Energy and Metabolism

MBB

Bio-chem III Semester

The Role of Energy and Metabolism

- All organisms require **energy** to complete tasks;
- Metabolism is the set of the chemical reactions that release energy for cellular processes.

Key Points

- All living organisms need energy to grow and reproduce, maintain their structures, and respond to their environments; metabolism is the set of the processes that makes energy available for cellular processes.
- Metabolism is a combination of chemical reactions that are spontaneous and release energy and chemical reactions that are non-spontaneous and require energy in order to proceed.

- Living organisms must take in energy via food, nutrients, or sunlight in order to carry out cellular processes.

- The transport, synthesis, and breakdown of nutrients and molecules in a cell require the use of energy.

Key Terms

- **metabolism**: the complete set of chemical reactions that occur in living cells

- **bioenergetics**: the study of the energy transformations that take place in living organisms

- **energy**: the capacity to do work

Energy and Metabolism

- All living organisms need energy to grow and reproduce, maintain their structures, and respond to their environments.
- Metabolism is the set of life-sustaining chemical processes that enables organisms transform the chemical energy stored in molecules into energy that can be used for cellular processes.

- Animals consume food to replenish energy; their metabolism breaks down the carbohydrates, lipids, proteins, and nucleic acids to provide chemical energy for these processes.
- Plants convert light energy from the sun into chemical energy stored in molecules during the process of photosynthesis.

