# The Many Colors of Blood

ISTOCK

*By Diana Lutz*

Have you ever seen blue blood? How about purple, green, or even colorless blood? This is no science fiction. Here on Earth, the blood of many animals can have one of these colors.

Horseshoe crabs in a touch tank at a North Carolina aquarium in Pine Knoll Shores were getting sick. The crabs, which look like crawling samurai helmets, had infected sores in their shells and were having trouble with their seven eyes. To find out what was wrong, veterinarian Michael Stoskopf took a blood sample.

When he looked at the blood under a microscope, Stoskopf saw that it was swarming with cells from the crabs' immune system, indicating that these cells were fighting the infection. Stoskopf also noticed that scrapings from the crabs' sores blossomed into bacterial colonies. This helped the veterinarian pick the right antibiotic for the crabs' infection. Once on this drug, the crabs perked right up, their sores healed, and they were soon lumbering about the tank.

The blood Stoskopf drew into his syringe was milky blue, but Stoskopf knew that this was not a sign of sickness: The blood of horseshoe crabs is normally blue. Many animals have red blood, but crabs, lobsters, spiders, and octopuses have blue blood. Certain bottom-dwelling marine worms have green blood. Sea squirts have purple blood. And a few rare animals have blood that is completely colorless. So what is the reason for all of these different colors of blood in animals?

WWW.PBS.ORG

**The blue blood of horseshoe crabs contains a chemical that immediately tells whether a drug is contaminated with bacteria. Up to 30% of a crab's blood is extracted and stored in bottles, here at a laboratory of Charles River Laboratories International, Inc., in Charleston, S.C.**

## Red blood versus blue blood

The blood of a horseshoe crab is blue because of a molecule called a respiratory pigment. In humans, this molecule contains iron, while the crab version contains copper, and that affects the color of blood.

A respiratory pigment binds to oxygen and carries it around the body, keeping organs and tissues oxygenated. When a pigment molecule binds to an oxygen molecule, it absorbs a certain color of light, and we see whatever light has not been absorbed. As a result, the pigment molecules have different colors, and so does the blood that contains them.

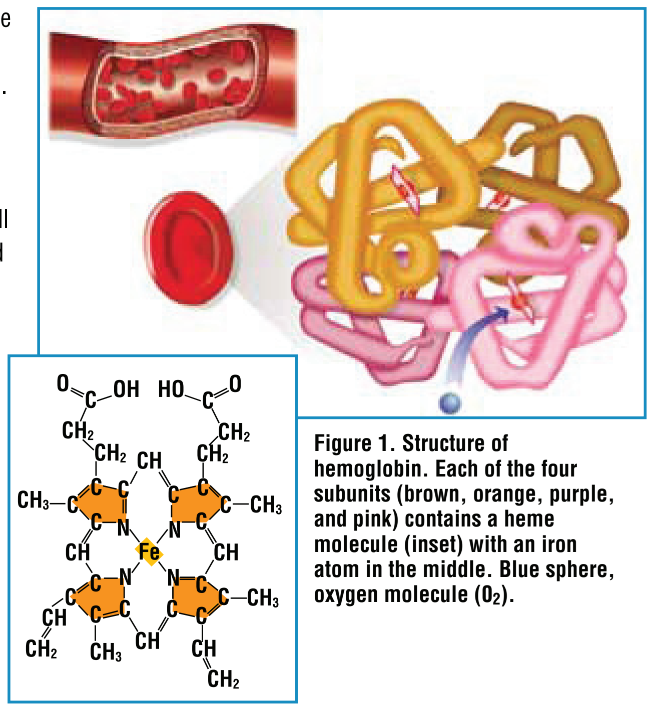


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**Figure 1. Structure of hemoglobin. Each of the four subunits (brown, orange, purple, and pink) contains a heme molecule (inset) with an iron atom in the middle. Blue sphere, oxygen molecule ($O_2$).**

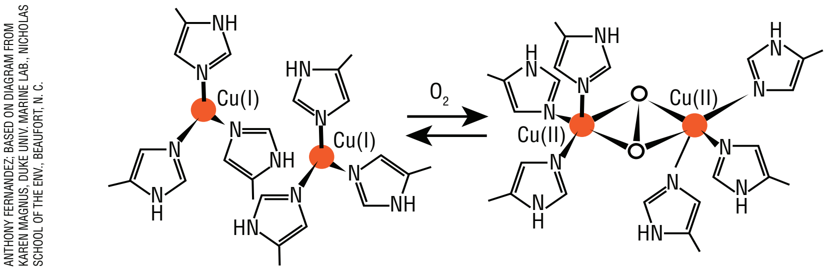



**Figure 2. Structure of a hemocyanin molecule's binding site before and after an oxygen molecule ($O_2$) binds to the copper atoms in the middle.**

