Kickoff:

Write out the chemical equation for photosynthesis.

4.1 Chemical Energy and ATP

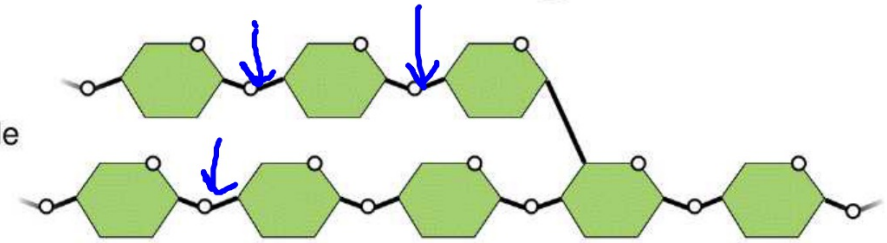
KEY CONCEPT

All cells need chemical energy.

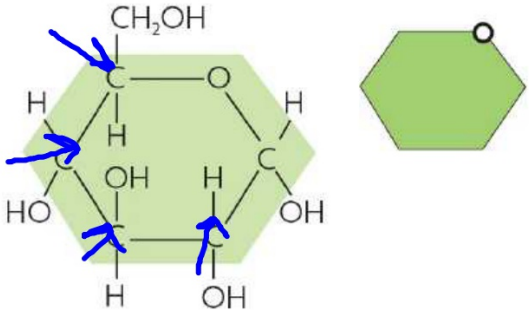
4.1 Chemical Energy and ATP

- **The chemical energy used for most cell processes is carried by ATP.**
  - Molecules in food store chemical energy in their bonds.

Starch molecule

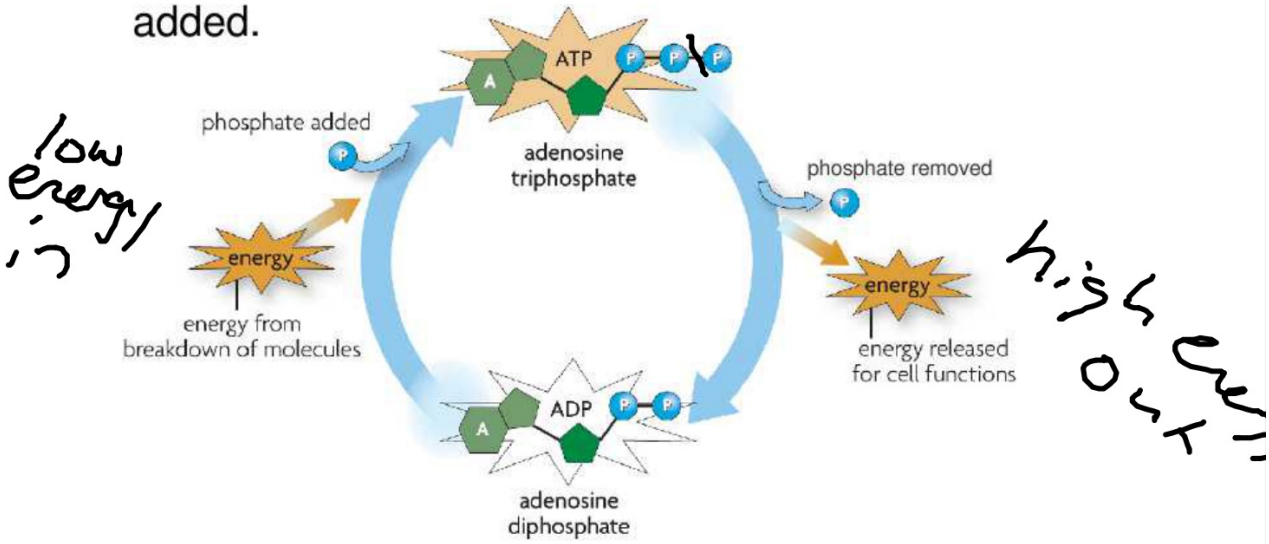


Glucose molecule

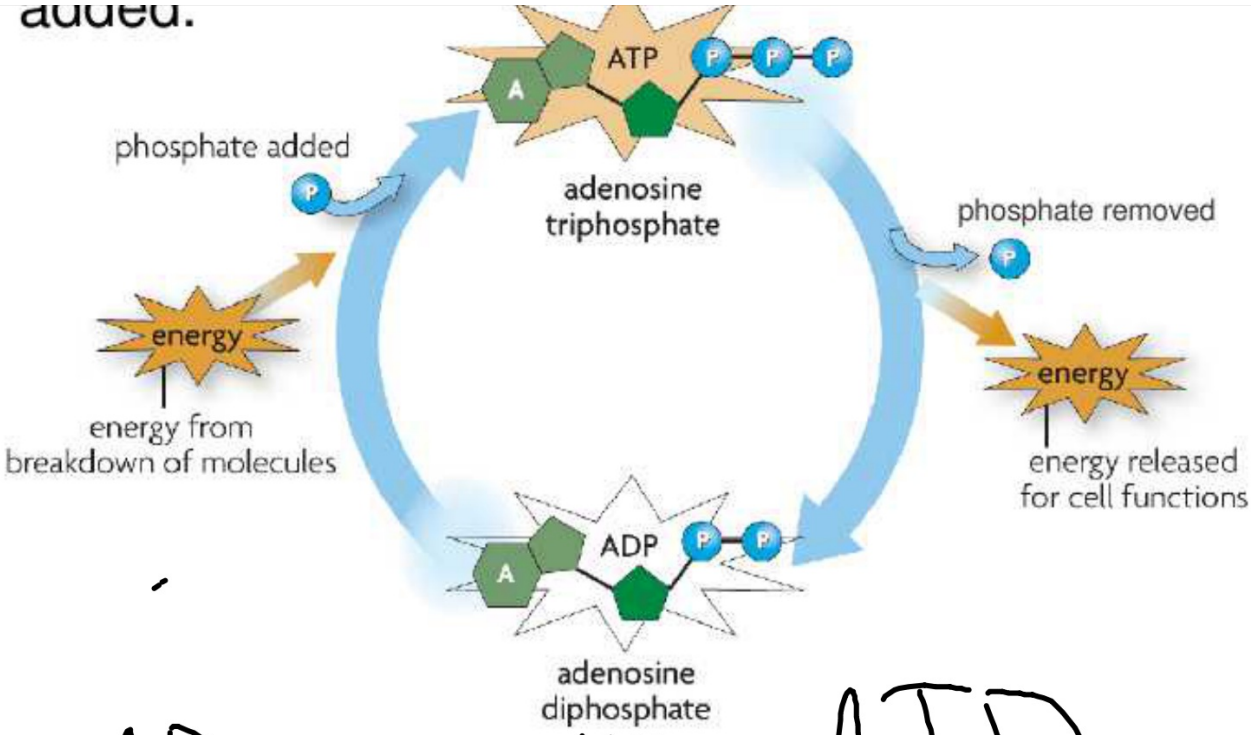


4.1 Chemical Energy and ATP

- ATP transfers energy from the breakdown of food molecules to cell functions.
  - Energy is released when a phosphate group is removed.
  - ADP is changed into ATP when a phosphate group is added.



added.



ADP + P ⇌ ATP

little energy

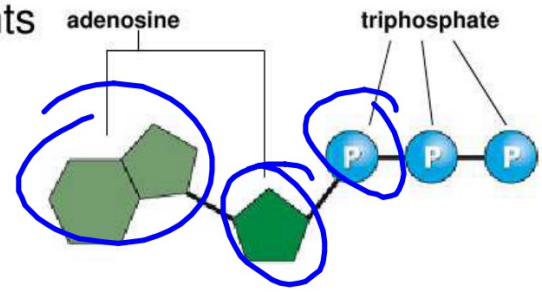
lot of energy

4.1 Chemical Energy and ATP

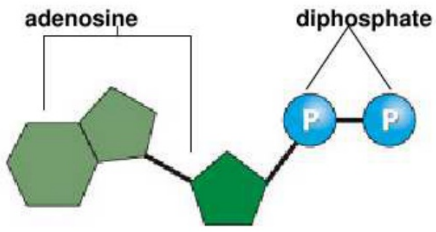
- **Organisms break down carbon-based molecules to produce ATP.**
  - Carbohydrates are the molecules most commonly broken down to make ATP.
    - not stored in large amounts
    - up to 36 ATP from one glucose molecule

nucleotide

36-38



tri=3



di=2

4.1 Chemical Energy and ATP

- Fats store the most energy.
  - 80 percent of the energy in your body
  - about 146 ATP from a triglyceride
- Proteins are least likely to be broken down to make ATP.
  - amino acids not usually needed for energy
  - about the same amount of energy as a carbohydrate

MOLECULE	ENERGY
Carbohydrate	4 calories per mg
Lipid	9 calories per mg
Protein	4 calories per mg

4.1 Chemical Energy and ATP

A few types of organisms do not need sunlight and photosynthesis as a source of energy.

- Some organisms live in places that never get sunlight.
- In chemosynthesis, chemical energy is used to build carbon-based molecules.
  - similar to photosynthesis
  - uses chemical energy instead of light energy

Bacteria

Chemosynthesis:

$6CO_2 + 6H_2O + 3\,H_2S > C_6H_{12}O_6 + 3H_2SO_4$

Kickoff:

What are three products from the light dependent reactions? What happens to eacl

Where and how is CO_2 transformed into glucose?

(If you can't answer these without your note you don't know it!)

4.2 Overview of Photosynthesis

KEY CONCEPT

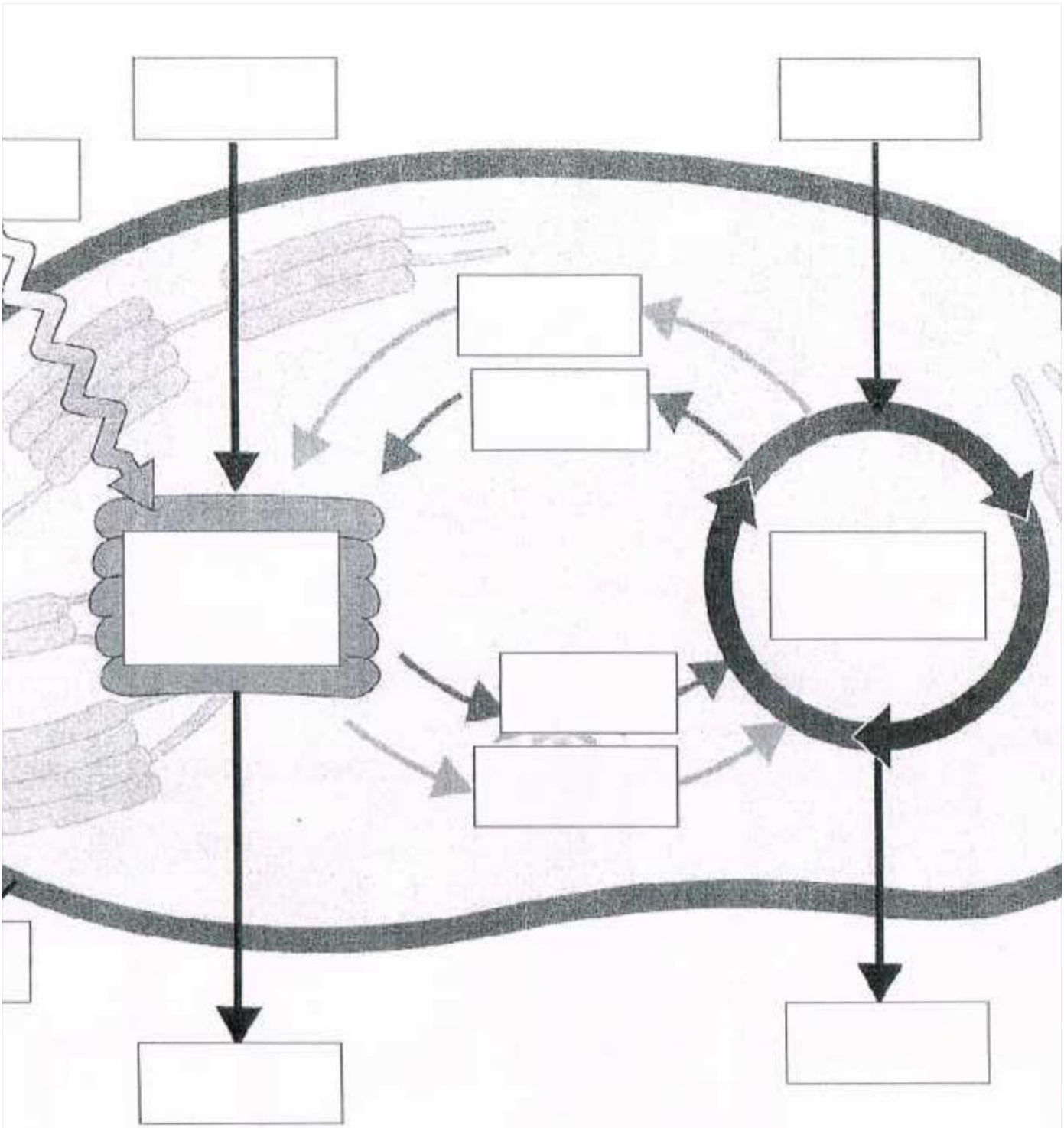
The overall process of photosynthesis produces sugars that store chemical energy.

Photosynthesis: An Overview

1. Light-dependent reactions
   (a) Photosystem II

   (b) Photosystem I

2. Light-independent reactions (Calvin Cyc



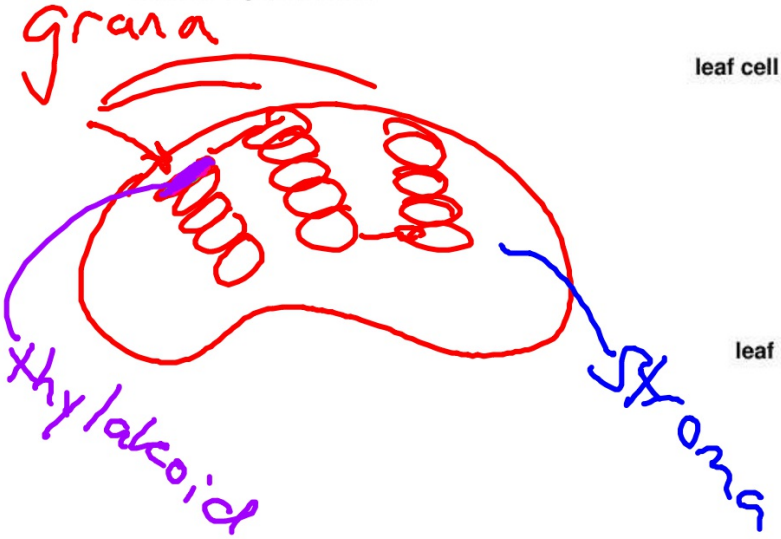
4.2 Overview of Photosynthesis

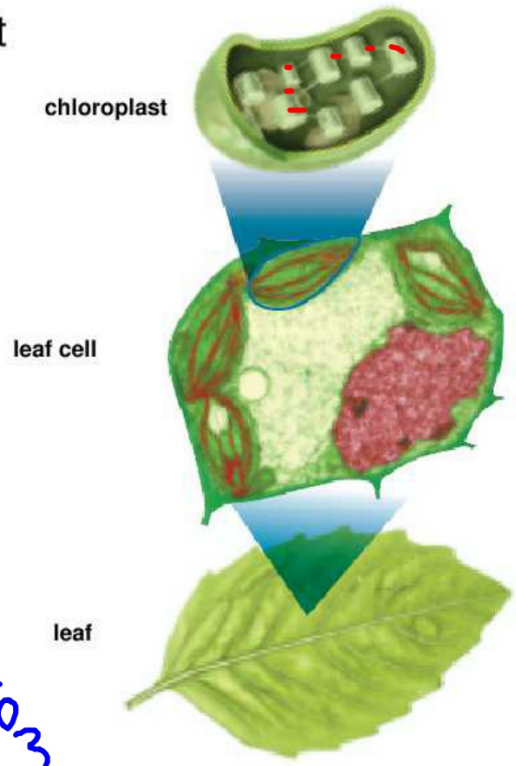
- **Photosynthetic organisms are producers.** autotrophs

  - Producers make their own source of chemical energy.
  - Plants use photosynthesis and are producers.
  - Photosynthesis captures energy from sunlight to make sugars.

