Welcome to the basics lecture on cellular respiration

Unit 3
Lecture 11: Cellular respiration

This video provides the content for your “Basics” class notes. It moves quickly, so pause it often while you write. Bring your notes to class.
As we said in the last lecture, glucose is a molecule with high-energy electrons. You can think of both respiration and photosynthesis as making up a single cycle – The high energy electrons in glucose are used to make ATP in the mitochondria, and then placed on water. The low energy electrons on water are excited back to high energy in the chloroplast, and placed back onto carbon to re-make glucose. We’ll do the first half of the cycle today, and the other half in our next lecture.
Moving electrons from glucose to the more electronegative oxygen releases a lot of energy. The many steps in cellular respiration are used to control the reaction and produce ATP.
This is the overview of all the reactions. Go to chapter 9 in your book now and fill in these boxes.

There are three major steps in respiration: glycolysis, citric acid cycle, and oxidative phosphorylation. Notice only glycolysis occurs outside the mitochondria.
We have an organelle to talk about before we begin the biochemistry. The mitochondrion is an organelle that has a double-membrane, like the nucleus. The outer membrane is smooth; the inner membrane has folds called cristae. There are two important fluid spaces in the mitochondrion. The very middle is called the matrix, and the fluid between the membranes is called the intermembrane space.
In this class, we are not interested in memorizing all of the intermediates and enzymes. There will be time for that in your biochemistry course. Instead, I want you to know the following about glycolysis:

1. It occurs in the cytosol, outside of the mitochondrion.
2. Glucose has some electrons removed.
3. Electrons are placed on an electron shuttle called NAD+ to make NADH.
4. Some ATP is made by substrate level phosphorylation.
5. The end product, pyruvate, is transported into the mitochondrion.
Glycolysis is the first place where we see our electron shuttle, NAD+. Here is the structure, although you don’t need to memorize it. Just recognize that it has a “plus” form, and then, once it picks up two electrons and a hydrogen from glucose, it is reduced and called NADH. This molecule will pick up electrons at several steps and deliver them to the electron transport chain.
The other aspect of glycolysis that is interesting is it makes a small amount of ATP. Not very much, because it is just moving a phosphate or two off the intermediates and onto ADP. Because this uses an enzyme only, it is called substrate-level phosphorylation.
Here is a small example from the middle of glycolysis. In the first reaction, NAD+ picks up a couple of electrons and becomes reduced. That reaction provides enough energy to add a phosphate group to the 3-carbon sugar in the middle. In the next reaction, the breaking of the phosphate bond is used to place the phosphate onto ADP, making ATP.

Enzymes are required for both of these reactions.
Now, let's look at the side road of fermentation. This is a two-step process that includes glycolysis, as we have seen already, and then a reversing of the reaction where the electrons that were removed from pyruvate are put right back onto it. The resulting molecule in mammals is lactate.

We most commonly think about fermentation occurring in situations without oxygen. We will discuss this in more detail, plus give exceptions, when we talk in class. For now, you should just be able to follow the electrons from glucose, to NADH, to lactate.
Normally, pyruvate is not turned into lactate, but is transported into the mitochondria to enter the citric acid cycle. Here is what you should learn:

1. It occurs in the matrix of the mitochondria
2. Pyruvate, which is a 3-carbon sugar, is fully oxidized to carbon dioxide.
3. The electrons are placed on the shuttles called NAD+ and FAD
4. And again, a bit more ATP is produced by substrate level phosphorylation.
Other Fuels

1. Only carbohydrates go through glycolysis.
2. Fats and proteins enter cellular respiration at the end of glycolysis or the citric acid cycle.

This scary figure shows that different foods enter cellular respiration in different locations. You don’t need to know the details – just know this:
Only carbohydrates enter at glycolysis.
Both proteins and fats enter later, at the end of glycolysis or the citric acid cycle.
Finally, the third step is oxidative phosphorylation, the big payoff phase. It is here that all of the electrons carried by the shuttles are put to use. Let’s have a look at how that works.
Oxidative phosphorylation occurs on proteins that are located on the inner membrane of the mitochondria.
One side of the chain is exposed to the matrix, the other is facing the intermembrane space.
The proteins are called the electron transport chain.
In the first step, NADH deposits its high-energy electrons on the first protein in the chain. The energy released when the electrons drop to a lower energy state is used to pump hydrogen ions into the intermembrane space.
The next protein accepts electrons from FADH2. Again, the energy released by the electron falling to a lower state pumps more hydrogen ion.
At the end of the transport chain, the electrons have become very low energy, and are allowed to bond to oxygen to form water, a low-energy reduced molecule.

All the hydrogen ions are allowed to move back across the membrane from high to low concentration through a final protein called ATP synthase. The energy provided by the protons is enough to bind a phosphate group to ADP, creating ATP. This process is called chemiosmosis.
Finally, I don’t want you to memorize how many ATP or NADH are made at each step. But I do want you to recognize that the majority of ATP occurs via chemiosmosis, rather than by the substrate level phosphorylation that occurs in glycolysis and the citric acid cycle.
This completes our basics video for today.
Write out the answers to the following questions to study for the basics quiz.

Prep for Basics Quiz

Do you know the following?

• Structure of a mitochondrion
• The location and products of glycolysis
• The location and products of the citric acid cycle
• The location of the electron transport chain
• The function of electron shuttles and electron transport
• The differences between substrate level phosphorylation and chemiosmosis
• Where the majority of ATP is produced in respiration
• The basics of fermentation