10798 - BLOSSOMS - Blood- The Stuff of LIfe.mp4

[MUSIC PLAYING]

Blood is the life fluid in each of us. It constantly circulates around our body all day, every day, feeding each of the 100 trillion cells that makes us who we are. Hi, my name is Melis Anahtar. I'm a second-year medical student in the Harvard -MIT Health Sciences and Technology Program. And today, I'm going to be telling you a little bit about blood. So we have to have a certain amount of blood in our body at any given time. And it has to be held within a narrow range of pressures. And as young, healthy people, we tend to take blood for granted. But in the hospital and the doctor's office, blood is frequently collected to detect and diagnose diseases. In fact, we are currently in a laboratory dedicated to studying blood. It's part of the Massachusetts Institute of Technology's hospital, called MIT Medical. And the talented technicians in this lab use sophisticated machines to analyze blood samples collected from patients in the hospital.

We are currently in the refrigerator at MIT Medical, and this is where the blood is stored. Not only can blood be analyzed in order to detect blood illnesses, but it can also be given to somebody in order to save their life. For example, maybe you know someone who's had surgery or has been in a car accident, where they've required a blood transfusion. Or, maybe you even know someone with a blood disease, like hemophilia or sickle cell anemia. These people are all alive thanks to a blood transfusion, which is the process of replacing blood that someone has lost by giving them blood that's been collected from a bunch of people.

Unfortunately, we don't know how to make artificial blood. So our only source of blood is from human volunteers. So it's really important that we all donate blood, of course, when we're of age. And luckily, the blood donation process is pretty fast and easy, and relatively painless, as demonstrated by this 16-year-old boy in this video.

[MUSIC PLAYING]

Seth Kurfman. I am 16.

[MUSIC PLAYING]

Everyone in my family donates blood. I always thought that it would be really cool if I could just come in and donate.

[MUSIC PLAYING]

It went really well. I didn't feel anything. I mean, at first, you feel this little pinch, but, that's it. It's just a pinch.

[MUSIC PLAYING]

And tell them that it's a lot easier than they probably think it is, and that, at first, it may seem a bit scary, but then, once you start, you don't feel anything at all.

By donating blood, this teenager is doing a heroic deed. Just one blood transfusion can save lives of up to three people. Who knows? Maybe one day, your life, or my life, will be saved by a blood transfusion.

So when people donate blood, they generally give about one pint, which is half of a liter. So that's a quarter of one of those big two-liter soda bottles, and it's about one and a half of a soda can. So, of course, if we're able to give away just one pint like that, and still be normal, we obviously have much more than one pint of blood in our body. So let's have you take a guess. How much blood do you think you have in your body? Is it maybe one liter? Five liters? Or 10 liters?

A newborn baby has about one cup of blood in its body, and an average 150-pound man has five liters of blood. So, did you guess correctly? An average sized man gives about 10% of his total blood volume in just a single blood donation. Amazingly, their blood volume will return to normal just a few days later.

So, why is blood so important? Why is it that someone can die within minutes from losing a massive amount of blood? And now that we're thinking about it, what is a massive amount of blood, anyway? We'll tackle all these questions in this section.

So obviously, we all lose a few drops of blood here and there every day from our daily cuts and scrapes. And our body is able to stop the bleeding using a blood clot, and then replace that blood. But you've all probably seen those horror videos, where the main character is shot in the chest, and blood comes gushing out, and they fall dramatically to the ground. So how much blood do you think they had to lose before they had that dramatic drop? That number, obviously, depends on how much blood the character had in his body to begin with.

So based on the fact that the average man has five liters of blood in his body, how much do you think he needs to lose before he dies? Take a guess, based on the fact that it must be more than 10% of total blood volume, since this is how much a person can normally donate without any negative consequences. So is it closer to 20%, 40%, or 60%?

It turns out that a person needs to lose about 40% of their total blood volume before dying of blood loss. And in the case of an average man, this is about two liters of blood, or one soda bottle. Later in the lesson, I'll show you how to approximately calculate how much blood that you have in your body.

So now that we have talked about the general importance of blood, let's discuss exactly what's in this red liquid that makes it so absolutely necessary for life. Technically, the human body is just a cleverly organized assembly of 100 trillion cells. So to understand the functions of blood, really all you need to do is think of everything that a human needs to survive, because an individual cell needs the same thing.