4.2 Overview of Photosynthesis

- Chlorophyll is a molecule that absorbs light energy.
- In plants, chlorophyll is found in organelles called chloroplasts.

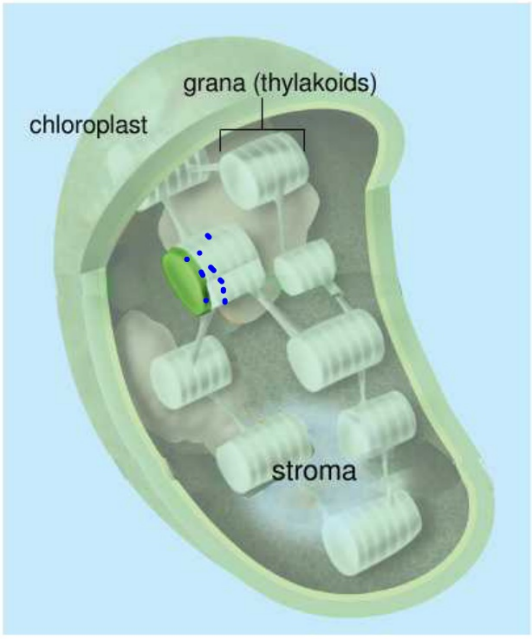




4.2 Overview of Photosynthesis

Photosynthesis in plants occurs in chloroplasts.

- Photosynthesis takes place in two parts of chloroplasts.
  - grana (thylakoids)
  - stroma



Photosynthesis: An Overview

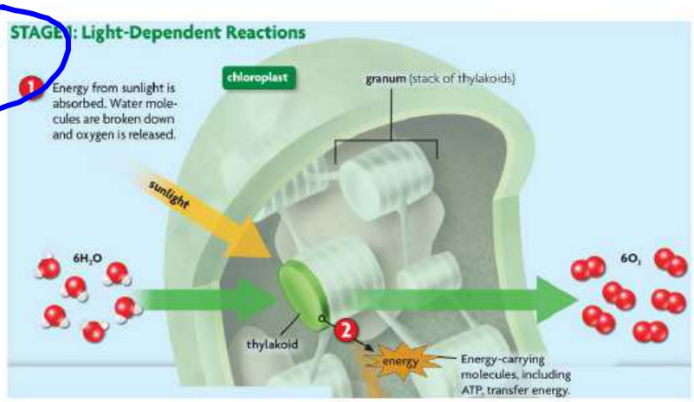
1. Light-dependent reactions
   (a) Photosystem II
   (b) Photosystem I
2. Light-independent reactions (Calvin Cycl

$CO_2 + H_2O \xrightarrow{sun} C_6H_{12}O_6 + O_2$

4.2 Overview of Photosynthesis

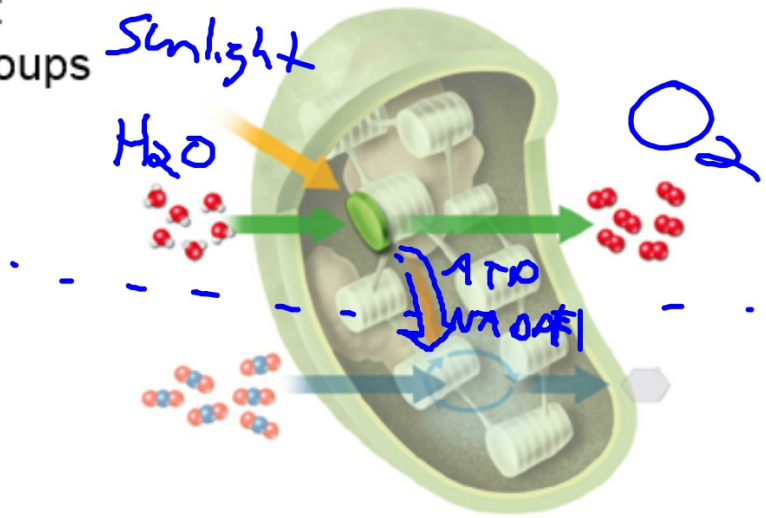
Step 1:

- The light-dependent reactions capture energy from sunlight.
  - take place in thylakoids Where?
  - water and sunlight are needed What?
  - chlorophyll absorbs energy What?
  - energy is transferred along thylakoid membrane How?
  - oxygen is released waste



4.3 Photosynthesis in Detail

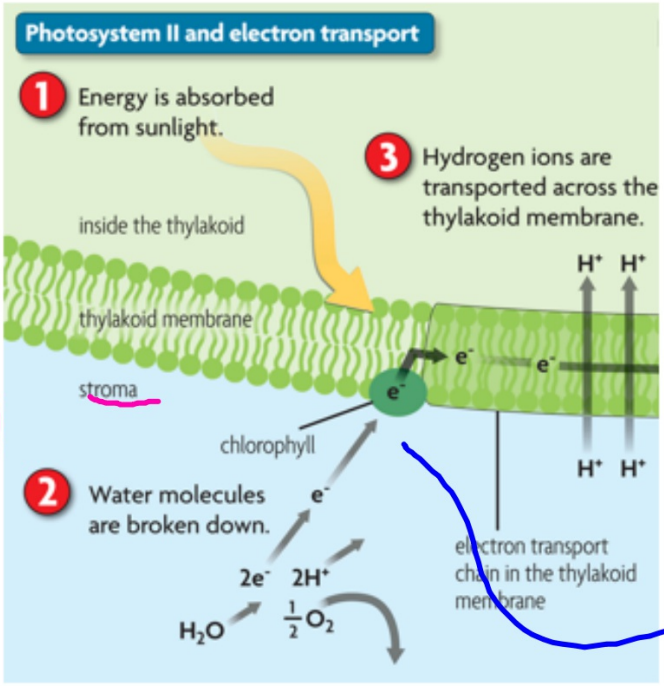
- **The first stage of photosynthesis captures and transfers energy.**
  - The light-dependent reactions include groups of molecules called photosystems.



Light-dependent reactions take place in and across the thylakoid membrane.

4.3 Photosynthesis in Detail

- Photosystem II captures and transfers energy.
  - chlorophyll absorbs energy from sunlight
  - energized electrons enter electron transport chain
  - water molecules are split
  - oxygen is released as waste
  - hydrogen ions are transported across thylakoid membrane



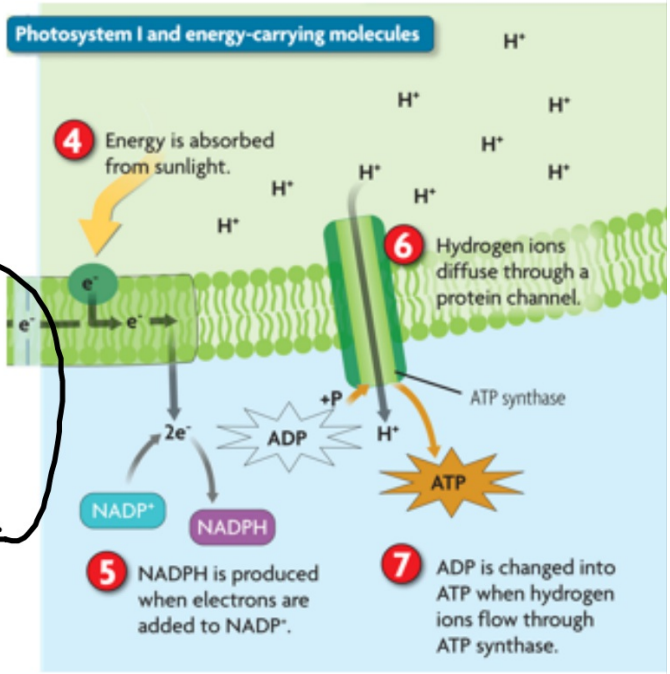
Photosystem II

Needs	makes
H_2O	O_2 (waste)
Sunlight	$H^+ + e^-$

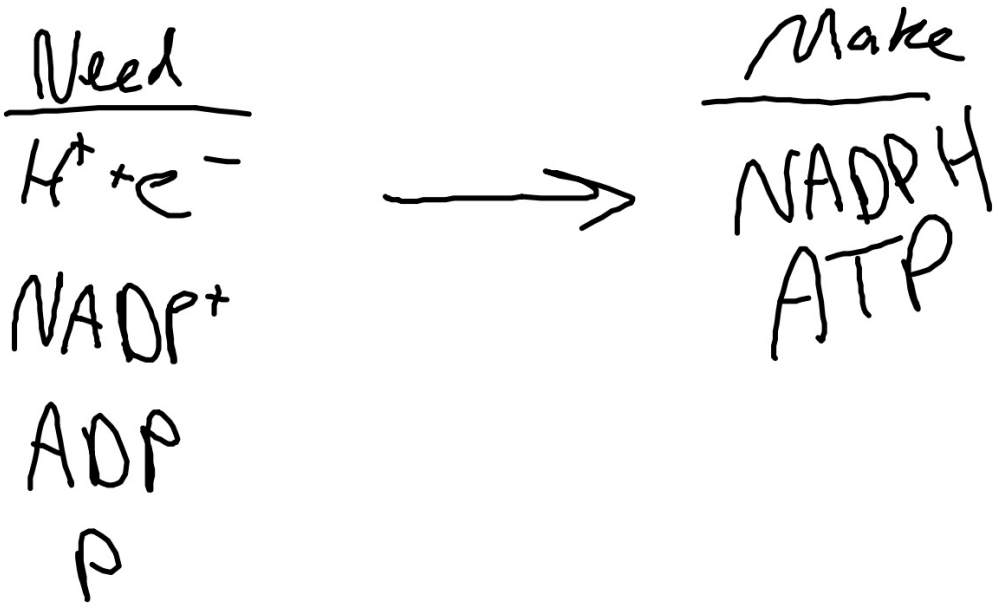
4.3 Photosynthesis in Detail

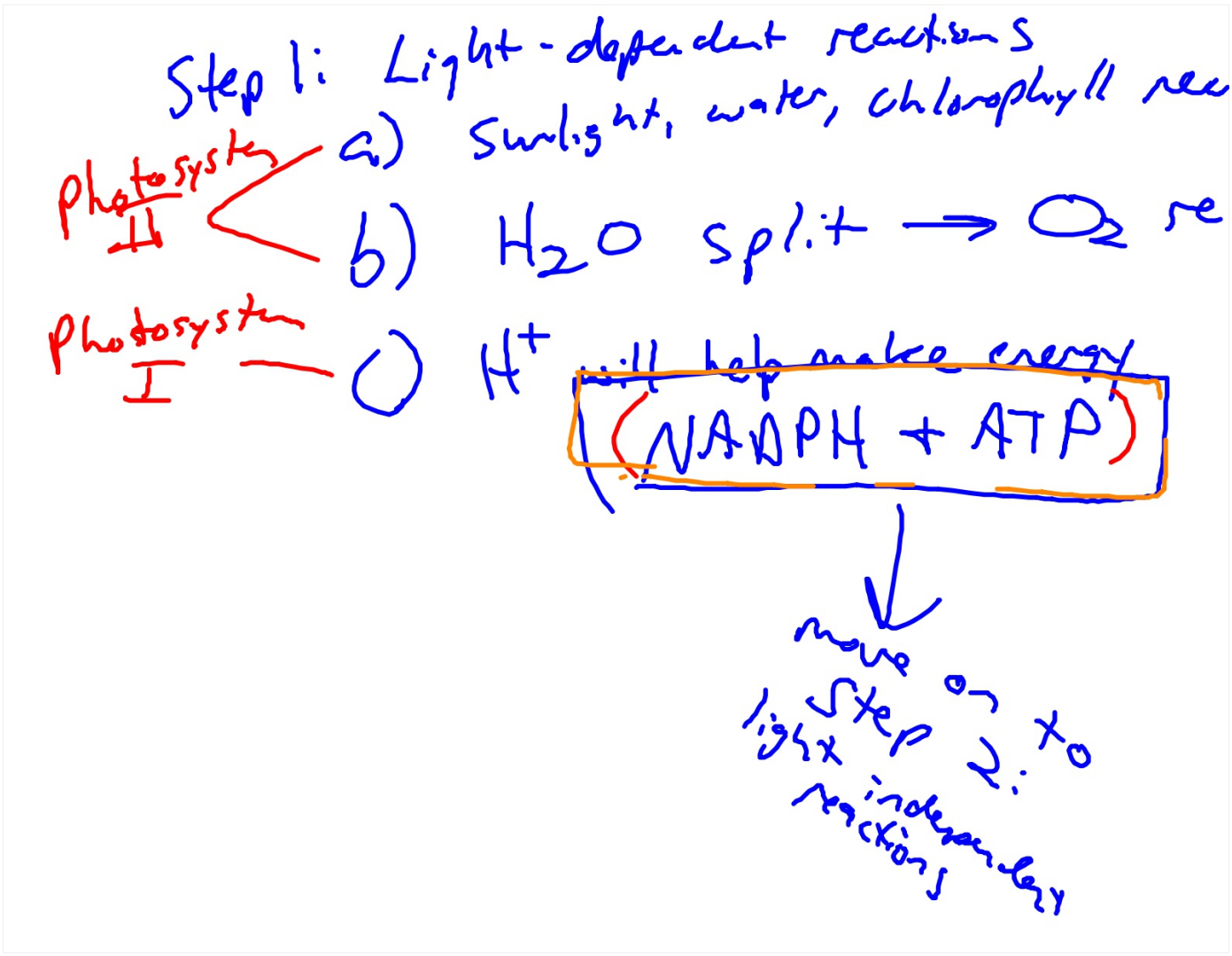
- Photosystem I captures energy and produces energy-carrying molecules.
  - chlorophyll absorbs energy from sunlight
  - energized electrons are used to make NADPH
  - NADPH is transferred to light-independent reactions

$NADP^+ + H^+ + e^-$



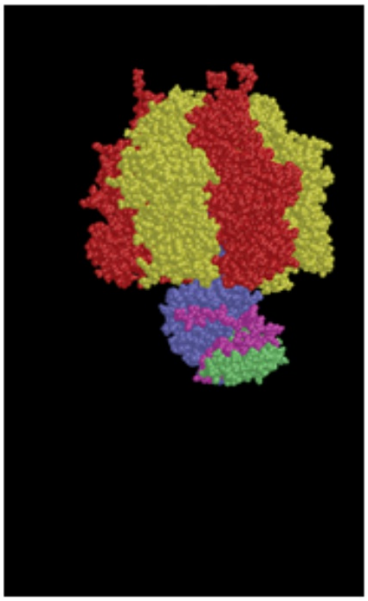
Photosystem I

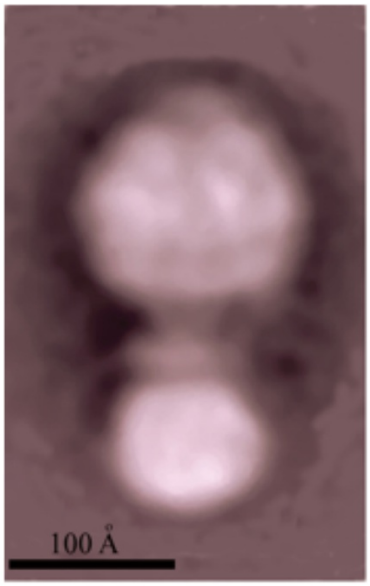



Step 1: Light-dependent reactions
Photosystem II
a) Sunlight, water, chlorophyll rec
b) H_2O split → O_2 re
Photosystem I
H^+ will help make energy
(NADPH + ATP)
move on
light
Step 2:
reactions