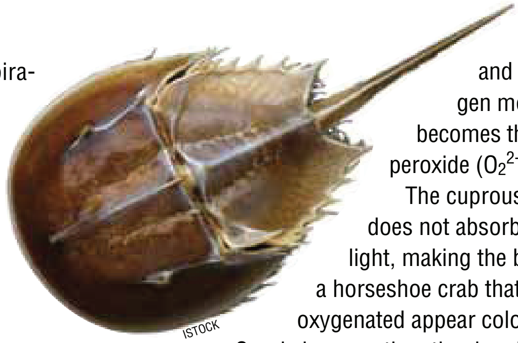
The human version of the respiratory pigment is called hemoglobin, and the crab version is called hemocyanin. In hemoglobin, when iron binds to oxygen, it absorbs mostly blue light, so it appears bright red. In hemocyanin, when copper binds to oxygen, it absorbs mostly red light and thus appears blue.

Hemoglobin is made of four proteins, each containing a large molecule called a heme (Fig. 1). The iron atom is in the middle of the heme. By comparison, hemocyanin in a horseshoe crab contains a whopping 96 pairs of copper atoms that bind to one oxygen molecule each. One of hemocyanin's binding sites (with one pair of copper atoms) is shown in Fig. 2.

Hemoglobin and hemocyanin differ in size, too. Hemocyanin is bigger than hemoglobin. It binds to 96 oxygen molecules, far more than the measly four bound by hemoglobin. Also, the hemocyanin molecules float free in the blood, whereas millions of the smaller hemoglobin molecules are packed into cells called red blood cells.

When a respiratory pigment is bound to oxygen, it has a different color from when it is not bound to oxygen. In hemoglobin, when iron atoms are not bound to oxygen, they appear dull red. But when iron atoms bind to oxygen, the entire heme group folds in such a way that it goes from a domed shape to a flat shape, which changes its color from dull red to bright red.

In hemocyanin, when copper atoms are not bound to oxygen, they have each donated an electron to surrounding atoms and are called cuprous ions ($Cu^+$). When an oxygen molecule binds to a pair of copper atoms, each atom in the pair gives up one electron to the oxygen molecule, resulting in two cupric ions ($Cu^{2+}$), and the oxygen molecule becomes the ion peroxide ($O_2^{2-}$).




**Horseshoe crab**

The cuprous ion does not absorb visible light, making the blood of a horseshoe crab that is not oxygenated appear colorless. Cupric ions, on the other hand, strongly absorb red light. With the red component of light absorbed, these ions look blue, which explains why the oxygenated blood of a horseshoe crab is blue.

The atoms that bind oxygen in respiratory pigments, such as iron and copper, are always transition elements, that is, elements that belong to groups 3 through 12 in the periodic table. The reason is that oxygen interacts strongly with atoms or ions if it receives electrons from them. Because transition metal ions give up or take back electrons easily, they can bind to oxygen easily and let go of it just as easily.

## Clear blood

The respiratory pigments are so important that when scientists heard of creatures that did not have any, they thought it was a hoax.

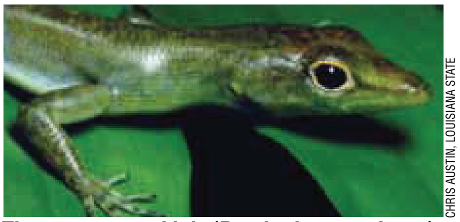

**An ice fish off the coast of Antarctica is seen from below.**

But there is at least one family of animals like this: the crocodile ice fish, sometimes called the bloodless fish, which live in the cold waters surrounding Antarctica.

The blood of these fish is white and looks like cream when it clots. Ice fish manage without a respiratory pigment because their blood does not carry oxygen very well, so they have more blood than any other fish. Also, water in the Southern Atlantic contains more oxygen than warmer water, because more oxygen dissolves in cold water than in warm water. Another reason these ice fish get by without a respiratory protein is that they are relatively inactive and slow moving, so they need less oxygen than active fish.

## Green blood

All animals with a backbone—also called vertebrates—have red blood, except for a type of lizard called the green-blooded skink. It lives in New Guinea, an island north of Australia that is home to some of the world's most unusual creatures, but none more unusual than this armor-plated lizard. Its blood, which is lime-green, colors all of its tissues in green, including its bones, tongue, and the lining of its mouth.




**The green tree skink *(Prasinohaema virens)* is one of five described species of green-blooded lizards from New Guinea.**

Why is the blood of this lizard green? Like people, skinks have red blood cells full of hemoglobin. In humans as well as in skinks, red blood cells have short lifetimes, so they are then taken out of circulation by the liver. When these cells are trashed, their hemoglobin is recycled. But this recycling process differs in humans and in skinks.

