DR. DREW, DENSITY, & DIFFUSION:

DR. CHARLES RICHARD DREW

GIVING LIFE THROUGH BLOOD RESEARCH

STEM^{2}D Topics:
Science, Mathematics

Target Audience:
Students, ages 8-14

STEM^{2}D .org

Smithsonian Science Education Center

NATIONAL MUSEUM of AFRICAN AMERICAN HISTORY & CULTURE
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DR. DREW, DENSITY, & DIFFUSION: Dr. Charles Richard Drew Giving Life Through Blood Research is part of the STEM2D Student Activity Series. The content was developed by the National Museum of African American History and Culture, Education Department, the Teaching and Learning Unit and generously supported by The Dow Chemical Company.

The layout was designed by the Smithsonian Science Education Center as part of Johnson & Johnson's WiSTEM^{2}D initiative (Women in Science, Technology, Engineering, Mathematics, Manufacturing, and Design), using a template provided by FHI 360 and JA Worldwide. This series includes a suite of interactive and fun, hands-on activities for girls (and boys), ages 5-18, globally.

Design and illustrations by Sofia Elian

DR. CHARLES RICHARD DREW
GIVING LIFE THROUGH BLOOD RESEARCH

BACKGROUND INFORMATION

Dr. Charles Drew was an African American physician and blood transfusion researcher in the early 20th century. His research laid the foundation for modern blood banking through the creation of blood collection and storage techniques, many of which are still used today. Through a series of lessons, participants will revisit Dr. Drew's story as an African American physician and researcher in the early 1900s by engaging in activities on density, diffusion, and the circulatory and respiratory systems. We want students to develop an appreciation for Dr. Drew's contributions and to understand the STEM principles behind his work.

National Portrait Gallery, Smithsonian Institution; gift of the Harmon Foundation

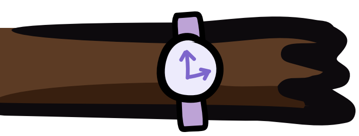
DR. DREW, DENSITY, & DIFFUSION:
Connecting the Circulatory and Respiratory Systems

Introductory Activity
(optional if time allows, otherwise skip to Activity 1)

Topics: Science, Mathematics
Target Audience: Students, ages 8-14

ACTIVITY DESCRIPTION

This activity will introduce your students to the circulatory and respiratory systems and the connections between them. Before beginning this activity with your students, find out what they already know about the circulatory and respiratory systems by introducing questions such as, "why do we breathe," and "why do our hearts beat?" Throughout the activity, there are opportunities for the students to share their predictions and the reasoning behind them on what they think will happen after doing different activities.



ESTIMATED TIME:
This session typically takes 20 minutes to complete.

STUDENT DISCOVERIES
Students will:

- Identify the interconnected nature of the circulatory and respiratory systems
- Participate in a team-based learning experience
- Learn how STEM^{2}D—science, technology, engineering, mathematics, manufacturing, and design—subjects are used in understanding the human body and the circulatory and respiratory system
- Build important STEM^{2}D skills such as measuring, decision-making, and problem-solving

GETTING READY

Materials: Suggested materials preparation prior to the activity with students.

- Activity Leader Checklist
- Tell My Story form
- PowerPoint: Dr. Drew, Density & Diffusion
- 1 Small rubber band (optional) per student
- Timer/clock/watch/cell phone per student

Estimated Materials Cost:

Activity leaders should plan to spend less than $0.10 per student ($3.00 per class) on materials when completing this activity with 24 students.

ACTIVITY LEADER PREPARATION

1. Read **Spark WiSTEM²D.** This is essential reading for all volunteers interested in working with youth, as it provides important background knowledge about STEM²D, strategies for engaging female students, and tips for working with groups of students. Download at STEM²D.org.

2. Review the **Activity Leader Checklist** for details and specific steps for planning and preparing to implement this activity.