4.3 Photosynthesis in Detail

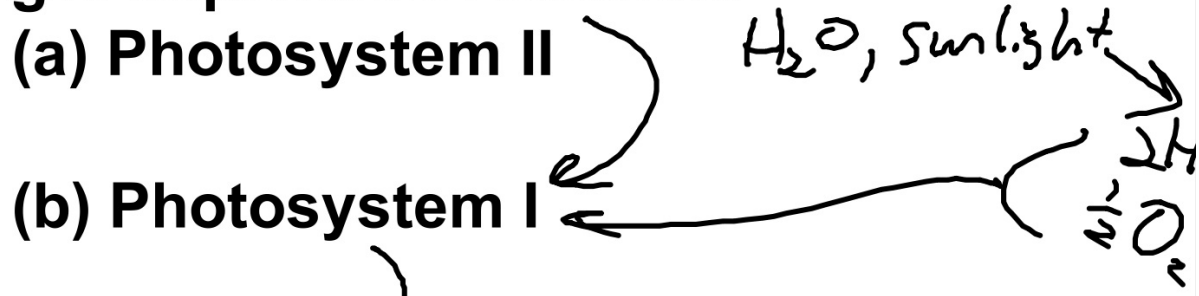
- The light-dependent reactions produce ATP. + NADPH
  - hydrogen ions flow through a channel in the thylakoid membrane
  - ATP synthase attached to the channel makes ATP





Photosynthesis (Process check)

1. Light-dependent reactions
   (a) Photosystem II
   (b) Photosystem I
2. Light-independent reactions (Calvin Cycl



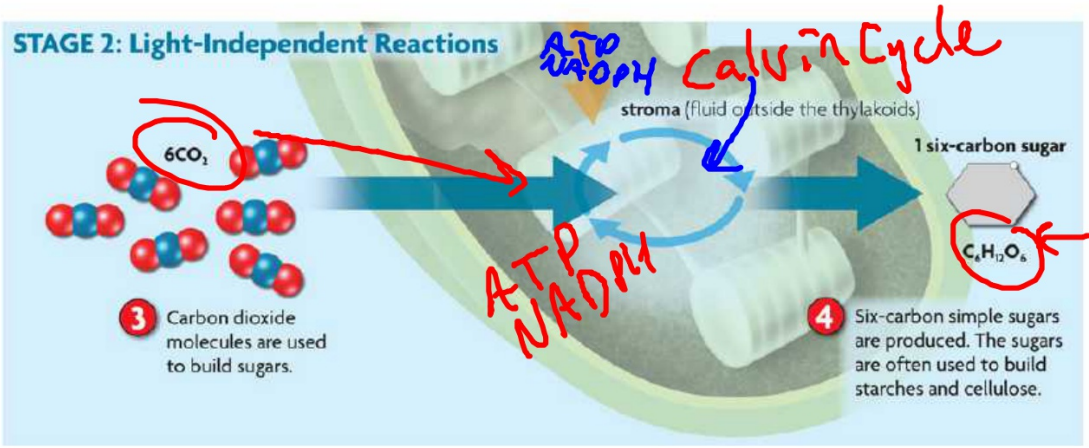
NADPH + ATP

$6CO_2 + 6H_2O \xrightarrow{sun} C_6H_{12}O_6 + 6O_2$

4.2 Overview of Photosynthesis

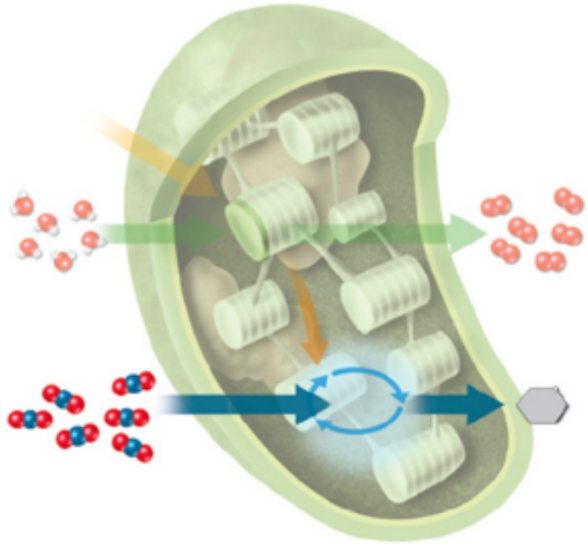
Step 2

- The light-independent reactions make sugars.
  - take place in stroma (where)
  - needs carbon dioxide from atmosphere (what) (NADP ATP)
  - use energy to build a sugar in a cycle of chemical reactions (glucose)



4.3 Photosynthesis in Detail

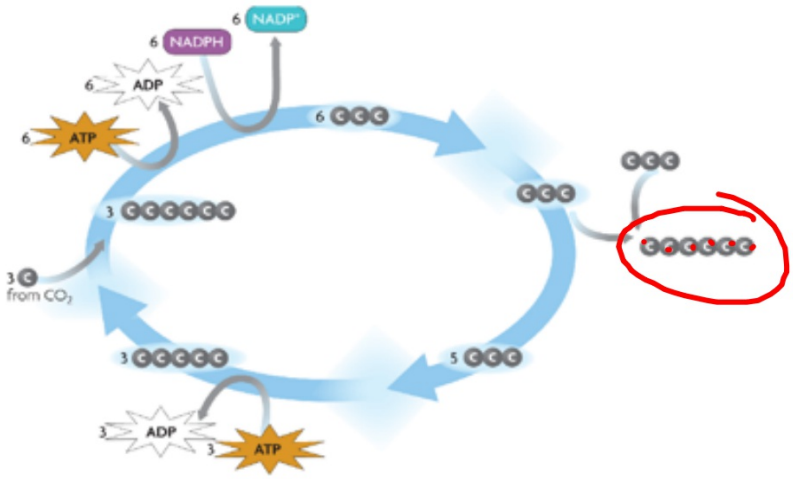
- **The second stage of photosynthesis uses energy from the first stage to make sugars.**
  - Light-independent reactions occur in the stroma and use CO_2 molecules.



Light-independent reactions take place in the stroma.

4.3 Photosynthesis in Detail

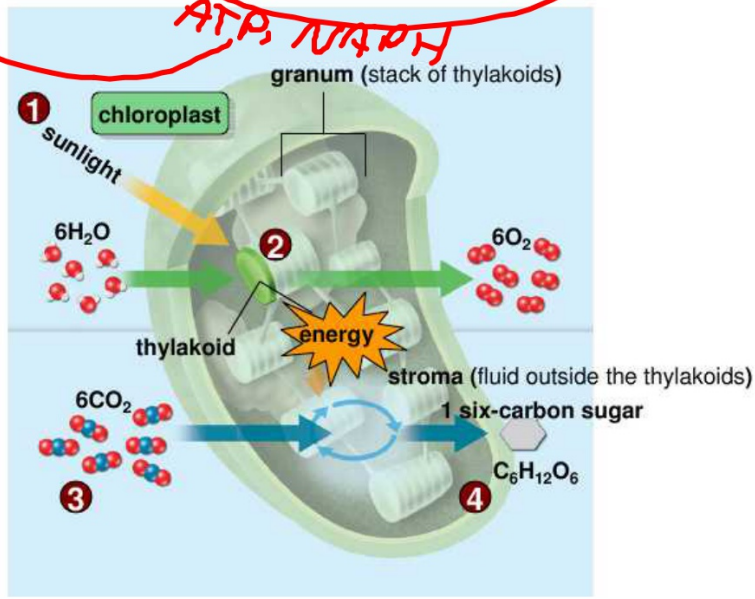
- A molecule of glucose is formed as it stores some of the energy captured from sunlight.
  - carbon dioxide molecules enter the Calvin cycle
  - energy is added and carbon molecules are rearranged
  - a high-energy three-carbon molecule leaves the cycle

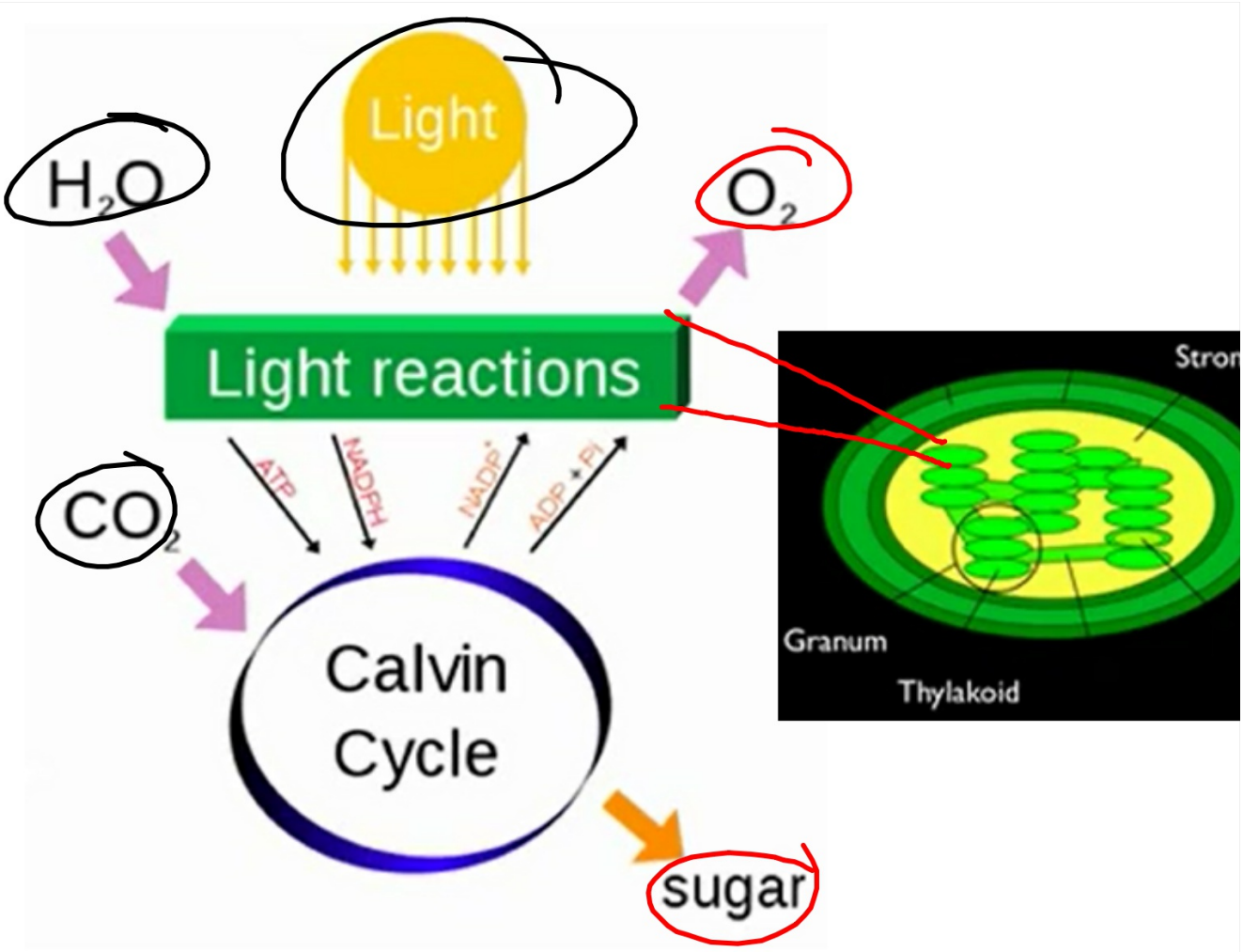


4.2 Overview of Photosynthesis

- The equation for the overall process is:

$$6CO_2 + 6H_2O \rightarrow C_6H_{12}O_6 + 6O_2$$




Light
H_2O
O_2
Light reactions
ATP
NADPH
NADP+
ADP + Pi
CO_2
Calvin Cycle
sugar
Granum
Thylakoid

Photosynthesis summary:

1. First, you need sunlight (light dependent reactions)

a) Photosystem II - H_2O is split with chlorophyll to release O_2 as waste in grana (thylakoid membrane)

b) Photosystem I - uses electrons to make NADPH (energy) to drive the next step ATP

2. Light-independent reactions (called the CALVIN CYCLE!, day or night)

a) Take CO_2 (from air), ATP and NADPH (from step one) to make glucose

PHOTOSYNTHESIS: *IN DETAIL*

Directions: Take notes below about the different steps involved in photosynthesis.

I. LIGHT-DEPENDENT REACTIONS

WHAT?

WHEN?

WHERE?

How?

Photosystem _____ starts the process of photosynthesis…

1. Chlorophyll absorbs energy from _____ as an H_2O molecule is split.
2. Energized _____ from H_2O enter the electron _____ chain (ETC) in t thylakoid membrane.
3. Movement of electrons through the ETC allows _____ ions to be actively transported across the _____ membrane.

Photosystem _____ comes after photosystem _____ …

4. More _____ molecules absorb energy from _____.
5. Energized electrons traveling through the ETC are used to create _____ (an energy _____).
6. NADPH is then transferred to the light – _____ reactions.

The light-dependent reactions also create a small amount of _____.

- Pumping of H+ ions across the membrane establishes a _____ _____
- A protein channel, ATP _____, allows H+ ions to diffuse _____ their concentration gradient and across the membrane, changing ADP → ATP.

II. Light-Independent Reactions

What?

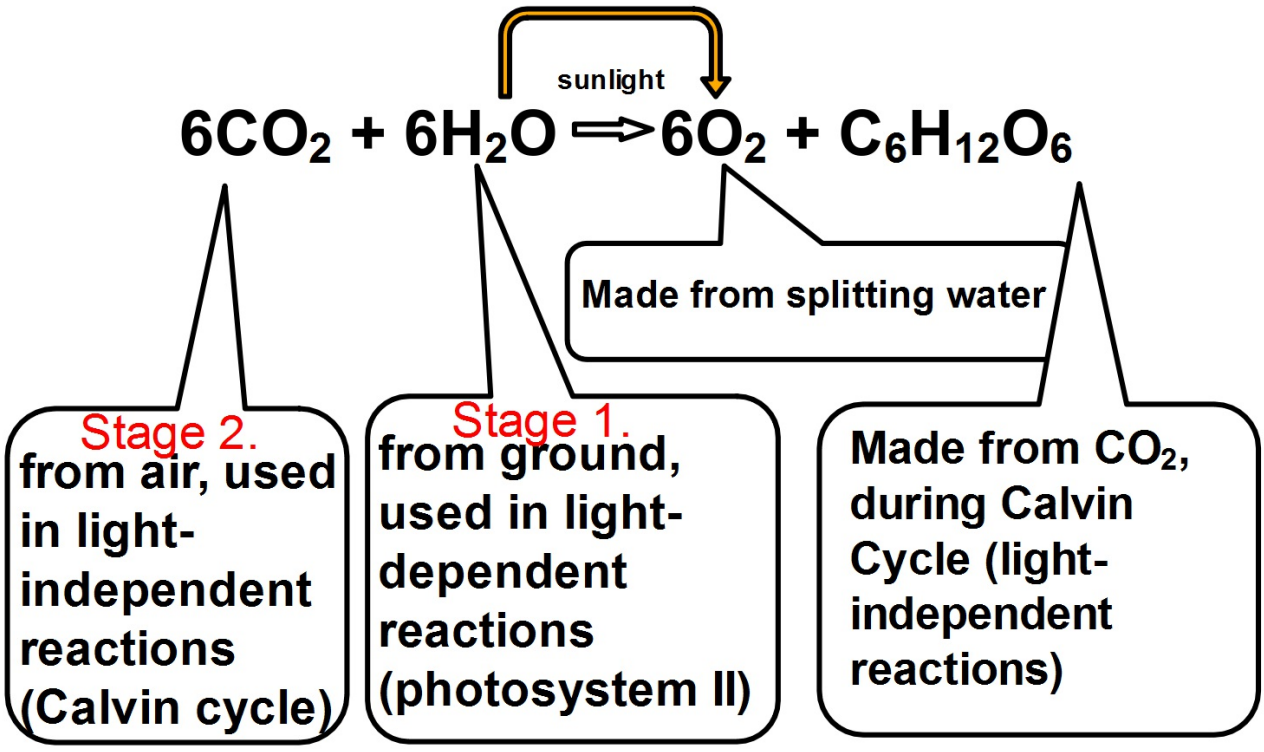
When?

Where?