In people, hemoglobin is recycled to form biliverdin, a green chemical. Biliverdin is then rapidly converted into a yellow chemical called bilirubin. Bilirubin is a toxic compound, so the liver filters it from the

| BLOOD COLOR | ANIMAL | WHY THIS COLOR? |
|---|---|---|
| Red | Humans | Hemoglobin contains iron that binds to oxygen, making blood appear red. |
| Blue | Horseshoe crab, octopus, lobster, spider | Hemocyanin contains copper that binds to oxygen, making the blood appear blue. |
| Green | Earthworm, leeches | Chlorocruorin contains iron that binds to oxygen, making the blood appear green. |
| Green | Skink (type of lizard), marine worms | Recycling of hemoglobin stuck halfway; biliverdin (green) accumulates in the body. |
| Violet | Lamp shells | Hemerythrin contains iron that binds to oxygen, making blood appear violet-pink. |
| Clear | Ice fish | Blood does not contain a respiratory protein. |

**The different colors of blood in animals**

blood as quickly as possible. If bilirubin builds up to high levels, the skin becomes yellow—a condition called jaundice, which can be fatal.

In skinks, the hemoglobin's disposal process is stuck halfway. Skinks cannot convert biliverdin into bilirubin, so biliverdin builds up in the blood. There is so much biliverdin in a skink's blood that even though the blood's respiratory pigment is red, the green color swamps the red color, and the blood appears green. The amount of biliverdin is 40 times higher than the highest level ever measured in a human being.

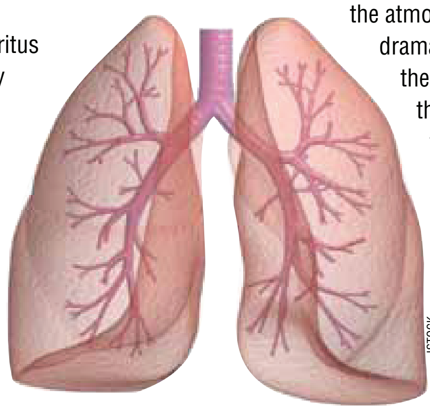
## Where do respiratory pigments come from?

Red blood, blue blood, green blood—Why are there are so many different respiratory pigments? In the case of hemocyanin, the answer may lie in an ancient protein called tyrosinase.

Kensal van Holde, emeritus professor of biochemistry and biophysics at Oregon State University in Corvallis, and Heinz Decker, a professor of molecular biophysics at the Johannes Gutenberg University, Mainz, Germany, have shown that hemocyanin is closely related to a protein called tyrosinase. This protein now plays a role in making melanin, the pigment that colors human hair and skin.

MIKE CIELSIELSKI

The scientists believe that the similarity between hemocyanin and tyrosinase is not accidental. They suggest that tyrosinase appeared on Earth about 2.4 billion years ago. At that time, the amount of oxygen in the atmosphere started to increase dramatically—an event called the Oxygen Catastrophe. For the microscopic organisms that had evolved before that time, oxygen was essentially a poison: These organisms did not need oxygen; in fact, being exposed to oxygen would have killed them.



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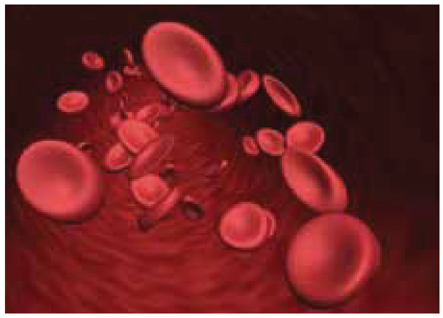

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"Tyrosinase, or a similar molecule, probably protected these early organisms," Decker says. "It probably took up the oxygen and incorporated it in molecules, such as melanin, that the organisms needed."

After the Oxygen Catastrophe, some organisms died and others adapted to the presence of oxygen. The organisms that survived benefited from the enormous amount of energy generated by processing oxygen in their bodies. Over time, the oxygen-binding tyrosinase probably evolved into the oxygen-transporting hemocyanin.

Perhaps the many colors of today's respiratory pigments are really the colors of desperation. Hardpressed by the Oxygen Catastrophe, nature may have churned through many solutions and found more than one key for the same lock (the lock being the ability to carry oxygen in the blood, and the keys being the different respiratory pigments).

"Our studies have shown that evolution has apparently come up with several independent ways to transport oxygen, and this happened at least four times," van Holde says. "This is typically how evolution works—not following some design, but making seemingly random changes in proteins and then retaining whatever stands the test of natural selection."


**SELECTED REFERENCES**

Carroll, S. *The Making of the Fittest*; W. W. Norton: New York, **2006**.

