Biology L.O.10

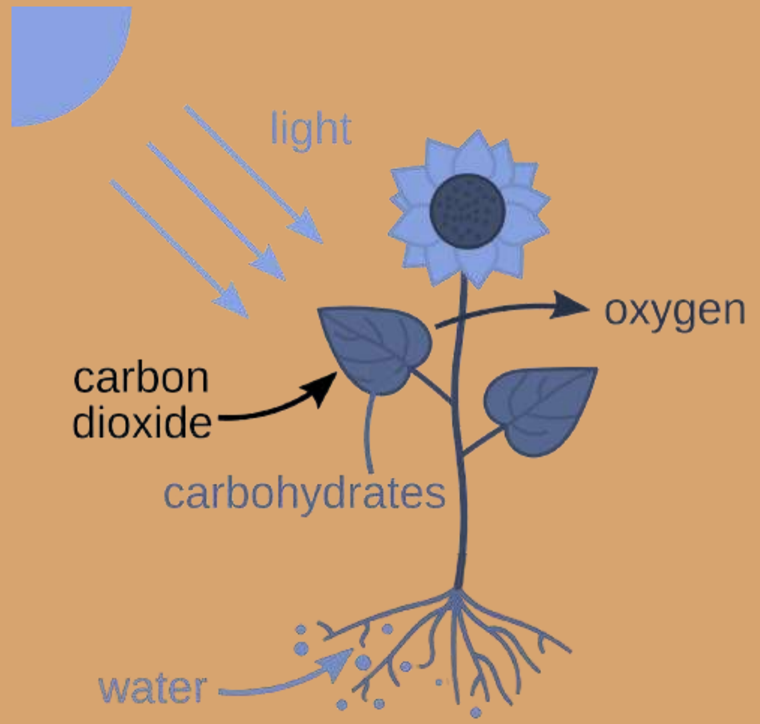
Qena Student Club

Photosynthesis

- **It's the process that converts solar energy into chemical energy.**
- **Autotrophs sustain themselves without eating anything derived from other organisms.**
- **They are the producers of the biosphere producing organic molecules from CO_2 and other inorganic molecules.**
- **Almost all plants are photoautotrophs, using the energy of sunlight to make organic molecules from H_2O and CO_2**

Photosynthesis

- Photosynthesis occurs in plants, algae, certain other protists, and some prokaryotes.
- They don't only feed themselves, they feed the entire world.



Photosynthesis

- **Heterotrophs** obtain their organic material from other organisms.
- They are consumers of the biosphere
- Almost all of them, **including humans**, depend on photoautotrophs for food and O_2

Photosynthesis

- **Photosynthesis consists of the light reactions & Calvin cycle**
- **The light reactions (In the thylakoids):**

I. **Split** H_2O
II. **Release** O_2
III. **Reduce NADP+ to NADPH**
IV. **Generate ATP from ADP by photophosphorylation.**

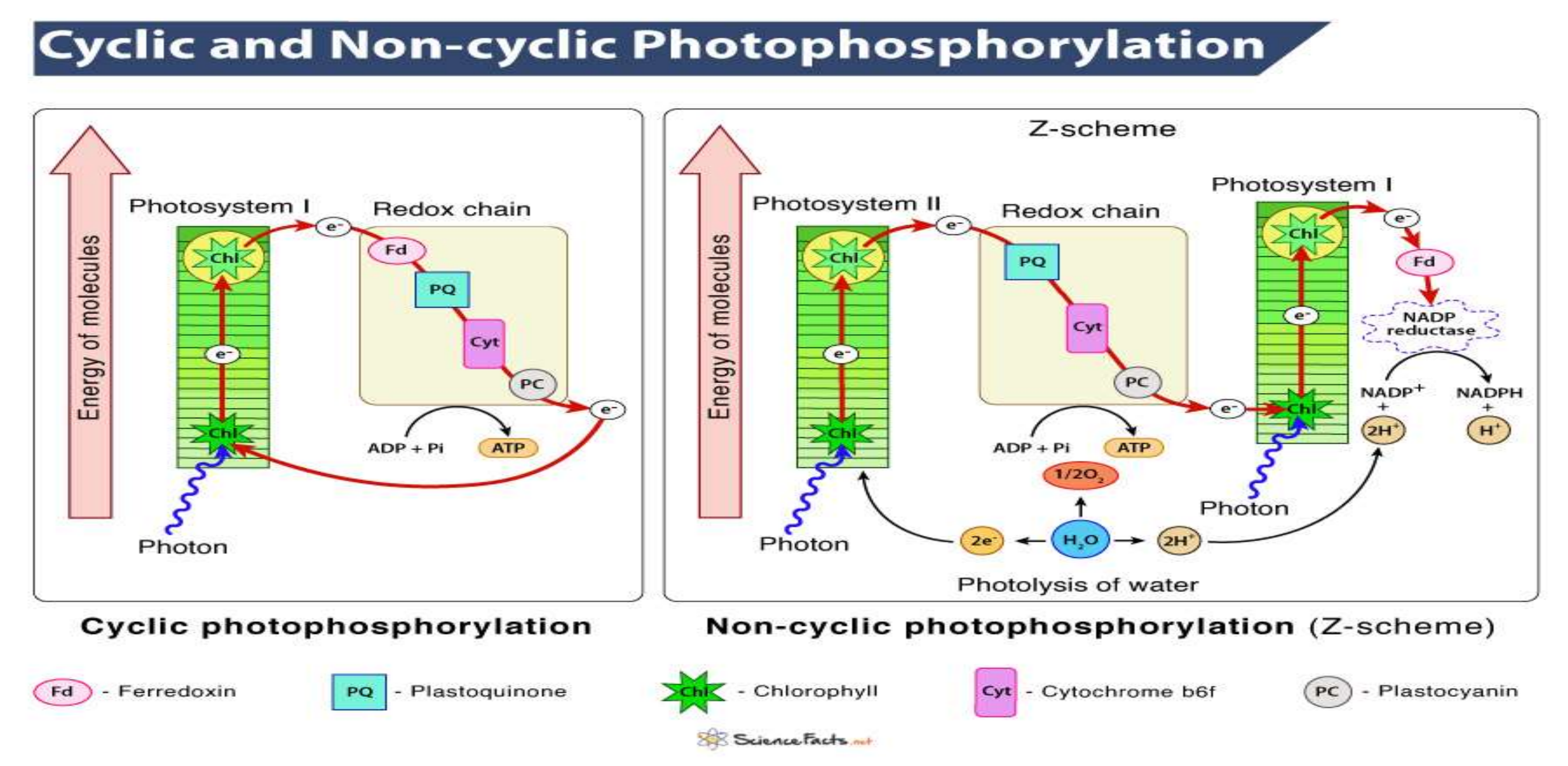
Light dependent reaction

- **Light reaction occurs in the thylakoids (the photo part of photosynthesis convert the solar light to chemical energy).**
- **In the light reaction: water is split ,providing a source of electrons and protons (hydrogen ions , H+) and giving off O2 as a by product (the waste product)**
- **Light absorbed by chlorophyll drives the transfer of electrons and hydrogen ions from water to an acceptor (NADP+), where they are temporarily stored.**

Types of light reaction

cyclic photophosphorylation

Non cyclic photophosphorylation



Non cyclic photophosphorylation

- **Process**: Non-cyclic photophosphorylation is the primary pathway for the conversion of light energy into chemical energy. It involves both photosystem II (PSII) and photosystem I (PSI). The process begins with the absorption of light by PSII, leading to the excitation of electrons. These electrons are then passed down an electron transport chain to PSI, ultimately resulting in the reduction of NADP+ to NADPH.
- **Purpose**: The primary purpose of this pathway is to generate both ATP and NADPH, which are essential for the subsequent dark reactions of photosynthesis. Additionally, this process is responsible for the photolysis of water, leading to the release of oxygen.
- **Electron Flow:**
- Electrons excited in PSII are transferred to PSI, and from there, they are used to reduce NADP+ to NADPH.
- The linear flow of electrons leads to a continuous need for electron replenishment in PSII, which is met by the splitting of water molecules.
- **Products Formed:**
- The key products of non-cyclic photophosphorylation are ATP and NADPH, crucial for the Calvin cycle.
- Oxygen is released as a by-product of water photolysis in PSII.

cyclic photophosphorylation

- **<u>Process</u>: In cyclic photophosphorylation, the flow of electrons is circular, beginning and ending at photosystem I (PSI). This process is initiated when PSI absorbs light, energising its electrons. These high-energy electrons are then transferred to a series of electron carriers in the thylakoid membrane and eventually return to PSI.**
- **<u>Purpose</u>: The primary aim of cyclic photophosphorylation is to produce ATP. Unlike non-cyclic photophosphorylation, it does not contribute to the reduction of NADP+ to NADPH, nor does it involve the splitting of water or the release of oxygen. This pathway is particularly important under conditions where the demand for ATP is higher than NADPH, such as in the dark reactions of photosynthesis.**
- **<u>Electron Flow</u>:**
- **Electrons in PSI, upon excitation by light, are transferred to a series of electron carriers.**
- **This electron transport creates a proton gradient across the thylakoid membrane, driving the synthesis of ATP through chemiosmosis.**
- **<u>Products Formed</u>:**
- **The sole direct product of cyclic photophosphorylation is ATP.**
- **This pathway does not produce NADPH and does not release oxygen as a by-product.**

