Chapter 4

Is the Earth Warming? The Greenhouse Effect, Cellular Respiration, and Photosynthesis

1

4.1 The Greenhouse Effect

- _____, the increase in Earth's average temperature, contributes to…
- The _____ – the retention of heat due to the accumulation of specific gases:
  - Methane
  - Nitrous oxide
  - Water vapor
  - Carbon dioxide (CO_2)

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The Greenhouse Effect

- CO_2 (and other gases) accumulate in the atmosphere
- Less heat escapes to space
- More heat remains in the atmosphere

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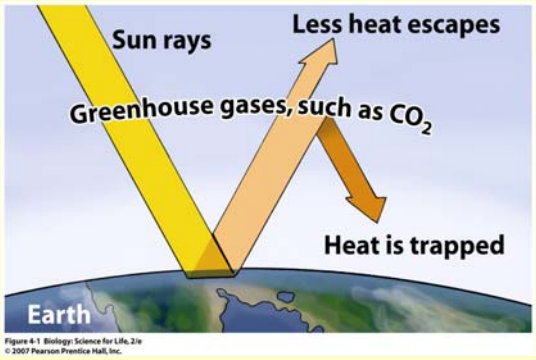

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The Greenhouse Effect

- It is important to have some greenhouse gases in the atmosphere
- If not, all the heat would escape and the planet would be too cold to support life

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Water, Heat, and Temperature

- Bodies of water absorb heat and keep temperatures stable
- Hydrogen bonds between water molecules are constantly breaking (absorbing heat) and reforming (releasing heat)

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Water, Heat, and Temperature

- _____ is the total amount of energy associated with the movement of atoms and molecules in a substance
- _____ is a measure of the intensity of heat

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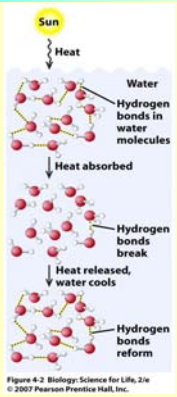

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Carbon Dioxide

- CO_2 is recycled between:
  - plants and animals
  - atmosphere
  - bodies of water
  - soil

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Carbon Dioxide

- Plants use energy from sunlight to produce organic molecules by the process of _____
  - Photosynthesis takes energy from the sun and turn it into energy in food
  - Photosynthesis also releases oxygen (O_2) into the atmosphere

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Carbon Dioxide

- In _____, plants and animals harvest energy from food and put it into ATP
- The metabolism of organic molecules by cellular respiration produces energy and water, as well as CO_2, which is put into the atmosphere

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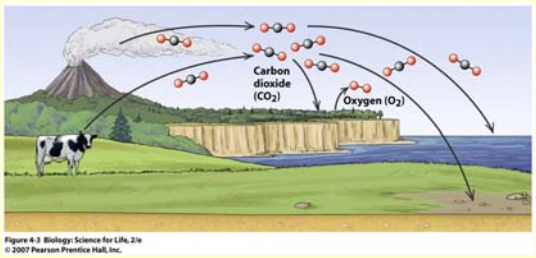

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Carbon Dioxide

- Burning of coal, oil, and natural gas (_____) are sources of extra CO_2

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Carbon Dioxide

- Energy also flows through organisms:
  - from the sun →
  - plants make food →
  - plants and animals use the food to make ATP →
  - Energy is lost as heat

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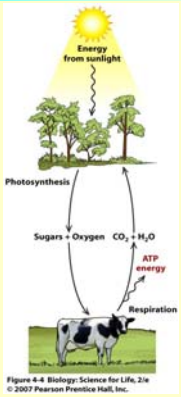

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Carbon Dioxide

- The oceans have served as Earth's largest carbon dioxide and heat reservoir
- But scientists question how much more can they hold (the oceans' ability to absorb carbon dioxide at the rate that it is being emitted into the atmosphere)
- Human activities have caused an increase in levels of carbon dioxide
- Mainly from burning fossil fuels

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Carbon Dioxide

- _____ is the buried remains of ancient organisms, mainly plants
- Heat and pressure have transformed the carbon into coal, oil, and natural gas which we use to generate electricity, gasoline, and home heating only
- Carbon dioxide levels have increased in the last 50 years
- Data indicate increases in CO_2 levels are correlated with higher temperatures

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Carbon Dioxide

- Past levels of carbon dioxide can be determined by looking at cores from ice sheets that have existed for thousands of years
- The snow on top of these ice sheets traps gas