Blood delivers nutrients and oxygen to cells. It carries away carbon dioxide waste. And transports vitamins and electrolytes. And it keeps our body at a constant temperature. Another very important function of blood is to protect us against the thousands of bacteria, viruses, and worms that are constantly trying to invade our bodies. So did you know that you essentially have a little military inside of your body to protect you against these bugs? So what makes up this military? We'll explore that question in this section.

To get us started, can you think of anything that's inside of your blood? It can be a cell type, a liquid, or a molecule. Why don't you talk to your neighbor to see what they say?

Let's figure out nature's recipe for blood, the stuff of life. So we'll use the equipment in this laboratory to carefully analyze a real human blood sample and figure out what its components are, and the proportion of all these components. The first thing we'll do is collect the blood, and then put the vial of blood that we just collected into a centrifuge. A centrifuge is a piece of equipment that works like the Gravitron ride at the amusement park. It spins an object really, really fast, so the heavier solid particles are pushed to the bottom of the tube and separated from liquid components.

Look at how the blood has separated into a clear, yellowish fluid and this solid red clump. This gives us a really awesome insight. So, blood may look like a homogeneous red liquid, but really, that red color comes from something solid that's suspended in the yellowish clear fluid.

Now, let's figure out how much of the blood that we've collected has separated into the yellow fluid and the red fluid.

So we started with 50 milliliters of blood, and after spinning it in the centrifuge, we were left with 27.5 milliliters of yellow fluid, and 22.5 milliliters of red fluid. That means that 45% of the blood is made up of the red fluid. Doctors will often refer to this number as the hematocrit. And we'll discuss it later.

So since we just calculated that the yellow fluid makes up 55% of the volume of whole blood, we can extrapolate that. So in order to make one liter of blood, we'll need 550 milliliters of this clear fluid, which is called plasma. Can you guess one fluid, protein, or electrolyte that's in this yellow liquid? Take a minute to discuss it with your classmates and teacher.

Plasma is mostly water, but it also has very important salts and proteins. The two main proteins are albumin and antibodies. Albumin is this big protein that prevents the liquid part of blood from leaking out of blood vessels and into tissues. Another tremendously important class of protein is the antibody. Antibodies are y-shaped proteins that your body makes to tag invading viruses, bacteria, and fungi for destruction. As you get older, and are exposed to more and more bugs-- that is, bacteria and viruses-- your body generates a larger collection of antibodies to protect you for life. Antibodies are the reason that many vaccines that you receive as a baby continue to protect you into your old age. Finally, plasma has proteins that help create blood clots.

Just to summarize what we've learned, let's write down the three functions of plasma. So, to sum up, plasma is the liquid component of blood. It prevents blood vessels from collapsing. It protects us against infections. And it enhances blood clotting.

Now let's figure out what's in that red clump. To do that, we're going to have to take a closer look. Let's use this microscope for that. I am going to take this glass slide, and add a drop of blood, and then smear it across. Then I'll add a dye, which makes the white cells look purple. And then we'll take a look under the microscope. Why don't you tell me what you see?

Check that out. I see three obviously different components. Can you pick out three different components in this smear, and can you describe them? Do you know what they're called? Work with your classmates and see what you can come up with.

Hopefully you're able to find red blood cells, white blood cells, and these tiny dots, which are called platelets. Red blood cells are donut-shaped disks that are the oxygen carriers in the blood. Each red blood cell contains a molecule called hemoglobin that enables it to have this amazing ability to bind molecules of oxygen. When a red blood cell goes into the lung's tiny blood vessels, it grabs oxygen from the air that you inhale. So since the red blood cell is in the blood, it gets carried from the lung to tissues in your body-- like muscle-- to deliver oxygen to cells in order for them to survive. After unloading the oxygen, the red blood cell can then pick up carbon dioxide-- a waste product that cells make-- and get rid of it in the lungs again. So that's the main purpose of the red blood cell-- to carry oxygen to cells all over your body, and to take away carbon dioxide that cells make that is toxic to them.

Think of the red blood cells as a type of logistics provider, delivering and picking up cargoes. Since you have 100 trillion cells in your body, there's a huge demand for oxygen, and you need enough red blood cells to be able to carry all this oxygen. I'll tell you that there are about five trillion red blood cells in just one liter of blood. Let's add this ingredient to the recipe.

Take another look at the blood smear. Did you see these big, purplish cells? These cells only look purple because of the dye that we use to visualize them under the microscope. Try not to get confused, because these cells are called white blood cells, in contrast to the red blood cells. Unlike red blood cells, which all look the same, there are many types of white blood cells. And they all serve to protect you from infection by making up part of your immune system.

