

**SCHOOL OF STUDIES IN ZOOLOGY**  
**JIWAJI UNIVERSITY, GWALIOR**



**Glycolysis and Gluconeogenesis**

**Subject** : Zoology

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**Unit** : I

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SOS in Zoology

# Glycolysis

- Glucose is the body's most readily available source of energy.
- After digestive processes break polysaccharides down into monosaccharides, including glucose, the monosaccharides are transported across the wall of the small intestine and into the circulatory system, which transports them to the liver.
- In the liver, hepatocytes either pass the glucose on through the circulatory system or store excess glucose as glycogen.
- Cells in the body take up the circulating glucose in response to insulin and, through a series of reactions called glycolysis, transfer some of the energy in glucose to ADP to form ATP .
- The last step in glycolysis produces the product pyruvate.

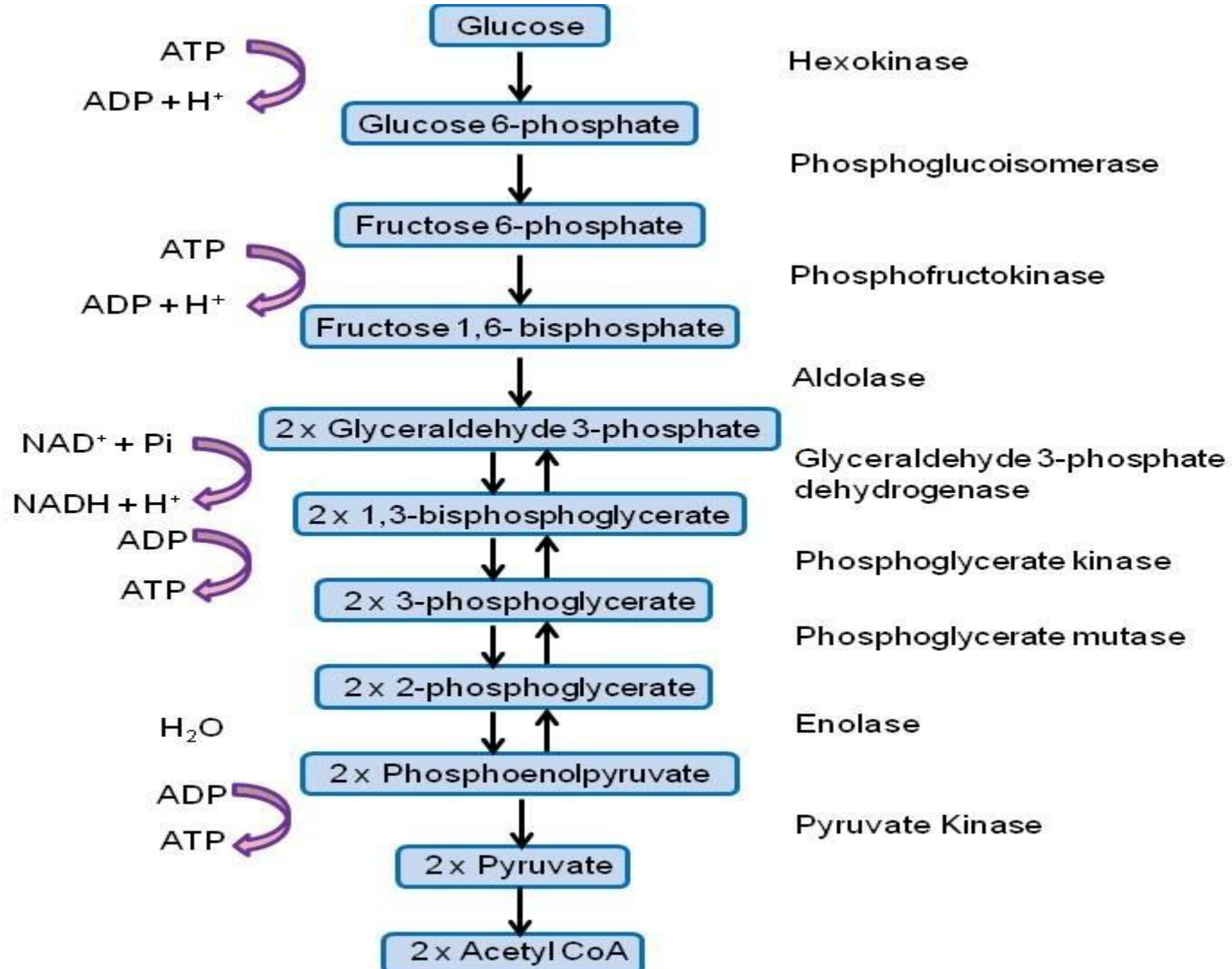
- $\text{Glucose} + 2\text{ATP} + 2\text{NAD} + 4\text{ADP} + 2\text{P} \rightarrow \text{Pyruvate} + 4\text{ATP} + 2\text{NADH} + 2\text{H}^+$
- One glucose molecule breaks down into two pyruvate molecules, and creates two net ATP molecules and two NADH molecules by glycolysis.
- Therefore, glycolysis generates energy for the cell and creates pyruvate molecules that can be processed further through the aerobic Krebs cycle (also called the citric acid cycle or tricarboxylic acid cycle); converted into lactic acid or alcohol (in yeast) by fermentation; or used later for the synthesis of glucose through gluconeogenesis.

