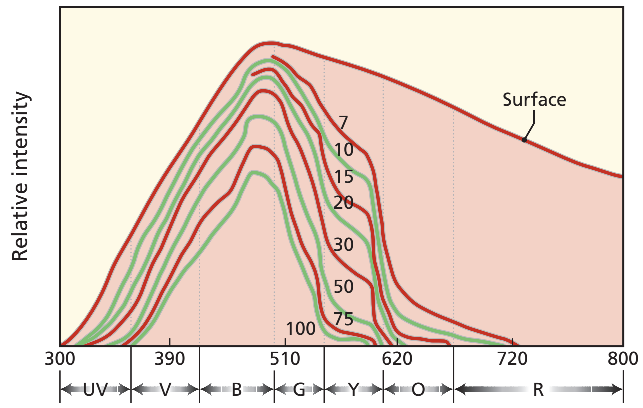


FIGURE 8.5C Properties of Light That Reaches the Earth's Surface The absorption of light energy in pure water. Total energy is reduced very quickly. The numbered lines show the intensity of light at different depths, measured in meters, below the water surface.By 100 meters, very little visible light penetrates the water column. The longer, red wavelengths are more rapidly removed.

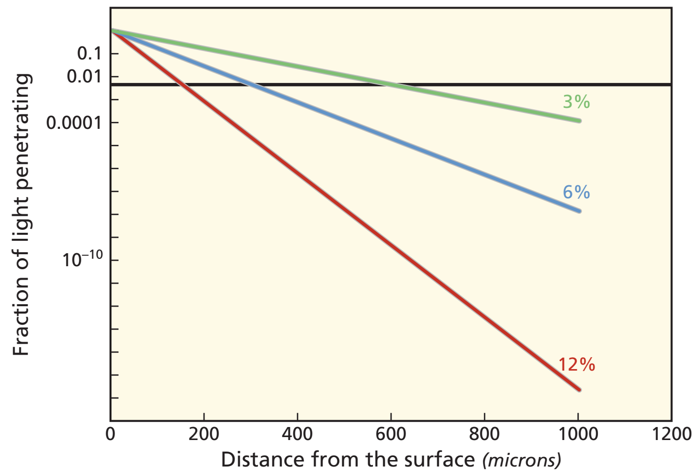


FIGURE 8.5D Light Penetration in a Leaf

Even in bright sunlight, energy is absorbed as it penetrates the surface of a leaf. How deeply can chloroplasts be located in a leaf and still receive enough light to stay above the compensation point? The attenuation of light through a transparent medium can be described by an equation known as Bouguer's Law. This law predicts an exponential decrease in light intensity with distance from the surface of the leaf. Figure 8.5D shows this relationship for three different concentrations of chloroplasts: 3, 6, and 12 percent of leaf volume. The horizontal black line represents the compensation point, assuming bright sun. Even with this favorable assumption, the chloroplasts should not be deeper than a few hundred microns (1 micron = 0.001 mm). Only those chloroplasts at distances above the black line get enough light. Because of this limitation, plants do not have thick round leaves, since light cannot penetrate the interior of such an organ. Leaves must be flat, with much surface area, because their chloroplasts must be concentrated on the surface layer of the leaf.

THE SIZE AND SHAPE OF ORGANISMS

8.6 The surface area to volume ratio of an organism affects its interaction with the environment

Organisms show tremendous variation in size. On the small end of the spectrum are the unicellular *Mycoplasma* (Figure 8.6A), which may weigh less than 0.1 picogram (10^{-13} grams). The largest animal that has ever lived is the blue whale (Figure 8.6A); each one weighs about 100,000 kilograms (10^{8} grams). But do new functional problems arise in very large organisms that are not present in small organisms? Perhaps a whale is no different than a *Mycoplasma* in the way it moves, acquires energy or dissipates heat, except it happens on a much larger scale.

