Student Name: Margaret A. Lambert
Subject: Biology
Topic: Circulation
Grade Level: 9/10th

Essential Questions: How did the discovery of blood circulation come to be? Who discovered it? How does this influence our modern understanding of medicine now?

Virginia Standards of Learning (SOLs):
The student will investigate and understand life functions of Archaea, Bacteria and Eukarya. Key concepts include: d) human health issues, human anatomy, and body systems;

Objectives:

Students will be able to Know:
- William Harvey was a medical doctor living in the first half of 17th Century England.
- That human circulation worked wasn't fully understood at this time.
- The circulatory system is a network of veins and arteries that transport blood around the body.
- Arteries can become blocked and blood flow can become constricted due to the build up of plaque on artery walls.

Student will Understand:
- Concepts that seem simple and obvious to us, were once in the past puzzles to be figured out.
- Models help us to be able to understand what is going on in our bodies.
- Scientific knowledge can save lives.
- Stories can be used as engaging ways to learn factual information.

Students will Do:
- Read and discuss a story titled, "William Harvey and the Farmer."
- Clarify the factual information vs. fictitious information in the story.
- Create a model of how blood travels through arteries in our bodies using a cup, a straw, and clay.
- Add on a "tourniquet" to the model in order to understand how a tourniquet can restrict the flow of blood to an area.
- Discuss the importance of our circulatory system.

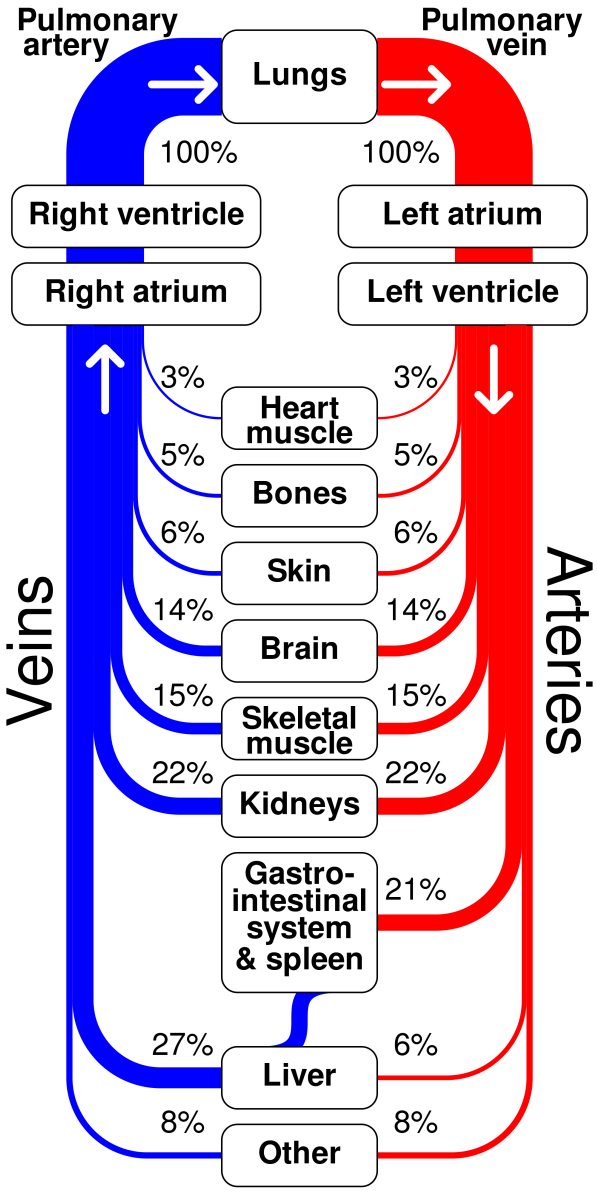
Background Information

This Storyline Lesson on the discovery of blood circulation will occur during a unit on Human Health and Wellbeing. This unit will also cover topics such as: viruses, germ theory, and homeostasis. This lesson on blood circulation will be incorporated into the portion of the unit on homeostasis. Students will learn about homeostasis by identifying the different cycles inside the human body that keep us all alive and functioning. During this Storyline Lesson, students will read a story about a patient involved in a farming accident. The brilliant doctor, a young William Harvey, demonstrates his newest discovery, a tourniquet, which stopped the flow of blood to the patient's arm so that the doctor could stitch up and cauterize the gash. Students will read the story, discuss the factual vs. fictitious parts of the story and then conduct and experiment investigating blood circulation.