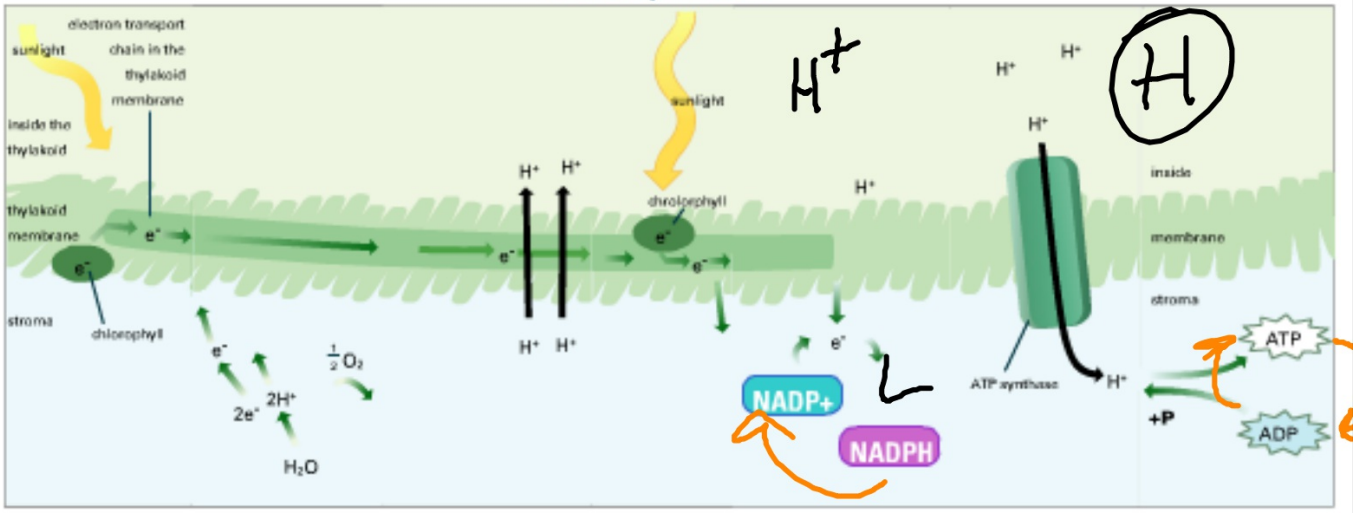
HOW?

1. CO_2 molecules enter the _____ cycle.
2. Energy from _____ and _____ (from the light-dependent reactions) is added; C atoms are rearranged.
3. A 3-C molecule _____ the Calvin cycle.
4. _____ 3-C molecules bond to form a 6-C _____ (glucose).
5. The remaining C molecules stay and will be used _____ in the Calvin cycle.

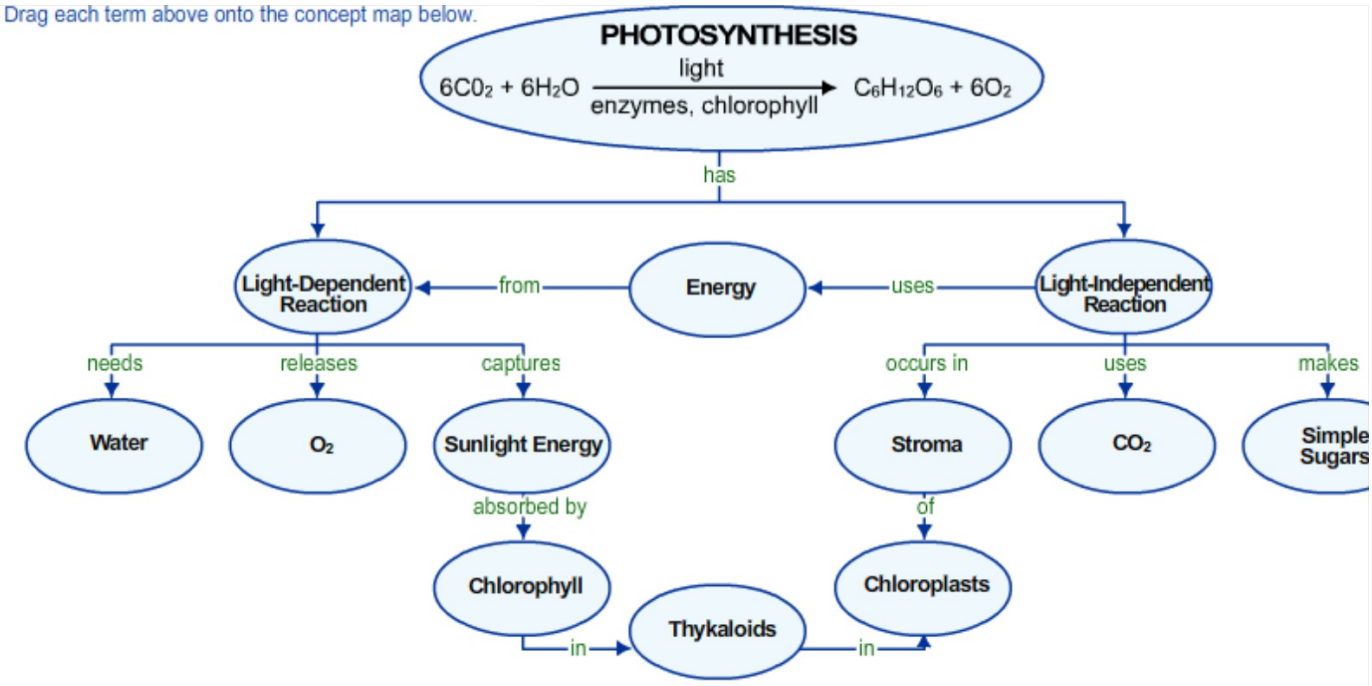
PHOTOSYNTHESIS



Photosynthesis



Drag each term above onto the concept map below.



Photosystem I

Needs

$H^+ + e^-$

$NADP^+$

$ADP + P$

Makes

NADPH

ATP

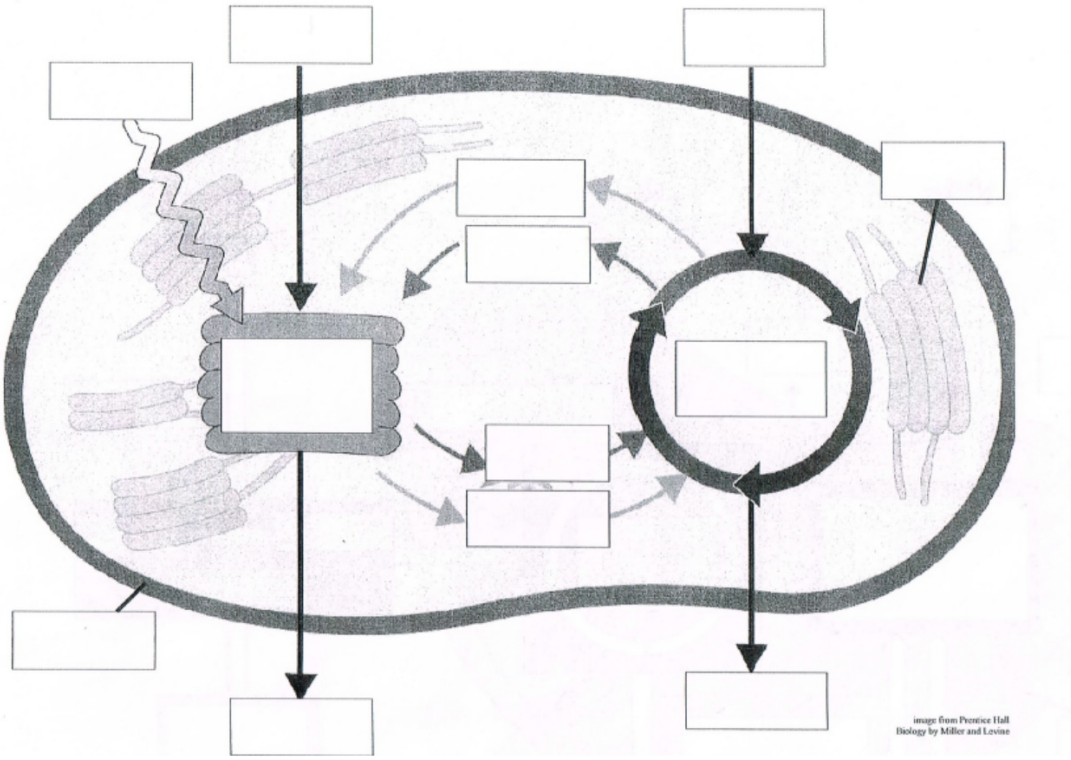
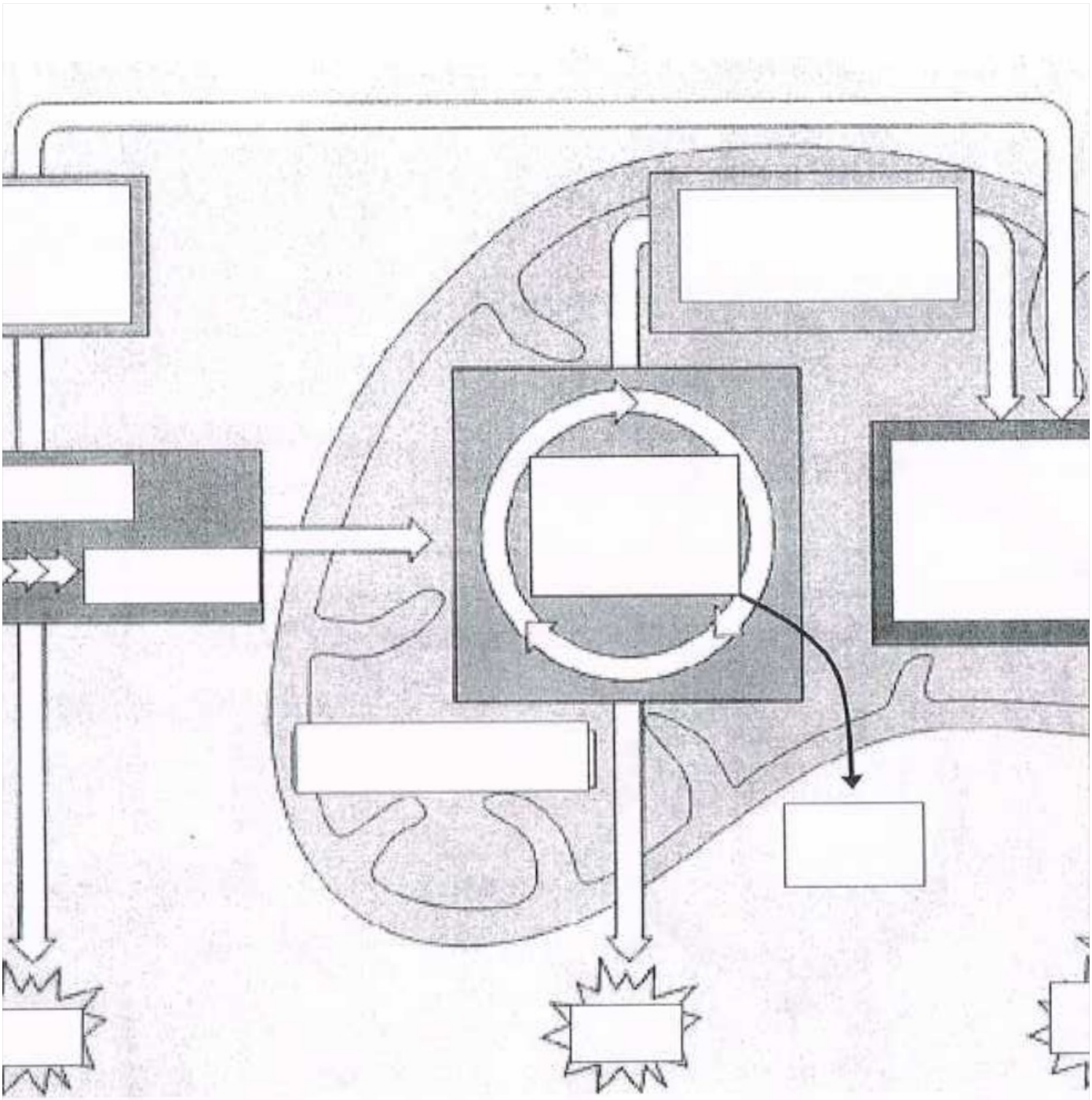
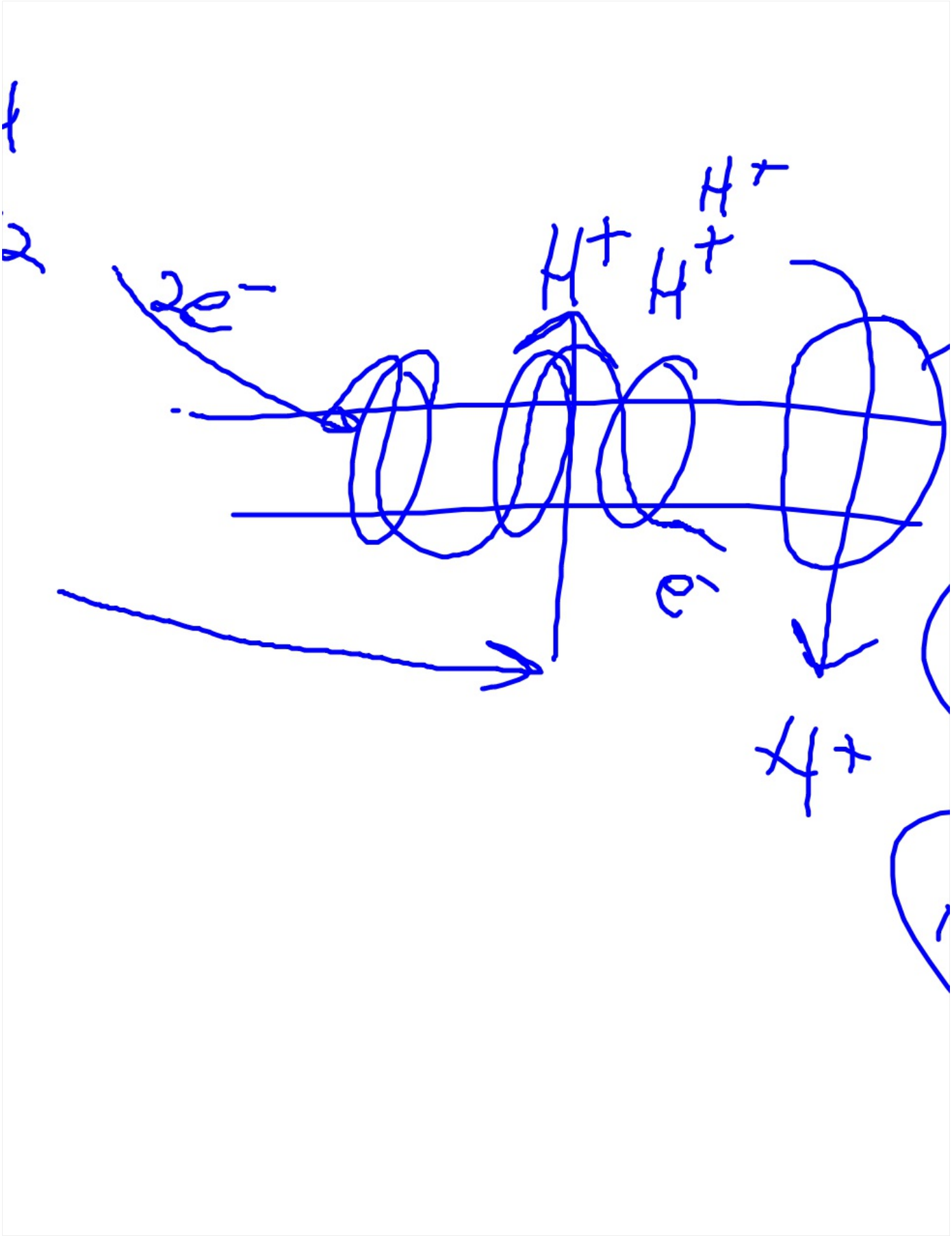


image from Prentice Hall
Biology by Miller and Levine




2e⁻
H⁺
H⁺
H⁺
e⁻
4+

the chemical reaction for aerob
on.