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The Greenhouse Effect, Organisms, and Their Environment

- The effects of warmer temperatures are numerous…
- Glacier National Park, Montana
  - Glaciers are shrinking and disappearing
  - From 150 glaciers in 1850 to 35 glaciers in 2005
- Mount Kilimanjaro in Tanzania has lost 82% of its ice cap since 1912
- Greenland icecap is thinner every year
- Many ice shelves have collapsed in Antarctica

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The Greenhouse Effect, Organisms, and Their Environment

- Effects of higher temperatures on habitat can be seen in polar bears in Hudson Bay:
  - Loss of habitat for main prey, seals
  - Shorter time that ice will support bears' weight
  - Begin hibernating in poor condition
  - Average weight declining
  - Fewer cubs are born

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The Greenhouse Effect, Organisms, and Their Environment

- Species affected by climate change:
  - Temperature-sensitive species need to move
  - Artic fox are moving northward and are being replaced by red fox
  - Edith's checkerspot butterfly now in higher elevation
  - Corals are damaged – but they can't move

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The Greenhouse Effect, Organisms, and Their Environment

- Effects on climate:
  - Sea levels rose 4-8 inches in the 20th century due to melting ice
  - Increases in rain and snow
  - Increases in storms (frequency and severity)

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The Greenhouse Effect, Organisms, and Their Environment

- Scientists need to investigate how warming affects:
  - Average temperature
  - Rainfall amounts
  - Severity of storms
  - Biological processes

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4.2 Cellular Respiration

- Cellular respiration converts energy stored in chemical bonds into energy used by cells
- Cells use **ATP** (**adenosine triphosphate**) as their energy source
- ATP can supply energy to cells because it stores energy obtained from food

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The Structure of ATP

- A nucleotide made up of an adenine (base), sugar, and three negatively-charged phosphates
- The negative charges repel each other, contributing to the stored energy of ATP

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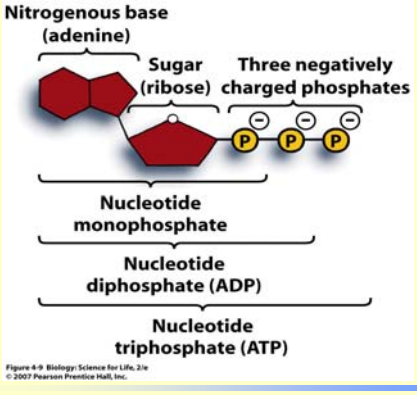

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The Structure of ATP

- When ATP (adenosine triphosphate) releases a phosphate, it becomes **ADP** (**adenosine diphosphate**)
- The phosphate released from ATP can be donated to another molecule (such as an enzyme) in a process called _____…

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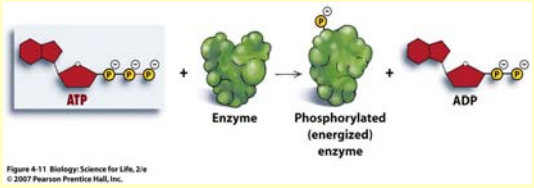

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The Functions of ATP

ATP helps carry out many functions in cells:

- Mechanical work – such as the movement of proteins in muscles
- Transport work – such as the movement of substances across membranes
- Chemical work – such as making complex molecules out of simple molecules

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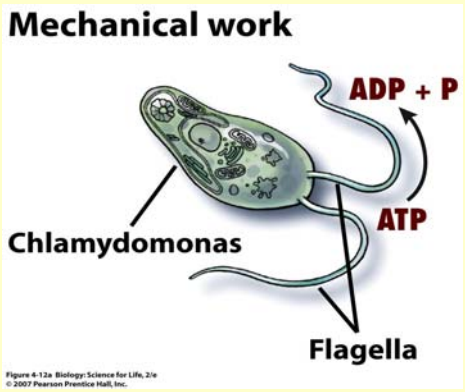

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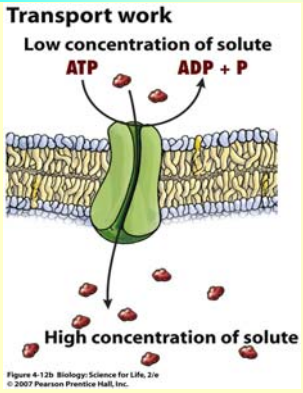

