Photosynthesis, Cellular Respiration, & Fermentation

You've already learned a little bit about photosynthesis thanks to our study of plant cells. You learned that photosynthesis happens in the chloroplasts that are found only in plant cells. Let's think about what else you've already learned.

You've already learned that there are two basic types of organisms when it comes to food: producers and consumers. Producers are able to make their own food. Consumers get the food they need by eating other organisms. You learned that only plants are producers, and that they make their own food by combining water (H_2O), carbon dioxide (CO_2) and energy from the sun to produce sugar ($C_6H_{12}O_6$) and oxygen (O_2). This process, you learned, is called photosynthesis. In the process of making sugar, plant cells also lock some of the energy they collected from sunlight into the sugar molecule.

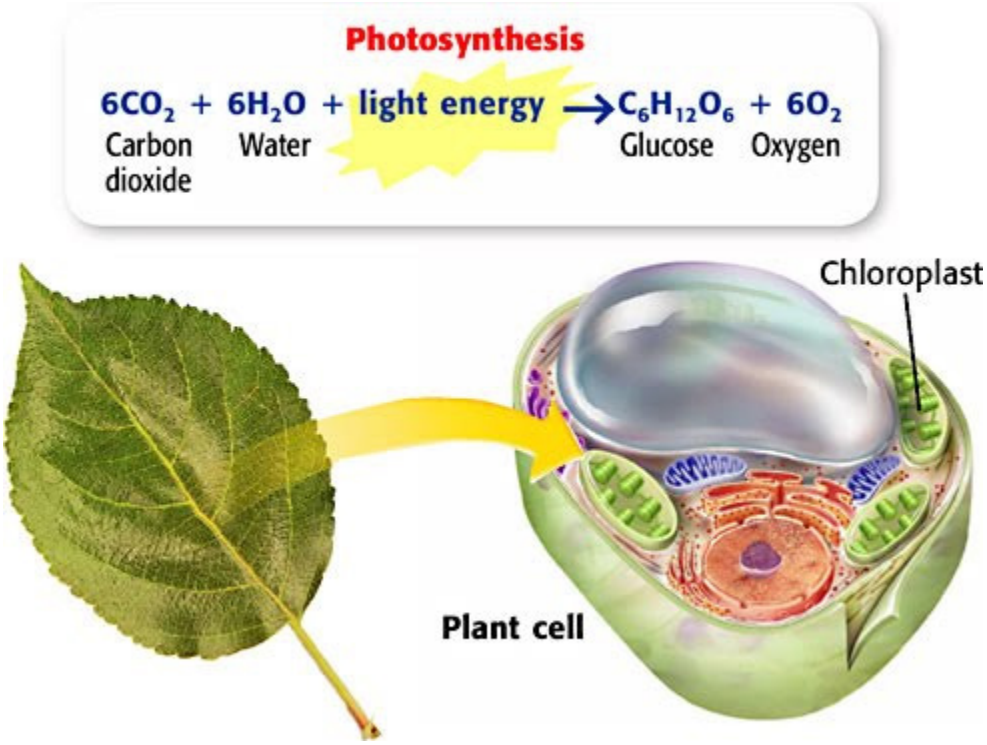
Okay, great. So how do cells (remember, both plant and animal cells need energy, and neither can directly use the energy provided by the sun) get the energy out of the sugar molecule? They do it with a process called cellular respiration. In cellular respiration, cells use oxygen to break the sugar molecule. That releases the energy which is then transferred to an ATP (adenosine triphosphate) molecule. ATP is the fuel that cells need for energy. And where does cellular respiration happen? As you've learned, it happens in those handy mitochondria.

So really, you already know all the basics. There are just a few details that you need to learn, and they are covered in Section 1 of Chapter 5 in your textbook and, of course, right here. Let's start with photosynthesis

Photosynthesis

If you were to look at plant cells under a microscope and compare them to animal cells, there are two things that you would notice immediately. First, you would notice the cell wall that surrounds the plant cell. You would notice it the same way that Robert Hooke noticed it. The second thing you would notice is that a plant cell is green and an animal cell is basically clear. If you were looking at a relatively large plant cell, and you were using a microscope like the ones we have at school, you would notice that not the entire plant cell was green. Instead, you would notice that there were large green objects inside of the plant cell. These large green objects, of course, are chloroplasts. And the reason that they are green is because they contain a green pigment called chlorophyll.

