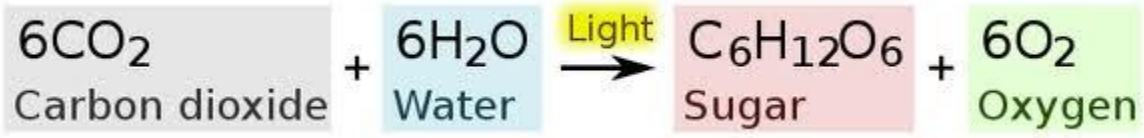
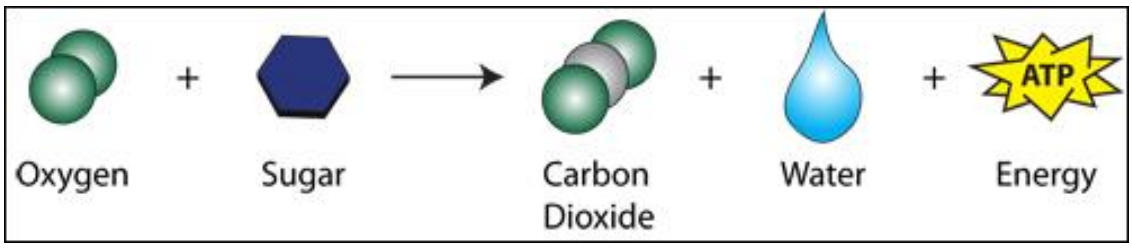
Botany – Plant Metabolism

I. Metabolism – _____

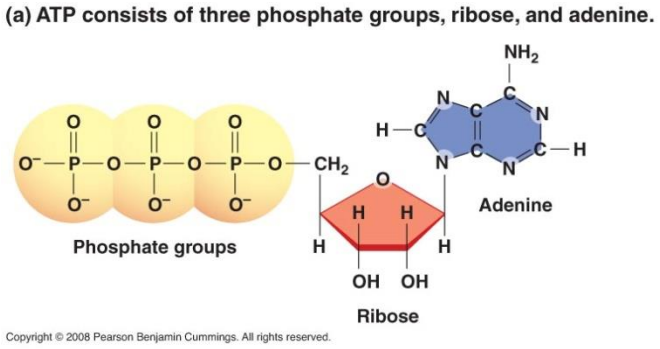
A. _____ – the process by which plant cells capture the radiant energy (E) of sunlight & store it in sugar (in the form of carbohydrates).



