

CONCEPT

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Cell Metabolism

A cell's daily operations are accomplished through the biochemical reactions that take place within the cell. Reactions are turned on and off or sped up and slowed down according to the cell's immediate needs and overall functions. At any given time, the numerous pathways involved in building up and breaking down cellular components must be monitored and balanced in a coordinated fashion. To achieve this goal, cells organize reactions into various enzyme-powered pathways.

What Do Enzymes Do?

Enzymes are protein catalysts that speed biochemical reactions by facilitating the molecular rearrangements that support cell function. Recall that **chemical reactions** convert **substrates** into **products**, often by attaching chemical groups to or breaking off chemical groups from the substrates. For example, in the final step of **glycolysis**, an enzyme called pyruvate kinase transfers a phosphate group from one substrate (phosphoenolpyruvate) to another substrate (ADP), thereby generating pyruvate and ATP as products (Figure 1).

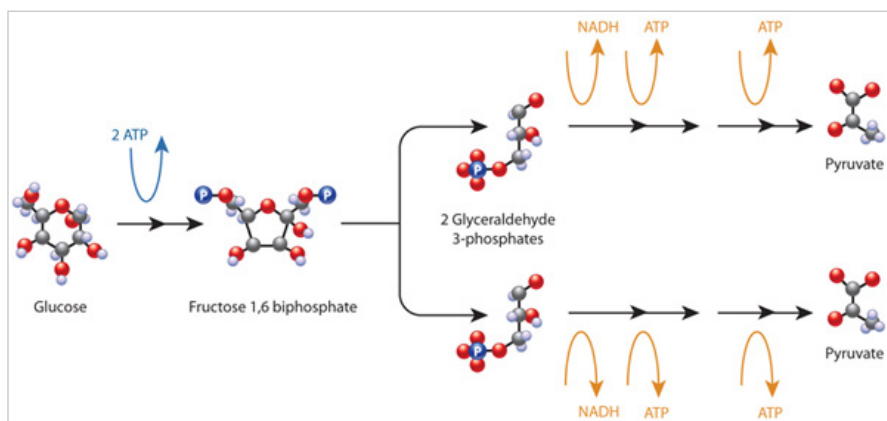


Figure 1: Glycolysis

Energy is used to convert glucose to a 6 carbon form. Thereafter, energy is generated to create two molecules of pyruvate.

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Figure Detail

Enzymes are flexible proteins that change shape when they bind with substrate molecules. In fact, this binding and shape changing ability is how enzymes manage to increase reaction rates. In many cases, enzymes function by bringing two substrates into close proximity and orienting them for easier electron transfer. Shape or conformational changes can also act as an on/off switch. For example, when **inhibitor molecules** bind to a site on an enzyme distinct from the substrate site, they can make the enzyme assume an inactive conformation, thereby preventing it from catalyzing a reaction. Conversely, the binding of **activator molecules** can make an enzyme assume an active conformation, essentially turning it on (Figure 2).

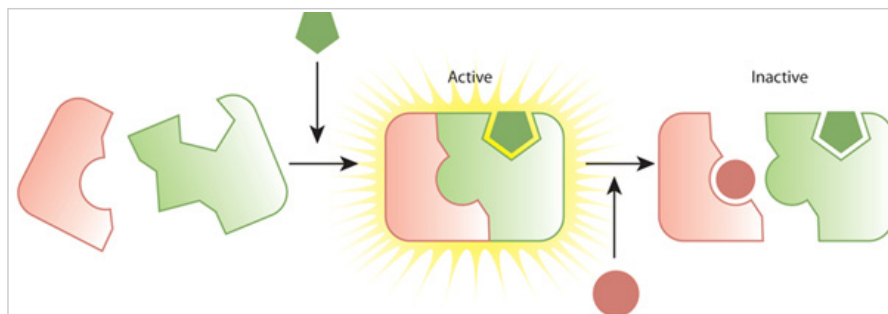


Figure 2: Activation and inactivation of enzyme reaction

Enzymes are proteins that can change shape and therefore become active or inactive. An activator molecule (green pentagon) can bind to an enzyme (light green puzzle shape) and change its overall shape. Note the transformation of the triangular point on the green enzyme into a rounded shape. This transformation enables the enzyme to better bind with its substrate (light pink puzzle piece). In contrast, an inhibitor molecule (pink circle) can prevent the interaction of an enzyme with its substrate and render it inactive.

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Figure Detail

What Are Metabolic Pathways?

Many of the molecular transformations that occur within cells require multiple steps to accomplish. Recall, for instance, that cells split one glucose molecule into two pyruvate molecules by way of a ten-step process called glycolysis. This coordinated series of chemical reactions is an example of a **metabolic pathway** in which the product of one reaction becomes the substrate for the next reaction. Consequently, the intermediate products of a metabolic pathway may be short-lived (Figure 3).

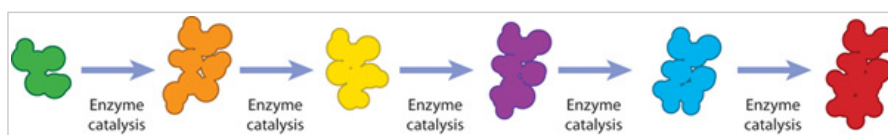


Figure 3: Reaction pathway

Enzymes can be involved at every step in a reaction pathway. At each step, the molecule is transformed into another form, due to the presence of a specific enzyme. Such a reaction pathway can create a new molecule (biosynthesis), or it can break down a molecule (degradation).

