5

Microbiology

Doctor 2017 | Medicine | JU

◉ Sheet ○ Slides

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Doctor

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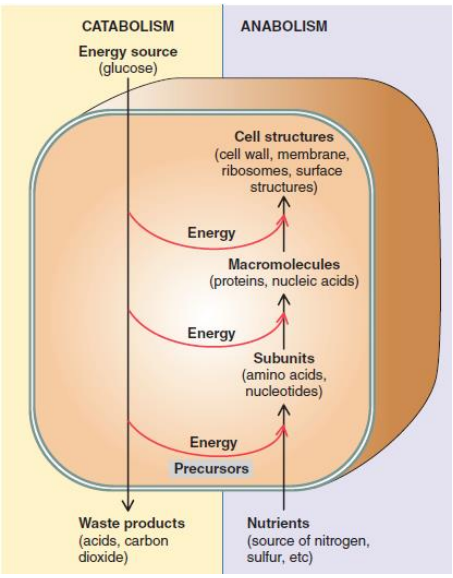
Bacterial Metabolism

-Metabolism has two components, **catabolism** and **anabolism**.



-Catabolism encompasses processes that harvest energy released from the **breakdown** of compounds (eg, glucose), and uses that energy to synthesize **ATP** for the cell to survive and grow. Some energy will be lost as **heat**.

-In contrast, anabolism, includes processes that utilize the energy stored in ATP (from catabolism) to **synthesize and assemble** the subunits, or building blocks of **macromolecules and organelles** that make up the cell.

-The amount of energy harvested from the same molecule like glucose varies according to the catabolic pathway taken by the cell.

-Prokaryotes are extremely diverse. Different bacteria use different metabolic pathways according to the nutrients available in their environment. They have different **growth requirements and metabolic byproducts**. This helps scientists in classifying and identifying bacteria.

-For example, this **differential media** contains **mannitol.** Which cannot be metabolized by all kinds of bacteria.
Some bacteria (in this case staphylococcus) can ferment it and produce an acid that will lower the pH of the media and cause a color change from **pink to yellow.**

-Initially, macromolecules must be broken down before entering the bacterium. The bacterium achieves this by **hydrolyzing** macromolecules (proteins, polysaccharides, lipids), by releasing enzymes, into smaller units then they pass through the cell membrane via passive or active transport.

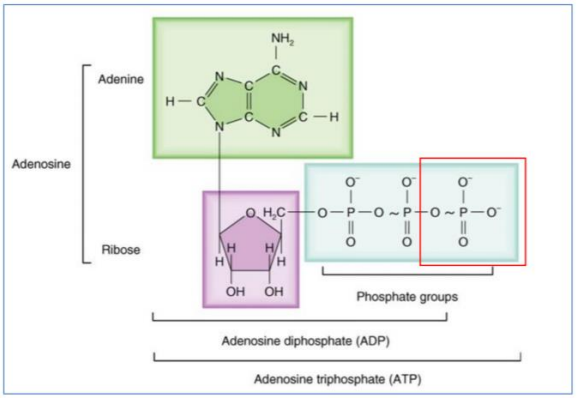
-The macromolecules have the essential elements (O,C,N,S,P) for building any macromolecule a bacterium needs (lipids, proteins, nucleic acids, etc….)

-Metabolism is a highly regulated process. Regulation can be done by controlling enzyme activity by **changing substrate concentration**.

Furthermore, the **inhibition of enzyme activity** by the end products (metabolites) of a pathway constitutes another mechanism of regulation.

ATP at the heart of metabolism

-ATP is made of the sugar ribose with adenosine and three phosphate groups.



