Vanderbilt Student Volunteers for Science

https://studentorg.vanderbilt.edu/vsvs/
VOLUNTEER INFORMATION

Team Member Contact Information

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Name: ___________________________ Phone Number: ___________________________

Teacher/School Contact Information

School Name: ___________________________ Time in Classroom: ___________________

Teacher’s Name: ___________________________ Phone Number: ___________________

VSVS INFORMATION

VSVS Educational Coordinator:
Paige Ellenberger 615-343-4379
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VSVS Office: Stevenson 5234

Co-Presidents: Carli Needle carli.d.needle@vanderbilt.edu
Meghana Bhimreddy meghana.bhimreddy@vanderbilt.edu

Secretaries: Emily Chuang emily.a.chuang@vanderbilt.edu
Derek Lee lynn.lee.1@vanderbilt.edu

Vanderbilt Protection of Minors Policy: As required by the Protection of Minors Policy, VSVS will keep track of the attendance – who goes out when and where.
https://www4.vanderbilt.edu/riskmanagement/Policy_FINAL%20-%20risk%20management%20v2.pdf

Before You Go:
The lessons are online at: https://studentorg.vanderbilt.edu/vsvs/lessons/
• Email the teacher prior to the first lesson.
• Set a deadline time for your team. This means if a team member doesn’t show up by this time, you will have to start the lesson without them.
• Don’t drop out from your group. If you have problems, email Paige or one of the co-presidents, and we will work to help you. Don’t let down the kids or the group!
• If your group has any problems, let us know ASAP.

Picking up the Kit:
• Kits are picked up and used for lessons in the VSVS Lab, Stevenson Center 5234.
• The VSVS Lab is open 8:30am – 4:00pm (earlier if you need dry ice or liquid N\textsubscript{2}).
• Assign at least one member of your team to pick up the kit each week.
• Kits should be picked up at least 30 minutes before your classroom time.
• If you are scheduled to teach at 8am, pick up the kit the day before.
• There are two 20 minute parking spots in the loading dock behind Stevenson Center. Please do not use the handicap spaces – you will get a ticket.

Just relax and have fun!
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### CLASSROOM ETIQUETTE

Follow Metro Schools' Dress Code!
- No miniskirts, shorts, or tank tops.
- Tuck in shirts if you can.
- Please dress appropriately.

Metro student standard attire guideline:

### COLLEGE Q&A SESSION

VSVS members should be candid about their experiences and emphasize the role of hard work and a solid body of coursework in high school as a means to get to college.
- Email the teacher prior to the first lesson.
  - They may want to have the students write down questions prior to your lesson.
  - They may also want to have a role in facilitating the discussion.
- Finish the experiment of the day and open up the floor to the students.
- Remind them of your years and majors and ask if they have specific questions about college life.
- If they are shy, start by explaining things that are different in college.
  - Choosing your own schedule, dorm life, extracurricular activities, etc.
  - Emphasize the hardworking attitude.

The following are some sample questions (posed by students):
- When is bedtime in college? Does your mom still have to wake you up in college?
- How much does college cost?
- What do you eat in college and can you eat in class in college?
- How much homework do you have in college?
Volunteer FAQ

→ What is VSVS?
VSVS stands for Vanderbilt Student Volunteers for Science.
Members of this organization volunteer to teach hands-on science lessons to 5th-8th grade classrooms in the Metro Nashville School District.

→ How often are lessons?
Each team teaches 1 lesson per week for 4 consecutive weeks throughout a semester.

→ What is the time commitment?
Relatively low!
Depending on your position, you'll attend between 1-3 training sessions at the beginning of the semester, and each of the 4 lessons take about 1.5 hours (30 minutes to run through each lesson beforehand and 1 hour to teach it).

→ Who will I be teaching with?
All volunteers are put into groups of up to 3 (based on availability) and assigned to a classroom.
If you have friends that you'd like to be partnered with, be sure to have one group member fill out a separate Partner Application so you can be appropriately matched!

→ Where will I be teaching?
Your team will be teaching your students over some virtual platform from the same room.
Team leaders will be responsible for finding their respective team's own place to “meet” their class and will be shown how to book rooms to teach from through Vanderbilt’s room booking website. VSVS will also be pointing out common spaces on campus as well as providing the VSVS side room first come, first serve. Social distancing rules and sanitation protocols will be enforced.

→ What are the lesson dates?
At the beginning of each semester, we send out a group assignment email that contains all of the relevant information for your group. It will have your teachers name and contact information, as well as the names and contact for all of your group members, and the date/time of your lessons.

→ What if I need to quit VSVS?
If you can no longer fulfill your commitment to VSVS, please reply to one of the emails we've sent you ASAP and let us know so that we can adjust accordingly.

→ Can graduate students participate in VSVS?
Yes -- you can either join as a regular volunteer and be assigned to a team and classroom OR you can serve as a floating volunteer (that is, if your schedule is very irregular but you know that you'll be available for at least a few of our weeks!). Just note which option you’d like in your application!

For additional questions, feel free to contact the VSVS Educational Coordinator at paige.ellenberger@vanderbilt.edu.
DIRECTIONS TO SCHOOLS

**H.G. HILL MIDDLE SCHOOL: 150 DAVIDSON RD**
HG Hill School will be on the right across the railroad lines.

**HEAD MAGNET SCHOOL: 1830 JO JOHNSON AVE**
The parking lot on the left to the Johnston Ave.

**J.T. MOORE MIDDLE SCHOOL: 4425 GRANNY WHITE PIKE**
From Lone Oak, the parking lot is on the right, and the entrance into the school faces Lone Oak, but is closer to Granny White.

**MEIGS MIDDLE SCHOOL: 713 RAMSEY STREET**
Going down Ramsey Street, Meigs is on the left.

**ROSE PARK MAGNET SCHOOL: 1025 9th AVE SOUTH**
The school is located on the left and the parking is opposite the school, or behind it (preferred).

**WEST END MIDDLE SCHOOL: 3529 WEST END AVE**
Parking is beside the soccer field, or anywhere you can find a place. Enter through the side door.

**EAST NASHVILLE MAGNET MIDDLE SCHOOL: 2000 GREENWOOD AVE**

**MARGARET ALLEN MIDDLE SCHOOL: 500 SPENCE LN**
From West End down Broadway, take 1-40E to exit 212 Rundle Ave. Left on Elm Hill to Spence Lane.
VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
http://studentorg.vanderbilt.edu/vsvs

Chromatography
Mini Lesson
Fall 2020

**Goal:** To demonstrate a technique or process for separating mixtures that is used by biologists, chemists, clinical scientists, and forensic scientists (detectives).

**Introduces/reinforces TASS:** 5PS1.4 Evaluate the results of an experiment to determine whether the mixing of two or more substances result in a change of properties.

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**VSVSer Lesson Outline**

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I. Introduction
a. What is a mixture? *Explain to the students that there are 2 types of mixtures and show examples of both.*
b. Making a homogenous mixture. *Explain chromatography as a process for separating mixtures. In today’s lesson, paper chromatography will be used to separate water-soluble inks into their component colors, starting with the separation of green into blue and yellow.*

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II. Activity
a. Chromatography Using a Green Pen to separate a Homogeneous Mixture. *Show students the proper procedure for setting up a chromatography experiment, using a 16 oz cup, a stick, green pen, and a paper strip. Each student pair will do this.*
b. Forensic Chromatography. *Each pair does a chromatogram of one of the four pens to help determine which pen was used to write a ransom note. After the chromatograms are finished, ask the students to compare their chromatograms with the chromatogram prepared from the guilty person’s pen to determine who is the guilty person.*

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III. Discussion/Review
a. Review of important concepts and terminology.

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https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND/OR VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. Before the lesson: In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

1) What are the 2 types of mixtures?

*Homogenous and heterogenous. Homogenous mixtures are comprised of different substances that are evenly mixed, while heterogenous mixtures are different substances that are unevenly mixed.*

2) How can you separate a mixture?

*By using chromatography. In our case, we will be using paper chromatography to separate ink.*

3) What kind of properties allow for mixture separation?

*Physical properties, such as the magnetic properties of iron filings that allow for magnets to separate them from sand*
Unpacking the kit and Set-Up:
While a VSVS member does the Mixing Colors demonstration:
1. Another member pours water into enough 16 oz cups to the marked level for pairs in the class, plus one for VSVSers to do demonstration
2. Remaining members will attach the chromatography paper already marked with the green pen to the sticks (see instructions on how to do this).
   Hold the paper strip so that the top edge of the paper is even with the top edge of the wooden stick.
   Tear a small piece of tape and tape the paper strip to the wooden stick so that the tape goes around the stick and is taped to both the front and the back of the paper strip.

