

ATP Production in Cells

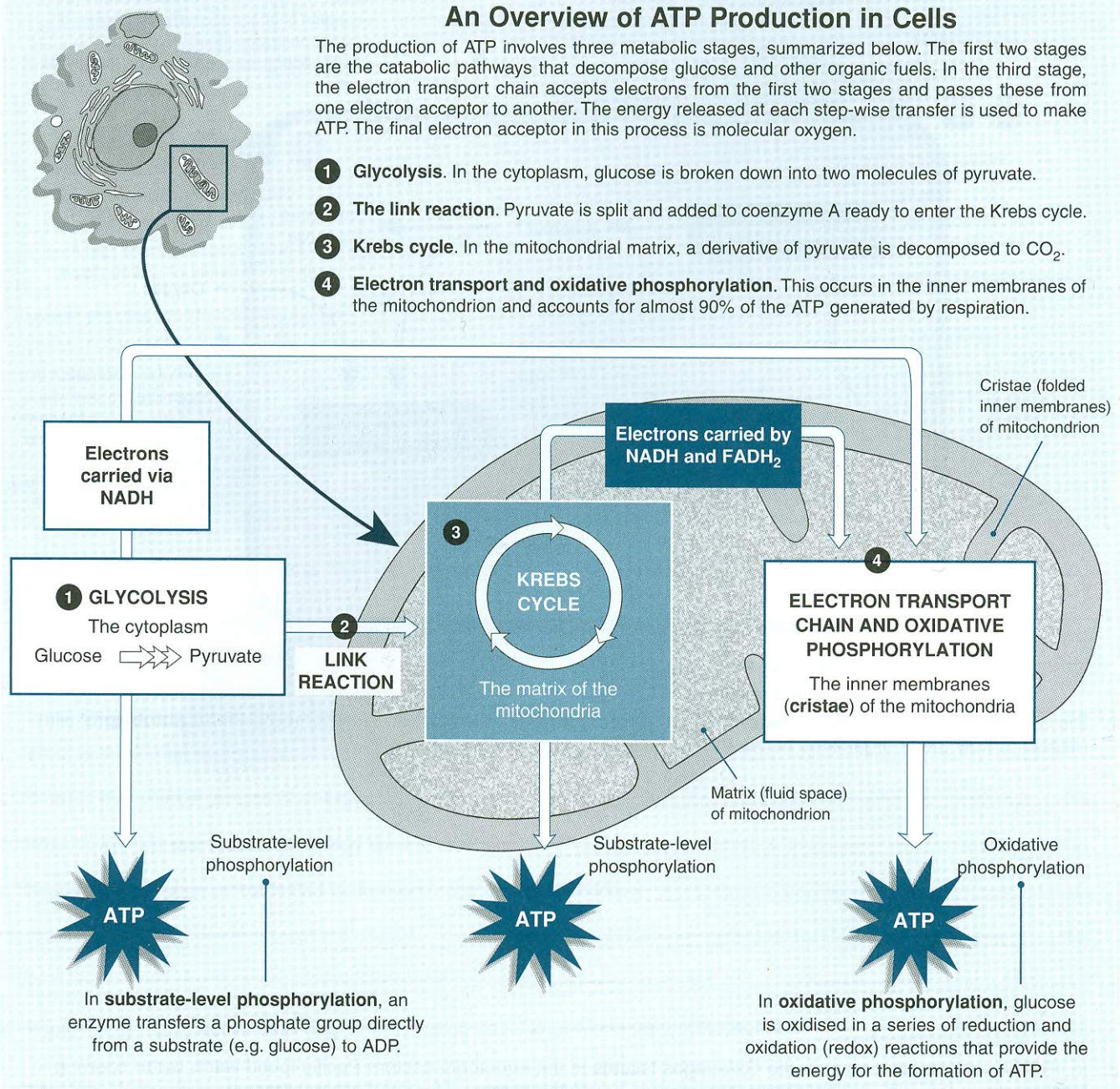
Glycolysis and cellular respiration are the processes by which organisms break down energy rich molecules (e.g. glucose) to release the energy in a useable form (ATP). All living cells respire in order to exist, although the substrates they use may vary. **Aerobic respiration** requires oxygen. Some plants and animals

can generate ATP using anaerobic pathways for short periods of time but the ATP yields from these pathways are low. Other organisms (bacteria) use only **anaerobic respiration** and live in oxygen-free environments. These organisms use some other final electron acceptor rather than oxygen (e.g. nitrate or Fe²⁺).