The Horseshoe Crab: www.horseshoecrab.org [Aug 2009]

Spelman, L. H.; Mashima, T. Y. *The Rhino with Glue-on Shoes and Other Surprising True Stories of Zoo Vets and their Patients*; Random House: New York, **2008**.

Perkins, S. The Iron Record of Earth's Oxygen. *Science News*, June 20, 2009, *175* (13), p 24.



***Diana Lutz*** is a science writer in Madison, Wis. Her most recent article, "Hollywood's Special Effects: How Did They Do That?" appeared in the December 2009 issue of *ChemMatters*.


# LESSON PLAN
# "THE MANY COLORS OF BLOOD"

**Article Summary:** Respiratory pigments are responsible for a variety of colors of blood in animals.

| CHEMISTRY CONCEPTS | KEY VOCABULARY |
|---|---|
| • Biochemistry | • Amino Acid |
| • Chemical and Physical Properties | • Gas Solubility |
| • Elements and Compounds | • Metallo-Oganic Compounds |
| • Equilibrium | • Proteins |
| • Molecular Geometry and Structure | • Respiratory Pigments |
| • Oxidation/Reduction | • Transition Elements |
| • Structure and Properties | |

# LINKS TO STANDARDS

## Next Generation Science Standards (NGSS)

### Student Performance Expectations


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- **HS-PS1-1.** Use the periodic table as a model to predict the relative properties of elements based on the patterns of electrons in the outermost energy level of atoms.

- **HS-LS4-4.** Construct an explanation based on evidence for how natural selection leads to adaptation of populations.

*For* **Extend (Optional)** *Portion of Lesson Outline*

- **HS-PS2-6.** Communicate scientific and technical information about why the molecular-level structure is important in the functioning of designed materials.

### Science and Engineering Practices (from NGSS Appendix F)

- Developing and Using Models

### Crosscutting Concepts (from NGSS Appendix G)

- Patterns

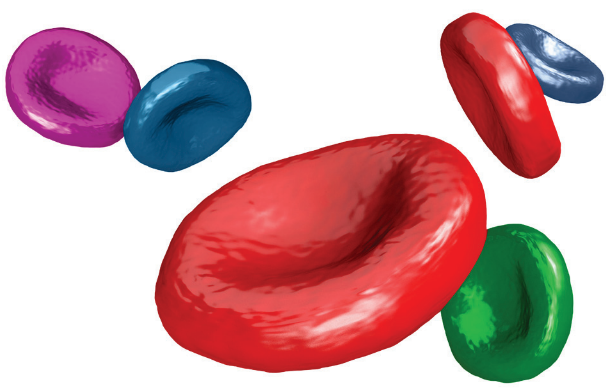
- Energy and Matter

- Structure and Function

### The Nature of Science (from NGSS Appendix H)

- Scientific Knowledge Is Based on Empirical Evidence

- Science Addresses Questions about the Natural and Material World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## Common Core State Standards (CCSS) for English Language Arts & Literacy in History/Social Studies, Science, and Technical Subjects

- **RST.9-10.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.

- **RST.9-10.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to *grades 9–10 texts and topics.*

- **RST.9-10.7.** Translate quantitative or technical information expressed in words in a text into visual form (e.g., a table or chart) and translate information expressed visually or mathematically (e.g., in an equation) into words.