4.4 Overview of Cellular Respiration

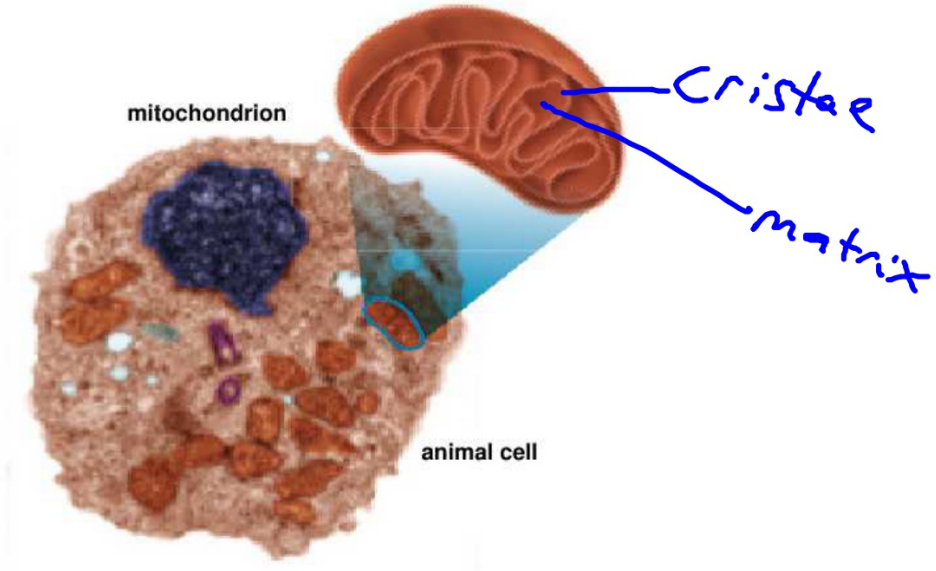
KEY CONCEPT

The overall process of cellular respiration converts sugar into ATP using oxygen.

$C_6H_{12}O_6 + 6O_2 \longrightarrow 36\text{-}38\ ATP + 6CO_2 + 6H_2$

4.4 Overview of Cellular Respiration

- **Cellular respiration makes ATP by breaking down sugars.**
  - Cellular respiration is aerobic, or requires oxygen.
  - Aerobic stages take place in mitochondria.



Aerobic Cellular Respiration

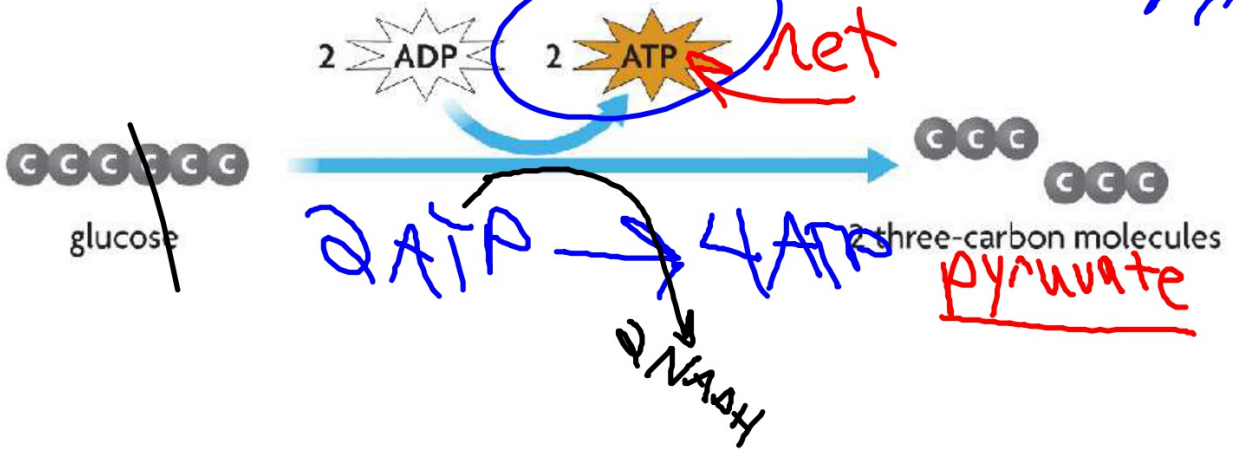
$C_6H_{12}O_6 + 6O_2 \xrightarrow{\text{energy}} 36\text{-}38ATP + 6CO_2 + 6$

$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ + 36-38 ATP

1. Glycolysis (2 ATP) — make — cytoplasm — anaerobic (no O_2)
2. Cellular respiration
   a) Krebs cycle (citric acid cycle) (4 ATP
   b) Electron transport chain (30-32 ATP)

4.4 Overview of Cellular Respiration

- Glycolysis must take place first.
  - anaerobic process (does not require oxygen)
  - takes place in cytoplasm
  - splits glucose into two three-carbon molecules
  - produces two ATP molecules
  - produces two NADH molecules

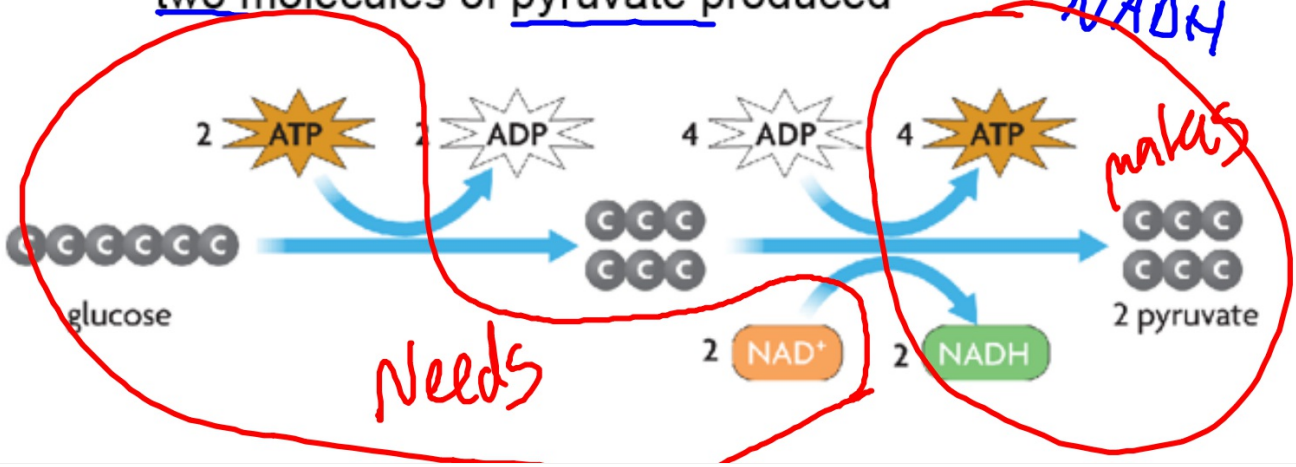


Glycolysis (cytoplasm anaerobic)

needs	makes
Glucose	2 pyruvate
2 ATP	4 ATP
2 NAD^+	2 NADH

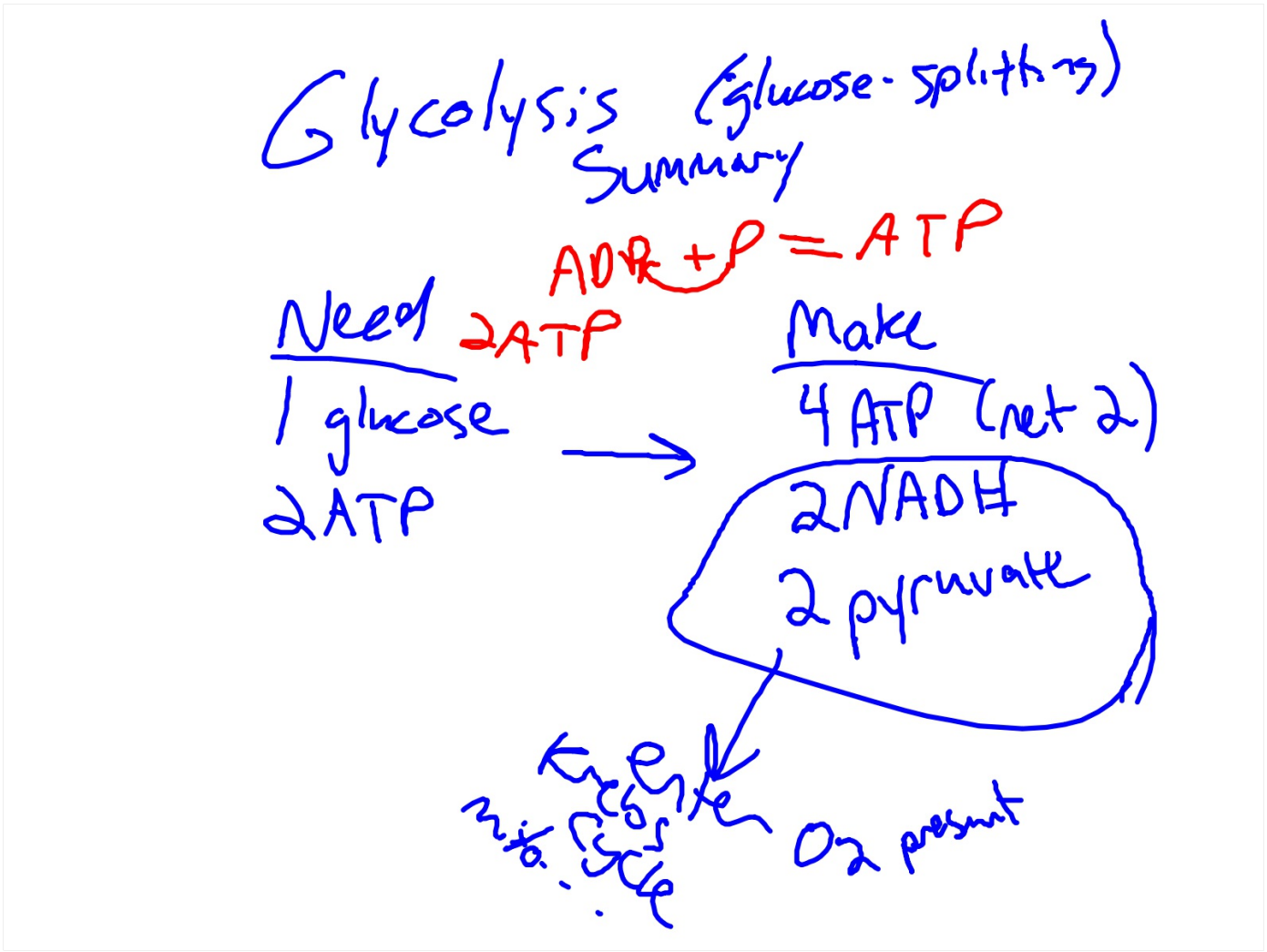
4.5 Cellular Respiration in Detail

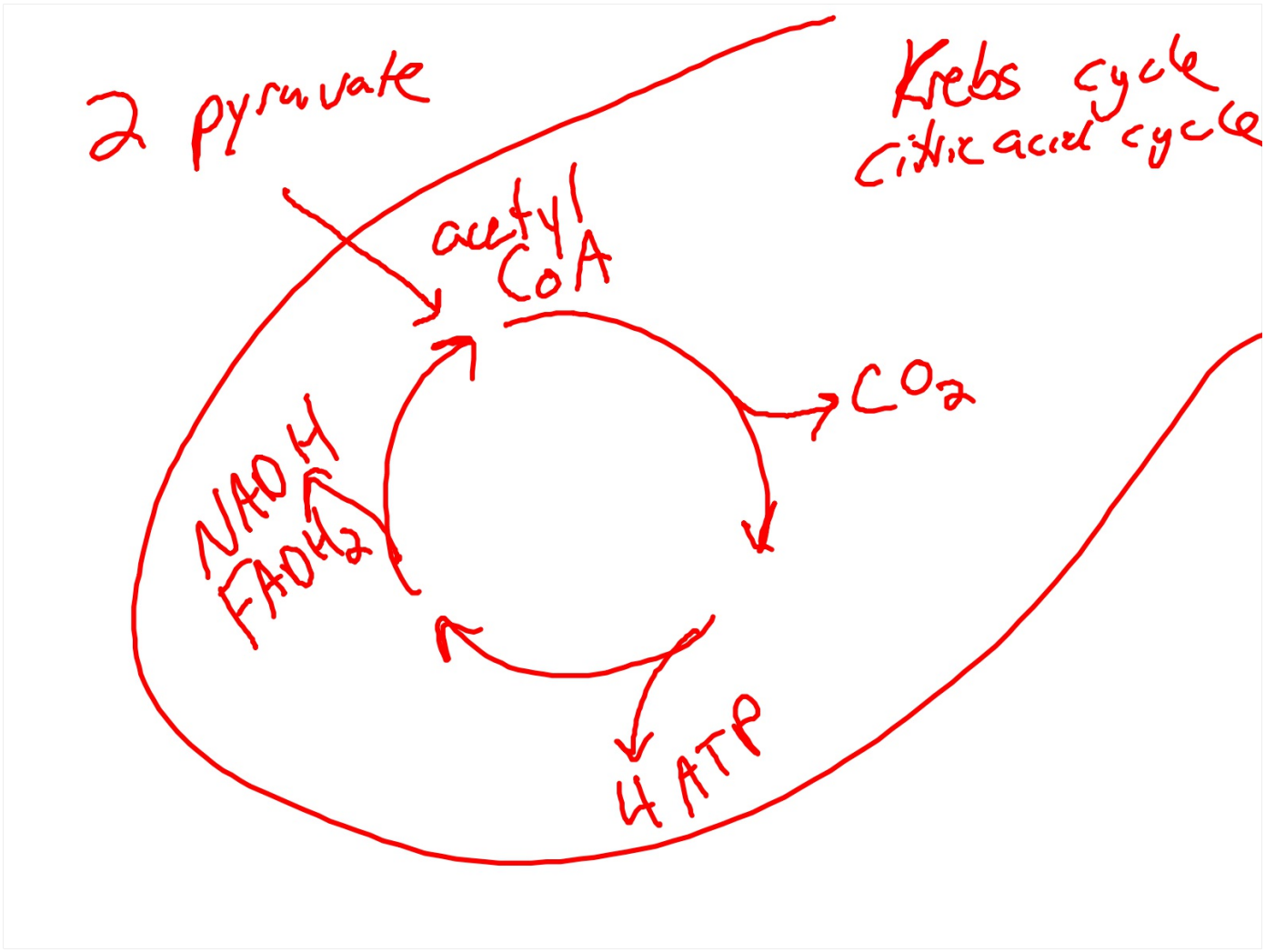
- **Glycolysis is needed for cellular respiration.**
  - The products of glycolysis enter cellular respiration when oxygen is available.
    - two ATP molecules are used to split glucose
    - four ATP molecules are produced
    - two molecules of NADH produced
    - two molecules of pyruvate produced

