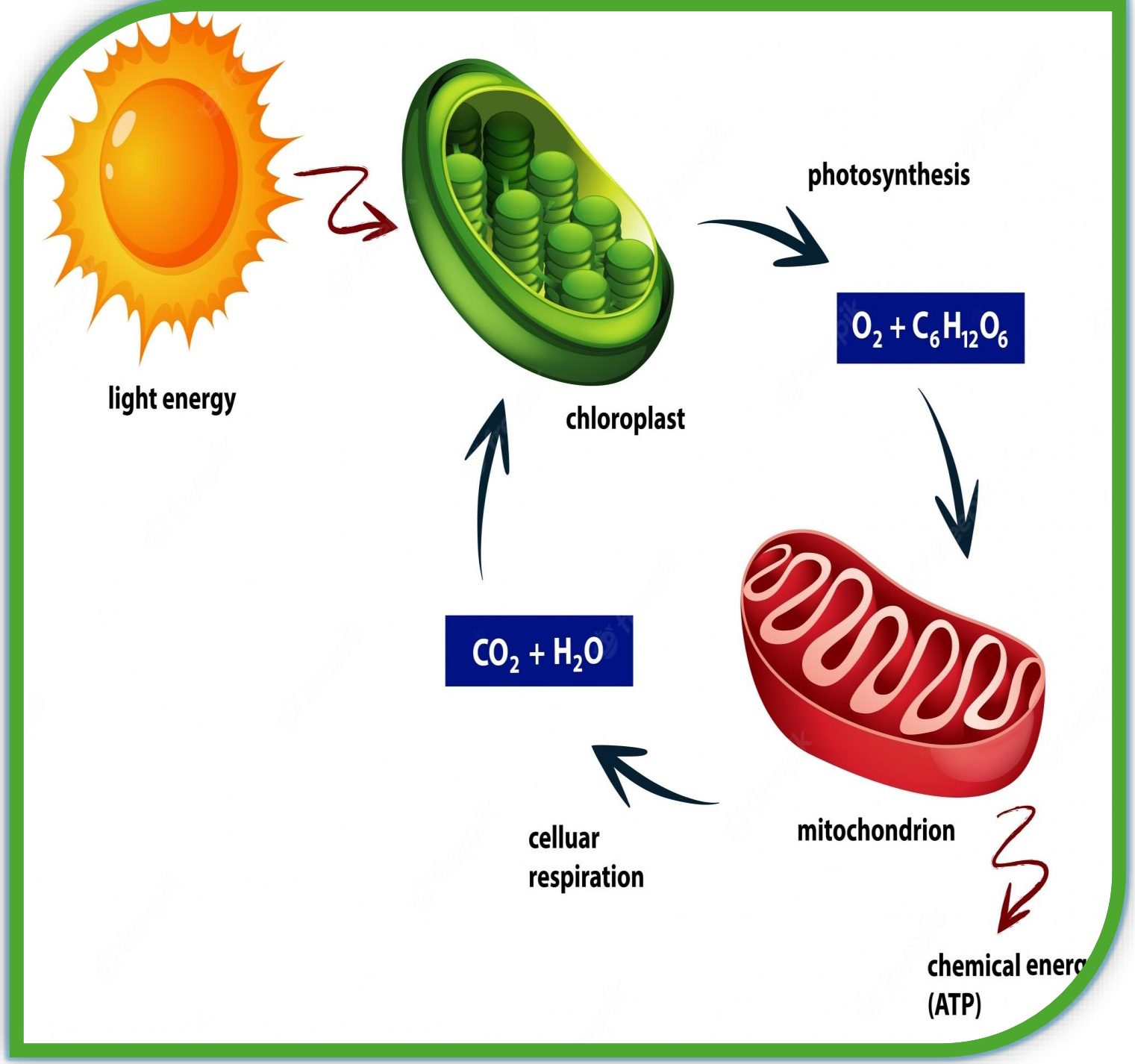
Cellular respiration

Presented By :
Dr. Aya El-Hanafy



Learning outcomes:

1

1- Understand the concept of cellular respiration

2

2- Summarize the main stages of cellular respiration: glycolysis, Krebs cycle, and oxidative phosphorylation.

3

3- Explain how ATP is generated and utilized as the main energy currency in the cell.

Introduction: Body Energy and ATP

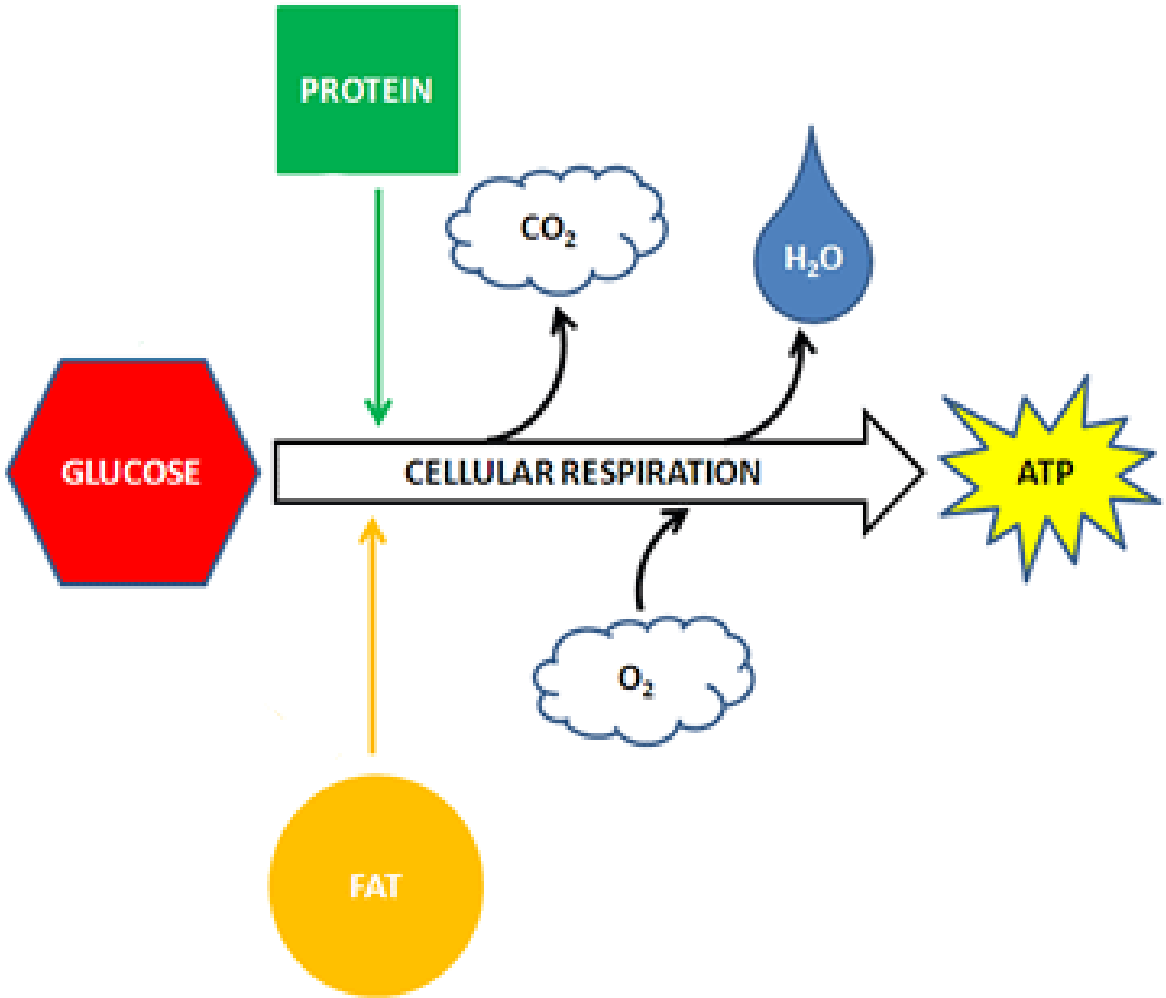
- Living cells require energy from outside sources
- Some animals, obtain energy by eating plants, and some animals feed on other organisms that eat plants

Figure 9.1 How do these leaves power the work of life for the giant panda?

Introduction: Body Energy and ATP

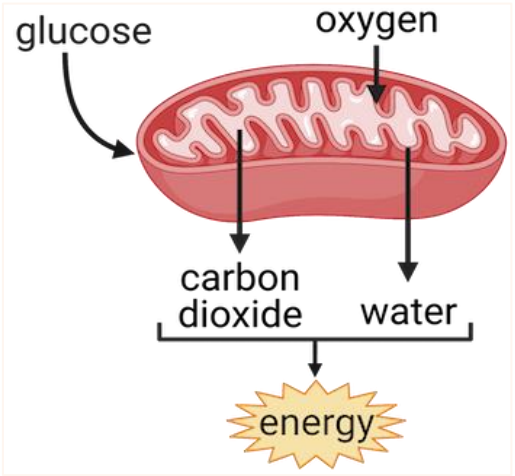
✓Energy is **stored** in organic and living matter

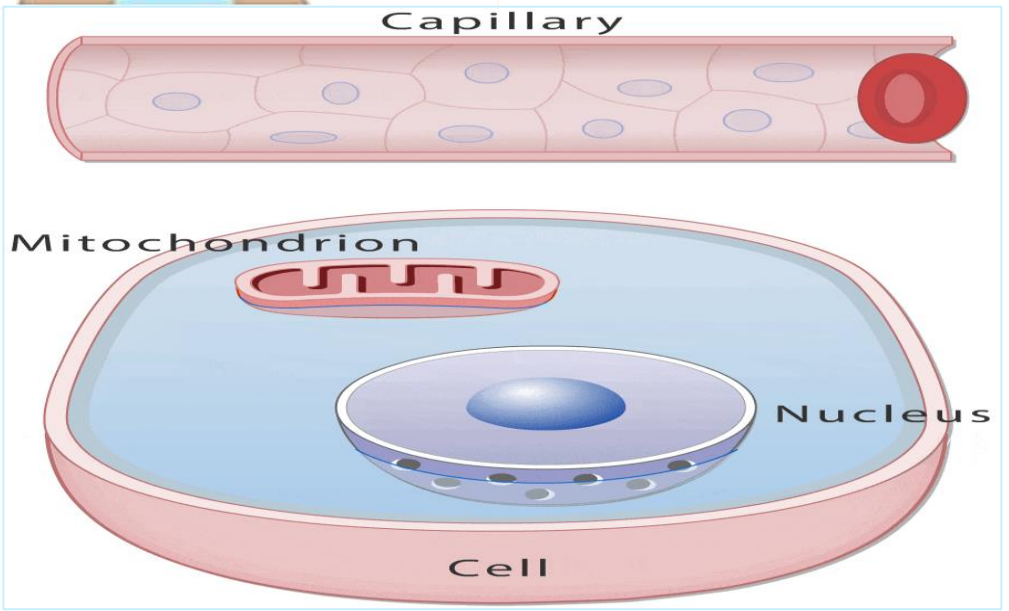
✓After eating and digesting food→ the free energy **liberated** during the degradation of food is collected in the form of high energy phosphate bonds (ATP) **(The energy currency of cell)**



