Photosynthesis: The Beginning of the Food Chain

Sugar molecules are produced by the process of photosynthesis in plants and certain bacteria. These organisms lie at the base of the food chain, in that animals and other non-photosynthesizing organisms depend on them for a constant supply of life-supporting organic molecules. Humans, for example, obtain these molecules by eating plants or other organisms that have previously eaten food derived from photosynthesizing organisms. Plants and photosynthetic bacteria are unique in their ability to convert the freely available electromagnetic energy in sunlight into chemical bond energy, the energy that holds atoms together in molecules and is transferred or released in chemical reactions. The process of photosynthesis can be summarized by the following equation:

(Solar) energy + $6CO_2$ + $6H_2O \rightarrow$ sugar molecules ($C_6H_{12}O_6$) + $6O_2$

During photosynthesis, chlorophyll molecules absorb energy from sunlight and use it to fuel the production of simple sugars and other carbohydrates. The resulting abundance of sugar molecules and related biological products makes possible the existence of non-photosynthesizing life on Earth.

Respiration

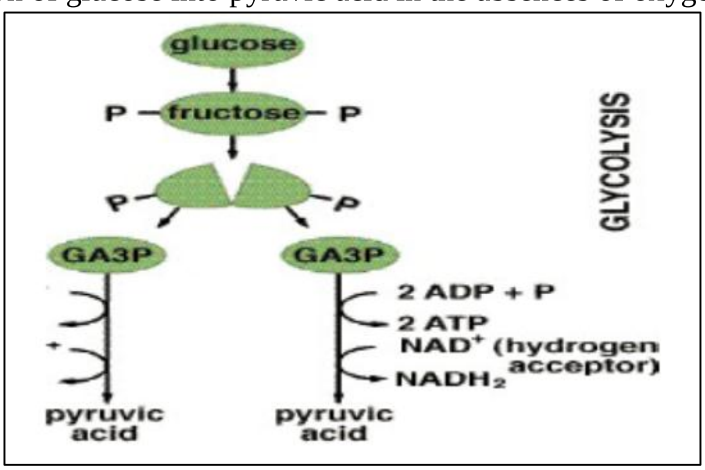
Respiration is the process where glucose formed by plants can completely oxidize into carbon dioxide and water.

$C_6H_{12}O_6+6O_2 \rightarrow 6CO_2+6H_2O+36ATP$

The step by step reaction in this process occurs in three stages:

1. Glycolysis

Glycolysis is the breakdown of glucose into pyruvic acid in the absences of oxygen.