B. _____ – the process by which plant cells release the E stored in sugar & capture it in ATP.



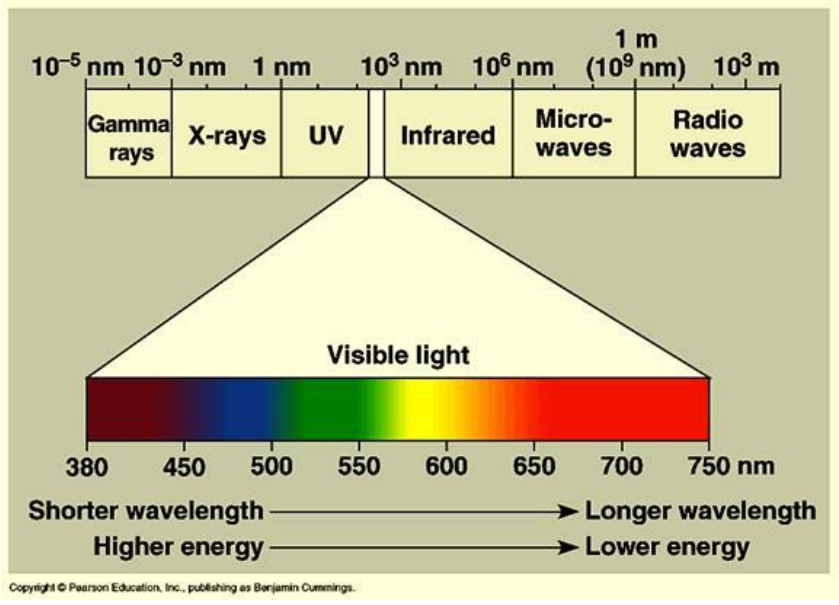
1. ATP – _____



II. Photosynthesis begins with light

A. What makes up light?

1. Review the diagram over the visible spectrum of light



2. As wavelength _____, energy _____
    a. Red has the _____ wavelength, but carries the _____ energy
    b. Violet has the _____ wavelength, but carries the _____ energy
    c. UV light carries _____ energy then visible light
        1) Why is UV light dangerous?

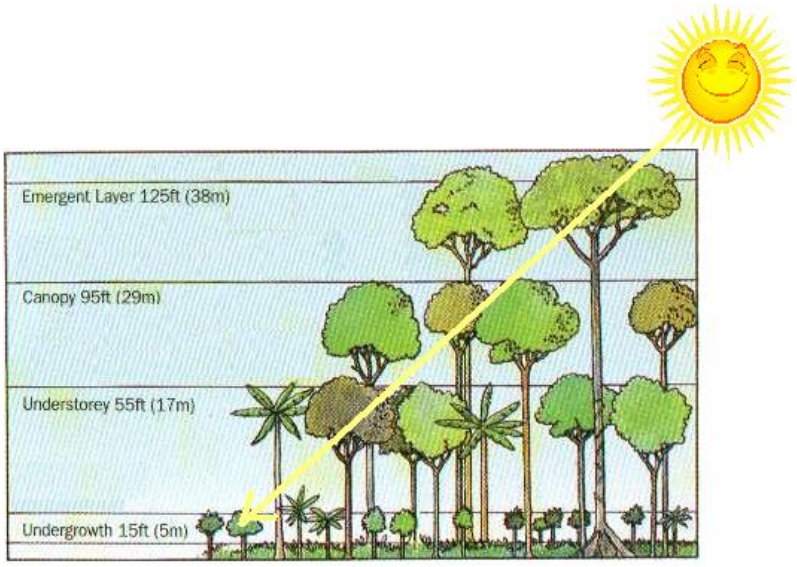
    d. Infrared light carries _____ energy than visible light.
        1) This is the same thing as _____

B. Why do we see colors?

Why are plants green?

Why should a greenhouse never have green glass?

C. Not all light that reaches plants is the same quality.



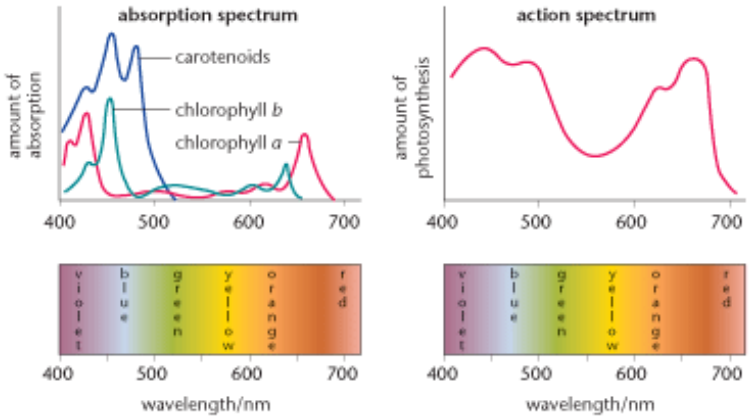
Review how light level changes as you pass through the strata of a tropical rain forest.

Emergent layer - _____ light quality; therefore it is the _____ efficient.
These plants primarily rely upon just have _____.

Undergrowth - _____ light quality. Mostly only the high energy Wavelengths of violet, blue, and green get through. These plants must be the _____ efficient. They primarily rely upon_____.