An Overview of ATP Production in Cells

The production of ATP involves three metabolic stages, summarized below. The first two stages are the catabolic pathways that decompose glucose and other organic fuels. In the third stage, the electron transport chain accepts electrons from the first two stages and passes these from one electron acceptor to another. The energy released at each step-wise transfer is used to make ATP. The final electron acceptor in this process is molecular oxygen.

- 1 **Glycolysis.** In the cytoplasm, glucose is broken down into two molecules of pyruvate.
- 2 **The link reaction.** Pyruvate is split and added to coenzyme A ready to enter the Krebs cycle.
- 3 **Krebs cycle.** In the mitochondrial matrix, a derivative of pyruvate is decomposed to CO₂.
- 4 **Electron transport and oxidative phosphorylation.** This occurs in the inner membranes of the mitochondrion and accounts for almost 90% of the ATP generated by respiration.



1. Describe precisely in which part of the cell the following take place:

- (a) Glycolysis: _____
- (b) Krebs cycle reactions: _____
- (c) Electron transport chain: _____

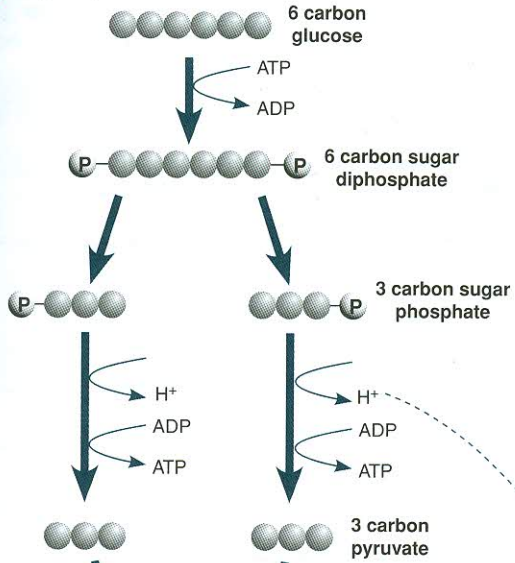
2. How does ATP generation in glycolysis and the Krebs cycle differ from ATP generation via the electron transport chain?

The Biochemistry of Respiration

Glycolysis and **cellular respiration** are catabolic, energy yielding pathways. The breakdown of glucose and other organic fuels (such as fats and proteins) to simpler molecules releases energy for the synthesis of ATP. All living cells respire in order to exist, although the substrates they use may vary. Glycolysis is the first stage of glucose catabolism and is anaerobic. The reactions

of cellular respiration oxidize the end product of glycolysis (**pyruvate**) in multiple steps to produce ATP. ATP generation in respiration is coupled to the movement of hydrogen ions down their electrochemical gradient via the membrane-bound enzyme ATP synthase. The final electron acceptor in this electron transport pathway is oxygen.

1 Glycolysis



Glycolysis in the cytoplasm

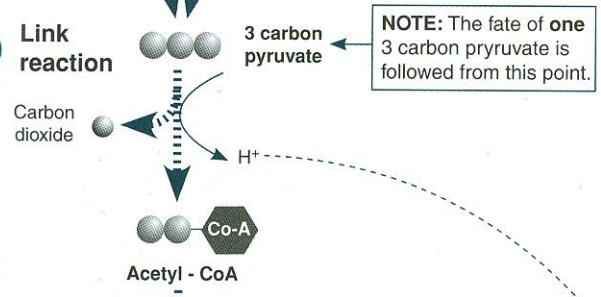
Breakdown of glucose (a 6-carbon sugar) to two molecules of pyruvate (pyruvic acid), during which a phosphate is added to ADP to form ATP. H_2 is also generated. No oxygen is required. The process uses two ATP and produces four, making a **net gain of 2ATP**.

