Name: ______________________________

Date: ________________ Period: ______

Biological Molecules: You are What You Eat

Crash Course Biology #3

1. What are the four biological molecules? Which three does this video focus on?

2. How did William Prout think was the best way to understand the human body?

3. The chemical formula of urea is _________________ , and in the presence of water it gives of __________________, which gives urine its smell.

4. Prout concluded all foodstuff fall into three categories:
    a. Saccharinous (_______________________________)
    b. Oleaginous (the __________)
    c. Albuminous (the ____________________)

5. All organisms either need to ________________________ or ______________ those three ingredients in order to live.

Carbohydrates

6. Carbohydrates are made up of sugars, and the simplest of them are called *monosaccharides*.
    Mono – Saccharides –

7. All biological energy is originally captured from the sun by plants as _________________ through photosynthesis.

8. Cells use glucose through a process called __________________________.

9. Sucrose is a ____________________________. What two monosaccharides make up a sucrose molecule?

10. Long chains of carbohydrates are called _______________________________.

11. The most common structural polysaccharide is plants is _____________________.

12. Plants store glucose in the form of _______________.

13. Humans tend to store carbohydrate energy as ___________________, which can be stored in our _______________.

Lipids

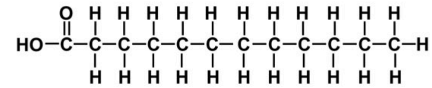
14. ______________ are unable to dissolve in water because their chemical bonds are mostly ____________________.

15. Fats are made up mainly of two chemical ingredients:
    a. ___________________ – alcohol
    b. ________________________ – long carbon-hydrogen chains that end in a carboxyl group.

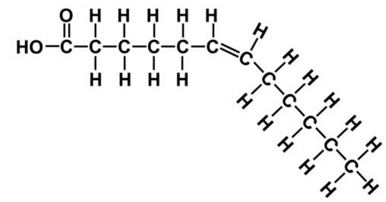
16. Three fatty acids and a glycerol make a __________________________.

17. A saturated fatty acid has all _______________ bonds between carbons, so it is saturated with _____________________.

Saturated Fatty Acid



Unsaturated Fatty Acid



18. An __________________________ fatty acid has _______________ bonds.

19. Unsaturated fats are liquids and are often referred to as _________.

20. Saturated fats form _______________ at room temperature.

21. _____________________ are unnatural, unsaturated fatty acids that are straight molecules.

22. Omega-3 fats are unsaturated at the 3 position and we can't ________________________ them.

23. Phospholipids are two fatty acids and a _____________________ group connected to a glycerol. They make up cell _________________________.

24. How do phospholipids, such as those in cell membrane walls, naturally arrange themselves?

25. ___________________ have a backbone of four interconnected carbon rings with various side chains.

26. _________________________ a steroid that binds with phospholipids to help form cell membranes.

27. Identify the two lipid hormones shown quickly in this episode.

Proteins

28. Proteins have many functions. They are _________________ regulating chemical processes, _______________________ that mark invaders for your immune system, and protein _______________________ related to emotions.

29. Proteins are made up of _____ different amino acids.

30. Amino acids have a ____________________ group at one end and an _____________ group at the other.

31. What element is showing up for the first time, which we must get from eating protein?

32. The ___ group, also called a side chain, determines the ___________ and __________________ of each amino acid.

33. Amino acids form long chains called____________________________.

34. There are ____ essential amino acids that we must get from eating foods.

ANSWERS

Biological Molecules: You are What You Eat

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1. What are the four biological molecules? Which three does this video focus on?
   Carbohydrates, lipids, proteins, nucleic acids – focus on first three

2. How did William Prout think was the best way to understand the human body?
   Through chemistry, and understand the chemistry by understanding what our body does to food

3. The chemical formula of urea is $CO(NH_2)_2$, and in the presence of water it gives of *ammonia*, which gives urine its smell.