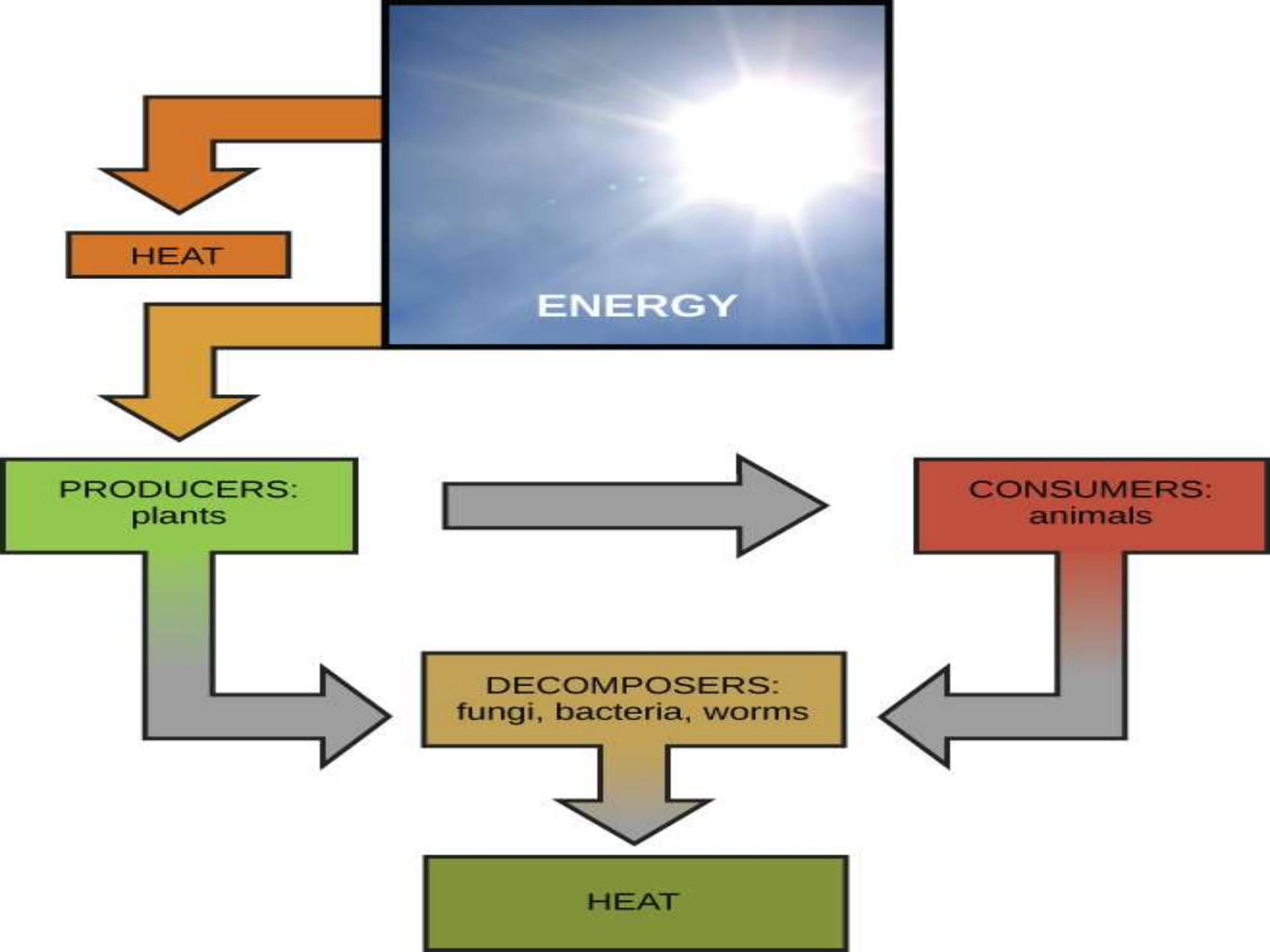
Bioenergetics and Chemical Reactions

- The term bioenergetics is used to discuss the concept of energy flow through living systems such as cells.

- Cellular processes such as the building and breaking down of complex molecules occur through step-by-step chemical reactions.

- Some of these chemical reactions are spontaneous and release energy, whereas others require energy to proceed.

- All of the chemical reactions that take place inside cells, including those that use energy and those that release energy, are the cell's metabolism.


ENERGY
HEAT
PRODUCERS:
plants
CONSUMERS:
animals
DECOMPOSERS:
fungi, bacteria, worms
HEAT

Bioenergetics

CELLULAR METABOLISM

- Every task performed by living organisms requires energy.
- Energy is needed to perform heavy labor and exercise, but humans also use a great deal of energy while thinking and even while sleeping.
- For every action that requires energy, many chemical reactions take place to provide chemical energy to the systems of the body, including muscles, nerves, heart, lungs, and brain.

- The living cells of every organism constantly use energy to survive and grow.

- Cells break down complex carbohydrates into simple sugars that the cell can use for energy.

- Muscle cells may consumer energy to build long muscle proteins from small amino acid molecules.

- Molecules can be modified and transported around the cell or may be distributed to the entire organism.

- Just as energy is required to both build and demolish a building, energy is required for both the synthesis and breakdown of molecules.

- Many cellular process require a steady supply of energy provided by the cell's metabolism.
- Signaling molecules such as hormones and neurotransmitters must be synthesized and then transported between cells.
- Pathogenic bacteria and viruses are ingested and broken down by cells.
- Cells must also export waste and toxins to stay healthy, and many cells must swim or move surrounding materials via the beating motion of cellular appendages like cilia and flagella.

TYPES OF ENERGY

Types of Energy

The various types of energy includes:

- Kinetic energy,
- Potential energy, and
- Chemical energy.

Key Points

- All organisms use different forms of energy to power the biological processes that allow them to grow and survive.

- Kinetic energy is the energy associated with objects in motion.

Contd..

- Potential energy is the type of energy associated with an object's potential to do work.

- Chemical energy is the type of energy released from the breakdown of chemical bonds and can be harnessed for metabolic processes.

Key Terms

- **chemical energy**: The net potential energy liberated or absorbed during the course of a chemical reaction.

- **potential energy**: Energy possessed by an object because of its position (in a gravitational or electric field), or its condition (as a stretched or compressed spring, as a chemical reactant, or by having rest mass).

