2·11–2·13 Lipids store energy for a rainy day.

A well-insulated harp seal, in Canada.

2·11 Lipids are macromolecules with several functions, including energy storage.

Lipids are a second group of macromolecules important to all living organisms. Lipids, just like carbohydrates, are made primarily from atoms of carbon, hydrogen, and oxygen, but the atoms are in different proportions. The lipids in your diet, for example, tend to have significantly more energy-rich carbon-hydrogen bonds than carbohydrates, and so contain significantly more stored energy.

What exactly is a lipid? That's not as easy to answer as you might expect. Lipids come in a wide variety of structures. They don't have any unique subunits (such as the simple sugars that make up disaccharides and polysaccharides) or particular ratios of atoms that serve as defining features. Consequently, lipids are defined based on their physical characteristics. Most notably, lipids do not dissolve in water and are greasy to the touch—think of salad dressings.

Q Why does a salad dressing made with vinegar and oil separate into two layers shortly after you shake it?

Lipids are insoluble in water because they tend to have long chains consisting only of carbon and hydrogen atoms, which, in contrast to water, are nonpolar. Nonpolar molecules (or parts of molecules) tend to minimize their contact with water and are considered **hydrophobic** ("water-fearing"). Lipids cluster together when mixed with water, never fully dissolving. Molecules that readily form hydrogen bonds with water, on the other hand, are considered **hydrophilic** ("water-loving").

One familiar type of lipid is *fat,* the type most important in long-term energy storage and insulation

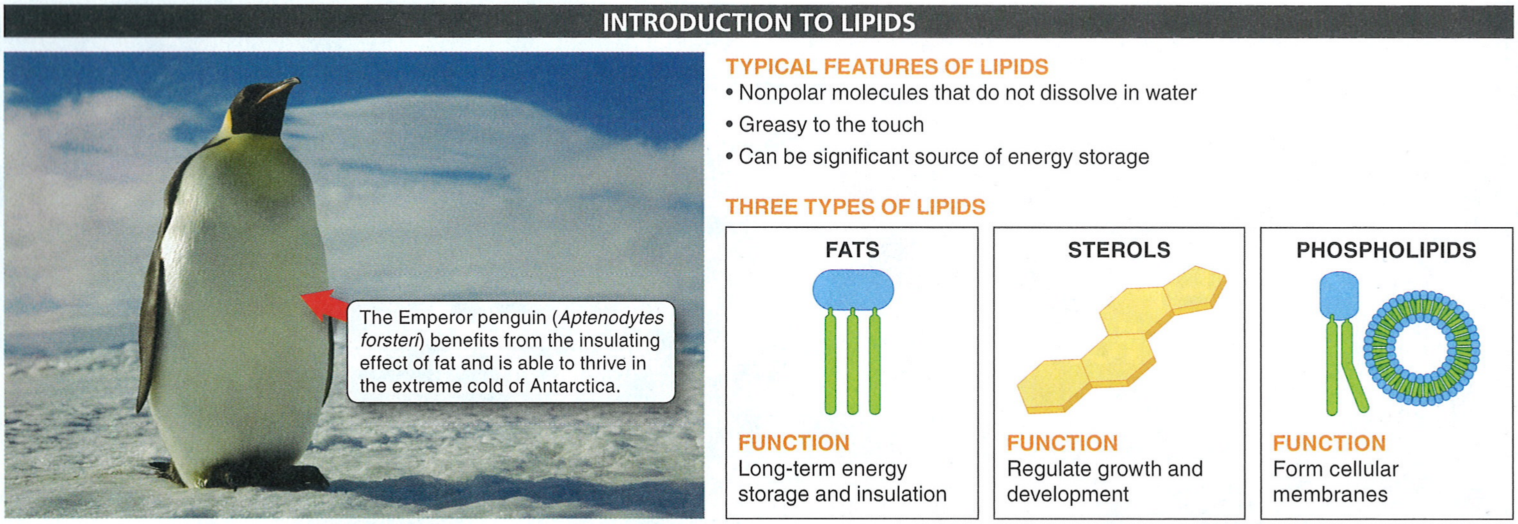


FIGURE 2-28 **Lipids serve many roles in the body.**

(**FIGURE 2-28**). (Penguins and walruses can maintain relatively high body temperatures, despite living in very cold habitats, due to their thick layer of insulating fat.) Lipids also include *sterols,* which include *cholesterol* and many of the sex hormones that play regulatory roles in animals, and *phospholipids,* which form the membranes that enclose cells.

