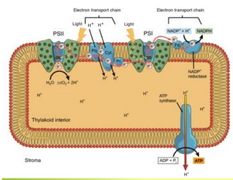
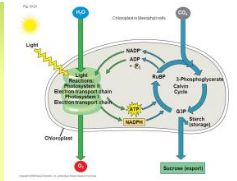
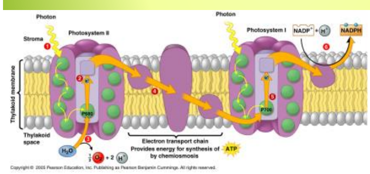
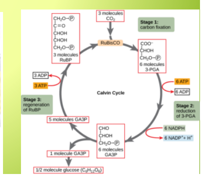
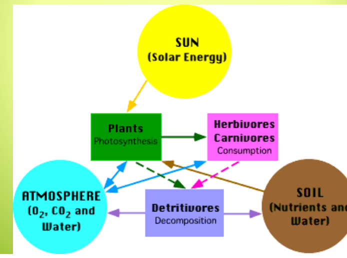



3.5 Photosynthesis

ENDURING UNDERSTANDING

ENE-1 The highly complex organization of living systems requires constant input of energy and the exchange of macromolecules



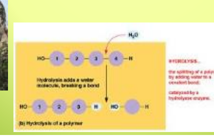
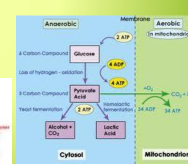
ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

- Organisms capture and store energy for use in biological processes
  - Autotrophs capture energy from physical sources in the environment.
    - Photosynthetic organisms capture energy present in sunlight.
    - Chemosynthetic organisms capture energy from small inorganic molecules present in their environment, and this process can occur in the absence of oxygen.



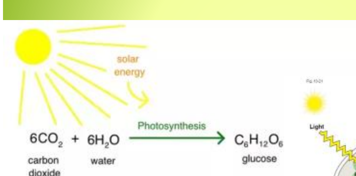
ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

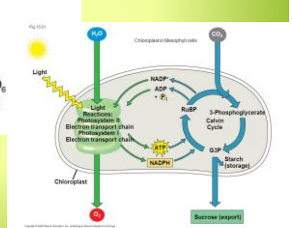
- Heterotrophs capture energy present in carbon compounds produced by other organisms.
  - Heterotrophs may metabolize carbohydrates, lipids and proteins by hydrolysis as sources of energy.
  - Fermentation produces organic molecules, including alcohol and lactic acid, and it occurs in the absence of oxygen.

ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

- Photosynthesis captures energy from the sun and produces sugars.

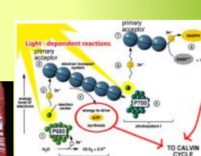




ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

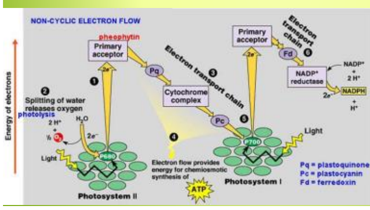
- Photosynthesis first evolved in prokaryotic organisms
- Scientific evidence supports that prokaryotic (cyanobacteria) photosynthesis was responsible for the production of an oxygenated atmosphere
- Prokaryotic photosynthetic pathways were the foundation of eukaryotic photosynthesis.

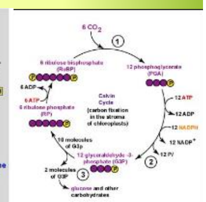




ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

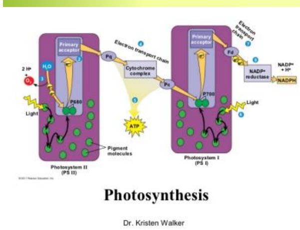
- The light-dependent reactions of photosynthesis in eukaryotes involve a series of coordinated reaction pathways that capture free energy present in light to yield ATP and NADPH, which power the production of organic molecules

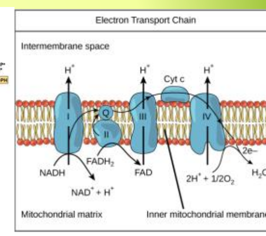




ENE-1.I Describe the photosynthetic processes that allow organisms to capture and store energy

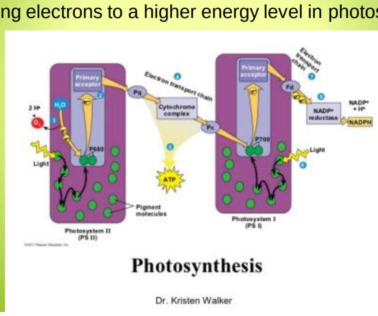
- Different energy-capturing processes use different types of electron acceptors.
  - $NADP^+$ in photosynthesis
  - NAD+ ,FAD, and Oxygen in cellular respiration





