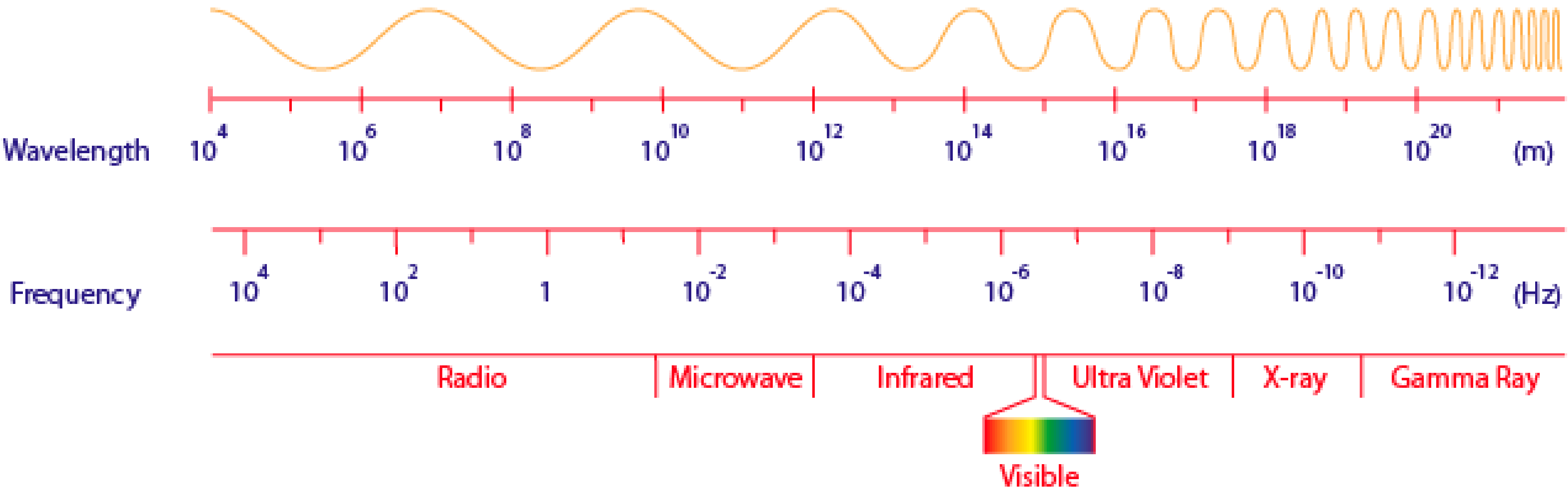
Electromagnetic Waves and Matter

Electromagnetic Waves

Notice how visible light is only a tiny band of the electromagnetic spectrum. The rest of the waves are different frequencies, higher or lower. Again, humans named the waves according to what we can see! Ultraviolet are higher frequency than we can see and infrared are lower frequency.

Visible light

The term visible light is a bit misleading. Who is it visible to? Humans, yes, then it's accurate. But, what about other animals and insects?



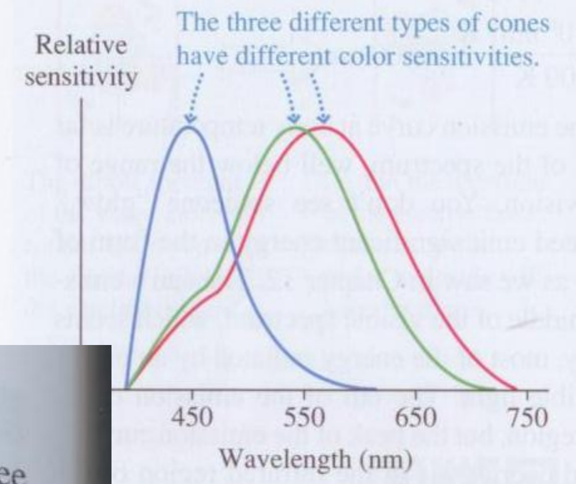
The photo of the flower on the left shows how it appears to our eyes, in visible light. But there's more to the story! The false-color view of the flower on the right shows its appearance in the ultraviolet, beyond the range of human vision, revealing pigments we can't see. Whose eyes are these pigments intended for?