4. Prout concluded all foodstuff fall into three categories:
   a. Saccharinous (*carbohydrates*)
   b. Oleaginous (the *fats*)
   c. Albuminous (the *proteins*)

5. All organisms either need to *synthesize* or *ingest* those three ingredients in order to live.

Carbohydrates

6. Carbohydrates are made up of sugars, and the simplest of them are called *monosaccharides*.
   Mono – *1* Saccharides – *sugar*

7. All biological energy is originally captured from the sun by plants as *glucose* through photosynthesis.

8. Cells use glucose through a process called *respiration*.

9. Sucrose is a *disaccharide*. What two monosaccharides make up a sucrose molecule?
   Glucose and fructose

10. Long chains of carbohydrates are called *polysaccharides*.

11. The most common structural polysaccharide is plants is *cellulose*.

12. Plants store glucose in the form of *starch*.

13. Humans tend to store carbohydrate energy as *glycogen*, which can be stored in our *livers*.

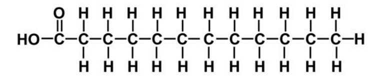
Lipids

14. *Lipids* are unable to dissolve in water because their chemical bonds are mostly *non-polar*.

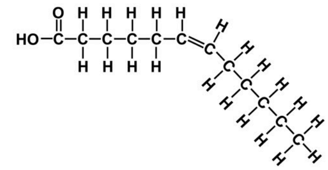
15. Fats are made up mainly of two chemical ingredients:
    a. *glycerol* – alcohol
    b. *fatty acids* – long carbon-hydrogen chains that end in a carboxyl group.

16. Three fatty acids and a glycerol make a *triglyceride*.

Saturated Fatty Acid



Unsaturated Fatty Acid



17. A saturated fatty acid has all *single* bonds between carbons, so it is saturated with *hydrogens*.

18. An *unsaturated* fatty acid has *double* bonds.

19. Unsaturated fats are liquids and are often referred to as *oils*.

20. Saturated fats form *solids* at room temperature.

21. *Trans-fats* are unnatural, unsaturated fatty acids that are straight molecules.

22. Omega-3 fats are unsaturated at the 3 position and we can't *synthesize* them.

23. Phospholipids are two fatty acids and a *phosphate* group connected to a glycerol. They make up cell *membranes*.

24. How do phospholipids, such as those in cell membrane walls, naturally arrange themselves? *Hydrophobic fatty acid tails facing each other, and hydrophilic phosphate ends facing outward*

25. *Steroids* have a backbone of four interconnected carbon rings with various side chains.

26. *Cholesterol* is a steroid that binds with phospholipids to help form cell membranes.

27. Identify the two lipid hormones shown quickly in this episode.
Estradiol (female sex hormone) and testosterone (male sex hormone)

Proteins

28. Proteins have many functions. They are *enzymes* regulating chemical processes, *antibodies* that mark invaders for your immune system, and protein *endorphins* related to emotions.

29. Proteins are made up of *20* different amino acids.

30. Amino acids have a *carboxyl* group at one end and an *amino* group at the other.

31. What element is showing up for the first time, which we must get from eating protein?
Nitrogen

32. The *R* group, also called a side chain, determines the *shape* and *function* of each amino acid.

33. Amino acids form long chains called *polypeptides*.

34. There are *9* essential amino acids that we must get from eating foods.

CrashCourse Biology #3 – Biological Molecules
Video Info: This video can be accessed via YouTube:
https://www.youtube.com/watch?v=H8WJ2KENlK0

Video length: 14:08. Using the table of contents provided by CrashCourse with the YouTube video, you can click and watch certain sections as desired.

Transcript (retrieved from https://nerdfighteria.info/v/2oKlKmrbLoU and re-formatted):

Introduction

Hello, and welcome to the kitchen. I wanted to invite you here today because last week we started off in my bathroom and I kinda feel bad about that. And also because as I'm making lunch today I wanted to, you know, sort of use it as a lab. During this time in my kitchen I'm going to talk to you about three different things: one, the three most important molecules on the Earth; two, possibly the grossest sandwich I am ever going to eat; and three, an obscure scientist who taught us everything that we know about urine.

