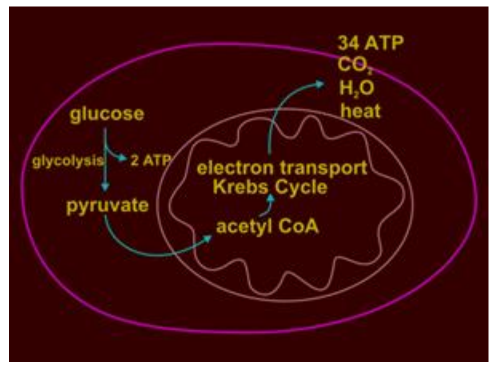
Fascinating Education Script
Fascinating Biology Lessons

Lesson 7: Take in Energy - Part 3

Slide 1: Introduction

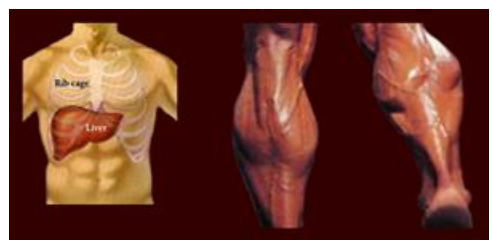
Slide 2: Storing glucose



Before glucose enters a cell and travels through glycolysis and then through the Krebs cycle, the electron transport chain, and oxidative phosphorylation, where was the glucose?

Where did it come from?

Obviously glucose comes from food, but we can't depend on finding food every time we need glucose. There must be a way to store glucose in the body and to tap those reserves when we need them. There is.

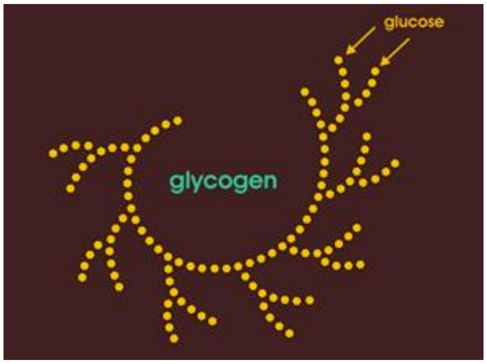


Glucose is stored in two main places the liver and muscles.

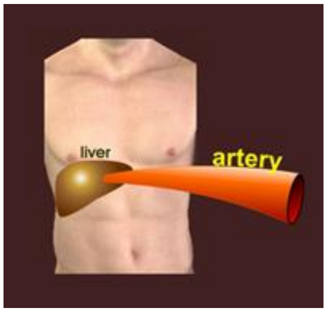
Slide 3: Muscles need a supply of glucose

It makes sense that muscles would have their own supply of glucose, because they need their own supplies of glucose. The last thing muscles want during an emergency is to have to wait for the blood to start delivering glucose from some distant location.

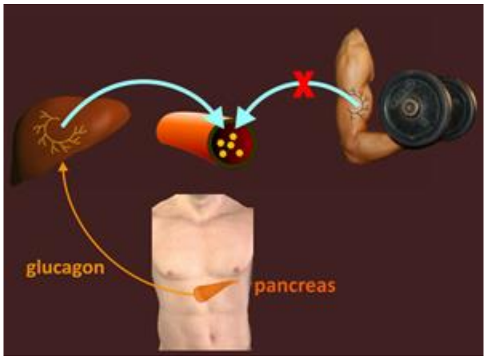
Slide 4: Glycogen



Glucose stored in the liver and in muscle is not stored as individual glucose molecules. Instead, individual glucose molecules are linked into a long, branching chain called glycogen. When the muscles need quick energy, they just snip molecules of glucose off their own glycogen. Those molecules of glucose stay in the muscles. None of them gets into the blood stream.



If some other organ besides muscle needs glucose, molecules of glucose have to be snipped off glycogen in the liver and released into the blood stream.

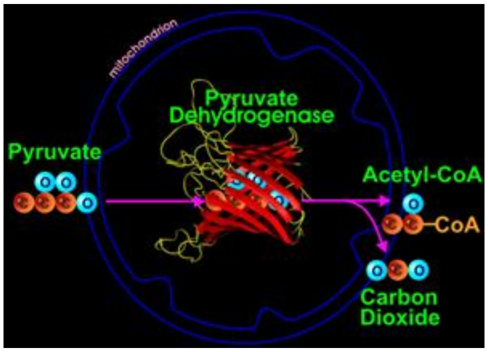


So while the muscles have their own private stock of glucose, the rest of the body has to make do with glucose delivered from the liver via the blood stream.