TAKE-HOME MESSAGE 2·11

Lipids are insoluble in water and greasy to the touch. They are valuable to organisms for long-term energy storage and insulation, in membrane formation, and as hormones.

2·12 Fats are tasty molecules too plentiful in our diets.

All fats have two distinct components: they have a "head" region and two or three long "tails" (**FIGURE 2-29**). The head region is a small molecule called **glycerol.** It is linked to "tail" molecules known as **fatty acids.** A fatty acid is simply a long hydrocarbon—that is, a chain of carbon molecules, often a dozen or more, linked together with one or two hydrogen atoms attached to each carbon.

The fats in most foods we eat are **triglycerides,** which are fats having three fatty acids linked to the glycerol molecule. For this reason, the terms "fats" and "triglycerides" are often used interchangeably. Triglycerides that are solid at room temperature are generally called "fats," while those that are liquid at room temperature are called "oils."

Fat molecules contain much more stored energy than do carbohydrate molecules. That is, the chemical breakdown of fat molecules releases significantly more energy. A single gram of carbohydrate stores about 4 calories of energy, while the same amount of fat stores about 9 calories—not unlike the difference between a $5 bill and a $10 bill. Because fats store

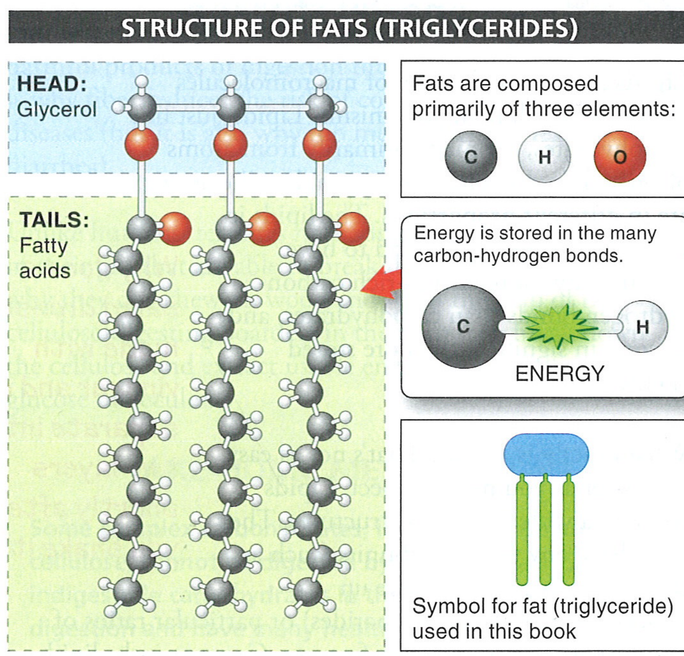


FIGURE 2-29 **Triglycerides have glycerol heads and fatty acid tails.**

FIGURE 2-30 **Animals (including humans!) prefer the taste of fats.**

Because fats store such large amounts of energy, a strong taste preference for fats over other energy sources has evolved in animals.

such a large amount of energy, a strong taste preference for fats over other energy sources has evolved in animals (**FIGURE 2-30**). Organisms evolving in an environment of uncertain food supply will build the largest surplus by consuming molecules that hold the most amount of energy in the smallest mass. This feature helped the earliest humans to survive, millions of years ago, but today puts us in danger from the health risks of obesity now that fats are all too readily available.