These different white blood cells have fancy names, like neutrophil, lymphocyte, monocyte, basophil, and eosinophil. Trust me, it's easier to remember these cells if you put them into context. So think of a situation where someone falls and scrapes their knee on the sidewalk. When the skin on their knee is torn off, the floodgates open for bacteria to get into the cut. And once bacteria get under the skin, they release toxins that destroy tissue, and then they can get into the blood and wreak havoc all over the body. Luckily for us, we have an immune system that's like a highly trained military that's exclusively designed to identify and kill a dangerous invader. In this case, bacteria. As we go through the types of cells and blood that make up the immune system, we'll come back to this analogy of war.

So, just to review, identify a neutrophil, lymphocyte, and monocyte on this image. Here's what you should have labeled the cells as. Let's talk a little bit about what these amazing cells actually do. So the first cell in your immune system's military is the neutrophil. Neutrophils are like the military's infantry, so they're trained to fight on foot, in hand-to-hand combat. And neutrophils are the first cells to arrive at the site of injury, and it's a physically demanding job. Here's what the neutrophil is supposed to look like.

Neutrophils are the first ones to respond to an infection, and they just love to gobble up bacteria. They don't care about the particular type of bacteria, like whether it's a streptococcus or a staphylococcus. They really just want to eat them. Check out this video of a neutrophil chasing a bacteria in a dish in the lab.

Neutrophils are white blood cells that hunt and kill bacteria. In this spread, a neutrophil is seen in the midst of red blood cells. Staphylococcus aureus bacteria have been added. The small clump of bacteria release a chemoattractant that is sensed by the neutrophil. The neutrophil becomes polarized and starts chasing the bacteria. The bacteria, bounced around by thermal energy, move in a random path, seeming to avoid their predator. Eventually, the neutrophil catches up with the bacteria, and engulfs them by phagocytosis.

Neutrophils are easy to spot because they have these funny nuclei that are made up of several lobes connected by thin strands of tightly-wrapped DNA. Well-functioning neutrophils are absolutely essential to human survival. People who are born without neutrophils that work properly have a disease called chronic granulomatous disease. And without medical treatment, they become very sick within the first few weeks of life from bacterial infections.

Now that you've learned about the fastest, boldest white blood cell, let's take a look at another leukocyte. This one's called a lymphocyte, and it has a single, big blue nucleus. Let's see if you and your classmates can take a look at the blood smears and see if you can find any neutrophils and lymphocytes.

Did you find any? You already know what neutrophils do, but these lymphocytes are much more clever and longer-lived than the neutrophils. They're able to specifically recognize certain bugs, say HIV, or the flu. And they can kill cells that have been infected by these viruses. They're like the Navy Seals because they're highly trained fighters that are very effective at destroying very specific threats. For each threat, they come up with a specialized plan of attack. Analogously, in the body, a different set of lymphocytes responds to the virus that causes the flu than to HIV. Babies born without lymphocytes have a disease called severe combined immunodeficiency disease (SCID). And they, too, can die within the first few months of life from both bacterial and viral infections, unless they're kept in very sterile environments.

So finally, there are these bigger white blood cells with a kidney bean-shaped nucleus. That's a monocyte, which is an immature form of a cell called a macrophage, that lives in your tissues and spends its whole life on the lookout for an infectious agent, which it can then gobble up. Now let's take some time with your classmates to see if you can find these different white blood cells in your sample.

This white blood cell is a monocyte. If you look at this image, which is a lower magnification so the cells look a little smaller, you can identify the lymphocytes and the neutrophils.

Getting back to our recipe, you can tell from the blood smear that there are far fewer white blood cells than red blood cells. One liter of blood has about 5 to 10 billion white blood cells. Compare that to 5 trillion red blood cells. Of these white blood cells, in a healthy person, about 60% are neutrophils, 35% are lymphocytes and 4% are monocytes. Then you can have a smattering of eosinophils and basophils, but we won't get into the details of those. Let's add these to our recipe.

Finally, if you've been paying attention, you'll see these tiny specs called platelets. Platelets clump together to form the blood clots that prevent you from bleeding to death after something as simple as a paper cut.

There are about 300 billion platelets per liter of blood. And people who don't have enough platelets have a condition called thrombocytopenia. They're not able to form blood clots, and are very likely to lose a lot of blood from holes both inside and outside their body. Let's add platelets to the recipe.

Wow! Blood is certainly complicated to make. Let's review the recipe. To prepare one liter of blood, you need 550 milliliters of plasma, which, as we talked about before, contains water, albumin, antibodies, electrolytes, et cetera. You need 5 trillion red blood cells. You need 10 billion white blood cells. And of these, 60% are neutrophils, 35% are lymphocytes, 4% are monocytes, and less than 1% percent are eosinophils and basophils.