3. See the **STEM²D Student Activities Overview** for additional information.

4. Take time to experiment with the activities in this guide to better understand the challenges facing the students.

Welcome and Introductions (15 minutes)

- Greet the students.
- Tell the students your name and your organization/company. Talk about your educational and career path. Use the **Tell My Story** form as a basis for your remarks. Be prepared to describe your job or a typical day, and provide information about your background including:
    - Your education – focus on secondary and post-secondary classes and courses
    - Current work projects
    - Interests and hobbies
    - Why you love STEM^{2}D, and how your work is connected.
- Ask the students or any volunteers helping today to introduce themselves.
- Use Conversation Starters to learn more about the students and their interests.
- Discuss the opportunities that exist in the local community to support students as they develop their interests and personal experiences.
- Tell the students that your career is only one of the many careers available in STEM^{2}D – science, technology, engineering, mathematics, manufacturing, and design.
- Explain that STEM^{2}D careers are high-demand, high-growth careers and are predicted to remain in demand over the next 10 years.
- Some STEM^{2}D careers do not require a college degree and offer young people exciting, high-paying opportunities. Stress the importance of gaining mathematics skills and engineering practices to succeed in any STEM^{2}D career.

CONVERSATION STARTERS: *CAREER PLANNING*

- When you consider your future, what are you most excited about?
- Do you see yourself working with others, for a large company, with your friends, for yourself? Why or why not?
- What does the perfect work day look like to you? Are you outdoors? Are you working alone, or with others? Do you solve problems? Do you fix or build things?

STEP-BY-STEP INSTRUCTIONS:

Measuring resting heart rate

- Students will sit still with minimal movement for 1-2 minutes.
- Next, they will use their pointer and middle fingers to find their pulse on their wrist.
- Then, they will count how many pulse throbs they feel for a period of 10 seconds. (Use a stopwatch or clock with a second hand for accuracy.)
- After counting the number of thumps, have them multiply that number by 6 to calculate their resting heart rates for a minute.
- The number they calculate represents how many times their hearts beat within a minute while they are resting.

Increasing heart rate with exercise

- First, have your students make a prediction about how much their heart rates will change after 30 seconds of exercise. Ask your students how many heart beats they will count in 10 seconds after doing jumping jacks for 30 seconds.
- Have your students find a spot on the floor where they can hold their arms to the sides and not hit anyone else.
- Next, have them do jumping jacks for 30 seconds.
- After finishing jumping jacks, have them go back to their chairs and measure their heart rates for 10 seconds, like they did before. Remember to have them multiply the number they get by 6 to find out their post-exercise heart rate.

Decreasing heart rate with deep breathing

- Have students sit in their chairs comfortably.
- Explain to the students that they will use a breathing exercise to affect their heart rate.
- Have the students make a prediction about what their heart rates will be after the one-minute breathing exercise.
- Have them all breathe in slowly on a four count and out on a four count. Count out loud, In-2-3-4, Out-2-3-4 (repeating for a minute).
- After completing the minute of deep breathing, have the students measure their heart rates again.
- Students should take their two fingers and measure their pulse for 10 seconds, then multiply by 6.
- Have them compare their resting numbers, their post-exercise predictions, their post-exercise measurements, their post-breathing exercise predictions, and their post-breathing exercise measurements.

EXTENDED LEARNING

Here are a few ways to extend the learning:

1. Talk about athletes having lower heart rates. Why does this occur? Explain that the heart is a muscle and it can work out to become stronger and more efficient.
2. This an opportunity to talk about blood pressure, family history, ways to lower blood pressure, and to add a math component to the lesson. Tell students the number of heart beats and the average lifetime and have them calculate the number of beats per day, hour, minute, etc.
3. This is an opportunity to have students discuss weight and size and guess which animal the 181-kilogram (400-pound) heart belongs to.
4. Ask the students why they think there are differences in animal heart size.
5. Why do we multiply by 6? What are the pros/cons of measuring for 10 seconds versus 60 seconds?
6. When do you think your heart rate is at its lowest versus when is it the highest?
7. What do you think you can learn about a person by examining their heart rate?
8. What do you think causes changes to your heart rate?

ACTIVITY MODIFICATIONS

For younger students:

- For students that are able, have them graph their heart rates. For students that are not ready for graphing, have them rank/order their heart rate values using the <, >, and = signs.

For older students:

- Have the students conduct an investigation to provide evidence that living things are made of cells by using microscopes and/or magnifying glasses. There are pre-made blood smear microscope slides that you can order.
- Have them do math calculations to determine how many beats their heart has taken to this point in their lives or will by a certain point in their lives. This will require basic multiplication and division skills.
- This is an opportunity to have students make graphs of resting versus post-exercise heart rate and maybe see if they can do grouping and comparison of the data. Data comparison can be relative absolute.