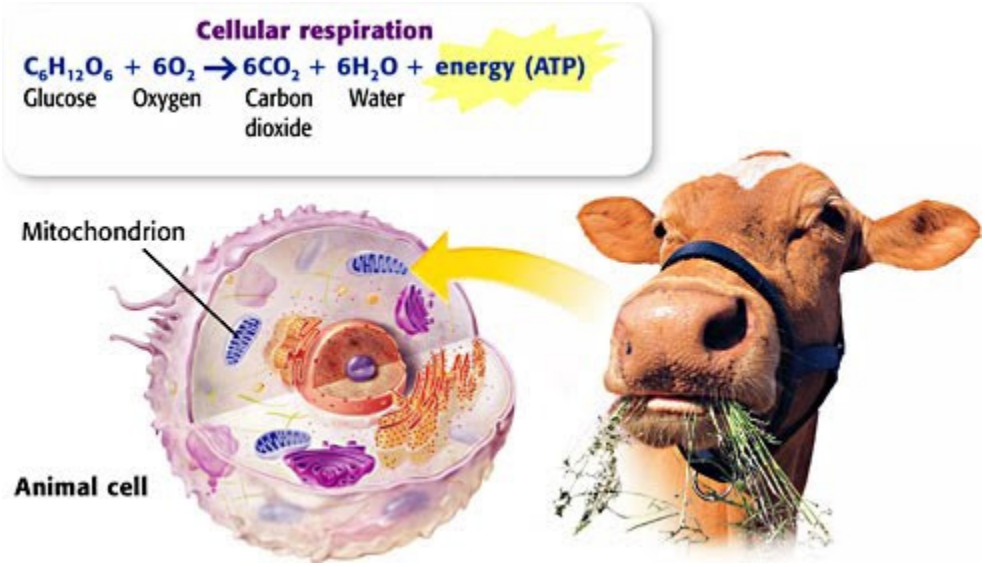
Have a look at this illustration from your book:



Do you notice how the chemical formula that defines photosynthesis looks a little different from the way you originally learned it? Instead of $CO_2 + H_2O$ + light it shows $6CO_2 + 6H_2O$ + light. That's because chemical equations, just like math equations, have to balance. The original formula takes one carbon atom (that's how many carbon atoms are in CO_2), 2 hydrogen atoms (that's how many hydrogen atoms there are in H_2O), and 3 oxygen atoms (2 that are in CO_2 and one that is in H_2O) and turns it into glucose (which contains 6 carbon atoms, 12 hydrogen atoms, and 6 oxygen atoms) and an oxygen molecule (O_2, which contains 2 oxygen atoms). That just doesn't add up! You can't magically turn 1 carbon atom from CO_2 into 6 carbon atoms in $C_6H_{12}O_6$. But if you do the math with the formula in the illustration above, you'll see that the number of atoms of carbon, oxygen, and hydrogen on both sides of the equation are correct. You will get way more practice balancing chemical equations when you study chemistry in 8th grade science.