The signal to break down glycogen in the liver into individual glucose molecules is a short peptide called "glucagon." Glucagon is synthesized in the pancreas and released when the blood sugar falls below about 90 mg of glucose per 100 ml of blood.

Slide 5: Glucose and the cell

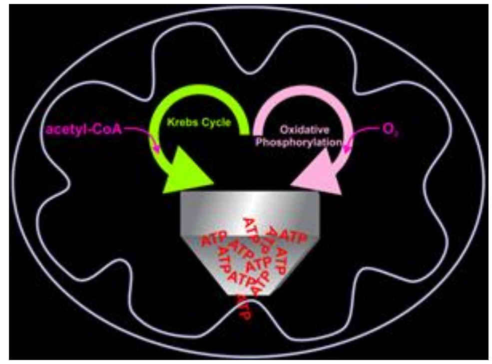
When glucose reaches a cell, it is immediately broken down into two pyruvates before entering the mitochondrion.



Each pyruvate is 3 carbons long. When pyruvate enters the mitochondrion, a huge enzyme grabs it. This enzyme, called pyruvate dehydrogenase, removes one of pyruvate's carbons and two of its oxygens to form CO_2, which we breathe out into the air.

What's left, though, is a 2 carbon molecule called acetyl which has been attached to coenzyme A. It is acetyl-CoA that enters the Krebs cycle.

Slide 6: Fat for energy

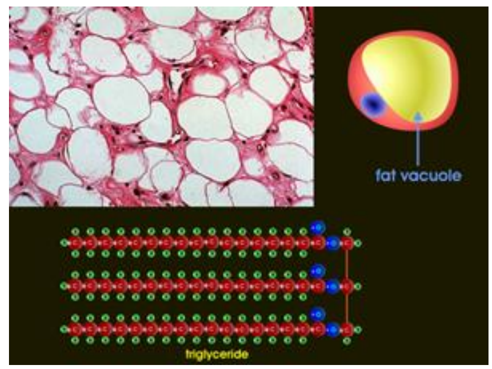


Inside a mitochondrion, the Krebs cycle and oxidative phosphorylation, working together, make gobs of ATP.

The Krebs cycle uses acetyl-CoA while oxidative phosphorylation uses oxygen. Now what difference does it make to the Krebs cycle where it gets acetyl-CoA? None whatsoever.

While glucose is a good source of acetyl-CoA, anything that can deliver 2-carbon fragments of acetyl-CoA would do, even fat.

Slide 7: Fat cells under a microscope



Here is a slide of fat cells.

Those large white areas are sacs, or vacuoles, that used to contain fat. The fat was washed away in the process of making the slide. Fat is a triglyceride consisting of a three long chain fatty acids connected to three carbon atoms from glycerol.

Combined, they form a triglyceride.

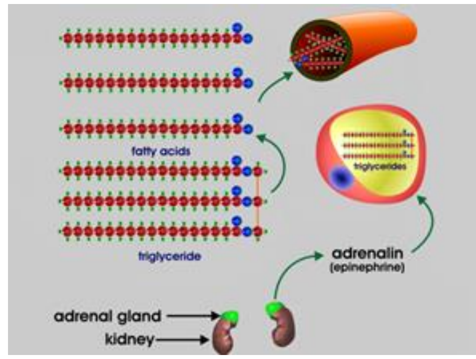
Do you see how easy it would be to chop the fatty acids into two-carbon fragments and attach them to coenzyme A?

Slide 8: Epinephrine

It might be easy to do, but something has to tell a fat cell to break apart its triglycerides. So when the body needs a sudden burst of energy to dunk a basketball, or when suddenly afraid and needing to escape, the adrenal glands, which sit right on top of the kidneys, release adrenalin into the blood stream.

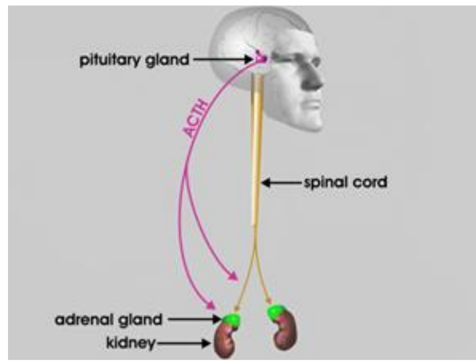
Adrenalin, or its other name, epinephrine, tells fat cells to break apart its triglycerides into fatty acids and release them into the blood stream.

Muscle cells pick up the fatty acids, chop them into two carbon fragments to make acetyl-CoA, and from there into ATP.