DR. DREW, DENSITY, & DIFFUSION:
Density Tower

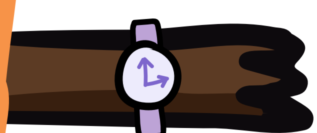
Activity 1

Topics: Science, Mathematics
Target Audience: Students, ages 8-14

ACTIVITY DESCRIPTION

The density tower activity introduces students to the concept of density and is easily connected to STEM concepts of weight and volume. Present this activity as a scenario.

Example: The students are working for a drilling company interested in collecting all of a particular liquid from the column. They will be responsible for predicting where the liquid will be in the column by using the density values and by measuring distance from the top of the graduated cylinder. To correctly complete their task, they must predict where each liquid will rest compared to the others. This activity will engage them in working with <, >, and = and will also encourage their use of a ruler either using metric or imperial units. Until you are confident in your students' abilities to pour and layer liquids gently, it is important that they follow the instructions below.



ESTIMATED TIME:
This session typically takes 20 minutes to complete.

STUDENT DISCOVERIES
Students will:

- Examine density using solid objects
- Examine density using liquids to create a multilayered density tower
- Describe why blood can be separated into its individual components
- Participate in a team-based learning experience
- Learn how STEM^{2}D—science, technology, engineering, mathematics, manufacturing, and design—subjects are used to safely separate and store blood for transfusions

- Build important STEM[2]D skills such as measuring, decision-making, and problem-solving

GETTING READY

Materials (per group)

- 1 250 milliliter graduated cylinder
- 7 Plastic bathroom cups
- 1 Box of food coloring
- 30 milliliters corn syrup
- 30 milliliters chocolate syrup
- 30 milliliters vegetable oil
- 30 milliliters rubbing alcohol
- 30 milliliters water
- 30 milliliters whole milk
- 30 milliliters fruit drink
- 3 craft sticks (for stirring)
- 5 Plastic pipettes
- 7 2-inch pieces of clear tape
- 1 permanent marker or pen
- 1 16 ounce empty clear water/soda bottle (optional for younger students)

Estimated Materials Cost:

Activity leaders should plan to spend ~$8 per group (<$100 per class). The $100 cost should be enough for multiple groups from multiple classes to participate (~30-40 groups). Graduated cylinders, bathroom cups, craft sticks, and pipettes are reusable. For the consumables, most/all of them will supply uses for multiple classes including the corn syrup, chocolate syrup, vegetable oil, rubbing alcohol, milk, and fruit drink.

STEP-BY-STEP INSTRUCTIONS:

- Students should label each cup with the name of the liquid it will hold.
- Each group should fill the bathroom cups ¾ full with each of the seven liquids.
- Add three drops of food coloring to the milk, water, and rubbing alcohol, and stir with a craft stick. Be sure to use different colors for each.
- The students should add the liquids in the following order:
    1. Corn syrup (pouring)
    2. Chocolate syrup (pouring)
    3. Whole milk (pipette)
    4. Oil (pouring)
    5. Fruit drink (pipette)
    6. Water (pipette)
    7. Rubbing alcohol (pipette)
- Students should make note of what happens when each liquid is added.
- Next, add sticky notes with the density measure of each liquid.
- Students should draw what they observe and mark where the different blood components would be in the density tower. To show where the different blood components would be, students will draw the density tower including the 7 layers that are described. Then, they will draw arrows that show where the different blood layers would be if they were in the density tower. For example, plasma and whole milk will be in roughly the same place, whereas the red blood cells would be in, or next to, the fruit drink layer.

Substance	Density
Corn syrup	1.4 g/ml
Chocolate syrup	1.18 g/ml
Whole milk	1.03 g/ml
Vegetable oil	0.93 g/ml
Fruit drink	1.13 g/ml
Water	1.0 g/ml
Rubbing alcohol	0.79 g/ml
Whole blood	~1.06 g/ml
Plasma	~1.03 g/ml
White blood cells	~1.07 g/ml
Red blood cells	~1.13 g/ml

EXTENDED LEARNING

Here are a few ways to extend the learning:

1. Besides density, what are the other visible differences between the different liquids and how else could students determine differences between the liquids?
2. Have the students provide examples of objects with same mass and different densities and same density and different mass.
3. How does the ability of materials to mix affect the density tower (solubility)?