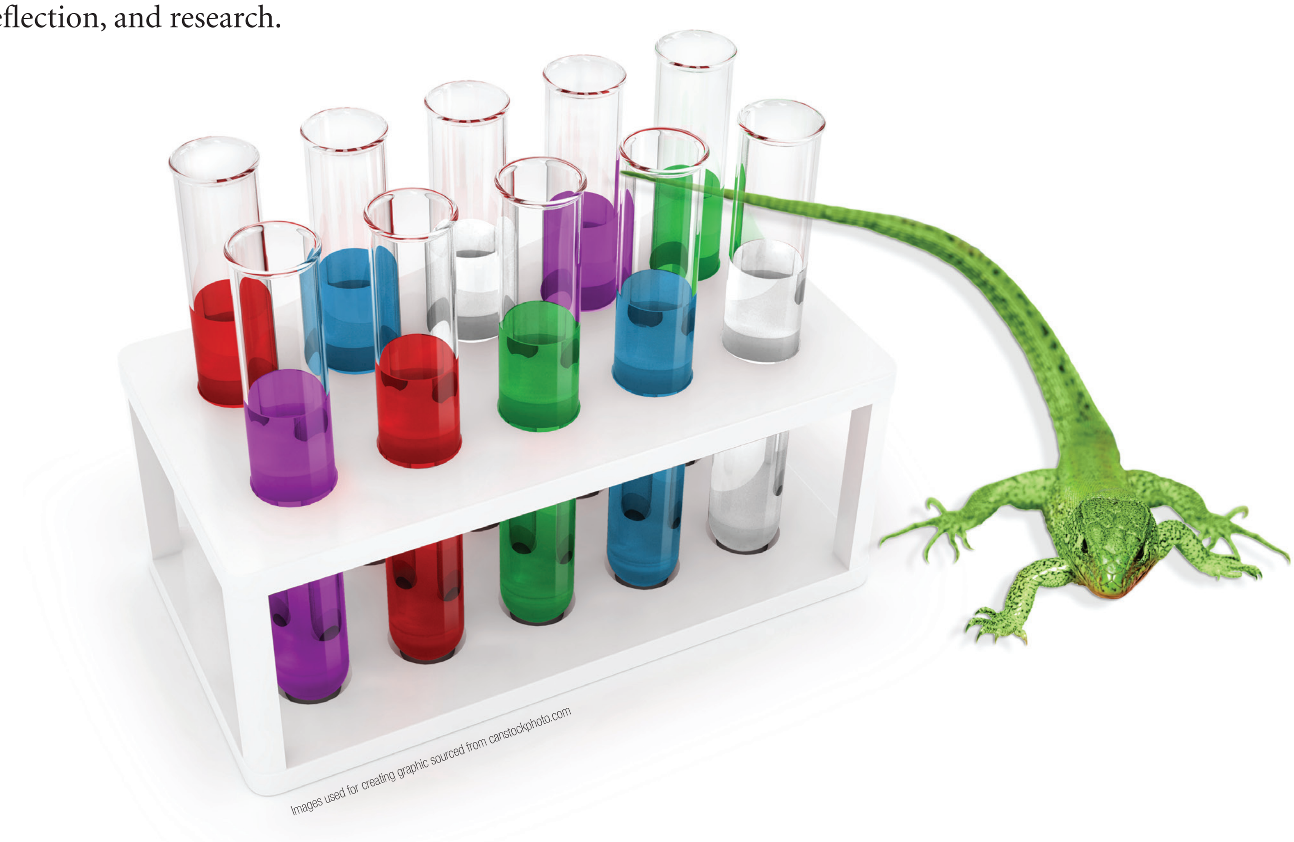
- **RST.11-12.1.** Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.

- **RST.11-12.4.** Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades *11–12 texts and topics.*

*For* **Extend (Optional)** *Portion of Lesson Outline*

- **WHST.9-10.4 and WHST.11-12.4.** Produce clear and coherent writing in which the development, organization, and style are appropriate to task, purpose, and audience.

- **WHST.9-10.9 and WHST.11-12.9.** Draw evidence from informational texts to support analysis, reflection, and research.



# OBJECTIVES

1. Students will compare and contrast respiratory pigments found in different animals.
2. Students will explain the characteristics of a selected respiratory pigment, including its structure, the atom(s) binding to oxygen, and the reason for the color observed.

# ASSESSMENTS

1. Formative Assessment:
   - Students will complete a graphic organizer (or use a Venn diagram) to compare and contrast hemoglobin and hemocyanin.
   - Students will complete a table by listing different respiratory pigments found in animals and the animals in which the pigments are found, along with the animals' habitats and blood colors.
2. Final Assessment: Students will write a report describing a respiratory pigment, using color-coding to emphasize the relationship of molecular structure and function. Students will include the name of the pigment, its structure, the transition element and ions involved, the color observed, and the names of animals in which the pigment is found.
3. Extend (Optional) Assessment: Students will write a letter to a pharmaceutical executive or prepare a brochure advocating the development of a synthetic alternative to horseshoe crab blood, basing their arguments on chemistry principles.

# TIME REQUIRED

90–135 minutes, depending on teacher choices

# MATERIALS FOR STUDENTS AND TEACHERS

- "The Many Colors of Blood" Article (one per student)
- Anticipation Guide (one per student) (p. 107; possible student answers on p. 108)
- Reading Guide (one per student) (p. 109; possible student answers on p. 111)
- Background Information for Teachers
- Internet for Optional Student Research

# SAFETY

All laboratory activities in this lesson are intended to be performed under the direct supervision of a qualified chemistry teacher. Relevant safety information appears near the activities and is intended to provide basic guidelines for safe practices as a starting point for best laboratory practices

# POSSIBLE STUDENT PRECONCEPTIONS

*These preconceptions may be discussed as students read the article or after (not before).*

1. **Blood inside our bodies is blue, but it turns red when exposed to oxygen.** Both deoxygenated (venous) blood and fully oxygenated (arterial) blood are red. Blood in the veins appears blue for a number of reasons. One of the most important reasons is that when light passes through the skin, the light scattering process is 100 to 1,000 times more probable than the light-absorption process.