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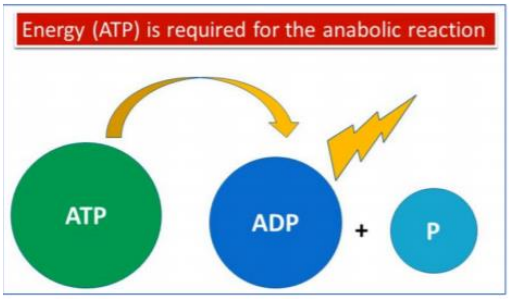
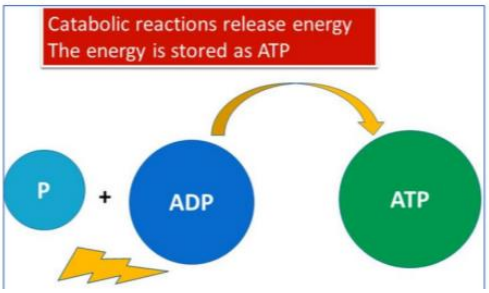




-ATP is made by adding a phosphate group to ADP (adenine diphosphate) through:

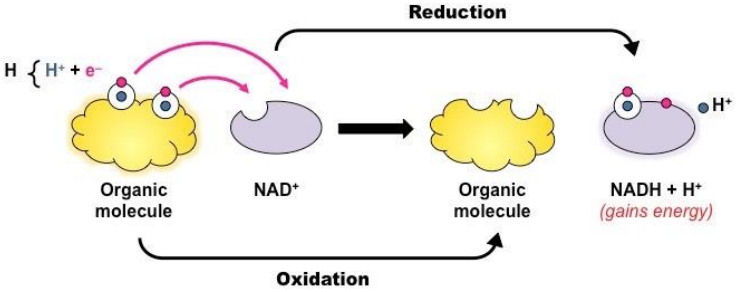
- **Oxidative phosphorylation**
- **Substrate level phosphorylation**
- **Chemiosmosis**
- **Photophosphorylation**

Oxidative phosphorylation

-Oxidative phosphorylation uses energy released by the electron transport chain to power ATP synthesis.

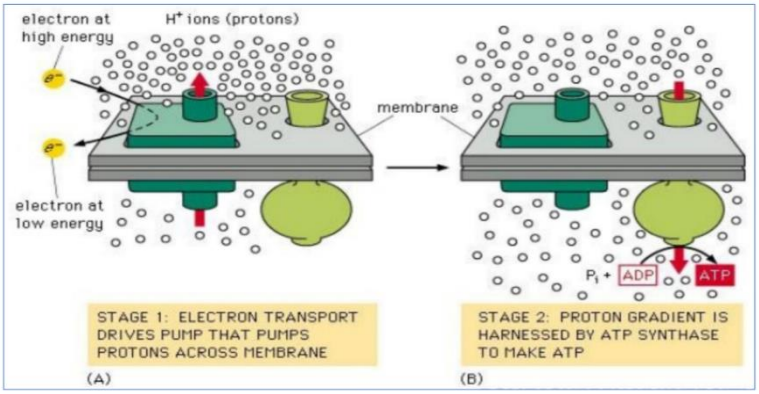
-The electron transport chain is a collection of molecules embedded in the **cell membrane** of prokaryotes and the inner mitochondrial membrane of eukaryotes.
-Each component of the chain becomes **reduced** when it accepts electrons from its "uphill" neighbor, which has **a lower affinity for electrons**. It then returns to its oxidized state form as it passes electrons to its "downhill" neighbor that has **greater affinity** for electrons **(affinity increases down the chain).** The electrons will finally be donated to **oxygen** and produce water.

-NAD+ will be reduced (it will gain **2 electrons)** to NADH by an organic molecule. The organic molecule will be oxidized.

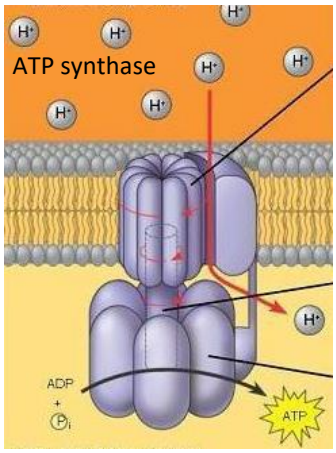


-NADH will then donate its **two electrons** to the first component of the electron transport chain.

-As electrons travel down the electron transport chain, **hydrogen pumps** are activated. These pumps export protons (H+) **out of the cell** (against their gradient) to generate **a gradient of H+ across the membrane**.