Put the following vocabulary words on the board:
   Mixture, chromatography, chromatogram, capillary action, forensic chromatography

Unpacking the kit:
1. What is a Mixture?
   1 bag of colored balls,
   1 8 oz jar with sand/iron filings mixture and a cow magnet

B. Demonstration – Making a Homogeneous Mixture
   1 bag containing: 1 jar blue water, 1 jar yellow water (each about ¼ filled)

II. Using Chromatography to Separate a Homogeneous Mixture (using a green Pen)
Materials:  (1 set is for VSVS to use as demo)
   • 16 16 oz. clear plastic cup with water to the mark (about 30 mL.)
   • 5 green pens
   • 16 chromatography strips that already have the green pen trace don the horizontal line AND prepared by VSVSers so that the paper is already attached to wood stick

III. Forensic Chromatography
Distribute the following materials to each pair:
   • 1 piece of chromatography paper
   • 1 16 oz clear plastic cup –students already have
   • 1 stick – students already have, but the green chromatogram needs to be removed.
   • 1 roll of clear tape
   • 1 paper towel
Note: Student pairs will need to share the black pens and tape
Distribute the 16 laminated chromatograms

Full Materials List:
3 250 mL bottles filled with water (use to put water to the mark (about 25-30 mL) into the 16-oz cups)
1 bag of colored balls
1 jar sand and iron filings and cow magnet
1 bag containing 1 125cc jar of blue water, 1 125cc jar yellow water (1/4 filled)
1 bag containing: 16 rolls of clear tape
1 bag containing 16 wooden sticks
1 bag containing 5 green pens
1 bag containing 16 chromatography strips with green horizontal line drawn 2 cm from the bottom of the strip
1 bag containing 16 chromatography strips (horizontal pencil line is drawn 2 cm from the bottom of the strip)
16 16 oz. clear plastic cups, marked at the 25 - 30 mL level
1 large bag containing 15 black pens labeled with suspects initials (PC, PS, JF or MM)
16 prepared laminated chromatograms from the "guilty" person’s pen (PC)
16 prepared laminated chromatograms from the 4 different pens
16 sheets of paper towel

1. Introduction

a. What is a Mixture?
   - Mixtures are made up of two or more different elements or compounds which can be separated by physical means.
     - Show students the bag of mixed balls. Explain that each differently colored ball represents an element or compound.
       - The balls are not connected, so they are a mixture.
       - Examples of mixtures include salt in water, air, soil, and sand. Mixtures can be made with any combination of phases of matter: solid in solid, (sand and iron filings), solid in liquid, (salt in water), gas in liquid (carbon dioxide bubbles in water) etc.
   - There are 2 types of mixtures: heterogeneous and homogeneous
     - In heterogeneous mixtures, the substances are unevenly mixed and you can see them.
     - In homogeneous mixtures, the different substances are evenly mixed so that you cannot see them. Mixing colored solutions is an example.

A. Demonstration 1: Using the magnetic property of iron to separate a heterogeneous mixture.

Materials: 1 8 oz jar with sand/iron filings mixture and a cow magnet

Tell students to look at the jar of sand.
   - Why do you think it is a mixture? Because it contains different kinds of particles.
     - Tell the students that sand is a collection of fragments of minerals, shells, fossils and organic matter. Sometimes it contains iron in the form of magnetite, which is magnetic. This is called Ironsand and can be found worldwide.
   - Ask students: Do you have any ideas how we can separate the iron from the sand? With a magnet. Be sure to point out that the iron is magnetic, and sand is not. Also be sure to mention that separation by magnetism is a physical means of separation.

Emphasize that a physical property of iron can be used to separate the mixture.
   - Tell students that you will use a cow magnet to separate the iron filings from the sand.
The cow magnet will already be in the jar. Pull it out of the sand and take it around the class to show the students the iron filings on it.

Share the following information with the students:
- Cow magnets are used by farmers to protect the cow’s stomachs from being punctured by small pieces of baling wire or other bits of wire that cows might eat with hay.
- Cows have four stomachs. The cow magnet is placed in the first stomach to attract bits of wire in order to keep them from entering the other three stomachs.
- Farmers or veterinarians open a cow’s mouth and place the cow magnet down its throat into the first stomach.
- Cow magnets are available from farm supply stores, farmer’s co-ops and science supply stores.

### B. Demonstration 2 – Making a Homogeneous Mixture

**Materials:** 1 bag containing: 1 jar blue water, 1 jar yellow water (about ¼ filled)

- Hold the jars up so the students can see them.
- Ask the students: *What color do you get when you mix blue and yellow?*
- Ask: "*What will happen if you combine the 2 liquids?* Accept responses.
- Pour the blue liquid the yellow liquid together and show students that the mixing of the blue and yellow liquids makes a green liquid.
- Ask students: Is this a homogeneous mixture? Why? *The blue and yellow liquids cannot be seen anymore.*
- Did a chemical change happen? Or a physical change? *(Physical).*

### II. Activity 1: Using Chromatography to Separate a Homogeneous Mixture (using a green Pen)

**Materials:** (1 set is for VSVS to use as demo)
- 16 oz. clear plastic cup with water to the mark (about 30 mL.)
- 5 green pens
- 16 chromatography strips that already have the green pen trace down the horizontal line, paper is already attached to wood stick

Ask students: What colors mixed together result in green? *blue and yellow*
Show the students the green pen and tell them that the green is a *mixture* of blue and yellow inks.

**Explaining: What is Chromatography?**

Explain to the students that chromatography is a physical way to *separate mixtures.*
In today’s lesson, paper chromatography will be used to separate water-soluble inks into their different colors, starting with a green pen and then a black pen to help solve a crime.

**Show students:**
- How the green pen was used to trace over the pencil line on the paper.
- How was the paper attached to the stick: hold the paper strip so that the top edge of the paper is even with the top edge of the wooden stick. Tear a small piece of tape and tape the paper strip to
the wooden stick so that the tape goes around the stick and is taped to both the front and the back of the paper strip.

- Take one of the 16 oz cups that contains 30 mL of water and gently place the stick across the 16 oz. cup so the stick and paper will not fall into the cup. The strip should hang free in the center of the cup without touching the sides.

- The bottom of the paper should be in the water, BUT make sure the green line does not touch the water

PASS MATERIALS OUT TO PAIRS OF STUDENTS

- Each VSVS member will help students do this experiment
- As the water starts to go up the paper strip, show the strip to the students and tell them that this capillary action will help separate the colors.

**Explanation:**

Liquids can climb up paper, string, and other substances through the process of capillary action. The liquid moves upward through small pores, or capillaries, that are found in paper towels, filter paper, chromatography paper, and other porous materials; this is what makes these materials absorbent. Scientists use this process to separate mixtures, including colors.

**Background** – Adapt to your class.
The paper is the support in this experiment. The solvent used (water in this case) has different degrees of absorption to the support. The greater the porosity of the paper, the better the capillary action or wicking, and the faster the water will climb. As the water moves up the paper strip, it dissolves the water-soluble pigments of the green pen mark. Each pigment travels at a different speed depending on its solubility in water and its absorption on the paper. The color separation is called developing a chromatogram (a color pattern). Chromatograms can be used to match and identify substances in biology, chemistry and forensic labs.

A simpler explanation is that the solvent carries the pigment farther if the pigment is more water soluble.

**III. Activity 2: Forensic Chromatography**

Tell students that:

- Chromatography is used in crime labs to separate components of "clue” substances such as blood, ink, or other mixtures found at the scene of the crime.
- Forensic scientists or detectives can also use the process of chromatography in their work.
  - The same pen will always show an identical pattern of separation into its separate colors. This is because pens include a specific ink that has a specific mixture of pigments.
  - This illustrates how scientists can use chromatography for analysis.
- Chromatography can be used to identify the pen that was used to write a ransom note.

Read or tell the following scenario to students and tell them they will use chromatography to determine “Whodunit!”

- **NOTE:** - You can change the scenario, BUT you cannot make it gory, have anything to do with sexual stories, or upsetting to young 5th graders.

The police (represented by Sam Suede, a hard-boiled police detective) have been called to the scene of a crime. The scene is a chemistry laboratory, and a small vial of Solution X has been stolen. A ransom note has been received, written in black ink, demanding one million dollars for the return of Solution
X. Through questioning, Sam Suede learns that rumors have been spreading that Solution X may be the long-awaited cure for the common cold!

Sam discovers that there are four prime suspects who all have a motive for committing this crime. They are as follows:

- Pam Chromatogram (Pen PC)
- Mary Masonite (Pen MM)
- Patrick Street (Pen PS)
- John Fingerprint (Pen JF)

Sam has obtained a pen from each of these suspects and has a chromatogram that was made from the ransom note. Sam needs your help in matching the suspect’s pen to the ransom note.