Color Vision

The cones, the color-sensitive cells in the retina of the eye, each contain one of three slightly different forms of a light-sensitive photopigment. A single photon of light can trigger a reaction in a photopigment molecule, which ultimately leads to a signal being produced by a cell in the retina. The energy of the photon must be matched to the energy of a molecular transition for absorption of the photon energy to take place. Each photopigment has a range of photon energies to which it is sensitive. Our color vision is a result of the differential response of three types of cones containing three slightly different pigments, shown in **FIGURE 25.42**.

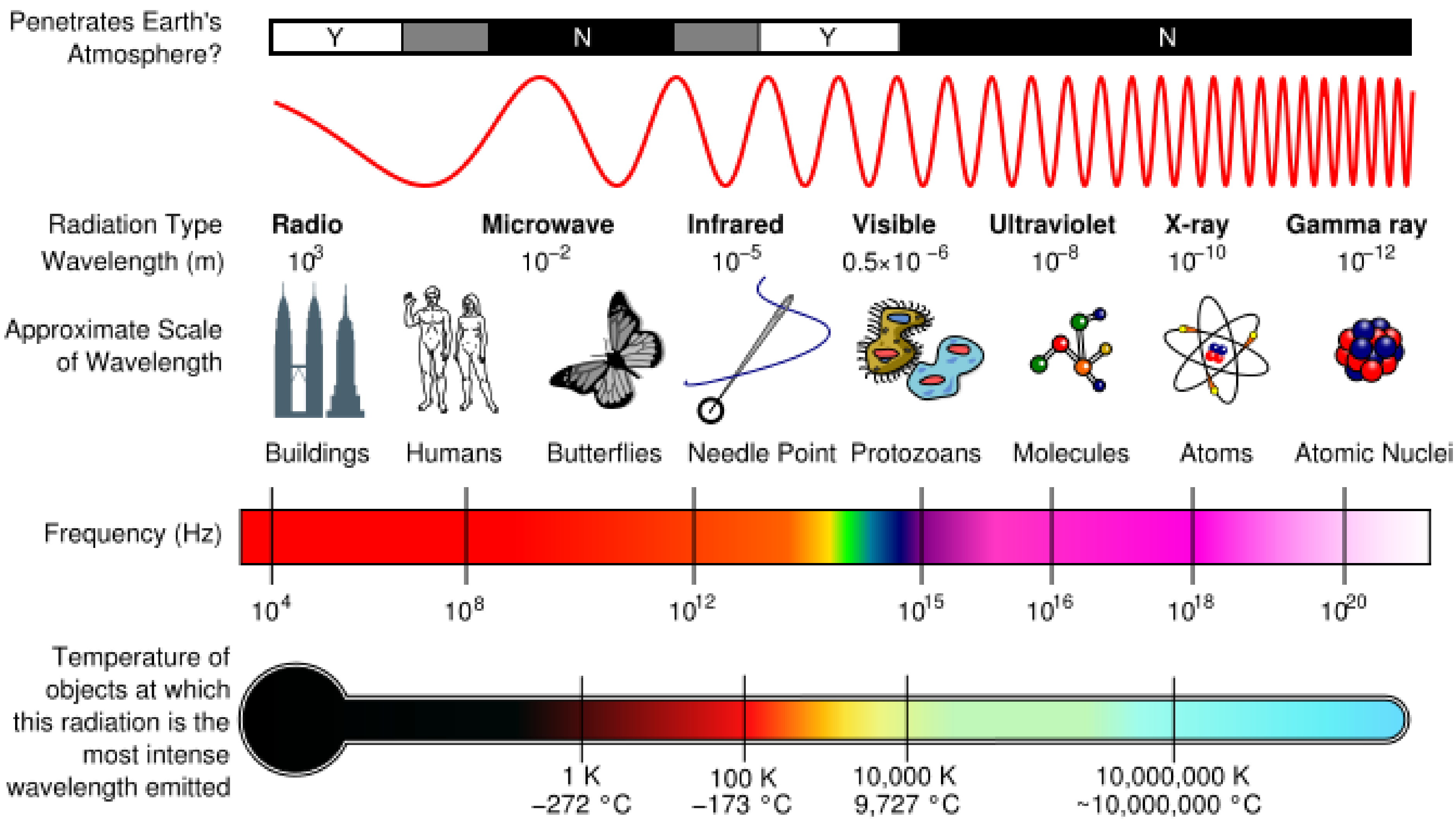
Humans have three types of cone in the eye, mice have two, and chickens four—giving a chicken keener color vision than a human. The three color photopigments that bees possess give them excellent color vision, but a bee's color sense is different from a human's. The peak sensitivities of a bee's photopigments are in the yellow, blue, and ultraviolet regions of the spectrum. A bee can't see the red of a rose, but it is quite sensitive to ultraviolet wavelengths well beyond the range of human vision. The flower in the right-hand photo at the start of the chapter looks pretty to us, but its coloration is really intended for other eyes. The ring of ultraviolet-absorbing pigments near the center of the flower, which is invisible to humans, helps bees zero in on the pollen.