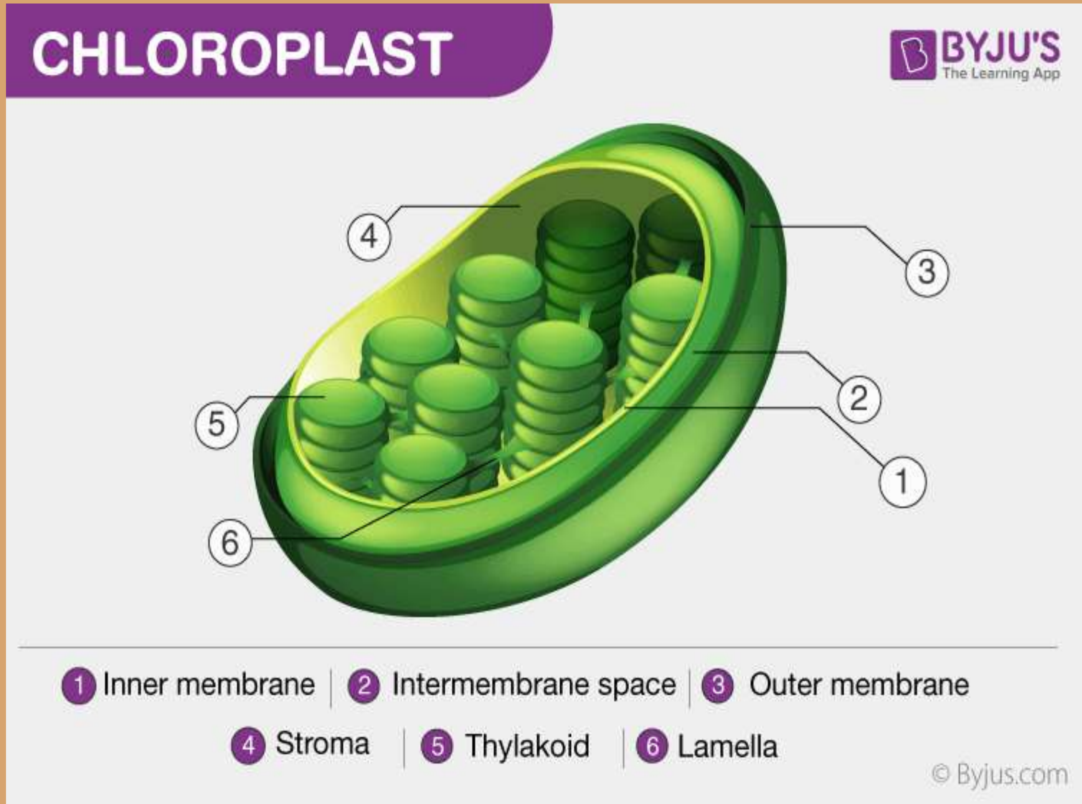
Cyclic Photophosphorylation	Non-Cyclic Photophosphorylation
Only Photosystem I is involved	Both Photosystem I and II are involved
P700 is the active reaction centre	P680 is the active reaction centre
Electrons travel in a cyclic manner	Electrons travel in a non – cyclic manner
Electrons revert to Photosystem I	Electrons from Photosystem I are accepted by NADP
ATP molecules are produced	Both NADPH and ATP molecules are produced
Water is not required	Photolysis of water is present
NADPH is not synthesized	NADPH is synthesized
Oxygen is not evolved as the by-product	Oxygen is evolved as a by-product
This process is predominant only in bacteria	This process is predominant in all green plants

chloroplast

- “Chloroplast is an organelle that contains the photosynthetic pigment chlorophyll that captures
- sunlight and converts it into useful energy, thereby, releasing oxygen from water.
- Chloroplasts are found in all green plants and algae. They are the food producers of plants. These are found in mesophyll cells located in the leaves of the plants. They contain a high concentration of chlorophyll that traps sunlight. This cell organelle is not present in animal cells.
- Chloroplast has its own extra-nuclear DNA and therefore are semiautonomous, like mitochondria. They also produce proteins and lipids required for the production of chloroplast membrane.

Functions of Chloroplast

The most important function of the chloroplast is to synthesise food by the process of photosynthesis.
Absorbs light energy and converts it into chemical energy.
Chloroplast has a structure called chlorophyll which functions by trapping the solar energy and is used for the synthesis of food in all green plants.
Produces NADPH and molecular oxygen (O_2) by photolysis of water.
Produces ATP – Adenosine triphosphate by the process of photosynthesis.
The carbon dioxide (CO_2) obtained from the air is used to generate carbon and sugar during the Calvin Cycle or dark reaction of photosynthesis.



Structure of Chloroplast

Membrane Envelope

It comprises inner and outer lipid bilayer membranes. The inner membrane separates the stroma from the intermembrane space.

Intermembrane Space

The space between inner and outer membranes.

Thylakoid System (Lamellae)

The system is suspended in the stroma. It is a collection of membranous sacs called thylakoids or lamellae. The green coloured pigments called chlorophyll are found in the thylakoid membranes. It is the sight for the process of light-dependent reactions of the photosynthesis process. The thylakoids are arranged in stacks known as grana and each granum contains around 10-20 thylakoids.

Stroma

It is a colourless, alkaline, aqueous, protein-rich fluid present within the inner membrane of the chloroplast present surrounding the grana.

Grana

Stack of lamellae in plastids is known as grana. These are the sites of conversion of light energy into chemical energy.

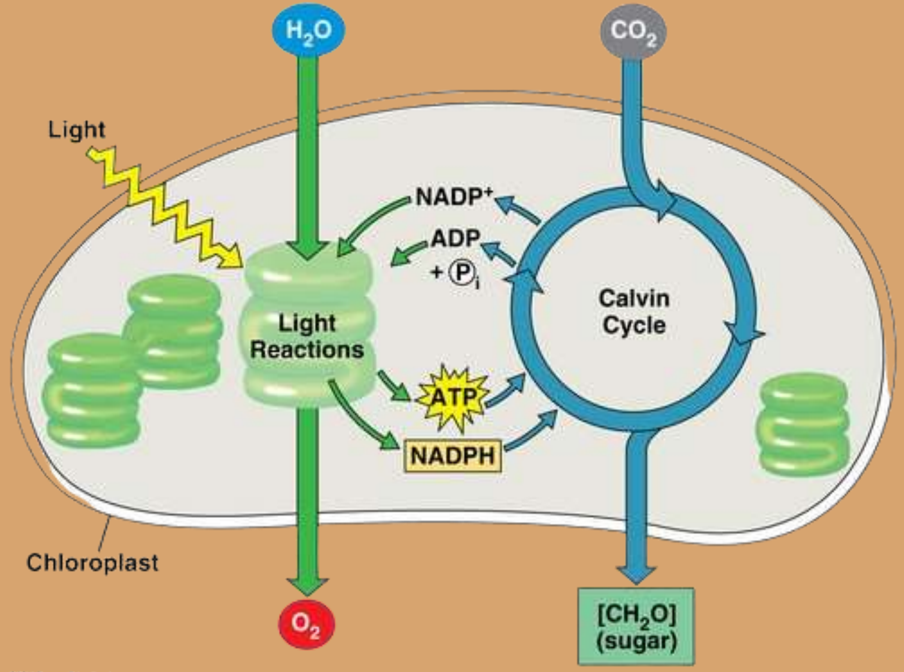
Chlorophyll

It is a green photosynthetic pigment that helps in the process of photosynthesis.

Also read: Light-dependent Reactions

The Calvin cycle

- The Calvin cycle (in the stroma) forms sugar from CO_2 using ATP and NADPH.
- The Calvin cycle begin with carbon fixation, incorporating CO_2 into organic molecules.



The Calvin cycle

- **The Calvin cycle**, like the citric acid cycle, regenerates its starting material after molecules enter and leave the cycle.
- The cycle builds up sugar from smaller molecules by using ATP and reducing power of electrons carried by NADPH.
- Carbon enters the cycle as CO_2 and leaves as sugar named **glyceraldehyde-3-phopate (G3P)**
- For net synthesis of 1G3P, the cycle must take place 3 times, fixing 3 molecules of CO_2