- Glycolysis include the enzymes responsible for the reactions.
- When glucose enters a cell, the enzyme hexokinase (or glucokinase, in the liver) rapidly adds a phosphate to convert it into glucose-6-phosphate.
- A kinase is a type of enzyme that adds a phosphate molecule to a substrate (in this case, glucose, but it can be true of other molecules also).
- This conversion step requires one ATP and essentially traps the glucose in the cell, preventing it from passing back through the plasma membrane, thus allowing glycolysis to proceed.
- It also functions to maintain a concentration gradient with higher glucose levels in the blood than in the tissues.
- By establishing this concentration gradient, the glucose in the blood will be able to flow from an area of high concentration (the blood) into an area of low concentration (the tissues) to be either used or stored.

- Hexokinase is found in nearly every tissue in the body.
- Glucokinase, on the other hand, is expressed in tissues that are active when blood glucose levels are high, such as the liver.
- Hexokinase has a higher affinity for glucose than glucokinase and therefore is able to convert glucose at a faster rate than glucokinase.
- This is important when levels of glucose are very low in the body, as it allows glucose to travel preferentially to those tissues that require it more.
- the enzyme glucose-6-phosphate isomerase converts glucose-6-phosphate into fructose-6-phosphate. Like glucose, fructose is also a six carbon-containing sugar.
- The enzyme phosphofructokinase-1 then adds one more phosphate to convert fructose-6-phosphate into fructose-1,6-bisphosphate, another six-carbon sugar, using another ATP molecule.
- Aldolase then breaks down this fructose-1,6-bisphosphate into two three-carbon molecules, glyceraldehyde-3-phosphate and dihydroxyacetone phosphate.

- The triosephosphate isomerase enzyme then converts dihydroxyacetone phosphate into a second glyceraldehyde-3-phosphate molecule.
- Therefore, by the end of this chemical- priming or energy-consuming phase, one glucose molecule is broken down into two glyceraldehyde-3- phosphate molecules.
- The second phase of glycolysis, the energy-yielding phase, creates the energy that is the product of glycolysis.
- Glyceraldehyde-3-phosphate dehydrogenase converts each three-carbon glyceraldehyde-3- phosphate produced during the energy-consuming phase into 1,3-bisphosphoglycerate.
- This reaction releases an electron that is then picked up by  $\text{NAD}^+$  to create an NADH molecule.
- NADH is a high-energy molecule, like ATP, but unlike ATP, it is not used as energy currency by the cell.

- Because there are two glyceraldehyde-3-phosphate molecules, two NADH molecules are synthesized during this step.
- Each 1,3-bisphosphoglycerate is subsequently dephosphorylated (i.e., a phosphate is removed) by phosphoglycerate kinase into 3-phosphoglycerate.
- Each phosphate released in this reaction can convert one molecule of ADP into one highenergy ATP molecule, resulting in a gain of two ATP molecules.
- The enzyme phosphoglycerate mutase then converts the 3- phosphoglycerate molecules into 2-phosphoglycerate.
- The enolase enzyme then acts upon the 2-phosphoglycerate molecules to convert them into phosphoenolpyruvate molecules.
- The last step of glycolysis involves the dephosphorylation of the two phosphoenolpyruvate molecules by pyruvate kinase to create two pyruvate molecules and two ATP molecules.