FIGURE 25.42 The sensitivity of different cones in the human eye.



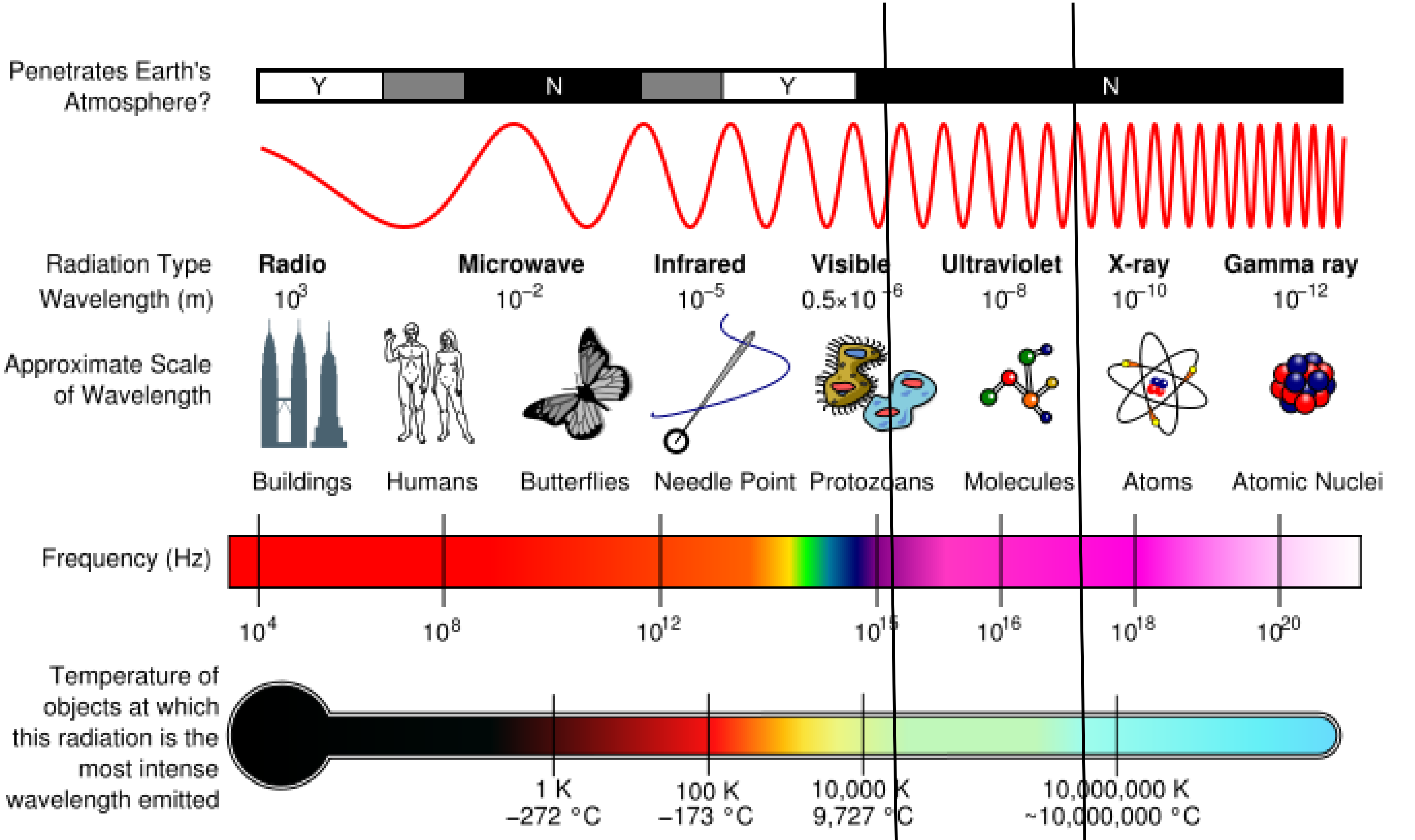
Electromagnetic waves

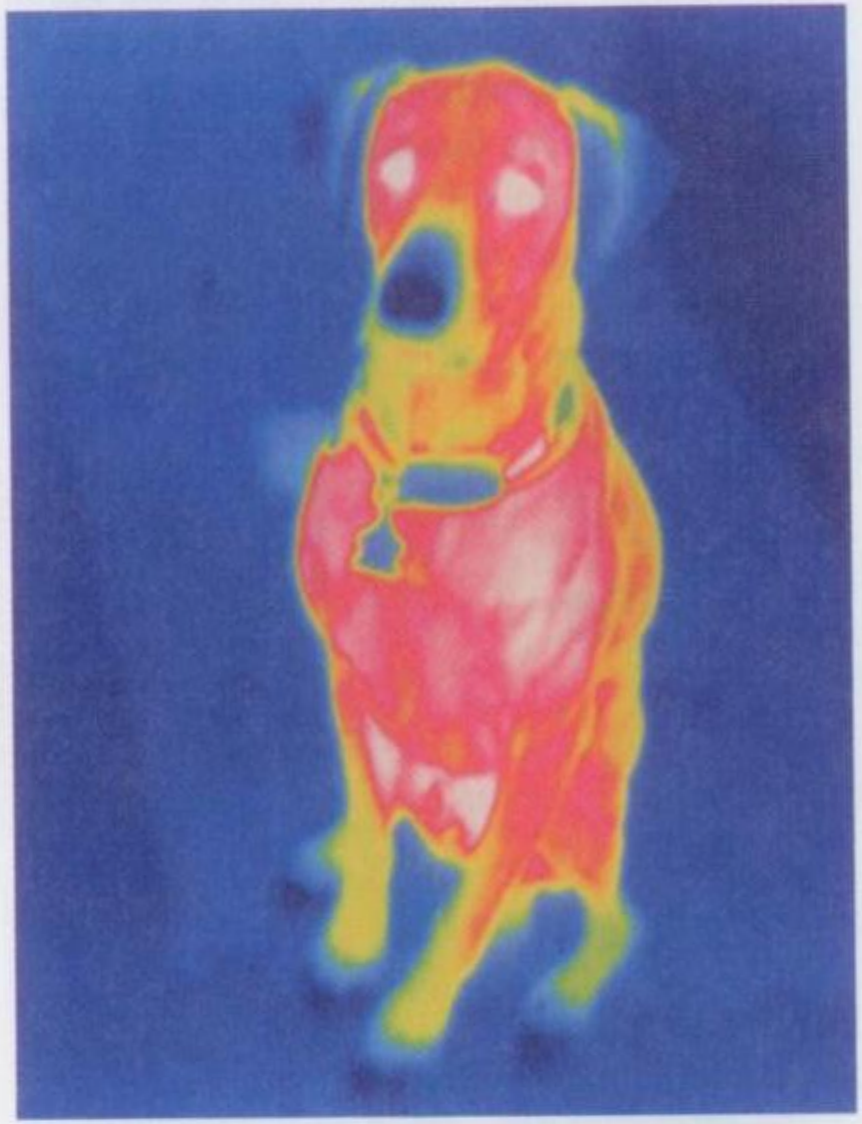
Here's another representation of Electromagnetic waves. This one shows you examples of the size of the different waves and at what temperature an object must be to emit these waves.



