Chapter 9
Cellular Respiration

Cells require outside energy to do cellular work.

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Energy flows (تتدفق) into most ecosystems (أنظمة بيئية) as sunlight

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Photosynthetic organisms trap a portion of the sunlight energy and transform it into chemical energy (organic molecules) and O2 is released.

(تحول النباتات جزء من الطاقة الشمسية إلى طاقة كيميائية)

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Cells use some of the chemical energy in organic molecules to make ATP; the energy source for cellular work

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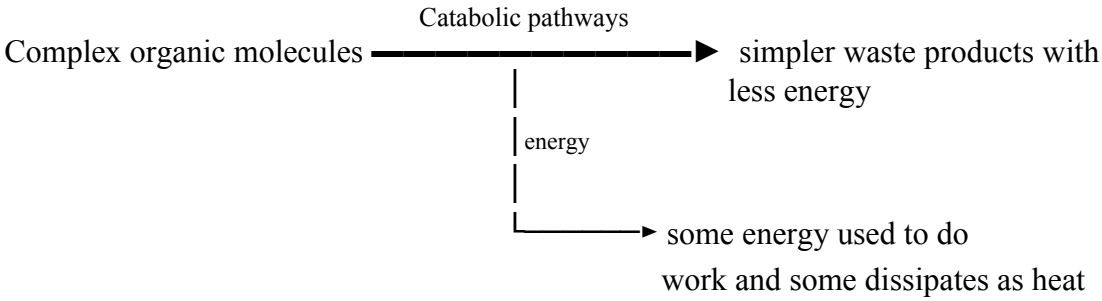
Energy leaves organisms as it dissipates as heat

- 8 The products of respiration (CO2 and H2O) are the raw materials for photosynthesis.
- 9 Photosynthesis produces glucose and oxygen, the raw materials for respiration.



Cellular respiration and fermentation are catabolic pathways.

Fermentation: (التخمر): An ATP-producing process in which both electron donors and acceptors are organic molecules.

- 10 can be an anaerobic (لاهوائي) process.

- 11results in partial degradation of glucose.

Cellular respiration: An ATP-producing process in which the final electron acceptor is an inorganic molecule, e.g. O2.

- 12most common than fermentation.
- 13Is an exergonic process (ΔG = - 686 kcal/mol).
- 14Can be summarized as the following:

organic molecule + oxygen ⟶ carbon dioxide + water + energy

cellular respiration is most often described as the oxidation of glucose:

$C_6H_{12}O_6 + 6O_2 \longrightarrow 6CO_2 + 6H_2O +$ Energy (ATP + heat)

Cell must recycle the ATP they spend for work

Catabolic process of respiration transfers the energy stored in food molecules to ATP. ATP (adenosine triphosphate): nucleotide with unstable phosphate bonds that cells hydrolyze for energy.

- 15The cell gain energy stored in ATP by enzymatically transferring terminal phosphate groups from ATP to other compounds.
- 16The compound receiving the phosphate from ATP is said to be phosphorylated and become more active in the process.
- 17Cells must recycle the ATP to continue cellular work. Respiration provides the energy to generate ATP from ADP and inorganic phosphate.

Redox reactions release energy when electrons move closer to electrogenic atoms.

Redox Reactions: Chemical oxidation-reduction reactions: reactions which involve a partial or complete transfer of electrons from one reactant to another.

Oxidation: Partial or complete loss of electrons.

Reduction: Partial or complete gain of electrons.

Electron transfer requires both a donor (مانح) and acceptor (مستقبل), so when one reactant is oxidized the other is reduced.

Electrons fall from organic molecules to oxygen during cellular respiration:

Cellular respiration is a redox process that transfers hydrogen from sugar to oxygen.

--------- oxidation ----------

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O +$ energy (used to make ATP)

--------- reduction ----------

- 18electrons of carbon and hydrogen lose potential energy as they shift towards oxygen.
- 19Released energy is used by cells to produce ATP.
- 20Carbohydrates and fats are excellent energy stores because they are rich in C and H.

The fall of electrons during respiration is stepwise (على خطوات) via NAD^+ and an electron transport chain

- 21hydrogens taken from glucose are not transferred directly to oxygen, but are first passed to a special electron acceptor: NAD^+
- 22NAD functions as a *coenzyme* in the redox reaction. It is:
  - found in all cells.
  - assist enzymes in electron transfer during redox reactions.