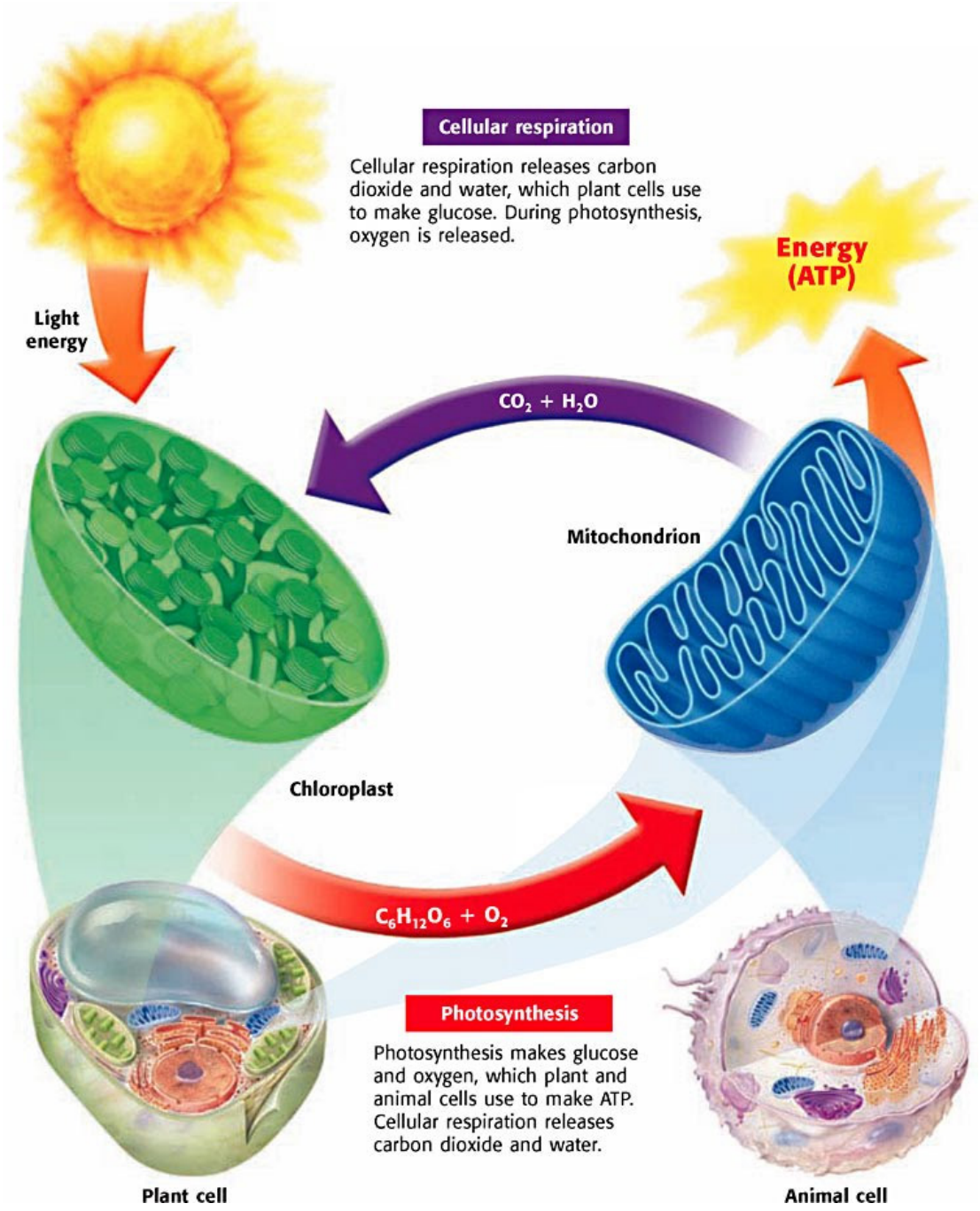
Cellular Respiration

It is tempting to think of cellular respiration as the opposite of photosynthesis. If you look at the illustration from our book, below, you'll see why:



Do you see the way the chemical formula for cellular respiration is the reverse of the chemical formula for photosynthesis? The only real difference is that in one, the energy is sunlight and in the second, the energy is the ATP molecule. It's that reversal that makes many people think of photosynthesis and cellular respiration as being opposites. They are not! Rather, they are complementary to one another. Without photosynthesis, there would be no sugar, without which there could be no cellular respiration. On the other hand, cellular respiration produces the H_2O and CO_2 that are needed for photosynthesis. It's really important for you to remember that cellular respiration in eukaryotic cells takes place in the mitochondria. Both animal cells and plant cells depend on cellular respiration for their energy needs, because both animal cells and plant cells need ATP. Plant cells may be able to use the energy from the sun to make sugar, but they can't use the sun's energy as fuel. They need ATP the same way that animal cells do, and ATP can only be formed through cellular respiration.

The illustration below from your book shows the way that photosynthesis and cellular respiration complement each other.