Distribute the following materials to each pair:

- 1 piece of chromatography paper
- 1 16 oz clear plastic cup – students already have
- 1 stick – students already have, but the green chromatogram needs to be removed.
- 1 roll of clear tape
- 1 paper towel
- 1 black pen – student pairs will need to share the black pens and tape

Each pair will follow the procedure demonstrated in Part II to obtain a chromatogram of one of the suspect’s pens.

Have each of the students do the following:

- Trace the pencil line with their black pen.
- Tell each student to mark the top of the chromatography paper near the stick with the initials on their pen (PC, PS, JF, or MM) with a pencil.
  - Hold up a stick with a piece of chromatography paper taped to it to make sure the students know where to place the initials – at the top near the stick.
- Take the 16 oz cup that contains 30 mL of water and gently place the stick across it so the stick and paper will not fall into the cup. The strip should hang free in the center of the cup without touching the sides.
- Wait about five or six minutes for development of the chromatogram.

After the chromatogram has developed enough so that the different colors can be identified, tell the students to:

- Lift the stick out of the cup and remove the chromatogram from the stick by holding the paper near the taped end and sliding it off the stick.
- Place the chromatogram on a sheet of paper towel.

Ask 4 students to describe the 4 different chromatograms. The results can be put on the board, or shown to the class. **Emphasize that each pen has a unique chromatogram.**

Distribute the 16 laminated chromatograms prepared from the guilty person’s pen and ask them to compare it to their chromatogram. Identify which pen matches the results from the ransom note.

Ask students: Who is the guilty person? **PC - Pam Chromatogram**

**IV. Discussion/Review**
Adapt to your class:

- In most of the variations of chromatography, a substance (ink dot, candy coating, leaf extract) is placed onto a support (paper strip).
- A solvent (water, alcohol) is then added, which moves up the support because of capillary action. As the solvent moves through the test substance, some of the test substance is dissolved in the solvent and carried up the support.
- Different types of substances move different distances, which depend on their differences of solubility in the solvent and their absorption on the paper. As a result, separation occurs.
- This is always constant for a particular support and solvent. Chromatograms of these substances are then compared with known chromatograms to identify the substances.

REVIEW QUESTIONS

1. Why does water move up the paper strip?
   Answer: capillary action

2. In the separation of the green ink, the blue pigment moves higher (faster) than yellow pigment. Why?
   Answer: The speed of movement of a component of a mixture, in this case colors, depends on its relative solubility in the solvent (water) and its relative strength of attachment (absorption) to the paper. The blue pigment is more soluble (more attracted to water than to the paper) and less absorbent (less attracted to the paper) so it moves faster up the paper strip.

References

2. J. Barer, Crime Lab Chemistry, Teacher’s Guide: Lawrence Hall of Science, University of California, Berkeley, CA.

Lesson written by Dr. Melvin Joesten, Emeritus Professor, Chemistry Department, Vanderbilt University
Pat Tellinghuisen, Program Coordinator of VSVS, 1998-2018, Vanderbilt University
Susan Clendenen, Teacher Consultant, Vanderbilt University
Dr. Todd Gary, former Coordinator of VSVS, Vanderbilt University
Answers Chromatography Observation sheet

Name: _________________________

Chromatography Part I: Separation of Green Colors

1. What did the color change to when the yellow and blue solutions were mixed?
   ______ green ________________

2. What happened to the marker’s green color on the chromatography paper?
   ______________ separated into yellow and blue ______

3. What can you conclude about the green ink? How many dyes are used to give it its color?
   ___2 dyes ________________________________

4. Which color traveled faster?
   ____ blue ________________________________

Chromatography Part II: Forensics Using Black Pens

5. Draw and label your results on the “chromatography paper” below. Include the initials of the suspect’s pen on the diagram.

6. Is your chromatogram the same as those from other black pens?
   ______ not all ______________________________

7. Whose pen was used to write the ransom note?
   _______ PC – Pam Chromatogram __________________
Goal: To explain how the environment helps determine what traits certain species possess.

Introduces/reinforces TASS: 7.LS1.6 Develop an argument based on empirical evidence and scientific reasoning to explain how behavioral and structural adaptations in animals and plants affect the probability of survival and reproductive success.

VSVSers  Lesson Outline

I. Introduction
a. What is a trait? Explanation of physical traits and why trait variations are important.
c. Adaptations. Explanation of adaptations as inherited traits that aid survival.
d. Setting up environment stations. Description of activity stations (to be set up by VSVSers).

II. Activity
a. Bird beak adaptation activity used to illustrate environmental adaptations

III. Discussion/Review
a. Students finish up observation sheet and match beak to bird. Overall review of traits, adaptations, and natural selection.

https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND/OR VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. Before the lesson:
In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.
1. What is a trait? Answer in intro.
2. What is not an example of a heritable trait? Answer in 1b.
3. What is natural selection? Answer in 1c.
4. What is an adaptation? What are some examples?
5. Give an analogy that explains traits, natural selection, and adaptation.
6. How will students determine which beaks were most beneficial in which environments? Using 2 tools to pick up the “food sources” in various environments.

Unpacking the kit and Set-Up:

1. Organize students in six groups (of 4-6). They will rotate through each of the environment stations this way (you may also choose to rotate the materials instead of students – this can make classroom management a bit easier!).
2. Remove all items from kit box.
3. While one VSVS member gives the introduction, other VSVS members should set up the environment stations on different tables in the room (you may need to pull desks together depending on the class set-up).
Full Materials List:

- 2 slotted spoons
- 2 turkey basters
- 2 sets tongs
- 2 pairs of pliers
- 2 staple removers
- 2 sets tweezers
- 1 vase
- 1 beaker
- 1 container river rocks
- 1 container styrofoam peanuts
- 1 dropper bottle red food coloring
- 1 container rice
- 1 container sunflower seeds
- 5 cutout mice
- 5 cutout fish
- 1 shallow container (for water at pond station)
- 2 pie pans for river bed & birdfeeder stations
- 2 meadow/garden environment handouts
- 2 river/stream environment handouts
- 2 pond environment handouts
- 2 forest environment handouts
- 2 birdfeeder environment handouts
- 2 lake environment handouts
- 6 two-minute timers
- 16 Student Handouts (with peppered moth & bird photos)
- 32 observation sheets
- 1 piece tree bark
- 2 L water

I. Introduction

Why is the science in this lesson important?
As its name implies, natural selection happens in nature without human interference, but a similar process called artificial selection still relies on the same principles. A rancher in Arizona is breeding his cattle to consume less grass yet still produce more beef. Plants have been bred to create bigger and sweeter fruits. Humans are able to control the prevalence of traits by increasing the fitness of desired traits with selective breeding. (Dogs have been bred to have particular sizes, colors, personalities, and even to be allergy friendly!)

Ask students what they know about Charles Darwin.
- English naturalist born in the 1800’s
- Studied different forms of life around the world.
- Darwin proposed his theory of natural selection
- Concluded that organisms changed over time to better survive in their specific environments.
- “I have called this principle, by which each slight variation, if useful, is preserved, by the term Natural Selection.” - Charles Darwin, On the Origin of Species
a. What is a Trait?

Ask the class the following:
1. Ask students to define the word “trait”.
   Answers should include: Traits are mostly physical characteristics or features that organisms have (e.g. hair color, eye color, skin color, height, weight, hitchhiker’s thumb, left/right handed, ability to curl tongue, morton’s toe, attached/unattached earlobes, nose shape, hair texture). A trait can be passed on to the offspring. Traits are why people look different from one another!

2. Ask students, “Why are there variations in a physical characteristic?”
   For example, there are many differences in hair colors (brown, red, blonde, etc.).
   Traits are influenced by genes. Genes carry information about traits which our parents have and pass down to us.
   Different combinations of genes influence an individual’s features. These variations help make a person unique.
   For example, there are different versions of a gene which influence hair color. Parents will pass down different variations of a gene to their children, causing each of them to possibly have a different hair color.
   - Traits, however, aren’t only influenced by genes. How we live in the environment also determines our traits. For example, height and weight are influenced both by the genes we have from our parents and by what we eat.

b. What is Natural Selection?

Ask students what they know about Natural Selection. Answers should include:

- It is the process by which an organism’s traits are passed on or selected based on their environment.
- Some organisms have traits that allow them to better survive in their environment. For example, an arctic fox is white, which allows it to blend into its surroundings (snowy tundra). This “camouflage” makes it easier for the fox to hunt its prey, thus improving his chances of survival.
- The organisms that manage to survive then reproduce, passing on the genes for their advantageous traits to their offspring.
- If a gene leads to a trait that gives a significant enough advantage to the organism, then the organisms with that gene will eventually out-populate those without the gene.
- This is why people describe the theory of natural selection as “the survival of the fittest.”