ACTIVITY MODIFICATIONS

For younger students:

- Create a station where they can create their own mixtures to determine if they are able to mix or remain separate. Needs are materials and small clear plastic bottles with caps for shaking.
- Have younger students deal with greater than or less than in terms of density and older students can use mathematics.
- Keep it simple and do a three-layered tower.
- Also use objects and materials that have very different densities that the students are familiar with, such as batteries, chocolate, marshmallows, Rice Krispies, rice, beans, etc.
- Make density comparisons using > and < signs.

For older students:

- How can we create our own centrifugation to show the separation more easily?
- Explain how they could measure density with mass and volume to be more technical. This may require a scale.

MISCONCEPTIONS

Heavier means denser.

- [Clarification] We measure things with weight and mass. One pound of steel weighs the same as 1 pound of feathers which weighs the same as 1 pound of butter. However, their densities are different. Even though they all weigh the same, the pound of feathers (least dense) takes up more space than the pound of steel (most dense). The pound of butter is in the middle.

Density of a substance is constant.

- [Clarification] Density of a substance does change with temperature. As you heat water, its density decreases. Evaporated water (steam) is the least dense form of water. Cooling water makes it denser. Water is most dense at 4°C and is less dense when it is ice, which is why ice floats on water.

You can change the density of a substance by changing the amount that you have.

- [Clarification] Changing the amount of a substance will only change the mass or the weight of an object, but its density will remain the same. For example, changing the density of water requires that you either heat it (making it less dense) or cool it (making it denser).

Boats must be less dense than water because they float (buoyancy and density confusion).

- [Clarification] Ships that float on water are denser than water, but they float because of the amount of water they displace. As they displace more water (buoyancy), it becomes easier for them to float on the surface of the water. If you changed the shape of a boat into a giant cube but kept it the same weight, it would sink.

DR. DREW, DENSITY, & DIFFUSION:
Diffusion in Liquids

Activity 2

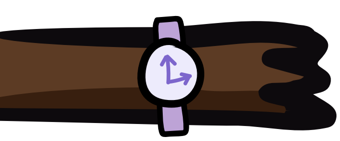
Topics: Science, Mathematics
Target Audience: Students, ages 8-14

ACTIVITY DESCRIPTION

The diffusion activity allows students to engage with the concept of diffusion in liquids by manipulating multiple variables impacting its speed including energy, temperature, and container shape (surface area). Diffusion is the random movement of molecules from an area of a high concentration to an area of low concentration. For these diffusion experiments, it is important that groups use the same color for all their experiments because dye molecules can be different molecular weights, which will lead to different results. This is also an interesting test to perform. Present this activity as a scenario.

Example: When presenting the diffusion and container shape activity to your students, turn it into a challenge to be addressed. You can use the real-life scenario that Dr. Drew and other blood researchers were faced with. Tell the students that we need to select the container that keeps the water from reaching equilibrium as long as possible. Like the experience of Dr. Drew, we want to use a container that slows the diffusion process. Dr. Drew was trying to slow the spread of potassium from the red blood cells into the plasma. You are trying to slow the movement of food coloring into the water.

There are two container options. Once the students identify the best container to use, they will then need to discover if the diffusion process can be slowed using different temperatures of water.



ESTIMATED TIME:

This session typically takes 30 minutes to complete.

STUDENT DISCOVERIES

Students will:

- Examine and describe the diffusion of food coloring in water
- Describe how the temperature of water impacts the speed of

diffusion

- Examine and describe how container shape and surface area affect the speed of diffusion in liquids
- Participate in a team-based learning experience
- Learn how STEM^{2}D—science, technology, engineering, mathematics, manufacturing, and design—subjects are used to safely separate and store blood for transfusions
- Build important STEM^{2}D skills such as measuring, decision-making, and problem-solving

GETTING READY

Materials (per group)

- Tap water
- Ice (or chilled water)
- Microwave/hot plate
- 30 milliliters of vegetable oil
- 1 Box of food coloring
- 3 16 ounce clear plastic cups
- 2 Plastic bathroom cups
- 2 craft sticks
- 1 250 milliliter graduated cylinder
- Timer/clock/watch/cell phone (if desired)
- 1 Thermometer (if desired)
- 1 Disposable coffee cup

Estimated Materials Cost:

Activity leaders should plan to spend $5 per group (<$100 per class). The $100 should be enough for multiple groups from multiple classes to participate (~30-40 groups). Many of the supplies are reusable such as the graduated cylinders, bathroom cups, craft sticks, and pipettes.

