Chapter 3:
Energy for Cells
What is considered the basic unit of life?

What is one thing that all cells require to maintain life?
Cells, Matter, and Energy

What is the Law of Conservation of Energy?

What do living things use to transform energy from one form to another?
Remember back to the life processes we looked at...

What was meant by *synthesis* and *decomposition*?

What about *assimilation*?
Cells, Matter, and Energy

What are the two major processes that are involved in transfer of energy throughout an ecosystem?

These are simply chemical reactions...

1) Define each of these processes based on what they do

2) Write the summary reactions for both of these processes in your notebooks
Cells, Matter, and Energy

Photosynthesis

Cell Respiration
Cells, Matter, and Energy

Photosynthesis

Cell Respiration
Conservation of energy states that energy cannot be created or destroyed. This diagram seems to indicate a loss of energy...explain how this is possible.
Read Pages 68-71

Define the following terms:

- Energy
- Potential Energy
- Kinetic Energy
- Chemical Energy
- Metabolism
Homework

Review Pages 68-71

Complete Questions #1-4 and 6-10 on page 72
Photosynthesis

Define photosynthesis, and write the summary reaction.
Photosynthesis and the Carbon Cycle

Draw a quick sketch of the major parts of the carbon cycle, including the role of photosynthesis.
Light

Wave Model: Light is a form of radiation, consisting of energy waves. The distance between peaks of a wave (wavelength) and the number of waves per second (frequency) determine the properties of the energy.

*Visible light* is a fairly narrow band within this spectrum, ranging from wavelengths of about 800 - 400 nm (nanometers).

White light consists of a mixture of all of these wavelengths. The color we perceive objects to be is a result of the light that is either absorbed or reflected from their surfaces.
Light
In this model, light is thought of as tiny particles, or "packets", of energy, called photons.

In this model, frequency is thought of as the amount of energy contained in an individual photon...the higher the frequency, the greater the available energy.

So, light with a higher frequency carries more energy than light with lower frequency.

(This can be seen easily when you look at penetration of light underwater.)
The Photon Model of Light

The deeper you go underwater, the more light is absorbed. Light with higher frequency (more energy) penetrates deeper than lower frequency light.

In the visible spectrum, which colors are lowest in frequency? Which colors would you lose first as you descend underwater?

What color would you expect objects to appear once you get into deeper water? (Still shallow enough that some sunlight reaches you.)
Loss of Color at Depth

In shallow water, most colors are still visible
Loss of Color at Depth

In deeper water, everything takes on a bluish-violet appearance.
If an object appears to be green, what does that tell us about the light that is striking that object?

What is a pigment?

If an object appears to be green, what does that tell us about the pigments that it contains?
Chloroplasts and Enzymes

Sketch the structure of the chloroplast.

Which part of the chloroplast contains the pigment *chlorophyll*?
Chloroplasts and Enzymes

What are enzymes?

How do enzymes function to control chemical reactions?
Chloroplasts and Enzymes

The "lock and key" model of enzyme action

Why are enzymes not considered "raw materials" in a reaction?
Stages of Photosynthesis

Photosynthesis is actually a series of reactions rather than a single process. We will be looking at a simplified version, but understand that in each of the steps we examine is in fact made up of several smaller steps.

The two main stages of photosynthesis are the *Light Reactions* and the *Dark Reactions*, or the *Calvin Cycle*.

The light reactions take place on the surface of the thylakoid membranes, while the dark reactions occur in the stroma.
Light and Dark Reactions

- Sunlight enters the chloroplast and is converted into chemical energy.
- Water (H₂O) is split to produce oxygen (O₂) and provide electrons.
- ATP and NADPH are produced during the light reactions in the grana.
- These energy carriers are used in the dark reactions (Calvin cycle) in the stroma.
- Carbon dioxide (CO₂) enters the chloroplast and is converted into glucose through the Calvin cycle.

Chloroplast

ATP, NADPH₂ (high energy)
ADP, NADP (low energy)
Light Reactions

The light reactions require sunlight energy.

As sunlight strikes chlorophyll on the surface of the chloroplast, the energy absorbed powers a reaction that breaks down a water molecule, releasing the oxygen.

The hydrogen from the water is split into protons and electrons. The electrons have absorbed the reaction energy, and are then passed along a series of carrier molecules on the surface of the thylakoid. This is called an electron transport chain.

Each time the electron is passed from one carrier to another, some of the energy it contains is lost.
Light Reactions

Illustrate the "hot potato" version of the ETC.
Light Reactions

The energy from the electrons is used to create high-energy molecules, such as ATP and NADPH \(_2\), in the stroma.