Electromagnetic waves

Ultraviolet are the wavelengths Bees are sensitive to and what gives us a tan. (marked by the two black lines) However, you can see this is a big range and it's only the end closest to visible light that is safe for tanning and what Bees see.

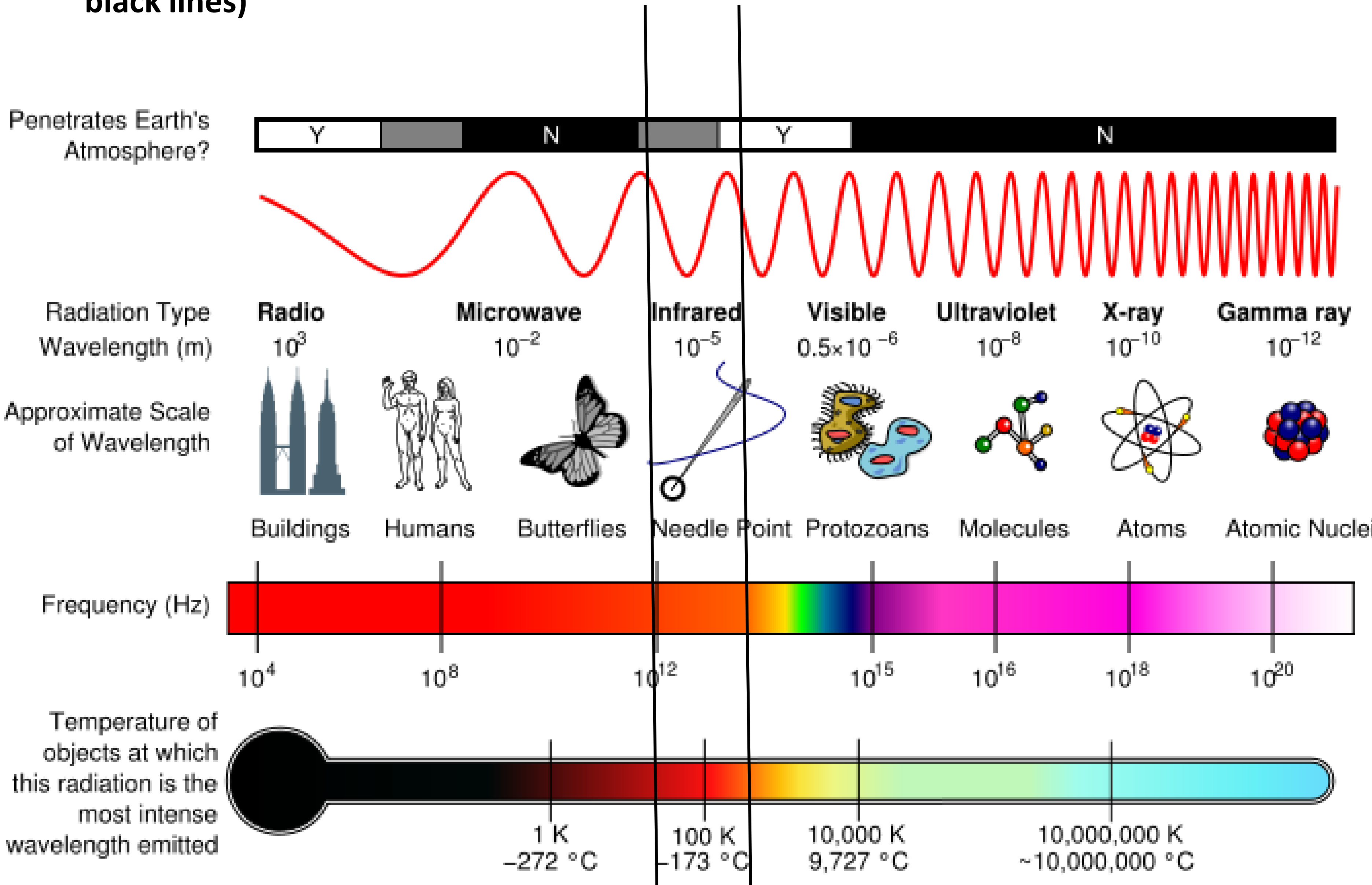




The infrared radiation emitted by a dog is captured in this image. His cool nose and paws radiate much less energy than the rest of his body.