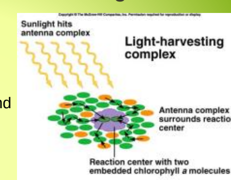
ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

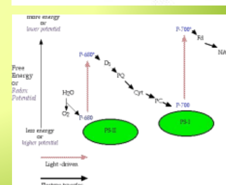
- During photosynthesis, chlorophylls absorb energy from light, boosting electrons to a higher energy level in photosystems I and II.



ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

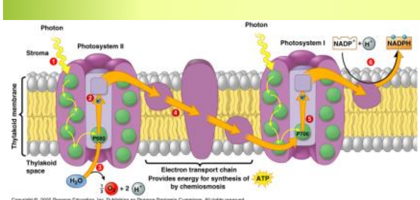
- Photosystems
  - A pigment complex and electron acceptor.
  - Pigment complex composed of chlorophyll a and b molecules, and carotenoids
  - Pigments absorb energy from light, boosting electrons to a higher energy level.
  - Energy is passed from one pigment molecule to another until wavelength is 680 or 700.

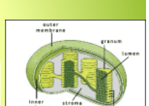




ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

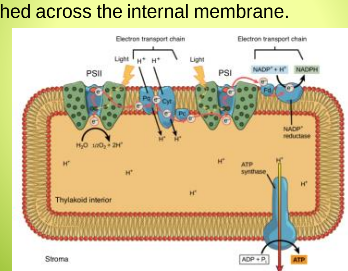
- Photosystems I and II are embedded in the internal membranes (thylakoids) of chloroplasts and are connected by the transfer of higher energy electrons through an electron transport chain (ETC).





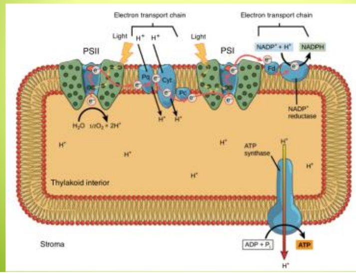
ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

- When electrons are transferred between molecules in a sequence of reactions as they pass through the ETC, an electrochemical gradient of protons (hydrogen ions) is established across the internal membrane.



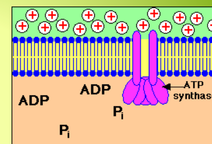
ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

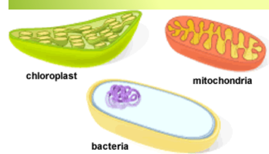
- The formation of the proton gradient is linked to the synthesis of ATP from ADP and inorganic phosphate via ATP synthase. (chemiosmosis)

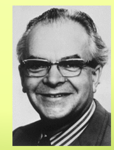


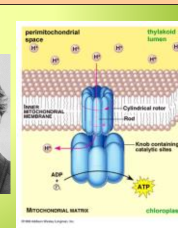
Chemiosmosis

- Proposed by Peter Mitchell(1961)
- H^+ ions flow from high to low concentration through ATP synthase
- ATP Synthase Complexes
  - Channel proteins that also serve as enzymes for ATP synthesis
  - Found in mitochondrial, chloroplast and prokaryotic cell membranes.



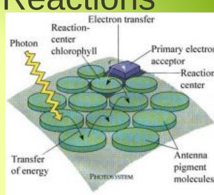


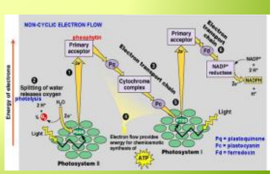




Light-dependent Reactions

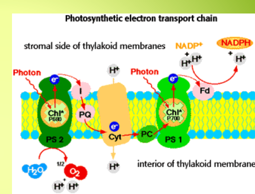
- Noncyclic Electron Pathway
  - The PS II pigment complex absorbs solar energy
  - High-energy electrons (e-) leave the reaction-center chlorophyll a molecule(P680)
  - PS II takes replacement electrons from H_2O, which splits, releasing O_2 and H^+
  - The H^+ ions temporarily stay within the thylakoid space.
  - High-energy electrons that leave PS II are captured by an electron acceptor, which sends them to an electron transport system.

