It would seem ideal if an organism's enzymes always existed in large quantities and functioned under all conditions. However, a variety of mechanisms ensures that this does not happen. Cellular needs and requirements continuously vary from cell to cell. The required enzymes of stomach cells differ from those of fat storage cells, skin cells, blood cells, and nerve cells. As cellular demands and conditions vary, so must the amounts and functionality of different enzymes.

Competitive inhibition

Enzyme activity can be regulated in several different ways. Environmental factors such as pH or temperature, as well as regulatory molecules, can either promote or reduce an enzyme's activity. Many kinds of regulatory molecules inhibit or promote enzyme function. In some cases of enzyme inhibition, an inhibitor molecule is similar enough to the substrate that it can bind to the active site and block the substrate from binding. When this happens, the enzyme is inhibited through **competitive inhibition.** Figure 5.39 shows how the rate of a chemical reaction decreases during competitive inhibition when compared to normal enzyme activity.

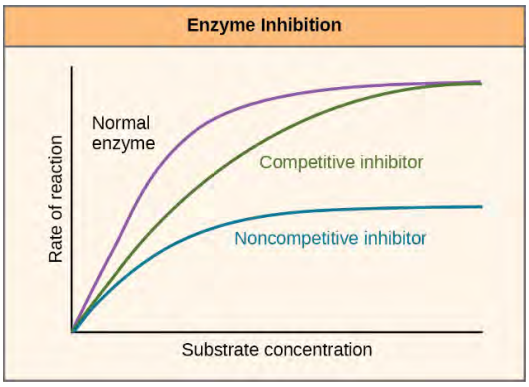

Figure 5.39 This plot shows the rate of reaction versus substrate concentration for an enzyme in the absence of the inhibitor and the enzyme in the presence of competitive and non-competitive inhibitors. (credit: Clark et al. / Biology 2E OpenStax)

Non-competitive inhibition

In **non-competitive inhibition**, an inhibitor molecule binds to the enzyme in a location other than the active site, often called an allosteric site**.** The inhibitor still prevents the substrate from binding to the active site; however, it does so by causing a conformational change that reduces the affinity or binding ability of the enzyme for its substrate. This type of inhibition is called **allosteric inhibition** (Figure 5.40). There are also **allosteric activators**. When an allosteric activator binds to the allosteric site in the enzyme, it induces a conformational change that increases the affinity of the enzyme's active site(s) for its substrate(s) (Figure 5.40).

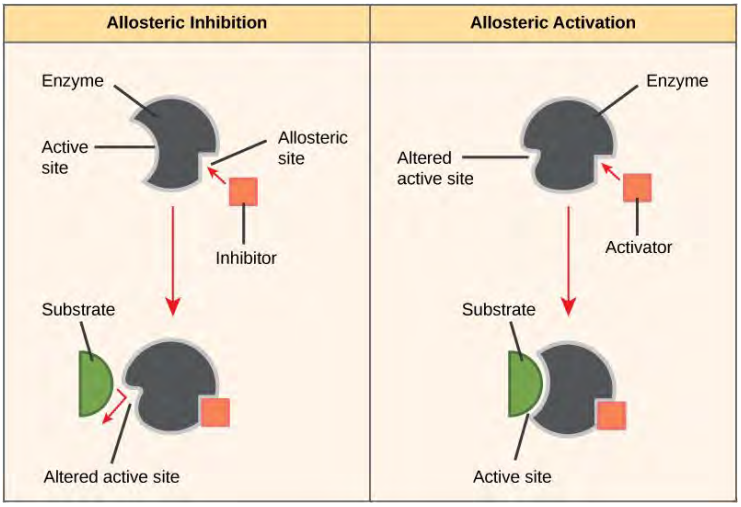

Figure 5.40 Allosteric inhibition works by indirectly inducing a conformational change to the active site. In contrast, in allosteric activation, the activator molecule modifies the shape of the active site to allow a better fit of the substrate. (credit: Fowler et al. / Concepts of Biology OpenStax)

CAREER CONNECTION - Pharmaceutical Drug Developer

Understanding how enzymes work and how they can be regulated are key principles behind the development of many pharmaceutical drugs on the market today. Biologists working in this field collaborate with other scientists to design pharmaceutical drugs (Figure 5.41).

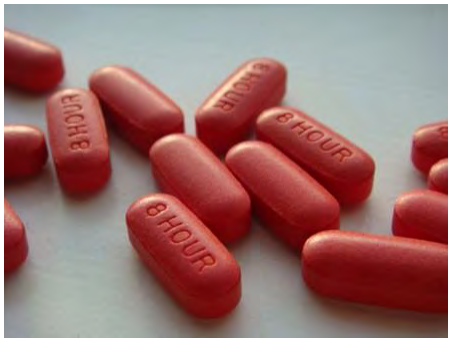

Figure 5.41 Pharmaceutical drugs can act on enzymes. (credit: Deborah Austin / Concepts of Biology OpenStax)

For example, consider statins, a class of pharmaceutical drugs that can reduce cholesterol levels. These compounds are inhibitors of the enzyme HMG-CoA reductase, which is the enzyme that synthesizes cholesterol from lipids in the body. By inhibiting this enzyme, the level of cholesterol synthesized in the body can also be reduced.