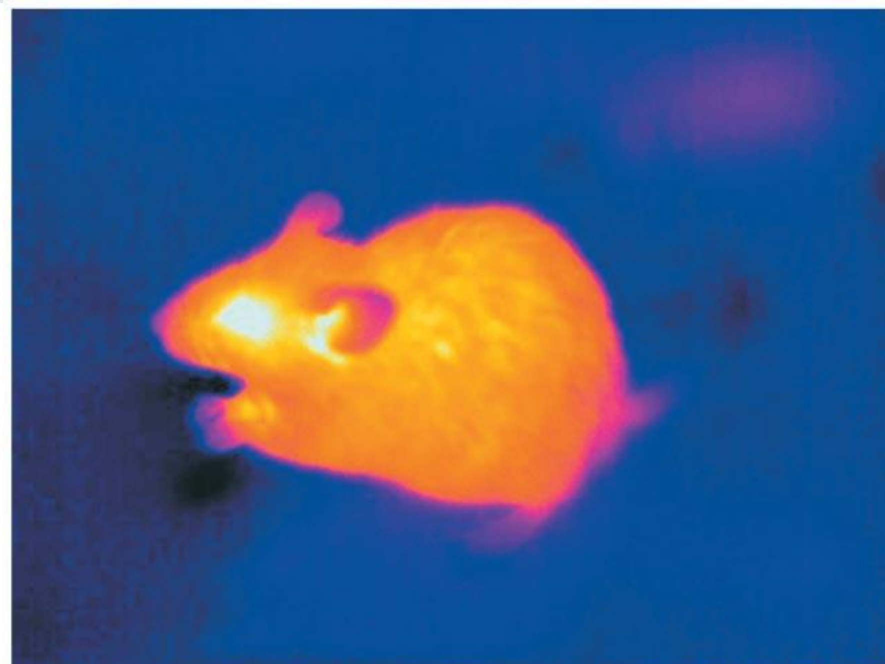
Electromagnetic waves

Infrared waves are what is emitted at everyday temperatures (marked by the two black lines)



Hunting with Thermal Radiation

▶ It's the pits . . . BIO Certain snakes—including rattlesnakes and other *pit vipers*—can hunt in total darkness. Prey animals are warm, and warm objects emit thermal radiation. In the top photo, notice the pits in front of the viper's eyes. These pits are actually a second set of vision organs; they have sensitive tissue at the bottom that allow them to sense this thermal radiation. The pits are sensitive to infrared wavelengths of $\approx 10\ \mu m$, near the wavelength of peak emission at mammalian body temperatures. Pit vipers sense the electromagnetic waves *emitted* by warm-blooded animals, such as the thermal radiation emitted by the mouse, shown in the lower image. They need no light to "see" you. You emit a "glow" they can detect.



Matter

As you know, each element and most compounds can exist as a solid, liquid, or gas. These three **phases** of matter are familiar from everyday experience. An atomic view of the three phases is shown in **FIGURE 12.1**.