- **kinetic energy**: The energy possessed by an object because of its motion, equal to one half the mass of the body times the square of its velocity.

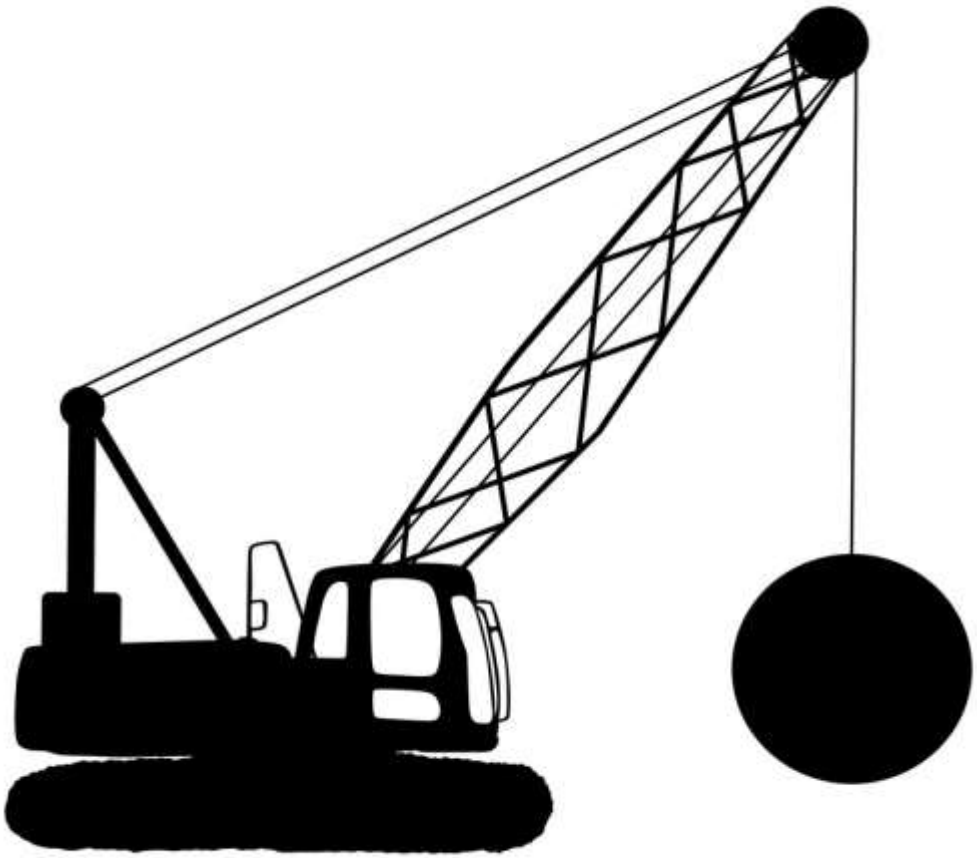
- Energy is a property of objects which can be transferred to other objects or converted into different forms, but cannot be created or destroyed. (recall thermodynamics laws)
- Organisms use energy to survive, grow, respond to stimuli, reproduce, and for every type of biological process.
- The potential energy stored in molecules can be converted to chemical energy, which can ultimately be converted to kinetic energy, enabling an organism to move.
- Eventually, most of energy used by organisms is transformed into heat and dissipated.

Kinetic Energy

- Energy associated with objects in motion is called kinetic energy. For example, when an airplane is in flight, the airplane is moving through air very quickly—doing work to enact change on its surroundings. The jet engines are converting potential energy in fuel to the kinetic energy of movement.

Another example..

- A wrecking ball can perform a large amount of damage, even when moving slowly.
- However, a still wrecking ball cannot perform any work (**Really?**)and therefore has no kinetic energy.
- A speeding bullet, a walking person, the rapid movement of molecules in the air that produces heat, and electromagnetic radiation, such as sunlight, all have kinetic energy.