So far we've talked about carbon and we've talked about water, and now we're going to talk about the molecules that make up every living thing, and every living thing in every living thing. I don't care if you're a bacterium, or if you're a blue whale, or if you're Lady Gaga, or if you're a mite living on the Queen of England's eyelashes. They're called biological molecules. These aren't just building blocks, these are the molecules necessary for every living thing on Earth to survive. They are essential sources of energy. They are the means for storing that energy. They are also the instructions that all organisms use to be born, to grow, and ultimately pass those same instructions on to the future generation. They are the ingredients for life, and we call them the carbohydrates, the lipids, the proteins, and the nucleic acids. And today we're just going to be talking about the first three. It's no coincidence that we classify them in the same way that we classify food, because...they're food. And for this classification, we have to thank a little-known English physician, who hundreds of years ago, dedicated his life to the study of human pee.

Biolo-graphy: William Prout (1:41)

Oh, my goodness, I'm back in the— That must mean it's time for the most awkwardly named segment here on Crash Course, the biolo-graphy.

His name was William Prout, and in the early 1800s, he became fascinated with human digestion, especially our urine. And that's because he thought that the best way to understand the human body was through chemistry, and the best way to understand the body's chemistry was to understand what it does to food. By day he was a practicing physician, but every morning before breakfast he did research in his home laboratory in London. And there he did many great things, like being the first to discover that our stomachs contained hydrochloric acid, and writing a breakthrough book about kidney stones called *An Inquiry Into the Nature and Treatment of Gravel, Calculus, and Other Diseases Connected with a Deranged Operation of the Urinary Organs*. And he was, of course, the first person to discover the chemical composition of pure urea, the main component of urine. For the record, here it is $CO(NH_2)_2$, and in the presence of water, urea gives off ammonia, which is why your pee smells.

Through his years of studying urine, Prout came to the conclusion that all foodstuffs fell into three categories: the saccharinous (carbohydrates), the oleaginous (the fats), and albuminous (the proteins). He went so far as to say that in order to be healthy, you needed to eat all three of these things, not just, ya know, sheep kidneys and gin, which is probably what most of London was living on at the time. But like many great minds, Prout was overlooked in his own lifetime, because while he was studying actual science, everyone else was walking around believing that the color of your urine was determined by your personality. This guy looks like a total jerk to me. And if you can tell that much by color, I wonder what you can tell by taste.

Carbohydrates (3:29)

Now, he didn't understand that there were biological molecules, he didn't understand what these things were, but he did understand that there were three ingredients necessary for life. And it turns out that all organisms either need to synthesize or ingest those ingredients in order to live.

We're gonna start out with the most basic of these ingredients for life, and that is the carbohydrate. You've no doubt heard of them, you may in fact be avoiding them like the plague, but the fact is that nothing and no one can avoid carbohydrates because they are the source of all energy that we have available to us.

Monosaccharides & Disaccharides (3:59)

Carbohydrates are made up of sugars, and the simplest of them are called monosaccharides. "Mono" for one, "saccharides" for the actual root of the word sugar. The star of the show here is glucose, because it's truly fundamental, by which I mean, like, number one on the global food chain, because it comes from the sun. All biological energy is originally captured from the sun by plants as glucose through photosynthesis. And every cell that needs energy uses glucose to get that energy through a process called respiration. In addition to glucose, there are other monosaccharides like fructose, which has the same molecular formula ($C_6H_{12}O_6$) but arranged differently. These subtle chemical differences do matter. Fructose, for example, is significantly sweeter than glucose. It's also processed by our bodies in different ways.

And then there are disaccharides which, like the name says, are just two monosaccharides put together. And the most famous of these is sucrose, which is simply a glucose molecule and a fructose molecule joined by a covalent bond. Mono- and disaccharides are pretty much little niblets of energy that are really easy for our bodies to process.

Polysaccharides (5:02)

But when these carbohydrates start to from longer and longer chains, their function and their roles change as well. Instead of being sources for instant energy, they become storehouses of energy or structural compounds. These are the polysaccharides. Instead of being just two or three monosaccharides put together, polysaccharides can contain thousands of simple sugar units. And because they're so big and burly, they're great for building with.