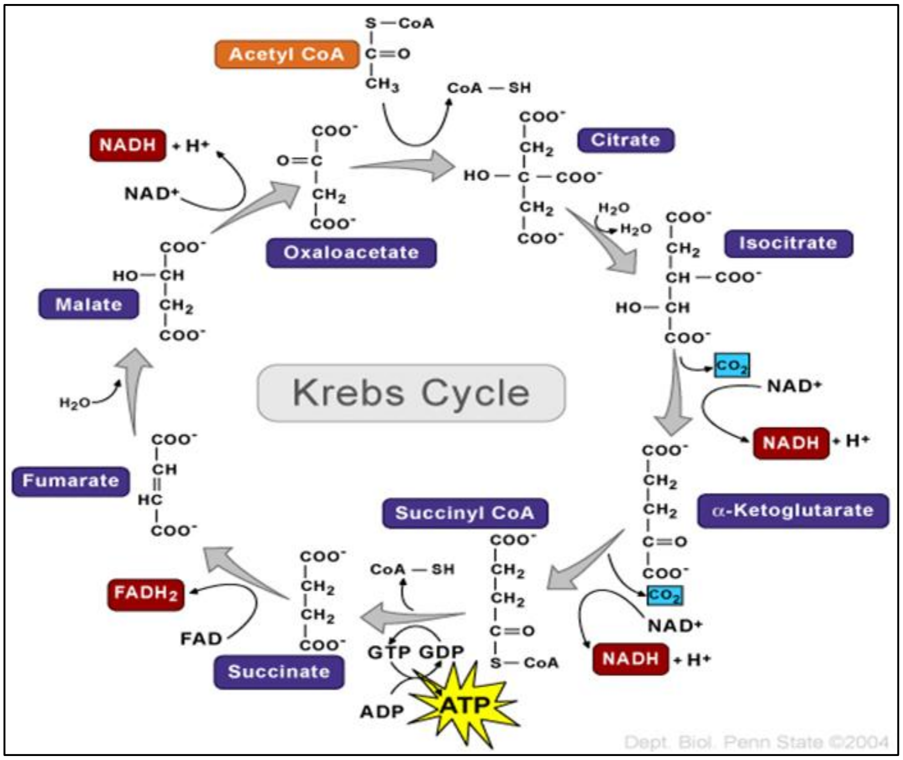


Reaction steps in glycolysis

2. Krebs cycle

Krebs cycle or citric acid cycle (also known as tricarboxylic acid cycle) is a series of oxidative reactions that occur in the mitochondria of the cell. The process involves further breakdown of the pyruvic acid that was produced during glycolysis into CO_2 and water in the presence of oxygen, enzymes and coenzyme located on the cristae of mitochondria in a cell.

During Krebs cycle, pyruvic acid is converted into acetyl coenzyme A complex; this acetyl coenzyme A complex combines with oxaloacetic acid to form citric acid. The citric acid goes through various intermediates with the release of 2 molecules of CO_2, reduced coenzymes (examples of coenzymes include, NADH, and FADH) and another one molecule of oxaloacetic acid. In each cycle, 2 molecules of carbon dioxide are released.



Krebs cycle

3. Electron Transport Chain or ETC

ETC reactions also occur inside the mitochondria. ETC is the process whereby the reduced coenzymes, NADH (Nicotinic Adenine Dinucleotide) and FADH (Flavo-Adenine Dinucleotide) released from the reactions of Krebs cycle undergoes oxidation, thereby generating electrons that are used to reduce oxygen into water. This involves highly exergonic (energy releasing) reactions.

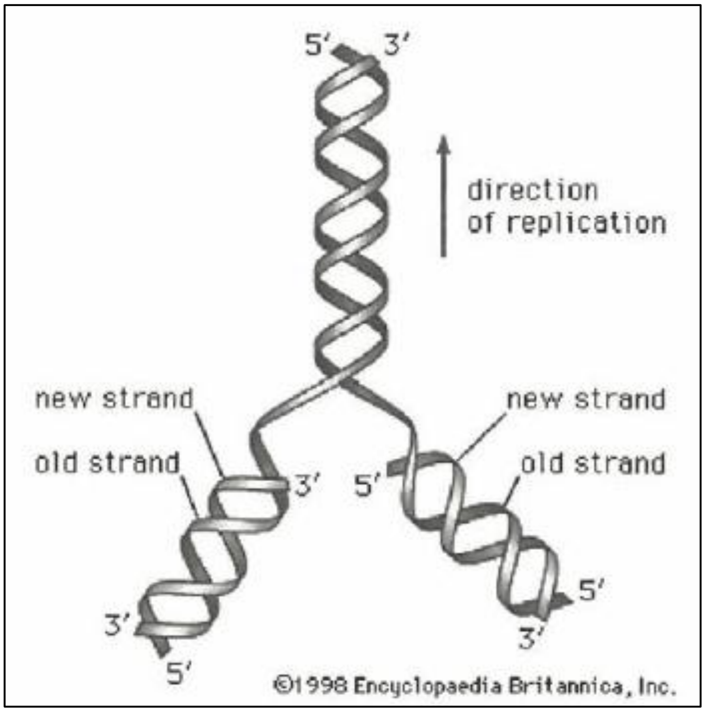
**Reactions whereby oxygen is used to produce ATP are collectively known as oxidative phosphorylation reactions. Another reaction that can allow the glucose to be broken down in the absence of oxygen is called fermentation. This is the process in which yeast (fungus) and bacteria can be used to produce wine.*

The Genetic Information of Cells

Cells can thus be seen as a self-replicating network of catalytic macromolecules engaged in a carefully balanced series of energy conversions that drive biosynthesis and cell movement. But energy alone is not enough to make self-reproduction possible. The cell must contain detailed instructions that dictate exactly how that energy is to be used. These instructions are analogous to the blueprints that a builder uses to construct a house. In the case of cells, however, the blueprints themselves must be duplicated along with the cell before it divides, so that each daughter cell can retain the instructions that it needs for its own replication. These instructions constitute the cell's heredity.

