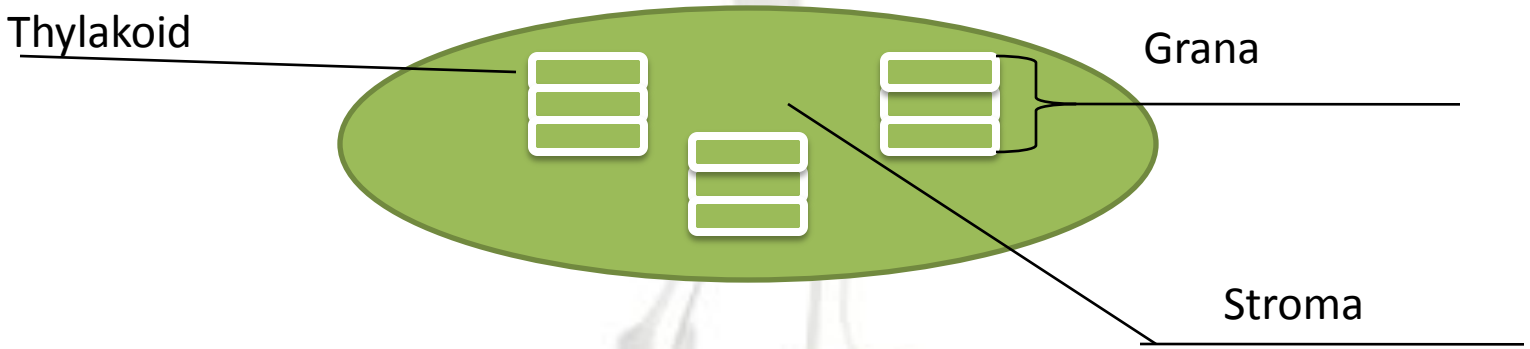
Photosynthesis

- Plants, some protists, and bacteria, create food molecules (sugars) from carbon dioxide and solar energy through the process of photosynthesis.
- Equation for photosynthesis:

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

Players of Photosynthesis

- Organelle: Chloroplast
- Chloroplast is divded into inner and outer portion of the organelle
  - Stroma: inner fluid portion
  - Thylakoid: Green disk membrane system (first stage of photosynthesis occurs)
  - Grana: Flatten channels and disk (thylakoid) arranged in stacks



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- Autotroph: Organisms that is self-nourishing.
- Heterotroph: organisms that must consume food.
- Bundle Sheath cells: Cells that are tightly wrapped around the veins of a leaf. Site of the Calvin Cycle in C_4 plants
- Mesophyll: interior leaf
- Mesophyll Cells: contains many chloroplast and host the majority of photosynthesis
- Photolysis: process by which water is broken up by an enzyme into hydrogen ions and oxygen atoms. Occurs in the light dependent reaction

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- Photophosphorylation: process by which ATP is produced during light-dependent reaction of photosynthesis
- Photorespiration: process by which oxygen competes with carbon dioxide and attaches to RuBP. Plants that experience this has a lower capacity of growth.
- Photosystem: cluster of light-trapping pigments involved in photosynthesis. Photosystem I and Photosystem II are two most important.

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- Pigment: a molecule that absorbs light of a particular wavelength. Pigments include carotenoids (orange), phycobilins, and chlorophyll
- Rubisco: an enzyme that catalyzes the first step of the Calvin Cycle in C_3 plants
- Stomata: Structure through which CO_2 enters a plant and water vapor and O_2 leave
- Transpiration: natural process by which plants lose H_2O via evaporation of leaves

Light Dependent Reactions

- Convert solar energy into ATP and NADPH, the reduced form of the electron receptor, NADP+.
- During these reactions, water is split, leaving oxygen as a waste product.
  - Why is oxygen considered to be a waste product?
- These reactions take place in photosystem in the choloroplast.

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- Photosystems comprise cluster of molecules composed of light-absorbing pigments and a reaction center, which includes a primary electron acceptor and two chlorophyll *a* pigment molecules.
- There are two photosystems work sequentially, with light first being absorbed by photosytem II and later by photosystem I

Steps to light dependent reactions

- 1- Photosystem II absorbs solar energy in the form of light.
- 2- The solar energy excites electrons in the reaction center of photosystem II, which the n enter an electron transport chain. These electrons originate from the splitting of water, which produces free electrons and O_2
- 3- As electrons pass down the electron transport chain, protons are pumped into the thylakoid membrane space of the chloroplast. Protons diffuse out of the thylakoid membrane space through an ATP synthase, creating ATP.