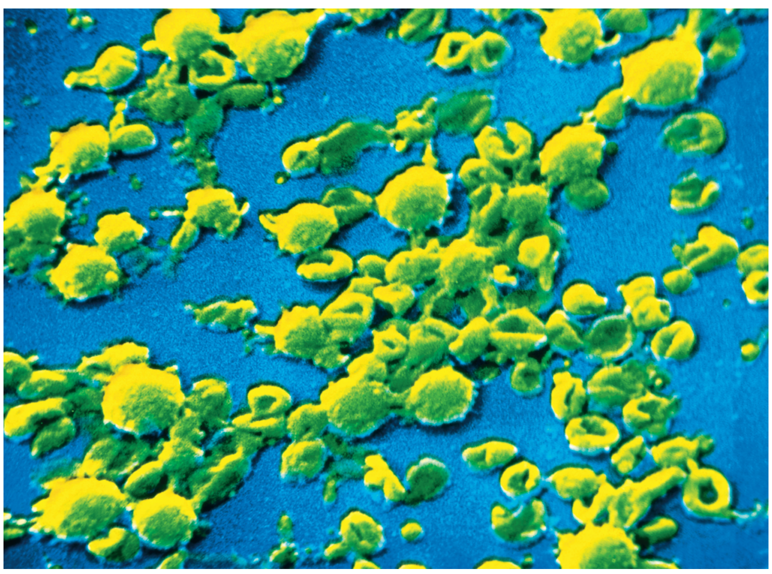
Surface Area to Volume Ratio In fact, new functional problems arise when organisms get larger. Some of the most important problems arise from changes in the surface area to volume ratio of an organism. We can roughly quantify these problems by considering a sphere. From high school geometry, recall that the surface area of a sphere is equal to $4\pi r^2$, where r is the radius of the sphere. The volume of the same sphere is equal to $(4/3)\pi r^3$. The ratio of surface area to volume is therefore equal to $3/r$. The biological meaning of this relationship is that as a sphere gets larger, it has less surface area per unit of volume. Larger organisms will have relatively smaller surface areas.

Since the volume of an organism is related to its overall size or weight, we can plot the surface area to volume ratio as a function of volume or size (Figure 8.6B). The relative surface area decreases for larger spherical objects. Although most plants and animals are not spheres, the same general relationship holds.

Why is this relationship important? Let's look at a couple of examples that show the relevance of the surface area to volume ratio. For instance, the weight or volume of an animal is related to how much heat it generates from metabolism. However, heat is lost to the environment through the animal's surface. Thus, the loss of metabolic heat energy by radiation depends on the surface area of the animal, not its volume. In another instance, the amount of water in a plant or animal is proportional to its size or volume. However, water is usually lost through the exposed surface of the plant or animal, so surface area is also the most relevant parameter in determining water stress.

The consequences of these relationships are often dramatic. Desert plants are under severe water stress; as a result, their photosynthetic surfaces are round and large to reduce the total surface area (Figure 8.6C). Plants that live in humid tropical areas, on the other hand, may have broad, very flat leaves because water loss is less of a concern and maximizing exposed area to the sun is more important.

The Importance of Scale Effects When we look at morphological or life-history characters in many species, we often see a relationship between the quantitative value of the character and the organism's size. Later in this chapter we consider the problem of support in the context of an organism's size. We will also examine methods for studying the relationship between size and functional characters. Such "scale effects" are some of the most important of all quantitative patterns in biology.