-Now that the gradient is established, protons will move back into the cell and they will activate an enzyme called **ATP synthase.**-This process in which energy is stored in the form of a **hydrogen ion gradient** across a membrane to drive the **synthesis of ATP** from ADP (via ATP synthase) is called **chemiosmosis.**



Substrate level phosphorylation

-The production of ATP by direct transfer of a phosphate group from an organic substrate to ADP by an enzyme.

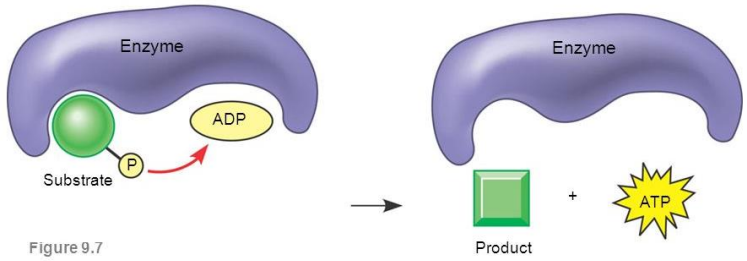
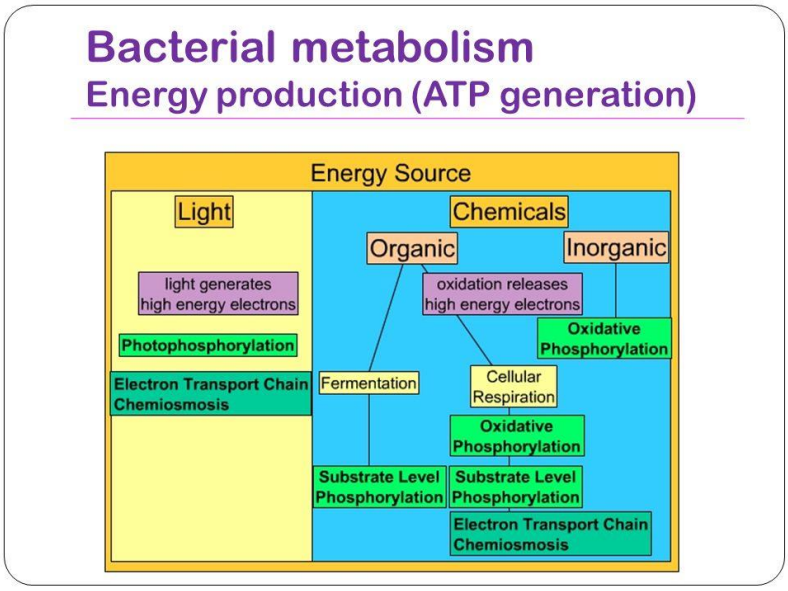


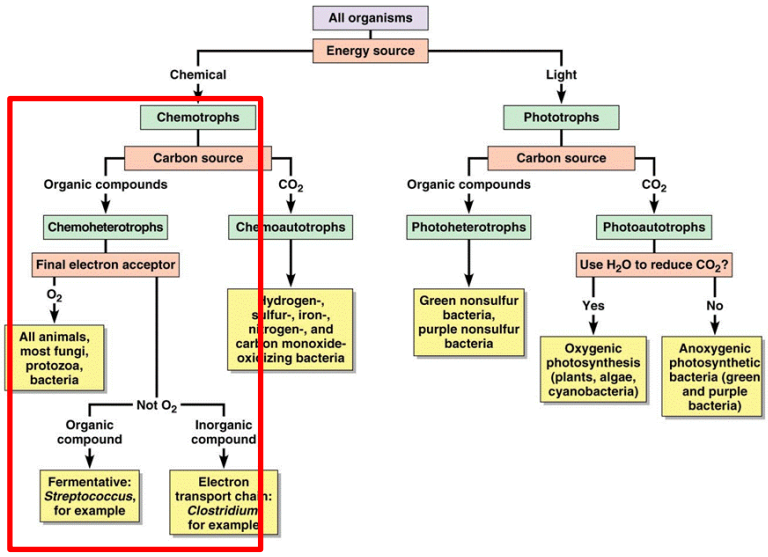
Figure 9.7

ATP Generation processes



-When light is the energy resource, it will generate high energy electrons that will feed the electron transport chain. Organisms that depend on light are called **phototrophs.** Plants get carbon from CO2, so they are called **photoautotrophs.**

-In the case of cellular respiration, the oxidation of organic molecules will generate electrons that will go to the electron transport chain and produce ATP. If the final electron acceptor is **O2** then it is **aerobic respiration**. In **anaerobic respiration** the final electron acceptor is an **inorganic molecule** ($SO4^{-2}$, NO3-). And it yields less ATP than aerobic respiration.