III. Plants capture the E of light with photosynthetic pigments

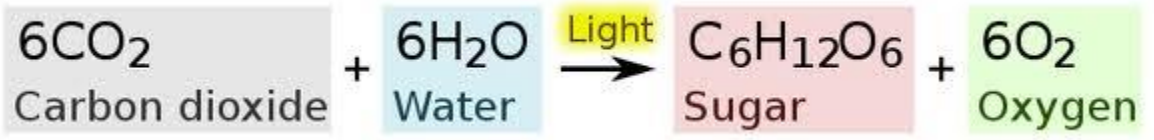
A. Review the diagram over the absorption of the photosynthetic pigments



1. _____, in land plants, is the main light-capturing pigment.
    a. Chlorophyll a is a _____pigment
    b. It is most efficient at _____& _____ wavelengths
2. Chlorophyll b serves as an accessory pigment
    a. Chlorophyll b is a _____ pigment
    b. It is most efficient at _____ & _____wavelengths
3. Chlorophyll transmits & reflects light in the _____ & _____ wavelengths, giving plants their green color
4. Chlorophyll is located in the _____of chloroplasts
5. _____ (carotene & xanthophylls) are accessory pigments that allow the utilization of a wider variety of wavelengths of light.
    a. Carotenoids are yellow, orange, or red pigments
    b. They are most efficient at _____ & _____ wavelengths
6. Why do shaded plants have more carotenoids?

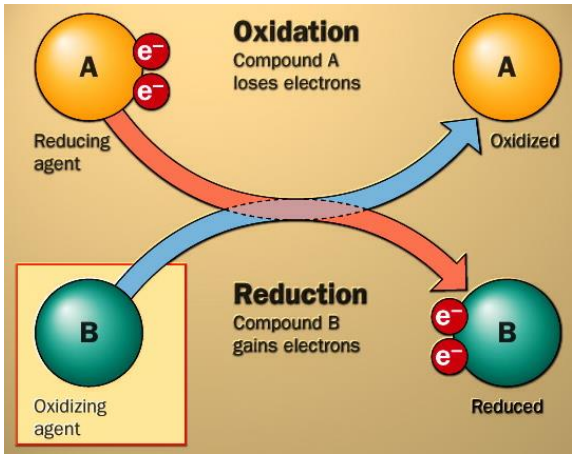
IV. Overview of Photosynthesis

A. A SUM OF THE REACTION OF PHOTOSYNTHESIS



B. Photosynthesis can be viewed as a coupled oxidation / reduction reaction.

Helpful Acronym: **O**xidation **I**s **L**osing Electrons, **R**eduction **I**s **G**aining Electrons: **OIL RIG**

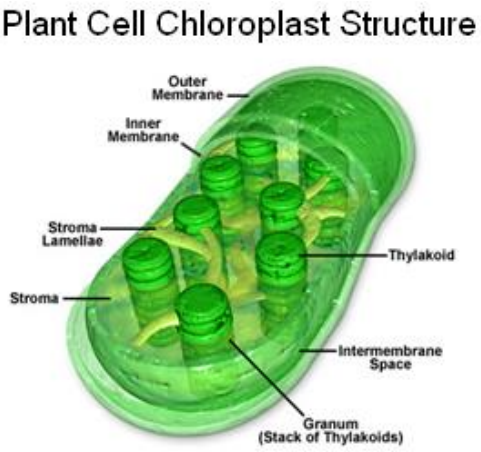


1. **Oxidation** – the loss of _____ &/or _____ (the loss of _____)
    a. **water** is oxidized as free _____ is created