So remember how we were talking about how a newborn has about one cup of blood in its body, while your average 150-pound man has about five liters of blood? So now, we can come up with a pretty good estimate for how much blood you have in your body. To do this, you have to know roughly what your body weight is. And if you only know your weight in pounds, convert it to kilograms by multiplying by 0.45 since 1 pound is 0.45 kilograms. I'll perform the calculations using an example body weight of 130 pounds. So 130 pounds times 0.45 kilograms per pound, equals 58.5 kilograms. Now you do the same thing.

Once you've determined your body weight in kilograms, you have to think about how much of your weight is made up of water, and how much of it is made up of other substances like fat and bones. We'll estimate that 60% of your body weight is water. So to calculate the weight in kilograms of all the water in your body, multiply your body weight in kilograms by 0.6. Then, convert the weight of water in kilograms to the volume by multiplying by the density of water, which is one liter per kilogram.

Great. Well we've already discussed that your body is made up of trillions of cells, and that these cells are all filled with water. But since our goal is to calculate how much blood you have, we want to consider all the water that's outside of the cells. It's helpful to know that, of all the water in your body, 2/3 of it is contained within cells, which is called intracellular fluid. And 1/3 of it is outside of cells, called extracellular fluid. Finally, blood makes up 1/3 of extracellular fluid. So to calculate the volume of blood in your body, we have to do the following. Take the total volume of water in the body, multiply it by 1/3 to get the volume of extracellular fluid in liters. In our example, we'll multiply 35.1 liters times 1/3 to get 11.7 liters of extracellular fluid. Now we need to multiply the volume of extracellular fluid by 1/3 to get the blood volume in liters. In the example, it's 11.7 liters times 1/3 to get 3.9 liters of blood. Perform these calculations using your own total water value to figure out your blood volume.

So, did you get a value? It should be about 7% of your total body weight as it's calculated in kilograms. So you'll remember that the average blood donation is about one pint. And you've just calculated that in your body, you have about 10 pints of blood. So when you donate blood, you're giving away about 10% of your total blood volume. And that's not a big deal. That blood can be replaced very quickly. In fact, it takes about a month. But then, consider someone who's just been in a car accident. They might require up to 100 pints of blood to recover from the accident and the subsequent surgeries. This means that the blood donations of over 100 people have to be pooled in order to save that one person.

1 out of 10 people who enter the hospital require a blood transfusion, which translates to someone needing blood every three seconds. Now you can appreciate why blood donations are so important. By this point, I hope you can appreciate the importance of blood. You should be able to name the components, what each component does, and give an estimate about how much blood you have in your body. So the next time you get a scrape or you feel your heart beat, I want you to put on some imaginary glasses, and in your head visualize the red blood cells, white blood cells, platelets, and antibodies that are coursing around in your blood. I want you to appreciate the complexity of blood, and how important it is your overall health. And, most of all, please consider donating blood when you come of the right age. Thank you for your attention.

Hello. Blood is a fascinating and complex fluid that we often take for granted. So, in this lesson, I hope to instill students with an appreciation for the complexity of blood so that the next time they see it, they can visualize the red blood cells, white blood cells, platelets, antibodies, other proteins, and fluid in general that are in the blood and see it more than just some red fluid.

So, in this lesson, we talk about two really important techniques that are often used in the hospital. Blood smears are a very common method for directly analyzing the subtler components of blood-- namely the red blood cells, white blood cells, and platelets. And also to confirm the results from automated lab equipment. By looking at the color, size, shape, and proportions of cellular components, doctors can diagnose a patient's disease. Blood smears are also a very common and reliable way of diagnosing malaria since the parasite can be seen inside of red blood cells.

Another commonly used technique is blood centrifugation. And in the lesson, we calculate the hematocrit, which is the packed red blood cell volume, and it's a very clinically relevant measure. The hematocrit is defined as the volume of red cells in the body divided by the total blood volume. And people with anemia have a hematocrit that's below 41%. And this hematocrit is a great approximation for the total red blood cell mass and blood oxygen carrying capacity.

In segments one, two, and three, we ask the students to estimate the total volume of blood in the body, and the volume of blood that someone must lose in order to risk death. The values that I cite, such as five liters of blood for a 150-pound man, are really just approximations. And then I go on to introduce the general functions of blood, and an analogy that compares the immune system to a military.