The Calvin cycle

- **The Calvin cycle has 3 phases:**

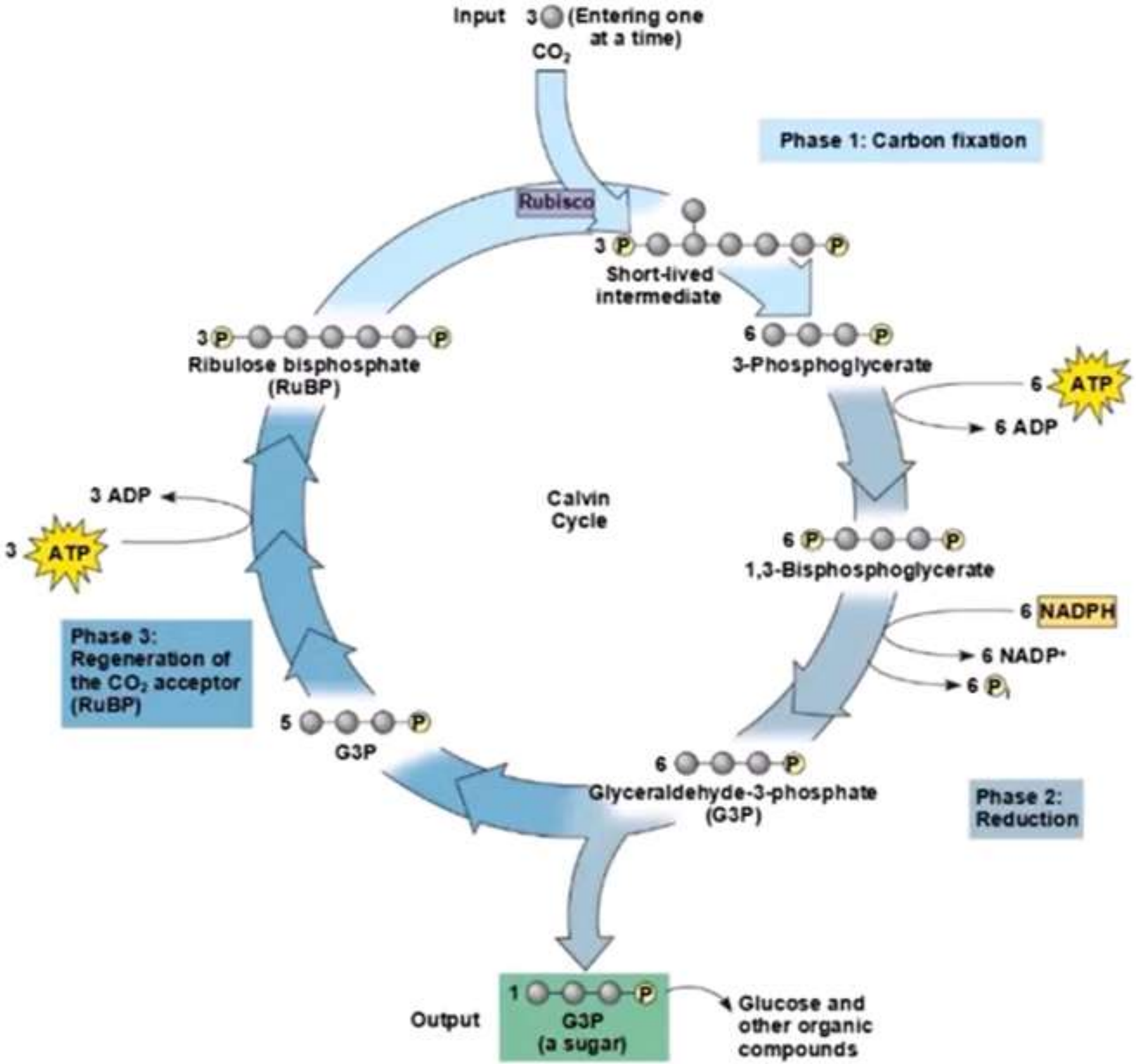
I. Carbon fixation (catalyzed by rubisco)

II. Reduction

III. Regeneration of CO_2 acceptor (RuBP)

Still complicated? Pictures help I guess :)

Fig. 10-18-3



Input
3 (Entering one at a time)
CO_2
Rubisco
Phase 1: Carbon fixation
3 P P
Short-lived intermediate
6 P
3-Phosphoglycerate
6 ATP
6 ADP
6 P P
1,3-Bisphosphoglycerate
6 NADPH
6 $NADP^+$
6 P_i
6 P
Glyceraldehyde-3-phosphate (G3P)
Phase 2: Reduction
Calvin Cycle
3 P P
Ribulose bisphosphate (RuBP)
3 ADP
3 ATP
Phase 3: Regeneration of the CO_2 acceptor (RuBP)
5 P
G3P
Output
1 P
G3P (a sugar)
Glucose and other organic compounds

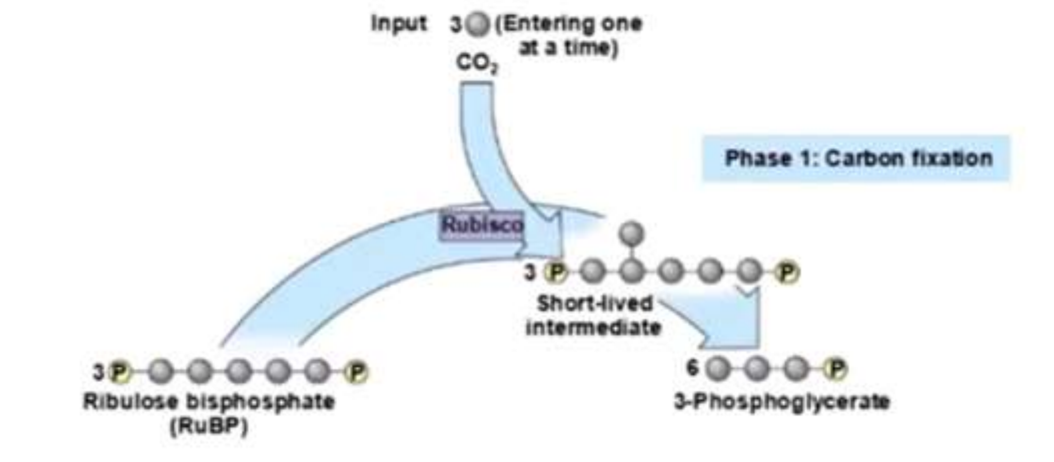
The Calvin cycle

Still complicated?:(Let’s break it down!!

The Calvin cycle

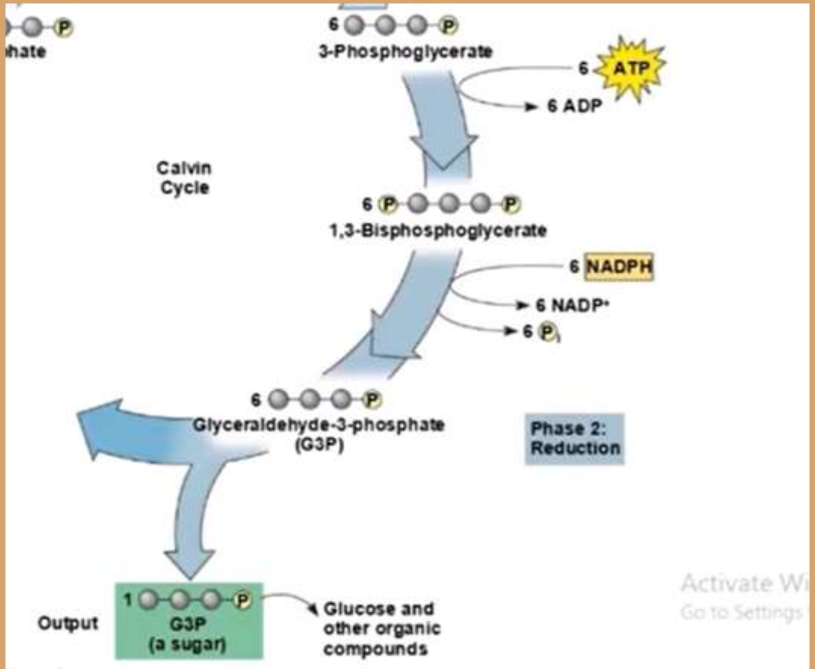
- Phase I carbon fixation:
- First, we have (RuBP) which is a Pentose sugar with two phosphate groups.
- Then, three CO_2 compounds enter at a time (Input).
- After that a 6-carbon compound is formed (unstable compound) it’s always decomposed into 2 compounds with 3 carbons each called

  3-Phosphoglycerate



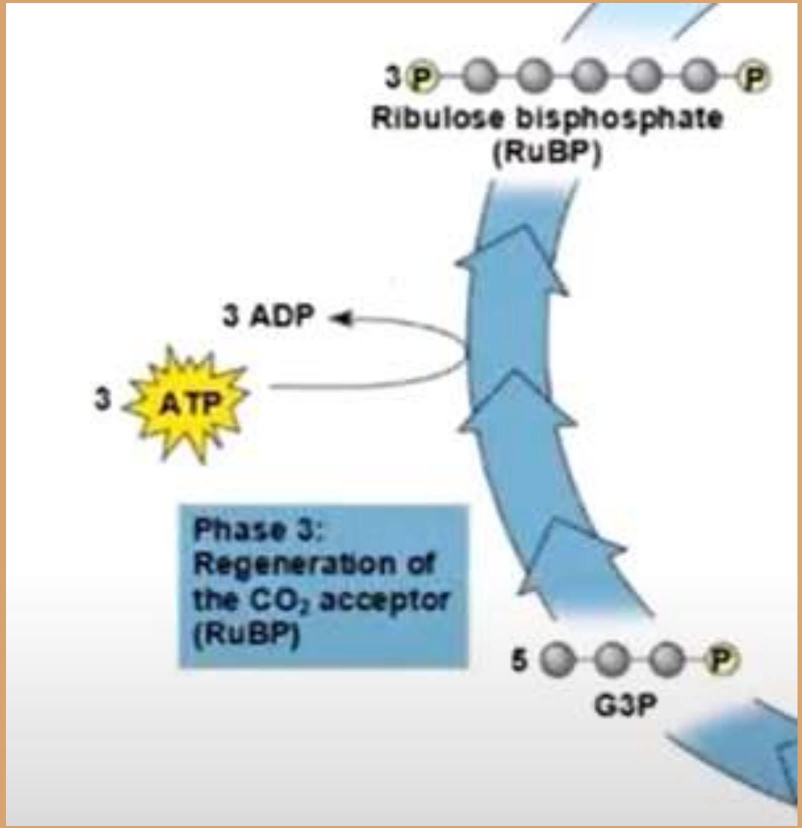
The Calvin cycle

- **Phase II reduction:**
- **the 3-Phosphoglycerate consumes 6ATP to be converted to 1,3-Biphosphoglycerate.**
- **Then it consumes 6NADPH to be converted to Glyceraldehyde-3-phosphate (G3P) and then 1G3P is the output.**



The Calvin cycle

- **Phase III Regeneration CO_2 acceptor:**
- **After we got 1G3P out of the cycle now we are left with 5G3P**
- **So, we consume 3ATP to make (RuBP)**
- **And that's *The Calvin cycle.***



Photosynthesis

- **Dehydration** is a problem for plants, sometimes requiring trade-offs with other metabolic processes, especially Photosynthesis
- On hot, dry days, plants close **stomata**, which conserves H2O but also limits Photosynthesis.
- The closing of the **stomata** reduces access to CO_2 and causes O_2 to build up.
- These conditions favor a seemingly wasteful process called **Photorespiration**.