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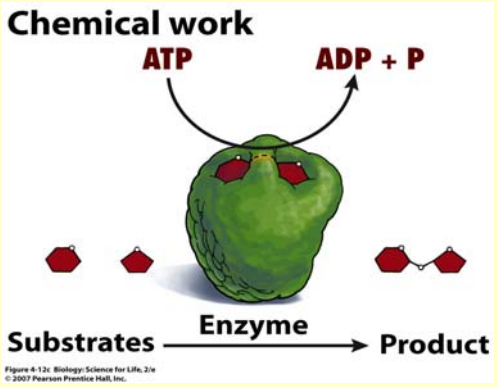

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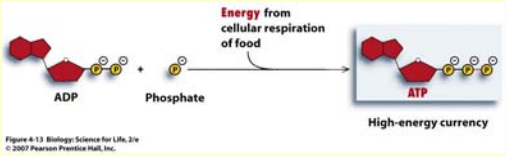
Cellular Respiration

- ATP is in high demand and is regenerated from ADP through cellular respiration



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Cellular Respiration

- Cellular respiration (also called _____) requires oxygen
- Humans breathe in to supply oxygen to their cells
- Exhalation gives off carbon dioxide, a waste product of respiration

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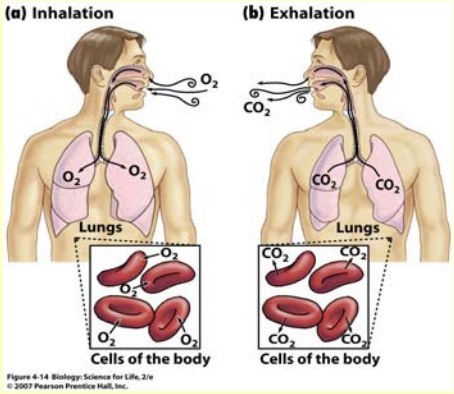

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A General Overview of Cellular Respiration

- All food is broken down to produce ATP
- Example: carbohydrates

The equation for carbohydrate breakdown:

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

glucose + oxygen → carbon dioxide + water

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Glycolysis, the Krebs Cycle, and Electron Transport

3 steps of cellular respiration:

- _____
- _____
- _____

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Glycolysis

- A 6-carbon glucose molecule is broken down into two 3-carbon **pyruvic acid** molecules
- Occurs in the fluid cytosol
- Does not require oxygen (is _____)
- Makes very little ATP (4 molecules)
- Hydrogens and their electrons are sent to the electron-transport system (ETS) for processing

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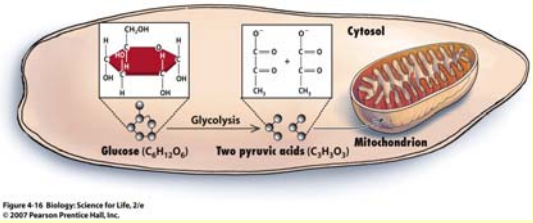

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Glycolysis

- After glycolysis, the two 3-carbon pyruvic acid molecules move into the mitochondria
- **Mitochondria** are organelles found in both plants and animal cells

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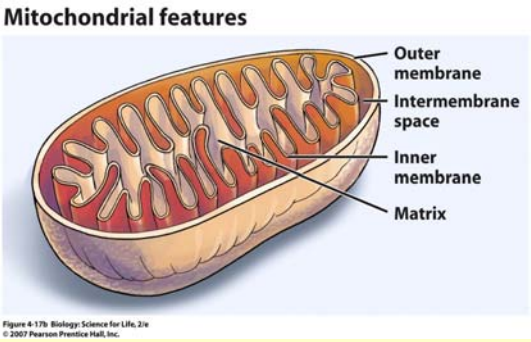

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Krebs Cycle

- The molecules move across the two mitochondrial membranes and into the matrix of the mitochondrion where the **Krebs cycle** begins

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Krebs Cycle

- The pyruvic acid molecules undergo many enzymatic steps in the mitochondrial matrix
- They are completely broken down
- The Krebs cycle strips them of carbon dioxide and electrons
- Carbon dioxide is released
- The hydrogens and their electrons are sent to the ETS for processing

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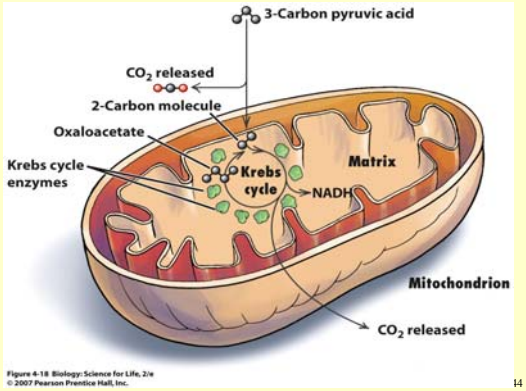

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Krebs Cycle

Where is the energy?