-Fermentation **does not** use the electron transport chain. The final electron acceptor will be an **organic molecule.**

-Organisms that use chemicals as their energy source and organic compounds supply them with carbon are called **chemoheterotrophs.**

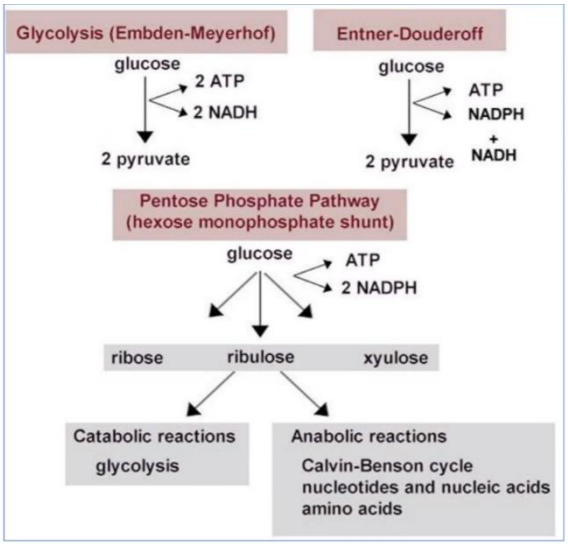
Carbohydrates are a major energy source

-Glucose is the most common molecule utilized by bacteria. Some types of bacteria can use other molecules like lactose or mannitol.

-Glucose is broken down to **2 pyruvate molecules** in glycolysis.

-Breaking down glucose can happen in **different pathways**. Embden–Meyerhof–Parnas (EMP pathway), pentose phosphate pathway (PPP) or Entner-Doudoroff pathway.

-Each pathway uses different enzymes and produces different metabolites that will be used later in anabolic or catabolic reactions.
Pentose phosphate pathway produces **ribulose.** This pathway is used when the bacterium needs to build nucleic acids.



EMP

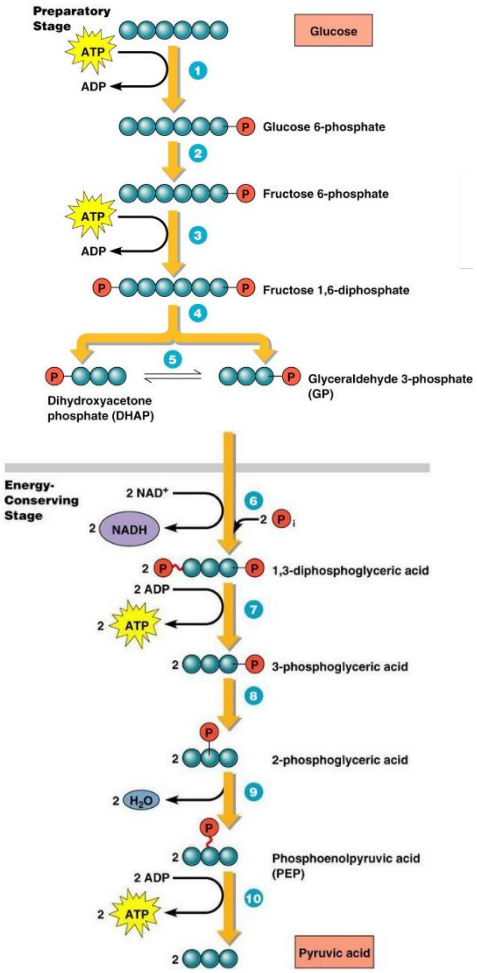
-EMP is the most used pathway for glycolysis.