Examples of Natural selection:

Tell the students that you are going to show them a real-world example of natural selection.
- Tell students to look at the handout of pictures of the peppered moths. Handout copies of the peppered moth handouts.
- Prior to the 1800’s, the peppered moth, found in England, was mostly light-colored. Dark colored moths were rare.
- The peppered moth liked to hang out on tree trunks. Industrial waste created during the Industrial Revolution darkened tree trunks where these peppered moths lived.
- Light-colored moths were spotted easily by predatory birds on the dark tree trunks and were eaten before they could reproduce.
• In contrast, the dark-colored moths blended in better with the dark tree trunks, making it more difficult for the birds to spot them. Thus, the dark-colored moths survived and reproduced.

Other Natural selection examples:
• Some insects have become immune to pesticides e.g. DDT is no longer effective in preventing malaria in some places
• Rat snakes come in a huge variety of colors depending on their environment.
• The most colorful peacock tails are the most effective at attracting a mate, so the tails got larger and more colorful and became what we are familiar with today.
• Deer mice started out dark brown to blend in with the forest, but those mice that moved to sandy desert in Nebraska adapted to become a light brown in order to blend in. The darker mice were killed by predators.
• When nylon was invented in the 1940’s, bacteria evolved that were able to eat the nylon.
• All humans used to become lactose intolerant as they became adults. However, when cows were domesticated, most humans acquired the ability to consume lactose in adulthood.

c. Traits that help organisms survive in a specific environment are called adaptations.

An adaptation is an inherited trait that helps an organism survive. In this lesson, students will discover that bird beaks are adapted for specific types of food and describe how adaptations work.

Examples of adaptations:
• Lizards with tails that fall off to escape predators
• Bats use sonar to hunt at night
• Milkweed produces a toxic substance to deter predators
• Spiders spin webs to catch prey
• Opossums play dead to avoid predators
• Rosebushes have thorns to avoid being eaten

d. Setting up the environment stations:
• Station #1 Meadow/Garden – colored water in a tall narrow vase to represent nectar in a flower (tools needed: 1 turkey baster, 1 slotted spoon, and two environment cards).
• Station #2 River/Stream – shallow dish with flat river rocks to represent fish in a river/stream (tools needed: 1 set tongs, 1 set tweezers, and two environment cards).
• Station #3 Pond – shallow container of water with Styrofoam peanuts floating to represent fish or other aquatic animals in the pond (tools needed: 1 slotted spoon, 1 turkey baster, and two environment cards).
• Station #4 Forest – piece of tree bark with rice scattered on the surface to represent insects on trees (tools needed: 1 set tweezers, 1 staple remover, and two environment cards).
• Station #5 Birdfeeder – shallow dish (pie pan) with sunflower seeds (tools needed: 1 set pliers, 1 set tongs, and two environment cards).
• Station #6 Lake – cardboard cutouts of mice and fish with staples in them to represent the tearing technique of birds of prey as they eat (tools needed: 1 staple remover, 1 set pliers, and two environments cards).
II. Activity

Explain to class; “Obviously, a hummingbird can’t gobble up a mouse and a hawk can’t drink nectar from a flower. Each type of bird has a special beak and tongue adapted for eating a certain type of food. In this activity, you’ll find out which bird beaks are best suited to different environments and a specific type of eating (ex. tearing, scooping, cracking, or picking).

Divide class into 6 groups and pass out a copy of the observation sheet to each student. Have each group start at a different environment station (or move the stations to them).

Tell students that the tools at each station represent a different type of bird beak that has adapted to its environment. Instruct students read about their environment on the environment handouts at their station and take turns using the tools provided to collect the “food” in each environment. As a group, they should determine which tool (beak) has adapted to their environment and circle it on the observation sheet. After they have finished at their starting station, have each group rotate to the next environment station (or rotate the materials for easier class management). Each rotation should take approximately 5 minutes (set a timer on your phone so time doesn’t get away from you!). Be sure to instruct them to leave the last column empty for now.

Repeat above until all groups have completed all environment stations.

III. Discussion/Review

Before bringing the class back together for review but after you have finished each station rotation, have students work together in their groups to determine which bird was represented by the appropriate beak at each environment station and fill out the last column on their observation sheet. Discuss as a class when they finish.

- Great Blue Heron – last row, represented by tongs. These birds have a large, tong-like beak that it uses to catch fish and swallow them whole.
- Bald Eagle – third row, represented by a staple remover. These birds have sharp, pointed beaks that allow them to tear into and eat their meals.
- Northern Cardinal – second row, represented by pliers. These birds have very short, cone-shaped beaks, which are strong enough to break open tough seeds and shells.
- Ruby Throated Hummingbird – first row, represented by the turkey baster. These birds have long hollow beaks, which protect their tongues as they probe flowers and drink nectar.
- Catbird – fifth row, represented by tweezers. These birds have small, sharp, pointed beaks for picking insects from leaves, bark, and twigs.
- Mallard – fourth row, represented by the slotted spoon. These birds have bills that act like strainers to filter tiny plants and animals from the water.

Ask the following questions to the class to conclude the lesson (allow students to discuss in groups before calling on anyone to answer):

a. What is a trait? Answer: Traits are mostly physical characteristics or features that you have, which can differ between people.
b. By what is a trait influenced? *Answer: Genes and environment.*

c. What is natural selection? *Answer: The process by which an organism's traits are passed on or selected based on their environment. (For example, a single giraffe cannot grow a longer neck in order to reach food on higher branches during its life but giraffes with shorter necks would not be able to reach food and would not survive long enough to have babies.)*

d. How does natural selection work? *Answer: Variations in a trait that allow an organism to survive better are passed down to the organism's offspring. (Remember the giraffes? The giraffe with a shorter neck that cannot reach the food will die, other giraffes that have longer necks will live and reproduce so there will be more long-necked giraffes!)*

e. How does environment and/or adaptations influence survival? *Answer: Organisms with traits that help them survive in an environment are selected for and organisms with traits that do not help them survive in an environment are selected against.*

f. What is an adaptation? *Answer: A trait that helps an organism survive in a specific environment.*

To wrap up – *adaptations* are physical or behavioral traits that make an organism better suited (more successful in getting food or finding a mate) for their environment; *natural selection* is the mechanism (process) that leads to adaptations!
Goal: To understand diffusion, the process in which there is movement of a substance from an area of high concentration of that substance to an area of low concentration.

Introduces/reinforces: 7.LS1.2 Conduct an investigation to demonstrate how the cell membrane maintains homeostasis through the process of passive transport.

VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE
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Diffusion
Fall 2020

VSVSer Lesson Outline

I. Introduction
Discuss the motion of molecules using examples such as the smell of cooking from a distance or the smell of perfume in the air when someone wearing perfume walks by.

A. Modeling Semi-Permeable Membranes
One VSVS member will show students how to use a container with a wire-screen separating rye seeds and bean seeds as a model for a semi-permeable membrane. The rye seeds, representing small molecules, pass through the screen but the bean seeds, representing large molecules, do not pass through the screen.

B. Dialysis tubing and Relative Sizes of Molecules
Show students the paper models of iodine, glucose, and starch. Discuss the relative sizes and point out that starch is a "polymer" molecule made up of hundreds of glucose molecules joined together.

II. Testing for Glucose and Starch
A. Glucose Test
Student use glucose test strips to become familiar with the positive test for glucose.

B. Starch Test
Students use iodine to test for starch.

III. Diffusion of Glucose and Starch
A. Glucose Diffusion
A VSVS volunteer should distribute the dialysis tubing (containing glucose and starch) in the cup to each pair of students.

B. Predicting Which Molecules Will Diffuse
While students are waiting, show them the paper models of the molecules again and have the students try to predict which molecules will diffuse through the tubing.

C. Testing for Diffusion of Glucose
Groups test for glucose after 10 minutes.

D. Testing for Diffusion of Starch
After a positive test for glucose outside the dialysis tubing has been obtained, students can add ALL the rest of the iodine to the water in the cup. Students should observe a purple/black color form inside the dialysis tubing.

IV. Review
Summarize the glucose and starch dialysis results for the whole class. As part of this review, show the models of iodine, glucose, and starch to make sure students understand the relationship of molecular size to their ability to diffuse through semi-permeable membranes.

LOOK AT THE VIDEO BEFORE YOU GO OUT TO YOUR CLASSROOM
https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.
Notes on solutions used:
The glucose solution is made to be 30%. The starch solution is made from soluble starch (a “handful” of starch “peanuts” in 1 L. water plus 1 tsp cornstarch. The solution mixture inside the dialysis tubing is 80% glucose/20% starch.