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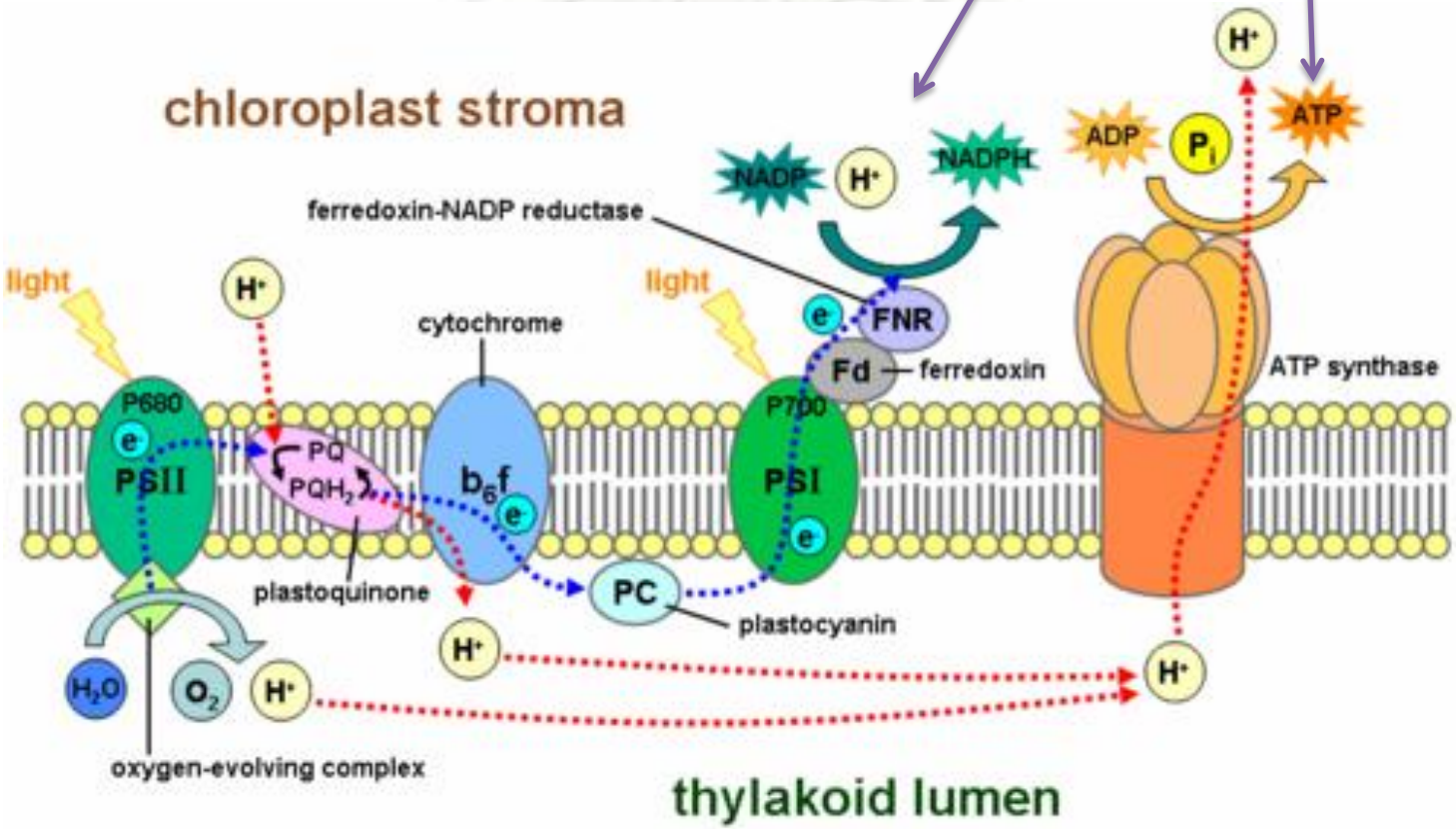
ATP and NADPH made in the light dependent reaction

- 4- Photosystem I accepts electrons from the electron transport chain and uses light energy to excite the electrons further.



Cellular Respiration and Light Dependent Reaction

- Cellular respiration and light dependent reactions of photosynthesis use similar processes to produce ATP.
- Scientist believe that the electron transport chain used in cellular respiration may have evolved from the transport system used in photosynthesis.

Calvin Cycle

- Uses ATP and NADPH from the light-dependent reaction to convert CO_2 into sugar that the plant can use.
- CO_2 is obtained through the stomata.
- Carbon fixation: incorporates the CO_2 into organic molecules
- The incorporation is completed by the energy rich enzyme rubisco (ribulose biphosphate carboxylase (RuBP)), a protein made during light-dependent reaction of photosynthesis . Abundant in leaves