Cellulose & Chitin (5:24)

In plants, cellulose is the most common structural compound. It's just a bunch of glucose molecules bound together, and it is the most common organic compound on the planet. Unfortunately, it's very difficult to digest. Cows can do it, but humans certainly can not, which is why you don't enjoy eating grass.

Starch & Glycogen (5:40)

Polysaccharides are also really good for storing energy, and not just structurally, but just as an energy store. And that's where we get bread. Now, really interesting thing here, bread is made up of starch, the most simple of which is called amylose. Amylose and cellulose look almost exactly identical, but one is grass and the other is bread. Like, chemistry! Plants store glucose in the form of starch, and it comes in lots and lots of different forms, from roots and tubers, to the sweet flesh of fruits, to the starchy seeds of the wheat plant that end up being milled into flour.

Ground-up grain is the main ingredient in the bread, of course, and most of the calories, or the energy content, comes from carbohydrates. When I eat this—and I'm gonna eat the hell out of it—I'm gonna be eating all of the chemical energy that this wheat plant got from the sun in order to feed its next generation of seeds, that we then stole for our own use. All for me! Now we, as human beings, can't grow fruits or tubers so we have to store our energy in a couple of different ways. The way that we tend to store carbohydrate energy is in glycogen, which is very similar to amylose or starch but has more branches and is more complicated. It's basically made up of the glucose that we have left over after we eat. And it sits in our muscles, really ready to use, and it's also stored in our livers. It's generally a pretty short term store. If we don't eat for, like, a day, pretty much all of our glycogen gets depleted. But over the longer term, the way that we store our energy is through fat.

Lipids (7:06)

All of our mom's worst enemies, the fat, which turn out to be, actually, really important, and are the most familiar sort of a very important biological molecule, the lipid.

Lipids are smaller and simpler than complex carbohydrates, and they're grouped together because they share an inability to dissolve in water. This is because their chemical bonds are mostly non-polar. And since water, as we learned in the previous episode, despises non-polar molecules, the two do not mix. It's like oil and water. In fact, it's exactly like oil and water. And if you've ever read a nutrition label, or seen this thing called the television, you're probably pretty conversant in the way that we classify fats. But then, you know, 99% of us have no idea what those classifications actually mean.

Fats (7:47)

Fats are made up mainly of two chemical ingredients: glycerol, which is a kind of alcohol; and fatty acids, which are long carbon-hydrogen chains that end in a carboxyl group. When you get three fatty acid molecules together and connect them to a glycerol, that's a triglyceride. These figure prominently in things like butter, and peanut butter, and oils, and the white parts of meat. These triglycerides can either be saturated or unsaturated. And I know that when we put the words "fat" and "saturated" into the same sentence, it sounds like an evening at KFC, but here we're talking about being saturated with hydrogen.

As you hopefully remember from our first lesson, carbon is very nimble in how it uses its four electrons. It can form single, or double, or even sometimes triple bonds. This means that if the carbon atoms in a fatty acid are connected to each other with single bonds, all of the carbon atoms end up connected to at least two hydrogen atoms, and one of them picks up a third. So the fatty acid is saturated with hydrogen. But when some of the carbon atoms are connected to each other with double bonds, all of those carbons' electrons are spoken for, and so they're not able to pick up those hydrogen atoms. This means that they're not saturated with hydrogen and are unsaturated fatty acids.

To demonstrate, may I direct your attention to this jar of peanut butter? Here you can kind of see both kinds of fats. The liquid stuff you see on the top here, that is the unsaturated fat, which we generally think of as oils. The pasty stuff down here also contains lots of unsaturated fat, but also contains saturated fat, which doesn't have any double bonds, so it can pack more tightly, and form solids at room temperature.

And there are also other fat classifications that you've heard of. Trans-fats, which everyone always tell you never to eat! They're right! Don't eat them! They don't exist in nature, and are basically unsaturated fatty acids that instead of kinking, go straight across, and so they're extra, super bad for you. Don't eat them. Omega-3 fats are fatty acids that are unsaturated at the 3 position which is, like, right there, and that's the only difference. But the reason why these are important is because we can't synthesize them ourselves. They're essential fatty acids, meaning that we need to eat them in order to get them.