1. Before the lesson:
In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.
1. What is diffusion?
2. What is a semi-permeable membrane, and what is the relationship between molecular size and ability to diffuse through a semi-permeable membrane?
3. Which molecule(s) is/are permeable through the dialysis tubing? Which is/are impermeable?
4. Which molecule is a polymer?
5. How can the presence of glucose be detected? How can the presence of starch be detected?

2. During the Lesson:
Here are some Fun Facts for the lesson – for VSVS members
Diffusion is a passive process, meaning that it occurs spontaneously, without the input of energy. The rate of diffusion is affected by size of molecule, steepness of concentration gradient, and temperature (related to the speed at which the molecules are moving).
Examples of diffusion in everyday life: the contents of a teabag diffuse into hot water, helium diffuses out of a balloon causing it to deflate, the smell of warm cookies diffuses throughout a room.
Water, oxygen, carbon dioxide, and various other essential molecules are constantly diffusing across the membranes of our cells.
The diffusion of water is called osmosis. Water molecules move across a membrane trying to achieve equilibrium. Example: a carrot placed overnight in fresh water will swell; a carrot placed in salt water will shrivel.

Set-Up
VSVS members do this while one member starts Introduction
Materials needed for set-up for 16 pairs:
16 6-oz plastic cups
16 pieces of dialysis tubing containing the glucose and starch mixture.
16 plastic plates
32 1oz cups water
Count the number of students and remove enough dialysis tubes for each pair. Place the dialysis tubes into individual 6oz cups and place each cup on a plate. Pour enough water into the cup so that the water JUST covers the tubing. **Set aside – do not give to students until Part III.**
- Take 32 1-oz cups and pour a little water in the bottom of each cup. Save for Section II.

Unpacking the Kit – what you will need for each part
While one team member starts the introduction, another should write the following vocabulary words on the board:
- diffusion, osmosis, dialysis tubing, glucose, starch, iodine, semi-permeable membrane
Refer to vocabulary words throughout the lesson when you encounter them.

Your Notes:
For Part IA: Introduction.
16 clear plastic containers with wire screen and seeds, 32 Observation Sheets

For Part IB: Relative Sizes of Molecules
1 dialysis tube containing glucose and starch
1 set of laminated paper models of iodine, glucose, and starch

For Part II: Testing for Glucose and Starch
For Part IIA. Glucose Test
16 Instruction Sheets, 16 plastic bags each containing 3 Glucose Test Strips (in a small bag) and 1 Glucose Test Results Chart (laminated), 16 1-oz bottles of 30% glucose, 16 1-oz cups of water, 16 tweezers

For Part IIB. Starch Test
Above materials plus additional materials:
16 1 oz. cups of water, 16 dropper bottles of iodine (in a protective plastic container), 16 oz containers of starch suspension (shake well)

For Part III: Diffusion of Glucose and Starch
IIIA Diffusion: 16 pieces of dialysis tubing placed in 6-oz plastic cups, (see set-up) 16 plastic plates, 32 Observation Sheets

IIIB: Predicting Which Molecules Will Diffuse
Paper models of the molecules from IB

For Part IIIC. Testing for Diffusion of Glucose
Glucose strips and tweezers from Part IIA

Part III D. Testing for Diffusion of Starch
Remaining iodine from Part IIB

I. Introduction

Learning Goals: Students define the term “semi-permeable membrane,” give real-world examples, and demonstrate how they can be used to separate different-sized molecules

Note: Organize the students into pairs
- Discuss the motion of molecules using examples such as the smell of cooking from a distance or the smell of perfume in the air when someone wearing perfume walks by.
  - This happens because molecules are in constant motion and gas molecules (perfume, aroma of cooking) mix (diffuse) with the air in the vicinity.

A. Modeling Semi-permeable Membranes
Materials
16 16 oz. clear plastic containers with wire screen and seeds
32 Observation Sheets
- Ask students: What is a semi-permeable membrane?

Your Notes:
- Include the following information in the discussion:
  - A **semi-permeable membrane** is a membrane in a cell that allows materials to pass into and out of a cell.
  - The openings in the membrane are large enough to allow some substances to move in and out of the cell, but are small enough to keep some substances from leaving or entering the cell.
- Give each **student** an observation sheet
- Give each **pair** one of the 16 oz. clear plastic containers with lids that contains a wire screen in the middle with rye seeds on one side and bean seeds on the other side. Rye and bean seeds are used to represent molecules of two different sizes. The wire grid screen represents a semi-permeable membrane (such as a cell membrane in plants or animals). The holes represent the pores or openings in the membrane.
- Ask one student to keep the container in view of all group members and shake the plastic container sideways, keeping the lid up and observe what happens.
- Ask students to explain what happened.
  - The students should observe that the rye seeds can pass through the wire screen (both ways) but the bean seeds cannot.
  - After a few minutes, the levels of seeds will no longer be equal because the side with the bean seeds will have some of the rye seeds as well.

### B. Dialysis tubing and Relative Sizes of Molecules

**Materials:**
1. dialysis tube containing glucose and starch
1. set of laminated paper models of iodine, glucose, and starch

- Show students the paper models of the three molecules, and tell them the names of the molecules. Do not discuss anything about these molecules except to tell them that the solutions they are using today contain these molecules.
- The VSVS instructor should hold up a dialysis tube with glucose and starch so that the class can see it.
  - Have the students observe that there are no fluids leaking out of the tubing.
  - Tell the students that the **dialysis tubing** is similar to a cell membrane, and that the students are going to discover which of the three molecules are small enough the pass through the tubing. Show the students the tubing in the prepared cups and point out the water just covering the tubing.
- Tell students to look at the diagram on the observation sheet and point out that the dialysis tubing contains starch and glucose molecules.
  - **Starch** molecules are represented by large S’s and **glucose** molecules are represented by G’s.
  - **Iodine** molecules, represented by I2’s, are shown outside the dialysis tubing because they will be added to the outer solution during the experiment.
  - **Water** is H2O
- Tell students that they will work in pairs for the following experiments.

**Your Notes:**
II. Testing for Glucose and Starch

Learning Goals: Students identify different indicators that can be used to systematically test for the presence of various molecules

Materials - distribute to each pair:
1 Instruction Sheet
1 plastic bag containing 3 Glucose Test Strips (in a small bag) and 1 Glucose Test Results Chart (laminated)
1 1-oz bottle of 30% glucose
1 1-oz cup of water
1 tweezer

Note: One VSVS volunteer will demonstrate the following procedure and will give the instructions; the other volunteers should monitor pairs to make sure procedures are being followed accurately and to give assistance as needed. Students can refer to the instruction sheet as they are doing the experiments but you will still need to guide them through the procedures.

- Tell the students that they need to know how to prove which molecules have moved through the membrane. They need to know how to test for glucose and starch.

A. Glucose Test
- Ask students if they know about testing for glucose with glucose strips.
  - Diabetics use these strips to monitor their glucose levels.
- Tell the students to place the 1-oz cup of water and the 1-oz glucose bottle on the appropriate circles on the observation sheet.
  - Take the cap off of the 1-oz glucose bottle.
Tell students not to touch the glucose test strip with their fingers - use the tweezers.
- Dip one end of the test strip into the 1 oz. plastic bottle labeled glucose. Hold the strip above the bottle to remove any excess solution.
  - Place this strip in the rectangle on the paper (below the 1 oz bottle).
- Then test the water cup with another glucose test strip, following the same procedure.
  - Wait a few minutes before checking the results.
- Tell students to compare the color of glucose test strips with the Glucose Results Color Chart, and record the values from the Glucose Results Color Chart on their observation sheets.
  - Yellow indicates no glucose and shades of green indicate the presence of glucose. The darker the shade of green, the more glucose is present.
  - Test strips dipped in glucose should be dark green indicating the presence of lots of glucose.
  - Use these strips to verify the final test results later in the lesson.

Note: The test strip dipped in water should be yellow indicating the absence of glucose. If anyone’s strip did turn green, try to determine the reason the strip turned green. This could happen due to contamination if glucose was spilled in the water or if a student touched the pad of the strip after handling the glucose set-up.

- Tell students to replace cap on 1-oz bottle of glucose.

B. Starch Test

Your Notes:
Distribute the following additional materials to each pair:

1. 1 oz. cup to use for testing water
2. 1 dropper bottle of iodine (in a protective plastic container)
3. 1 oz container of starch suspension (shake well)

- Tell students to place the 1-oz cup of water and the 1-oz starch container on the appropriate circles on the observation sheet.
- They should shake the 1-oz starch container and then remove the cap.
- Tell students to add one squirt of iodine to both the 1 oz cup containing water and the 1-oz container of starch.
- Tell students to check for a color change and record the color, if any, on their observation sheet. *A dark purple/black color indicates the presence of starch in the starch container. The water cup should be a light orange/yellow or amber color which indicates the presence of iodine only.*
- Then have students put the cap back on the 1-oz starch container.