Mycoplasma agassizii

Blue whale

FIGURE 8.6A Organisms Vary Greatly in Size

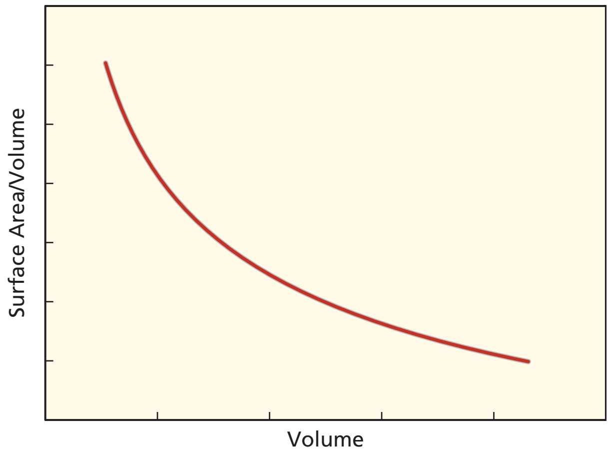


FIGURE 8.6B Relative Surface Area Decreases for Larger Organisms

In evolutionary biology, scale effects must frequently be taken into account. For instance, suppose two populations of an organism have evolved in different thermal environments, one hot and the other cold. One hypothesis might be that the metabolic rate of the organism in the hot environment is higher due to genetic changes following evolution. A controlled experiment would raise individuals from both populations to a common temperature and measure their metabolic rates. Before comparing these metabolic rates, the experimenters must also determine that the individuals from each population are the same size, since larger individuals will have higher metabolic rates when all other factors are equal. This is an example of a scaling effect. While it might be interesting that there are size differences between individuals from each population, that is certainly a different effect than is the case where two individuals of the same size have different metabolic rates.

FIGURE 8.6C These plants differ in the amount of exposed surface area. These differences reflect the varying levels of water stress in the tropics and deserts.

8.7 Changes in size have a major effect on organismal structure and function

As organisms change in size, they are likely to encounter a variety of new problems. Some of these problems have been the subject of previous modules in this chapter. For instance, for the very smallest organisms, which are 2 mm or less in diameter, diffusion can supply the cell with all its oxygen needs. However, larger organisms need some type of specialized delivery system for oxygen. Animals that rely on blood for gas transport have circulatory systems to deliver oxygen and take up carbon dioxide to body tissues. Animals with open circulatory systems have a limited ability to control the velocity and distribution of blood. Closed circulation found in all vertebrates and some invertebrates has blood flowing through a continuous circuit of tubes.

Plants and animals also encounter increasing problems with support as they get bigger. The greater mass of large organisms means greater gravitational forces. Plants eventually bend and break under their weight unless their trunks are thick enough to withstand gravity. From the physical properties of wood, the thickness of tree trunks required to prevent collapse can be calculated (Figures 8.7A and 8.7B). The required thickness of a tree's trunk grows exponentially as the size of the tree increases (notice the log scale in Figure 8.7A). Actual trees are not as large as the theoretical curve would permit. This finding is reasonable, since real trees have to withstand other forces, such as wind from storms, in addition to gravity.

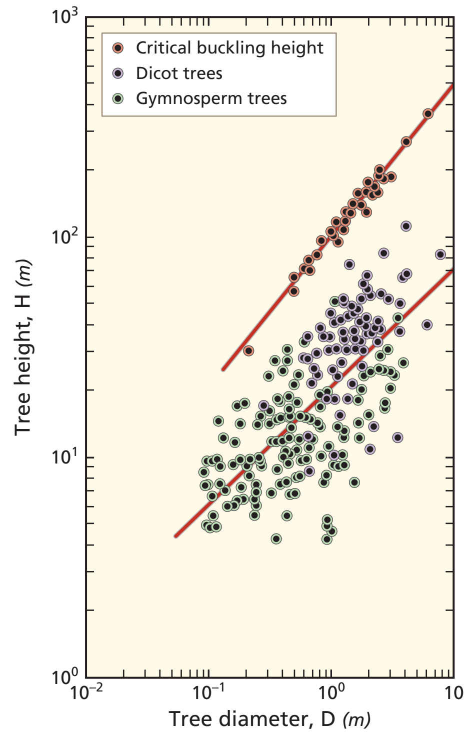


FIGURE 8.7A The Diameter of Tree Trunks Determines Buckling Height A tree buckles under its own weight if the trunk is too narrow.

