Science News
EDUCATOR GUIDE


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May 9 & May 23, 2020

Beets Bleed Red, but Chemists Turn It Blue

SOCIETY FOR SCIENCE & THE PUBLIC

May 9 & May 23, 2020

Beets Bleed Red, but Chemists Turn It Blue

About this Guide

In this Guide, based on the online *Science News* article "Beets bleed red but a chemistry tweak can create a blue hue," students will learn how light and chemical structures affect color and how chemists apply that knowledge to create pigments. Students will then pair up to research a pigment of their choice.

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the online *Science News* article "Beets bleed red but a chemistry tweak can create a blue hue," which explores how scientists altered the molecular structure of a pigment molecule from beets. A version of the story, "Beets bleed red, but chemists turn it blue," can be found in the May 9 & May 23, 2020 issue of *Science News*. Related standards include NGSS-DCI: HS-PS1; HS-PS3; HS-PS4.

> **Student Comprehension Worksheet —** These questions are formatted so it's easy to print them out as a worksheet.

Cross-curricular Discussion Q&A — Students will review concepts of light and chemical structures to explore color. Then, students will partner up to research a pigment of their choice and present their findings to the class. Related standards include NGSS-DCI: HS-PS1; HS-PS3; HS-PS4.

> **Student Discussion Worksheet —** These questions are formatted so it's easy to print them out as a worksheet.

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Article-based Comprehension, Q&A

Directions for teachers: After your students read the online *Science News* article "Beets bleed red but a chemistry tweak can create a blue hue," ask them to answer the following questions. A version of the story, "Beets bleed red, but chemists turn it blue," can be found in the May 9 & May 23, 2020 issue of *Science News*.

1. What literary device is used to hook the reader? Paraphrase the information given.

The story's lead uses rhyme, parodying the traditional poem "Roses are red." Chemists took red pigment from beet juice and made it blue, so the resulting blue dye could possibly be used in consumable goods.

2. Why can't chemists get natural blue colorings from certain blue animals for use in cosmetics and other products?

Chemists can't get blue coloring from blue jays, butterflies and dragonflies because these animals don't get their color from pigment molecules. The color is created through light scattering — structures on birds' feathers and butterfly and dragonfly wings reflect blue wavelengths of light, so the feathers and wings are perceived as blue.

3. Why are natural blue pigments from foods, like blueberries, hard to bottle and use in cosmetics and other products?

Pigments from foods that are naturally blue, like blueberries, don't last long so are not useful for creating shelf-stable blue products.

4. What is one technique that chemists use to adjust the colors of pigment molecules? Explain why the technique changes the color of the pigment molecule.

Chemists can change a pigment molecule's color by adjusting the molecule's chemical structure. The structural change alters the wavelengths of light the molecule absorbs and reflects, resulting in a color change.

5. How did chemists use this technique to create a blue dye from beets? Make sure to mention what molecules were used.

Beets get their reddish-purple color from a pigment molecule with alternating single and double bonds. To turn beet pigment blue, chemists removed a portion of the original molecule and added more of those alternating bonds with a compound called 2,4-dimethylpyrrole.

6. What did chemists do to test the dye's durability? What were the results of those tests?

Chemists tested the dye under acidic conditions that cause many blues to fade or change color. The dye did not change color or fade in that test. The chemists also successfully colored fabric, yogurt and hair with the dye in lab tests.

7. Is the blue dye toxic? Is it safe for people to consume? Explain.

BeetBlue does not contain toxic metals. In lab tests, the dye was nontoxic to live zebrafish embryos and human cells. But many additional tests are needed to determine if the dye is safe to consume.

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Student Comprehension Worksheet

Directions: After reading the online *Science News* article "Beets bleed red but a chemistry tweak can create a blue hue," answer the following questions.

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7. Is the blue dye toxic? Is it safe for people to consume? Explain.

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Cross-curricular Discussion, Q&A

Directions for teachers:

After students read the online *Science News* article "Beets bleed red, but a chemistry tweak can create a blue hue," review science concepts including visible light and chemical structures, and how those concepts relate to color. Then use the discussion questions to help your class connect those concepts to the article. Finally, show students "The Chemistry of Color" video. Partner students up to discuss two questions about the source and application of pigments, and use the given prompt to research a pigment of their choice. Bring the class back together and have the pairs share information about their pigment.

Want to make it a virtual lesson? Post the online *Science News* article "Beets bleed red but a chemistry tweak can create a blue hue," the link to "The Chemistry of Color" video and the student discussion worksheet to your virtual classroom platform. You can use a video conferencing platform to lead a class discussion. Students should then watch the video and pair up to answer the questions and the research prompt using a video conferencing platform, or talking by phone. Students can collaborate in a shared document during the conversation. Pairs should post their responses to the research prompt to your virtual classroom's discussion board and give feedback on another pair's response.