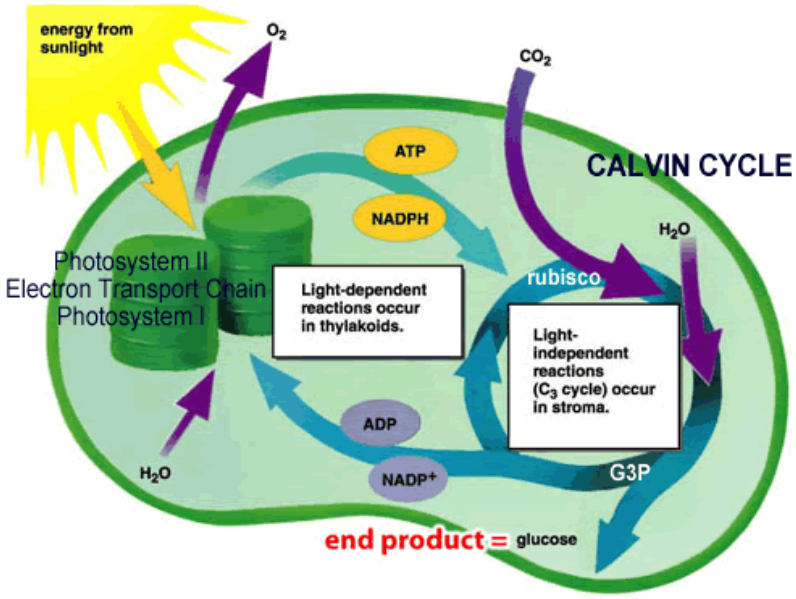
2. _____ – the gain of electrons &/or hydrogen (the gain of E)
    a. **carbon dioxide** is reduced as it is changed to _____ (carbohydrates)

C. Review of the structures of a chloroplast

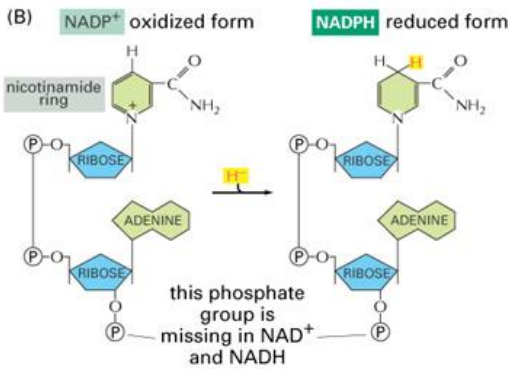
1. Double membrane bound, stacks of _____ membranes called _____, & a fluid called the _____.



D. Photosynthetic reactions can be divided into light-dependent & light-Independent. THESE REACTIONS BOTH OCCUR IN EVERY SINGLE PLANT SIMULTANEOUSLY DURING THE DAY.



1. **Light-dependent reactions** (require light or they will not occur)
   a. Take place on the _____



b. Water molecules are split (oxidized) to produce oxygen and H^+

1) $H^+ + NADP^+ \rightarrow$ NADPH

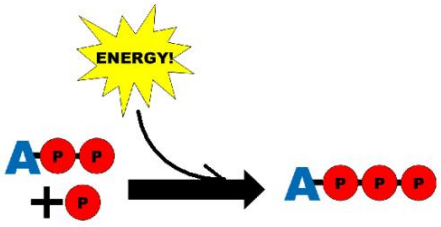
2) NADPH is like a charged battery that can be used to do work.

c. The energy of sunlight excites the photosynthetic pigments of _____

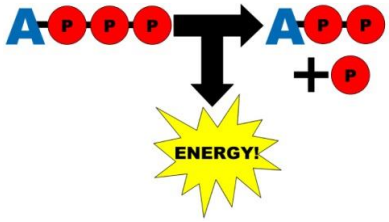
1) They eject electrons, which travel down the electron transport system, releasing energy.