STEP-BY-STEP INSTRUCTIONS:

Diffusion in water (teacher demonstration)

- Ask the students to provide predictions about what will happen when several drops of food coloring are added to the water.
- Place several drops of food coloring into the water.
- The students do not need to wait until the food coloring becomes equilibrated in the cup, but they should understand that the process of diffusion and molecular movement is continuously going even when we cannot detect it. Adding the food coloring allows us to observe this process.

Through Dr. Drew's eyes: Connecting diffusion and temperature

- Each team should have two plastic cups.
- Fill one with cold water and the other with water that has been heated in the microwave for 1 minute. Use the disposable coffee cup to heat water in the microwave. Be careful when handling the heated water.
- Students should make a prediction: which cup will the food coloring diffuse in and reach equilibrium faster?
- Make sure the cups have equal amounts of water.
- Add four drops of food coloring into the middle of each cup. Use the same color for each cup.
- Observe for a period of 5-10 minutes. What do you observe? Is diffusion taking place faster in one cup versus the other? If so, why do you think that is the case? How could we test this hypothesis?
- Note: This is the perfect time to incorporate the use of the thermometer and the timing device for older students to measure how much the temperature affects the speed of diffusion. Younger students can focus on <, >, or = signs.

Through Dr. Drew's eyes: Connecting diffusion and container shape

- Each group of students should have a graduated cylinder and a clear 16 oz plastic cup.
- Each container should be filled with 200 milliliters of room-temperature water. The water should be the same temperature for each container.
- Students should make a prediction: which water-filled container will the food coloring diffuse in and reach equilibrium faster?
- Next, pour 30 milliliters of vegetable oil into two plastic cups.
- Add six drops of food coloring into each cup with vegetable oil and stir vigorously until the food coloring is evenly mixed. Note that the food coloring will not mix fully with the oil because it is water based.
- Gently pour the oil into each container with the water.

- Students should note what they observe in each container and where equilibrium is reached first.
- Observe the oil layer, water layer, and the interface (area where the oil and water touch) for 5-10 minutes. What do you notice in each of the containers?
- As dye moves into the water, what happens to the vegetable oil?
- As dye moves from the oil, what happens to the water?
- Have the students describe the similarities and differences between this activity and Dr. Drew's experiences. Encourage the students to think about differences in time, temperature, etc.

EXTENDED LEARNING

Here are a few ways to extend the learning:

1. What are the pros and cons of different blood storage containers?
2. What other type of gradients are there (pressure, temperature, etc.)? How are they similar and different to each other?
3. Who is Frederick McKinley Jones? What is his connection with blood collection and blood storage?
4. Why does refrigeration slow the spoiling of blood?

ACTIVITY MODIFICATIONS

For younger students:

- Students that are ready can learn how to measure the surface area of different shapes
- Why someone would create new technology?
- What difficulties are likely to arise in the process of creating new technology?
- Can you think of anything you know that has been changed drastically since you have been alive? (House phone to cell phone; cabs to ride apps, etc.)
- What is a problem that you could work to improve? How would you do it? What would you need to know? Who would you need to work with? Would you need to know history or other disciplines?

For older students:

- These could be used as an enhancement opportunity for students. All of the Engineering, Technology and Applications of Science Standards from the Next Generation Science Standards (ETS) could be

  - Why would someone create this?
  - What difficulties likely arose in the process?
  - Can you think of anything you know that has been change drastically since you have been alive?
  - What is a problem that you could work to improve? How would you do it? What would you need to know? Who would you need to work with? Would you need to know history or other disciplines? What technological or scientific advances would need to be in place for you to solve this problem?
- Have the students identify something in their lives that needs improving. Have them create a plan they would carry out to make those improvements in the real world.
- Students that are ready can learn how to measure the surface area of two-dimensional and three-dimensional objects and connect it back to the activity with diffusion in different containers.
- How does diffusion relate to air and water pollution and its impact for the people of the world?

MISCONCEPTIONS

Diffusion happens quickly (e.g., shark detecting blood in the water)

- [Clarification] Diffusion is an incredibly slow process that relies on the movement of individual molecules. For example, if you add drops of food coloring to a gallon of water, it may take hours for the dye to spread uniformly throughout the water. The speed of diffusion can be increased in a process known as facilitated diffusion. With facilitated diffusion, molecules spread out evenly faster due to movements of air or water currents (e.g., using a spoon to stir the water-dye mix). Facilitated diffusion requires energy input. Sharks can detect blood in the water quickly from a distance because of the water currents.