The light reactions consist of two of these electron transport chains, or *photosystems*; at the end of the first chain, the electrons are given back to a second molecule of chlorophyll, which absorbs sunlight and re-energizes them before sending them to the second electron transport chain. At the end of the second chain, the electrons are joined with the protons, creating more high-energy molecules.

A single thylakoid will contain many photosystems, all operating simultaneously.
Light Reactions

Summarize the light reactions:
Dark Reactions (Calvin Cycle)

The name dark reactions can be misleading. While the light reactions can only occur in sunlight, the dark reactions can occur without the presence of light, but darkness isn't necessary...this process is going on all the time.

12 sets of light reactions are required to provide enough high-energy molecules for each set of dark reactions.
Dark Reactions (Calvin Cycle)

These reactions occur in the stroma.

Six carbon dioxide molecules are absorbed from the air, and put together to form two molecules of PGAL, which are then combined to form a single molecule of glucose.

During this process, several other things happen:

• the high-energy molecules created during the light reactions are used up to power the reactions
• the hydrogens from the broken water molecules are added to the carbon dioxide, since glucose also contains hydrogen
• the excess oxygen and hydrogen are released as water (6 water released per cycle)
Photosynthesis

Summarize the stages of photosynthesis, and the major events that take place during each stage.
Dark Reactions (Calvin Cycle)

Let's add up all the parts:
*remember how many water were broken during the light reactions

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<th>Dark Reactions</th>
<th>TOTALS</th>
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Question #16, Page 81

Read this question and answer parts a, b, and c.
(a) At what temperature was the algae most active?
(b) What can be inferred from the fact that there was no change in color in the algae at 2 °C?
Question #16, Page 81

(c) How was the temperature related to the rate of photosynthesis in these algae?
Factors Affecting Photosynthesis

What other factors do you think might affect photosynthesis?
Cellular Respiration

What is cellular respiration?

Where does cell respiration take place in the cell?
Cellular Respiration

Draw the structure of the mitochondria.
Homework

Questions #1-5 page 85

1) List three activities that take place in the cell that rely on molecules of ATP

Any three activities that require the cell to use energy; for example:

- protein pumps;
- movement;
- digestion;
- endocytosis;
- running chemical reactions;
- making complex molecules (synthesis);
- etc.
Homework

Questions #1-5 page 85

2) Make a diagram of ATP and show how energy is released from this molecule.

ATP, or adenosine triphosphate, contains high-energy phosphate bonds. When the third phosphate is removed, the energy in the bond is released, and ADP (adenosine diphosphate) is produced.
3) What is glycolysis? Where does it occur?

Glycolysis involves splitting a molecule of glucose into two pyruvic acid molecules. This stage of cell respiration takes place in the cytoplasm.
4) Identify the main phases of cell respiration. Which of these produces the most ATP?

The four main phases of cell respiration are:

- Glycolysis
- Pyruvic Acid Breakdown (PAB) or the transition reaction
- Krebs cycle
- Electron Transport Chain (PAB)

The ETC produces most of the ATP
How is oxygen important for the release of energy in aerobic cellular respiration?

Oxygen acts as the final electron acceptor at the end of the ETC.

Oxygen will combine with the electrons and protons (hydrogen) to form molecules of water.
The process of cellular respiration can be divided into four stages, each occurring in a specific area within the cell.

1) Glycolysis

2) Pyruvic Acid Breakdown (PAB), also called the *transition reaction*

3) Krebs Cycle

4) Electron Transport Chain
Stages of Cellular Respiration

The process of cellular respiration can be divided into four stages, each occurring in a specific area within the cell.

1) Glycolysis - takes place in the cytoplasm. This is the breaking in half of glucose to form two molecules of pyruvic acid, or pyruvate.

   It does take some energy to start things off. At the beginning of glycolysis, two ATP are used to trigger the reaction. However, four ATP are produced at the end of glycolysis, for a total gain of two ATP.

   In addition, there are two other high-energy molecules formed, called NADH. These pass their hydrogens onto another molecule called FADH in the mitochondria. The hydrogens will be used later in the electron transport chain
Stages of Cellular Respiration

So, to summarize Glycolysis:

- glucose splits into two molecules of pyruvic acid, or pyruvate.
- *two* ATP used, *four* ATP produced; total gain:*two* ATP.
- *two* NADH₂ formed, which switch to two FADH₂
2) Pyruvic Acid Breakdown - also called the transition reaction.

This is a short stage that takes place as pyruvate is transferred from the cytoplasm and into the mitochondria.

CO₂ is released, and the two remaining carbons are joined to a coenzyme* to form Acetyl coenzyme-A, or acetyl CoA. In addition, another high-energy molecules (NADH ₂) are formed.