2) Some of the E is used to create a H^+ gradient across the thylakoid membrane that drives _____

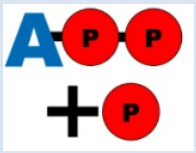
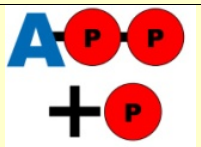
a) ADP + $P_i \rightarrow$ ATP



2. **Light-independent reactions** (can occur in the dark, don't require light)
   a. Take place in the _____
   b. The energy stored in ATP is used to reduce carbon dioxide to form glucose
      1) NADPH donates H to CO_2
         a) NADPH → $NADP^+$
      2) The energy required to reduce CO_2 is derived from ATP
         b) ATP → ADP + P_i
   c. Make sugar

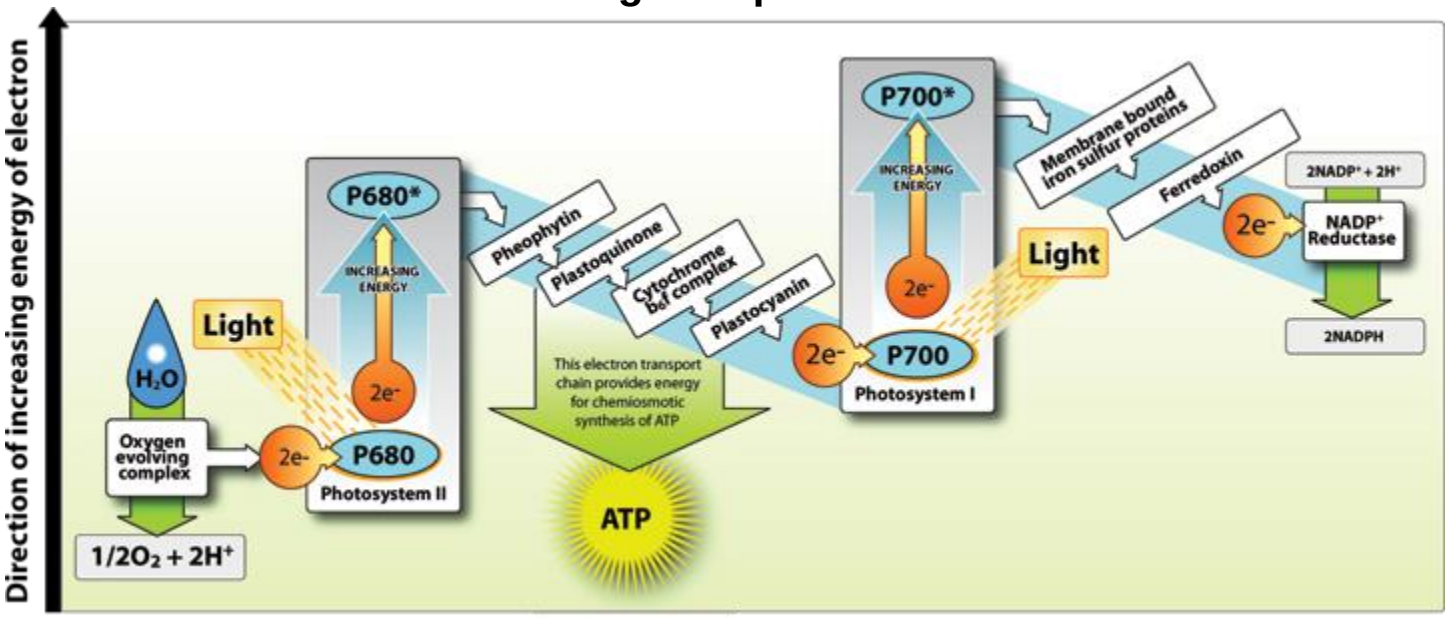


3. Overview of Reactants and Products

Light-dependent Reactions (occurs on thylakoid membranes)		Light-independent Reactions (occurs in the stroma)	
Uses **Reactants**	Produces **Products**	Uses **Reactants**	Produces **Products**
 Photosystem II ejects 2 electrons (e^-)			
 Split H_2O → H^+ and e^- (from roots)	 (released to air)	 We will oxidize the electron carrier to release the H^+	 The H^+ will be inserted into the CO_2
 An electron carrier that will become reduced		 (from air)	
 The energy to make ATP comes from the e^- passed down the electron transport chain			

E. _____ – a group of protein, chlorophyll, & carotenoid molecules contained on the thylakoid membranes. The photosystems were numbered as they were discovered, but they are actually used in reverse order.