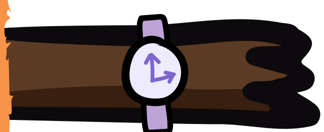
DR. DREW, DENSITY, & DIFFUSION:
Diffusion in Red Blood Cells

Activity 3

Topics: Science, Mathematics
Target Audience: Students, ages 8-14

ACTIVITY DESCRIPTION

This activity will introduce the students to how diffusion can occur across a membrane, like it does in our bodies. The students will build on their earlier concepts of diffusion to construct a physical model of the red blood cells in our bodies and how diffusion of gases occurs in our bodies. When presenting the red blood cell model to your students, this is an opportunity to engage students in the concepts of surface area, volume, size, and scale.



ESTIMATED TIME:
This session typically takes 30 minutes to complete.

STUDENT DISCOVERIES
Students will:

- Create and use a model to demonstrate how oxygen and carbon dioxide can move into and out of the red blood cells by diffusion
- Participate in a team-based learning experience
- Learn how STEM^{2}D—science, technology, engineering, mathematics, manufacturing, and design—subjects are used to safely separate and store blood for transfusions
- Build important STEM^{2}D skills such as measuring, decision-making, and problem-solving

GETTING READY

Materials (per group)

- 2 4 inch pieces of dialysis tubing
- 1 Color from the box of food coloring

- 4 Plastic bathroom cups
- Water
- 6 Rubber bands
- 1 Disposable coffee cup
- 1 permanent marker
- Timer/clock/watch/cell phone (if desired)
- 1 Thermometer (if desired)
- 1 craft stick
- 1 Plastic pipette

Estimated Materials Cost:

Activity leaders can expect to spend ~$5 per group (~$50 per class). The $50 should be enough for multiple groups from multiple classes to participate (~30-20 groups). Many of the supplies are reusable such as the dialysis tubing, bathroom cups, rubber bands, coffee cups, craft sticks, and pipettes. For the consumables, you will be able to get multiple uses from food coloring.

STEP-BY-STEP INSTRUCTIONS:

All of the experiments below can be done with different temperatures of water. To observe results more quickly, use warmer water and vice versa.

Oxygen in

- Cut a 4-inch-long piece of dialysis tubing.
- Close one end using a rubber band tight enough so that no liquid can pass through.
- Fill the dialysis tubing ~60-75% full of water.
- Close the other end of the dialysis tubing using a rubber band tight enough so that liquid can neither exit nor enter the tubing.
- Using a disposable coffee cup, heat water for 1 minute in the micro-wave.
- Add three drops of food coloring to the heated water and stir.
- Use the heated and dyed water to fill a plastic bathroom cup ¾ full.

- Place the tied dialysis tubing inside the plastic bathroom cup with dyed water.
- Check the tubing every 5 minutes for 15 minutes, making observations about what you notice.
- After 15 minutes, compare the color of the water to the color of un-dyed water. Write down what you observe.
- To check the final color of the water in the tubing, remove the rubber bands and pour it in a clean plastic cup for comparison with fresh water.

Debrief: Allow students time to discuss how the dialysis tubing is a semi-permeable membrane, like that of your red blood cells and it allows some materials to pass through but not others. Lead them to understand that like the **oxygen** in your body, the dye moves down the concentration gradient from the cup to inside the tubing. The dye is more concentrated in the water outside of the tubing and moves to a place of lower concentration by the random movement of the dye and water molecules.

Carbon dioxide out

- Cut a 4-inch-long piece of tubing.
- Close one end using a rubber band tight enough so that no liquid can pass through.
- Fill the dialysis tubing ~60-75% full of water.
- Add three drops of food coloring to the tubing.
- Close the other end of the dialysis tubing using a rubber band tight enough so that liquid can neither exit nor enter the tubing.
- Wipe as much of the dye as you can from the end and outside of the tubing by using a paper towel.
- Using a disposable coffee cup, heat water for 1 minute in the microwave.
- Use the heated water to fill a plastic bathroom cup ¾ full.
- Place the tied dialysis tubing with the dyed water inside the plastic bathroom cup.
- Check the plastic bathroom cup every 5 minutes for 15 minutes, making observations about what you notice.
- After 15 minutes, remove the tubing from the water and compare the color of the water in the cup to the color of fresh water. Write down what you observe.