Tell the students they must not disturb the cup and the dialysis tubing.

### Learning Goals:
- **Students identify different indicators that can be used to systematically test for the presence of various molecules**
- **Students identify different indicators that can be used to systematically test for the presence of various molecules**

### III. Diffusion of Glucose and Starch

**Materials:**
Distribute the earlier prepared 6 oz. plastic cups containing a piece of dialysis tubing in water for each pair and plates.

**A. Glucose Diffusion**
Tell students that diffusion of glucose takes time, but it has already been happening while they have been discussing diffusion. They need to leave the dialysis tubing for another **10 minutes** to allow time for diffusion to occur. Go on with section B while students wait.

**B. Predicting Which Molecules will Diffuse**

**Materials:**
1 set of laminated paper models of iodine, glucose, and starch (paper models are stored in binder)

- Review the relative size of the molecules by showing the students the paper models of the three molecules again.
- Discuss the relative sizes of the molecules, pointing out that the results of today’s activities will be dependent upon the different sizes of iodine, glucose, and starch molecules.
- Point out that starch is a "polymer" molecule made up of hundreds of glucose molecules joined together.
- Have the students refer back to their seed containers.
  - Tell the students that this is a good model for a semi-permeable membrane.

**Your Notes:**

______________________________________________________________________________

______________________________________________________________________________
The small rye seeds represent small molecules, such as water, iodine, or glucose that can pass through a porous membrane both ways while larger molecules cannot.

The larger bean seeds represent large molecules such as starch molecules that cannot pass through the semi-permeable membrane.

- Ask the students if they can predict which way the different molecules will move.
  - The iodine is a small molecule and can move from the water outside the tubing, to inside it.
  - The starch is a large molecule and cannot get outside the tubing.
  - The glucose is small and should be able to move from inside the tubing to the water on the outside.

- Tell students that the molecules of substances have been diffusing in the experiments set up earlier in the lesson and it is time to check on these experiments and investigate what has been happening.
- Caution students to wait for instructions before they do the experiments.

### C. Testing for Diffusion of Glucose

**After the tubing has been in the water for about 10 minutes:**

- Ask students to dip a clean glucose test strip into the water close to the dialysis tubing (it may even touch the tubing) and place the test strip on the appropriate rectangle of the observation sheet.
- While students are waiting for the results of this test, ask them what the results of the glucose test strip will tell them.
  - If the test strip remains yellow, then no glucose was able to pass through the dialysis tubing.
  - If the test strip turns green, then glucose was able to pass through the dialysis tubing.
- Ask students to check the glucose test strip, compare its color with the Glucose Results Color Chart, and record the value on their observation sheet.
- The glucose test strip should turn green within 1 minute, indicating the presence of glucose in the water. This shows that glucose molecules have passed through the dialysis tubing. If it did not turn green, test again (close to the tube) after several more minutes have passed
- Ask students to look at the plastic container of seeds. Ask them if this were a model of the glucose experiment, which seeds represent the glucose molecules.
  - The small seeds are the glucose molecules because they could travel through the dialysis tubing.
- Ask students to refer to the diagram on the observation sheet and use arrows to show the direction glucose molecules have moved.

### D. Testing for Diffusion of Starch

- Have students unscrew the lid on the iodine bottles and add all the rest of the iodine to the water in the cup that is holding the dialysis tubing. The solution should be a light orange/yellow or amber color.

**Note:** This part MUST be done after a positive test for glucose has been obtained. **The glucose test strips will not work after iodine has been added to the water.**

- If a positive test occurs when the iodine is added to the water around the dialysis tubing, the tubing has a leak. If this happens, empty their cup, rinse with water, and place a newly rinsed dialysis tubing in the cup and add iodine again. (Use the extra bottle of iodine that was provided.) If all else fails, have them observe the results of another group.
Ask students to observe the solution inside the dialysis tubing and the water surrounding it for a few minutes.
  o If they observe a color change, they should record it on their observation sheet.
  o *Students should observe a purple/black color inside the dialysis tubing*.

Ask students what this purple/black color tells them.
  o The purple/black color indicates that iodine molecules have passed through the dialysis tubing and detected the presence of starch inside the dialysis tubing. Since the outside solution is not purple/black, starch molecules have not passed through the dialysis tubing into the water.

Tell students to look at the plastic container of seeds.
  o Ask them if this were a model of the iodine and starch experiment, which seeds represent the iodine molecules and which represent the starch molecules.
  o The large seeds are the starch molecules because they could not get out of the dialysis tubing; the small seeds are the iodine molecules because they could travel through the dialysis tubing.

Ask students to refer to the diagram on the observation sheet and use arrows to show the direction iodine molecules have moved.

### IV. Review

<table>
<thead>
<tr>
<th>Learning Goals:</th>
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<tbody>
<tr>
<td>• Students define the term “semi-permeable membrane,” give real-world examples, and demonstrate how they can be used to separate different-sized molecules</td>
</tr>
<tr>
<td>• Students identify different indicators that can be used to systematically test for the presence of various molecules</td>
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Summarize the glucose and starch dialysis results for the whole class. Refer to diagram on observation sheet during review.
  - Glucose gave a positive test in the water surrounding the dialysis tubing. Therefore, glucose molecules traveled through the dialysis tubing.
  - The water in the cup remained yellow (the color of iodine), not the purple color found when starch is present. Therefore, starch molecules did not travel through the dialysis tubing into the water.
  - However, there is a purple-black color inside the tubing. Therefore, iodine molecules traveled into the dialysis tubing and reacted with the starch molecules.
  - Show the molecule models of iodine, glucose, and starch to the students again to emphasize the relationship between molecular size and the ability to diffuse through a semi-permeable membrane like dialysis tubing.

**Collect used dialysis tubing in a large ziploc bag or dispose of them at the school. Return all unused tubing.**

**Pour contents of water in all cups down the drain. Return all cups to lab in plastic garbage bag. Please do not let glucose solutions leak into lesson box – that makes for a very sticky mess to clean.**

**Return used 1-oz bottles of glucose and starch and all solution containers to the VSVS lab for re-use.**


Lesson written by Pat Tellinghuisen, Coordinator of VSVS, Vanderbilt University

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We gratefully acknowledge the assistance of Ann Orman and Kay Boone, MNPS teachers.
Observation Sheet - Answers  Name ____________________________

Vocabulary Words: diffusion, osmosis, dialysis tubing, glucose, starch, iodine, semi-permeable membrane

GLUCOSE TEST

What color is the glucose strip after it is dipped in water?
no color

What color is the glucose strip after it is dipped in glucose solution?
green

STARCH TEST

What color is the water after iodine is added?
pale yellow – the color of dilute iodine

What color is the starch solution after iodine is added?
Blue/Black

Predict the Direction of Movement of the Molecules:
Remembering what size beans crossed the wire screen, predict which molecules will diffuse in what direction in the experiment. Draw arrows next to a starch (S), glucose (G) and iodine (I₂) molecule in the cup diagram below, to show the predicted diffusion direction.

DIALYSIS TUBING TESTS

10 minutes after dialysis tubing is added to water: What is the color of the glucose strip when it is dipped into the liquid closest to the tubing?

5 minutes after the iodine is added: What is the color of solution inside dialysis tubing

Were your predictions for the movement of the molecules correct?
VANDERBILT STUDENT VOLUNTEERS FOR SCIENCE

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Investigating Ionic, Covalent and Metallic Bonding

Fall 2020

Acknowledgement: We want to thank NASA and the Tennessee Space Consortium for funds to purchase the Elenco Snap Circuit™ kits.

Goal: To measure the conductivity of solids and solutions using an LED in a circuit.

Introduces/reinforces TASS: 7.PS1.2 Compare and contrast elemental molecules and compound molecules. 7.PS1.5 Use the periodic table as a model to analyze and interpret evidence relating to physical and chemical properties to identify a sample of matter.

VSVSer Lesson Outline

_____ I. Introduction
a. Students are introduced to ionic, molecular and metallic compounds.
b. Explain Static and Current electricity.
c. Explain conductors and nonconductors.

_____ II. Explaining the Circuit – Demonstration
a. Explain the circuit and LED.
b. Demonstrate how the students will use the red and black lead wires to test conductivity.
c. Students discover that an electrical current will flow through a metal nail (which has metallic bonding) but not through a plastic cap.

_____ III. Conductivity of Solutions
a. Explain that some solutions conduct an electrical current.
b. Students will test a number of solutions. Make sure they understand the importance of rinsing off the metal leads of the red and black wires in distilled water between each conductivity test.

_____ IV. Experiment: Using a Polymer to Distinguish Between Ionic and Molecular Compounds
a. Students test ionic and molecular compounds by adding each type of compound to a gel of sodium polyacrylate and observing results.