These are the Light-Dependent Reactions

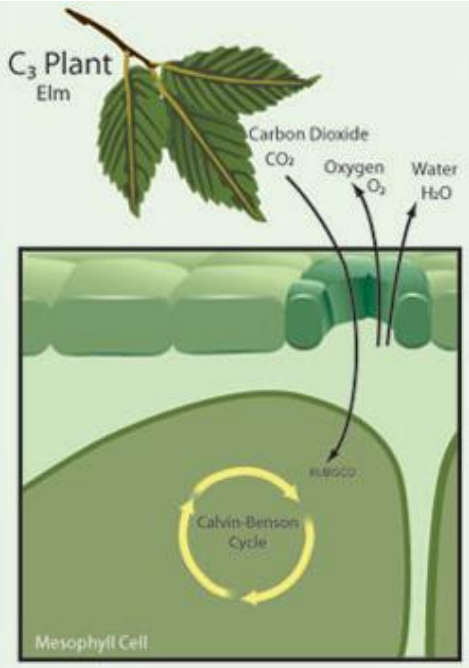


1. **Photosystem II**
    a. A photon of light strikes photosystem II, energizing an electron
    b. The energized electron moves down the electron transport system
        1) This E is used to convert ADP + P_i to ATP
    c. The electron is passed to photosystem I
2. **Photosystem I**
    a. The electron is re-energized by sunlight and passes to a carrier molecule $NADP^+$. H^+ from the stroma combines with electrons to form NADPH.
    b. The NADPH will be utilized in the light-independent reactions to form _____.
3. The original electron from Photosystem II is replaced by splitting water.
    a. $H_2O \rightarrow 2H^+ + 2\ e^- + ½\ O_2$

F. There are 3 types of photosynthesis: _____ **photosynthesis**
Plants first evolved in the ocean. They then moved onto land. The first land plants hung out near the coastline (LOTS of water) = **C_3 Photosynthesis**
As plants moved away from the coastline it became hotter and drier = **C_4 Photosynthesis** (such as we see in grasslands)
The most difficult climate was the desert, with less than 8 inches of rain annually = **CAM Photosynthesis.**

1. Photosynthesis always involves taking C from 6 CO_2 and "_____" it to form a 6 C molecule, glucose.
    a. Remember, plants get CO_2 from the air. They must open their somata in order allow CO_2 into the leaf's mesophyll where photosynthesis is taking place.
    b. When the stomata are open, water vapor leaves the plant through transpiration

2. **C_3 photosynthesis** is the ancestral pathway for carbon fixation and occurs in all taxonomic plant groups.



a. C_3 photosynthesis initially fixes CO_2 into a 3 C molecule that will eventually become glucose.

b. Benefits of C_3 photosynthesis _____ system (it takes the least ATP to make glucose).

c. Costs of C_3 photosynthesis _____ must be abundant. In order for C_3 photosynthesis to be efficient, the stomata must stay open to let in **lots of CO_2**.

1. When temperatures are high, and water is low, C_3 plants begin to go through photorespiration.

d. _____ consumes oxygen, releases carbon dioxide, generates no ATP, and decreases photosynthetic output.