Potential Energy

- What if that same motionless wrecking ball is lifted two stories above a car with a crane? If the suspended wrecking ball is not moving, is there energy associated with it?

Contd..

- **Yes**, the wrecking ball has energy because the wrecking ball has the potential to do work.

- This form of energy is called potential energy because it is possible for that object to do work in a given state.

- Objects transfer their energy between potential and kinetic states.
- As the wrecking ball hangs motionlessly, it has 0% kinetic and 100% potential energy.
- Once the ball is released, its kinetic energy increases as the ball picks up speed.
- At the same time, the ball loses potential energy as it nears the ground.

- Other examples of potential energy include the energy of water held behind a dam or a person about to skydive out of an airplane.

Chemical Energy

- Potential energy is not only associated with the location (position) of matter, but also with the structure of matter.
- A spring on the ground has potential energy if it is compressed, as does a rubber band that is pulled taut.
- The same principle applies to molecules. (**YES**)

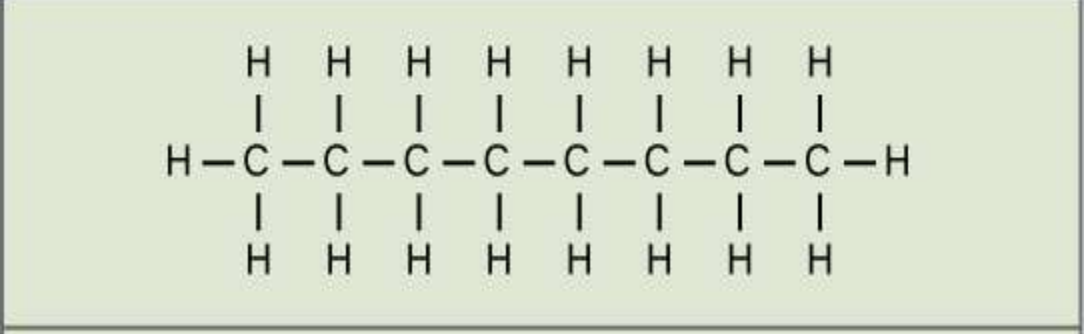
Contd..

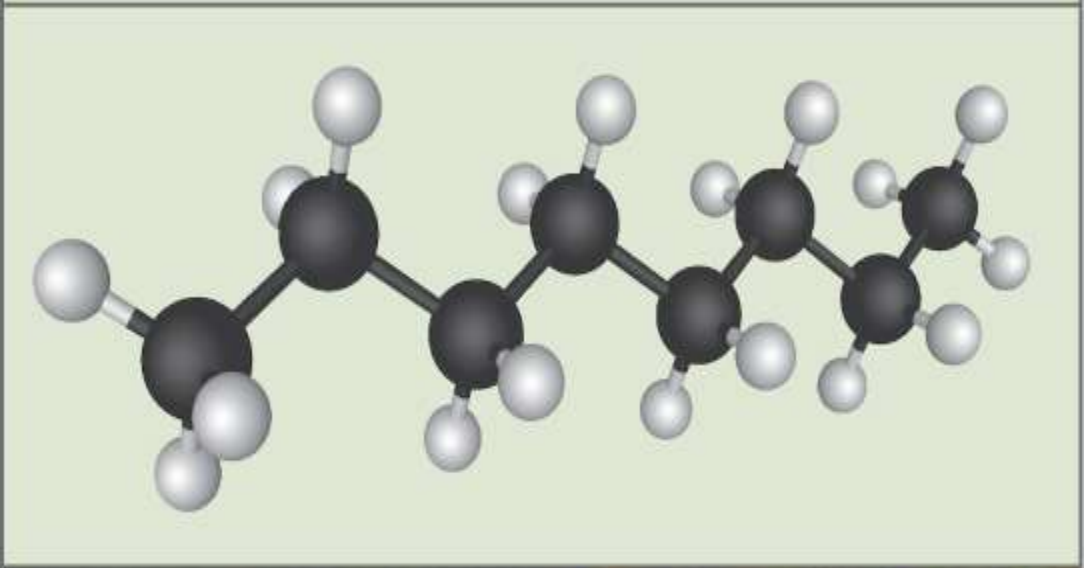
- On a chemical level, the bonds that hold the atoms of molecules together have potential energy.