# Anaerobic Respiration

- When oxygen is limited or absent, pyruvate enters an anaerobic pathway.
- In these reactions, pyruvate can be converted into lactic acid.
- In addition to generating an additional ATP, this pathway serves to keep the pyruvate concentration low so glycolysis continues, and it oxidizes NADH into the NAD<sup>+</sup> needed by glycolysis.
- In this reaction, lactic acid replaces oxygen as the anaerobic respiration.
- This is an effective pathway of ATP production for short periods of time, ranging from seconds to a few minutes.
- The lactic acid produced diffuses into the plasma and is carried to the liver, where it is converted back into pyruvate or glucose via the Cori cycle.
- Similarly, when a person exercises, muscles use ATP faster than oxygen can be delivered to them. They depend on glycolysis and lactic acid production for rapid ATP production. Aerobic.

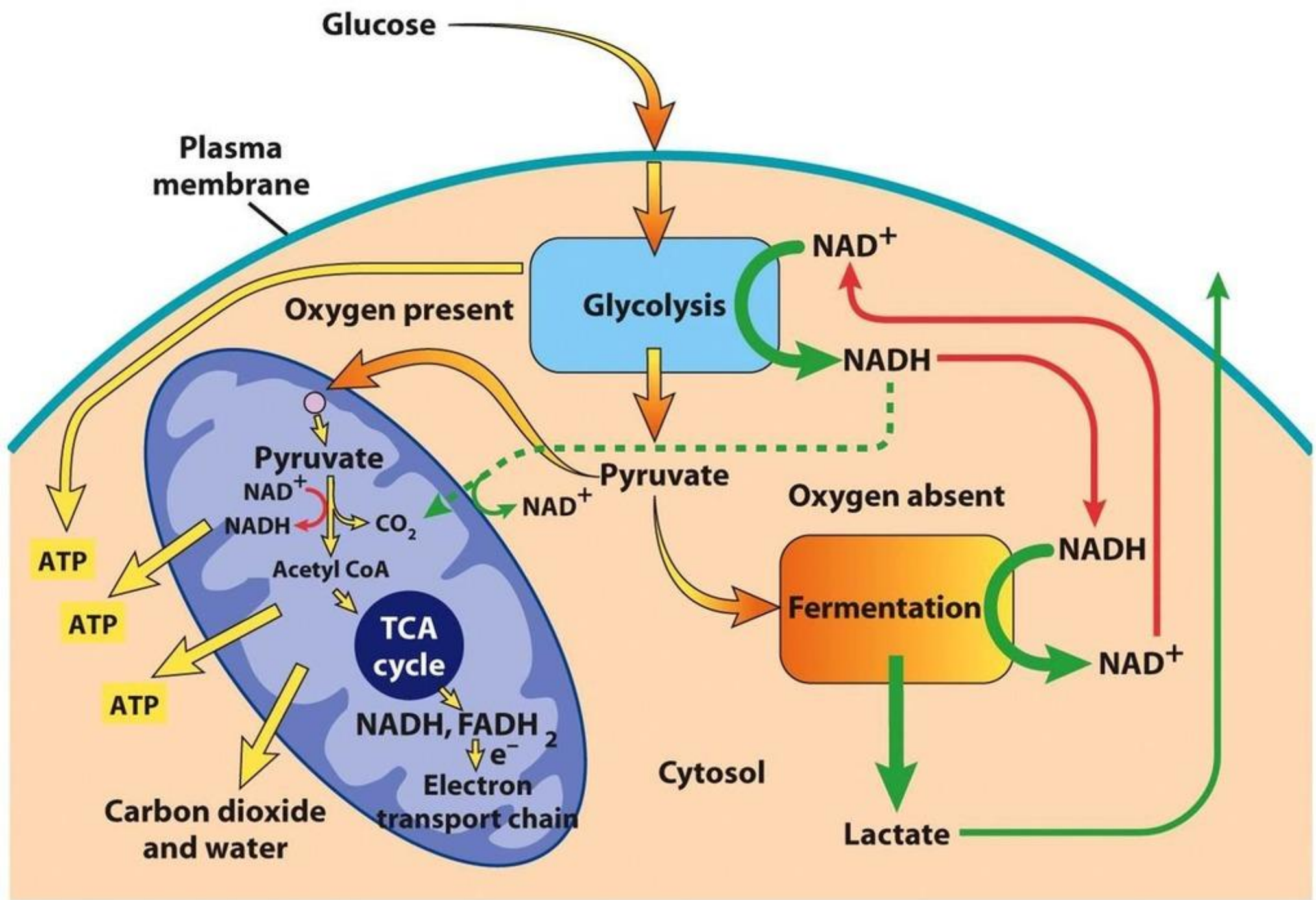
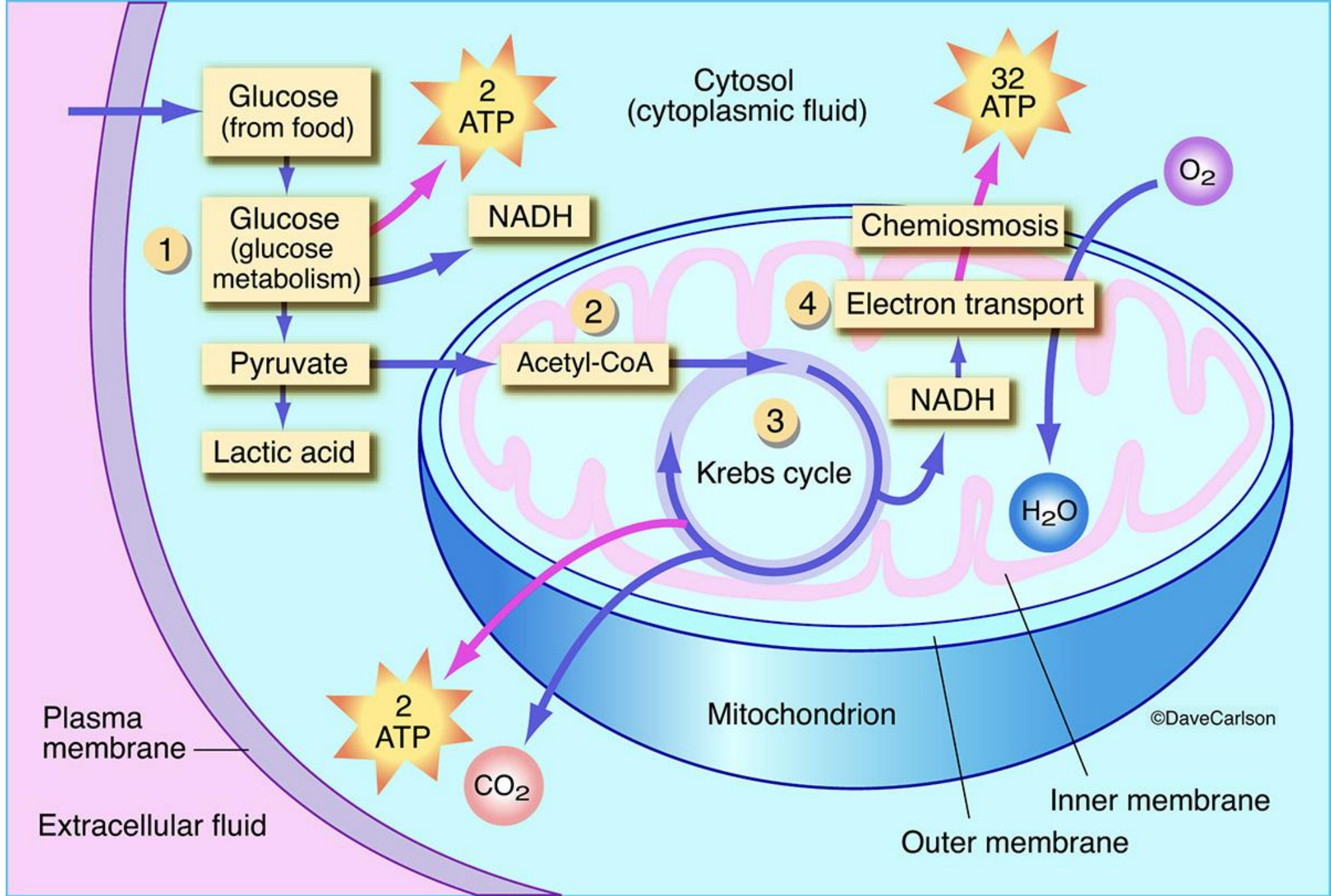