Debrief: Allow students time to discuss how the dialysis tubing is a semi-permeable membrane, like that of your red blood cells and it allows some materials to pass through but not others. Lead them to understand that like the **carbon dioxide** in your lungs, the dye moves down the concentration gradient from inside of the tubing to the water in the cup. The dye is more concentrated inside of the tubing and moves to a place of lower concentration by the random movement of the dye and water molecules.

Student Reflection (10 minutes)

Have the students reflect on this activity by answering the following questions:

- What did you learn about Dr. Drew??
- Was it fun? What made it fun?
- Who are you going to tell about today's activity? Why?
- What did you learn from (list an activity you completed)?
- Might you consider a career in engineering design? Explain.

After a few minutes, ask the students to share their thoughts.
Thank the students for participating.

This is a great time to present each student with a certificate that has been prepared ahead of time with each student's name and signed by the Johnson & Johnson volunteer. Also, pass out the WiSTEM^{2}D posters to each student.

EXTENDED LEARNING

Here are a few ways to extend the learning:

1. In this experiment the diffusion process happens over a matter of minutes. Why does this process happen faster in our bodies?
2. What would happen if the diffusion process in our cells took as long as it does in this activity?
3. Why do we need to breathe? Why can't we rely on diffusion to take move oxygen and carbon dioxide for us?

ACTIVITY LEADER REFLECTIONS

- After the activity, take a few minutes to reflect on the following:
- What went well and what could be improved?
- What would you do differently next time?
- How comfortable did you feel leading the learning experience?
- Do you have a better understanding of the STEM^{2}D concepts?
- How useful was the information presented in the Spark WiSTEM^{2}D?
- Will you volunteer for this type of experience again?

ACTIVITY MODIFICATIONS

For younger students:

- Connect these activities with scales of size and time.
- Try the dialysis tubing activity using different temperatures of water and do comparisons using <, >, or = signs to compare the speed at which the dye moves.
- Have the students predict and measure how long it takes for the water in the cups to equilibrate with the water in the tubing in terms of color.

For older students:

- Connect these activities with lung diseases and how they interfere with gas exchange in the lungs.
- Connect these activities with scales of size and time.
- Try the dialysis tubing activity using different temperatures of water and have the students graph the speed at which diffusion occurs as water temperature increases.
- Have students investigate diseases of red blood cells, impacts on the individual, who tends to have the disease, and benefits (if any) of having the disease (e.g., sickle cell anemia, iron deficiency, Thalassemia, etc.).

MISCONCEPTIONS

Red blood cells are not living

- [Clarification] Red blood cells are living cells. Unlike most of the other cells in your body, they do not possess many of the organelles that other cells have, such as mitochondria and a nucleus. The red blood cell possesses a limited metabolism, which is highly dependent on glucose for energy production (like most cells).

Red blood cells of all animals are like human red blood cells

- [Clarification] Although human red blood cells do not have nuclei, the red blood cells of animals such as birds and amphibians do have nuclei.

STEM^{2}D CAREER CONNECTIONS

Expose your students to the following careers, including required education, training, and job responsibilities:

- Physicians
- Nurses
- Athletic trainers
- Phlebotomists
- Molecular biologists
- Protein biologists
- Sports performance coaches (VO2 max)
- Materials scientists
- Inventors
- Earth scientists
- Hydrologists
- Archaeologists

References

Information about Dr. Charles Drew

- Hardwick, R. (1967). Charles Richard Drew: Pioneer in Blood Research. New York, USA. Charles Scribner's Sons.
- Love, S. (1996). One Blood: The Death and Resurrection of Charles R. Drew. The University of North Carolina Press Chapel Hill and London.
- https://profiles.nlm.nih.gov/BG/
- https://www.youtube.com/watch?v=hANr29x4yTA

History of blood transfusions and donation

- https://stanfordbloodcenter.org/a-brief-history-of-blood-transfusion-through-the-years/
- https://www.redcrossblood.org/donate-blood/blood-donation-process/

what-happens-to-donated-blood/blood-transfusions/history-blood-transfusion.html

- http://www.aabb.org/tm/Pages/highlights.aspx
- http://givingblood.org/about-blood/history-of-blood-banking.aspx
- https://www.blood.co.uk/the-donation-process/after-your-donation/the-journey-of-a-blood-donation/

Information about the heart

- https://cvm.ncsu.edu/10-amazing-animal-heart-facts/
- https://www.youtube.com/watch?v=TmcXm-8H-ks
- https://www.youtube.com/watch?v=xWkeidr2T8o
- https://www.healthline.com/health/blood-cell-disorders

Information about the blood storage container Dr. Drew used

- https://patents.google.com/patent/US2301710A/en

ACTIVITY LEADER CHECKLIST:

DID YOU . . .