Launch

Students will be given the following image of a modern day interpretation of the circulatory system and will be asked to brainstorm what activities during their days use require the most amount of blood flow. Students will be directed to the percentages of the Sankey Circulation Diagram below and will be told that each

percentage corresponds to the amount of blood, which is proportioned to each given organ or body part. Lastly, students will be asked to brainstorm how scientists originally learned enough about the circulatory system to make the chart below. They will write down their ideas and the teacher will elicit them from the entire class and discuss as a group. The teacher will then ask the students to set aside the Sankey Circulation Diagram until the very end of the lesson when they will have an opportunity to refer back to it and think about it in a new light.



Sankey Circulation Diagram: the lines and percentages given are proportional to the amount of blood that flows from the heart out to the other parts of the body.

Explore

The Story of William Harvey and the Farmer
The year was 1618 and the place was England. King James was the ruler of the good people of England. The Thirty Year War (1618-48), a religiously sparked ordeal between the Protestants and the Catholics, which would end up involving the major powers of Europe—England, Sweden, France, Spain, Austria, and Germany had not yet begun and the people of England were content with their lives, for the most part. Farmers were farming, bakers were baking, merchants were selling, and all

was as it should be.

In this time, in this merry Ol' England lived a farmer, Henry Higgins, whose family had farmed the same patch of land for generation upon generations, 7 to be exact. Henry Higgins was an ambitious farmer who was sought to transform his families' land into the greatest amount of wealth that he could. He was driven by the thought of making the most of what he was given, as well as feeding and clothing his wife and 4 children. Henry raised animals for milk and meat and grew vegetables a plenty: potatoes, onions, garlic, carrots, cabbage, and corn, but that wasn't enough for him. Henry was savvy in the ways of economics. He knew that having a more diverse farm would lead to more economic stability. If the weather was terrible one year and all his carrots and cabbage and corn were rubbish, then Henry could always fall back on raising and selling his livestock. If his milk cows ran dry one year or a disease wiped out all of his swine, then Henry could fall back on his vegetables. Henry was a hardworking and bright farmer.

One day, Henry Higgins was out in his fields taking the kitchen scraps out to feed the pigs, on of his favorite tasks because he loved watching the pigs move around and delight in devouring the food scraps he gave them. He even loved the little snorts they made. Henry's mind was wandering while he walked over towards the pig pen and he found himself thinking about how interesting it was that both pigs and humans breathed and ate and slept and did all the same things and yet there were so many differences between himself and the pigs he loved so much. He wondered how similar pigs were to himself and he wondered if his pigs thought about how similar they were to humans at all. Henry stopped himself from daydreaming and finished up his feeding and turned to leave the pig pen. As he turned to leave, he noticed that one of the fence posts on the corner of the field was falling down, so he went over to investigate. *Hm….* he thought, *the soil must have shifted and caused this post to loosen in the ground. I better fix this before the post falls over entirely and my cows get out. That's just what I'd need!* Henry made his way over to his barn where he kept all of his equipment: his rakes, shovels, scythe for reaping wheat, saws, and plows. As Henry was reaching up for a shovel that was hanging high up on the side of a rickety wooden shelf he had been meaning to tighten up, he caught his footing and faltered forward as the shelf fell on top of him, farm equipment and all! *OUCH! Blast it all!* Screamed Henry as he lay there stunned. He tried to move, but soon found that all of the equipment on top of him kept him pinned down. Stunned and dazed and feeling some unidentified pain, Henry started to move his feet and kicked off the shovel and saws that rested on them. He picked up tools and pushed the shelving pieces with his left arm, but found that his right arm wasn't moving. One of the metal stakes he uses for driving the fence posts into the ground had landed in his forearm and had been driven into his muscle by the force of the heavy shelf landing on top of it. Henry's right arm was useless and he could feel something wet starting to pool beneath him. He was bleeding, and not just a little bit. Henry managed to kick the shelf off of him with this legs and scoot himself to an open patch of dirt in the middle of the barn. *I've got to do something to stop all this blood,* thought Henry between twangs of pain and dizziness. The loss of blood was already starting to affect his thinking.