Figure 5-5 Cell and Molecular Biology, 5/e (© 2008 John Wiley & Sons)

# Aerobic Respiration

- In the presence of oxygen, pyruvate can enter the Krebs cycle where additional energy is extracted as electrons are transferred from the pyruvate to the receptors  $\text{NAD}^+$ , GDP, and FAD, with carbon dioxide being a “waste product”.
- The  $\text{NADH}$  and  $\text{FADH}_2$  pass electrons on to the electron transport chain, which uses the transferred energy to produce ATP.
- As the terminal step in the electron transport chain, oxygen is the terminal electron acceptor and creates water inside the mitochondria.



Anaerobic

Membrane

Aerobic

In mitochondria

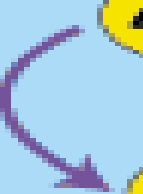
6 Carbon Compound

Glucose

2 ATP

Loss of hydrogen - oxidation

4 ADP



4 ATP

3 Carbon Compound

Pyruvate Acid

+O<sub>2</sub>

CO<sub>2</sub> + H<sub>2</sub>O

Yeast fermentation

2 ATP

Homolactic fermentation

34 ADP

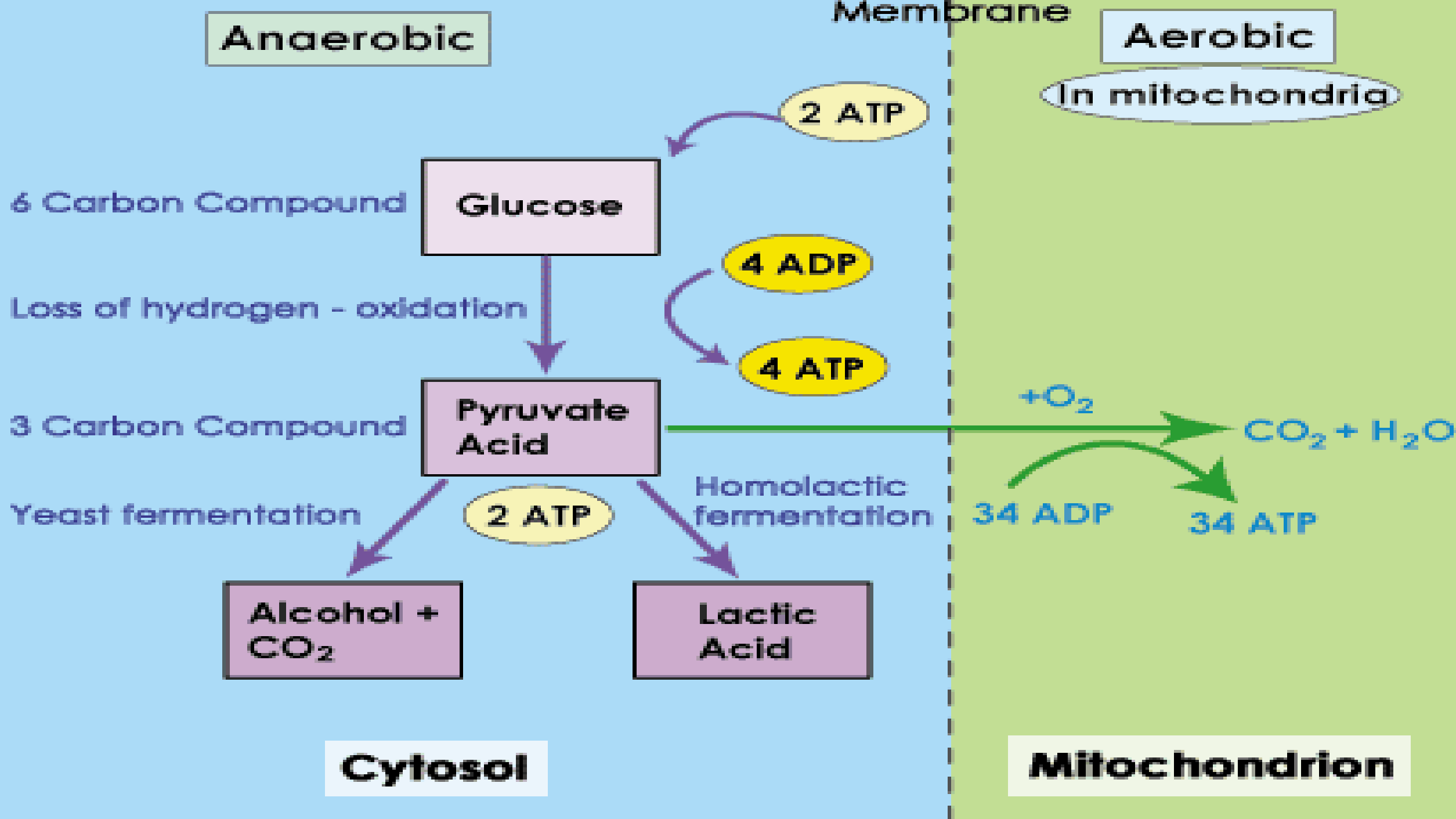
34 ATP

Alcohol + CO<sub>2</sub>

Lactic Acid

Cytosol

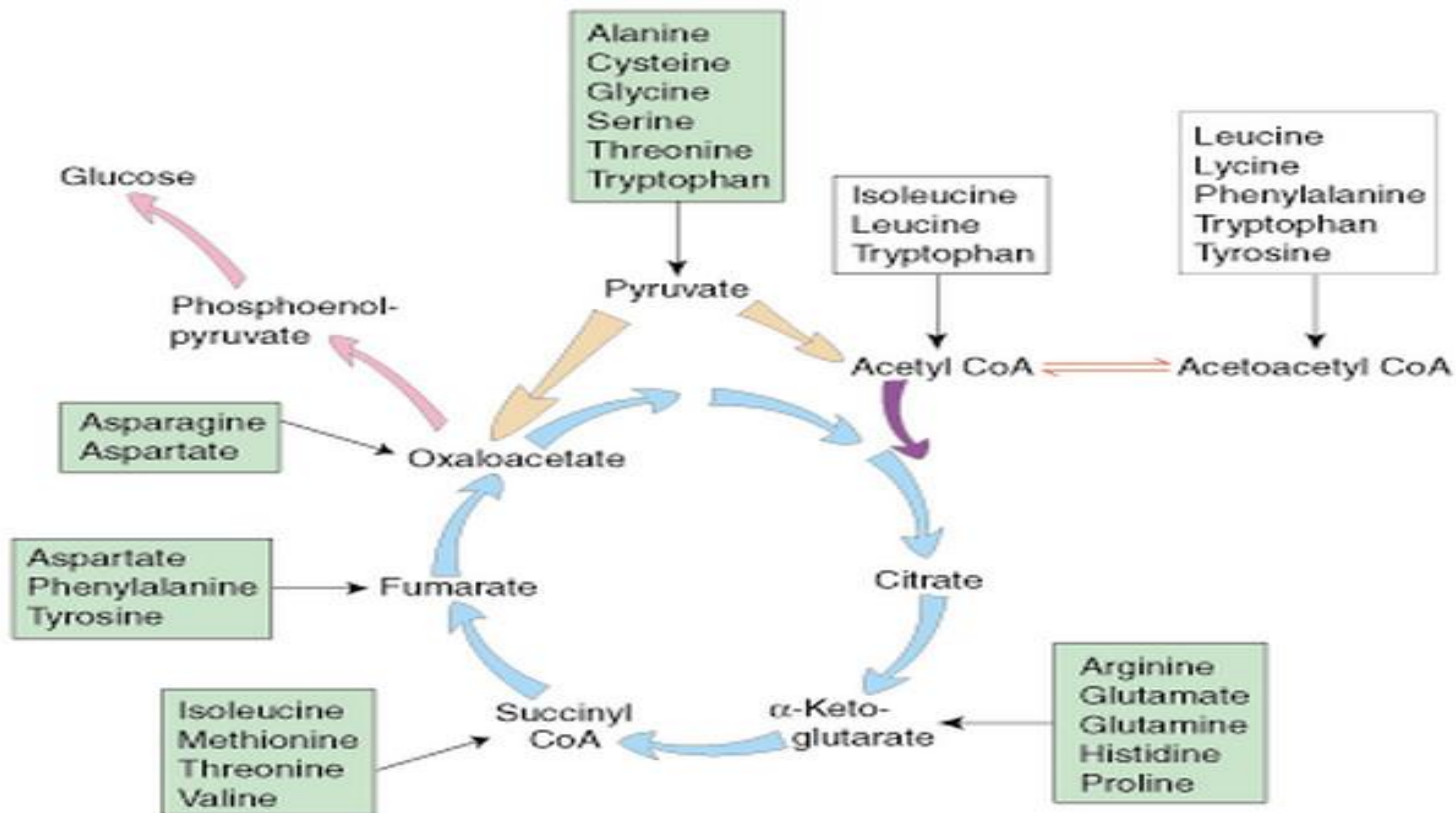
Mitochondrion



# Gluconeogenesis

- Gluconeogenesis is the synthesis of new glucose molecules from pyruvate, lactate, glycerol, or the amino acids alanine or glutamine.
- This process takes place primarily in the liver during periods of low glucose, that is, under conditions of fasting, starvation, and low carbohydrate diets.