- ☐ Read Spark WiSTEM2D? This is essential reading for all volunteers interested in working with youth. It defines the STEM2D principles and philosophy and provides research-based strategies and tips for engaging and interacting with female students. Download at www.STEM2D.org.
- ☐ Visit the implementation site and observe the young people? (optional) If visiting, take note of the following:
  - ☐ How does the site encourage orderly participation? For example, do the young people raise their hands when responding to questions or during discussions? How are interruptions handled? Do you see any potential problems with managing the class of young people?
  - ☐ What does the site do to make each student feel important and at ease?
  - ☐ How is the room arranged? Will you need to move desks or chairs for any part of your presentation?
  - ☐ How can you engage the site representative in your presentation?
- ☐ Meet with and finalize the logistics with the Site Representative?
  - ☐ Confirm the date, time, and location of the activity?
  - ☐ Confirm the number of students attending? Knowing this will help you decide how to group the students into teams, as well as the appropriate materials to purchase.
- ☐ Recruit additional volunteers, if needed?
- ☐ Prepare for the activity:
  - ☐ Read the entire activity text prior to implementation?
  - ☐ Customize the activity, if desired, to reflect your background and experiences, as well as the cultural norms and language of the students in your community?
  - ☐ Complete the Tell My Story Form, which will prepare you to talk about your educational and career path with the students?
  - ☐ If teams are needed for this activity, please ask the teacher in advance to organize the students into teams.
- ☐ Practice your presentation, including the hands-on, minds-on activity? Be sure to:
  - ☐ Do the activity; make sure you can explain the concepts to students, if needed, and that you know the correct answers.
- ☐ Obtain the required materials (see the Materials and Estimated Materials Costs sections) and, if asked for in the Getting Ready section, photocopy the Student Handouts and Materials Testing Sheets. In addition:
  - ☐ Organize the materials to ensure each team has everything listed in the Materials section—keep in mind some materials are shared among the teams.
- ☐ Prepare the space? Specifically:
  - ☐ Make sure tables and chairs are arranged to accommodate teams of students.
  - ☐ Bring a camera, if desired, to take photographs.
- ☐ Obtain and collect permission slips and photo release forms for conducting the activity if applicable?
- ☐ Have fun!

“Tell My Story” Form

This form will help volunteers serving as activity leaders prepare to talk about their STEM²D interests, education, and career path.

ABOUT YOU

Name: ______________________________

Job Title: ______________________________

Company: ______________________________

When/Why did you become interested in STEM²D? ______________________________

____

____

What do you hope young people, especially girls, will get out of this activity? ______________________________

____

FUN FACT

Share a little about your background. Ideas:

- Share a memory from childhood where you first had your “spark” or “interest” in STEM.
- Detail your journey; highlight what you have tried, what you learned, steps to success, etc.
- Failures or set backs are also great to talk about—difficulties, and/or challenges and how you overcame them.

EDUCATION AND CAREER PATH

What classes/courses did you take in secondary school and in college that helped or interested you most? ______________________________

How did you know you wanted to pursue a STEM²D career?

____

What was your postsecondary path, including the institution you attended and your degree? *If you switched disciplines, make sure you explain why to the students.*

____

What your current position entails. *Be sure to include how you use STEM²D on a typical work day.*

____

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Johnson & Johnson

Dr. Charles Drew: Giving Life Through Blood Research

1. **Activity 1: Density tower**
    - Define *Density*:
    - What is your Hypothesis?
    - What are your observations?

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2. **Activity 2: Diffusion in Liquids**
    - Define *Diffusion*:
    - Will the food coloring spread faster in cold water or hot water? Why?
    - Which container shape will reach equilibrium first? Why?

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3. **Activity 3: Diffusion in Red Blood Cells**
    - What is your Hypothesis?
    - Why does this process happen faster in our bodies?

WiSTEM²D
Women in Science, Technology, Engineering, Math, Manufacturing, and Design