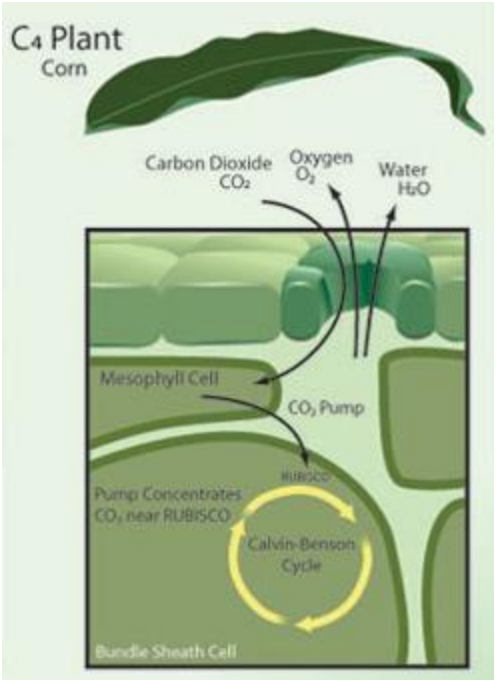
1. Generally occurs on hot, dry, bright days, when the stomata close to conserve water.
2. This allows the concentration of O_2 to exceed that of CO_2 in the leaf.

e. In C_3 plants, the _____ cells (cells that surround and protect leaf veins) usually do not contain chloroplasts.

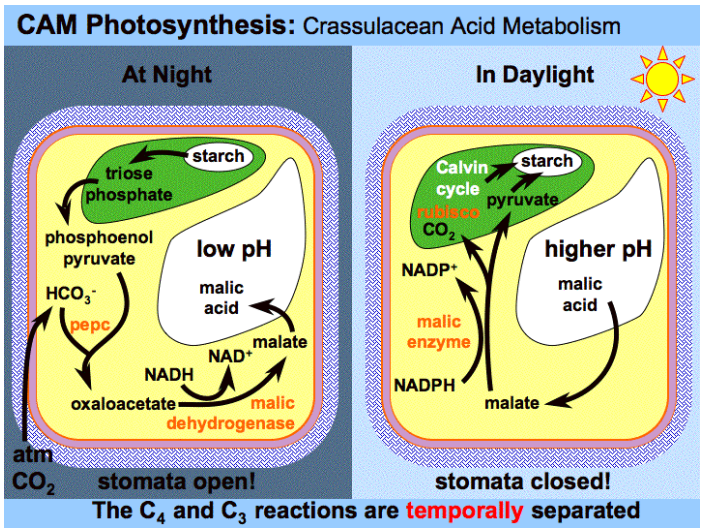
f. Examples of C_3 plants: most trees, grain crops, potatoes, sugar beets.

3. **C_4 photosynthesis** occurs in the more advanced plant taxa and is especially common among _____, such as grasses and sedges, but not very common among dicots.

a. C_4 photosynthesis initially fixes CO_2 into a 4 C molecule that will eventually become glucose.
b. Benefits of C_4 photosynthesis
   i. At _____, C_4 plants have photosynthetic rates that are **two to three times faster** than those of C_3 plants.
   ii. C_4 plants **lose less water** during photosynthesis.
c. Costs of C_4 photosynthesis
   i. Under milder climatic conditions, C_3 plants are more efficient at fixing carbon dioxide.
d. In C_4 plants, the bundle sheath cells usually do have chloroplasts.



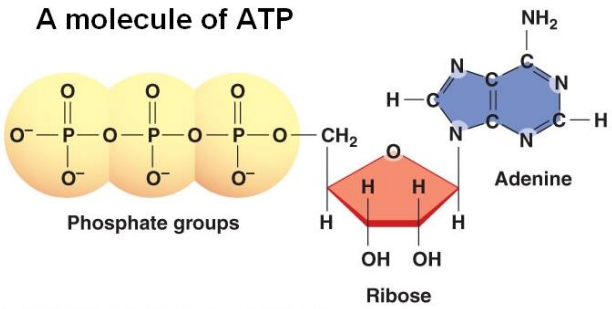
4. **Crassulacean Acid Metabolism (_____)** – usually found in succulents & other dry environment plants. The process allows C fixation while maximally conserving H_2O.



a. During the day, the light-dependent reactions produce ATP & NADPH, but the _____ C fixation cannot occur.
b. At night, the stomata open, allowing CO_2 to enter. Using CO_2 + ATP + NADPH, _____ is formed.
3. The next day, malate is broken down, freeing CO_2 to produce _____.