Introduction: Body Energy and ATP

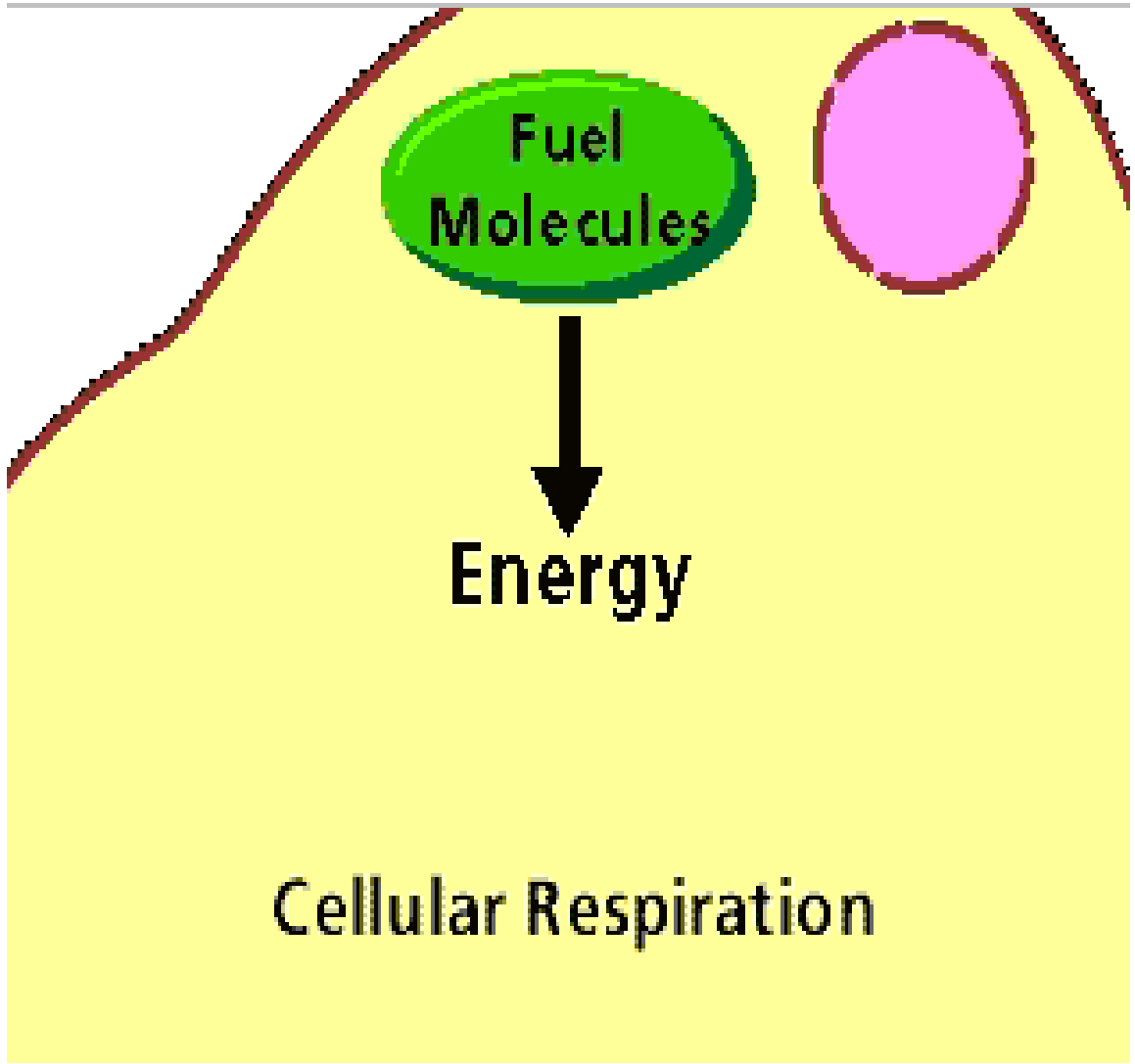
- **Oxygen** is essential molecule required for metabolism and health
- Our bodies use oxygen we breath to **convert foodstuffs such as fat and sugar into energy** “Cellular respiration “



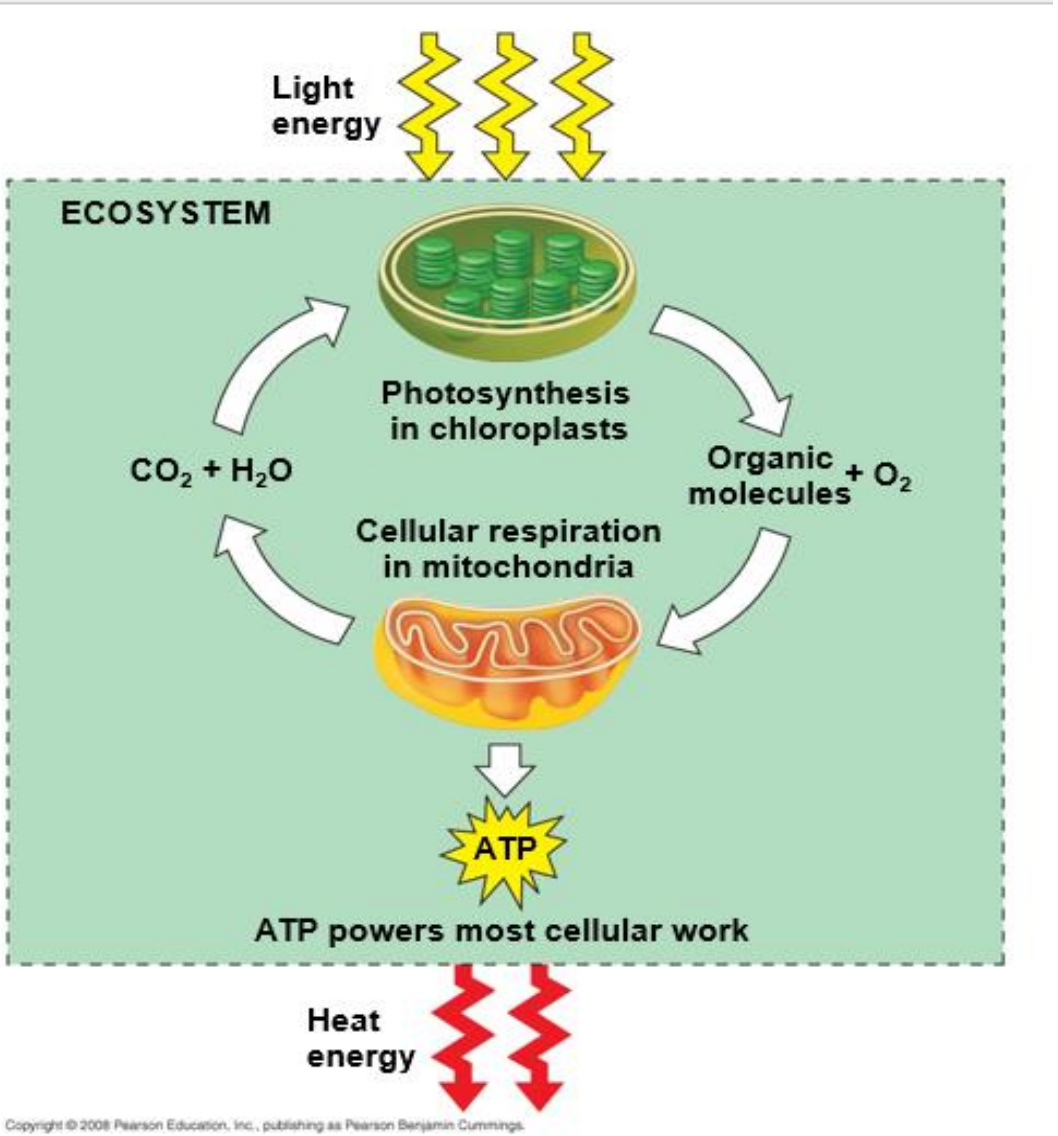


Cellular Respiration

- It is the vital process where cells break down glucose (food) (using oxygen), releasing carbon dioxide and water, and produce ATP (usable energy).
- This generated energy is used for all cell functions like growth, movement, and maintenance

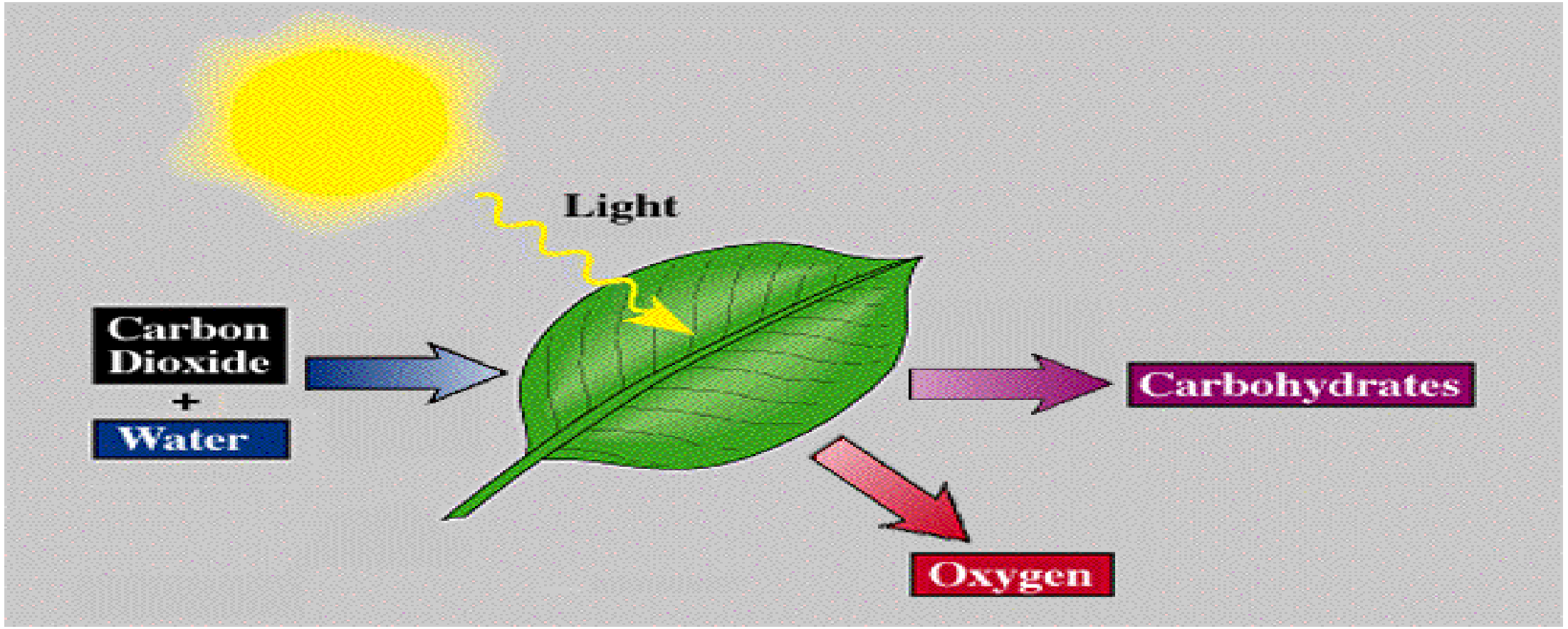


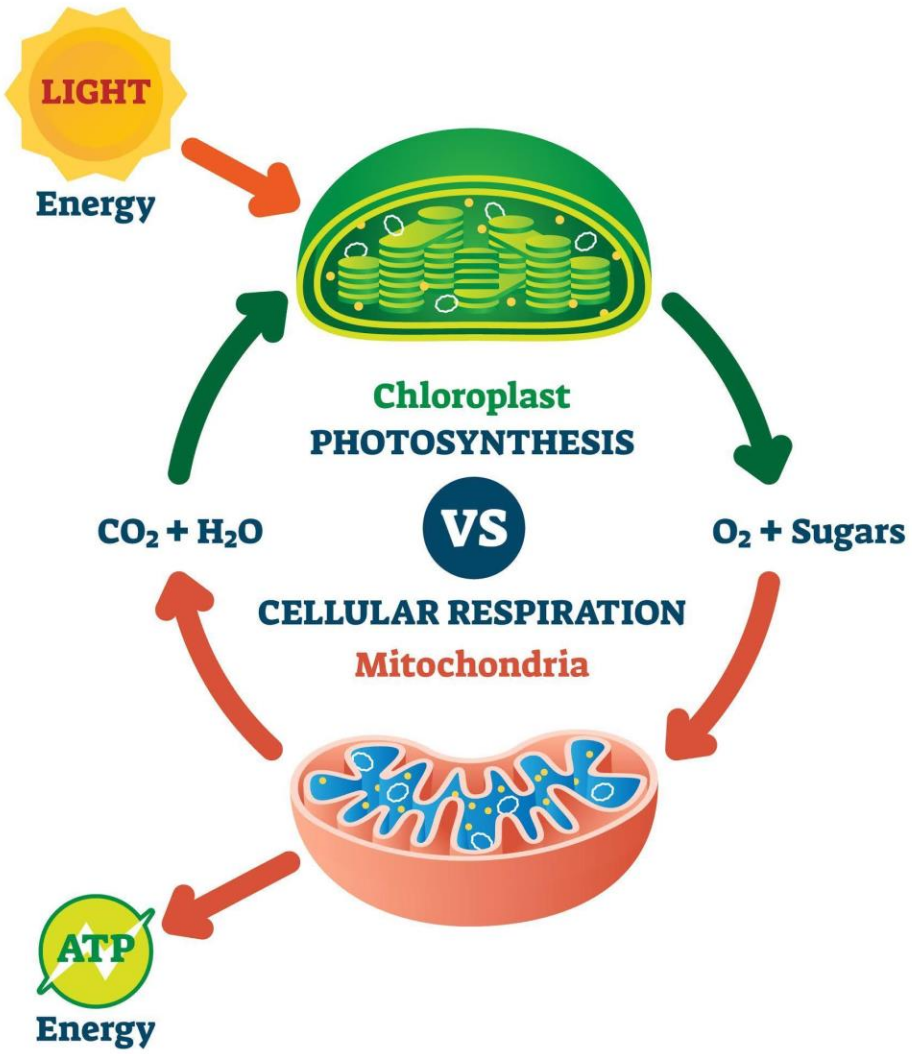
- Energy flows into an ecosystem as sunlight and leaves as heat
- Photosynthesis generates O_2 and organic molecules, which are used in cellular respiration
- Cells use chemical energy stored in organic molecules to regenerate ATP, which powers work