Review topics

Visible light
Visible light is the portion of the electromagnetic spectrum that humans can see. Wavelengths in this part of the spectrum range from about 380 nanometers to about 740 nanometers, and are perceived as the colors of the rainbow: red, orange, yellow, green, blue, indigo and violet. Each color has its own wavelength and frequency. Red light has the longest wavelength and lowest frequency and energy, and violet light has the shortest wavelength and highest frequency and energy. White light is the combination of all of the colors in the visible light spectrum.

Light and color
Matter that doesn't emit its own light appears as certain colors based on the wavelengths absorbed and reflected. Absorbed wavelengths correspond to the energy required for the matter's electrons to go from a ground state, or an occupied state, to an excited state, or unoccupied state. Wavelengths that aren't absorbed are reflected, detected by our eyes and perceived as color. Note that the reflected color is complementary to the absorbed color. Matter that doesn't absorb any wavelengths appears white, and matter that absorbs all wavelengths appears black.

Chemical structures of pigments
Pigments are molecules within an object that make it a specific color. Many pigment molecules have structures with alternating single and double bonds called conjugated bonds. This bond pattern helps

determine the energy required for electrons within molecules to transition to an excited state. That energy requirement dictates which wavelengths the electrons absorb, and therefore the pigment's color.

Pigment molecules with few conjugated bonds have electrons that require a relatively high amount of energy to transition from a ground state to an excited state, so the electrons absorb high-energy wavelengths of visible light (green, blue, indigo or violet). These pigment molecules therefore tend to appear red, orange or yellow.

Pigment molecules with many conjugated bonds have electrons that require relatively little energy to transition, so the electrons absorb low-energy wavelengths of visible light (red, orange or yellow). These pigment molecules therefore tend to appear green, blue, indigo or violet.

A pigment's color is complementary to the wavelengths its electrons absorb. Beta-carotene, for instance, is a pigment molecule found in carrots. The molecule has 11 conjugated bonds and absorbs high-energy blue light, so beta-carotene appears orange — the complementary color to blue.

Discussion questions
After reviewing the chemistry of color with your class, use the following questions to discuss the online *Science News* article "Beets bleed red, but a chemistry tweak can create a blue hue."

1. How do you think beets get their red hue?

I think beets appear red because the pigment they contain absorbs green light and reflects other wavelengths of visible light, which appear red to our eyes. Red is complementary to green.

2. How did researchers create blue dye out of red beet juice? Were the changes chemical or physical? Draw a simple diagram to represent the changes that were made to the beet pigment, and indicate whether the before or after molecule has more conjugation.

Researchers chemically modified the red pigment in beets to make the blue dye. The team cleaved off one part of the molecule and replaced it with a compound that contained more alternating single and double bonds. The additional bonds allowed the dye to absorb more orange light and reflect more blue light. Diagrams shown should represent a beet pigment molecule being cut into two sections, and a new molecule replacing one of the two sections. The resulting molecule should contain additional alternating single and double bonds.

3. How might the change you outlined above affect the energy required for the electrons to transition in each molecule? Explain how the change in transition energy affects the color seen. Illustrate your answer by drawing a simple diagram of electrons transitioning from a ground state to an excited state in the red

beet pigment, as well as in the blue dye.

The addition of conjugated bonds to the red beet pigment's chemical structure decreased the energy required for electrons to transition from a ground state to an excited state. The modified molecule therefore absorbs lower-energy wavelengths of light (orange) than the red beet pigment (green) and appears blue (as opposed to red). Diagrams should show a smaller difference in energy between ground state and excited state for electrons for the new molecule.

4. What scientific information do you think researchers needed to know in order to make the blue dye?

Researchers needed to know the beet pigment's molecular structure, and understand how the molecule interacted with light. Researchers also needed to know how to alter the beet pigment's molecular structure to change the wavelengths of light it absorbed and reflected. The scientists also needed to determine a chemical process, or mechanism, to create the new molecule.

Partner pigment exploration

With a partner, watch "The Chemistry of Color" video to learn about the sources and applications of pigments. Discuss the questions below with your partner before using the research prompt to report on a pigment of your choice. Finally, be prepared to present your findings to the class.

Where do pigments come from? Give as many examples as possible.

How are pigments used?

Research prompt: Either using an example given in the video, or based on your own search, choose a natural or synthetic pigment to research. Draw your pigment's chemical structure (be sure to show all of its elements and indicate the bonds between them). Determine how your pigment interacts with light and explain what colors of visible light it absorbs and reflects. Describe where the pigment comes from and how it is used.

Beets Bleed Red, but Chemists Turn It Blue

Student Discussion Worksheet

Directions: After discussing with your class how visible light and chemical structures relate to color, you will pair up with a partner and watch "The Chemistry of Color" video. The video describes the sources and applications of pigments. Discuss the questions below with your partner before using the research prompt to report on a pigment of your choice. Finally, be prepared to present your findings to the class.

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