Phospholipids (9:42)

All this is starting to make me pretty hungry. But before we get to more food stuff, there are some unappetizing sort of lipids that we also need to talk about. So remember that triglycerides are three fatty acids connected to a glycerol. Swap one of those fatty acids out for a phosphate group, and you have a phospholipid. These make up cell membrane walls. Since that phosphate group gives that end a polarity, it's attracted to water. The other end is non-polar and it avoids water. So if you were to scatter a bunch of phospholipids into some water, they would automatically arrange themselves like this, with hydrophobic ends facing each other and the hydrophilic ends sticking out to face the water. Every cell in your body uses this natural structure to form its cell wall, in order to keep the bad stuff out and the good stuff in.

Steroids (10:26)

Another class of lipids is the steroids. Steroids have a backbone of four interconnected carbon rings, which can be used to form hundreds of variations. The most fundamental of them is cholesterol, which binds with phospholipids to help form cell walls. But these can also be activated to turn into different lipid hormones.

Proteins (10:43)

And so now we approach the most complicated, powerful, polymorphously awesome chemicals in our body: the protein. And by complicated, I mean that they are probably the most complicated chemical compounds on the planet. In fact, they're so amazing that we're gonna do a separate episode on them and how they are created by DNA. But right now, in you, there are tens of thousands of proteins doing everything they can to keep you alive. There are enzymes regulating chemical processes, helping you digest food, there are antibodies connecting themselves to invaders like bacteria and viruses so that your immune system can get 'em, there are protein endorphins that, like, mess around with your brain and make you, like, feel emotions. They're everywhere! They do everything! And proteins do all of this stuff using just 20 different ingredients, and these are the amino acids.

Amino Acids (11:32)

Just like fatty acids, amino acids have a carboxyl group at one end. And on the other end they have an amino group. Amino acid. Now hey, I don't know if you noticed this, but this is the first time that nitrogen has shown up in our food. This is super important because, despite the fact that nitrogen is, like, everywhere, it's 80% of the air, we can't just pull it out of the air and put it into our bodies. We have to get nitrogen from food, and so we have to eat foods that are high in protein like this egg, which by its very virtue, because all the white part is protein, it contains a goodly amount of nitrogen.

Now in the middle of the amino and the acid group is a carbon, and it shares one of its electrons with a good ol' hydrogen, and the other electron is free to be shared with R, which is just a kind of fill-in-the-blank. We call it the R group. It can also be called a side chain, and there are 20 different kinds of side chains. Whatever fits in that blank will determine the shape and the function of that amino acid. So if you put this in there, you get valine, which is an amino acid that does a lot of stuff, like protecting and building muscle tissue, and if you put this in there, you get tryptophan, which may be best known for its role in helping you regulate mood and energy levels.

Polypeptides (12:37)

Amino acids form long chains called polypeptides. Proteins are formed when these polypeptides not only connect but elaborate and, frankly, really elegant structures. They fold. They coil. They twist. If they were sculptures, I would go the museum every day just to look at them, and I'd walk straight past the nudes without even looking.

But protein synthesis is only possible if you have all of the amino acids necessary, and there are nine of them that we can't make ourselves: histidine, isoleucine, leucine, lysine, methionine, phenylalanine, threonine, tryptophan, and valine. By eating foods that are high in protein, we can digest them down into their base particles, and then use these essential amino acids in building up our own proteins. Some foods, especially ones that contain animal protein, have all of the essential amino acids, including this egg.

Conclusion (13:25)

And that concludes this triple-decker sandwich of biological awesomeness which is all we need to be happy, healthy people. And I'm sure, because of that, it's going to be delicious. … Nope.

Thank you for watching this episode of Crash Course. We'll be discussing something else very interesting next week, I don't even... I don't even know what it is. Don't forget, go back, reinforce what you have learned today by going back and watching bits that you may not feel like you got completely. We'll also, of course, be available on Facebook and Twitter if you would like to ask us questions or give us suggestions there. <belch>