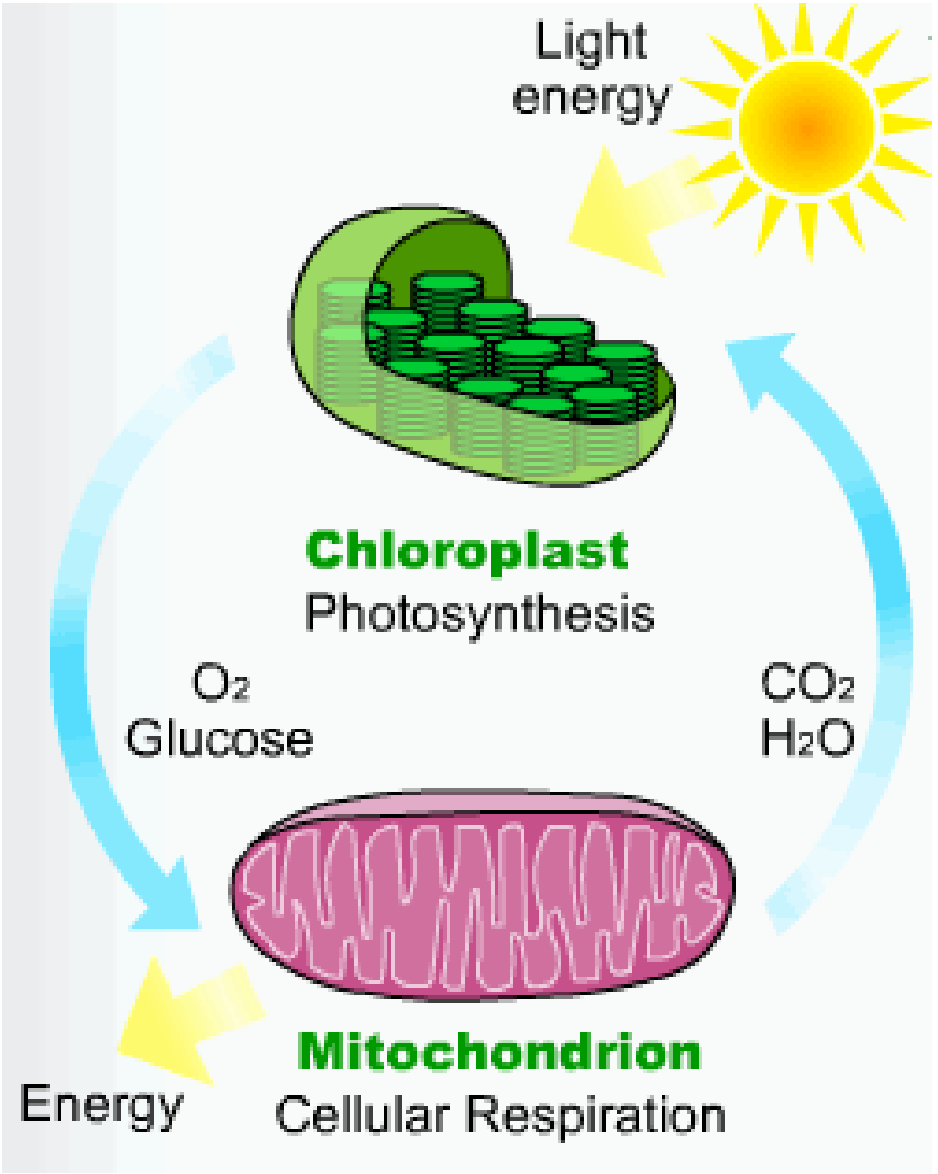


Photosynthesis:

Energy from sunlight is used to drive the synthesis of glucose from CO_2 and H_2O, and oxygen is released




LIGHT
Energy
Chloroplast
PHOTOSYNTHESIS
$CO_2 + H_2O$
VS
O_2 + Sugars
CELLULAR RESPIRATION
Mitochondria
ATP
Energy


Light
energy
Chloroplast
Photosynthesis
O_2
Glucose
CO_2
H_2O
Mitochondrion
Cellular Respiration
Energy

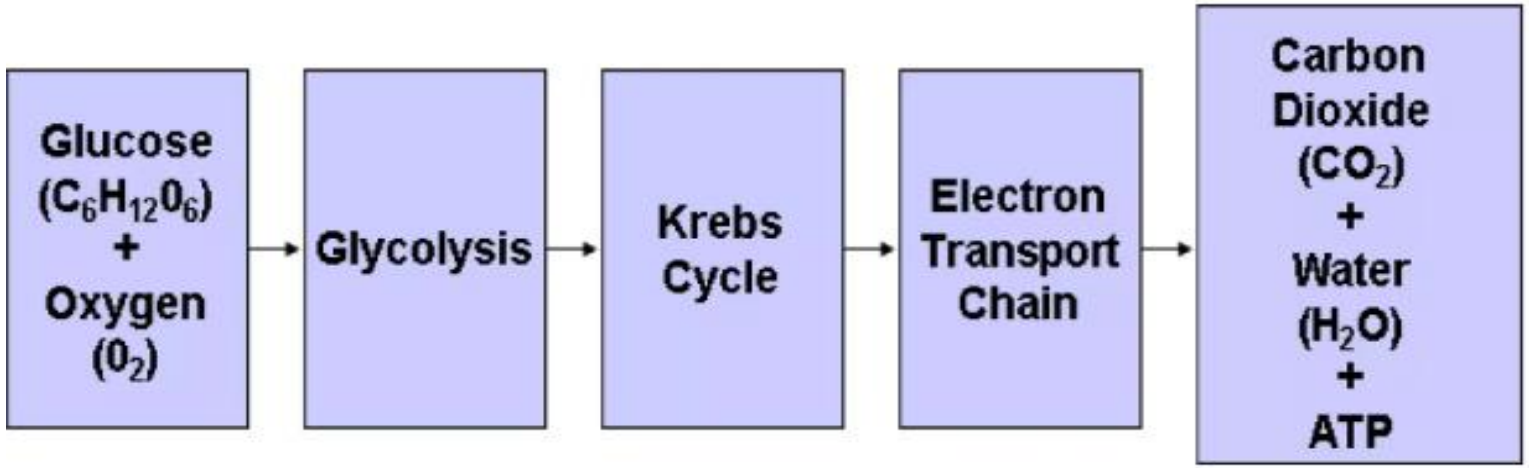
Catabolic pathways yield energy (ATP) by oxidizing organic fuels

- Several processes are central to cellular respiration and related pathways
- **Cellular respiration** includes both aerobic and anaerobic respiration but is often used to refer to aerobic respiration
- **Aerobic respiration** consumes organic molecules and O_2 and yields ATP
- **Anaerobic respiration (Fermentation)** is similar to aerobic respiration but consumes compounds other than O_2

- Glucose is the 1ry fuel for cellular respiration
- Although carbohydrates, fats, and proteins are all consumed as fuel, it is helpful to trace cellular respiration with the sugar glucose:

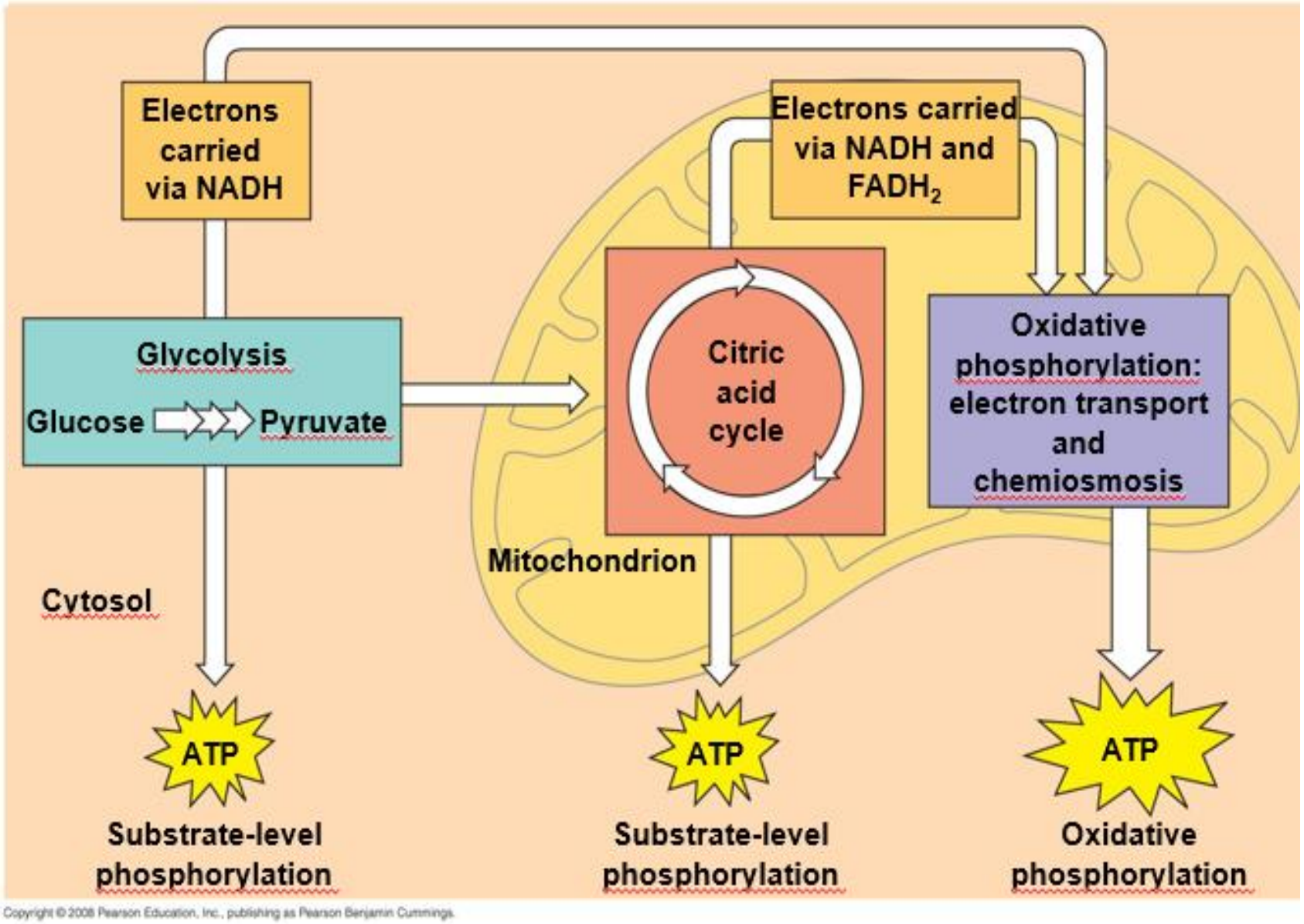
Stages of Cellular Respiration

- Cellular respiration has three stages:
  - **1. Glycolysis** (breaks down glucose into two molecules of pyruvate)
  - **2. The citric acid cycle** (completes the breakdown of glucose)
  - **3. Oxidative phosphorylation (ETC)** (accounts for most of the ATP synthesis)

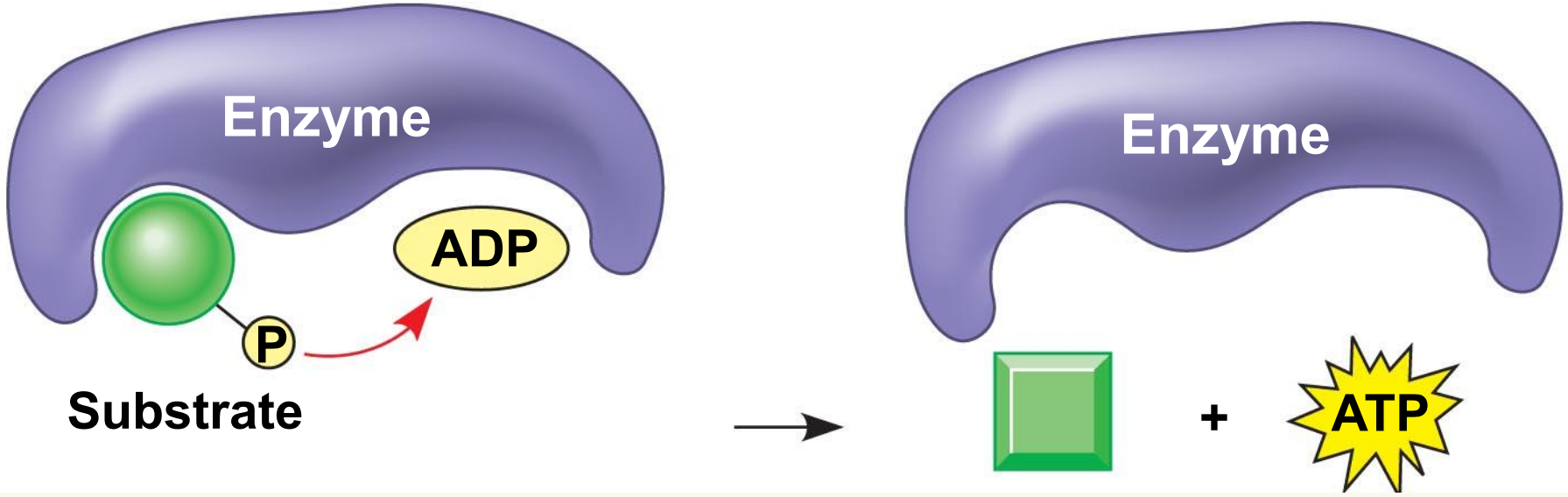


Stages of Cellular Respiration

- **Oxidative phosphorylation** accounts for almost 90% of the ATP generated by cellular respiration
- A smaller amount of ATP is formed in glycolysis and the citric acid cycle by **substrate-level phosphorylation**