DNA: The Genetic Material

The chromosomes-dark-staining threads in the cell nucleus-carried the information for cell heredity. It was later shown that chromosomes are about half DNA and half protein by weight. James Watson and Francis Crick proposed a model for the structure of the double-stranded DNA molecule (called the DNA double helix). In this model, each strand serves as a template in the synthesis of a complementary strand. Subsequent research confirmed the Watson and Crick model of DNA replication and showed that DNA carries the genetic information for reproduction of the entire cell. Later discoveries identified small amounts of additional genetic information present in the DNA of much smaller chromosomes located in two types of organelles in the cytoplasm. These organelles are the mitochondria in animal cells and the mitochondria and chloroplasts in plant cells.



DNA replication

RNA: Replicated From DNA

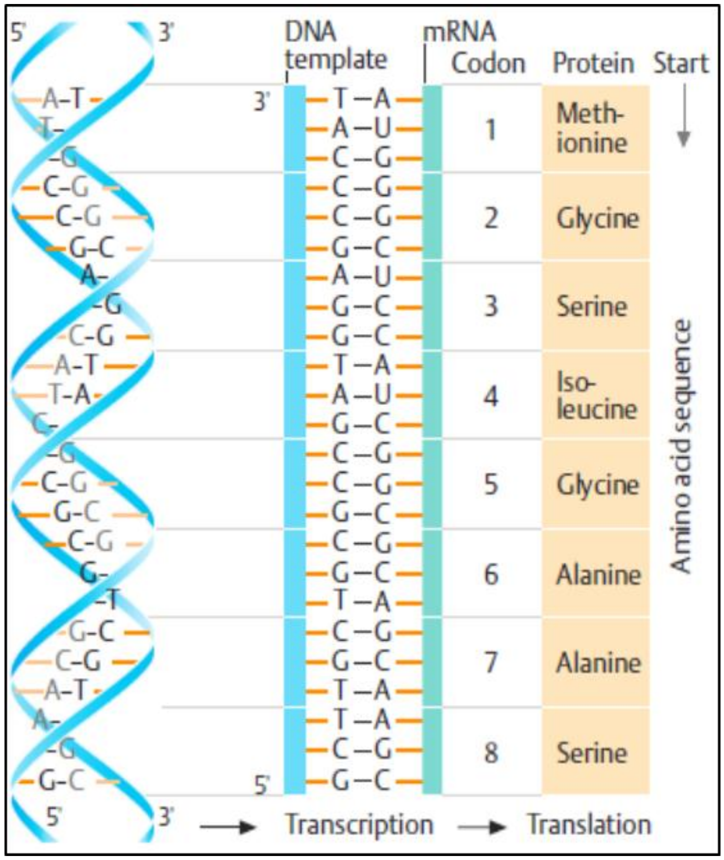
All the RNA in present-day cells is synthesized by special enzymes that construct a single stranded RNA chain by using one strand of the DNA helix as a template. Although RNA molecules are synthesized in the cell nucleus, where the DNA is located, most are transported to the cytoplasm before they carry out their functions.

The RNA molecules in cells have two main roles. Some, the ribozymes, fold up in ways that allow them to serve as catalysts for specific chemical reactions. Others serve as "messenger RNA," which provides templates specifying the synthesis of proteins. Ribosomes, tiny protein-synthesizing machines located in the cytoplasm, "read" the messenger RNA molecules and "translate" them into proteins by using the genetic code. In this translation, the sequence of nucleotides in the messenger RNA chain is decoded three nucleotides at a time, and each nucleotide triplet (called a codon) specifies a particular amino acid. Thus, a nucleotide sequence in the DNA specifies a protein, provided that a messenger RNA molecule is produced from that DNA sequence. Each region of the DNA sequence specifying a protein in this way is called a gene.