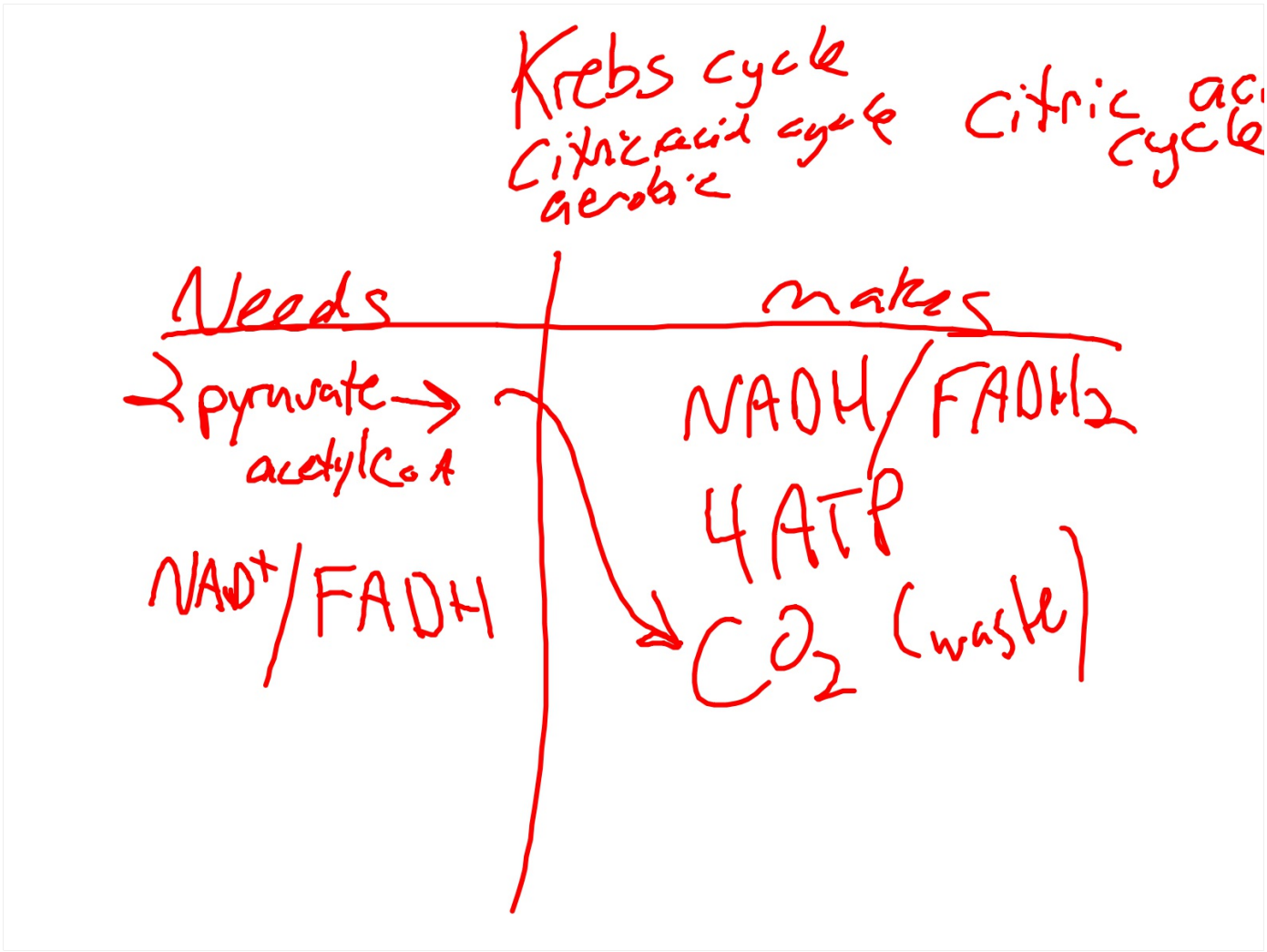


Glycolysis (cytoplasm) anaerobic

Need	make
2 ATP	4 ATP (profit 2
Glucose	2 pyruvate
NAD^+	2 NADH

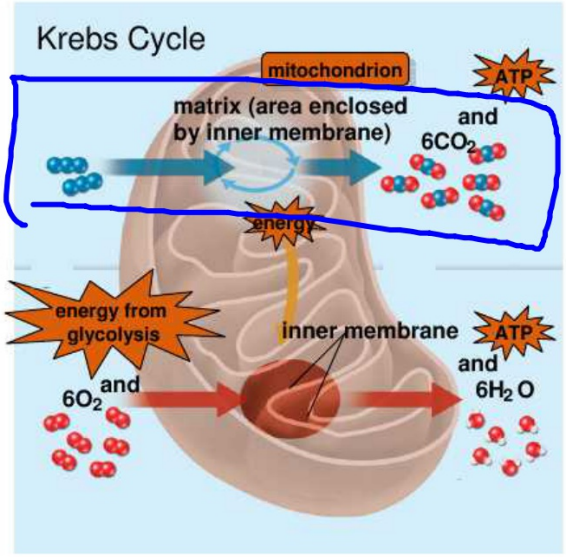

Glycolysis (glucose-splitting)
Summary
ADP + P = ATP
Need 2ATP
1 glucose
2ATP
Make
4 ATP (net 2)
2 NADH
2 pyruvate
Krebs
Cycle
O2 present

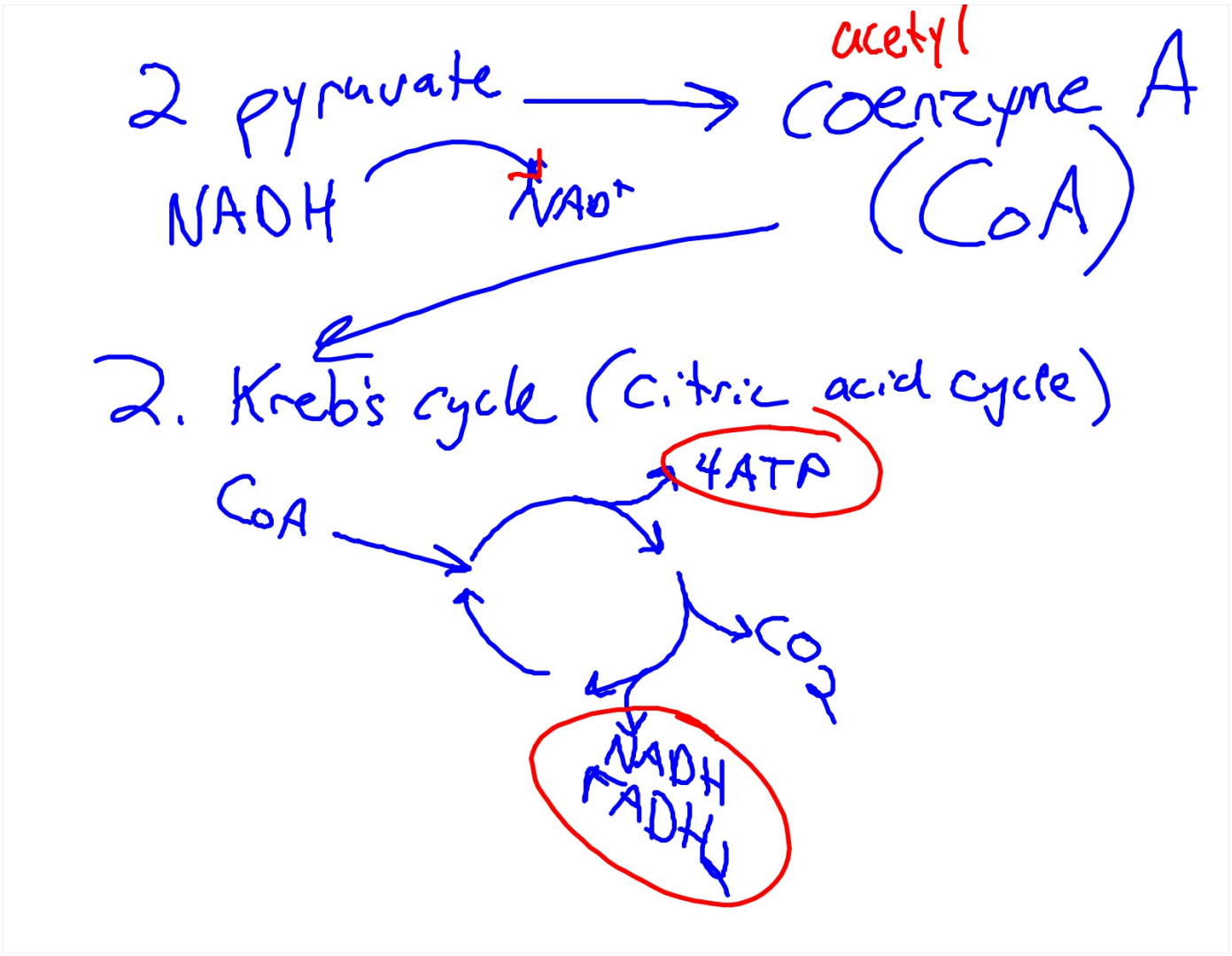

2 pyruvate
Krebs cycle
citric acid cycle
acetyl CoA
CO_2
NADH
$FADH_2$
4 ATP


Krebs cycle
Citric acid cycle
aerobic
Citric ac
cycle
Needs
makes
2 pyruvate
acetylCoA
NAD+/FADH
NADH/FADH2
4 ATP
CO2 (waste)

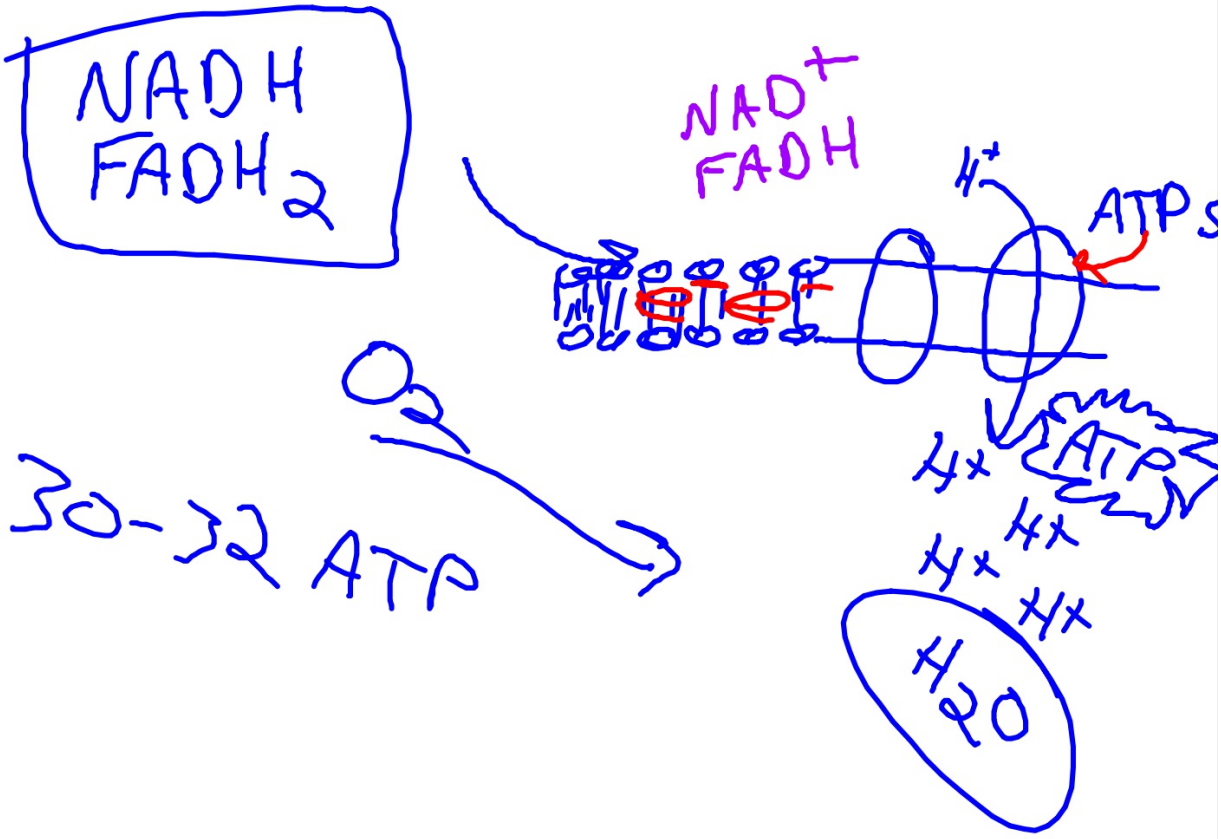
4.4 Overview of Cellular Respiration

- **Cellular respiration is like a mirror image of photosynthesis.**
  - The Krebs cycle transfers energy to an electron transport chain.
    - takes place in mitochondrial matrix
    - breaks down three-carbon molecules from glycolysis
    - makes a small amount of ATP
    - releases carbon dioxide
    - transfers energy-carrying molecules




2 pyruvate
acetyl
coenzyme A
(CoA)
NADH
NAD+
2. Krebs cycle (citric acid cycle)
CoA
4ATP
CO2
NADH
FADH2

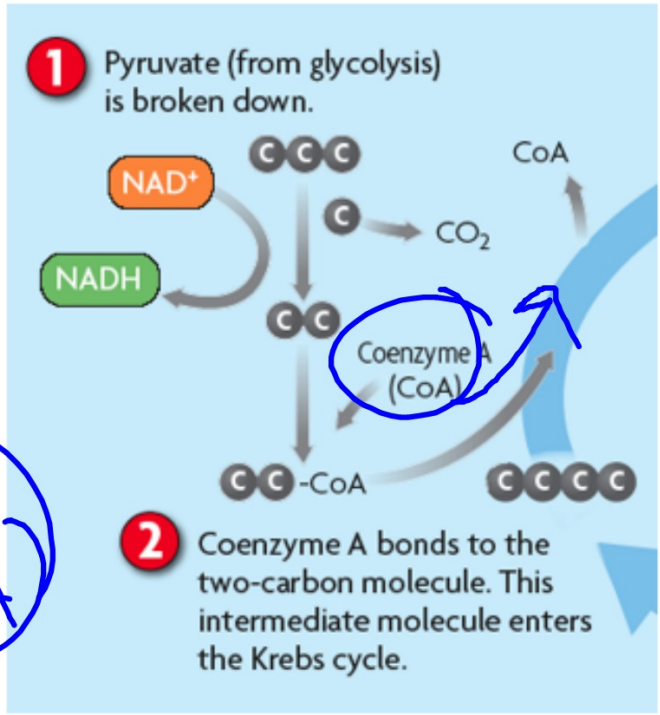
3. Electron transport chain (ETC)



4.5 Cellular Respiration in Detail

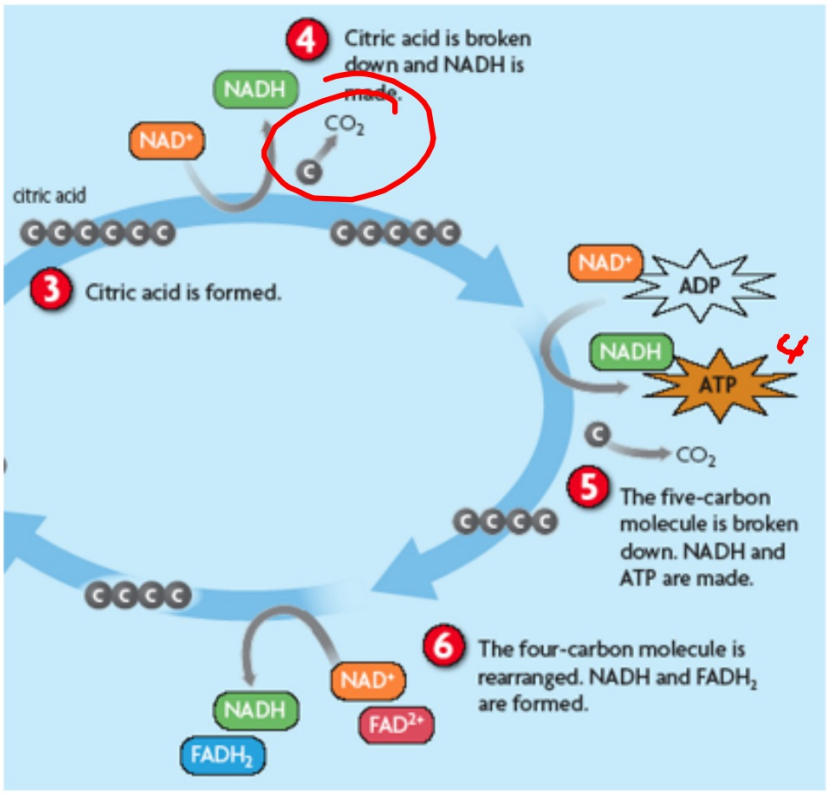
- **The Krebs cycle is the first main part of cellular respiration.**
  - Pyruvate is broken down before the Krebs cycle.
    - carbon dioxide released
    - NADH produced
    - coenzyme A (CoA) bonds to two-carbon molecule

pyruvate → Acetyl CoA



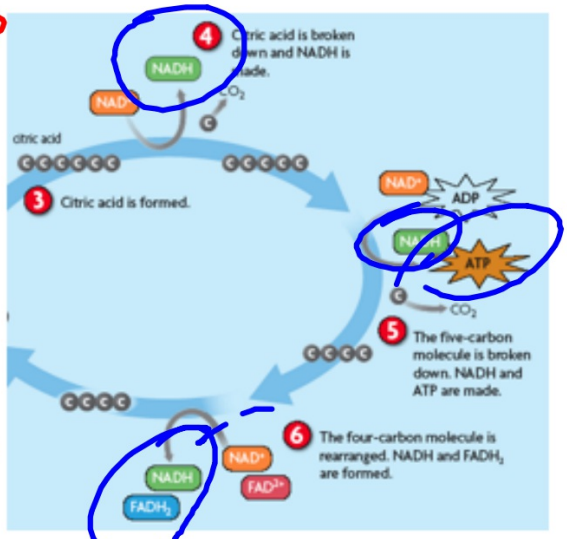
4.5 Cellular Respiration in Detail

- The Krebs cycle produces energy-carrying molecules.