Animals face similar problems. Skeletons serve as the support systems of vertebrates. The width of critical bones increases much faster than does the size of the animals in which they are found (Figures 8.7C and 8.7D). Do the requirements of bone size place natural limits on the size of land animals? They might, but before that limit is reached other factors come into play, including the dissipation of heat. Excess heat generated by metabolism must be dissipated from the skin surface. While there are several factors that affect the dissipation of heat in large animals, their small surface area to volume ratio is an important one. It is no coincidence that the largest known animals—whales—live in the ocean. Life in the ocean means that the surface of the whale is in contact with water, which has a much higher heat transfer capacity than air and so can more effectively remove heat. ❖

FIGURE 8.7B Redwoods are one of the largest terrestrial plants; they must have a correspondingly wide base to support the entire structure.

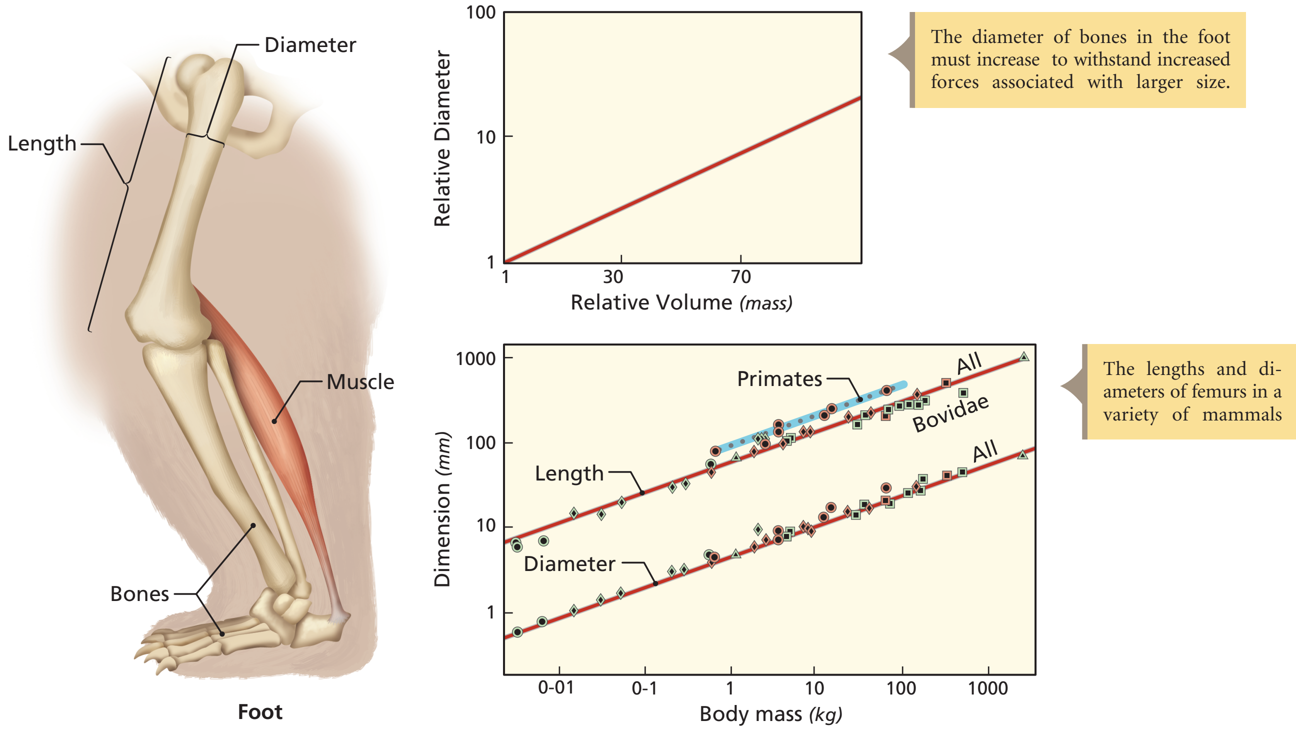


FIGURE 8.7C **Larger Animals Require Thicker Bones.**

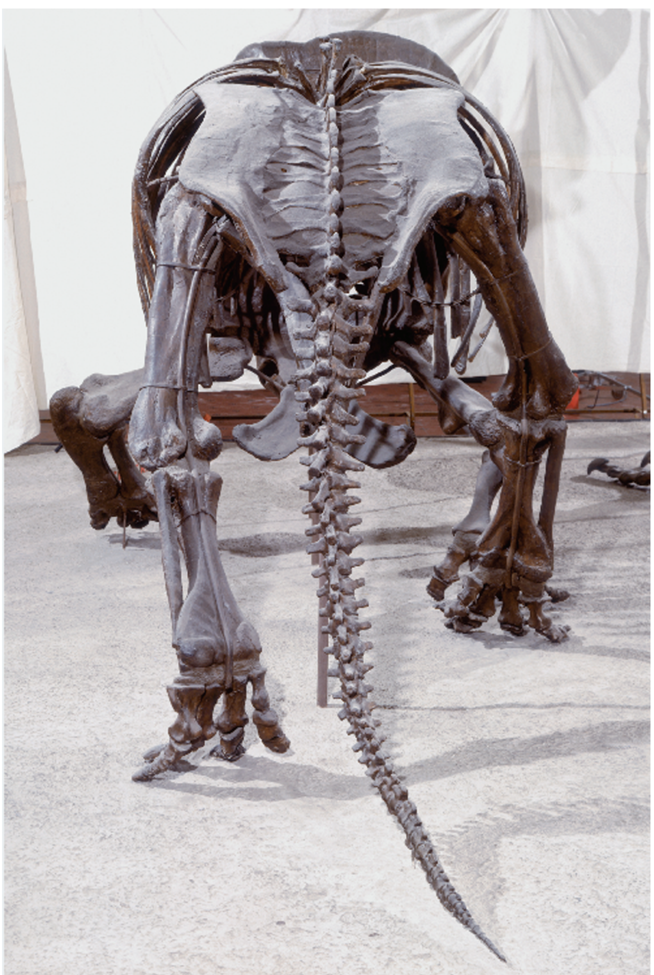


FIGURE 8.7D The triceratops, which is thought to have weighed 6–8 tons, was supported by immense legs.

8.8 Allometric methods are used to quantify changes in form and function associated with size

One way to study and understand a physiological process is to compare that process in many different organisms and see how it changes. However, organisms differ in size; and that alone might lead to differences in the physiological phenomenon under study. How could we determine if the change in a physiological character was simply due to a size difference, or whether some other factors were important?

It would take less energy to support 100 kg of elephant than it would 100 kg of mice.