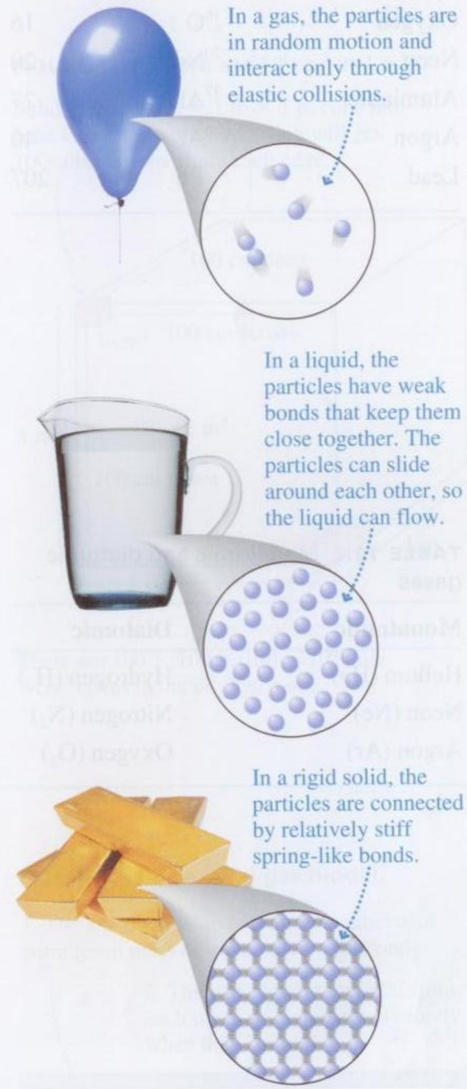
- A **gas** is a system in which each particle moves freely through space until, on occasion, it collides with another particle or the wall of its container.
- In a **liquid,** weak bonds permit motion while keeping the particles close together.
- A rigid **solid** has a definite shape and can be compressed or deformed only slightly, as we saw in Chapter 8. It consists of atoms connected by spring-like molecular bonds.

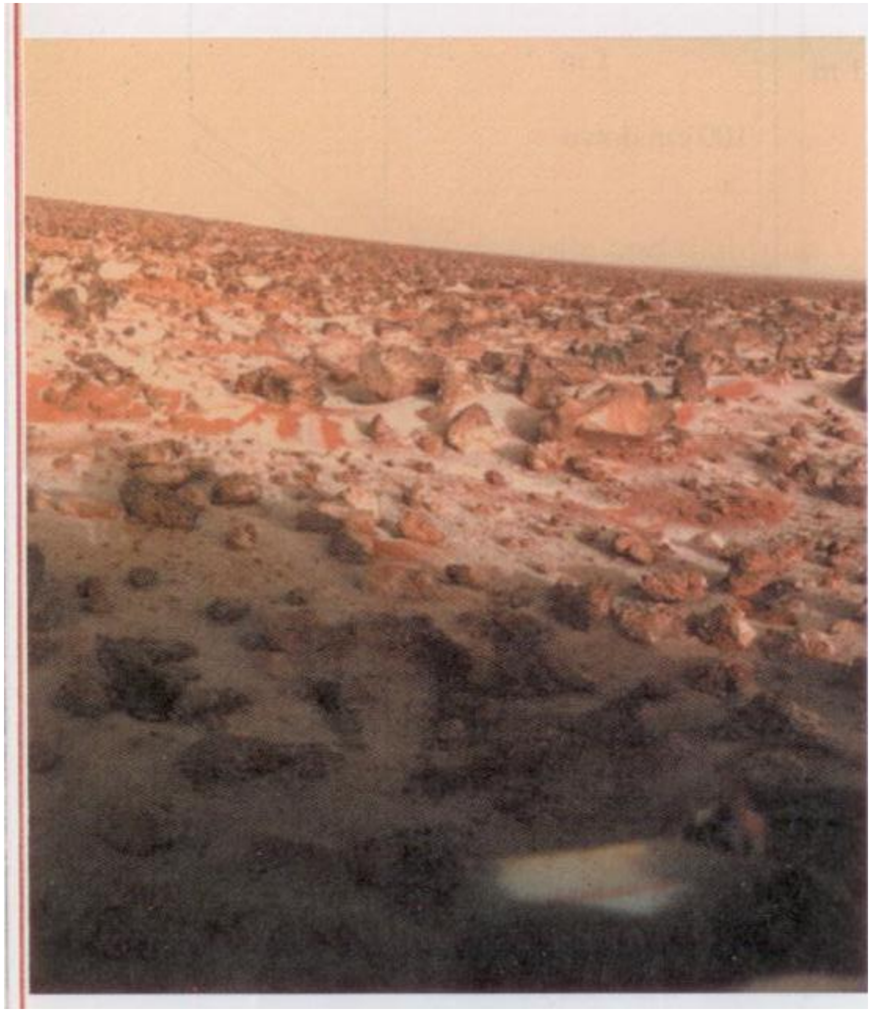
Our atomic model makes some simplifications that are worth noting. The basic particles of the gas in Figure 12.1 are drawn as simple spheres; no mention is made of the nature of the particles. The balloon might contain either helium (in which the basic particles are helium atoms) or air (in which the basic particles are nitrogen and oxygen molecules). A helium atom and a nitrogen molecule are quite different from each other, but many of the properties of the gas as a whole do not depend on the nature of the particles—a gas of helium atoms or oxygen molecules may behave identically. In such cases, we will simply refer to gas *particles,* which may be either atoms or molecules.