4.5 Cellular Respiration in Detail

- The Krebs cycle produces energy-carrying molecules.
  - NADH and $FADH_2$ are made
  - intermediate molecule with CoA enters Krebs cycle
  - citric acid (six-carbon molecule) is formed
  - citric acid is broken down, carbon dioxide is released, and NADH is made
  - five-carbon molecule is broken down, carbon dioxide is released, NADH and ATP are made
  - four-carbon molecule is rearranged



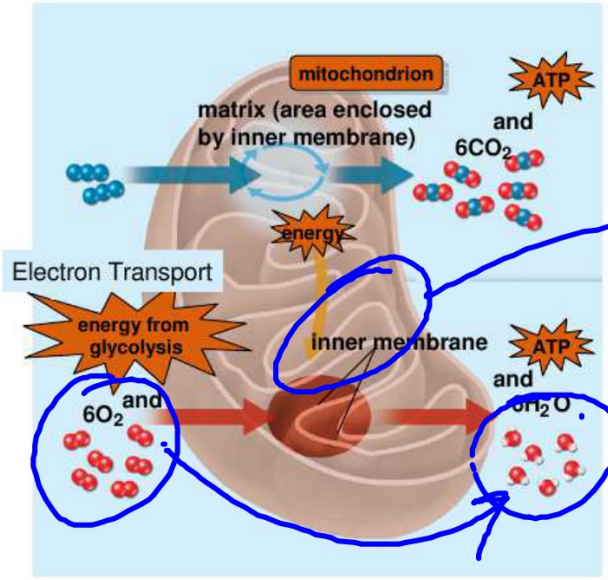
Krebs cycle / citric acid cycle

1. pyruvate → coenzyme A
   (CO_2 is released)

2. CoA enters Krebs cycle / citric acid
   makes: CO_2 (waste)

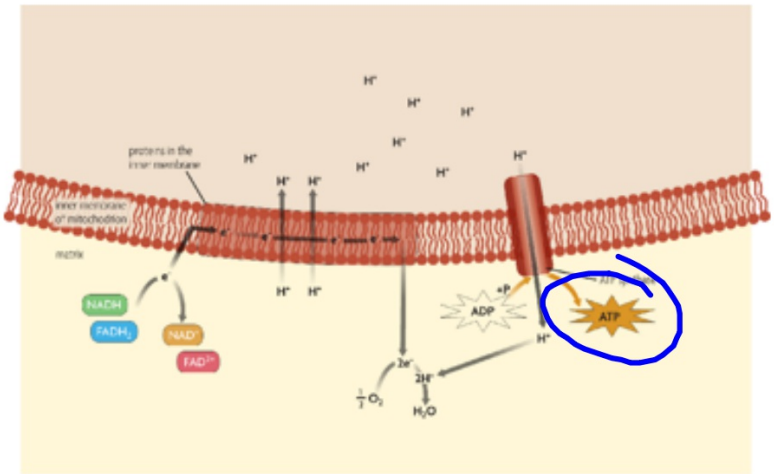
4.4 Overview of Cellular Respiration

- The electron transport chain produces a large amount of ATP.
  - takes place in inner membrane
  - energy transferred to electron transport chain
  - oxygen enters process
  - ATP produced
  - water released as a waste product



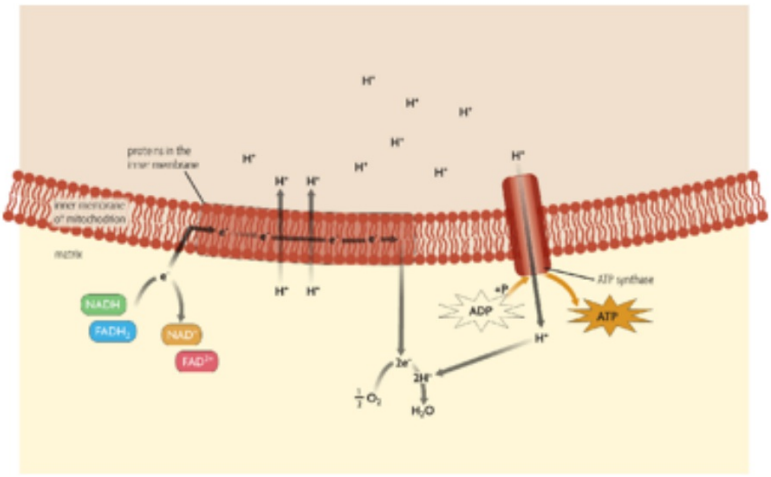
4.5 Cellular Respiration in Detail

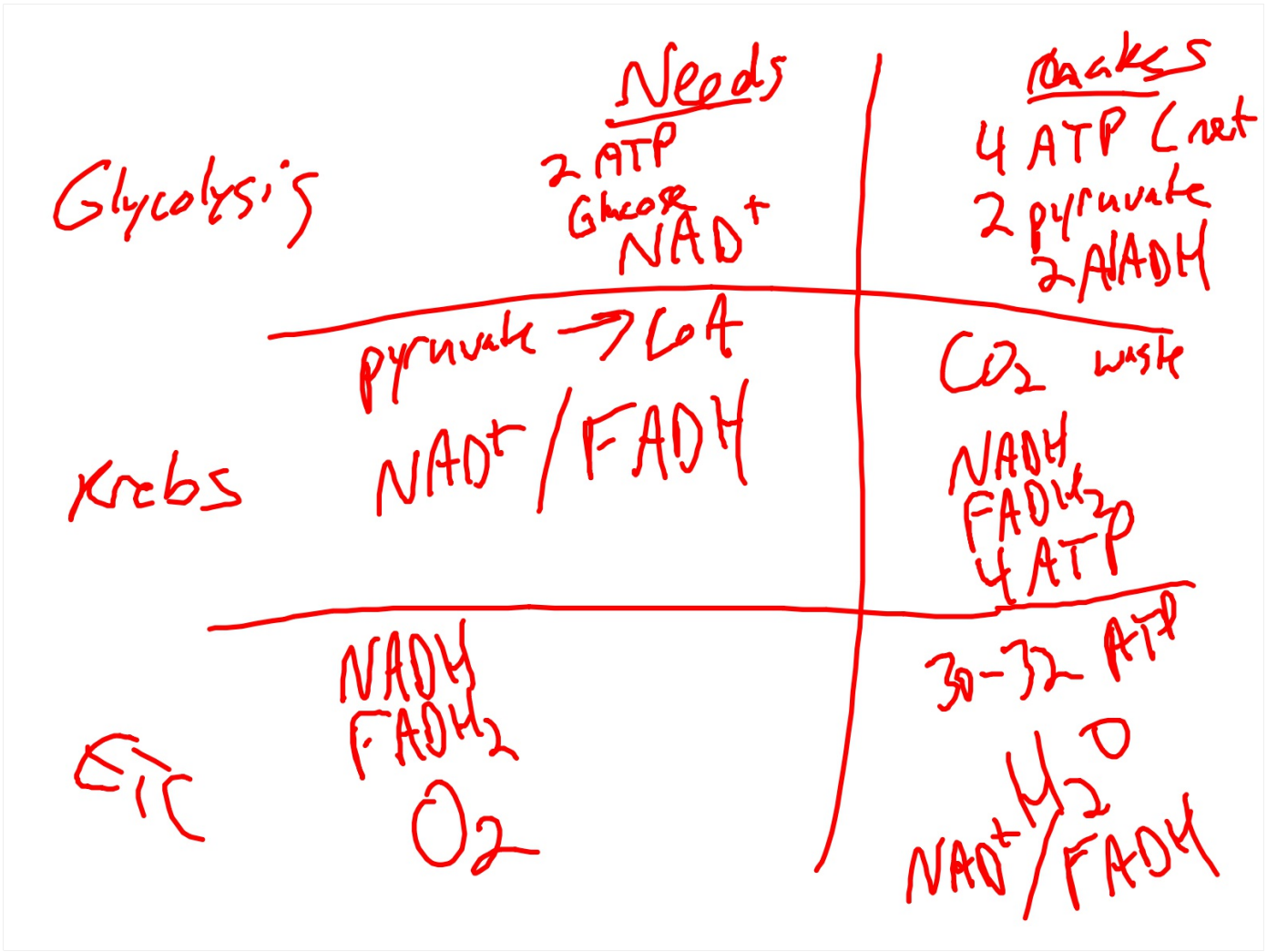
- **The electron transport chain is the second main part of cellular respiration.**
  - The electron transport chain uses NADH and $FADH_2$ to make ATP. 30-32 ATP used: NAD^+, FADH
    - high-energy electrons enter electron transport chain
    - energy is used to transport hydrogen ions across the inner membrane
    - hydrogen ions flow through a channel in the membrane



4.5 Cellular Respiration in Detail

- **The electron transport chain is the second main part of cellular respiration.**
  - The electron transport chain uses NADH and $FADH_2$ to make ATP.
  - The breakdown of one glucose molecule produces up to 38 molecules of ATP.
    - ATP synthase produces ATP
    - oxygen picks up electrons and hydrogen ions
    - water is released as a waste product




Needs
Makes
Glycolysis
2 ATP
Glucose
NAD+
4 ATP (net
2 pyruvate
2 NADH
pyruvate → CoA
CO2 waste
Krebs
NAD+ / FADH
NADH
FADH2
2 ATP
4 ATP
ETC
NADH
FADH2
O2
30-32 ATP
H2O
NAD+ / FADH

Consider the following two groups of processes:

-light dependent reactions and electron transport chain
-Calvin cycle and Krebs cycle

Which pair is nearly identical?
Which is nearly the opposite?
Explain.

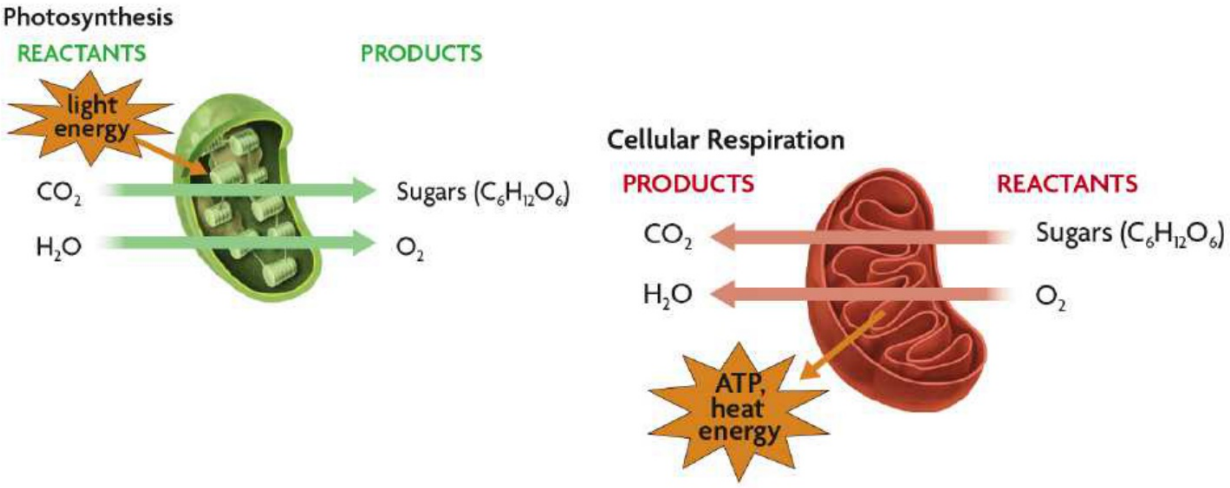
	What goes in	What comes o
Kickoff:		
Glycolysis:		
Krebs/citric acid cycle		
ETC:		

4.4 Overview of Cellular Respiration

- The equation for the overall process is:

  $C_6H_{12}O_6 + 6O_2 \rightarrow\rightarrow\rightarrow\rightarrow\rightarrow\rightarrow 6CO_2 + 6H_2O$

- The reactants in photosynthesis are the same as the products of cellular respiration.



?

1. One _____ molecule enters into glycolysis.
2. Two ATP molecules _____ glucose into _____ molecules.
3. The 3-C intermediates are _____ to create two _____ molecules.
4. Four _____ and two _____ molecules are pr energy carriers that will go to the _____ cycle.

ate molecules are broken down and converted into _____ in the the Krebs cycle.

One _____ is produced, which goes into the Krebs cycle.

_____ CO_2 is released.

LE (CITRIC ACID CYCLE)

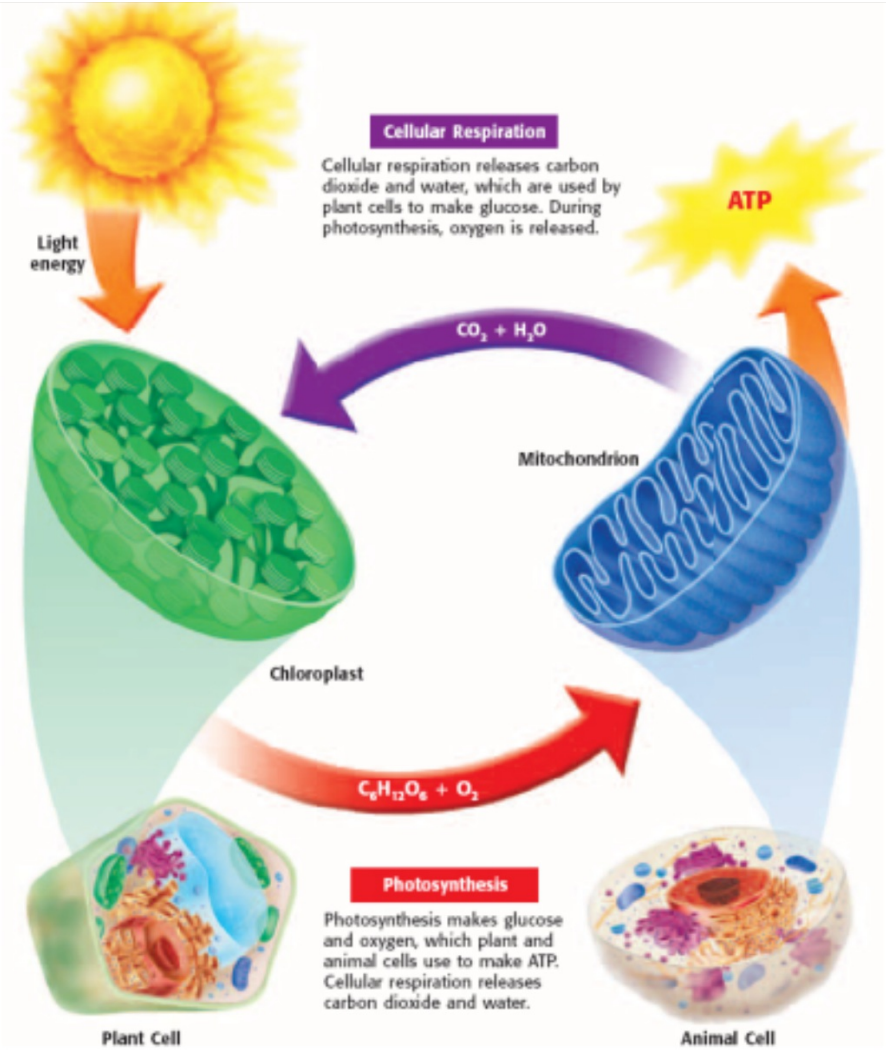
TRANSPORT CHAIN (ETC)