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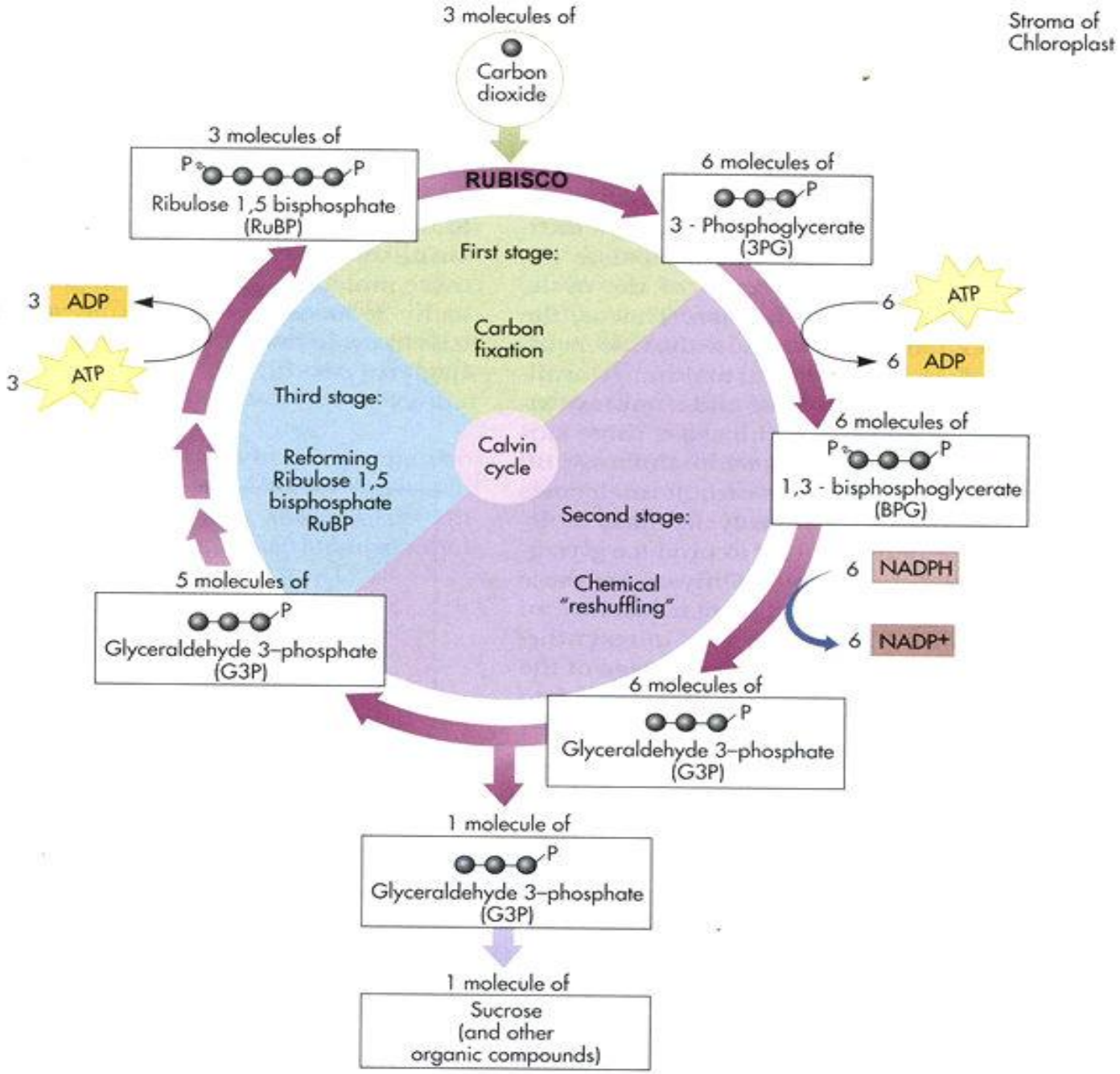
- CO_2 is split into:
  - 3 carbon molecule PGA (3-phosphoglycerate)
  - Converts PGA into 3-carbon sugar molecule glyceraldehyde 3-phosphate
  - Used to make glucose and sucrose
- The production of a single 3-carbon sugar molecule require 3 CO_2, 9 ATP, 6 NADPH



Calvin Cycle Diagram

Photorespiration

- When the enzyme rubisco incorporates oxygen, rather than CO_2, into organic molecules, plants create energy through the process of photorespiration.
- Occurs most in arid regions where plants must close their stomata to prevent water loss to the air.
- The results in a buildup of oxygen levels in the leaf, which makes rubisco more likely to bind with the oxygen.
- Detrimental to plants because it consumes more ATP to produce each 3-carbon sugar.
- Three different categories this type of method: C_3 pathway, CAM pathway, and C_4 pathway

C_3 Plants

- Found in areas with moderate temperature and above amount of rainfall
- Exacerbated in Hot arid climates, where the rate of photosrespiration increases as the temperature goes up.
- Consequently C_3 plants are rarely found in these climates
- Located in the temperate zones
- Examples: Wheat, barley, and sugar beets

C_4 Plants

- Use the enzyme PEP carboxylase to fix CO_2 in the mesophyll cells of their chloroplast.
- The fixed CO_2 is then shuttled to specialized structures known as bundle-sheath cells, where it is released and incorporated into the Calvin Cycle.
- Energetically expensive, but limits photorespiration by allowing high concentration CO_2 to build up in the bundle-sheath cells
- Examples: Corn and sugar cane are common in warm environments

CAM Plants (Crassulacean acid metabolism)

- Plants reduce photorespiration and conserve water by opening their stomata only at night.
- CO_2 enters through the stomata and is fixed into organic acids, which are then stored in the cell's vacuole .
- During the day, the acids break down to yield high levels of CO_2 for use in the Calvin cycle
- Common in dry environments
- Examples: Pineapples and cacti