   - Cheong, W.; Prahl, S. A.; Welch, A. J. A Review of the Optical Properties of Biological Tissues. IEEE *Journal of Quantum Electronics,* 1990, 26, pp. 2166–2185. Cited in Kienle, A.; Lilge, L.; Vitkin, I. A.; Patterson, M.; Wilson, B.; Hibst, R.; Steiner, R. Why Do Veins Appear Blue? A New Look at an Old Question. *Applied Optics Journal of the Optical Society,* 1996, *35* (7), pp. 1151–1160.

   - Anthis, N. Why Are Veins Blue? Science Blogs: The Scientific Activist, April 17, 2008: http://scienceblogs.com/scientificactivist/2008/04/17/why-are-veins-blue (accessed April 2016.).

2. **People of royalty have blue blood; nonroyals have red blood.** The term "blue blood" comes from the Spanish term "sangre azul" (sangre = blood, azul = blue). It refers to royalty and has its origins in Spain after the recapture of Spain from the Moors. The Moors, who had earlier conquered and settled Spain, produced offspring who inherited their darker skin. Darker skin makes it difficult to see the color of veins at the surface, which appear blue in lighter skinned people. Long after the Moors left and monarchies were re-established, more people with light skin, which enables their surface veins to be noticed, were born. Therefore, there was an association between royalty and "blue blood." The term was eventually adapted by monarchies in other countries.

   - American Heritage Dictionaries, Eds.; *Spanish Word Histories and Mysteries: English Words that Come from Spanish;* Houghton Mifflin: Boston, 2007; pp. 29–31: http://tinyurl.com/nwlvc9e (accessed April 2016.).

3. **How can a red blood cell function if it is not alive?** It is true that a red blood cell lacks a nucleus, which is found in other cells. But the red blood cell essentially operates through a variety of chemical reactions, the principal reaction being the binding of oxygen molecules to the ferrous ion in the heme portion of the hemoglobin found in the red blood cell. The gain and loss of the oxygen is dependent on the partial pressures of oxygen within the cell and within the cells that make up surrounding tissue. It is a nonbiological process that is not dependent on a functioning live cell.

# LESSON OUTLINE


## Engage

*Think-Pair-Share. Accept all student ideas at this time.*

- Display the following questions on a screen or write them on the board, and ask students to think about their answers to the questions.

    1. What chemicals do you think might be found in blood?

    2. How might the chemicals in blood affect the color?

    3. What color is our blood? Do you think that all animals have the same blood color? Explain."

- After a minute or so, ask students to share their answers with the person sitting next to them or their lab group.

- After students have shared their answers, have a class discussion about the questions.

## Explore

*Choose one of the following options.*

**Option 1**

- Give students a copy of the Anticipation Guide (p. 107), and ask them to complete the first column (Me) by writing "A" or "D" to indicate their agreement or disagreement with each statement in the third column (Statement).

- As a class, discuss students' opinions about each statement and what they hope to learn from reading the article.

- Give students a copy of the article "The Many Colors of Blood" and ask them to read it. Ask them to complete the second column (Article) in the Anticipation Guide as they read the article by writing "A" or "D" in the column to indicate the article's agreement or disagreement with each statement.

- Ask students to cite text from the article that supports or refutes their original opinion about each statement in the space below each statement. (This could be assigned as homework.)

- After students complete their Anticipation Guides, discuss what they learned from their reading.

**Option 2**

- Give students a copy of the article "The Many Colors of Blood" and ask them to read it.
- Ask students to write down questions they have as they read the article and information from the article that surprises them.

## Explain

- Give each student a copy of the Reading Guide (p. 109).
- Ask students to complete the Reading Guide, using information from the article.
- After students complete their Reading Guides, discuss their answers with the class.

## Elaborate

- Use kinetic molecular theory to explain why cold water contains more dissolved oxygen than warm water.
- Inform students that tyrosinase is related to hemocyanin, not hemoglobin. Answer the following question: "How does this statement support the ideas of Professor Kensal van Holde at Oregon State University and Professor Heinz Decker at the Johannes Gutenberg University in Germany?" Direct students to use information from the article to support their answers.
- Give students the opportunity to ask questions related to the article.


## Evaluate

Ask students to write a report describing a respiratory pigment of their choice, using color-coding to emphasize the relationship of molecular structure and function. Ask them to include the name of the pigment, its structure, the transition element and ions involved, the color observed, and the names of animals in which the pigment is found.