Coenzyme: small nonprotein organic molecule that is required for some enzymes to function.

- 23during oxidation of glucose, NAD functions as an oxidizing agent by trapping electrons from glucose. These reactions are catalyzed by enzymes called: *dehydrogenases* , which:
  - remove a pair of hydrogen atoms (2 electrons+2 protons) from substrate.
  - deliver (يوصل) the 2 electrons and one proton to NAD.
  - release the remaining proton into the surrounding solution.
- 24The high energy electrons transferred from substrate to NAD are then passed down the *electron transport chain* to oxygen, powering ATP synthesis.

Respiration Process:

There are three metabolic stages of cellular respiration:

1. **glycolysis:**

- 25occurs in the cytosol
- 26partially oxidize glucose into two pyruvate molecules
- 27No carbon dioxide is released
- 28Occurs whether or not oxygen is present.
- 29The reaction occurs in two phases: energy investment phase and energy pay off phase.
- 30Produces two ATP molecules and two NADH.

((refer to the book for details and diagrams)).

2. **Krebs Cycle**:

- 31occurs in the mitochondrial matrix
- 32completes glucose oxidation by breaking down pyruvate derivitatives (مشتقات) into carbon dioxide.

The Cycle:

- 33Before Krebs cycle begins, a number of steps occur within a multienzyme complex in the mitochondria:
  - -0 a carboxyl group is removed from the pyruvate and released as CO2.
  - -1 The remaining molecule is oxidized to form acetate and NAD^+ is reduced to NADH.
  - -2 Coenzyme A is attached to acetate by an unstable bond forming acetyl CoA.
- 34The acetyla part of acetyl CoA is added to oxaloacetate to form citrate which is pregressivlely (بخطوات متلاحقة) decomposed back to oxaloacetate.
- 35For each turn (دورة) of Krebs cycle, two carbons exit completely as CO2, three NADH and one $FADH_2$ are formed.
- 36One ATP is made by substrate-level phosphorylation .
- 37There are two turns of Krebs cycle for each glucose molecule oxidized.
- 38For each glucose: 2 ATP is produced
  6 NADH is produced
  2 $FADH_2$ is produced
  3 CO2 are released

3. **Electron Transport Chain**:

- 39is located at the inner membrane of the mitochondria.
- 40Accepts energized electrons from reduced coenzymes (NADH and $FADH_2$) that are harvested during glycolysis and krebs cycle. Oxygen pulls these electrons down the elctron transport chain to a lower energy state.
- 41Couples this exergonic slide of electrons to ATP synthesis or *oxidative phosphorylation.*

Oxidative phosphorylation: ATP production that is couples to the exergonic transfer of electrons from food to oxygen.

Substrate-level phosphorylation: ATP production by direct enzymatic transfer of phosphate from an intermediate substrate in catabolism to ADP.

- 42The electron transport chain is made of electron carrier molecules embedded in the inner membrane of mitochondria.
- 43Each carrier in the chain has a higher electronegativity than the carrier before it, so electrons are pulled downhill towards oxygen.
- 44Most carriers are protein molecules except for ubiquinone (Q).
- 45Electrons are transferred along the chain as in the following:

NADH is oxidized and flavoprotein is reduced as high energy electrons from NADH are transferred to FMN

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flavoprotein is oxidized as it passes electrons to an iron sulfur protein, FeS.

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FeS is oxidized as it pass electrons to ubiquinone Q

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Q passes electrons on to a succession of electron carriers, most of which are cytochromes.

↓

cyt a_3 , the last cytochrome passes electrons to oxygen.

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As molecular oxygen is reduced it also picks up two protons from the medium to form water. For every two FADH2, one oxygen is reduced to two H2O molecules.

Chemiosmosis:

A process of ATP generation in chloroplast (photophosphorylation) and mitochondria. (oxidative phosphorylation). The movement of electrons down an electron transport chain is used to pump hydrogen ions across a membrane, thereby building a concentration gradient of hydrogen ions across the membrane. The hydrogen ions diffuse back across the membrane through pores of the ATP synthesizing enzyme "ATP synthaze". The energy of their concentration gradient drives ATP synthesis.

Cellular Respiration is remarkably efficient in the transfer of chemical energy from glucose to ATP:

-3 estimated efficiency in eukaryoptic cells is about 38%

-4 energy lost in the process is released as heat.