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Sometimes, the enzymes involved in a particular metabolic pathway are physically connected, allowing the products of one reaction to be efficiently channeled to the next enzyme in the pathway. For example, pyruvate dehydrogenase is a complex of three different enzymes that catalyze the path from pyruvate (the end product of glycolysis) to acetyl CoA (the first substrate in the citric acid cycle). Within this complex, intermediate products are passed directly from one enzyme to the next.

How Do Cells Keep Chemical Reactions in Balance?

Cells are expert recyclers. They disassemble large molecules into simpler building blocks and then use those building blocks to create the new components they require. The breaking down of complex organic molecules occurs via **catabolic pathways** and usually involves the release of energy. Through catabolic pathways, **polymers** such as proteins, nucleic acids, and polysaccharides are reduced to their constituent parts: amino acids,

nucleotides, and sugars, respectively. In contrast, the synthesis of new macromolecules occurs via **anabolic pathways** that require energy input (Figure 4).

Cells must balance their catabolic and anabolic pathways in order to control their levels of critical **metabolites** — those molecules created by enzymatic activity — and ensure that sufficient energy is available. For example, if supplies of glucose start to wane, as might happen in the case of starvation, cells will synthesize glucose from other materials or start sending fatty acids into the citric acid cycle to generate ATP. Conversely, in times of plenty, excess glucose is converted into storage forms, such as glycogen, starches, and fats.

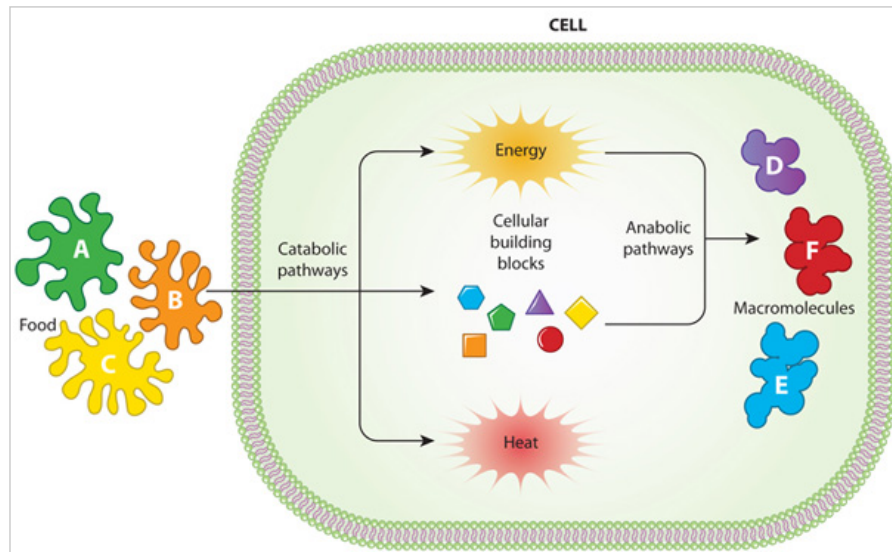


Figure 4: Catabolic and anabolic pathways in cell metabolism

Catabolic pathways involve the breakdown of nutrient molecules (Food: A, B, C) into usable forms (building blocks). In this process, energy is either stored in energy molecules for later use, or released as heat. Anabolic pathways then build new molecules out of the products of catabolism, and these pathways typically use energy. The new molecules built via anabolic pathways (macromolecules) are useful for building cell structures and maintaining the cell.

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How Do Cells Manage All Their Chemical Reactions?

Not only do cells need to balance catabolic and anabolic pathways, but they must also monitor the needs and surpluses of all their different **metabolic pathways**. In order to bolster a particular pathway, cells can increase the amount of a necessary (rate-limiting) enzyme or use activators to convert that enzyme into an active conformation. Conversely, to slow down or halt a pathway, cells can decrease the amount of an enzyme or use inhibitors to make the enzyme inactive.

Such up- and down-regulation of metabolic pathways is often a response to changes in concentrations of key metabolites in the cell. For example, a cell may take stock of its levels of intermediate metabolites and tune the glycolytic pathway and the synthesis of glucose accordingly. In some instances, the products of a metabolic pathway actually serve as inhibitors of their own synthesis, in a process known as **feedback inhibition**

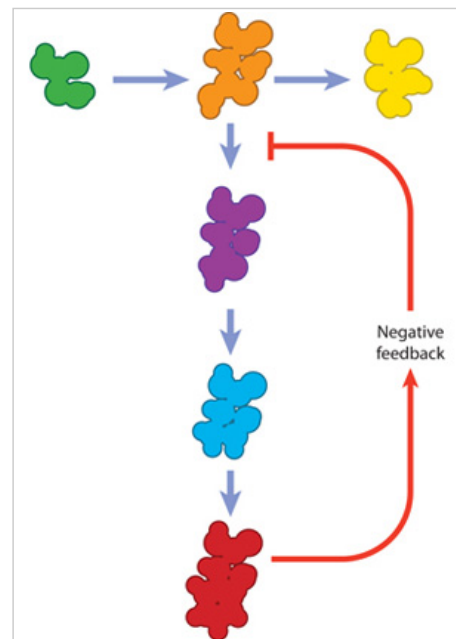


Figure 5: Feedback inhibition

When there is enough product at the end of a reaction pathway (red macromolecule), it can inhibit its own synthesis by interacting with enzymes in the synthesis pathway (red arrow).

(Figure 5). For example, the first intermediate in glycolysis, glucose-6-phosphate, inhibits the very enzyme that produces it, hexokinase.

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[Figure Detail](#)

Conclusion

The management of biochemical reactions with enzymes is an important part of cellular maintenance. Enzymatic activity allows a cell to respond to changing environmental demands and regulate its metabolic pathways, both of which are essential to cell survival.

eBooks

This page appears in the following eBook

[Essentials of Cell Biology, Unit 1.5](#)