Do you see what I don't like about this illustration? Is it clear from this illustration that plant cells also have mitochondria? Not clear enough, in my opinion! So remember! **Plant cells have mitochondria, too!**

Fermentation

What happens when there is not enough oxygen to keep the cellular respiration reaction alive? Your book makes it seem like the answer is very simple. Let's start with the simple answer in your book. If there is not enough oxygen for cells to perform cellular respiration, they resort to another method of producing energy called fermentation. They still break down the sugar molecule to release the energy so that it can be transferred to an ATP molecule, but they do it without oxygen. In cellular respiration, CO_2 and H_2O are produced along with the energy. In fermentation, CO_2 and something called lactic acid are produced. Just like your book explains, you've probably experienced fermentation yourself when you've had to run the Wednesday mile and you've really pushed yourself to get a good grade. You know that burning or stinging sensation that you feel in your muscles when you push yourself running? That's caused by a buildup of lactic acid in your muscles. No matter how hard your lungs and heart work to get oxygen to the cells in your leg muscles, they still aren't getting enough to produce all the energy they need through cellular respiration. So, they are forced to switch to fermentation, and lactic acid is produced.

There are some organisms that get all of their energy needs from fermentation. One common example is yeast. Yup. That same stuff that you drop into the bread maker. You should have noticed that there were lots of bubbles in the tubes containing the yeast and sugar water in our classroom. You've already seen live yeast cells in class that I projected from a microscope to the screen. A few classes got lucky and were able to see some yeast cells that were in the process of reproducing. I know you're going to be happy to hear this: yeast cells reproduce by budding! Just when you thought it was safe to forget all about budding and the pain it has caused you on past tests, it's back!

So how does yeast make bread rise? It's pretty simple, really. Bread is made mostly of flour. You probably already know that bread is "carbs", or carbohydrates. Do you remember what carbohydrates are? That's right, they are just long strings of sugar molecules. Yeast uses those sugar molecules to get the energy it needs, and in the process it creates CO_2. That CO_2 makes bubbles inside of the bread dough, and those bubbles make the dough get larger, or rise.

There is another way that fermentation caused by yeast is important. Grape juice also contains a lot of sugar. When yeast is added to grape juice, it uses the sugar for energy. Yes, it produces CO_2, but it also produces alcohol. That's how grape juice is turned into wine!

The Global Warming Connection

Remember An Inconvenient Truth, the Al Gore documentary movie? One of the scenes in the movie showed the earth at night as photographed from space. Vice President Gore said that the large red areas were forests burning. There are plenty of naturally-occurring forest fires, but humans purposely set forests ablaze, too. In Brasil, for example, parts of the rainforest are burned to create more land for crops and housing. Think about what this means for global warming.

Global warming is caused by too much carbon dioxide in the atmosphere. The carbon dioxide acts as a blanket. When sunlight hits the earth, it can't radiate back into space because of the carbon dioxide and other greenhouse gases that are present in the atmosphere. So, the earth gets hotter.

Burning forests is a double-whammy. First, removing trees means that they aren't there anymore to convert carbon dioxide into sugar and oxygen. Second, when we burn the trees, we are releasing all of the carbon dioxide that they have collected. When mitochondria combine glucose with oxygen to produce energy, they are "burning" the sugar through a process called oxidation. There are many examples of oxidation in real life. When a nail gets rusty, that's oxidation. And, of course, when something burns, that's oxidation, too. The only difference between rusting, burning, and the way that mitochondria release the energy from a glucose molecule is the speed of the reaction. Rusting is very slow oxidation and burning is very fast oxidation. So burning the sugar in the trees is just a very fast version of what mitochondria do: the sugar releases carbon dioxide and energy in the form of heat. Some trees have been alive for hundreds or even thousands of years! So when we burn them, we are releasing hundreds or thousands of years worth of "captured" carbon dioxide.

Conclusion

That's it, folks. If you can remember the chemical formula for both photosynthesis and cellular respiration, if you can explain how the two processes complement one another, and if you can explain what happens when there is not enough oxygen for cellular respiration, then you've learned what you need to have learned.

Videos

These videos will help you to understand photosynthesis and cellular respiration. Don't be afraid of the complicated scientific vocabulary! You will understand more than you think if you just stop once in a while and try to make a connection between what is going on in the video and what you have already learned.

Photosynthesis
https://www.youtube.com/watch?v=g78utcLQrJ4
Cellular Respiration
https://www.youtube.com/watch?v=Py4R_Up2uBc

L.A. Unified School District teacher
https://sites.google.com/site/mochebiologysite/online-textbook/photosynthesis