The basic particles in the liquid water in Figure 12.1 are water molecules. We ignore the structure of the molecules, so when we speak of the bonds that hold the particles in the liquid state, we are referring to the relatively weak intermolecular bonds among the water molecules, not the strong bonds between the hydrogen and oxygen atoms that form the molecules. The basic particles of the gold bars in Figure 12.1 are gold atoms. The bonds that hold these atoms together are the bonds that give the solid its structure. But there are solids composed of molecules that are held together by bonds between the molecules; water ice is one such example. In this case, the particles are the molecules, and the bonds that form the solid are the bonds between the molecules.

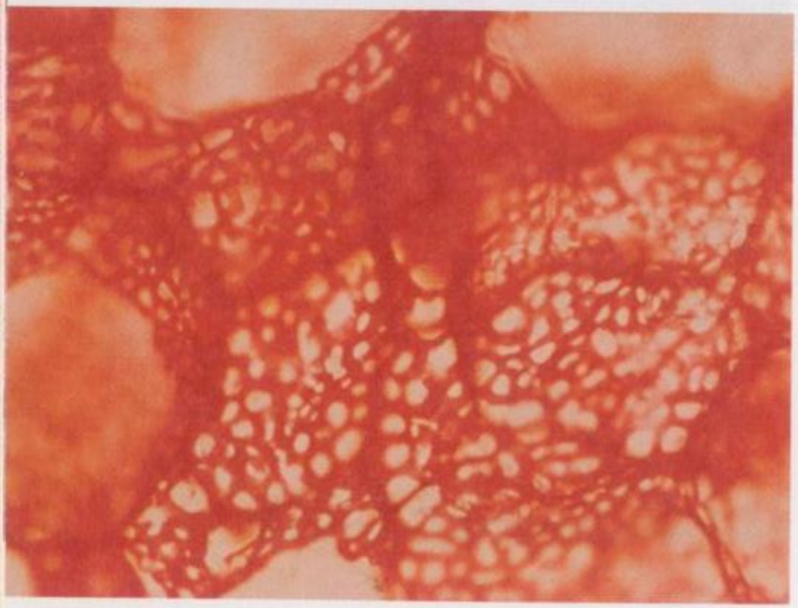
MP PhET: States of Matter
PhET: Gas Properties

FIGURE 12.1 Atomic models of the three phases of matter: solid, liquid, and gas.





Martian airsicles The atmosphere of Mars is mostly carbon dioxide. At night, the temperature may drop so low that the molecules in the atmosphere will slow down enough to stick together—the atmosphere actually freezes. The frost on the surface in this image from the Viking 2 lander is composed partially of frozen carbon dioxide.



◀**Gas exchange in the lungs** BIO When you draw a breath, how does the oxygen get into your bloodstream? The atomic model provides some insight. The picture is a highly magnified view of the alveoli, air sacs in the lungs, surrounded by capillaries, fine blood vessels. The thin membranes of the alveoli and the capillaries are permeable—small molecules can move across them. If a permeable membrane separates two regions of space having different concentrations of a molecule, the rapid motion of the molecules causes a net transport of molecules in the direction of lower concentration, as we might expect from the discussion of why heat flows from hot to cold in Chapter 11. This transport—entirely due to the motion of the molecules—is known as **diffusion.** In the lungs, the higher concentration of oxygen in the alveoli drives the diffusion of oxygen into the blood in the capillaries. At the same time, carbon dioxide diffuses from the blood into the alveoli. Diffusion is a rapid and effective means of transport in this case because the membranes are thin. Diffusion won't work to get oxygen from the lungs to other parts of the body, because diffusion is slow over large distances, so the oxygenated blood must be pumped throughout the body.