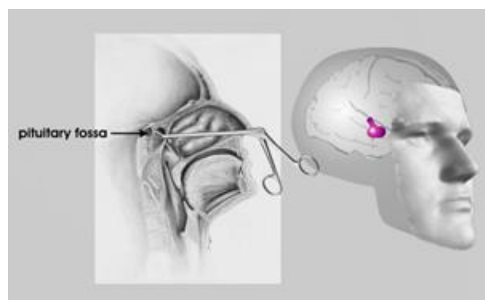
In times of emergency, getting fatty acids into the blood stream is, well, an emergency. There's no chance to make a mistake, so the body uses two simultaneous signals to the adrenal glands to release adrenalin. Both signals originate in the brain because the brain is what senses the need for quick action.

One of the brain's signals shoots down the spinal cord and into nerves supplying the adrenal glands.



The other signal stimulates the pituitary gland at the bottom of the brain to release a hormone into the blood stream. The pituitary hormone is formally known as adrenocorticotropic hormone but, nobody can pronounce it so we just call it ACTH. ACTH tells the adrenal glands to release adrenalin.

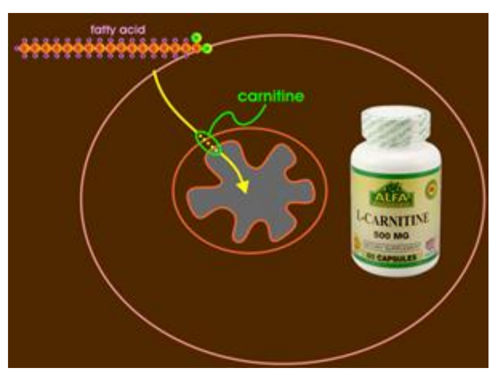
The pituitary gland controls not only the adrenal glands but also the thyroid gland, the reproductive system, and growth.



The pituitary gland is so important that it's protected in its own cubby hole of bone called the pituitary fossa.

As protected as the pituitary gland is, if it ever develops a tumor or infection, surgeons can get at the pituitary gland by going through the nose and drilling through the bone at the back of the nose to snip out the tumor or drain the infection. Cool!

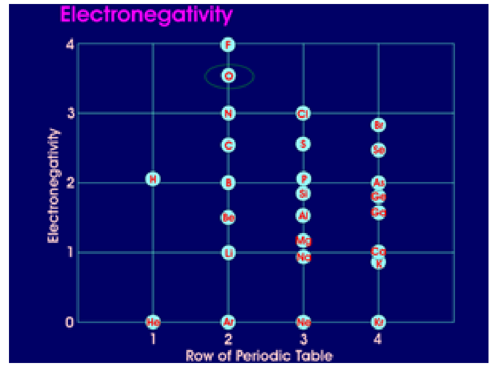
Slide 9: Carnitine



Once fatty acids reach the muscle cells, they have to get into the mitochondria to be chopped up into two-carbon fragments. A special molecule called carnitine helps transport fatty acids into the mitochondria. Athletes sometimes take carnitine to enhance ATP transport and give them that extra edge.

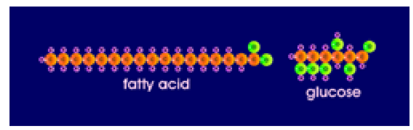
Slide 10: Oxidation releases energy

Fat is a great source of energy. In fact, pound for pound there is more than twice as much energy in fat than there is in glycogen.



Why is that? Where is energy stored in a molecule? In its electrons.

And what atom accepts electrons from almost any other atom and thereby releases the energy stored in those electrons?



Oxygen. Only fluorine is more electronegative than oxygen.

Carbohydrates are already partially oxidized because oxygen atoms have attached themselves to every carbon atom. Except for the end carbon, fatty acids don't have oxygen atoms attached to the carbon atoms, so they have twice the oxidizing potential as carbohydrates.

By oxidizing a molecule, energy is released. If you oxidize molecules fast enough, you see and feel the energy as light and heat.

Slide 11: Why don't plants have fat?

Why don't plants have fat? Because they don't need fat.

Why do animals need fat and plants don't? Because animals move about, and to do that, they need a lightweight, highly concentrated source of high energy, like fat. The reason fat is so lightweight is that it contains no water. Why not? Because oil and water don't mix.

