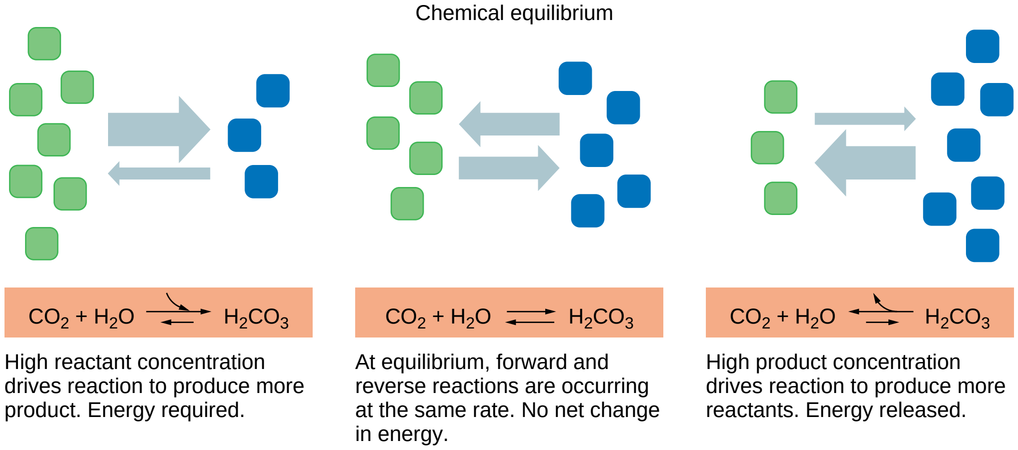
FIGURE 5.11
Chemical Equilibrium.
Reversible chemical reactions proceed toward a "middle point" known as equilibrium. Determined by the concentration of products and reactants, at equilibrium a reaction is equally likely to proceed in either direction. By manipulating these concentrations, living cells can "drive" reactions in a particular direction.



However, there may be different amounts of products and reactants at equilibrium—it is their rate of formation that equalizes. At chemical equilibrium, energy is not being gained or lost. When a reaction departs from equilibrium (that is, when either reactants or products accumulate), energy is lost or gained.

Because all activities of life require energy, cells must remain far from chemical equilibrium for their metabolic processes to occur. They do this by continually preventing the accumulation of reactants in metabolic pathways. For example, the large difference in free energy between glucose and its breakdown products, carbon dioxide and water, propels cellular metabolism strongly in one direction—as soon as glucose enters the cell, it is quickly broken down to release energy. This energy allows the cell to stave off equilibrium by continuously forming new products required for life.

Oxidation and Reduction Reactions Link, Forming Electron Transport Chains

Most energy transformations in organisms occur in chemical reactions called oxidations and reductions. In **oxidation,** a molecule loses electrons. The name comes from the observation that many reactions in which molecules lose electrons involve oxygen. Oxidation is the equivalent of adding oxygen because oxygen strongly attracts electrons away from the original atom. Oxidation reactions, such as the breakdown of glucose to carbon dioxide and water, are catabolic. That is, they degrade molecules into simpler products as they release energy.

In **reduction,** a molecule gains electrons. Reduction changes the chemical properties of a molecule. Reduction reactions, such as the formation of lipids, are usually anabolic. They require a net input of energy.

Oxidations and reductions tend to be linked, occurring simultaneously, because electrons removed from one molecule during oxidation join another molecule and reduce it. That is, if one molecule is reduced (gains electrons), then another must be oxidized (loses electrons). Such linked oxidations and reductions form electron transport chains, which we will see in the next two chapters.

Many energy transformations in living systems involve carbon oxidations and reductions. Reduced carbon contains more energy than oxidized carbon. This is why reduced molecules such as methane (CH_4) are explosive, whereas oxidized molecules such as carbon dioxide (CO_2) are not. The same principle applies to other compounds: The more reduced they are, the more energy they contain. Anyone who has ever dieted is at least intuitively familiar with this concept of energy content. Saturated fats are highly reduced, and they contain more than twice as many kilocalories by weight as proteins or carbohydrates. Thus, a fatty meal of a bacon double cheeseburger with fries and a shake may contain the same number of kcal (and thus the same amount of energy) as a bathtub full of celery sticks.

5.3 MASTERING CONCEPTS

1. What does metabolism mean in a cellular sense?
2. How are anabolism and catabolism opposites?
3. Distinguish between endergonic and exergonic reactions.
4. What distinguishes a reaction that has reached chemical equilibrium?
5. What are oxidation and reduction reactions, and why are they linked?

OLC

5.4 ATP Is Cellular Energy Currency

ATP, through high-energy phosphate bonds, temporarily stores energy that a cell uses for a wide variety of activities.

Organisms store potential energy in the chemical bonds of nutrient molecules. It takes energy to make these bonds, and energy is released when bonds of these molecules are broken. Much of the