C_3 PLANTS AND photorespiration

- **In most plants (C_3 plants), initial fixation of CO_2 , via rubisco, forms a 3-Carbon compound.**
- **In Photorespiration, rubisco adds O_2 instead of CO_2 in the Calvin cycle**
- **Photorespiration consumes O_2 and organic fuel and releases CO_2 without producing ATP or sugar.**

C_3 PLANTS AND photorespiration

- **Photorespiration may be an evolutionary relic because rubisco first evolved at a time when the atmosphere had far less O_2 and more CO_2**
- **Photorespiration limits damaging products of light reactions that build up in the absence of the Calvin cycle.**
- **In many plants, Photorespiration is a problem because on a hot, dry day it can drain as much as 50% of the carbon fixed by Calvin cycle.**

C_4 PLANTS

- C_4 **plants minimize the cost of photorespiration by incorporating CO_2 into <u>4-carbon compounds</u> in mesophyll cells.**
- **This step requires the enzyme PEP carboxylase.**
- **PEP has a higher affinity for CO_2 than rubisco does; it can fix CO_2 even when its concentration are low.**
- **These four-carbon compounds are exported to bundle-sheath cells, where they release CO_2 that is used in the Calvin cycle.**

CAM PLANTS

- Some plants, including succulents, use **crassulacean acid metabolism (CAM)** to fix carbon
- **CAM plants** open their stomata at night incorporating CO_2 into organic acids.
- Stomata close during the day, & CO_2 is released from ogranic acids and used in the **Calvin cycle**.

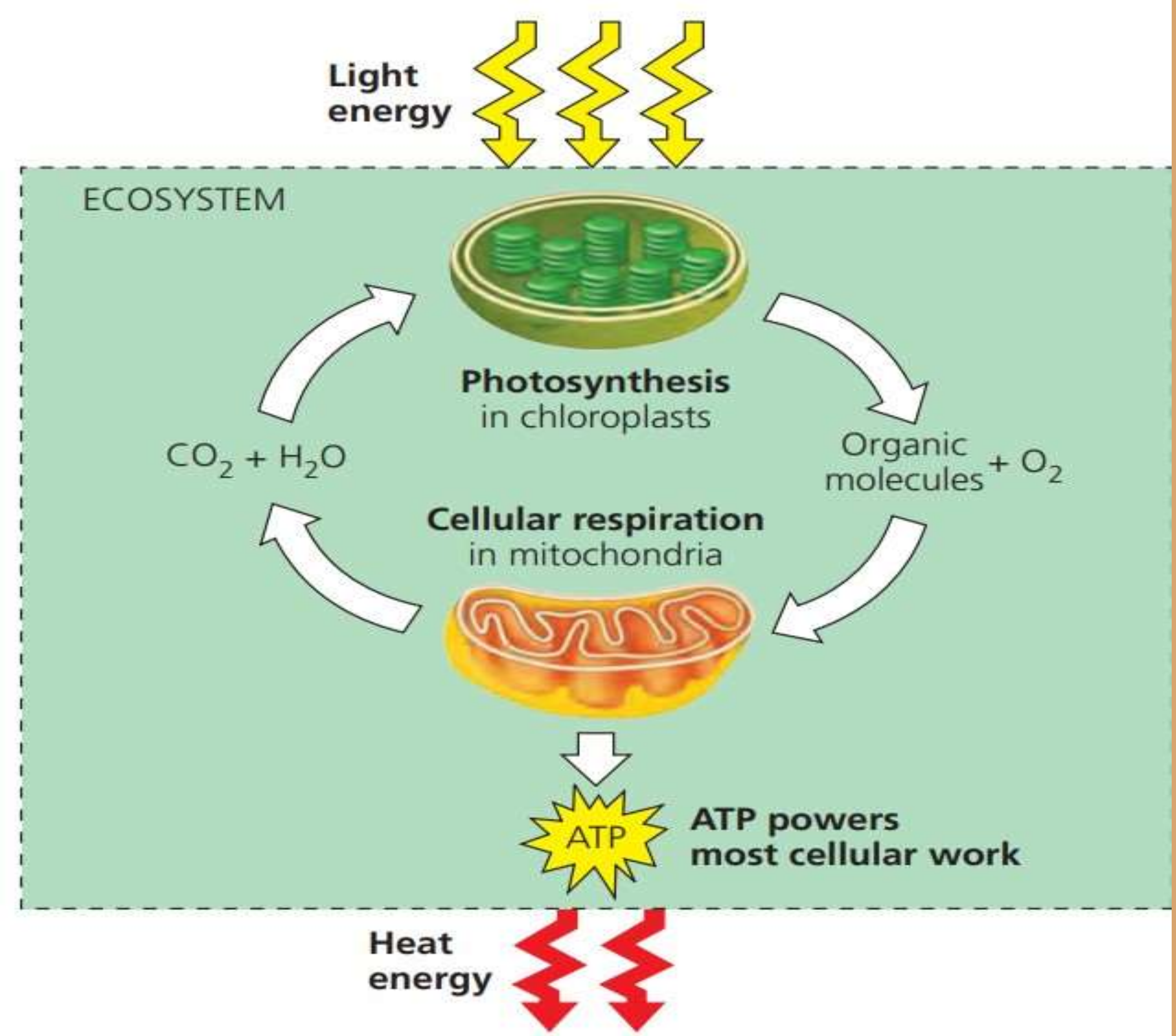
Importance of Photosynthesis

- **The energy entering chloroplasts as sunlight gets stored as chemical energy in organic compounds.**
- **Sugar made in chloroplasts supplies chemical energy and carbon skeletons to synthesis the organic molecules of cells**
- **Plants store excess sugar as starch in structures such as roots, tubers, seeds and fruits.**
- **In addition to food production, photosynthesis produce the O_2 in our atmosphere**

Cellular respiration

- Living things require energy from outside sources to perform their many tasks_ for example, assembling polymers, pumping substances across membranes, moving, and reproducing.
- cellular respiration is the process by which organisms use oxygen to break down food molecules to get chemical energy for cell functions.
- (Cellular respiration & Photosynthesis): Photosynthesis generates oxygen, as well as organic molecules used by the mitochondria of eukaryotes as fuel for cellular respiration. Respiration breaks this fuel down, using oxygen (O_2) and generating ATP.
- The waste products of this type of respiration, carbon dioxide (CO_2) and water (H_2O), are the raw materials for photosynthesis.
- Cells used chemical energy stored in organic molecules to regenerate ATP .

Cellular respiration



Cellular respiration

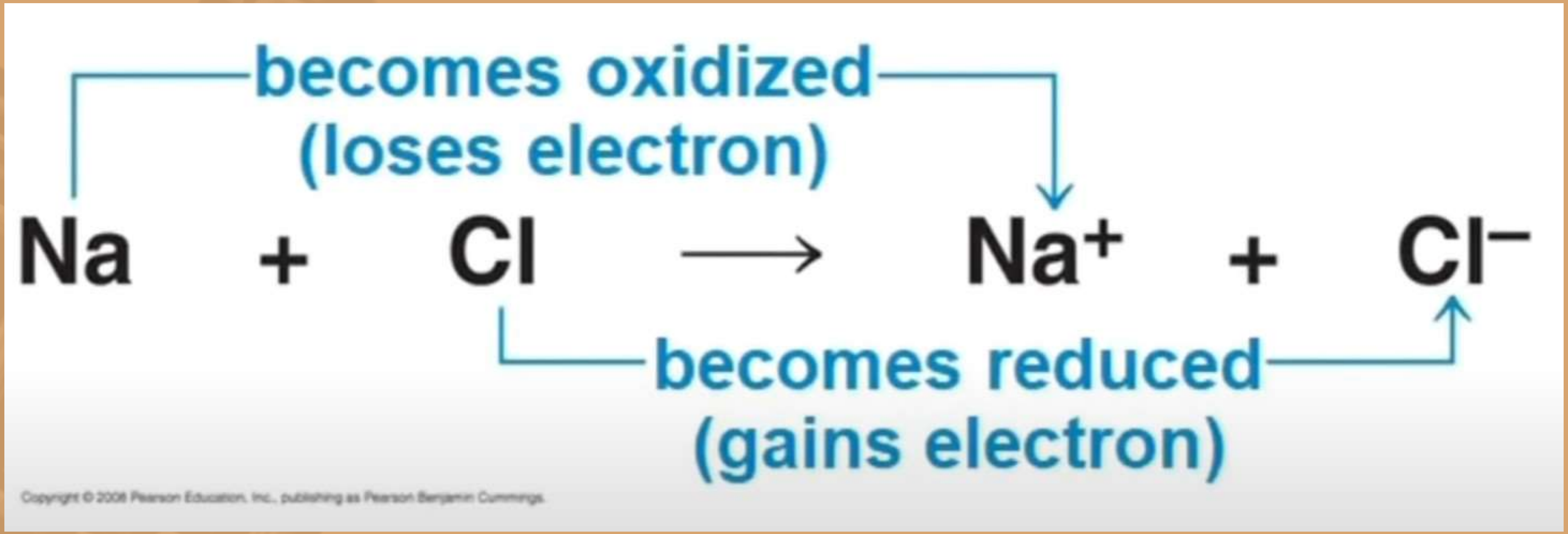
- Cellular respiration includes both AEROBIC RESPIRATION and ANAEROBIC RESPIRATION but is often used to refer to AEROBIC RESPIRATION .
- AEROBIC RESPIRATION : consumes organic molecules and o_2 and yields ATP .
- ANEAROBIC RESPIRATION : is similar to AEROBIC but it consumes compounds other than o_2 .