If we consider a simple cube with edge length L, it is easy to compute its surface area ($6L^2$), and its volume (L^3). Even when the volume is not a cube, the surface area is proportional to L^2 and the volume (V) to L^3. These relationships imply that an organism's length is proportional to $V^{1/3}$ and the surface area is proportional to $V^{2/3}$ (Figure 8.8A). In practice, if there appears to be a relationship between a character and weight raised to the two-thirds power, it is reasonable to suppose that the character is affected by the surface area of the organism.

The study of the relationships between physiological characters and size is called **allometry**. These types of relationships can be written mathematically as:

$$\text{character} = aV^b$$

where a and b are constants, and V may be the volume but more often is the weight of an organism.

If we take logarithms of this equation, it looks like this:

$$\log(\text{character}) = \log(a) + (b)\log(V)$$

Therefore, the slope of this log-linear equation is b.

The metabolic rates of some mammals and birds are plotted against their weights on a log scale in Figure 8.8B. The slope of this line is 0.75. Thus, the metabolic rate of animals increases faster than expected if it were determined by surface area ($b = 0.67$), but slower than expected if it were directly related to weight ($b = 1$).

These allometric relationships are important when comparing animals of different sizes. For instance, if you wanted to compare the metabolic rates of seed-eating birds to the metabolic rates of insect-eating birds, you would first need to account for the sizes of the birds. For example, if the insect-eating birds happened to be larger on average than the seed-eating birds, we would expect the total organismal metabolic rates to be greater due to the size differences alone.

