Cellular Respiration

Producers and Consumers
Plants and other autotrophs (self-feeders):
Make their own organic matter from inorganic nutrients.
Heterotrophs (other-feeders):
Include humans and other animals that cannot make organic molecules from inorganic ones.
Autotrophs are producers because ecosystems depend upon them for food.
Heterotrophs are consumers because they eat plants or other animals.

Chemical Cycling between Photosynthesis & Cellular Respiration
The ingredients for photosynthesis are carbon dioxide and water.
CO₂ is obtained from the air by a plant’s leaves.
H₂O is obtained from the damp soil by a plant’s roots.
Chloroplasts in the cells of leaves:
Use light energy to rearrange the atoms of CO₂ and H₂O, which produces sugars (such as glucose, other organic molecules and oxygen.
Plant and animal cells perform cellular respiration, a chemical process that:
Primarily occurs in mitochondria
Harvests energy stored in organic molecules
Uses oxygen
Generates ATP
The waste products of cellular respiration are:
CO₂ and H₂O
Used in photosynthesis
Animals perform only cellular respiration.
Plants perform:
Photosynthesis and cellular respiration
Cellular respiration and breathing are closely related.
Cellular respiration requires a cell to exchange gases with its surroundings.
Breathing exchanges these same gases between the blood and outside air.

The Overall Equation for Cellular Respiration
A common fuel molecule for cellular respiration is glucose.
The overall equation for what happens to glucose during cellular respiration:

The Role of Oxygen in Cellular Respiration
Cellular respiration can produce up to 32 ATP molecules for each glucose molecule consumed.
During cellular respiration, hydrogen and its bonding electrons change partners.
Hydrogen and its electrons go from sugar to oxygen, forming water.
This hydrogen transfer is why oxygen is so vital to cellular respiration.

Redox Reactions
Chemical reactions that transfer electrons from one substance to another are called:
Redox reactions for short
The loss of electrons during a redox reaction is called oxidation.
The acceptance of electrons during a redox reaction is called reduction.
During cellular respiration glucose is oxidized while oxygen is reduced.

Why does electron transfer to oxygen release energy?
When electrons move from glucose to oxygen, it is as though the electrons were falling.
This “fall” of electrons releases energy during cellular respiration.
Cellular respiration is:
A controlled fall of electrons
A stepwise cascade much like going down a staircase

NADH and Electron Transport Chains
The path that electrons take on their way down from glucose to oxygen involves many steps.
The first step is an electron acceptor called NAD⁺.
The transfer of electrons from organic fuel to NAD⁺ reduces it to NADH.
The rest of the path consists of an electron transport chain, which:
Involves a series of redox reactions
Ultimately leads to the production of large amounts of ATP

An Overview of Cellular Respiration
Cellular respiration:
Is an example of a metabolic pathway, which is a series of chemical reactions in cells
All of the reactions involved in cellular respiration can be grouped into three main stages:
Glycolysis
The citric acid cycle
Electron transport

The Three Stages of Cellular Respiration
With the big-picture view of cellular respiration in mind, let’s examine the process in more detail.

Stage 1: Glycolysis
A six-carbon glucose molecule is split in half to form two molecules of pyruvic acid.
These two molecules then donate high energy electrons to NAD⁺, forming NADH.
Glycolysis:
Uses two ATP molecules per glucose to split the six-carbon glucose
Makes four additional ATP directly when enzymes transfer phosphate groups from fuel molecules to ADP
Thus, glycolysis produces a net of two molecules of ATP per glucose molecule.

Stage 2: The Citric Acid Cycle
The citric acid cycle completes the breakdown of sugar.
In the citric acid cycle, pyruvic acid from glycolysis is first “prepped.”
The citric acid cycle:
Extracts the energy of sugar by breaking the acetic acid molecules all the way down to CO₂
Uses some of this energy to make ATP
Forms NADH and FADH₂

**Stage 3: Electron Transport**
Electron transport releases the energy your cells need to make the most of their ATP.
The molecules of the electron transport chain are built into the inner membranes of mitochondria.
The chain functions as a chemical machine that uses energy released by the “fall” of electrons to pump hydrogen ions across the inner mitochondrial membrane.
These ions store potential energy.
When the hydrogen ions flow back through the membrane, they release energy.
The hydrogen ions flow through ATP synthase.
ATP synthase takes the energy from this flow and synthesizes ATP.
Cyanide is a deadly poison that:
Binds to one of the protein complexes in the electron transport chain
Prevents the passage of electrons to oxygen
stops the production of ATP

**The Versatility of Cellular Respiration**
In addition to glucose, cellular respiration can “burn”:
Diverse types of carbohydrates
Fats
Proteins

**Adding Up the ATP from Cellular Respiration**
Cellular respiration can generate up to 38 molecules of ATP per molecule of glucose.

**Fermentation in Human Muscle Cells**
After functioning anaerobically for about 15 seconds:
Muscle cells will begin to generate ATP by the process of fermentation.
Fermentation relies on glycolysis to produce ATP.
Glycolysis:
Does not require oxygen
Produces two ATP molecules for each glucose broken down to pyruvic acid
Pyruvic acid, produced by glycolysis, is reduced by NADH, producing NAD⁺, which keeps glycolysis going.
In human muscle cells, lactic acid is a by-product.

**Fermentation in Microorganisms**
Fermentation alone is able to sustain many types of microorganisms.
The lactic acid produced by microbes using fermentation is used to produce:
Cheese, sour cream, and yogurt dairy products
Soy sauce, pickles, olives
Sausage meat products
Yeast are a type of microscopic fungus that:
Use a different type of fermentation
Produce CO₂ and ethyl alcohol instead of lactic acid
This type of fermentation, called alcoholic fermentation, is used to produce:
Beer
Wine
Breads