Henry saw an old rag nearby and grabbed it with his good hand. He dabbed at the wound and then had a bright idea! Henry remembered one day while he was at the market, selling his goods, he had seen a young Doctor, William…. something or other….. William… Harvey, that was it. William Harvey was demonstrating at the market a way to temporarily stop the flow of blood from a wound. Henry had gone over to investigate the demonstration because he was fascinated by human bodies and anatomy. Henry remembered the Doctor Harvey taking a long strip of cloth and tying it around the upper part of his assistant's arm and leaving it a little loose. Doctor Harvey, then took a rod and

slid it underneath the cloth and twisted and twisted it until it was quite tight. Doctor Harvey's assistant winced a little as Doctor Harvey tightened the cloth with the rod. Doctor Harvey stopped and directed the crowd to look closely at the color of the arm below the cloth. As Henry had watched, with his own eyes, he saw the color drain from the assistant's arm and change from a flush reddish color to a pale bluish shade. Doctor Harvey explained that what was happening was that the tightness of the cloth and rod, or what he called a…. *Henry thought for a moment, his memory temporarily blanking….* "turn….turn…." "tourniquet!" Doctor Harvey told the crowd that the tourniquet he had placed on the assistants' upper arm was successfully blocking the flow of red blood to the lower arm, which is why the reddish color is absent in the lower arm and it appears bluish and pale. Dr. Harvey continued by mentioning that scientists of old, such as Aristotle, and his medical teacher, Fabrizi of Acquapendente both understood and taught the central tenets of the structure of the body, which is that: all living things (including humans) have organs which have the form, or structure they have due to the task they were created for. An example is that our muscles, which are shaped like long strings connected to our bones are used to help us pick things up and also to protect our less strong bones from becoming damaged. Dr. Harvey called this logical way of thinking; "living anatomy" and he said that, while "living anatomy" helps us to understand why the organs in our bodies do, it hasn't helped to explain why and how our blood flows. Fabrizi, Dr. Harvey's teacher had discovered that the many larger veins in our bodies have valves in them, which keep the blood flowing in only one direction—towards the heart. Fabrizi thought that this valve mechanism was creature to keep our blood from pooling in our legs or from rushing down our bodies from our brains with too great a force. Dr. Harvey said that, while he respected the work of his mentor, Fabrizi, he disagreed with this explanation. Dr. William Harvey explained to the small crowd that was growing larger by the moment, that his experiments (including the tourniquet demonstration, among others) had showed him that blood flows in a circular fashion in the human body and is carried from organ to organ via a network of tiny arteries and even smaller capillaries, which are then returned to the heart, the central part of the body, by veins with one-way valves inside. The crowd listened intently as Dr. William Harvey explained how he had learned all about the circular flow of blood in the bodies of animals and humans by observing and even cutting open animals to see the blood flowing through a living creature. The most amazing part of the demonstration though, as Henry Higgins remembered it, was that, as soon as Doctor Harvey lightened the tension on the tourniquet, the color came back to the assistant's lower arm and a sense of relief spread over the assistant's face. Doctor Harvey ended his lecture by explaining that they loss and regain of color to the skin below the tourniquet was caused by the blood returning to the lower arm.