Substrate-level phosphorylation

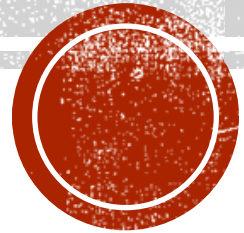


ATP (The energy currency of cell)

- ✓ **High**-energy phosphate compound.
- ✓ Synthesized by Substrate Phosphorylation of ADP

ADP +P → ATP

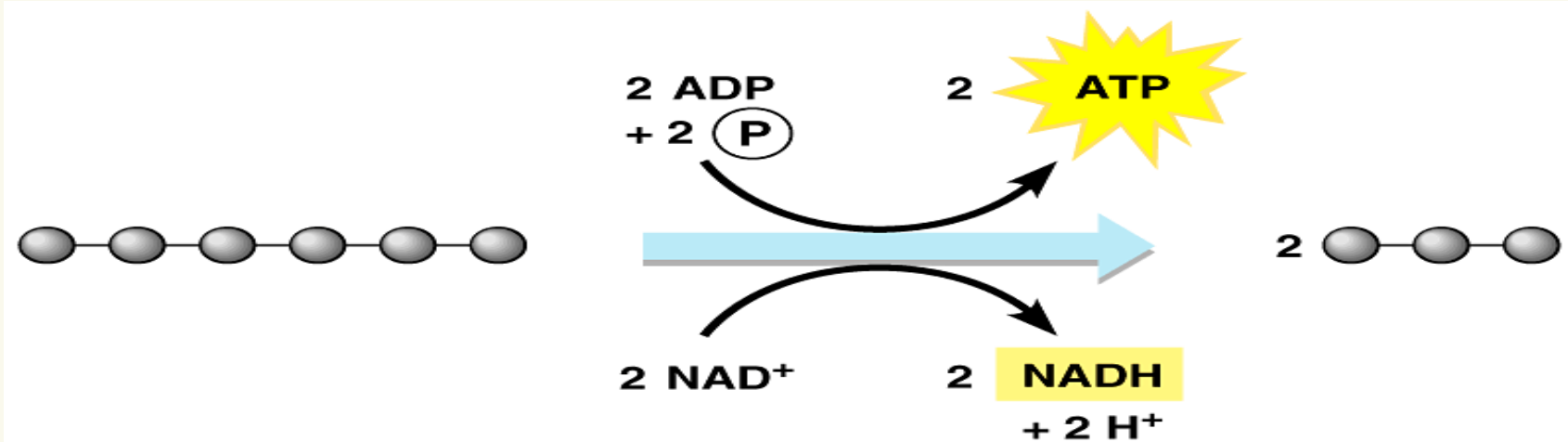
Cellular respiration (I. Glycolysis)



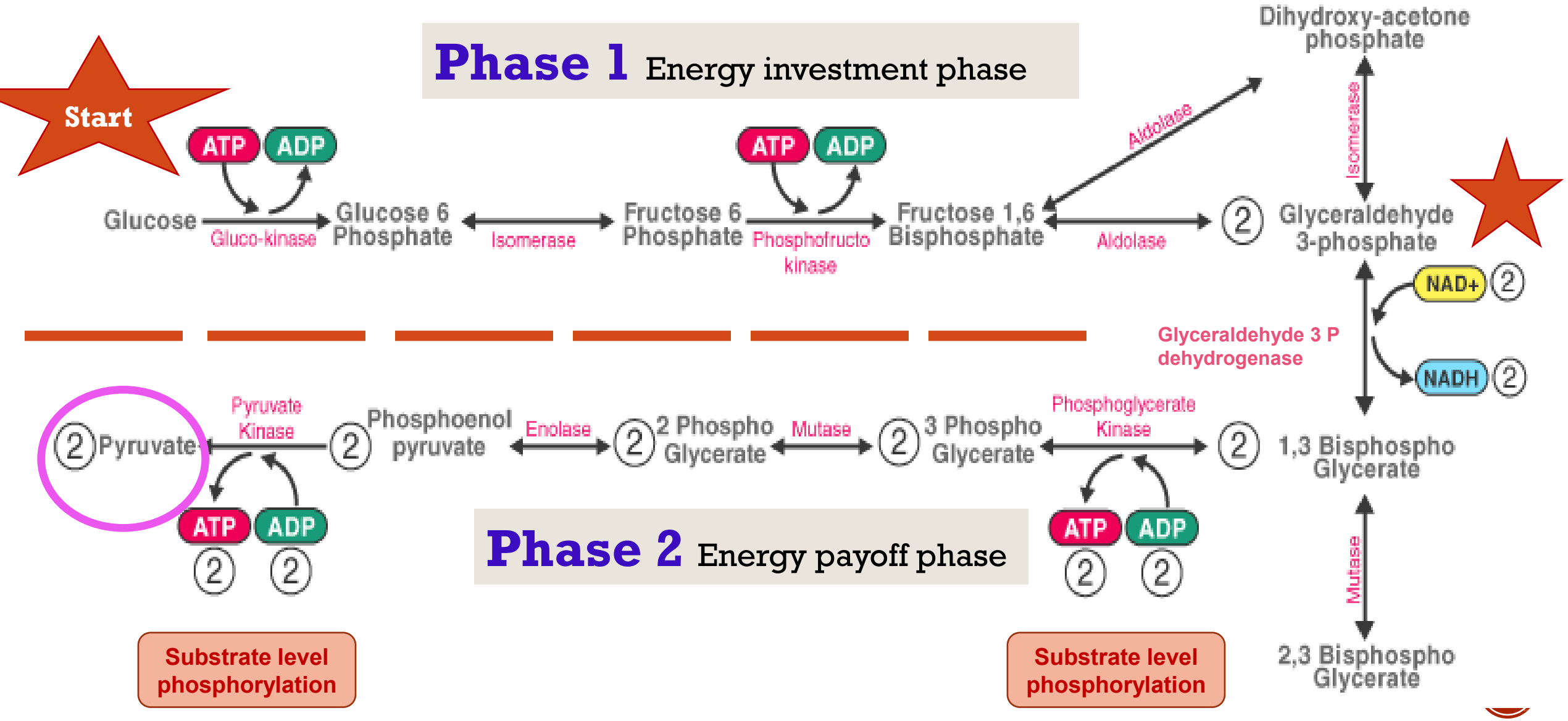
Definition of Glycolysis.
(Glyco / sugar. & lysis / breakdown

- **It is** a series of biochemical reactions occurring in **cytoplasm, involving breakdown of glucose (6C) to :**
  - ✓**2 molecules pyruvic acid (3C) (in presence of O_2 "Aerobic") or**
  - ✓**2 molecules of lactic acid (3C) (in absence of O_2 "Anerobic") .**

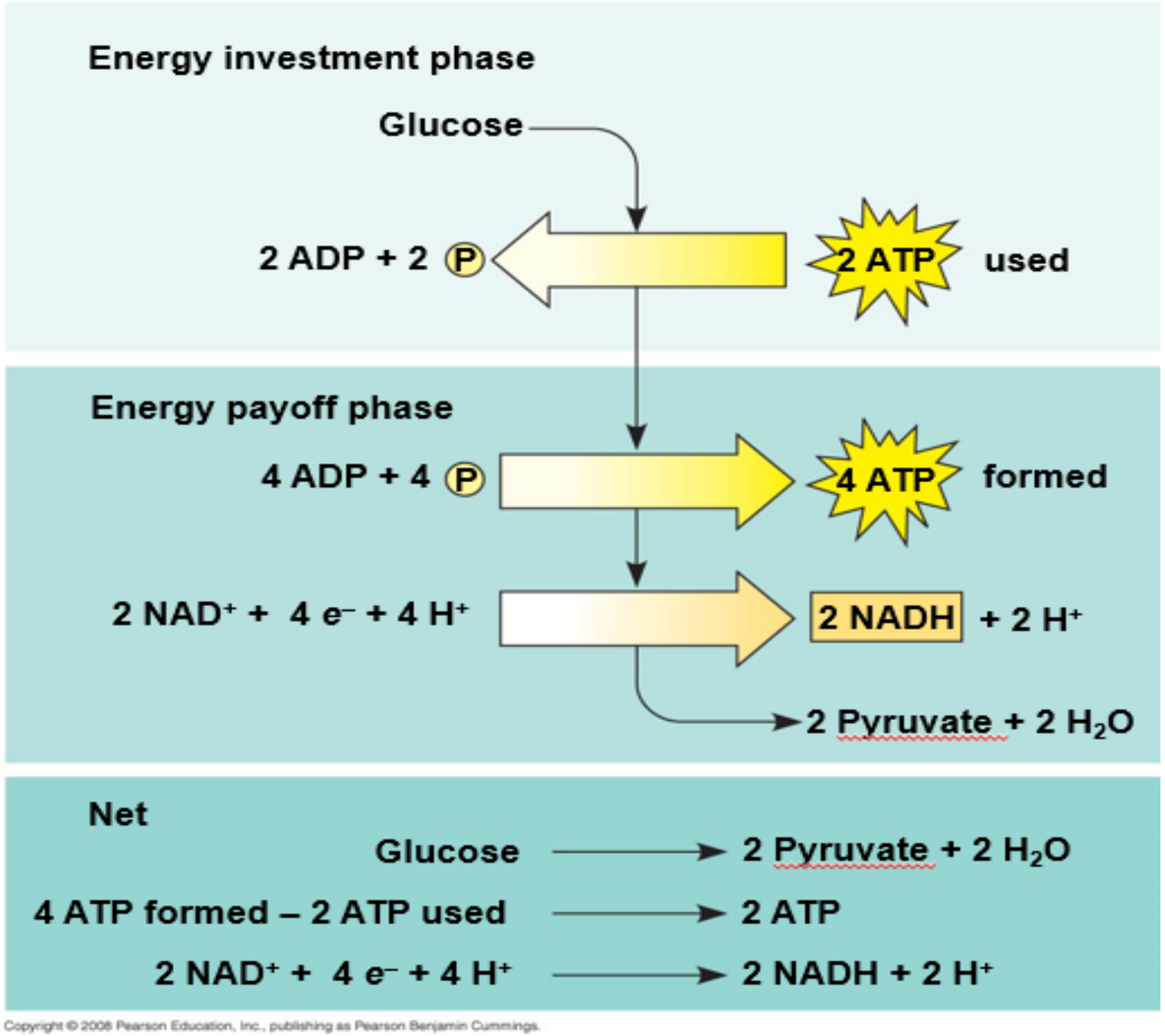
- **with a net generation of 2 ATP & 2 NADH**



2 Phases of glycolysis (10 enzymatic reactions)

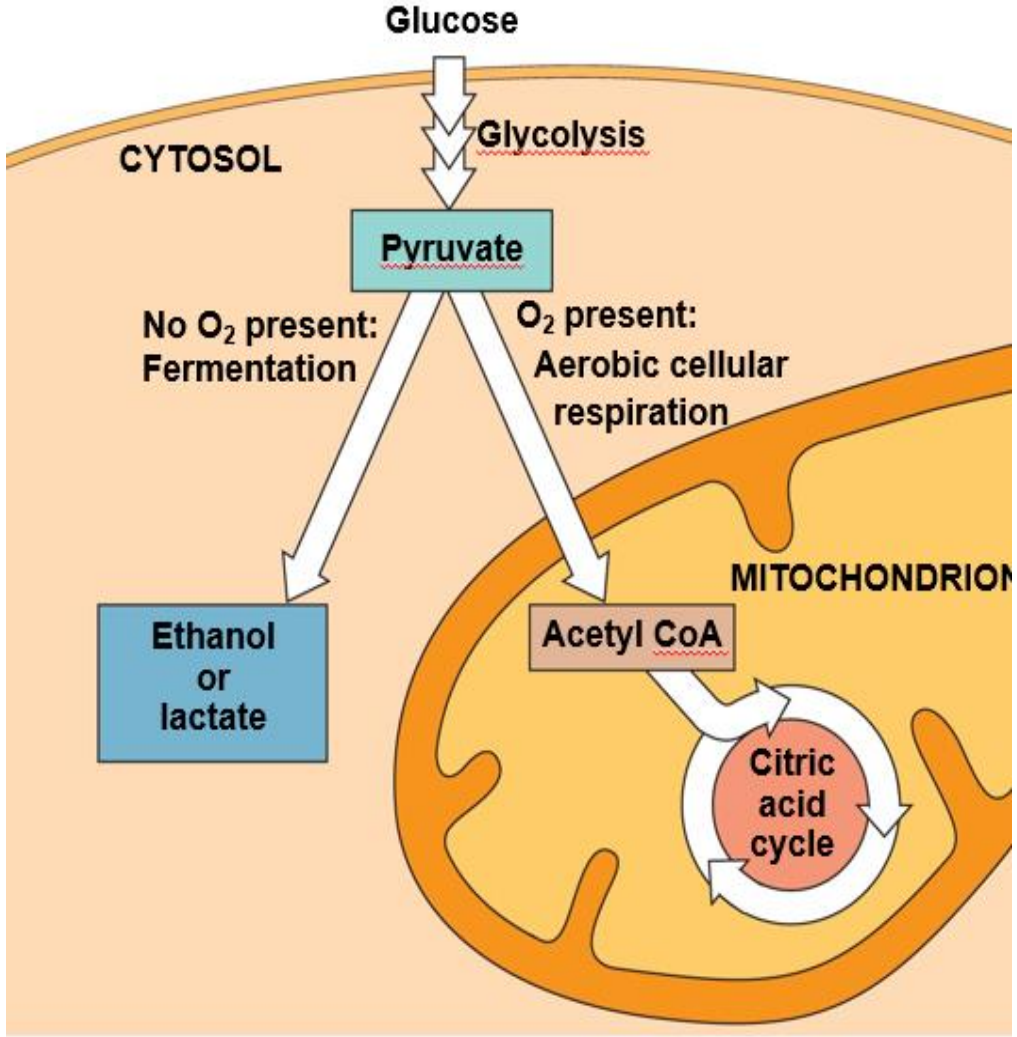


Energy production during Aerobic Glycolysis

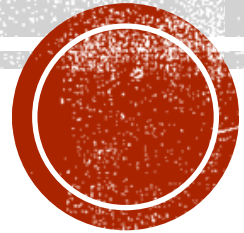


Fermentation and anaerobic respiration enable cells to produce ATP without the use of oxygen