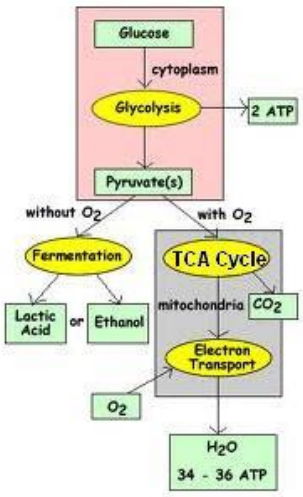
V. Glucose metabolism – how plant cells release & utilize the E stored in sugar

A. Remember a few things…
1. Cells can't directly use the E stored in sugar
2. Cells break the sugar molecule, releasing its stored E
3. Cells store that released E by making _____
4. ATP can be used by the cells to do any work



B. **Cellular respiration** is the gradual oxidation of sugar, in the presence of oxygen, that produces energy (which is stored as ATP – adenosine triphosphate).

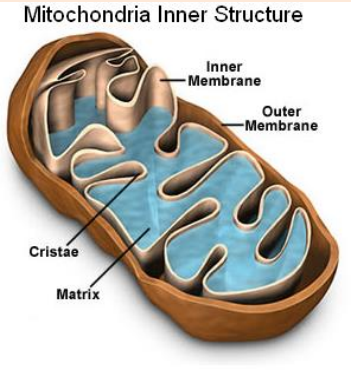
C. All cells begin the breakdown of sugar through _____



1. Glycolysis occurs in the _____ of the cell.
2. Glycolysis is an anaerobic (not requiring O_2) oxidation of glucose to produce _____.
3. SUM of the formula of GLYCOLYSIS…

Glucose (a 6 C molecule) → 2 Pyruvate (a 3 C molecule) + _____

4. If you are a bacteria or yeast cell, this may be all the E that you need, but complex plant & animal cells must be more efficient.
   a. Complex cells use _____ to carry out _____.

The Structure of a Mitochondria	Did You Know?
 Mitochondria are double-membrane bound organelles. The inner membrane is folded into **cristae**. The cristae provide the surface upon which **cellular respiration occurs**.	Each day, **2 million molecules** of ADP are phosphorylated (changed into ATP) in our bodies: **160kg/day**. Each ATP Synthase enzyme can phosphorylate up to 100 molecules of ADP per second! This phosphorylation is a chemiosmotic process, driving the flow of ions across a selectively permeable membrane. In this case, the ions flowing are protons. A concentration, charge, and pH gradient is set up across the inner membrane, and the osmotic pressure to return to equilibrium is used to synthesize ATP from ADP. The way the mitochondria sets this up is through the electron transport chain. The big picture here is that high energy electrons created by the TCA cycle (also known as the Kreb's Cycle) are used to reduce molecules of O_2 into water, and the energy given off is used to drive a series of proton pumps pumping protons out of the matrix space and into the intermembrane space of the mitochondria. These protons are then let back in by ATP synthase, driving the phosphorylation of ADP into ATP.

D. **Cellular respiration** – requires the presences of O_2
   1. Occurs on the inner membrane of the mitochondria
   2. _____
      a. The two pyruvates from glycolysis are converted to two _____ (This is a 2 C sugar)
      b. The acetyl groups are caught by a carrier molecule, coenzyme A (_____).
      c. SUM of the TRANSITION STEP

         2 Pyruvic acids → 2 CO_2 + 2 Acetyl Groups
         2 Acetyl Groups + 2 Coenzyme A → 2 **Acetyl CoA**

      d. The 2 Acetyl CoA enter the _____ (also known as the Kreb's cycle).

   3. **TCA Cycle**
      a. This is a complex chemical reaction that can be summed up as follows…
         2 Acetyl CoA → CO_2 + H_2O + _____

   4. In conclusion, the YIELD of CELLULAR RESPIRATION can be summed up in the following formula…