- This type of potential energy is called chemical energy, and like all potential energy, it can be used to do work.

For Example..

- Chemical energy is contained in the gasoline (petrol) molecules that are used to power cars.
- When gas ignites in the engine, the bonds within its molecules are broken, and the energy released is used to drive the pistons.
- The potential energy stored within chemical bonds can be harnessed to perform work for biological processes.
- Different metabolic processes break down organic molecules to release the energy for an organism to grow and survive.





Chemical energy: The molecules in gasoline (octane, the chemical formula shown) contain chemical energy. This energy is transformed into kinetic energy that allows a car to race on a racetrack.

METABOLIC PATHWAYS

Key Points

- A metabolic pathway is a series of chemical reactions in a cell that build and breakdown molecules for cellular processes.
- Anabolic pathways synthesize molecules and require energy.
- Catabolic pathways break down molecules and produce energy.
- Because almost all metabolic reactions take place non-spontaneously, proteins called enzymes help facilitate those chemical reactions.

Key terms

- **catabolism**: destructive metabolism, usually including the release of energy and breakdown of materials
- **enzyme**: a globular protein that catalyses a biological chemical reaction
- **anabolism**: the constructive metabolism of the body, as distinguished from catabolism

Metabolic Pathways

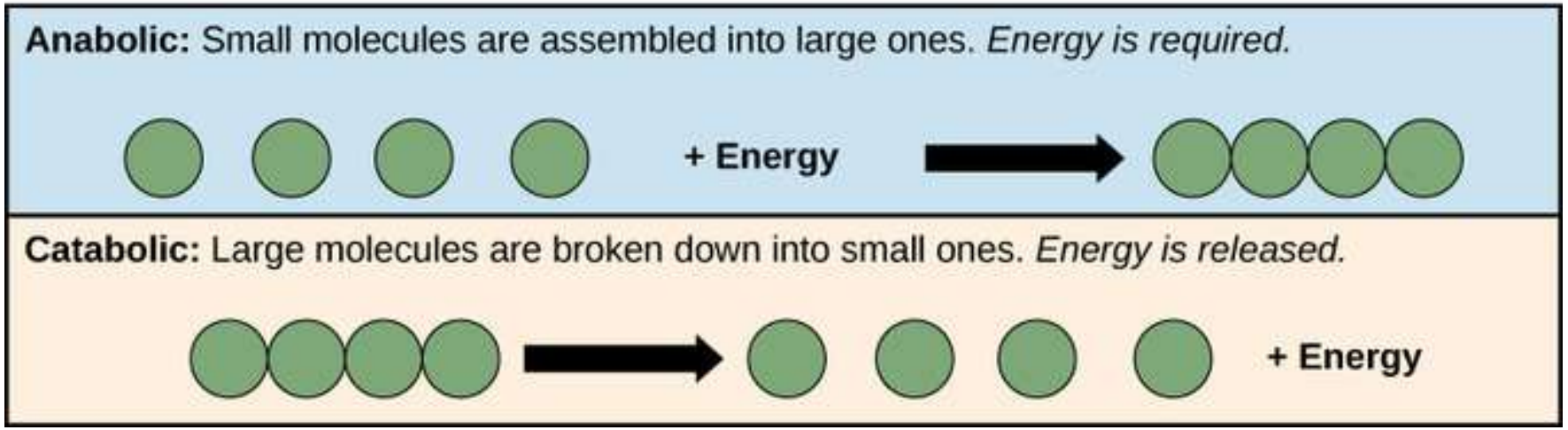
- The processes of making and breaking down carbohydrate molecules illustrate two types of metabolic pathways.
- A metabolic pathway is a step-by-step series of interconnected biochemical reactions that convert a substrate molecule or molecules through a series of metabolic intermediates, eventually yielding a final product or products.