- Most cellular respiration requires O_2 to produce ATP
- Glycolysis can produce ATP with or without O_2 (in aerobic or anaerobic conditions)
- In the absence of O_2, glycolysis couples with fermentation (anaerobic respiration) to produce ATP

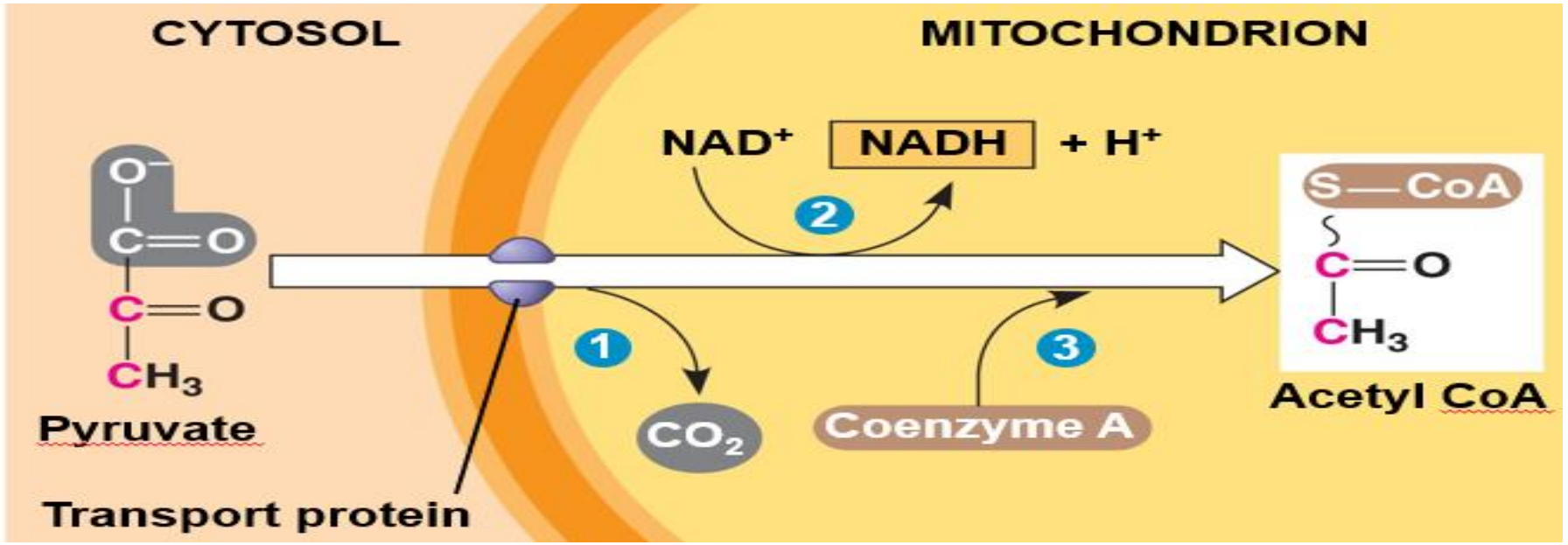


Cellular respiration
(II. Citric acid cycle “Krebs's cycle”)



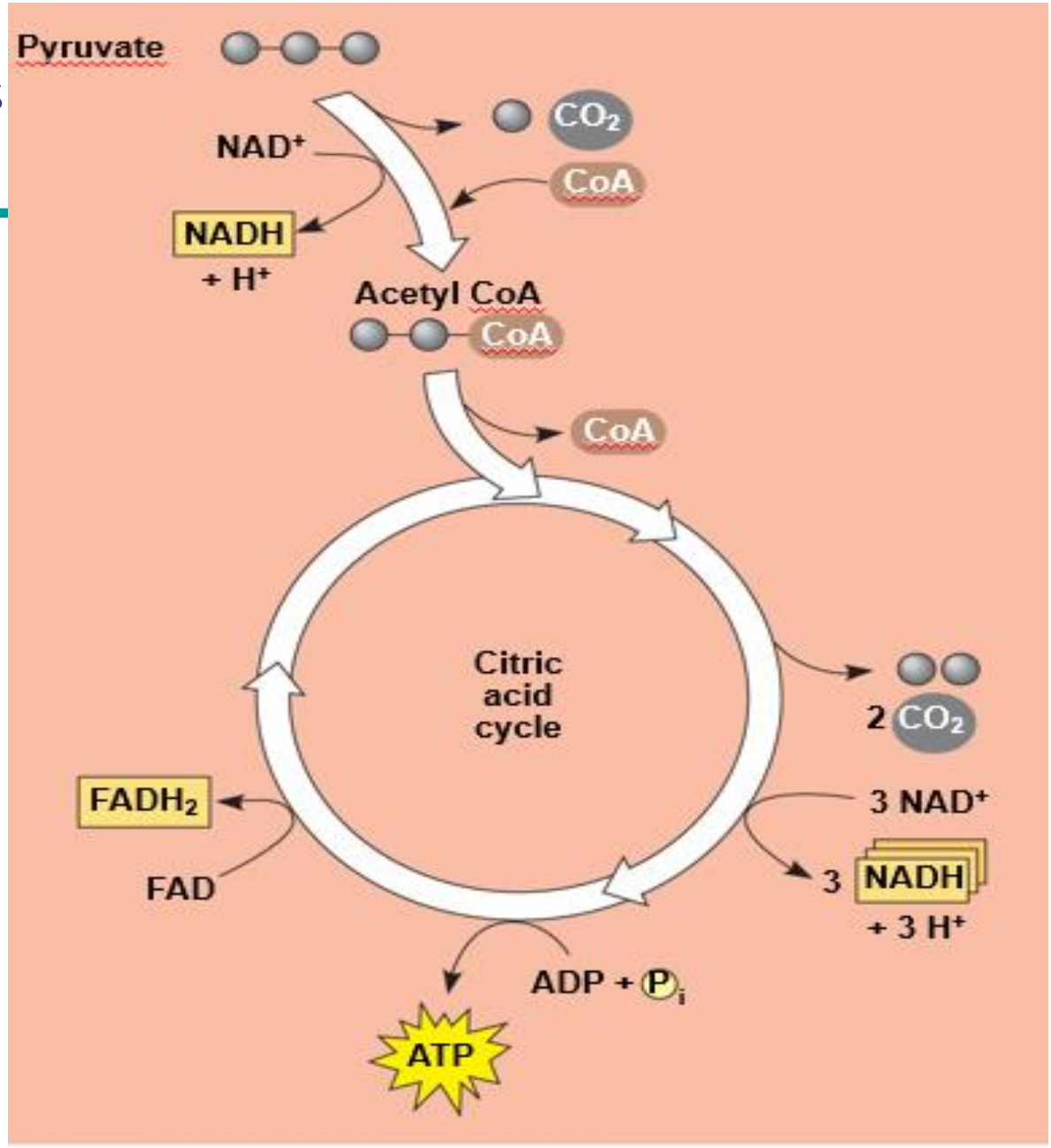
The citric acid cycle completes the energy-yielding oxidation of organic molecules

- In the presence of O_2, 2 pyruvate enters the mitochondrion
- Before the citric acid cycle can begin, each pyruvate must be converted to **acetyl CoA**, which links the cycle to glycolysis and 2 molecules of NADH are generated.



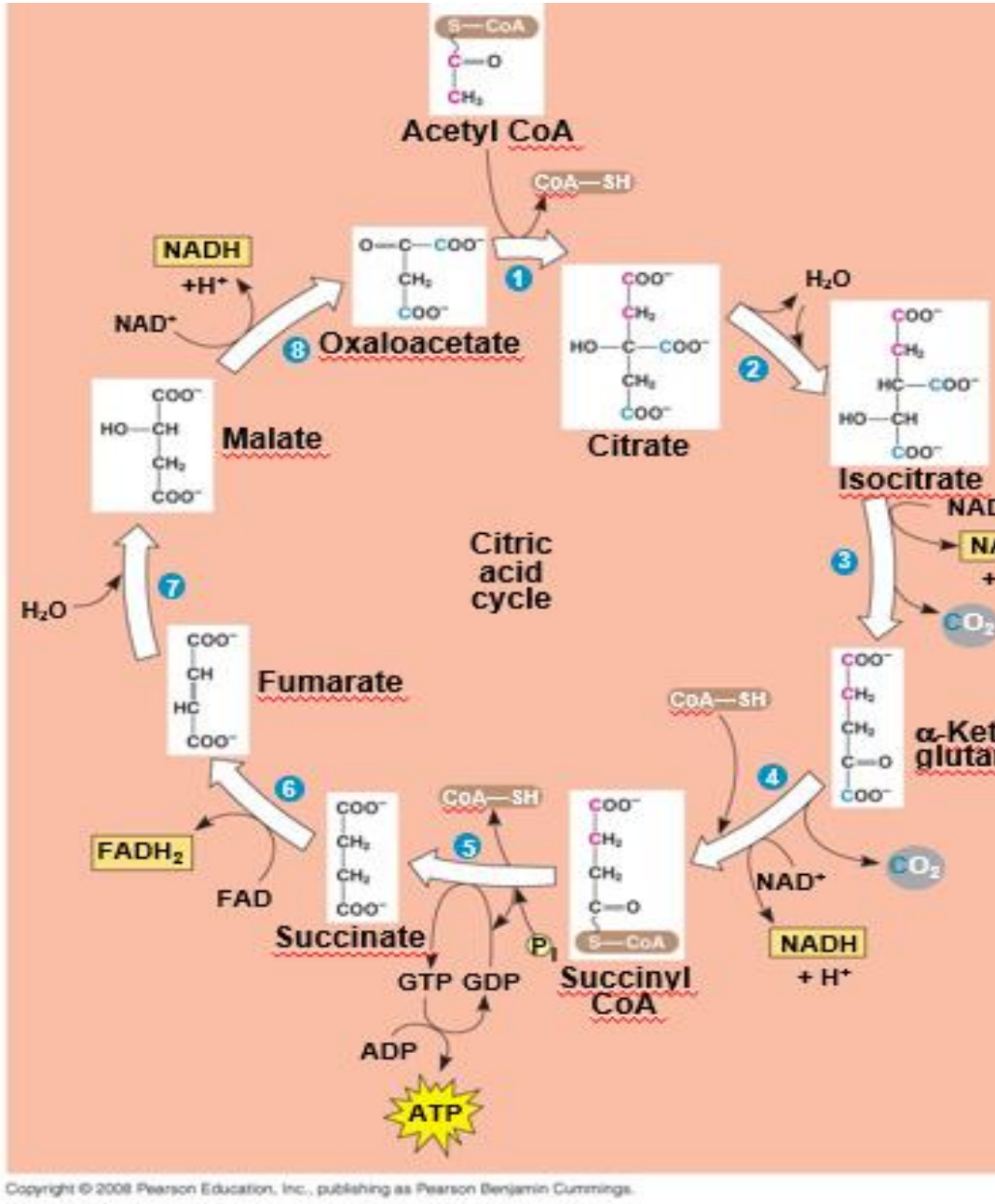
Citric acid cycle “ Krebs's cycle “

- The citric acid cycle, also called the Krebs cycle, takes place within the mitochondrial matrix
- The cycle oxidizes organic fuel derived from pyruvate, generating **1 ATP, 3 NADH, and 1 $FADH_2$** per turn

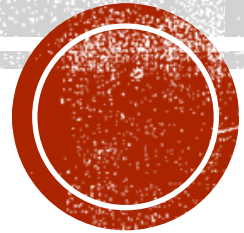


Citric acid cycle “ Krebs's cycle “

- The citric acid cycle has eight steps, each catalyzed by a specific enzyme
- Acetyl CoA joins the cycle by combining with oxaloacetate, forming citrate
- The next seven steps decompose the citrate back to oxaloacetate, making the process a cycle.
- The NADH and $FADH_2$ produced by the cycle relay electrons extracted from food to the electron transport chain (ETC).