- So, the question can be raised as to why the body would create something it has just spent a fair amount of effort to break down? Certain key organs, including the brain, can use only glucose as an energy source; therefore, it is essential that the body maintain a minimum blood glucose concentration.
- When the blood glucose concentration falls below that certain point, new glucose is synthesized by the liver to raise the blood concentration to normal.

- Gluconeogenesis is not simply the reverse of glycolysis. There are some important differences .
- Pyruvate is a common starting material for gluconeogenesis. First, the pyruvate is converted into oxaloacetate.
- Oxaloacetate then serves as a substrate for the enzyme phosphoenolpyruvate carboxykinase (PEPCK), which transforms oxaloacetate into phosphoenolpyruvate (PEP).
- From this step, gluconeogenesis is nearly the reverse of glycolysis. PEP is converted back into 2-phosphoglycerate, which is converted into 3-phosphoglycerate.
- Then, 3-phosphoglycerate is converted into 1,3 bisphosphoglycerate and then into glyceraldehyde-3-phosphate.
- Two molecules of glyceraldehyde-3-phosphate then combine to form fructose-1-6-bisphosphate, which is converted into fructose 6-phosphate and then into glucose-6-phosphate.





# **AGING AND THE BODY'S METABOLIC RATE**

- The human body's metabolic rate decreases nearly 2 percent per decade after age 30.
- Changes in body composition, including reduced lean muscle mass, are mostly responsible for this decrease.
- The most dramatic loss of muscle mass, and consequential decline in metabolic rate, occurs between 50 and 70 years of age.
- Loss of muscle mass is the equivalent of reduced strength, which tends to inhibit seniors from engaging in sufficient physical activity. This results in a positive-feedback system where the reduced physical activity leads to even more muscle loss, further reducing metabolism.
- There are several things that can be done to help prevent general declines in metabolism and to fight back against the cyclic nature of these declines.
- These include eating breakfast, eating small meals frequently, consuming plenty of lean protein, drinking water to remain hydrated, exercising (including strength training), and getting enough sleep.

- These measures can help keep energy levels from dropping and curb the urge for increased calorie consumption from excessive snacking.
- While these strategies are not guaranteed to maintain metabolism, they do help prevent muscle loss and may increase energy levels.
- Some experts also suggest avoiding sugar, which can lead to excess fat storage. Spicy foods and green tea might also be beneficial. Because stress activates cortisol release, and cortisol slows metabolism, avoiding stress, or at least practicing relaxation techniques, can also help.