Cellular respiration

- The transfer of electrons during chemical reactions release energy stored in organic molecules .
- The released energy is ultimately used to synthesize ATP .
- Chemical reactions that transfer electrons between reactants are called oxidation _ reduction reactions , or redux reduction .
- 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 receptor is called the oxidizing agent .

Cellular respiration

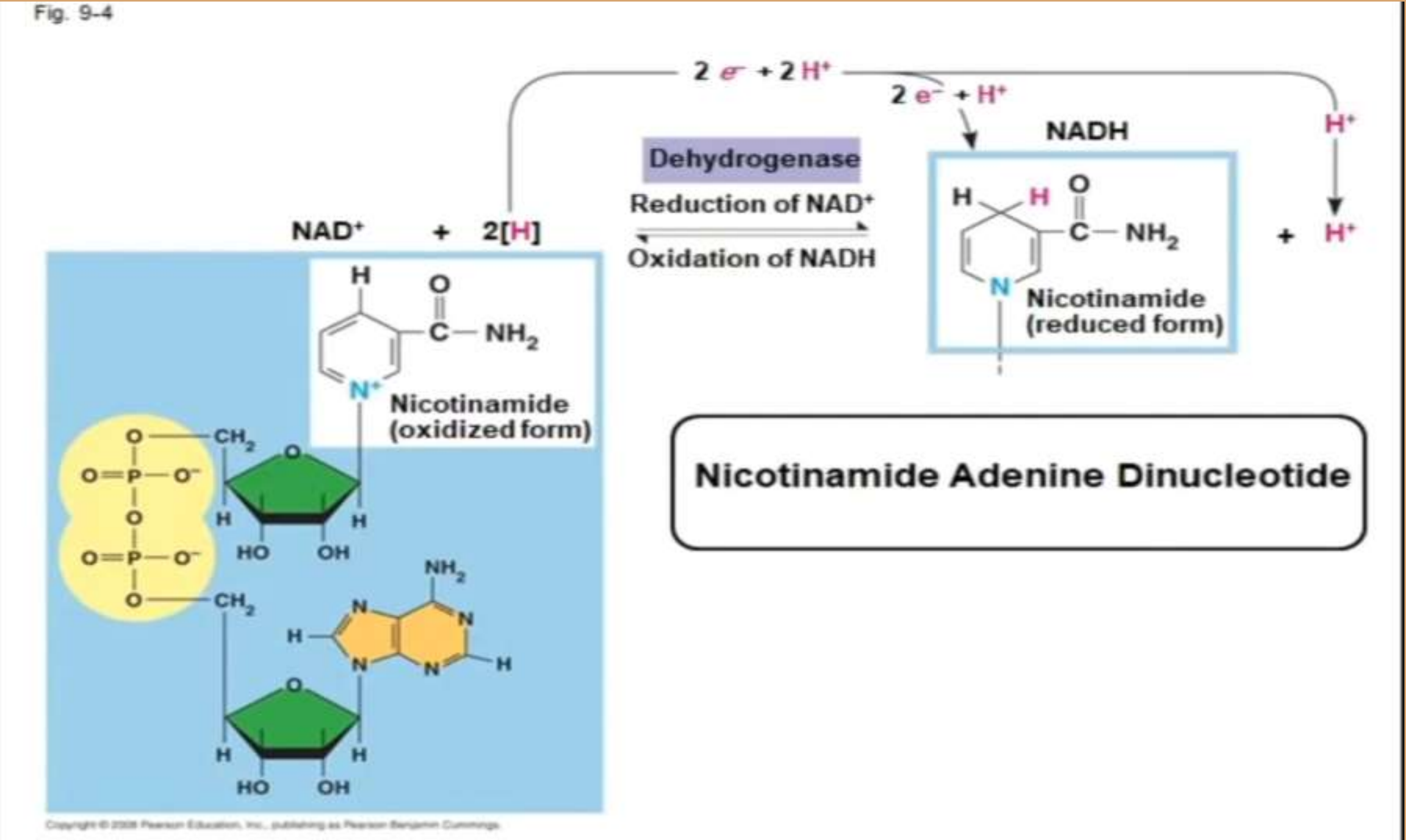
- For example :



Cellular respiration

- During cellular respiration , the fuel (such as glucose) is oxidized , and o is reduced.
- In cellular respiration ,glucose and other organic molecules are broken down in series of steps .
- Electrons from organic compounds are usually first transferred to NAD+, a coenzyme
- As an electron acceptor , NAD+ functions as an oxidized agent during cellular respiration .
- Each NADH (the reduced form of NAD+)represents stored stored energy that is tapped to synthesize ATP .

Cellular respiration



Nicotinamide Adenine Dinucleotide

Cellular respiration

- NADH passes the electrons to **the electron transport chain** .

- Unlike an uncontrolled reaction, the electron transport chain passes electrons in a series of steps instead of one explosive reaction.

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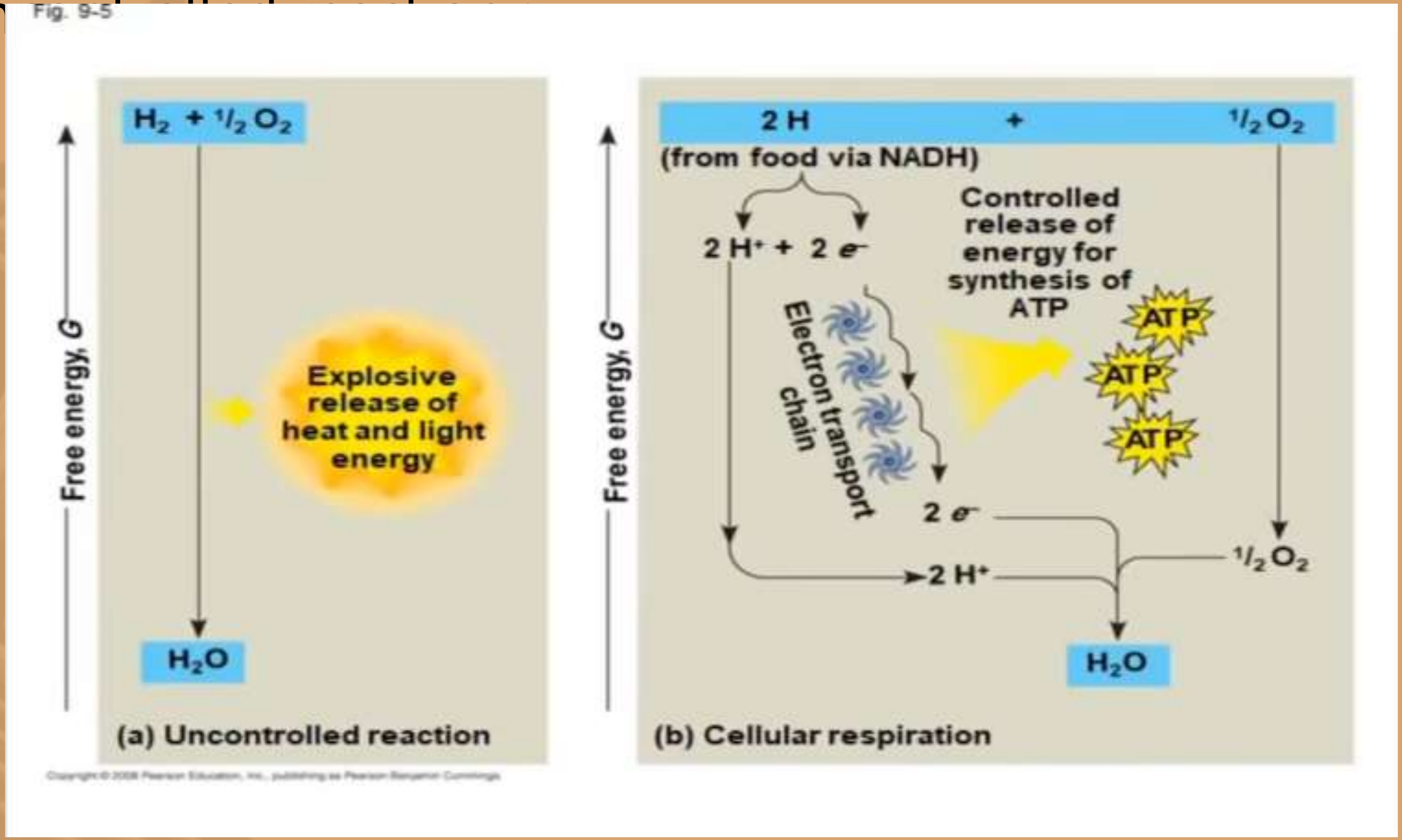
- O pulls electrons down the chain in an energy yielding tumble .

- The energy yielded is used to regenerate ATP.