## *SUGGESTED RUBRIC*

| SCORE | DESCRIPTION | EVIDENCE |
|---|---|---|
| 4 | Excellent | Complete, demonstrates deep understanding; clearly details respiratory pigment: includes appropriate color-coding, name, structure, elements and ions involved, color, and names of animals with the pigment; examples come from the article and optional outside research (with quality references). |
| 3 | Good | Complete, but lacks some details about respiratory pigment; demonstrates some understanding. |
| 2 | Fair | Incomplete; few details provided about respiratory pigment; some misconceptions evident. |
| 1 | Poor | Very incomplete; no details provided about respiratory pigment; many misconceptions evident. |
| 0 | Not Acceptable | So incomplete that no judgment can be made about student understanding. |

## Extend (Optional)

- Ask students to read more about how horseshoe crab blood is used in pharmaceuticals, directing them to **Related Resources,** on p. 112.
- Ask students to write a letter to a pharmaceutical executive or prepare a brochure advocating the development of a synthetic alternative to horseshoe crab blood, basing their arguments on chemistry principles (Extend (Optional) Assessment, p. 101).

## *SUGGESTED RUBRIC*

| SCORE | DESCRIPTION | EVIDENCE |
|---|---|---|
| 4 | Excellent | Complete; clearly supports argument with key details of chemical principles involved; includes examples from the article as well as outside research; references are included; demonstrates deep understanding; engaging and appropriate for audience. |
| 3 | Good | Complete, but argument is not fully supported with details of chemical principles involved; includes some examples and references; arguments demonstrates some understanding; may not engagement the audience. |
| 2 | Fair | Incomplete; few details of chemical principles involved; no examples from the article are included; some misconceptions evident; not engaging or appropriate. |
| 1 | Poor | Very incomplete; no details of chemical principles involved; many misconceptions evident. |
| 0 | Not Acceptable | So incomplete that no judgment can be made about student understanding. |

NAME: ________________________________

## Anticipation Guide for "The Many Colors of Blood"

*Before reading the article*, in the first column, write "A" or "D" to indicate your agreement or disagreement with each statement. *As you read*, compare your opinions with information from the article and write "A" or "D" in the second column to indicate the article's agreement or disagreement with each statement. In the space under each statement, cite text from the article that supports or refutes your original opinion.

| ME | ARTICLE | STATEMENT |
|---|---|---|
| | | 1. All animals, including humans, have red blood. |
| | | 2. The color of an organism's blood depends on the respiratory pigment molecule in the organism. |
| | | 3. Hemoglobin (found in humans) and hemocyanin (found in crabs) differ only in the identity of the metal ion found in the middle of the heme. |
| | | 4. Respiratory pigments are the same color regardless of whether they are bound to oxygen. |
| | | 5. Only transition metals bind oxygen in respiratory pigments. |
| | | 6. Animals without a respiratory pigment are found only in very cold water. |
| | | 7. Green-blooded skinks from New Guinea have red blood cells containing hemoglobin. |
| | | 8. Our livers filter bilirubin, a toxic yellow compound, from our blood. |
| | | 9. Organisms that existed before the Oxygen Catastrophe 2.4 billion years ago needed more oxygen than is currently in the atmosphere. |
| | | 10. The blood of ice fish is clear because it has no respiratory protein. |

## Possible Student Answers to the Anticipation Guide for "The Many Colors of Blood"

*Before reading the article*, in the first column, write "A" or "D" to indicate your agreement or disagreement with each statement. As you read, compare your opinions with information from the article and write "A" or "D" in the second column to indicate the article's agreement or disagreement with each statement. In the space under each statement, cite text from the article that supports or refutes your original opinion. Possible student answers are provided in red.

| ME | ARTICLE | STATEMENT |
|---|---|---|
| | D | 1. All animals, including humans, have red blood. "How about purple, green, or even colorless blood? … Here on Earth, the blood of many animals can have one of these colors." |
| | A | 2. The color of an organism's blood depends on the respiratory pigment molecule in the organism. "The blood of a horseshoe crab is blue because of a molecule called a respiratory pigment." |
| | D | 3. Hemoglobin (found in humans) and hemocyanin (found in crabs) differ only in the identity of the metal ion found in the middle of the heme. "Hemoglobin and hemocyanin differ in size, too. Hemocyanin is bigger than hemoglobin." |
| | D | 4. Respiratory pigments are the same color regardless of whether they are bound to oxygen. "When a respiratory pigment is bound to oxygen, it has a different color from when it is not bound to oxygen." |
| | A | 5. Only transition metals bind oxygen in respiratory pigments. "The atoms that bind oxygen in respiratory pigments, such as iron and copper, are always transition elements …" |
| | A | 6. Animals without a respiratory pigment are found only in very cold water. "Crocodile ice fish, sometimes called the bloodless fish … live in the cold waters surrounding Antarctica." |
| | A | 7. Green-blooded skinks from New Guinea have red blood cells containing hemoglobin. "There is so much biliverdin in a skink's blood that even though the blood's respiratory pigment is red, the green color swamps the red color, and the blood appears green." |
| | A | 8. Our livers filter bilirubin, a toxic yellow compound, from our blood. "In people, hemoglobin is recycled to form biliverdin. … Biliverdin is then rapidly converted into a yellow chemical called bilirubin. Bilirubin is a toxic compound, so the liver filters it from the blood." |
| | D | 9. Organisms that existed before the Oxygen Catastrophe 2.4 billion years ago needed more oxygen than is currently in the atmosphere "These organisms did not need oxygen; in fact, being exposed to oxygen would have killed them." |
| | D | 10. The blood of ice fish is clear because it has no respiratory protein. "Blood does not contain a respiratory protein." |