- For example, one metabolic pathway for carbohydrates breaks large molecules down into glucose.
- Another metabolic pathway might build glucose into large carbohydrate molecules for storage.
- The first of these processes requires energy and is referred to as anabolic. The second process produces energy and is referred to as catabolic.

Consequently, metabolism is composed of these two opposite pathways:

- **Anabolism** (building molecules)
- **Catabolism** (breaking down molecules)

Metabolic pathways



Anabolic and catabolic pathways: Anabolic pathways are those that require energy to synthesize larger molecules. Catabolic pathways are those that generate energy by breaking down larger molecules. Both types of pathways are required for maintaining the cell's energy balance.

Anabolic Pathways

- Anabolic pathways require an input of energy to synthesize complex molecules from simpler ones.
- One example of an anabolic pathway is the synthesis of sugar from CO_2.
- Other examples include the synthesis of large proteins from amino acid building blocks and the synthesis of new DNA strands from nucleic acid building blocks.
- These processes are critical to the life of the cell, take place constantly, and demand energy provided by ATP and other high-energy molecules like NADH (nicotinamide adenine dinucleotide) and NADPH.

Catabolic Pathways

- Catabolic pathways involve the degradation of complex molecules into simpler ones, releasing the chemical energy stored in the bonds of those molecules.
- Some catabolic pathways can capture that energy to produce ATP, the molecule used to power all cellular processes.
- Other energy-storing molecules, such as lipids, are also broken down through similar catabolic reactions to release energy and make ATP.

Importance of Enzymes

- Chemical reactions in metabolic pathways rarely take place spontaneously.
- Each reaction step is facilitated, or catalyzed, by a protein called an enzyme.
- Enzymes are important for catalyzing all types of biological reactions: those that require energy as well as those that release energy.

Organisms break down carbohydrates to produce energy for cellular processes, and photosynthetic plants produce carbohydrates.

METABOLISM OF CARBOHYDRATES

Key Points

- The breakdown of glucose living organisms utilize to produce energy is described by the equation:
- $C6H12O6+6O2 \rightarrow 6CO2+6H2O+energy=C6H12O6+6O2 \rightarrow 6CO2+6H2O+energy.$
- The photosynthetic process plants utilize to synthesize glucose is described by the equation:
- $6CO2+6H2O+energy \rightarrow C6H12O6+6O26CO2+6H2O+energy \rightarrow C6H12O6+6O2.$

- Glucose that is consumed is used to make energy in the form of ATP, which is used to perform work and power chemical reactions in the cell.
- During photosynthesis, plants convert light energy into chemical energy that is used to build molecules of glucose.

Key Terms

- **adenosine triphosphate**: a multifunctional nucleoside triphosphate used in cells as a coenzyme, often called the “molecular unit of energy currency” in intracellular energy transfer
- **glucose**: a simple monosaccharide (sugar) with a molecular formula of C6H12O6; it is a principal source of energy for cellular metabolism

Metab. Of Carbohydrates

- Carbohydrates are one of the major forms of energy for animals and plants.
- Plants build carbohydrates using light energy from the sun (during the process of photosynthesis), while animals eat plants or other animals to obtain carbohydrates.
- Plants store carbohydrates in long polysaccharides chains called starch, while animals store carbohydrates as the molecule glycogen.

- These large polysaccharides contain many chemical bonds and therefore store a lot of chemical energy.
- When these molecules are broken down during metabolism, the energy in the chemical bonds is released and can be harnessed for cellular processes.

- **Energy Production from Carbohydrates (Cellular Respiration)**

- **Producing Carbohydrates (Photosynthesis)**

Pl recall your concepts….on respiration and photosynthesis