Cellular respiration

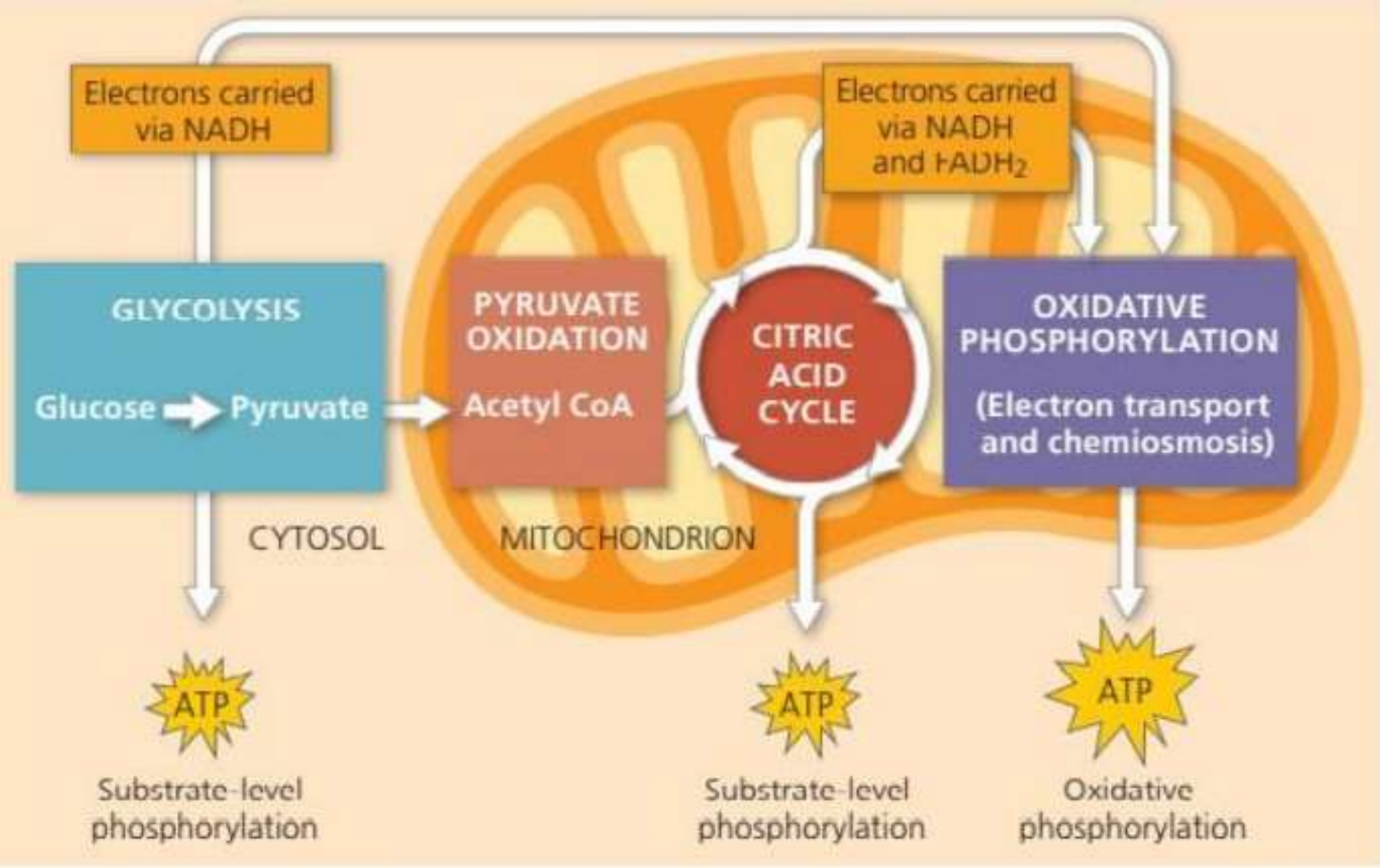
- And here is the difference between the controlled and the un



Cellular respiration

- Cellular respiration has three stages :
- Glycolysis : (breaks down glucose into two molecules of pyruvate)
- The citric acid cycle or {the Krebs cycle} or {TCA} : completes the breakdown of glucose .
- Oxidative phosphorylation : (accounts for most of the ATP synthesis)
- 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** .

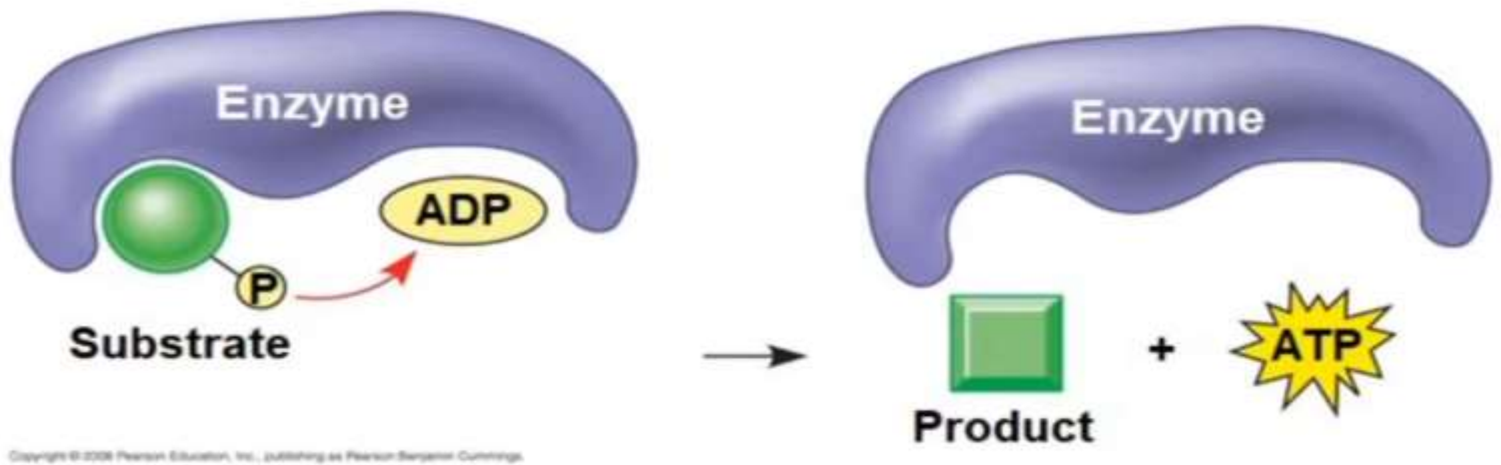
Cellular respiration



Cellular respiration

The substrate-level phosphorylation :

Fig. 9-7



GLYCOLYSIS

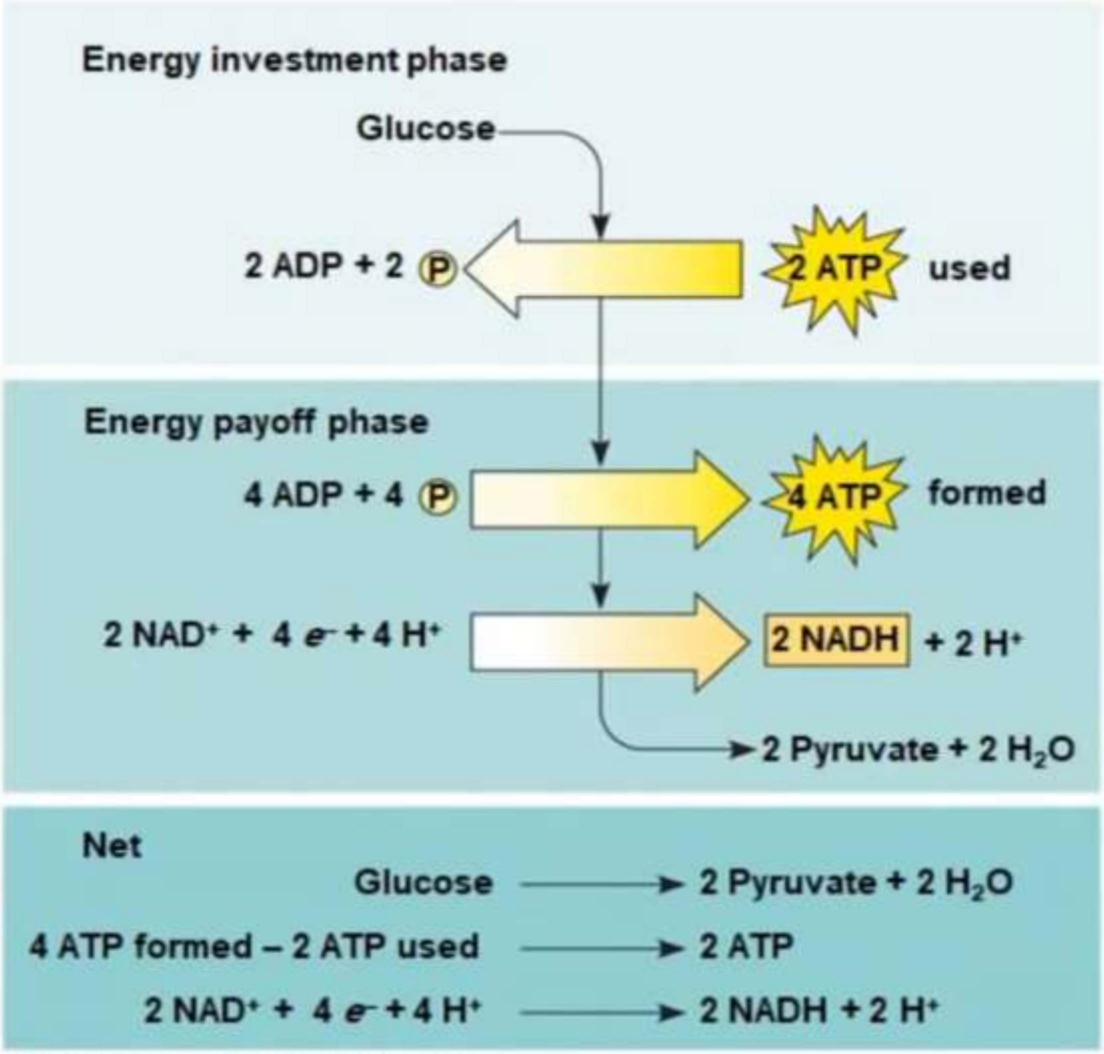
- Glycolysis occurs in the cytoplasm and has two major phases :