_____ V. Review
a. Review the results of the lesson and the vocabulary words.

https://studentorg.vanderbilt.edu/vsvs/lessons/
USE THE PPT AND/OR VIDEO TO VISUALIZE THE MATERIALS USED IN EACH SECTION.

1. Before the lesson:
In the car ride, read through this quiz together as a team. Make sure each team member has read the lesson and has a fundamental understanding of the material.

1. What is the difference between static electricity and current electricity? Static electricity is the build-up of electrical charge. Current electricity is moving electrical charge.
2. How can you tell the difference between a good conductor and a poor conductor through a conductivity test? Answer in III
3. Will an ionic compound or a molecular compound conduct electricity when dissolved in water? Why? Answer in III
4. Is sugar solution a conductor? Why? Sugar is not a conductor because it is a molecular compound that does not split up into ions in water.
5. At the conclusion of the lesson should the leads be snapped together before they are placed back in the kit? No
Full Materials List:

- 1 model of NaCl and water compounds
- 1 plastic bag containing an assembled grid and nail and plastic bottle cap
- 16 sets of grids with assembled circuit
- 16 sets of instruction sheets
- 32 observation sheets
- 64 jars containing: salt, sodium bicarbonate, sugar, and glucose
- 80 2oz cups
- 16 bags containing 4 taster spoons, 1 chemwipe tissue, 4 toothpicks
- 16 100 mL bottles distilled water
- 16 10 oz cups
- 16 12 oz cups (the opaque ones)
- 2 containers sodium Polyacrylate
- 4 teaspoons
- 1 1L container of distilled water
- 16 Plates
- 16 6-well plates

Do not hand out materials until you have discussed the following background information.

Unpacking the Kit – What you will need for each section:

For Part I. Introduction
While one person is giving the Introduction, another VSVS member writes the following vocabulary words on the board: ionic compounds, ionic bonds, molecular compounds, covalent bonds, conductors, insulators. Other VSVSers count the number of students in the class and put 1 tsp sodium polyacrylate into a 12 oz cup (the opaque one) and 200mL water into 10 oz cups.

For Part II. Explaining the Circuit – Demonstration
Materials for demonstration: 1 grid with assembled circuit, plus a bag with a nail and a bottle cap for demonstrating conductivity
Materials for each pair: 1 grid with assembled circuit, 1 instruction sheet, 2 observation sheets

For Part III. Conductivity of Solutions
Materials for each pair: 1 grid with assembled circuit
4 jars containing: salt, sodium bicarbonate, sugar, and glucose, 5 2oz cups, 1 bag containing 4 tasterspoons, 1 chemwipe tissue, 4 toothpicks, water bottle

For Part IV. Using a Polymer to Distinguish Between Ionic and Molecular Compounds
Materials for each pair: 1 10 oz cup containing 1tsp sodium Polyacrylate, 1 10 oz cup containing 200 ml water, 1 teaspoon
1 Plate, 1 6-well plates,
4 jars containing: salt, sodium bicarbonate, sugar, and glucose, 1 bag containing 4 tasterspoons, 1 chemwipe tissue, 4 toothpicks from Part III

For Part V. Experiment: Investigating the Effect of Adding Ionic and Molecular Compounds to Sodium Polyacrylate

I. Introduction
Note: This section is meant to be a refresher of material they have already learned in class. It is more important that you get to the experimental parts.
Materials
1. model of ionic NaCl and water compounds

While one person is giving the Introduction, another molecular VSVS member writes the following vocabulary words on the board: ionic compounds, ionic bonds, molecular compounds, covalent bonds, conductors, insulators.

Ask students: What are the different types of bonding that can form between atoms? 
Answer: ionic, covalent or metallic

1. Ionic Compounds:
• Show students the model of sodium chloride and explain that the sodium chloride crystal has a repeating pattern of equal numbers of Na⁺ and Cl⁻ ions in 3 dimensions. This is called a crystal lattice.
• An ionic compound forms between positive and negative ions that are created when atoms either lose or gain electrons.
• Some ions are formed from single atoms, such as the sodium and chloride ions in salt (sodium chloride). Some ions are made of more than one atom, such as the bicarbonate ion (HCO₃⁻) in sodium bicarbonate (NaHCO₃).

2. Molecular Compounds:
• Show students the plastic bag containing the water molecules. The hydrogen and oxygen molecules are covalently bonded.
• A molecular compound is made up of atoms that are covalently bonded. Covalent bonds are formed when atoms share electrons.

3. Metals:
• Explain to students that metals easily lose valence electrons and become metal ions.
• Metallic bonds, like covalent bonds, also involve sharing electrons.
• But in metals, the electrons are shared over millions of atoms, while in molecular compounds, the electrons are shared between just 2 or 3 atoms.
• For example, in a covalently bonded compound like oxygen (O₂), electrons are shared between the 2 oxygen atoms; however, in a metallically bonded compound like a gold bar, electrons are shared over all gold atoms in that bar. You might hear metallic bonding referred to as a ‘sea of electrons’ for this reason.

One of the differences in properties between ionic and covalent compounds is the ability to conduct an electrical current when they are added to water.
Most metals, unlike either ionic or covalent compounds, conduct electricity as solids and don’t need to be dissolved in water.
Tell students that they are going to conduct an experiment to determine if a compound is ionic or covalent.

Why is the science in this lesson important?
• In the food service/production industry, cooking equipment may be sanitized with harsh chemicals that have high concentrations of ions. A conductivity test can be used to determine if the cleaning agent has been sufficiently rinsed away. If there is still significant conductivity when pure water is in contact with the equipment, then the equipment should be further rinsed to remove the cleaning agent.
• Public water facilities often monitor the conductivity of their output water to determine how much material is dissolved in the water (total dissolved solids). It is important to note that this test only accounts for the dissolved solids that are conductive. However, this method would be useful to determine if water has been demineralized, that is, if hard water has been effectively treated to remove some of the contaminating ions. As another example, conductivity tests can be used to determine if desalination processes have removed all of the salt from ocean water so that it becomes fit for human consumption.

II. Explaining the Circuit – Demonstration

<table>
<thead>
<tr>
<th>Learning Goals: Students define static and current electricity and observe that metallic compounds conduct electricity and molecular compounds do not.</th>
</tr>
</thead>
</table>

**Materials**

1 grid with assembled circuit, plus a bag with a nail and a plastic bottle cap for demonstrating conductivity

Ask students if they know what the 2 types of electricity are:

1. **Static electricity** is the build-up of electrical charge. It does not flow. Lightning is an example of static electricity being “discharged” after having been built up.
2. **Current electricity** is moving electrical charge, usually electrons. Some materials have more “free” electrons than others. Current electricity flows through a completed circuit.

**Demonstration**

<table>
<thead>
<tr>
<th>Learning Goals: Students learn what an LED is, and understand how it is used to show that a circuit is complete.</th>
</tr>
</thead>
</table>

**Materials per pair**

1 set of grids with assembled circuit
1 set of instruction sheets
2 observation sheets

VSVS team members should hold up the demonstration circuit to show the students. Tell the students to look at **Diagram 1 and their circuit board**. Point out the different parts – batteries, circuit connectors, black and red leads, resistor and LED light.

Point out that a “lead” is a wire wrapped in an insulator.

**Explain LED’s to the students:** LED’s (Light Emitting Diodes) are more sensitive than light bulbs and glow brightly with small currents.

**VSVS information only:** LED’s are made from semiconductors. They can be damaged by high currents and so are used with resistors to limit the current. Do NOT allow the students to remove the resistor.

Ask the students what you should do to make the LED glow.

**Answer:** Touch the black and red lead together to complete the circuit.

Show the students that this is correct and that the LED emits light. **Tell the students that the circuit is closed when the red and black leads are touching.**

**Electrical current can flow through LEDs in one direction only.** Show the students the direction of flow. **Current flows from the positive end (”knob”) of the battery to the negative (“flat”) end.**

Tell the students that electricity flows through some materials better than others.
• **Conductors** are materials that allow the movement of electrons through them. Metals have many “free” electrons that can easily move, and therefore are good conductors. “Free” electrons are those not strongly held by the atom’s nucleus. Since they are not strongly held, they are able to “jump” from one atom to another.

Now touch the end of one lead wire to the head of the nail and the end of the other lead to the point of the nail. The LED again lights up indicating that the circuit is closed. The metal nail is a good conductor of electricity and completes the circuit.

**Remember that metallic bonding involves a “sea of electrons” that allows electrical currents to flow.**

Repeat with the bottle cap, putting the ends of the leads on opposite sides of the bottle cap. The LED will not light up, indicating the plastic bottle cap is not a conductor. Plastic bottle tops are made from molecular compounds, which have covalent bonds.