-It happens in two main stages: preparatory stage and the energy conserving stage.

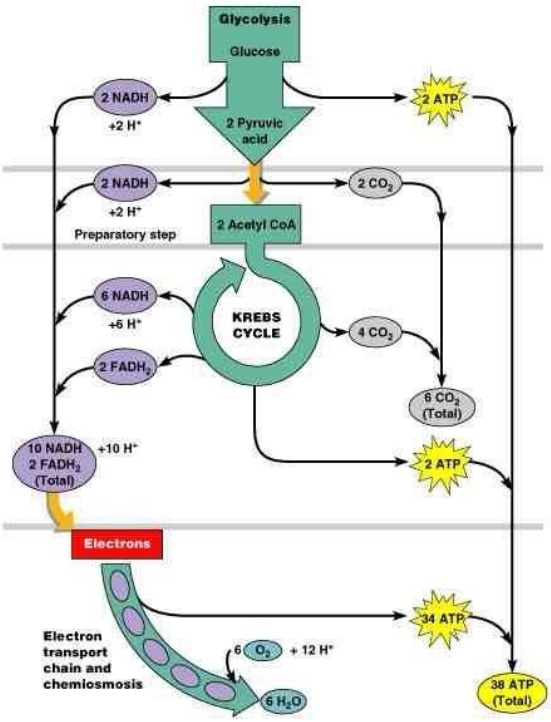
-**Preparatory stage**: the first half of glycolysis. Energy will be consumed to convert glucose into other smaller molecules. **2 ATP molecules are consumed**.

- **Energy conserving stage**: the second half of glycolysis. **4 ATP and 2 NADH** molecules are generated.

-**Total** energy from one glucose molecule: **2 ATP and 2 NADH.**



Aerobic respiration (Krebs cycle)



-After glycolysis, pyruvate can continue in different metabolic pathways according to the needs of the cell.

-In aerobic respiration, pyruvate will continue to Krebs cycle after turning it into acetyl-coA.

-The process of turning pyruvate (3C) to acetyl-coA (2C) yields energy.

-in Krebs cycle: waste products like CO2 are generated. ATP and NADH will also be generated.

-All NADH and FADH2 produced in the process of aerobic respiration will go to the electron transport chain to yield ATP by chemiosmosis.

-NADH= 3ATP
-FADH2= 2ATP

-**Summary:**
2ATP, 2NADH from glycolysis.
2NADH from the formation of acetyl-coA.
2ATP, 6NADH and 2FADH2 from Krebs cycle.
38 TP in total.

-**4ATPs** are produced by **substrate level phosphorylation** and **34 ATPs** by **oxidative phosphorylation.**

Note: in **eukaryotes**, aerobic respiration generates **36 ATP** molecules.

Fermentation

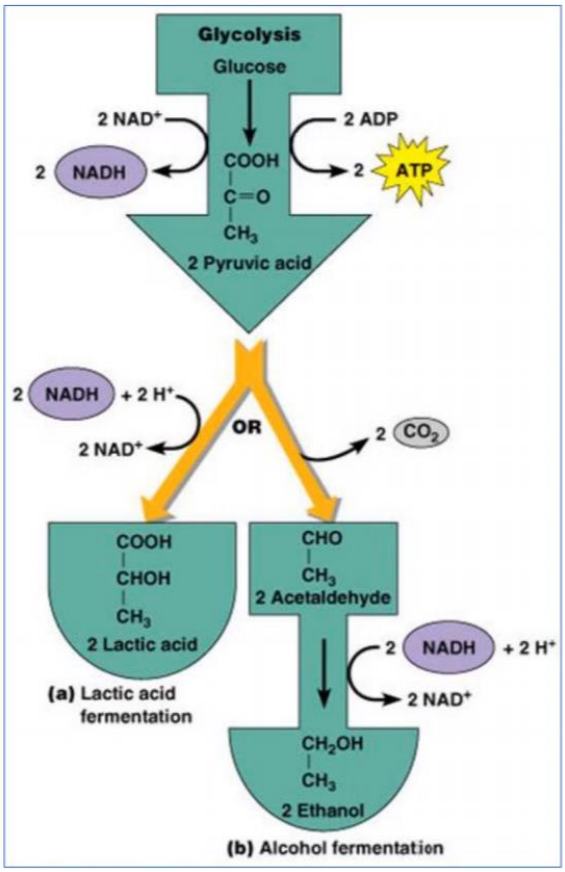
-Fermentation does not need **oxygen, the electron transport chain nor Krebs cycle.**

-The final electron acceptor is an **organic molecule**.

