

Blood is a very complex and fascinating fluid that we tend to take for granted. In this lesson, I hope to instill students with a greater appreciation for and understanding of blood, so that the next time they see it, they perceive it as a complex mixture of cells and proteins that are absolutely essential for survival, instead of just a red liquid.

This lesson also demonstrates two techniques that are frequently used in the hospital. Blood smears are a very common method for directly analyzing the cellular 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. In the lesson, we calculate the hematocrit, or packed red blood cell volume, which is a very clinically relevant measurement. The hematocrit is defined as the volume of red cells in the body divided by the total blood volume. People with anemia have a hematocrit below 41%. Hematocrit is a great approximation for total red blood cell mass and blood oxygen carrying capacity.

In Segments 1, 2, and 3, 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 5L of blood for a 150 pound man, are just approximations. Then, I introduce the general functions of blood and the analogy that compares the immune system to a military.

In Segment 4, by determining the "recipe" for blood, students will understand each of the components of blood and their function. After spinning down a vial of blood, we calculate the hematocrit and discuss the components of plasma. I ask the students to guess a component of plasma, just to get them thinking. 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 5, I introduce two of the most important proteins in plasma, which are albumin and antibodies. There is a schematic representation of an antibody in the Power Point slide set. Antibodies are generated by B cells in response to foreign proteins, called antigens, which can be components of bacteria, viruses, etc. Then we turn our attention to blood smears. I have 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 Power Point 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 one to ten white blood cells per image, and the white blood cells look so small that it's hard to tell their identity. Thus, I have also provided high magnification images that focus on specific white blood cell types. These images are all in the Power Point slide set.

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

In segment 6, we analyze a blood smear in detail to learn about cellular components of blood. We begin by discussing the red blood cell and its oxygen carrying abilities. There is a great video on YouTube that illustrates oxygen transport by HeartStartSkills. To introduce students to the different types of white blood cells, show the labeled images in the Power Point slide set, then the unlabeled image 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, the neutrophil. Neutrophils are pretty easy to pick out because they are relatively numerous and have a very characteristic multilobed nucleus, 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 chase them. I also talk about a disease that results from dysfunctional neutrophils, called Chronic Granulomatous Disease, which is a very rare genetic disease that affects about 1 in 200,000 people in the U.S. It has an X-linked inheritance pattern and can be caused by mutations in several genes, all of which participate in the pathway that enables immune cells like neutrophils, monocytes, and macrophages to produce reactive oxygen species that destroy bacteria after ingesting them.

In Segment 7, 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 8 and 9, we review the recipe for blood and step through a series of calculations to estimate each student's blood volume. The students will need a calculator and paper, and should be comfortable with converting between units, such as pounds to kilograms. Hopefully the students will know approximately how much they weigh, and if not, it might be necessary to give them an estimate or ask them to complete the exercise with an example weight. I work through the exercise using an example of a 130 lb (or 58.5 kg) person. I hope that this exercise helps students to appreciate how much of their blood is given in a single blood donation, and appreciate the amazing ability of the human body to replenish the donated blood within a month.

I want the students to walk away with the lesson that blood is a complex mixture of cells and fluids that is absolutely critical for survival. We can't make artificial blood, so people who donate their blood are truly saving lives. To drive home the importance of donating blood, I explain that a single person who is badly injured may require infusions of up to 100 pints of blood, which is equivalent to donations from 100 people.

Thanks for your attention. If you or your students want to learn more about this topic, I'd highly suggest the American Red Cross' website at <http://www.redcrossblood.org>. and I hope you and your students enjoy the lesson!