Cofactors and Coenzymes

Many enzymes do not work optimally, or at all, unless bound to other specific non-protein helper molecules. They may bond either temporarily through ionic or hydrogen bonds, or permanently through stronger covalent bonds. Binding to these molecules promotes the optimal shape and function of their respective enzymes. Two examples of helper molecules are cofactors and coenzymes. **Cofactors** are inorganic ions such as iron and magnesium, whereas **coenzymes** are organic helper molecules. Like enzymes, these molecules participate in reactions without being altered and can be reused. Vitamins are a source of coenzymes (Figure 5.42). Vitamin C is a coenzyme for enzymes used to synthesize the important protein, collagen. Enzyme function is, in part, regulated by the abundance of various cofactors and coenzymes, which may be supplied by an organism's diet or, in some cases, produced by the organism.

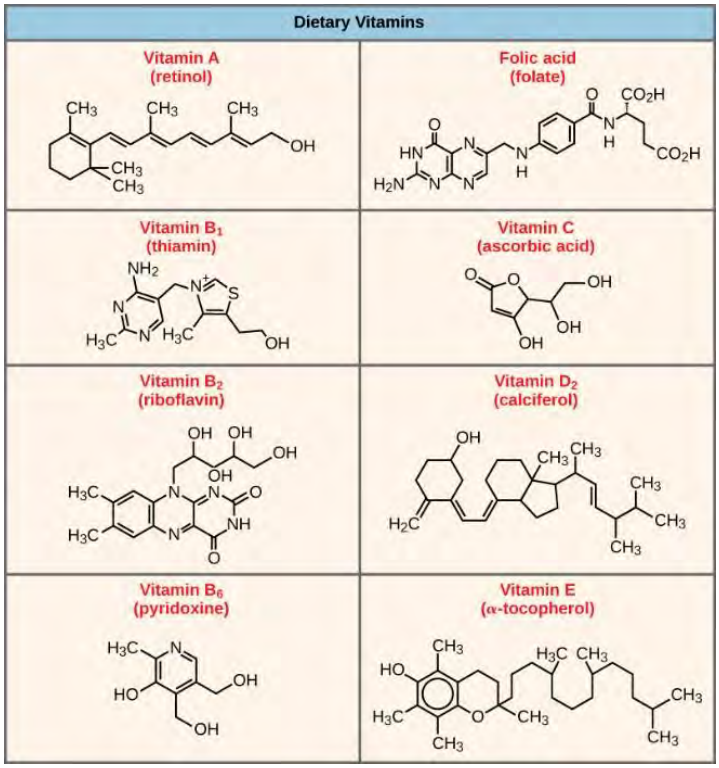

Figure 5.42 Shown are the molecular structures for Vitamin A, folic acid, Vitamin B1, Vitamin C, Vitamin B2, Vitamin D2, Vitamin B6, and Vitamin E. Vitamins are important coenzymes or precursors of coenzymes. (credit: Clark et al. / Biology 2E OpenStax)

Feedback Inhibition in Metabolic Pathways

As mentioned in section 5.4, the chemical reactions of metabolic pathways do not take place on their own. Each reaction step is facilitated or catalyzed by an enzyme. Without the enzymes, the metabolic pathway would not occur promptly. Enzymes involved with metabolic pathways are regulated in various ways. Perhaps the most relevant source of regulation is the products of the chemical reactions themselves. Cells have evolved in such a way that they can use the products of their chemical reactions for feedback inhibition of enzyme activity. **Feedback inhibition** occurs when an end product from the reaction is used to inhibit the starting reactants or enzymes involved in the chemical reaction (Figure 5.43). This inhibition will slow down or stop the production of the final product.

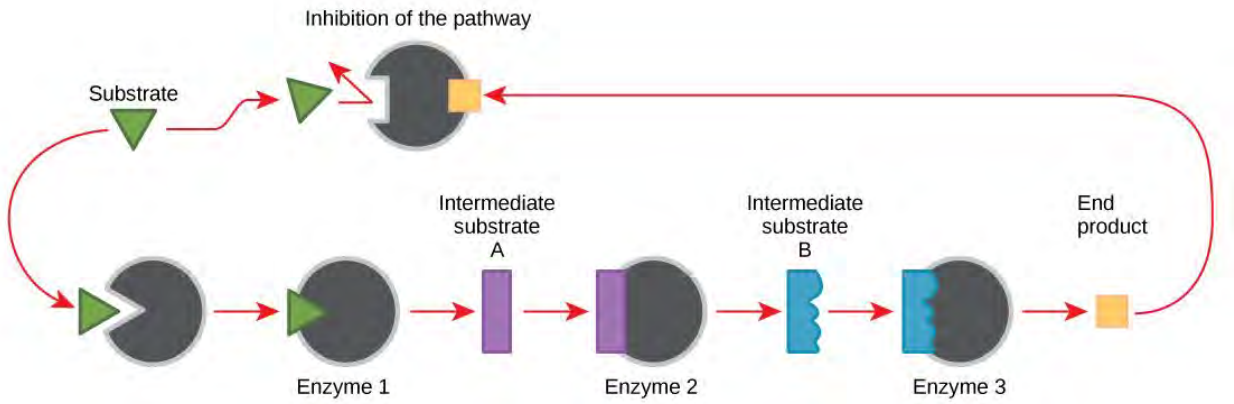

Figure 5.43 shows a metabolic pathway with feedback inhibition. (credit: Clark et al. / Biology 2E OpenStax)