### III. Conductivity of Solutions of Ionic and Molecular Compounds

**Learning Goals: Students understand that solutions of ionic solutions conduct electricity and solutions of molecular compounds do not.**

**Materials per pair**

- 1 set of grids with assembled circuit
- 4 jars containing: salt, sodium bicarbonate, sugar, and glucose
- 5 2oz cups
- 1 bag containing 4 taster spoons, 1 chemwipe tissue, 4 toothpicks
- 1 water bottle

**Background information for VSVS members only (electrolytes and non-electrolytes are not in the 7th grade vocabulary):**

Conducting liquids are called **electrolytes**. An **electrolyte** contains electrically charged ions that can conduct electricity. Some examples of electrolytic solutions are acids and bases and salt solutions such as sodium chloride (table salt) in water.

A **non-electrolyte** does not allow the flow of electric current because it does not have electrically charged ions that can conduct electricity. Some examples of non-electrolytic solutions are distilled water, sugar water.

**Electrolytes** are important to humans because they are necessary for proper cellular function, muscle function, and neurological function. A greater level of **electrolytes** is needed during strenuous muscular activity because more **electrolytes** are lost due to increased sweating. This is the reason why Gatorade and other sports drinks advertise that they replenish **electrolytes**.

**Hand out** the jars of solids to each group.

Tell the students to follow the **instruction sheet** and to record their results.

Tell students to:

- Rinse the metal ends of the black and red lead wires by dipping them into the cup of distilled water. Tell the students they will need to do this in between each test, to avoid contaminating the next test sample with the one just tested (make sure that the students know what contamination means).
- Place the 5 2oz cups containing distilled water on top of the diagram on the **instruction sheet**.
• Place the corresponding jar of solid next to the cup. Make sure that the students have the order correct. **Students must remove only ONE lid at a time, and replace it after pairs have tested the liquid.**

• Students **MUST** test the solutions in the order given, 1-5
  o The non-conducting solutions are tested first, followed by conducting solutions. This will help avoid contamination of the solutions.

1. **Testing distilled water:**
   Put the metal ends of both lead wires in the cup containing distilled water, as far apart as possible, and note if the LED is glowing. (It should not). Remove the leads.

2. **Testing water plus sucrose (sugar):**
   Remove the lid of the 1st jar (sugar) and add 1 mini spoon to the water. Stir with a toothpick, and then snap the toothpick in half so it cannot be used again. Repeat the conductivity test. Record your results. Replace the lid on the jar. The LED should not glow.
   Rinse the metal ends of the wires in the distilled water jar.

3. **Testing water plus glucose:**
   Remove the lid of the 2nd jar (glucose). Repeat the conductivity test. Record your results. Replace the lid. The LED should not glow.
   Rinse the metal ends of the wires in the rinse cup.

4. **Testing water plus sodium chloride (salt):**
   Remove the lid of jar 3 (salt).
   Repeat the conductivity test. Replace the lid. Record your results. The LED should glow.
   Rinse the metal ends of the wires in the rinse cup.

5. **Testing water plus sodium bicarbonate (baking soda):**
   Remove the lid of the 4th jar and repeat the conductivity test. Replace the lid. The LED should glow.
   Record your results. Rinse the metal ends of the wires in the rinse cup.

Ask students if they can explain the results.

1. **Distilled water** does not contain ions and thus does not conduct electrical currents. Distilled water is a molecular compound with covalent bonds. (Note that TAP water can conduct an electrical current because it can contain metal salts that are ionic.)

2. **Sugar molecules** and **glucose** molecules are molecular compounds that do not split up into ions in water, and so do not conduct electrical currents.

3. **Solid salt** and **solid sodium bicarbonate** will not conduct electricity because the sodium, chloride and bicarbonate ions are not free to move around in the solid form. However, when they are dissolved in water, the units dissociate completely into ions, and so are **conductors** of an electric current.

IV. **Experiment: Using a Polymer to Distinguish Between Ionic and Molecular Compounds**

**Materials per pair**
- 1 12 oz cup containing 1tsp sodium Polyacrylate
- 1 10 oz cups containing 200 ml water
- 1 teaspoon
- 1 Plate
- 1 6-well plates
4 jars containing: salt, sodium bicarbonate, sugar, and glucose
1 bag containing 4 taster spoons, 1 chemwipe tissue, 4 toothpicks from Part III

Sodium Polyacrylate is a superabsorbent polymer found in disposable diapers and moisture absorbent for automobile and jet fuels. A superabsorbent polymer can absorb and retain extremely large amounts of liquid relative to its own mass. This polymer absorbs about 300 times its weight of tap water (800 times its weight of distilled water because the ions in tap water reduce the absorbing properties of the polymer).

Note for VSVS members only: It is a polymer that consists of repeating units of the monomer. The picture is a single unit.

It is able to absorb large amounts of water because the sodium ions (Na+) that are attached to it are replaced by water. Point to the diagrams of sodium polyacrylate on their handout. Point out the Na+ ions that are replaced by water molecules.

Making a gel with sodium polyacrylate.
- Give each pair a (10 oz) cup containing the sodium polyacrylate and a 10 oz cup containing 200 mL tap water.
- Tell them to pour the water into the cup with the sodium polyacrylate and stir with a spoon.
- Observe that all the water is absorbed (forms a gel) immediately.

VSVS Information only: Sodium polyacrylate will continue to absorb water until there is an equal concentration of water inside and outside the polymer. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules. Sodium polyacrylate, uses osmosis to soak up water. Because there is a higher concentration of water outside the sodium polyacrylate, it draws in the water through osmosis. Each sodium polyacrylate molecule is able to attract and hold thousands of water molecules.
V. Experiment: Investigating the Effect of Adding Ionic and Molecular Compounds to Sodium Polyacrylate

Fill each well with about 1 tsp of the gel.
- a. Add 1 mini spoon sugar to well 1
- b. Add 1 mini spoon glucose to well 2
- c. Add 1 mini spoon sodium chloride (salt) to well 4
- d. Add 1 mini spoon sodium bicarbonate (baking soda) to well 5

Observe what happens to the gel.
Either the gel collapses into a watery mess (for the ionic compounds) or it is not affected (for the molecular compounds).

Ask students: Based on the previous experiment, which compounds are ionic or molecular?
   *Answers:* Sugar and glucose are molecular.
   Sodium Chloride and sodium bicarbonate are ionic.

Which compounds caused the gel to breakdown?
   *Answers:* The ionic compounds
   The solids that have no effect are the molecular compounds that are covalently bonded.

Explanation: The compounds that cause the breakdown contain a combination of metals and non-metals and are ionic compounds. Charged particles or ions from ionic compounds interfere with the stability of the polymer/water interactions in the gel. When sodium chloride and sodium bicarbonate are added to the hydrated polymer, the sodium ions from them attract the water. As a result, water molecules diffuse back out of the polymer. The addition of the salt breaks the "gel" polymer apart as water leaves the polymer to try to balance the water concentration inside and outside the polymer network.

VI. Review

How can we distinguish between ionic and molecular compounds using an electrical circuit?
How can we distinguish between ionic and molecular compounds using the polymer sodium polyacrylate?
Go over the observation sheet with the students.

Lesson modifications by:
   Dr. Mel Joesten, Emeritus Professor of Chemistry, Vanderbilt University
   Pat Tellinghuisen, VSVS Director, Vanderbilt University
Conductivity Answer Sheet

A. Testing the Circuit.

1. What happens when you touch the ends of the jumper cables together?

   **The LED lights up.**

   Explain: **Touching the ends of the leads together completes the circuit.**

B. Conductivity Tests with Solids

Which of the following materials cause the LED to light up?

Circle your answer.

1. iron nail  bright light
2. bottle cap  no light

On this basis, what material has metallic bonding? – iron nail

Which material is a molecular compound? Plastic cap

C. Conductivity Tests with Solutions

Which of the following solutions makes the LED glow brightly, dimly, or not at all?

Circle your answer.

1. distilled water  no light
2. sugar water  no light
3. glucose plus water  no light
4. salt water  bright light
5. sodium bicarbonate plus water  dim light

On the basis of the above results, which materials are ionic compounds?

**Sodium chloride and sodium bicarbonate**

Which materials are molecular compounds

**distilled water, sugar and cornstarch**

D. Testing the reaction of a polymer gel with ionic and covalent compounds

What happened to the polymer gel when the following were added?

1. Sucrose (sugar)  nothing
2. Glucose  nothing
3. Sodium chloride (salt)  gel becomes watery
4. Sodium bicarbonate  gel becomes watery

On the basis of the above results, which materials “extract” water from the gel?

**The ionic compounds, sodium chloride and sodium bicarbonate**