Cellular respiration (III. Electron Transport Chain & oxidative phosphorylation)



During oxidative phosphorylation, electron transport couples to ATP synthesis

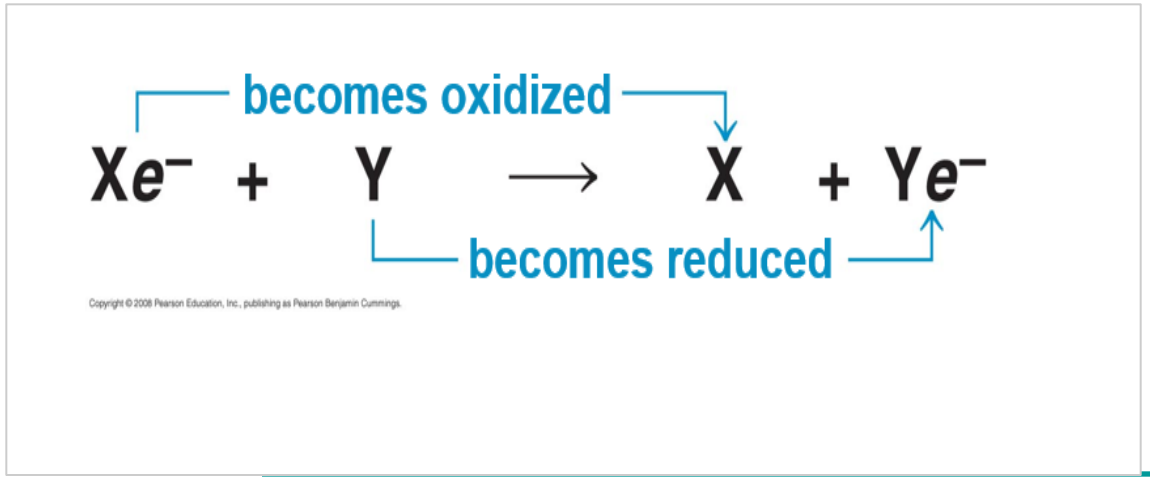
- Following glycolysis and the citric acid cycle, NADH and $FADH_2$ account for most of the energy extracted from food
- These two **electron carriers** donate electrons to the electron transport chain.
- The transfer of electrons during chemical reactions releases energy stored in organic molecules.
- This released energy is ultimately used to synthesize ATP

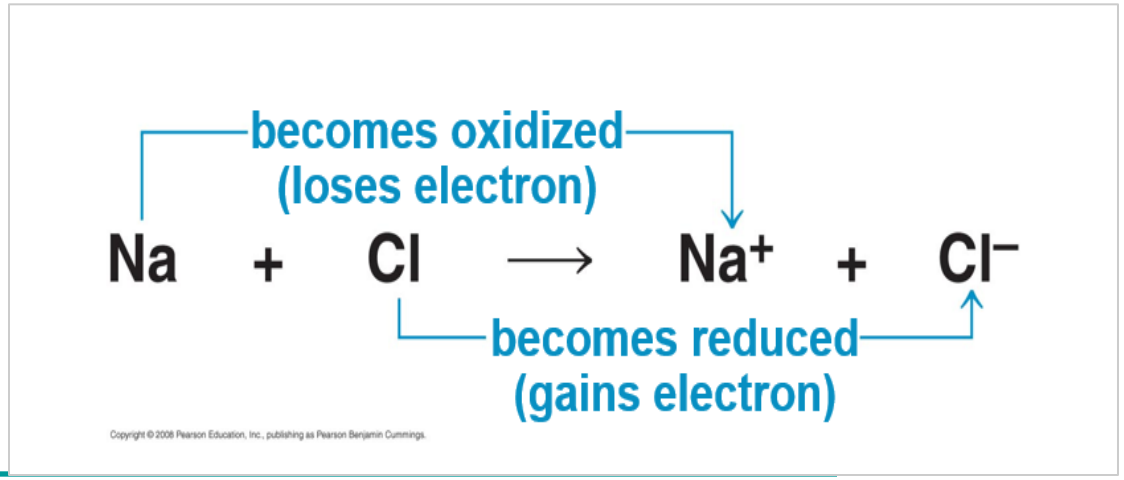
Redox Reactions: Oxidation and Reduction

- Chemical reactions that transfer electrons between reactants are called **oxidation-reduction reactions**, or **redox reactions**

The Principle of Redox

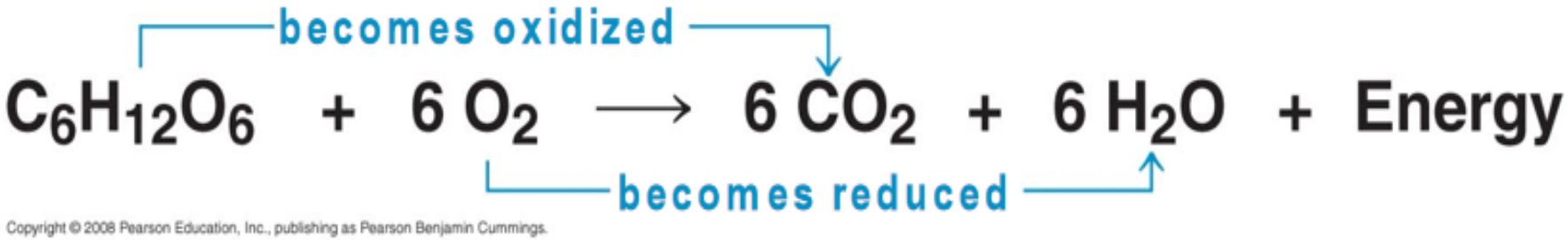
- In **oxidation**, a substance **loses** electrons, or is oxidized
- In **reduction**, a substance **gains** electrons, or is reduced (the amount of positive charge is reduced)
- The electron donor is called the **reducing agent**
- The electron acceptor is called the **oxidizing agent**





Oxidation of Organic Fuel Molecules During Cellular Respiration

- During cellular respiration, the fuel (such as glucose) is oxidized, and O_2 is reduced:

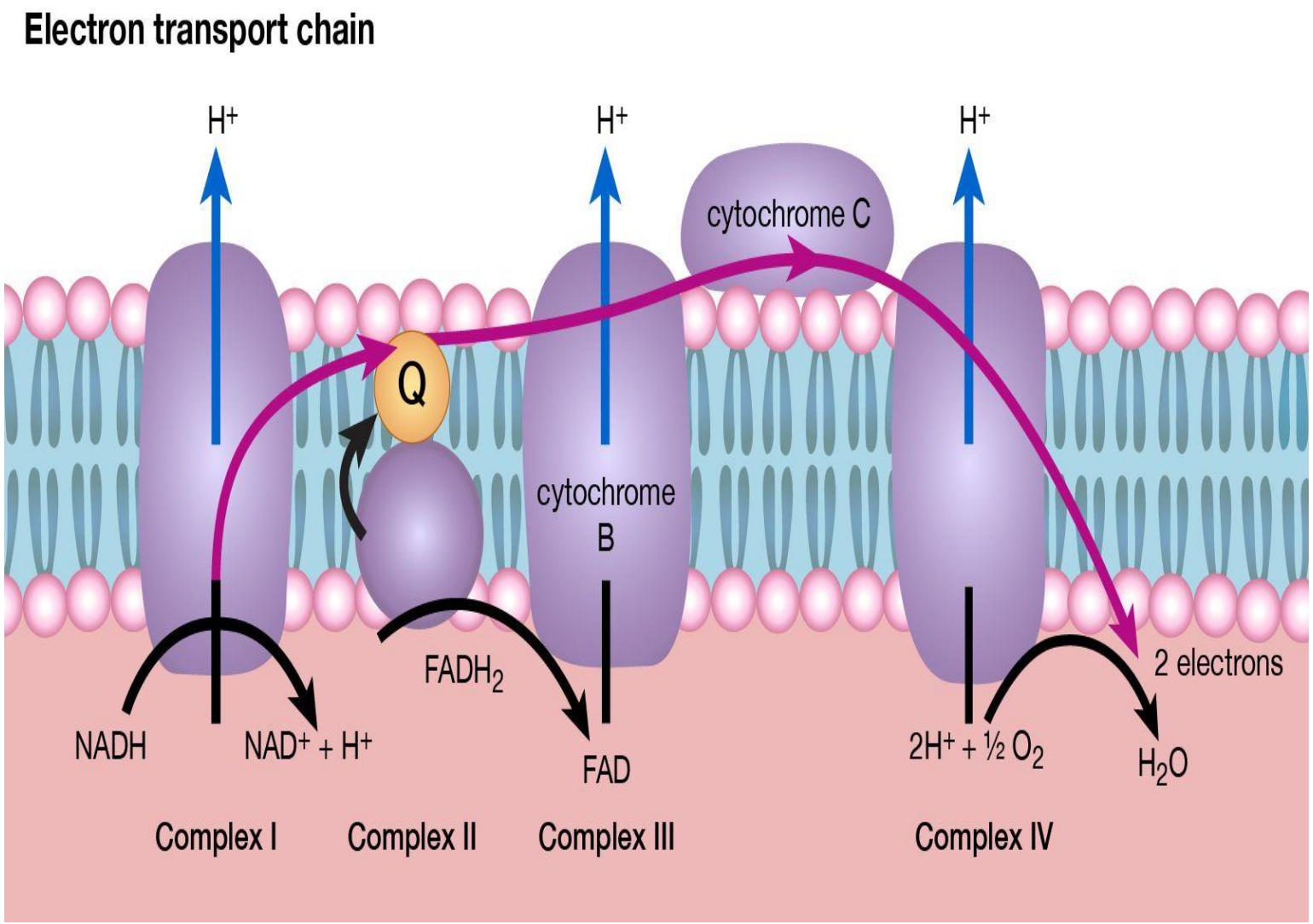


Stepwise Energy Harvest via the Electron Transport Chain

- In cellular respiration, glucose and other organic compounds are broken down in a series of steps and release electrons
- Electrons from organic compounds are usually first transferred to **NAD^+** producing NADH (the reduced form of NAD^+) or FAD producing FADH2
- Electrons are transferred from NADH or $FADH_2$ to the electron transport chain
- Electrons go down the chain and are finally passed to O_2, forming H_2O

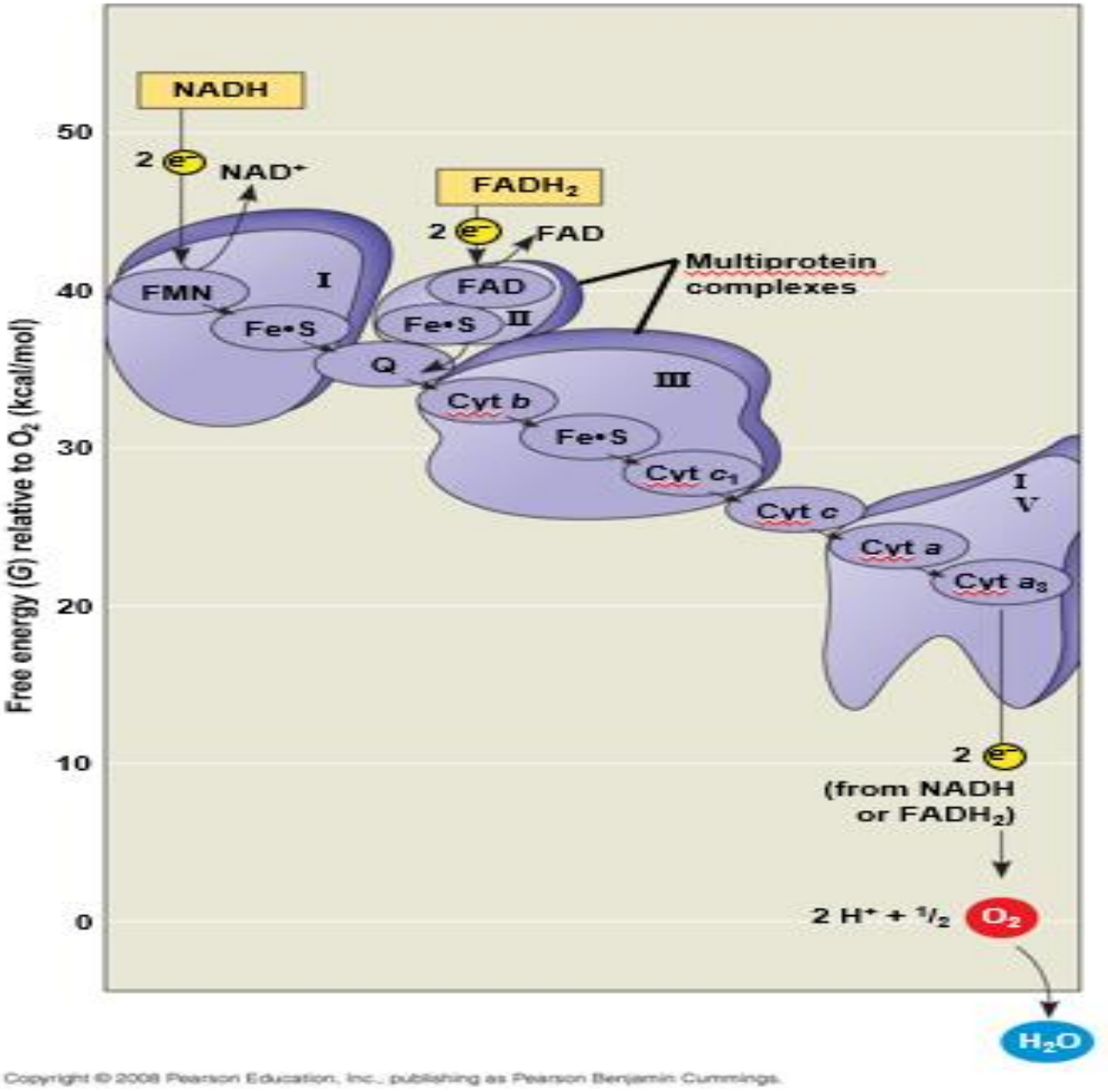
The Pathway of Electron Transport

- Most of the electron transport chain's components exist in multiprotein complexes inside the mitochondrion
- The carriers alternate reduced and oxidized states as they accept & donate electrons