Henry Higgins was amazed, at the time, with the demonstration, but didn't think about it at all until now as he was bleeding out of his upper arm with a metal spike sticking out of him. Henry Higgins grabbed the rag with his good arm and tied it as best his could with his left arm. It wasn't very tight, which allowed him to grab a hammer and slip it underneath the cloth and tighten and twist the hammer around and around. As Henry did so, he could feel the pressure on his arm and he even swore he could feel a faint pulsing in his arm. Henry noticed that the tighter the cloth got on his arm, the less blood drained out of him. Once he had the homemade cloth tourniquet twisted until he could twist no more, and he couldn't see any blood draining out, Henry fumbled to his feet and stumbled back to the farmhouse to get assistance from his wife and children. Henry left the spike in because somewhere he had heard that if you pull something stuck into you out too fast, you will bleed. Henry knew that his wife had sewing needles and cauterizing power and would be able to stop the bleeding and sew him up. He just hoped that his newly make tourniquet would hold during the procedure to stop the blood from flowing too soon. In that moment, as Henry was cursing the state

of affairs that had brought him to this point, he was extremely grateful for that Doctor William Harvey who had come to the market place and demonstrated how to use a tourniquet. If it wasn't for that demonstration and Henry's ability to remember how to make one, Henry has no idea if he would be okay after an accident like that. As it looked now, Henry would be fine and on the mend in a few days time, and his arm would be back to fully functional within a month. He knew that this would be hard on all the farm work that needed to get done but he thought to himself, "*that fence post can wait to be fixed for now. I'm just glad I'll get my arm back.*" Henry Higgins told himself, that after his arm was healed up, he would go find Doctor William Harvey and shake his hand and thank him in person.

The End.

Fact:

- William Harvey was a real medical doctor who lived in England during the first half of the 17th Century (1578-1657).
- William Harvey demonstrated the effectiveness of a using a tourniquet to temporarily stop blood flow to an area.
- Farming could be a dangerous livelihood and farmers would often mend their own wounds and keep supplies like cauterizing powders and suture (sewing) kits on hand.
- A tourniquet would have been a very effective tool to help Henry Higgins stop the blood loss until he could get help. There are many stories of people in remote situations self applying tourniquets and then seeking help.

William Harvey discovered that…

- the circulation mechanism is designed for the movement of liquid, not air. The blood on the right side, although carrying air, is still blood.
- the heart is the source of blood movement, not the liver, as previously thought.
- the heart contracts at the same time as a pulse is felt.
- the ventricles squeeze blood into the aorta and pulmonary artery
- the pulse is not produced by the arteries puling blood in, but by blood being pushed by the heart into the arteries, enlarging them
- there is no to-and-fro movement in the veins, but a constant flow of blood to the heart.

Fiction:

- William Harvey did not actually present his tourniquet demonstration at markets.
- Henry Higgins is a fictitious character.

Activity

Students will follow the directions in the activity below to learn how blood flow changes according to the diameter of the artery (straw). Another dimension will be added onto this activity where a string will be tied around the straw to simulate a tourniquet being placed around a person's arm to stop the blood from flowing.

Lesson Plan Format – http://www.sciencebuddies.org/science-fair-projects/Classroom_Activity_Teacher_Modeling_Blood_Flow.shtml

Summarize

The teacher will review the fact/fiction section of the story and will make sure that students have the opportunity to ask clarifying questions. Afterwards the teacher will ask them to compare/contrast images of the circulatory system, as it was understood during Dr. William Harvey's time with our modern day model. Students will be asked to fill in a chart detailing the differences in what knowledge was known in each period, based on the story and the activity they just finished. Students will have room to write out any further questions they have about circulation or William Harvey.

Assessment:

- Students will demonstrate their understanding of how the rate of blood flow changes with the diameter of a straw by completing the lab activity and filling out a lab report in their notebooks recording the difference in the rate of flow.
- Students will also turn in their homework assignment answering wrap-up questions about William Harvey's discoveries as a way to cement the concepts in their minds.

Closure:
The teacher will review the connections between the story "William Harvey and the Farmer" with the follow-up activity and will ask students to discuss what they've learned about blood flow. A follow-up homework reading about William Harvey and his discoveries will be given to students with a few wrap-up questions.

Accommodations for individual differences:
Students who need assistance with reading will be able to listen to an audio version of the homework assignment using GoogleVoice. All students will have a copy of the story so they will be able to follow along and read with the teacher.

Behavioral and organizational strategies: Students will be expected to conduct themselves well during the lab portion of class and rules/regulations laid out in the beginning of the year will be reviewed before the lab starts.