*(Remember though that PAB happens twice for every glucose, so really there are two CO₂ and two NADH produced by this stage!)*
Stages of Cellular Respiration

* A *coenzyme* is a molecule that allows, or helps, enzymes to control their chemical reactions. Many enzymes cannot act without the presence of a coenzyme.

Many vitamins act as coenzymes, which is why they are needed in the diet...without the vitamins, some of the enzymes that control cell function cannot operate correctly.
Stages of Cellular Respiration

So, to summarize Pyruvic Acid Breakdown:

- pyruvic acid moves into mitochondria
- CO2 given off (one per pyruvate, so 2 total)
- NADH2 formed (one per pyruvate, so 2 total)
- Acetyl CoA formed (2)
Stages of Cellular Respiration

3) Krebs cycle - takes place in the matrix of the mitochondria. This stage involves a cyclic reaction; a molecule oxaloacetate is joined to the acetyl CoA to form citric acid. (The Krebs cycle is also called the Citric acid cycle.)

A series of reactions happens, splitting this molecule apart; several other things happen as well:

- a single ATP is formed, as well as four other high-energy molecules (NADH 2 and FADH 2)
- two carbon dioxide molecules are released
- three water molecules are absorbed (remember hydrolysis?)
Stages of Cellular Respiration

At the end of the cycle, a new molecule of oxaloacetate is formed. (This is why it's called a cycle...the molecule you start with is reformed at the end, so it can be re-used.)

*Remember: two pyruvic acids are formed during glycolysis, so the Krebs cycle happens *twice* for each glucose.

So, in total, how many of each are used or formed:

**Water:** 3 used per cycle x 2 cycles = 6 water used

**Carbon dioxide:** 2 formed per cycle x 2 cycles = 4 CO₂ formed

**ATP:** 1 formed per cycle x 2 cycles = 2 ATP
So, to summarize Krebs Cycle:

- Acetyl CoA broken down
- CO2 given off (2 per cycle, so 4 total)
- Water used (3 per cycle, so 6 total)
- ATP formed (1 per cycle, so 2 total)
- NADH2 and FADH2 formed (4 per cycle, so 8 total)
Stages of Cellular Respiration

4) Electron Transport Chain - takes place on the *cristae* of the mitochondria. (Remember the light reactions in photosynthesis? They are also an ETC, and where do they happen? What does that tell you about ETCs?)

An ETC needs energized electrons. Where do these come from?

The high-energy molecules formed during PAB and Krebs cycle. These molecules release hydrogen, losing energy as they do. The hydrogens pass their electrons on to the ETC, and they are passed along the chain, losing a bit of energy with each transfer. In all, 12 of these molecules have been formed, each giving $H_2$.

This energy is used to form a total of 32 ATP molecules.
4) One final step needs to be explained...what happens to all of those electrons at the end of the ETC?

Remember where they came from? NADH₂ and FADH₂

Hydrogen atoms...at the end to the ETC, the electrons are joined up with the protons again to form hydrogen. However, hydrogen is a dangerous element to have around. The cell combines the hydrogen with oxygen to form water.

Since there were a total of 24 hydrogens passed to the ETC, 12 oxygens are needed to form a total of 12 H₂O...in other words, 6 O₂ molecules are used.
Stages of Cellular Respiration

By the way, you are NOT expected to remember this, but there is a reason only 32 ATP get made by 12 pairs of electrons running through the ETC... this is for those of you who realize that 32 doesn't divide by 12.

There are actually two ETCs...one takes the electrons from NADH, the other from FADH₂. Each pair of electrons from a NADH results in 3 ATP being produced, while each FADH₂ results in only 2 ATP.

If you add them all up, there were a total of four FADH₂ and a total of eight NADH₂.

So,

4 FADH₂ x 2 ATP per FADH₂ = 8 ATP
8 NADH₂ x 3 ATP per NADH₂ = 24 ATP

8 + 24 = 32 ATP from the ETC
Summary of Cell Respiration

- **Glycolysis**: Glucose to NADH2 and ATP
- **Krebs Cycle**: Acetyl CoA to NADH2 & FADH2, ATP, CO2, O2
- **Electron Transport Chain**: NADH2 & FADH2 to ATP, H2O
## Summary of Respiration

Complete the following chart:

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## Summary of Respiration

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Homework

Review Section 3.3 on Aerobic Respiration.

Practice writing out the stages in order, including the major steps of each

Be prepared to review all steps on Tuesday.

Mr. Higginbotham will be available for help during noon hour on Monday...there are no classes due to career day, but anyone who would like to spend some time reviewing is welcome to bring lunch up to the room and run through the stages or ask questions.