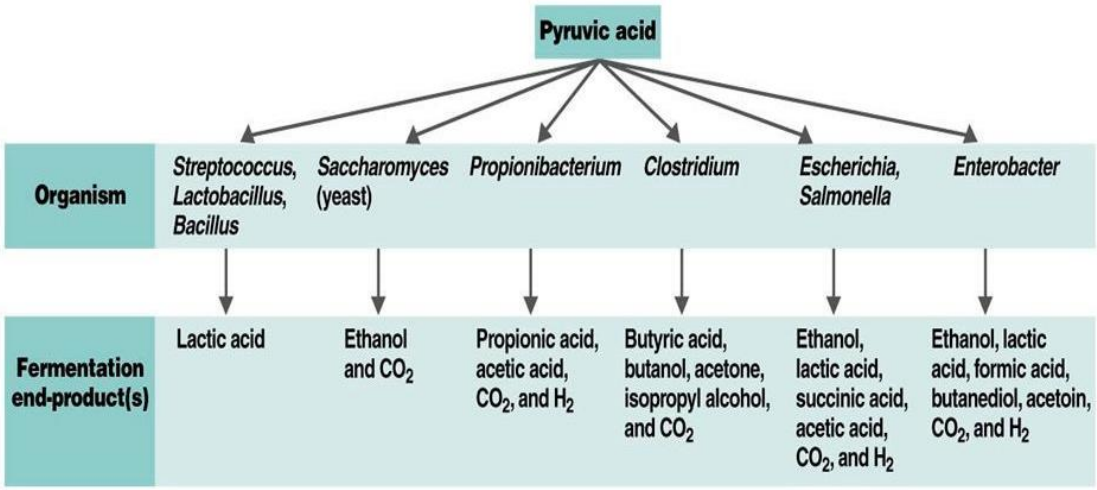
-It can take place even if oxygen is present.

-In glycolysis, 2 ATP molecules will be produced by **substrate level phosphorylation**. This is all the ATP fermentation can produce per one glucose molecule.

-The 2 NADH molecules produced by glycolysis will **donate their electrons** to turn pyruvate into different end products (lactic acid or alcohol).



-Different bacteria can use different sugars and pathways, therefore, different end products.



-We can use fermentation in our lives in many ways.

-Lactobacilli can be added to yoghurt since it ferments pyruvic acid to **lactic acid** which gives yoghurt its sour taste.

-**Ethanol** released from the fermentation of yeast can be used in beer and wine production.

-Yeast can also be used in making dough. **Carbon dioxide** will make the dough rise.

-The end products help microbiologists **in identifying the type of bacteria** in a culture.

Summary

TABLE 5.5 **Aerobic Respiration, Anaerobic Respiration, and Fermentation Compared**

Energy-Producing Process	Growth Conditions	Final Hydrogen (Electron) Acceptor	Type of Phosphorylation Used to Generate ATP	ATP Molecules Produced per Glucose Molecule
Aerobic respiration	Aerobic	Molecular oxygen (O_2)	Substrate-level and oxidative	36 or 38*
Anaerobic respiration	Anaerobic	Usually an inorganic substance (such as NO_3^-, SO_4^{2-}, or CO_3^{2-}), but not molecular oxygen (O_2)	Substrate-level and oxidative	Variable (fewer than 38but more than 2)
Fermentation	Aerobic or anaerobic	An organic molecule	Substrate-level	2

*In prokaryotic aerobic respiration, 38 ATP molecules are produced; in eukaryotic aerobic respiration, 36 ATP molecules are produced.

Good Luck