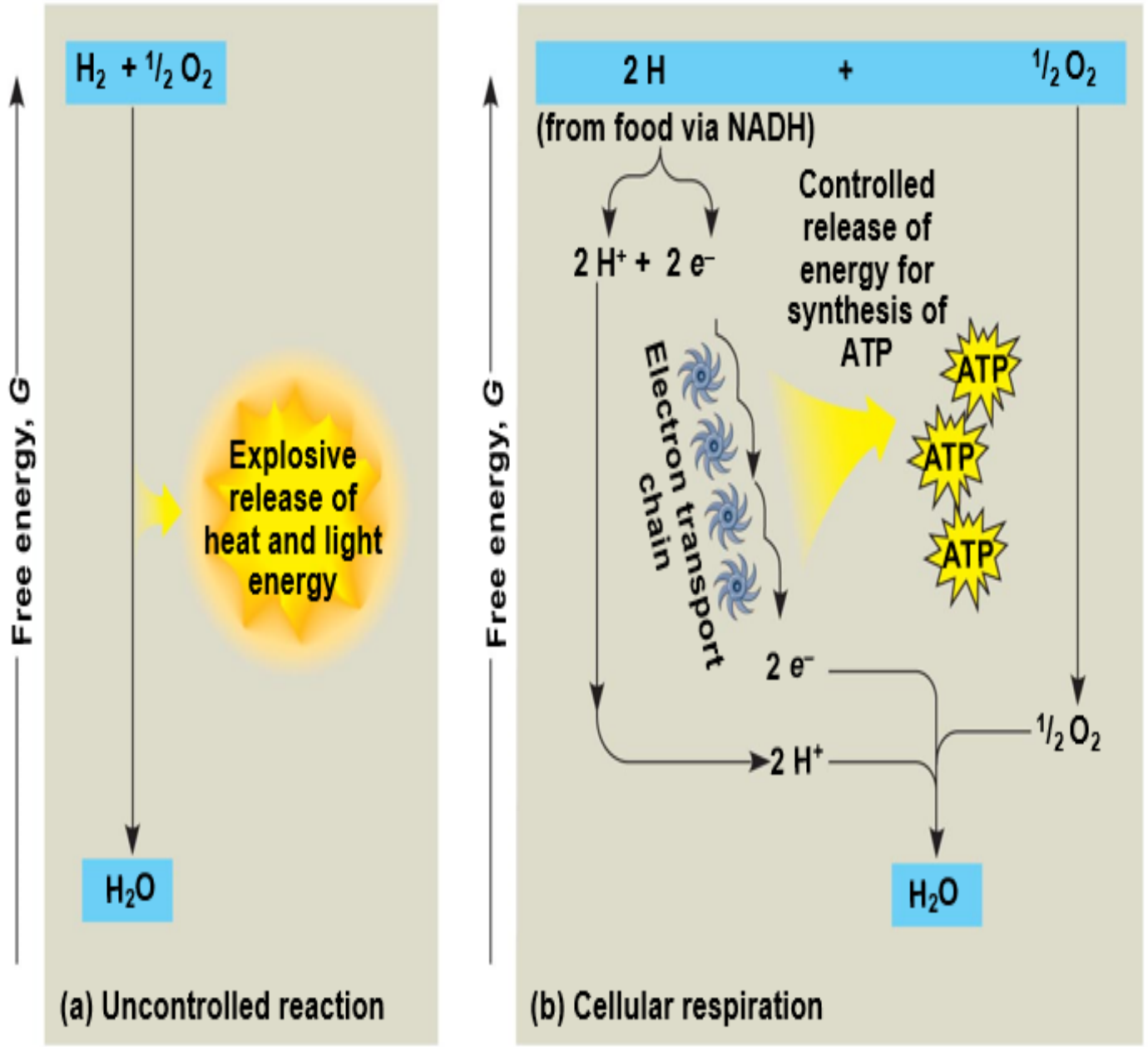
The Pathway of Electron Transport

- The chain's function is to break the large energy drop from food to O_2 into smaller steps that release energy in manageable amounts



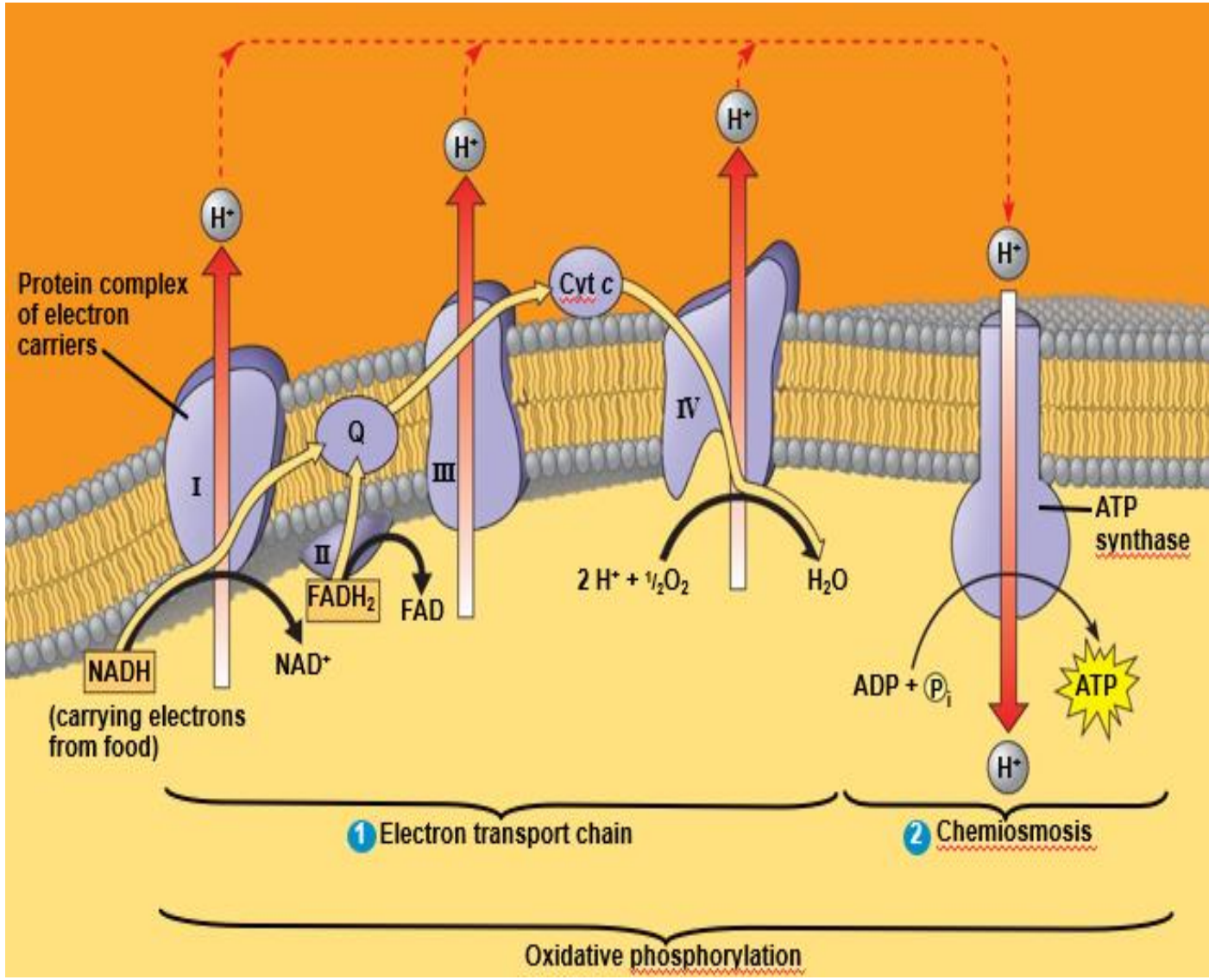
Stepwise Energy Harvest via the Electron Transport Chain

- Unlike an uncontrolled reaction, the electron transport chain passes electrons in a series of successive steps instead of one explosive reaction
- The energy yielded is used to generate ATP



Stepwise Energy Harvest via the Electron Transport Chain

- The process that generates most of the ATP is called oxidative phosphorylation because it is powered by redox reactions in ETC



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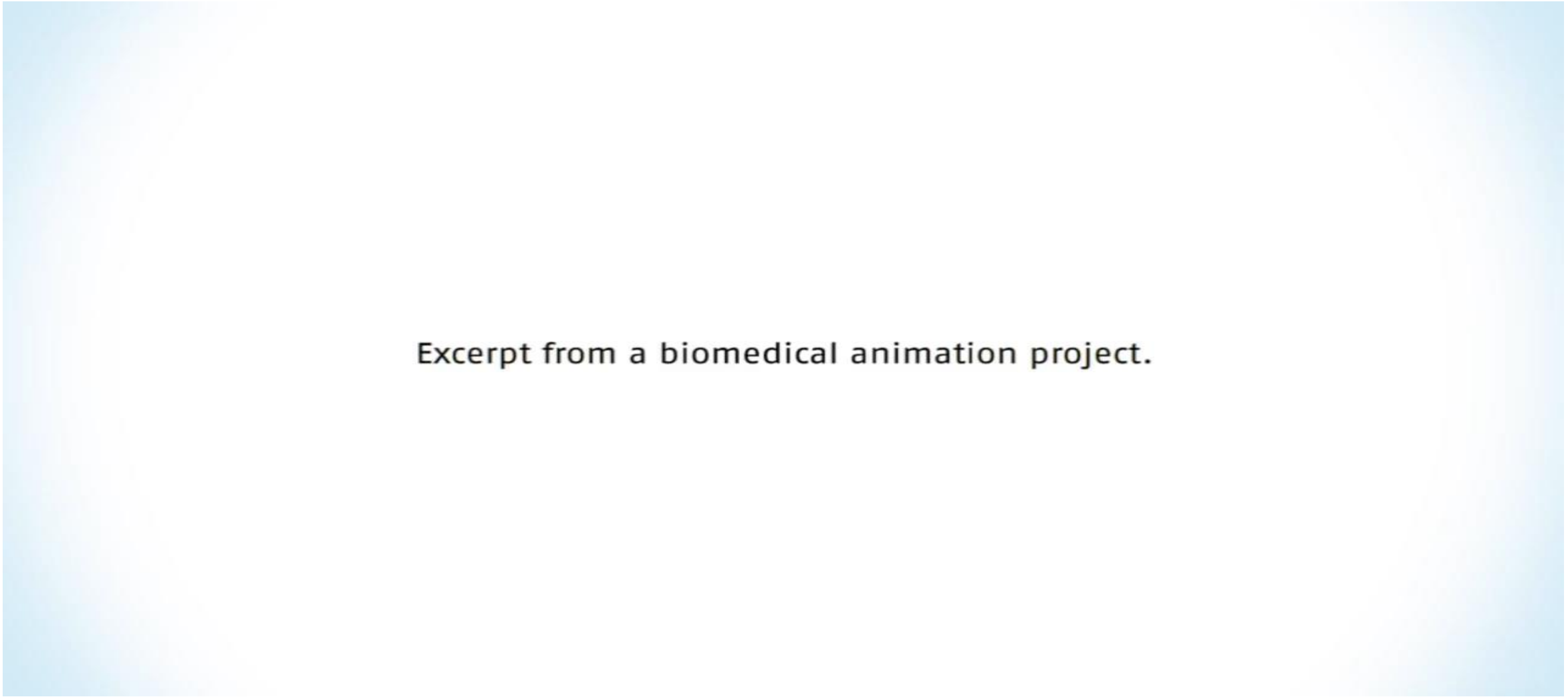


ATP Production by Cellular Respiration

- During cellular respiration, most energy flows in this sequence:

  Glucose → NADH+H, FADH2 → electron transport chain → proton-gradiant → ATP

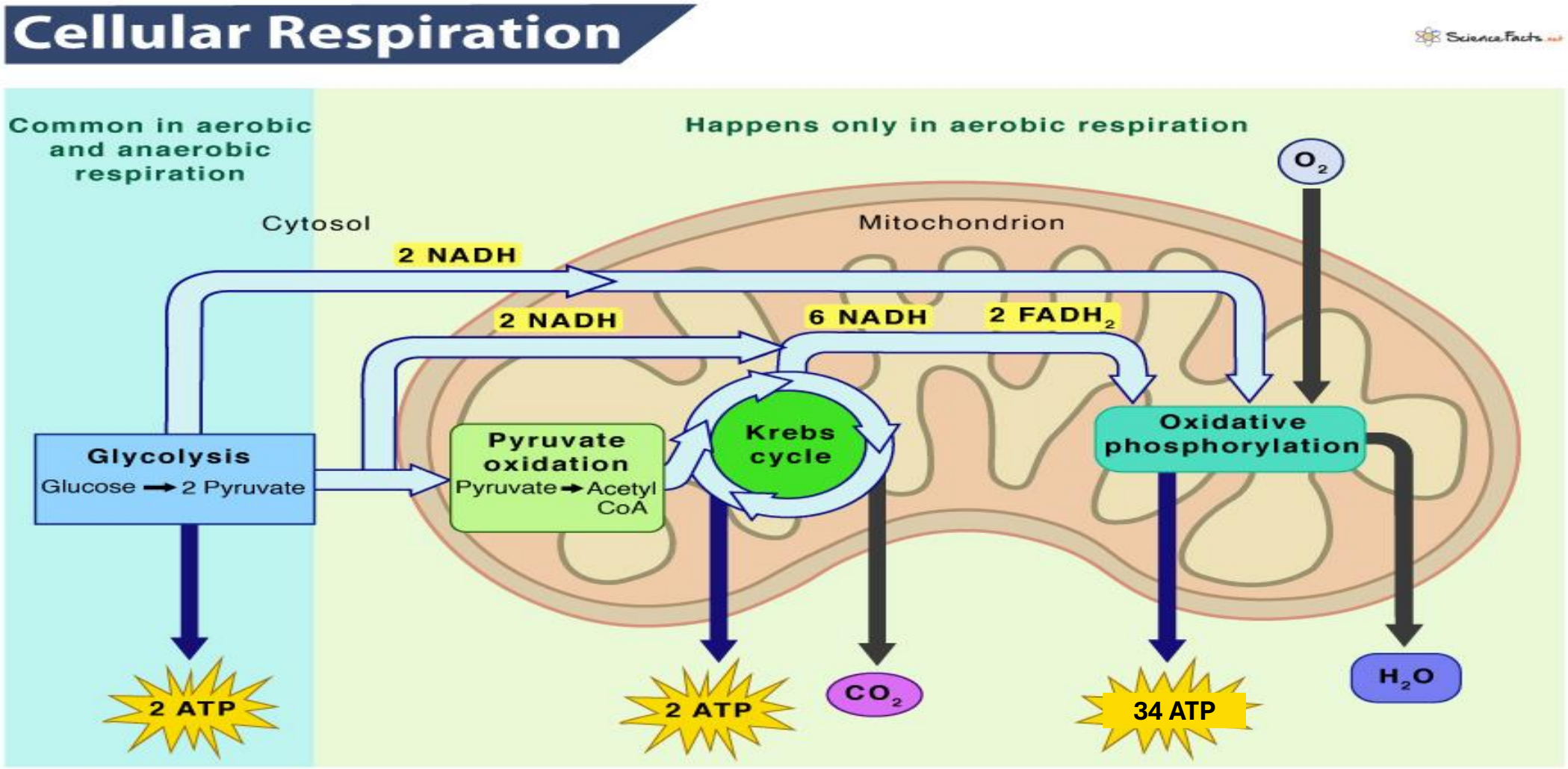
- About 40% of the energy in a glucose molecule is transferred to ATP during cellular respiration, making about 38 ATP

NADH= 3 ATP
FADH2= 2 ATP

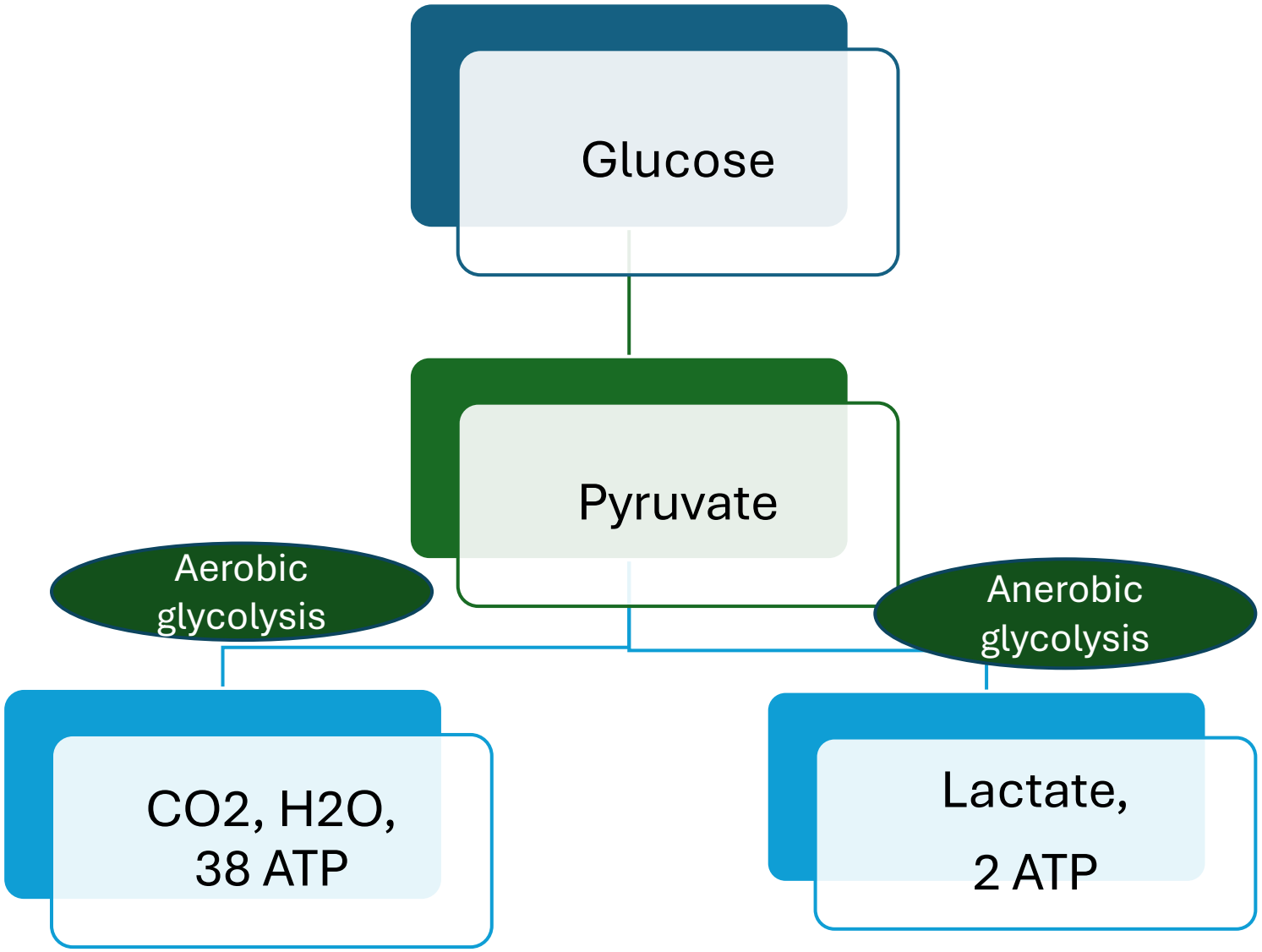
Total ATP production in aerobic respiration

Cellular Respiration Step	Energy Molecules Produced	ATP Totals
Glycolysis	2 ATP 2 NADH	2 ATP 6 ATP
Oxidative Decarboxylation	2 NADH	6 ATP
Krebs Cycle	6 NADH 2 $FADH_2$ 2 ATP	18 ATP 4 ATP 2 ATP
TOTAL		38 ATP

Total ATP production in aerobic respiration



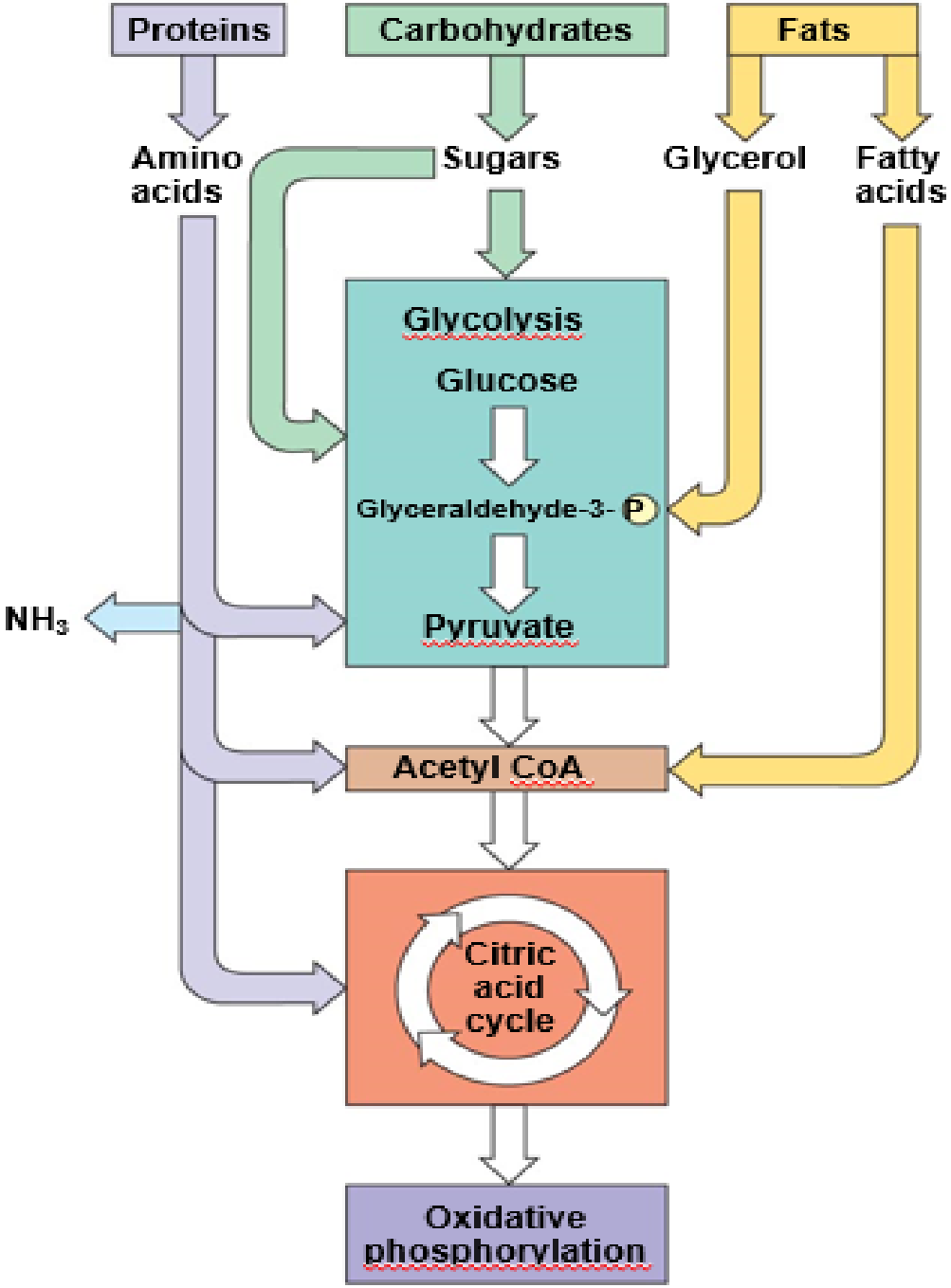
Energy from Aerobic & Anerobic respiration



Aerobic respiration	Anaerobic respiration
In presence of oxygen	In absence of oxygen (as in muscular exercise)
Releases 38 ATP molecules	Releases only 2 ATP molecules
More efficient	Less efficient

Glycolysis and the citric acid cycle connect to many other metabolic pathways

- Gycolysis and the citric acid cycle are major intersections to various catabolic and anabolic pathways
- Catabolic pathways funnel electrons from many kinds of organic molecules into cellular respiration



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References

- Campbell Biology. 11th ed. New York: Pearson; 2017.
- Lippincott's Illustrated Reviews: Biochemistry, 8th edition
- Chatterjea's Textbook of Medical Biochemistry, 8th edition.
- https://www.youtube.com/watch?v=eBI3U-T5Nvk
- https://www.youtube.com/watch?v=OYQPQEOdCU8


A GOAL
WITHOUT
A PLAN
IS JUST A
WISH