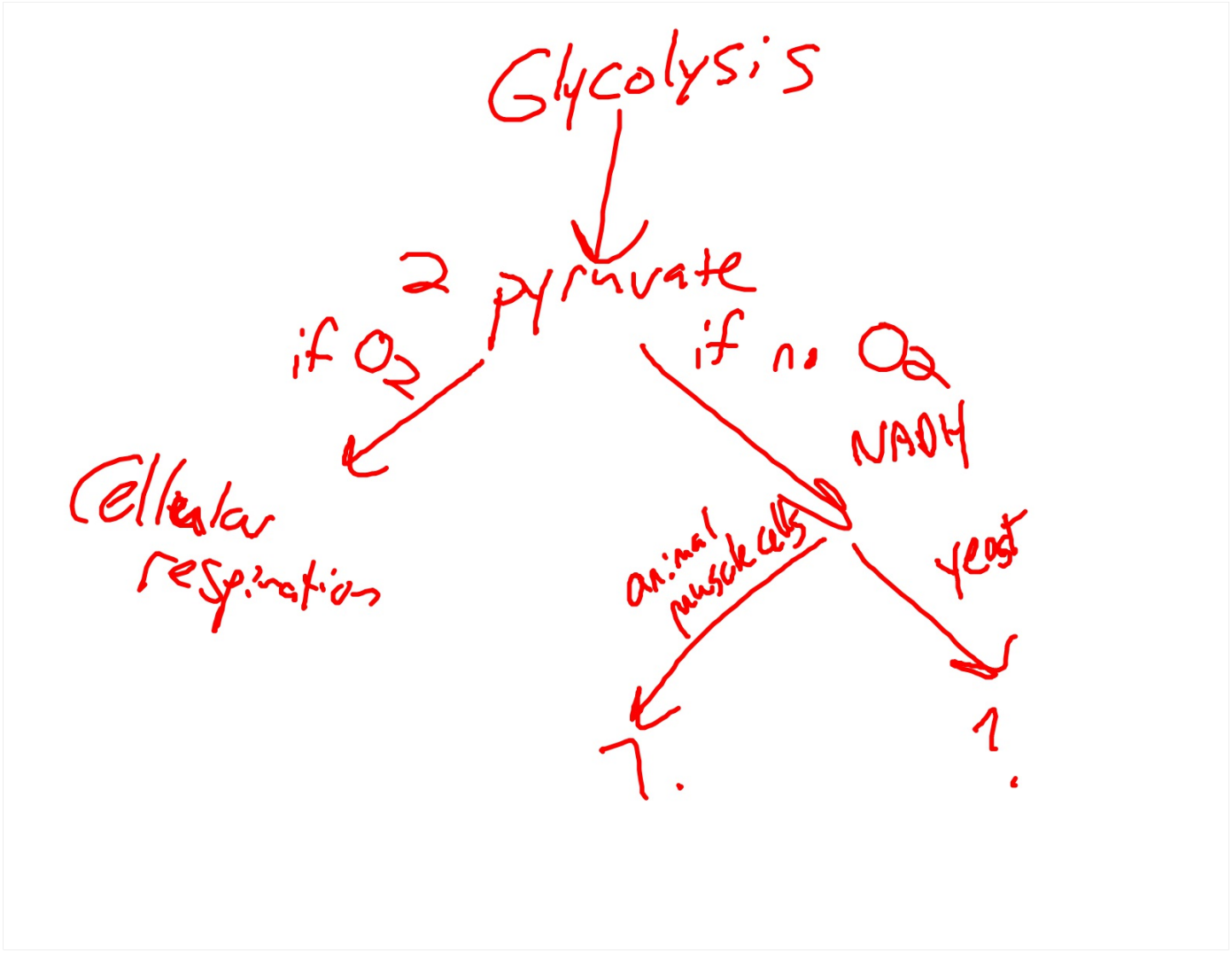
NADH and $FADH_2$ _____ electrons to proteins in the _____ mitochondrial membrane.

Movement of _____ through the membrane results in the _____ of H+ ions across the membrane.

At the end of the ETC, electrons are _____ by O_2, producing

_____ ions flow down their concentration _____ membrane, producing ATP.


Cellular Respiration
Cellular respiration releases carbon dioxide and water, which are used by plant cells to make glucose. During photosynthesis, oxygen is released.
ATP
Light energy
$CO_2 + H_2O$
Mitochondrion
Chloroplast
$C_6H_{12}O_6 + O_2$
Photosynthesis
Photosynthesis makes glucose and oxygen, which plant and animal cells use to make ATP. Cellular respiration releases carbon dioxide and water.
Plant Cell
Animal Cell


Glycolysis
2 pyruvate
if O2
if no O2
NADH
Cellular respiration
animal muscle cells
yeast
1.
1.

4.6 Fermentation

KEY CONCEPT

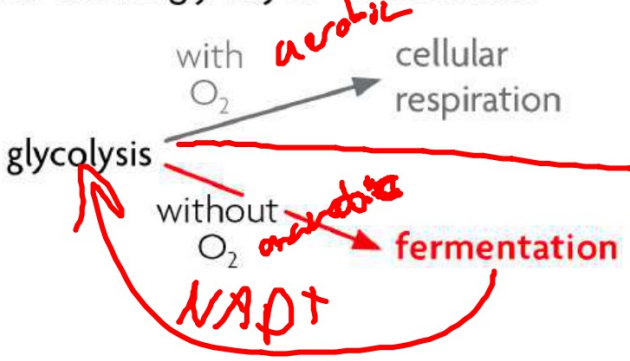
Fermentation allows the production of a small amount of ATP without oxygen.

4.6 Fermentation

Fermentation allows glycolysis to continue.

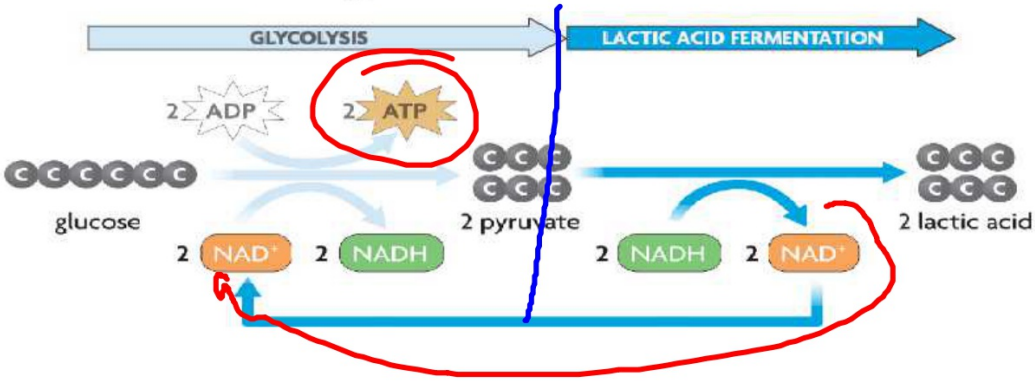
- Fermentation allows glycolysis to continue making ATP when oxygen is unavailable.
- Fermentation is an anaerobic process.
  - occurs when oxygen is not available for cellular respiration
  - does not produce ATP

Fermentation is an anaerobic process that allows glycolysis to continue.



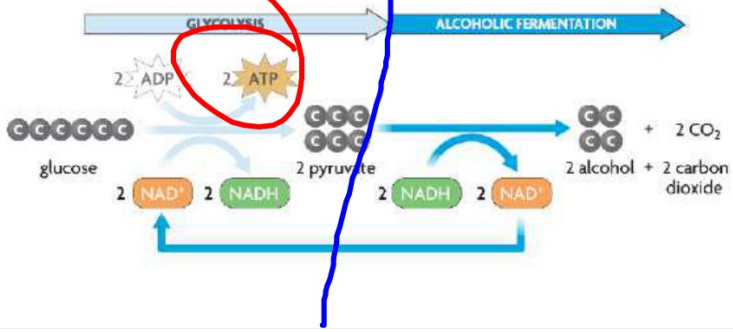
4.6 Fermentation

- Fermentation allows glycolysis to continue making ATP when oxygen is unavailable.
- NAD^+ is recycled to glycolysis
- Lactic acid fermentation occurs in muscle cells.
  - glycolysis splits glucose into two pyruvate molecules
  - pyruvate and NADH enter fermentation
  - energy from NADH converts pyruvate into lactic acid
  - NADH is changed back into NAD^+



4.6 Fermentation

- **Fermentation and its products are important in several ways.**
  - Alcoholic fermentation is similar to lactic acid fermentation.
    - glycolysis splits glucose and the products enter fermentation
    - energy from NADH is used to split pyruvate into an alcohol and carbon dioxide
    - NADH is changed back into NAD^+
    - NAD^+ is recycled to glycolysis



4.6 Fermentation

- Fermentation is used in food production.
  - yogurt
  - cheese
  - bread

Anaerobic Respiration

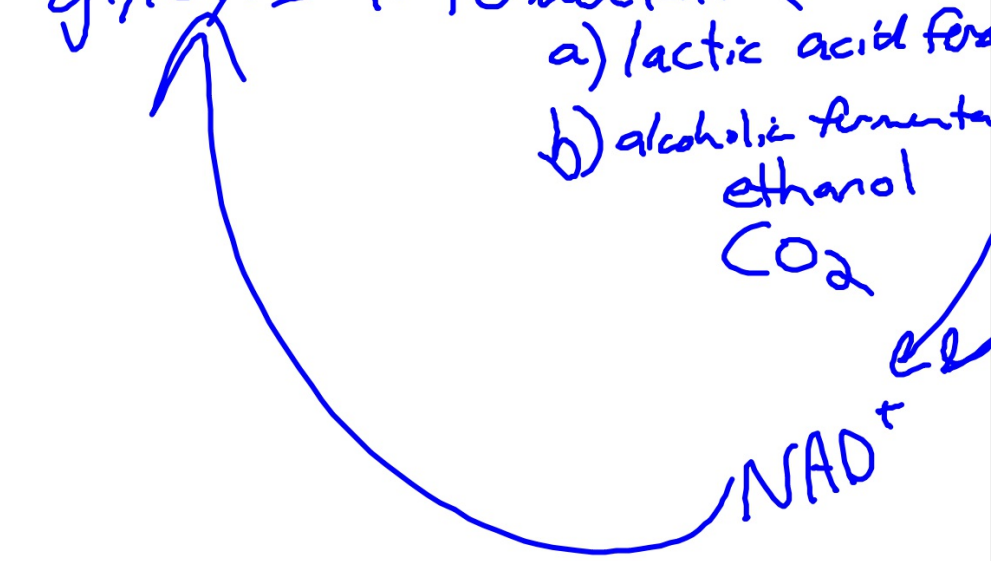
glycolysis + fermentation

a) lactic acid fer

b) alcoholic fermenta

ethanol

CO_2



TYPES OF FERMENTATION (ALSO CALLED *ANAEROBIC RESPIRATION*)...

FERMENTATION

Two _____ and NADH produced in glycolysis enter fermentatic

Energy from _____ changes pyruvate into lactic _____

NADH is changed into _____, which recycles back to glycolysi

ERMENTATION

Two pyruvates and _____ produced in glycolysis enter ferment

_____ from NADH changes pyruvate into an _____
actic acid molecule.

NADH is changed into NAD+, which recycles back to _____.

Name _____ Period _____ Date _____

Photosynthesis & Cellular Respiration Worksheet

Vocabulary: Match the phrases on the left with the term that best fits. Not all terms will be use, and some may be used more than once.

____1. Organisms that make their own food
____2. Site of photosynthesis
____3. Process occurs in cytoplasm
____4. $C_6H_{12}O_6$
____5. Process does not require oxygen
____6. Process requires oxygen
____7. Adenosine triphosphate
____8. Energy storing molecule
____9. The anaerobic process of splitting glucose and forming two molecules of pyruvic acid
____10. The ability to do work

A. Chloroplasts
B. Anaeorobic
C. Aerobic
D. Glucose
E. ATP
F. Kreb's cycle
G. Glycolysis
H. Energy
I. ADP
J. Autotrophs

11. Fill out the table below:

	Cellular Respiration (Reactants and Products: see equation on the board)	**Photosynthesis**
Reactants		
Products		
What organelle?		

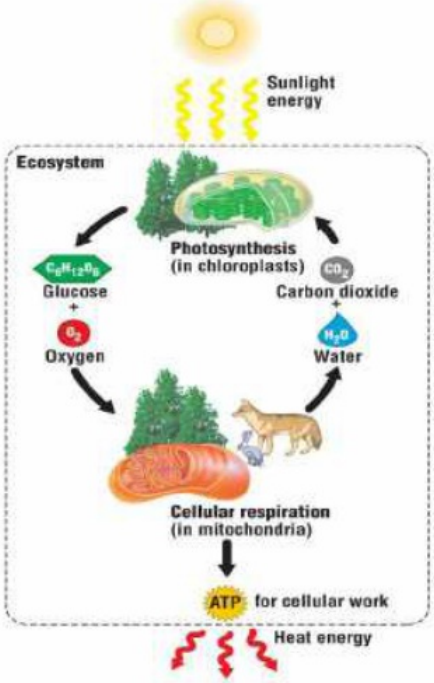
12. Use the picture to the right to help you describe the relationship between photosynthesis and cellular respiration:

_____

_____

_____

_____



13. What kind(s) of organisms perform photosynthesis?

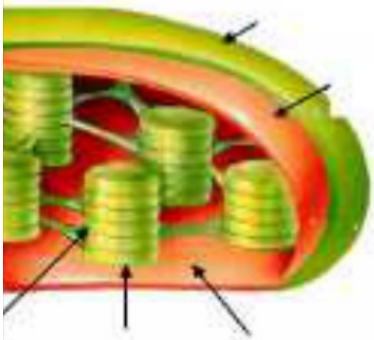
_____

14. What kind(s) of organisms perform cellular respiration?

_____

of the leaf does the most photosynthesis take place? Why?

synthesis, what role does the stoma/stomata play?



3. Label the various parts of the chloroplast.

4. Name the two major parts of photosynthesis and **draw an arrow to where they take place in the Chloroplast to the left.**

1. _____

2. _____

cellular respiration splits glucose?

of cellular respiration are the most ATP's made?

part does most of respiration occur?

important?

following steps under the appropriate process and put them in the

vin Cycle, Glycolysis, Electron Transport Chain, Light Reactions, Kreb Cycle

Cellular Respiration

1.

2.

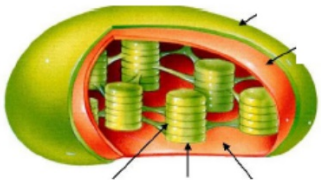
3.

Rearrange the following pieces to create the equation for **photosynthesis**: *Oxygen, Carbon Dioxide, Water, Glucose, Sunlight,*

Rearrange the following pieces to create the equation for **respiration**: *Oxygen, Carbon Dioxide, Water, Glucose, ATP,*

1. In what part of the leaf does the most photosynthesis take place? Why?

2. During photosynthesis, what role does the stoma/stomata play?



3. Label the various parts of the chloroplast.

4. Name the two major parts of photosynthesis and **draw an arrow to where they take place in the Chloroplast to the left.**

1. _____

2. _____

5. Name the 3 chemical products of the light reactions. Which two get passed on to the Calvin Cycle? Which one leaves the leaf?

6. What is the product made in the Calvin Cycle?

7. How are the equations for photosynthesis and respiration similar? How are they different?

8. Which step in cellular respiration splits glucose?

9. In which step of cellular respiration are the most ATP's made?

9. In which step of cellular respiration are the most ATP's made?

10. In what cell part does most of respiration occur?

11. Why is ATP important?

12. Organize the following steps under the appropriate process and put them in the appropriate order.

Calvin Cycle, Glycolysis, Electron Transport Chain, Light Reactions, Kreb Cycle

Photosynthesis	*Cellular Respiration*
1.	1.
2.	2.
	3.