-energy investment phase
-energy payoff phase

The glycolysis is done in **ten** stages:

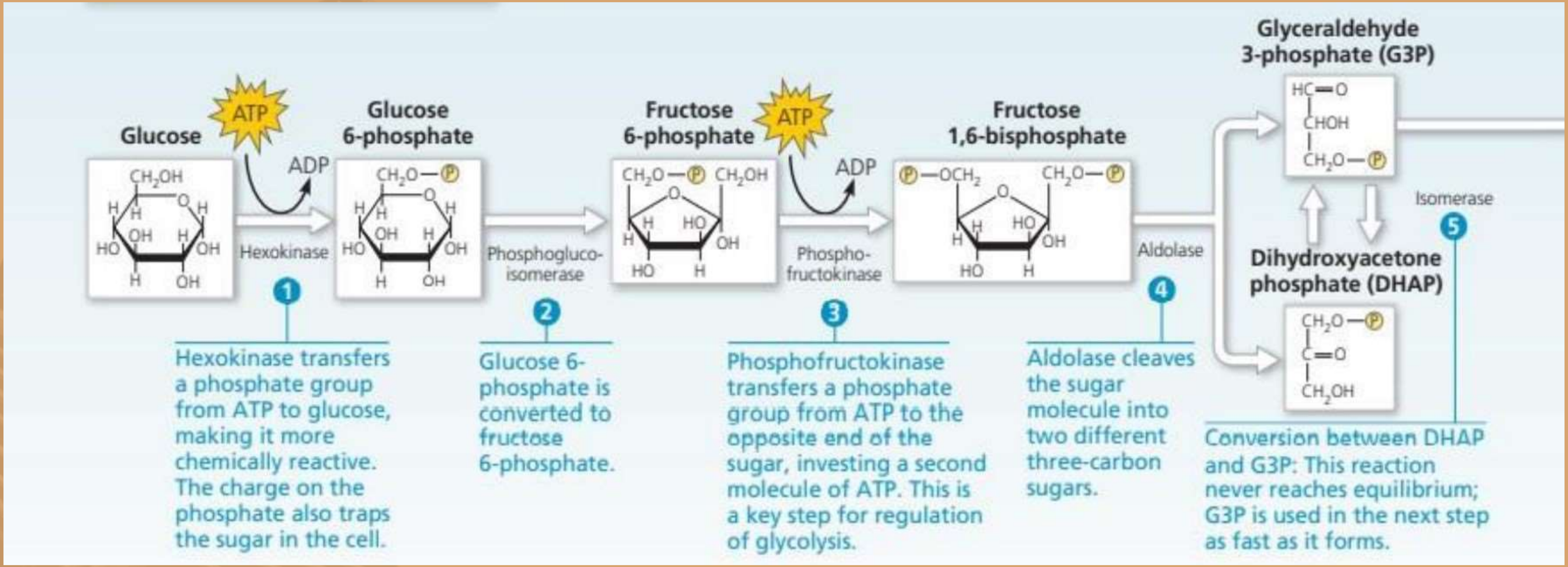
GLYCOLYSIS

Fig. 9-8



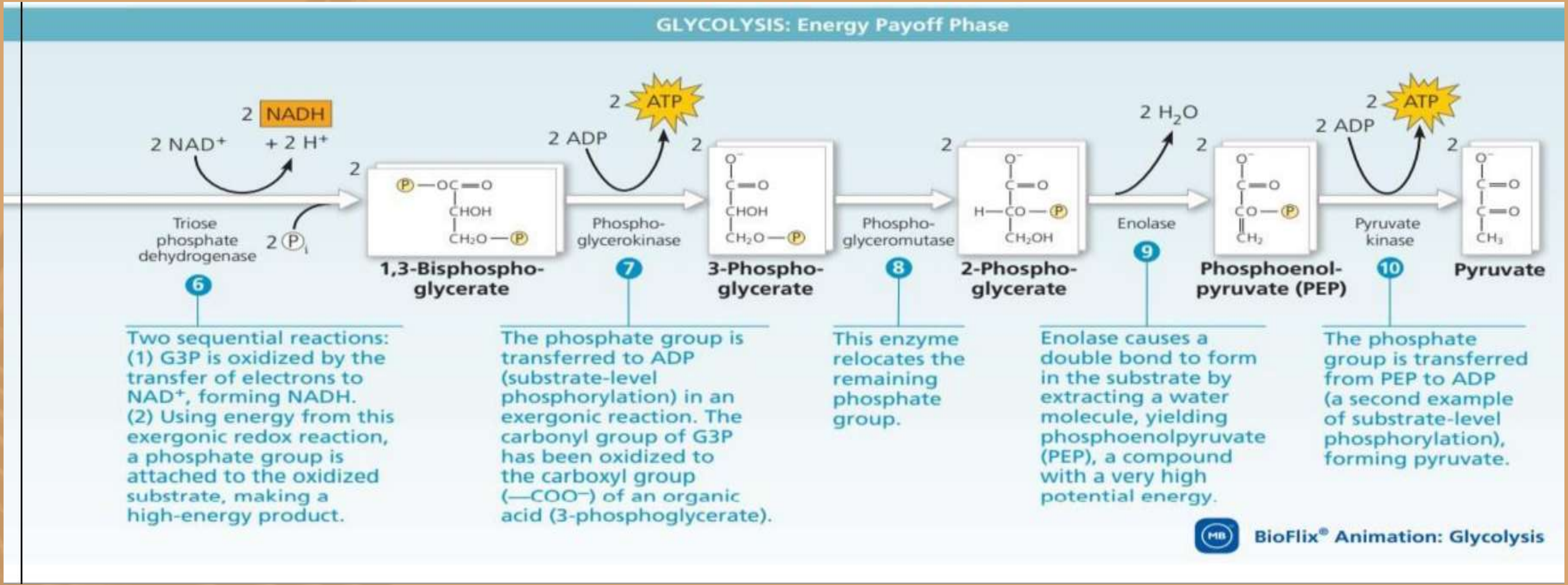
GLYCOLYSIS

- And here is first 5 the stages of the glycolysis :



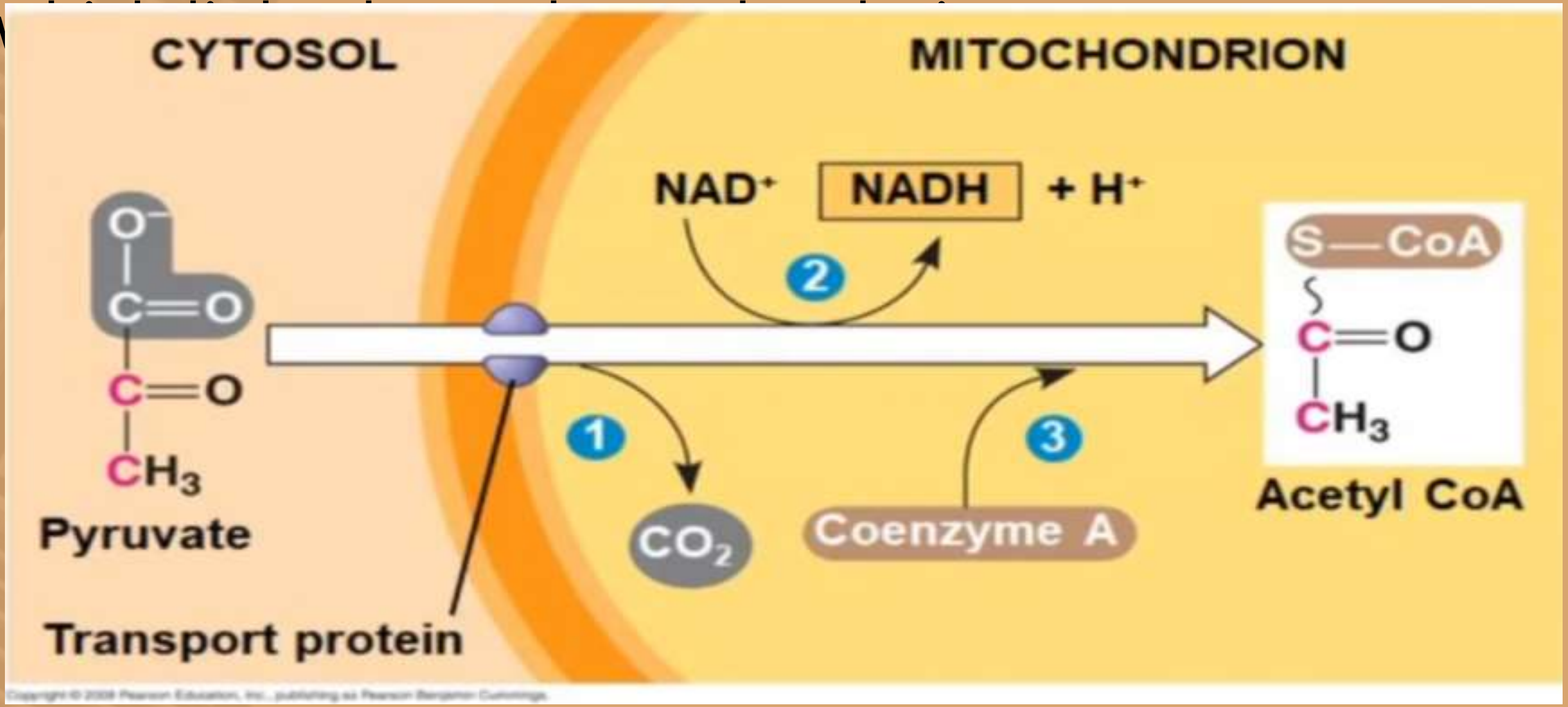
GLYCOLYSIS

- Here is the second stages of the glycolysis :