An important distinction is made between "saturated" and "unsaturated" fats (**FIGURE 2-31**). These terms refer to the hydrocarbon chain in the fatty acids. If each carbon atom

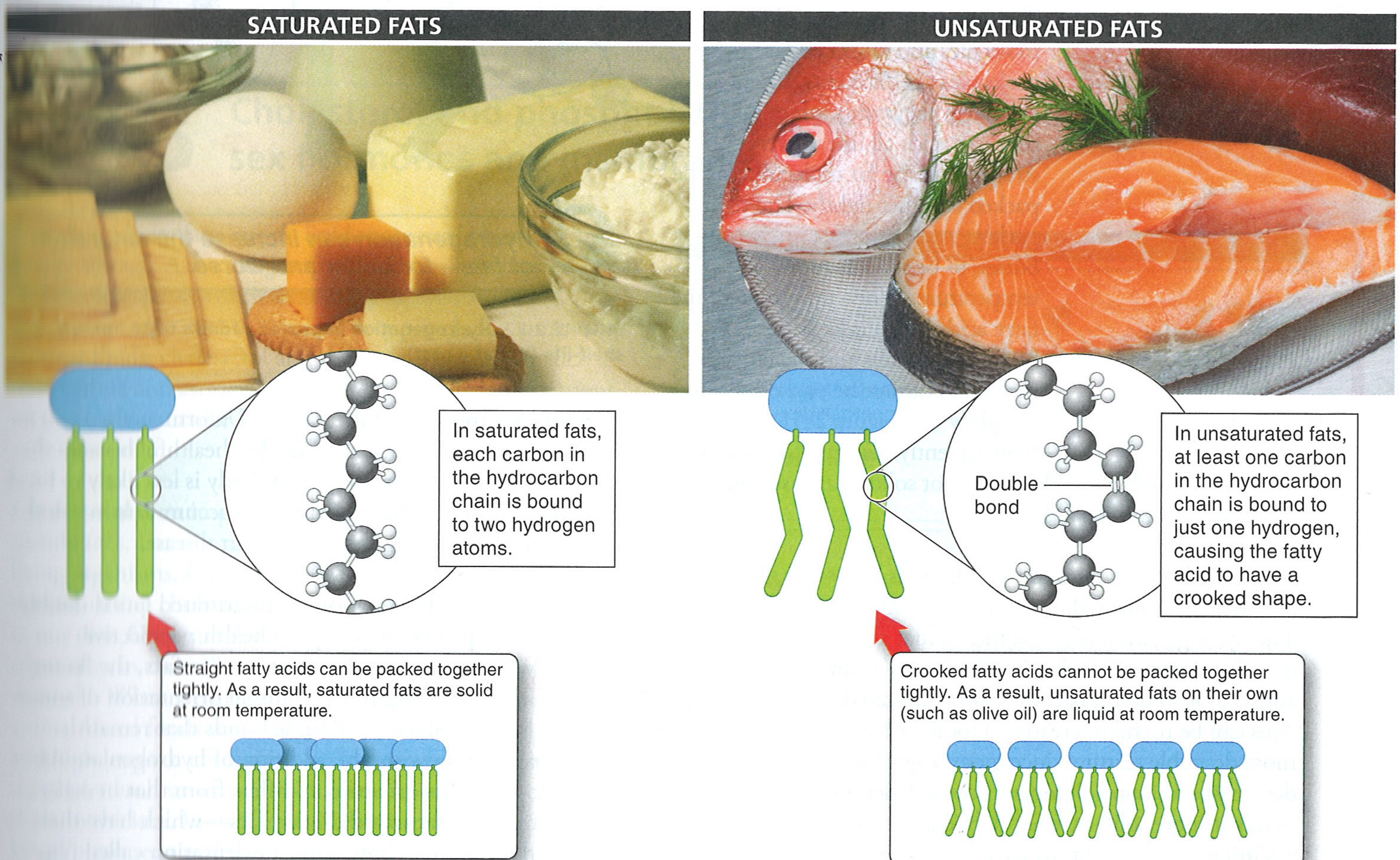


FIGURE 2-31 **Degrees of saturation.** Fatty acids (and thus the fats that contain them) can be unsaturated or saturated.

in the hydrocarbon chain of a fatty acid is bonded to two hydrogen atoms, the fat molecule carries the maximum number of hydrogen atoms and is said to be a **saturated fat.** Most animal fats, including those found in meat and eggs, are saturated. They are not essential to your health and, because they accumulate in your bloodstream and can narrow the vessel walls, they can cause heart disease and strokes.