By the aforementioned mechanisms, DNA molecules catalyze not only their own duplication but also dictate the structures of all protein molecules. A single human cell contains about 10,000 different proteins produced by the expression of 10,000 different genes. Actually, a set of human chromosomes is thought to contain DNA with enough information to express between 30,000 and 100,000 proteins, but most of these proteins seem to be made only in specialized types of cells and are therefore not present throughout the body.

Cells and tissues

In multicellular organisms, cells are organized into tissues. These organizations consist of structurally and functionally similar cells and of intercellular material. By definition, tissues are absent from unicellular organisms. Even among the simplest multicellular species, such as sponges, tissues are lacking or are poorly differentiated. But multicellular animals and plants that are more advanced have specialized tissues that can organize and regulate an organism's response to its environment.



Protein synthesis

Animal Tissues

Early in the evolutionary history of animals, tissues became aggregated into organs, which themselves became divided into specialized parts. An early scientific classification of tissues divided them on the basis of the organ system of which they formed a part (e.g., nervous tissues). Embryologists have often classified tissues on the basis of their origin in the developing embryo, such as ectodermal, endodermal, and mesodermal tissues. Another method classified tissues into four broad groups' epithelial, endothelial, stroma, and connective according to cell composition. In this classification, epithelial tissues are composed of cells that make up the body's outer covering and the membranous covering of internal organs, cavities, and canals, and endothelial tissues are composed of cells that line the inside of organs. Stroma tissues are composed of cells that serve as a matrix in which the other cells are embedded, whereas connective tissues represent a rather amorphous category composed of cells and an extracellular matrix that serve as a connection from one tissue to another.

The most useful of all systems, however, breaks down animal tissues into four classes based on the functions that the tissues perform. These four tissue classes are epithelial tissue, connective tissue, nervous tissue, and muscle tissue. According to this system, epithelial tissues include the layers of cells closely bound to one another that form continuous sheets covering body surfaces internally and externally. Thus, epithelial tissues are those tissues that may come into contact with foreign substances. Connective tissues are groups of cells that maintain the form of the body and its organs and that provide cohesion and internal support. The connective tissues include several types of fibrous tissue that vary only in their density and cellularity, as well as the more specialized and recognizable variants—bone, ligaments, tendons, cartilage, and adipose (fat) tissue.

Plant Tissues

The ways in which cells are organized into tissues in plants differ fundamentally from the ways in which they are organized into tissues in animals. Vascular plants possess specialized conducting tissues, which transport nutrients and water to all parts of the plant. In contrast, nonvascular plants, such as bryophytes (liverworts, hornworts, and mosses), lack these tissues. Bryophytes further lack true leaves, stems, and roots. As a result, these plants absorb water and nutrients directly through leaf like and stem like structures or through cells that form during certain phases of the reproductive cycle.

In vascular plants, such as angiosperms and gymnosperms, cell division takes place almost exclusively in specific tissues known as meristems. Apical meristems, which are located at the tips of shoots and roots in all vascular plants, give rise to three types of primary meristems, which in turn produce the mature primary tissues of the plant. The three kinds of mature tissues are dermal, vascular, and ground tissues. Primary dermal tissues, called epidermis, make up the outer layer of all plant organs (e.g., stems, roots, leaves, flowers). They help deter excess water loss and invasion by insects and microorganisms. The vascular tissues are of two kinds: water-transporting xylem and food-transporting phloem. Primary xylem and phloem are arranged in vascular bundles that run the length of the plant from roots to leaves. The ground tissues, which comprise the remaining plant matter, include various support, storage, and photosynthetic tissues. Secondary, or lateral, meristems, which are found in all woody plants and in some herbaceous ones, consist of the vascular cambium and the cork cambium. They produce secondary tissues from a ring of vascular cambium in stems and roots. Secondary phloem forms along the outer edge of the cambium ring, and secondary xylem (i.e., wood) forms along the inner edge of the cambium ring. The cork cambium produces a secondary dermal tissue (periderm) that replaces the epidermis along older stems and roots.

References

THE CELL 2011, Kara Rogers, Published by Britannica Educational Publishing 1st edition.