In segment four, we'll determine the recipe of blood, so students can understand the components of blood, and the function of each of these components. So we'll start by spinning down a vial of blood, and then calculating the hematocrit. And, just for fun, I'll ask the students to guess and see if they can guess any of the components of plasma. Plasma is 90% water by volume, and it contains dissolved proteins, glucose, clotting factors, hormones, mineral ions like sodium potassium chloride, and more.

In segment five, I introduce two of the most important proteins in plasma, which are albumin and antibodies. There is a schematic representation of antibody in the PowerPoint slide set. Antibodies are generated by B cells in response to foreign proteins, which are called antigens. And these antigens can be components of bacteria, viruses, and more.

And then we turn our attention to blood smears. And I've included several photos of blood smears that were taken at both high and low magnifications. If possible, it would be helpful to print out these PowerPoint slides for the students to use. It's easy to tell the red blood cells from white blood cells. And keep in mind that the white blood cells have been stained purple using the Wright's stain. Since there are about a thousand times more red blood cells than white blood cells in blood, the blood smears consequently have many, many more red blood cells than white. At low magnification, it's common to see only 1 to 10 white blood cells per image. And the white blood cells look so small that it's hard to tell their identity. To fix this problem, I've also provided high magnification images that focus on specific white blood cell types. These images are all in the PowerPoint slide set.

So to quickly review how a blood smear is made, the blood is collected in a tube which contains EDTA anticoagulated blood. And a small drop of blood is placed on the surface of a clean glass slide near the edge. The clean edge of a glass slide is then used to spread the drop of blood across the entire slide, creating a thin, uniform layer. The blood smear is allowed to completely dry, and then it's stained using a combination of dyes, which is called the Wright's stain. That makes it much easier to differentiate the blood cell types.

So, in segment six, we analyze a blood smear in order to teach students about some of the components of blood. And the first component that we look at is the red blood cell. And then we talk about the oxygen carrying abilities of red blood cells. And there is a really great video that was created by HeartStart Skills about oxygen carrying abilities of red blood cells. And it would be really helpful to show this video in your classroom, if you have a chance. To introduce students to the different types of white blood cells, show the labeled images in the PowerPoint slide set, and then the unlabeled images to see if the students can remember which is which.

Then we go on to discuss the most prevalent white blood cell in the blood, which is the neutrophil. Neutrophils are pretty easy to pick out because they're relatively numerous and they have a very distinct nucleus. It has many lobes, which gives rise to their alternative name of polymorphonuclear cells. The neutrophil video is meant to show the students the incredible way in which the neutrophils can detect bugs, like bacteria, and then proceed to chase them.

I also talk about a disease that results from dysfunctional neutrophils. And the disease is called chronic granulomatous disease, and it's really rare. It only affects about 1 in 200,000 people. It has an x-linked inheritance pattern, and it can be caused by mutations in several different genes. But all these genes play a similar role in the ability of immune cells, like neutrophils, monocytes, and macrophages to be able to produce radical oxygen species that they use to kill bacteria.

In segment seven, we continue the blood smear analysis and discuss lymphocytes and monocytes. Lymphocytes can be further divided into B cells, T cells, and natural killer cells. B cells produce and secrete antibodies. T cells coordinate the immune response and kill infected cells. And natural killer cells also kill virally infected cells and cancerous cells.

In segments eight and nine, we review the recipe for blood and step through a series of calculations that allow them to calculate how much blood there is in their body. So in order to do this, the students will probably need a calculator and paper. And they'll also need to know their weight. So, if they know their weight in pounds, it'll be necessary for them to convert that weight into kilograms. And if they don't know their weight, it might be helpful just to give them a weight to work with. For example, I worked through all the calculations using a weight of 130 pounds.

I hope that this exercise helps students to appreciate not only how much blood they have their body, but how much blood is given in a single donation. And also the amazing ability of the body to be able to replenish this lost blood in a little over a month. By the end of the lesson, I just want students to appreciate the fact that blood is this really complex mixture of cells and proteins and different fluids, and that blood is absolutely essential for survival. And we can't make artificial blood, so it's necessary for people to donate blood. Just to drive home that point, I give the example of someone who's been in a car accident, where they require 100 pints of blood to recover from their accident and the subsequent surgeries. So, to get that 100 pints of blood, 100 people need to donate in order to save that one life.

So in conclusion, thank you very much for your attention. And I hope that you and your students enjoy the lesson. And I'd also recommend the website of the American Red Cross, which is at www.redcrossblood.org and they have some really great information there. So, thank you.

[MUSIC PLAYING]