- The energy from the food is:
  - Directly put into ATP (1 molecule)

  Or:
  - Put into transport molecules
    - ✓NADH

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The Electron Transport Chain

- Series of proteins in the inner mitochondrial membrane
- Passes electrons down the chain and are picked up by oxygen
- Converts the energy of H electrons received from glycolysis and the Krebs cycle to the high-energy phosphate bonds of ATP
- The hydrogen ions and electrons are ultimately bonded to oxygen to form water

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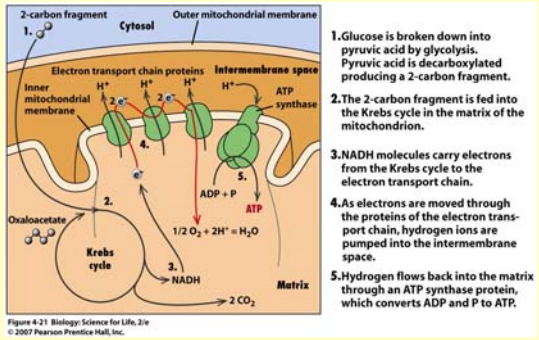

1. Glucose is broken down into pyruvic acid by glycolysis. Pyruvic acid is decarboxylated producing a 2-carbon fragment.
2. The 2-carbon fragment is fed into the Krebs cycle in the matrix of the mitochondrion.
3. NADH molecules carry electrons from the Krebs cycle to the electron transport chain.
4. As electrons are moved through the proteins of the electron transport chain, hydrogen ions are pumped into the intermembrane space.
5. Hydrogen flows back into the matrix through an ATP synthase protein, which converts ADP and P to ATP.

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The Electron Transport Chain

- Each molecule of glucose is broken down, resulting in carbon dioxide and water and ATP energy
- 32 ATP molecules are produced
- Overall, during cellular respiration, glucose is broken down into carbon dioxide and water, and 36 ATPs are produced

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Metabolism of Other Nutrients

- Proteins and fats are also food molecules that contain energy
- They are broken down, but not in exactly the same steps

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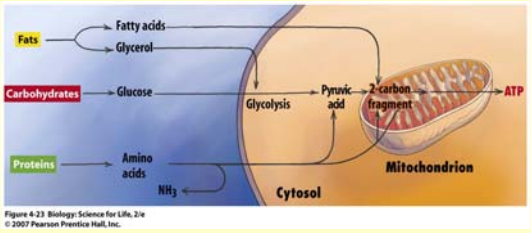

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Metabolism of Other Nutrients

- Fats are broken down into glycerol and fatty acids
- These enter the Krebs cycle to produce ATP as well as carbon dioxide and water
- Fats are broken down if carbohydrates are not available

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Metabolism of Other Nutrients

- Proteins are broken down into their component amino acids
- These amino acids can then be used to make other proteins
- If necessary, amino acids can be broken down for energy, but only if carbohydrates and fats are not available

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Global Warming and Cellular Respiration

- Increased global temperatures speed up the life cycle of the spruce bark beetle
- Beetles bore holes in bark of spruce trees causing the spruce trees to die

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Global Warming and Cellular Respiration

- Without cold winters, the spruce bark beetles continue to multiply
- Warmer temperatures make enzymes work faster, so metabolic processes work faster; beetles mature twice as quickly
- More beetles means more dead trees, which increases forest fires releasing CO_2 in the air and heat into the atmosphere

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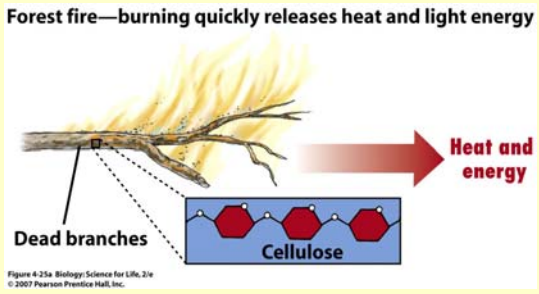

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Global Warming and Cellular Respiration

- Cellular respiration itself does not cause global warming
- The increase in carbon dioxide in the air may be caused by human activities like
  - Burning fossil fuels