Resources/References: Articles and Books

Bynum, William. *A Little History of Science.* 2012. Yale University Press. Chapter 13, pp. 68-73. "Round and Round – Harvey"

Isabelle, Aaron D., *Teaching Science Using Stories: The Storyline Approach.*

https://www.famousscientists.org/william-harvey/

Appendix: Images and Links

William Harvey – portrait with circulation photo
https://www.famousscientists.org/william-harvey/

Arm – Tunicate Drawing
https://upload.wikimedia.org/wikipedia/commons/thumb/6/6b/William_Harvey_%281578-1657%29_Venenbild.jpg/220px-William_Harvey_%281578-1657%29_Venenbild.jpg

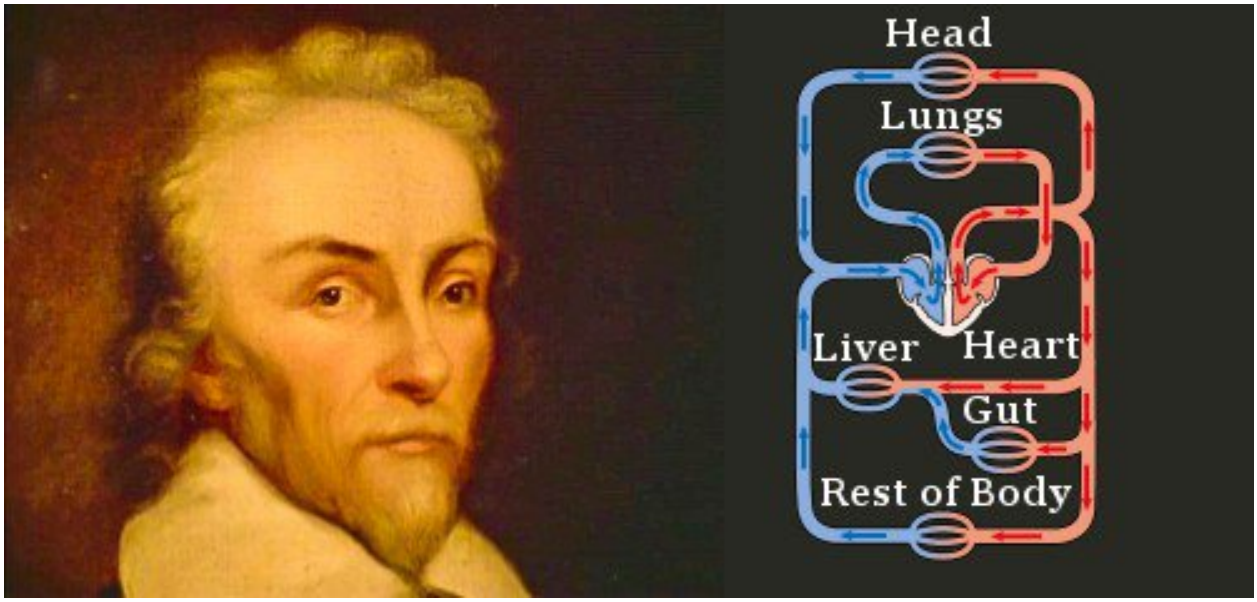
When he was later asked about he possibility of carrying out further experiments, Harvey (we have slightly modernized his English) said:

"You know very well the storm my previous research caused. It is often better to grow wise in private at home, than to publish what you have amassed with infinite labor, to stir up storms that may rob you of peace and quiet for the rest of your days."
--WILLIAM HARVEY

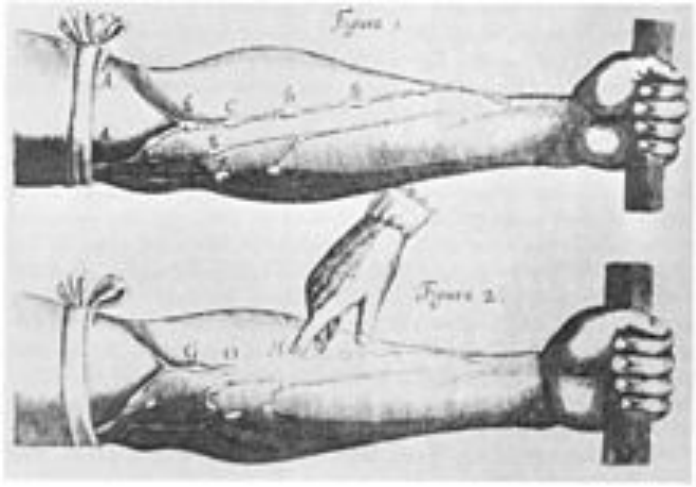
Harvey's Main Conclusions about Blood Circulation