An **unsaturated fat** is one in which some of the carbon atoms are bound to only a single hydrogen. Most plant fats are unsaturated. Unsaturated fats may be *mono-unsaturated* (if a fatty acid hydrocarbon chain has only one pair of neighboring carbon atoms in an unsaturated state—that is, has only one double bond) or *polyunsaturated* (if more than one pair of carbons is unsaturated—there's more than one double bond). Unsaturated fats are still high in calories, but because they can lower cholesterol, they are generally preferable to saturated fats. Foods high in unsaturated fats include avocados, peanuts, and olive oil. Relative to other animals, fish tend to have less saturated fat.

Q How will the "chewy-ness" of a cookie differ depending on whether you make it with butter or vegetable oil as the lipid? Which is better for your health?

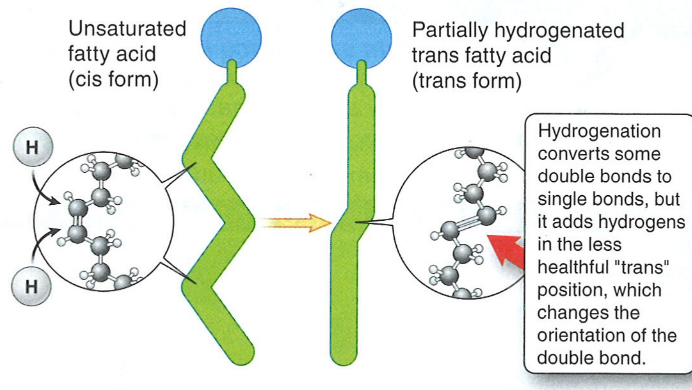
The shapes of unsaturated fat molecules and saturated fat molecules are different. When saturated, the hydrocarbon tails of the fatty acids all line up very straight and the fat molecules can be packed together tightly. The tight packing causes the fats, such as butter, to be solid at room temperature. When unsaturated, the fatty acids have kinks in the hydrocarbon tails and the fat molecules cannot be packed together as tightly (see Figure 2-31). Consequently, unsaturated fats, such as canola oil and vegetable oil, do not solidify as easily and are liquid at room temperature.

The ingredient list for many snack foods includes "partially hydrogenated" vegetable oils. The hydrogenation of an oil means that a liquid, unsaturated fat has had hydrogen atoms added to it so that it becomes more saturated. This can be useful in creating a food with a more desirable texture, since increasing a fat's degree of saturation changes its consistency and makes it more solid at room temperatures. By attaining just the right degree of saturation, it is possible to create foods, such as chocolate, that are near the border of solid and liquid and

Q Many snack foods contain "partially hydrogenated" vegetable oils. Why might food producers add hydrogen atoms to a vegetable oil?

HYDROGENATION

Hydrogenation is the artificial addition of hydrogen atoms to an unsaturated fat. This can improve a food's taste, texture, and shelf-life.



Hydrogenation can increase the saturation of fats—for better and worse.

FIGURE 2-32 Hydrogenation improves a food's taste, texture, and shelf-life (but at a cost).

"melt in your mouth" (**FIGURE 2-32**). Unfortunately, hydrogenation also makes the food less healthful because saturated fats are less reactive—your body is less likely to break them down—and so are more likely to accumulate in your blood vessels, increasing the risk of heart disease.

Hydrogenation of unsaturated fats is doubly problematic from a health perspective because it also creates **trans fats,** the "trans" referring to the unusual orientation of some or all of the double bonds that remain following the addition of hydrogen atoms. This orientation differs from that in other unsaturated dietary fats—which have their double bonds in an orientation called "cis." Trans fats in your diet cause your body to produce more cholesterol, further raising