The citric acid cycle

- In the presence of o_2 pyruvate enters the mitochondrion .
- Before the citric acid cycle can begin , pyruvate must be converted to acytel COA
- ,

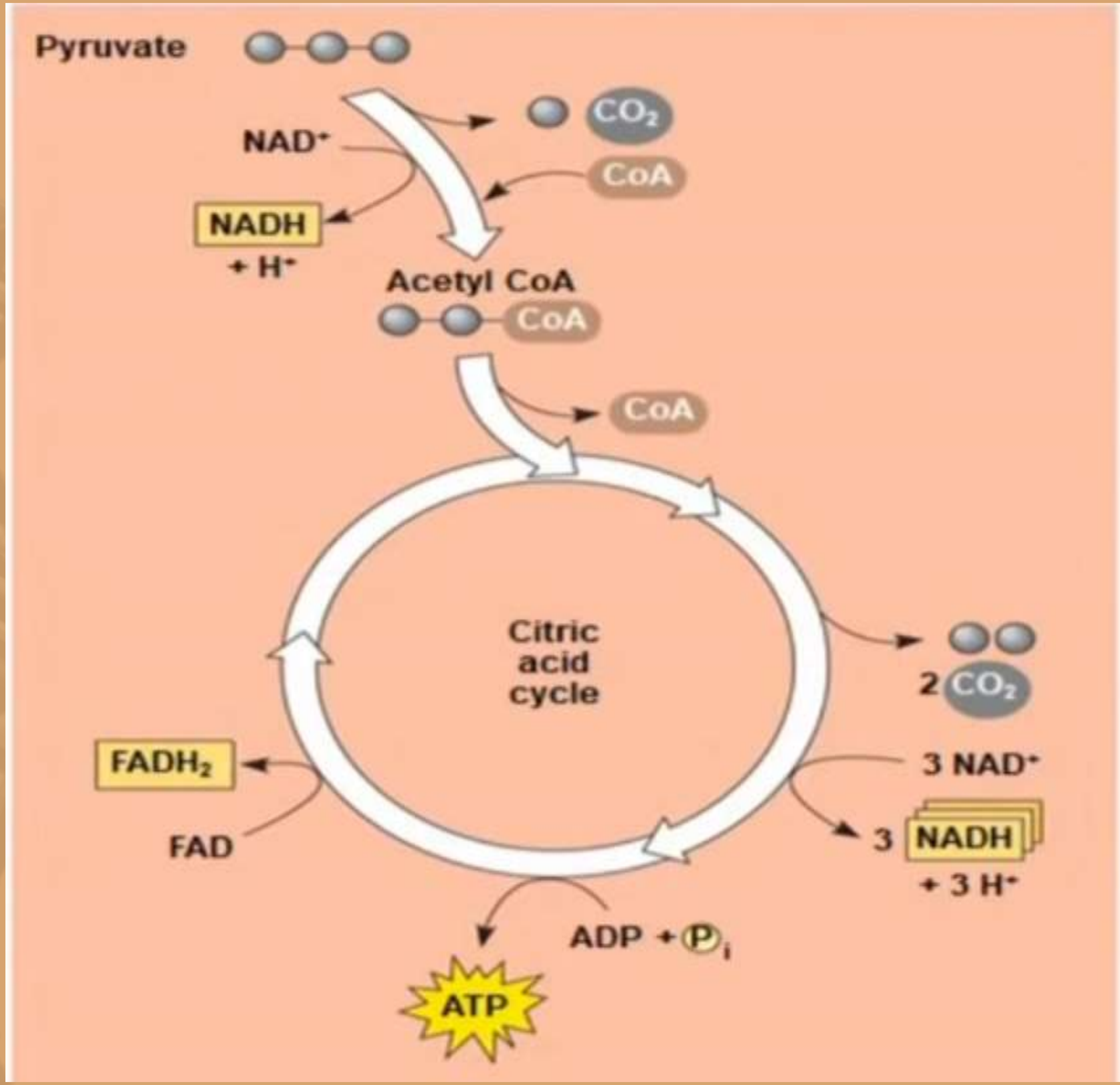


The citric acid cycle

- The citric acid cycle also called the **Krebs cycle** , takes places within the mitochondrial matrix .

- The cycle oxidizes organic fuel derived from pyruvate , generating 1 ATP , 3 NADH
- , and 1 $FADH_2$ per turn .

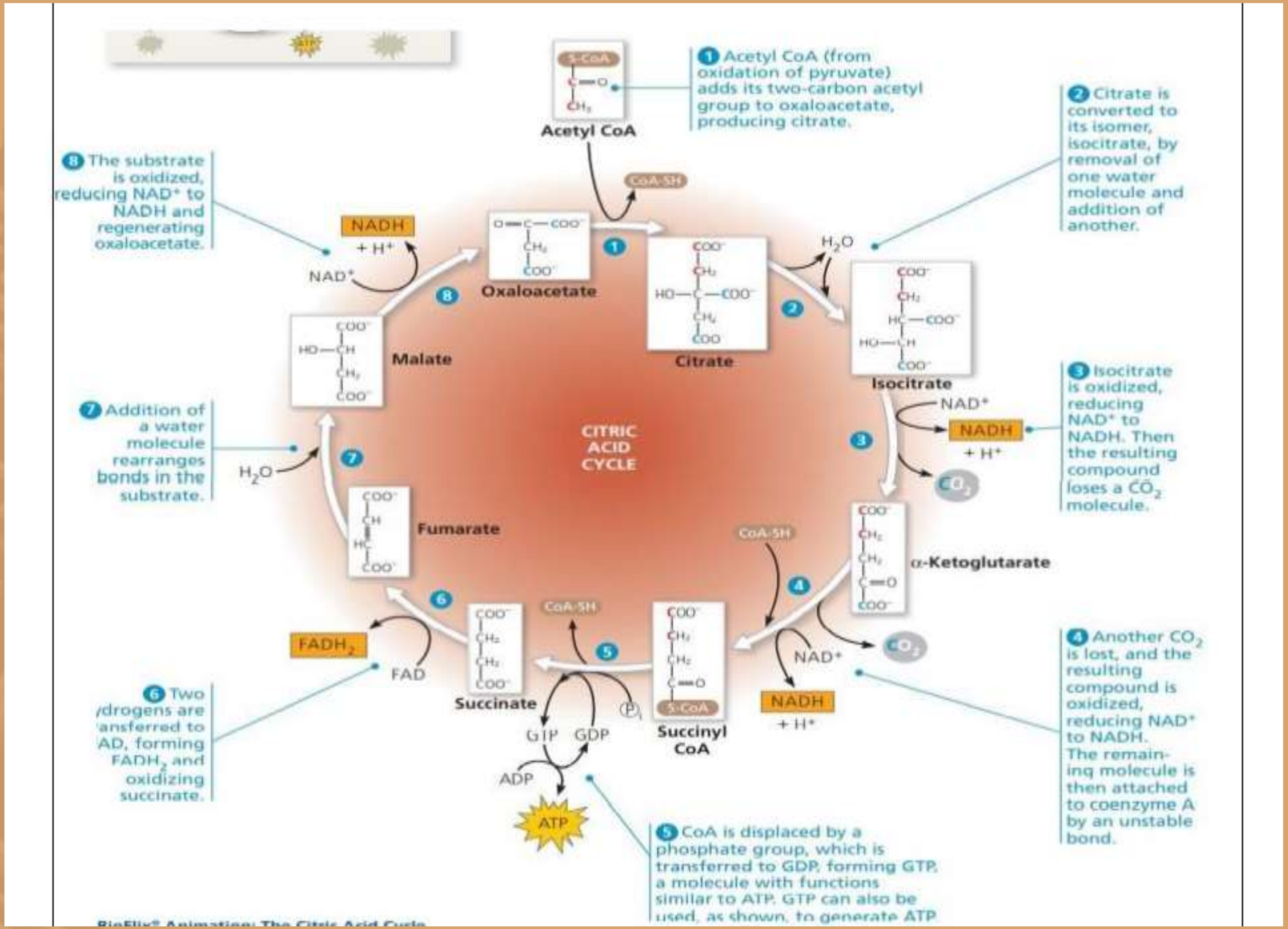
The citric acid cycle



The citric acid cycle

- The citric acid cycle has eight steps , each catalyzed by a specific enzyme .
- The acetyl group of acetyl COA joins the cycle by combining with oxaloacetate ,forming citrate
- The next 7 steps decompose the citrate back to oxaloacetate , making the process a cycle .
- The NADH and^{2} FADH produced by the cycle relay electrons extracted from food to the electron transport chain

The citric acid cycle



Thank you

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