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4.3 Photosynthesis

- Photosynthesis
  - Removes carbon dioxide from the air and turns it into sugar (food)

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

carbon dioxide + water + light energy → glucose + oxygen

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A General Overview of Photosynthesis

- The sun is the ultimate source of energy for our planet
- In photosynthesis, plants use light energy to rearrange the atoms of CO_2 and H_2O into carbohydrates

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A General Overview of Photosynthesis

- In land plants, CO_2 enters and oxygen is released through structures on the surface of the leaf called _____

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A General Overview of Photosynthesis

- Plants use the carbohydrates they produce to supply their cells with energy
- Plants—and the animals that eat them—liberate the energy stored in the chemical bonds of sugar through cellular respiration

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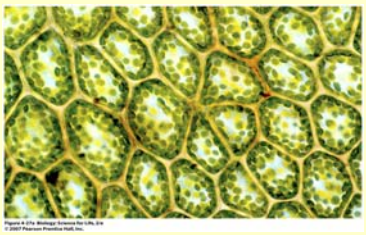
The Light Reactions and Calvin Cycle

- _____ are structures in plant cells that allow them to carry out photosynthesis



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The Light Reactions and Calvin Cycle

- Chloroplasts are comprised of:
  - outer membrane and inner membrane (together form the chloroplast envelope)
  - _____– a thick fluid that houses some of the enzymes of photosynthesis
  - _____ – disk-like membranous structures suspended in the stroma; called grana when in stacks

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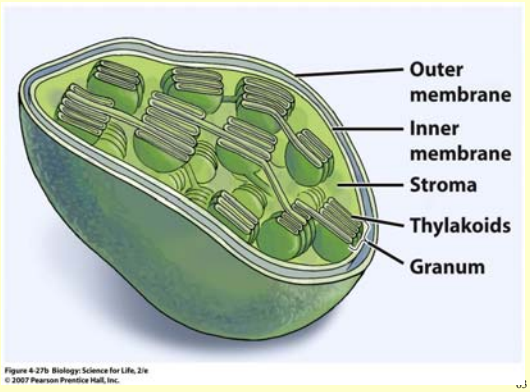

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The Light Reactions and Calvin Cycle

- Pigment molecules called chlorophyll are on the surface of the thylakoid membrane
- Chlorophyll molecules absorb and capture light energy from the sun
- Chlorophyll gives plants their green color

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The Light Reactions and Calvin Cycle

- Light is made up of rays with different colors, or levels of energy, and each energy level has a different wavelength
- Humans can see the visible light portion:
  - Longer wavelengths (red, orange, yellow); Shorter wavelengths (green, blue, indigo, and violet)

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The Light Reactions and Calvin Cycle

- In the fall, the leaves of deciduous trees (the ones whose leaves fall off) turn colors
  - The chlorophyll is broken down
  - The other pigments in the leaves reflect the red, yellow and orange wavelengths to our eyes

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The Light Reactions and Calvin Cycle

- Step 1: *photo-*
  - **Light reactions**
    - ✓_____
- Step 2: *-synthesis*
  - **Calvin cycle (dark reactions)**
    - ✓_____

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The Light Reactions

- Chlorophyll absorbs light energy
- Electrons are excited
- The excited electron is captured by a higher energy level

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The Light Reactions

- The electrons are transferred to an electron transport chain in the thylakoid membrane
- The electrons are passed down the chain
- A little bit of ATP is produced

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The Light Reactions

- The ATP made is released into the stroma for the Calvin cycle
- To replace the electrons that are used to make ATP, molecules of water are split into oxygen, H^+ and electrons

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The Light Reactions

- The electrons that travel down the electron chain end up in the energy transport molecule NADPH
- The NADPH is transferred into the stroma for the Calvin cycle

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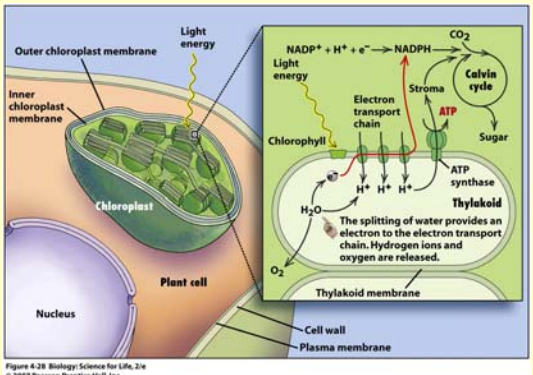