The results in Figure 8.8B can also be used to address whether metabolic rate per kilogram, or **specific metabolic rate**, of an animal is different for small and large animals. When analyzed this way, the specific metabolic rates decrease with size of the organism. In other words, it would take less energy to support 100 kg of elephant than it would 100 kg of mice.

The principles of allometry can also be applied to plants. In Figure 8.8C the total mass of seed per fruit is plotted against fruit biomass. The slope of this line is just about 1, indicating that the mass of seeds changes in proportion to the mass of fruits that contain them. In a similar fashion, in Figure 8.8D, we see that the number of seeds in the cones of conifers changes in direct proportion to the mass of the cones.

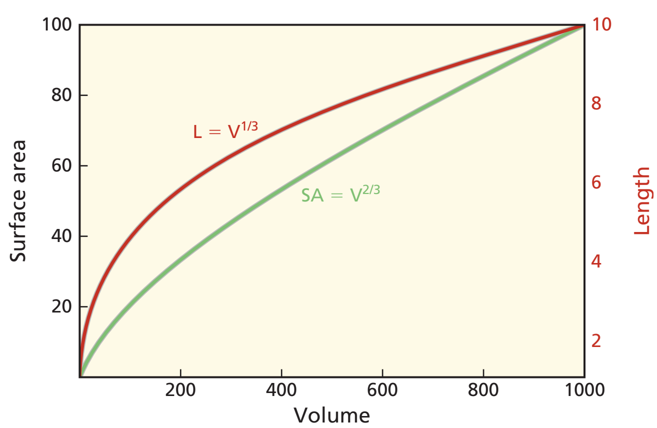


FIGURE 8.8A Linear Dimensions and Surface Area Are Related to Organismal Volume Physiological characters that are related to the length or surface area of an organism will also show a relationship to the volume or weight of an organism.

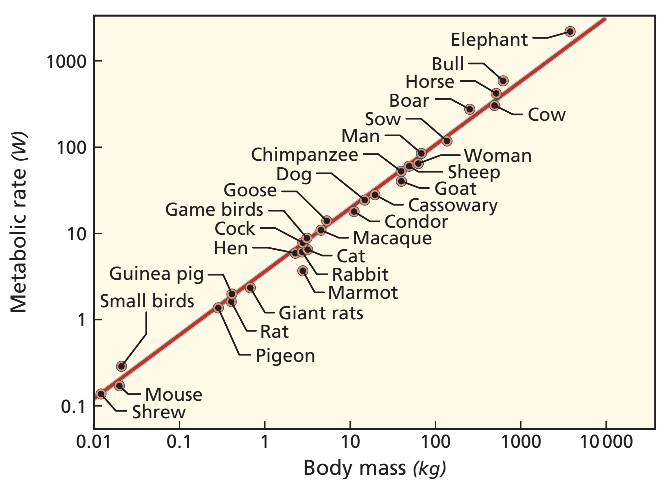


FIGURE 8.8B Metabolic Rate Increases with Weight to the Three-fourths Power The metabolic rates of many birds and mammals as a function of size. Each axis has been log transformed. Metabolic rate is proportional to $(\text{weight})^{0.75}$.

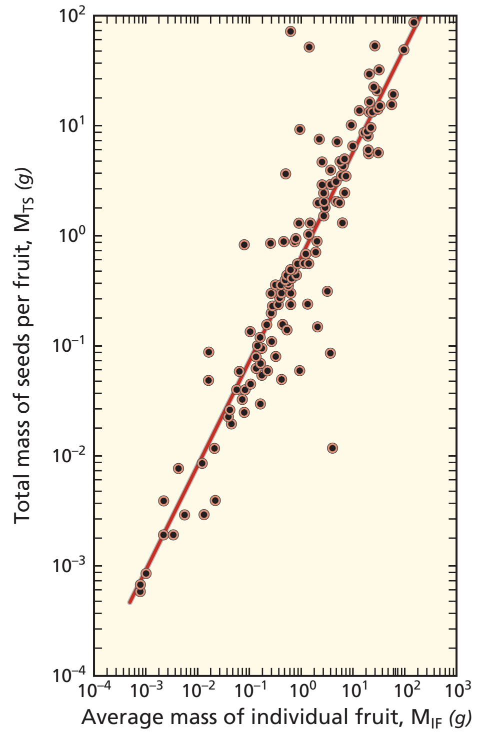


FIGURE 8.8C Seed Mass vs. Fruit Mass
The slope of this line is 0.93.