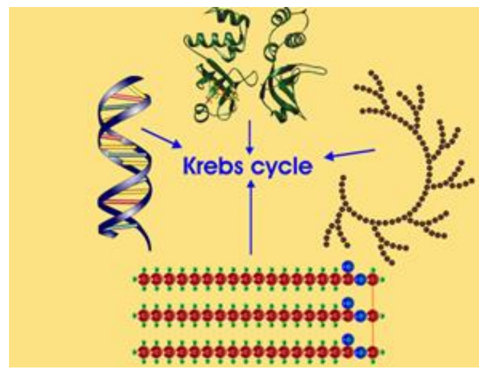
Slide 12: Fats and oils

The only place you find fat in a plant is in its seeds, where fats are present as oils. Oils and fats are the same thing, just that a fat is solid at room temperature, oils are liquid. So olive oil, peanut oil, canola oil, sunflower oil, and corn oil all come from squeezing the oil out of those plants' seeds.

A germinating seed use its oil for energy to grow before its stem pokes through to the surface and starts making its own ATP from sunlight.

Slide 13: Sources of energy during starvation

Okay, so we now have two ways to feed the Krebs cycle: glycogen and triglycerides.



What about DNA and proteins?

Can they also be metabolized into smaller molecules and fed directly into the Krebs cycle. Yes. This comes in handy during times of starvation for both plants and animals.

We use up our stores of liver glycogen within a couple of days of starvation, but we can still rely on fat, protein, and even DNA to ensure a continued supply of vital ATP.

Slide 14: Starch

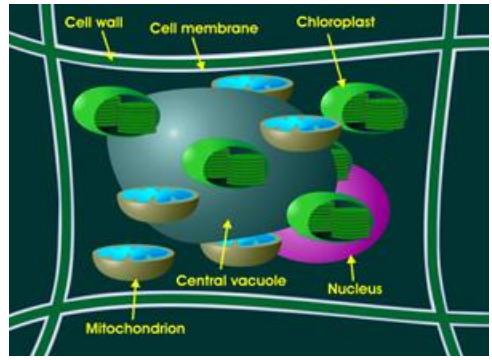
If plants don't use oil for energy except when they're first starting out and they rely almost exclusively on carbohydrates, where do they store their carbohydrates?

Animals store their carbohydrates as glycogen in liver and muscle. Do plants store their carbohydrates as glycogen?

No, plants store their carbohydrates not as glycogen, but as starch. Starch is just like glycogen in that it is a long-chain of glucose molecules but in starch, the glucose molecules are connected to each other in a slightly different way than they are in glycogen.

Starch may be stored in a plant's tubers, as with potatoes, or in its roots, as with sweet potatoes, in its seeds, or in its fruit.

Slide 15: Do plants have mitochondria?



If plants take in CO_2 and give off oxygen, does that mean that plants don't have mitochondria? No.

Plants do have mitochondria to make lots of ATP, and those mitochondria use oxygen just like an animal's mitochondria. Plants just make more oxygen in chloroplasts than they use in their mitochondria.

Slide 16: Do bacteria have mitochondria?

Do bacteria use mitochondria to make ATP? No.

Bacteria and mitochondria are about the same size, so there's no room for a mitochondrion in a bacterium. However, this does not mean that bacteria can't use oxygen to extract energy from glucose. They do use oxygen to oxidize organic molecules, but the enzymes that break down pyruvate to make ATP are within the bacteria, not within mitochondria.

Slide 17: What you know so far

1. Ready access to glucose requires a way to store it and a way to get at those stores when you need to. Glucose for muscle is stored in the muscles themselves as muscle glycogen, but for everything else, glucose is stored in the liver as liver glycogen.

2. The signal to break down liver glycogen into molecules of glucose is the hormone glucagon released from the pancreas.

3. While glucose is a great source of acetyl-CoA to run the Krebs cycle and make ATP, fat is also a good source of acetyl-CoA. The signal to break triglycerides into fatty acids for release into the bloodstream during emergencies is the hormone adrenaline made in the adrenal glands.

Slide 18: What you know so far

4. Fats are a compact source of energy, ideal for mobile animals but unnecessary for immobile plants. Plant seeds, however, do store oils as they need a source of lightweight, densely packed energy.

5. Plants store their energy in the form of starch such as the edible starch in potatoes, sweet potatoes, and fruits.

6. While plants do make ATP, they don't make enough to supply all the energy needs. So plants also use mitochondria to make ATP, and those mitochondria use oxygen. Fortunately for us, plants make more oxygen in their chloroplasts than they use in their mitochondria.

7. Bacteria are too small to house mitochondria, so the enzymes that metabolize glucose lie within the bacterial membranes.