Harvey showed for the first time that the arteries and veins circulate blood through the whole body. He showed that the heart's beat produces a constant circulation of blood through the whole body. He refuted many of the then standard beliefs of how the heart and blood system worked, establishing that:

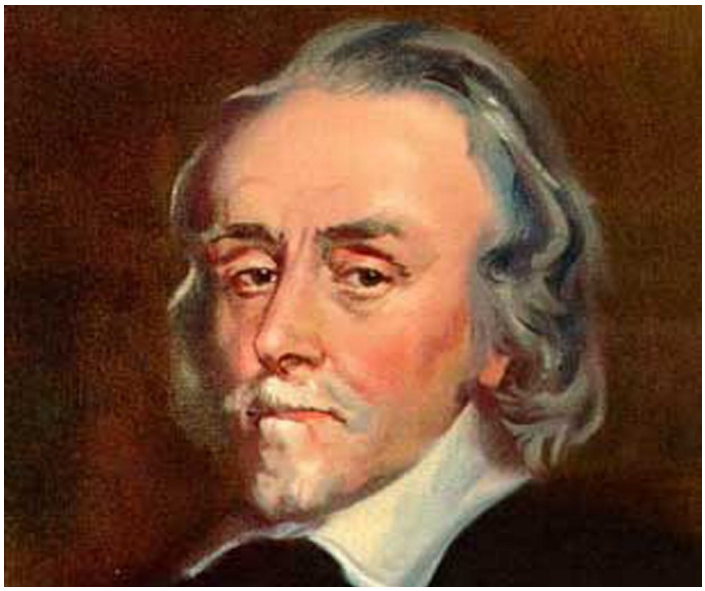
- blood in the arteries and the veins is all of the same origin, not manufactured in different parts of the body
- the blood sent through the arteries to the tissues is not consumed there
- the circulation mechanism is designed for movement of liquid, not air. The blood on the right side, although carrying air, is still blood
- the heart is the source of blood movement, not the liver
- the heart contracts at the same time as a pulse is felt
- the ventricles squeeze blood into the aorta and pulmonary artery
- the pulse is not produced by the arteries pulling blood in, but by blood being pushed by the heart into the arteries, enlarging them
- there are no vessels in the heart's septum: all of the blood in the right ventricle goes to the lungs and then through the pulmonary veins to the left ventricle
- • Similarly, all of the blood in the left ventricle is sent into the arteries, round by the smaller veins into the venae cavae, and then to the right ventricle again. In this way, the circulation is complete. The blood has come back to where it began its circuit of the body there is no to-and-fro movement of blood in the veins, but a constant flow of blood to the heart.



William Harvey and a rudimentary image of the circulatory system, as he understood it.



Harvey's knowledge came from observations he made of blood flowing through the veins and arteries of living animals that he cut open.



William Harvey (1578-1657)

William Harvey discusses his theory of blood circulation with King Charles the First.


EXERCITATIO
ANATOMICA DE
MOTV CORDIS ET SAN-
GVINIS IN ANIMALI-
BVS,
GVILIELMI HARVEI ANGLI,
Medici Regij, & Professoris Anatomiæ in Col-
legio Medicorum Londinensi.
FRANCOFVRTI,
Sumptibus GVILIELMI FITZERI.
ANNO M. DC. XXVIII.

In 1628, aged 50, Harvey published his masterpiece – usually referred to as *De Moto Cordis* – the Motion of the Heart. Its full title in English is: *Anatomical Studies on the Motion of the Heart and Blood in Animals*.