Total ATP yield per glucose*

Glycolysis	2 ATP
Krebs cycle	2 ATP
Electron transport	34 ATP

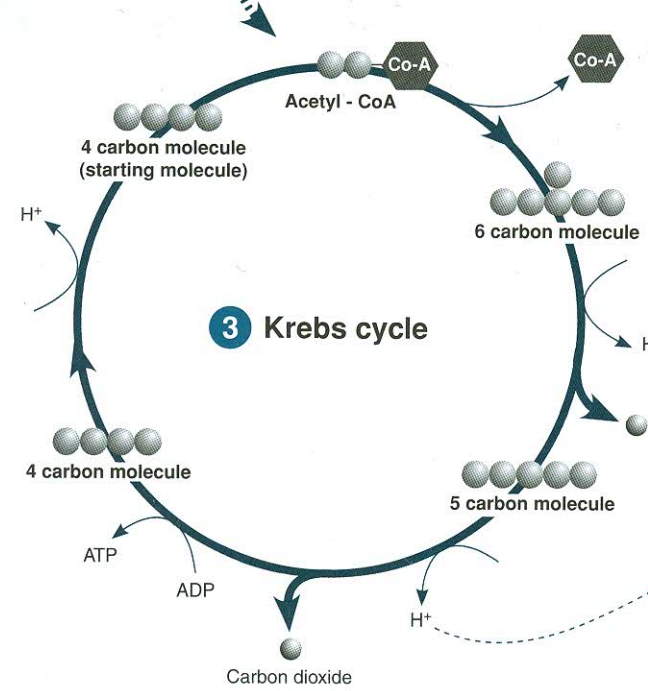
*This represents the theoretical maximum yield. True yield are usually less than this due to electrons being lost along the electron transport chain.

2 Link reaction



Link reaction

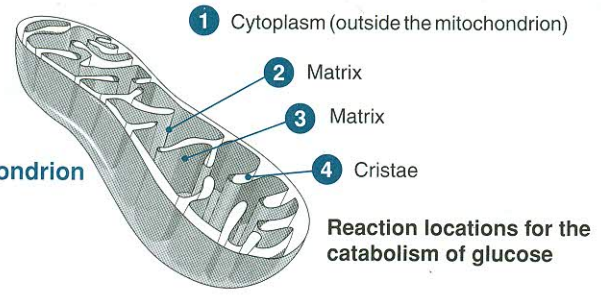
Pyruvate enters the mitochondrion and carbon dioxide is removed. Coenzyme A (CoA) picks up the 2-carbon fragment of the pyruvate to form **acetyl coenzyme A**.



3 Krebs cycle

Krebs cycle

The acetyl group passes into a cyclic reaction and combines with a 4-carbon molecule to form a 6-carbon molecule. The CoA is released for reuse. Successive steps in the cycle remove carbon as carbon dioxide.

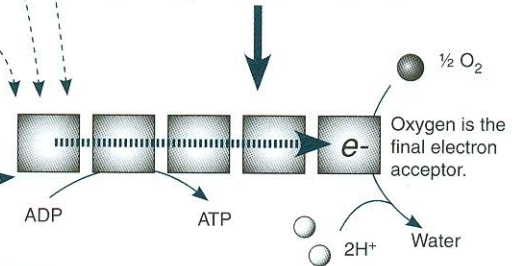


Reaction locations for the catabolism of glucose

Hydrogens are transported by hydrogen carriers (NAD⁺ and FAD) to the electron transport chain.

Electron transport chain

The hydrogens are passed along a series of hydrogen and electron carriers, located on the membranes of the cristae. Energy is released and captured as ATP. Oxygen is the final electron acceptor and is reduced to water.



4 Electron transport chain