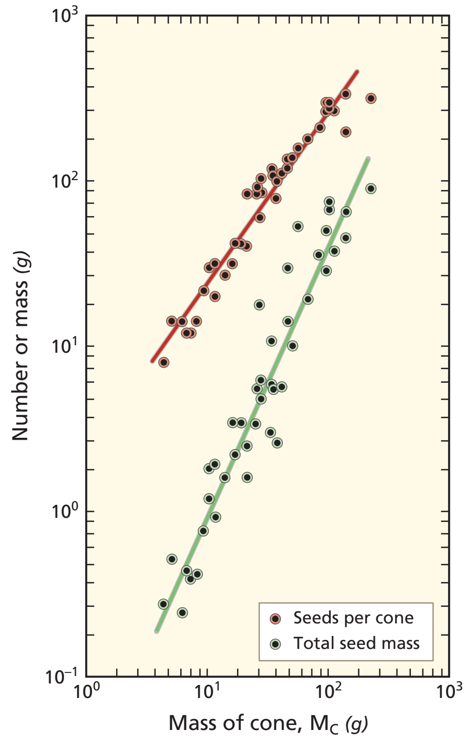


FIGURE 8.8D Seed Number vs. Cone Mass
The slope of this line is 1.06.

SUMMARY

1. Ectotherms utilize external energy to warm their bodies. Endotherms use their own metabolism to generate internal heat. Metabolic rates are affected by temperature, and thus endotherms are able to maintain normal body functions over a broader range of environmental temperatures than ectotherms are.

2. The temperature coefficient, or Q_{10}, measures the rate at which chemical reactions change due to temperature increases of 10°C. Most biological reactions increase from two- to threefold.

3. Organisms can be found over a wide range of environmental temperatures, from −1.86°C to 90°C. Some animals survive freezing temperatures by producing a form of antifreeze from glycoproteins.

4. Our atmosphere filters out much of the high-energy radiation from sunlight.

5. Plants are limited to growing in areas where the light intensity is great enough to at least balance their metabolic requirements. This light intensity is called the compensation point.

6. The surface area to volume ratio of a round organism will decrease with increasing radius of the organism. Since the exchange of heat and the loss of water occurs through the surface of an organism, the size and shape of plants and animals directly affects their ability to exchange heat and retain water.

7. Many characteristics of plants and animals are correlated to the size of the organism. The study of the relationship between physiological measures and size is called allometry.

REVIEW QUESTIONS

1. Many animals cool themselves by sweating or panting. What are the physical processes that make sweating and panting effective means of cooling?

2. Fruit-fly larvae generate 1 mL of CO_2 per hour at 25°C. If we assume that the metabolic rate has a Q_{10} of 2, how much CO_2 would a larva generate at 28°C?

3. Why must chloroplasts be located near the surface of leaves?

4. Discuss three types of problems that confront plants and animals as their size increases.

5. Plant seed mass increases with the size of the plant. Suppose it has been determined that for the standard allometric equation, $b = 0.75$ for seed mass. As plant size is doubled, how much greater would the mass of the seeds be?

KEY TERMS

acclimation
allometry
cold-blooded
compensation point
conduction
convection
ectotherm
endotherm
evaporation
freeze-intolerant
freeze-tolerant
glycoprotein
heat shock protein
heat shock response
homeotherm
poikilotherm
radiation
Q_{10}
specific metabolic rate
temperature coefficient
warm-blooded

FURTHER READINGS

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