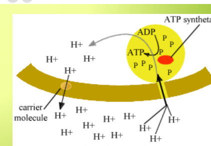




Light-dependent Reactions

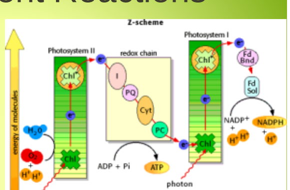
- ATP Production
  - The thylakoid space acts as a reservoir for H+ ions; each time H_2O is split, two H^+ remain.
  - As electrons move carrier-to-carrier, they give up energy to pump H^+ from stroma into thylakoid space.
  - Chemiosmosis occurs forming ATP in the stroma.

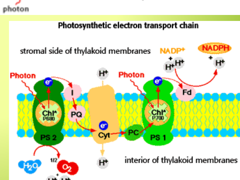




Light-dependent Reactions

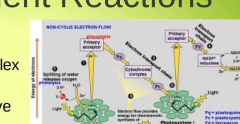
- Low-energy electrons enter PS I.
- High-energy electrons leave reaction-center chlorophyll a(P700) and are captured by an electron acceptor.
- The electron acceptor passes them on to $NADP^+$
- $NADP^+$ takes on $2H^+$ to become NADPH + H^+
- NADPH and ATP are used by enzymes in stroma during light-independent reactions.

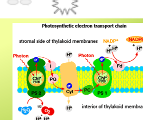




Light-dependent Reactions

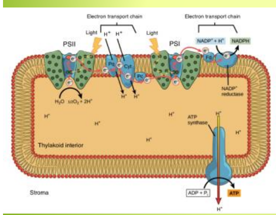
- Cyclic Electron Pathway
  - PS I (P700) pigment complex absorbs solar energy.
  - High-energy electrons leave PS I reaction-center chlorophyll a molecule.
  - Excess NADPH block it formation pathway
  - Electrons enter and travel down electron transport system producing extra ATP

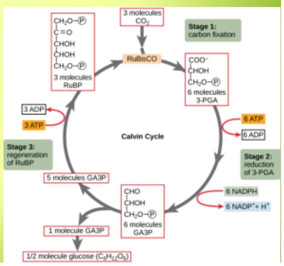




ENE-1.J Explain how cells capture energy from light and transfer it to biological molecules for storage and use

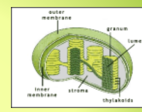
- ❑ The energy captured in the light reactions and transferred to ATP and NADPH powers the production of carbohydrates from carbon dioxide in the Calvin cycle, which occurs in the stroma of the chloroplast.

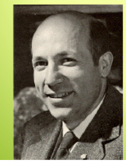


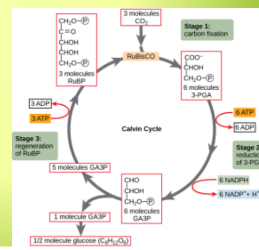


Light-independent Reactions

- Take place in the stroma
- Occur in either the light or the dark.
- Use NADPH and ATP to reduce CO_2.
- Called the Calvin Cycle (C3 Cycle) after Melvin Calvin

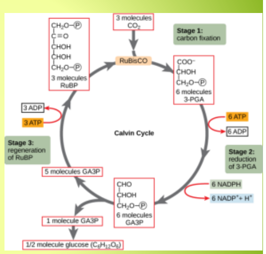






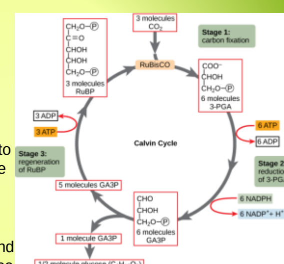
Light-independent Reactions

- Calvin Cycle Has Three Stages
  - Fixing Carbon Dioxide
    - The attachment of CO_2 to an organic compound.
    - RuBP (ribulose bisphosphate) is a five-carbon molecule that combines with carbon dioxide.
    - Enzyme RuBP carboxylase(Rubisco) speeds reaction
    - Rubisco is 20-50% protein in chloroplasts.



Light-independent Reactions

- Reducing PGA
  - Six-carbon molecule immediately breaks down
  - Forms two PGA (C3). Molecules (phosphoglycerate)
  - Each PGA molecule undergoes reduction to PGAL (glyceraldehyde phosphate).
  - Light-dependent reactions provide NADPH (electrons) and ATP (energy) to reduce PGA to PGAL.



Light-independent Reactions

- Regenerating RuBP
  - Every three turns of Calvin cycle, five molecules of PGAL are used to re-form three molecules of RuBP.
  - Every three turns of Calvin cycle, there is net gain of one PGAL molecule; five PGAL regenerate RuBP.
  - First molecule identified by Calvin was PGA [C3], a three-carbon product; Calvin cycle is also known as C3 cycle