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Calvin Cycle

- The ATP and the NADPH in the stroma contain energy that will be transferred to sugar
- The Calvin cycle is a series of enzymes located in the stroma that uses the ATP and NADPH produced during the light reactions to convert CO_2 into sugars

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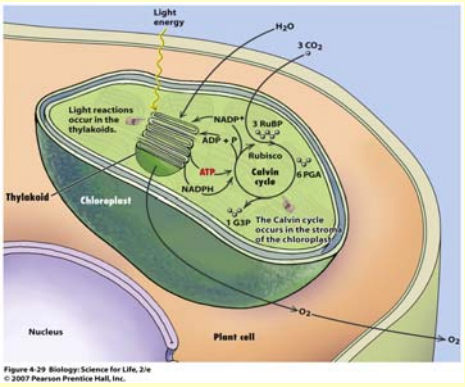

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Calvin Cycle

- The products of photosynthesis are the reactants for cellular respiration
- The products of cellular respiration are the reactants for photosynthesis

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Global Warming and Photosynthesis

Deforestation:

- Trees are cut for logging, farming, or development
- With fewer trees, less CO_2 is removed for photosynthesis
- CO_2 levels may rise in the atmosphere
- Replanting young trees may help increase the rate at which CO_2 is removed from the atmosphere because young trees have a faster net photosynthetic rate than older trees

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C_3, C_4, and CAM Plants

- Stomatal openings through which plant cells bring CO_2 into leaves are surrounded by _____ that open and close
- Water can also move through the stomatal openings in _____
- **Photorespiration** is a series of reactions triggered by the closing of stomatal openings to prevent water loss

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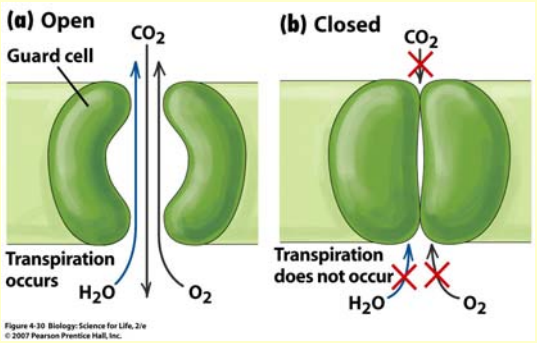

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C_3, C_4, and CAM Plants

- **C_3 plants** – normal photosynthesis; most abundant type of plant; includes soybeans, wheat and rice
- **C_4 plants** – live in hot climates; need to conserve water; can make sugar, but this takes more ATP than normal; avoid photorespiration; example - corn
- **CAM plants** – bring in CO_2 only at night; stored as acid until daytime; examples – jade plant and other succulent (water-storing) plants

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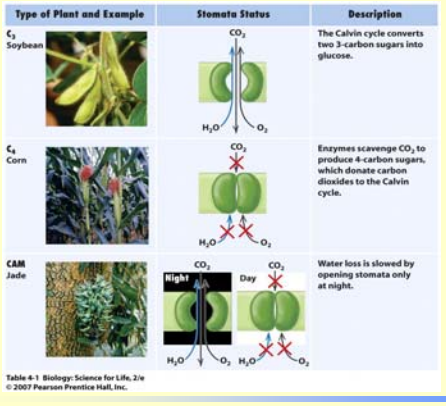

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4.4 Decreasing the Effects of Global Warming

- Since we all share the same planet, efforts to reduce levels of CO_2 emissions are looked at from globally as well as locally
- Some industrialized countries were among the highest emitters of CO_2 from 1990-1999…

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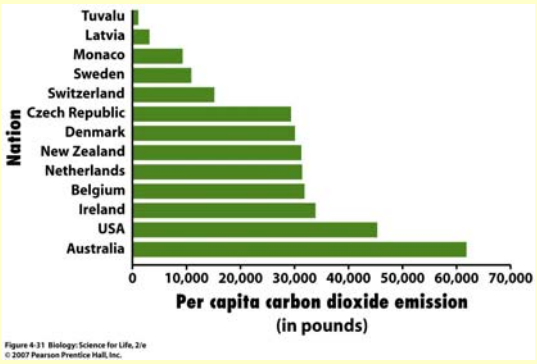

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Decreasing the Effects of Global Warming

- Most CO_2 emissions come from industry, followed by transportation, commercial, residential, and agricultural emissions
- About 2700 pounds of carbon per person per year comes from residential emissions and 2300 pounds from transportation
- Reductions on the individual level are possible…

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