NAME: ________________________________

## Reading Guide for "The Many Colors of Blood"

- *As you read the article*, compare and contrast the properties of hemoglobin and hemocyanin in the graphic organizer below (or use a Venn diagram).

| HEMOGLOBIN | HEMOCYANIN |
|---|---|
| | |
| SIMILARITIES | |
| | |

- Complete the following table by listing four other respiratory pigments found in animals and the animals in which the pigments are found, along with the animals' habitats and blood colors.

| RESPIRATORY PIGMENT | ANIMAL(S) | HABITAT | BLOOD COLOR |
|---|---|---|---|
| 1. | | | |
| 2. | | | |
| 3. | | | |
| 4. | | | |

- How does the habitat where an animal is found affect the amount of oxygen it requires?

- Complete the following table to reflect on the main ideas in the article.

| | |
|---|---|
| 3 | Perhaps your friends wonder why some animals do not have red blood. Write *three things* you learned about blood from reading the article that you would like to share with your friends.<br>1.<br>2.<br>3. |
| 2 | Write *two things* you learned about chemistry from reading the article.<br>1.<br>2. |
| 1 | Write a *one-sentence summary* (15 words maximum) describing the main point of the article. |
| CONTACT! | Describe a *personal experience* about the colors of blood in animals that connects to something you read in the article—something that your personal experience validates. |

## Possible Student Answers to the Reading Guide for "The Many Colors of Blood"

Possible student answers are provided in red. Students may not need to cite all of the information included.

- *As you read the article*, compare and contrast the properties of hemoglobin and hemocyanin in the graphic organizer below (or use a Venn diagram).

| HEMOGLOBIN | HEMOCYANIN |
|---|---|
| Iron bonds to oxygen<br>Appears red<br>Four proteins<br>Smaller<br>Found in red blood cells<br>Oxygenated blood is bright red<br>Found in humans | Copper bonds to oxygen<br>Appears blue<br>96 proteins<br>Larger<br>Floats freely in the blood<br>Oxygenated blood is colorless<br>Found in mollusks |
| **SIMILARITIES** | |
| Respiratory pigments<br>Transition elements bind oxygen<br>Iron and copper release or bind oxygen atoms easily | |

- Complete the following table by listing four other respiratory pigments found in animals and the animals in which the pigments are found, along with the animals' habitats and blood colors.

| RESPIRATORY PIGMENT | ANIMAL(S) | HABITAT | BLOOD COLOR |
|---|---|---|---|
| 1. chlorocruorin | leech, earthworm | land | green |
| 2. hemerythrin | lamp shells (brachiopods) | water | violet |
| 3. biliverdin | skinks, marine lizards | land and water | green |
| 4. none | ice fish | deep water | none |

- How does the habitat where an animal is found affect the amount of oxygen it requires? Animals that live in very cold water do not require as much oxygen because they are slow-moving, and cold water dissolves more oxygen than warm water.

- Complete the following table to reflect on the main ideas in the article. Individual student answers will vary.

# RELATED RESOURCES

*You may direct students to the resources in this section, but be sure to tell them that they should learn to evaluate the validity of resources on their own.*

## For Students

### *ChemMatters* Articles

- The following article describes how investigators identify and describe human blood to solve crimes: Rohrig, B. The Forensics of Blood. *ChemMatters*, Feb 2008, pp. 4–7.

- This article explains how to preserve, store, and transfuse blood safely and explains how blood carries oxygen and carbon dioxide throughout the body. Bruce, N. How Chemistry Helps Make Blood Transfusion Safer. *ChemMatters*, Feb 2008, pp. 8–10.

## For Students and Teachers

*All resources in this section were accessed in March 2016.*

The following resources are very informative about horseshoe crabs and the threat to their survival resulting from their use in the medical industry:

- ERDG (Ecological Research & Development Group). The Horseshoe Crab and Public Health. The Horseshoe Crab, 2013: http://horseshoecrab.org/med/med.html

- Madrigal, A. C. The Blood Harvest. *The Atlantic*, Feb 26, 2014: http://www.theatlantic.com/technology/archive/2014/02/the-blood-harvest/284078

The following article discusses a genetic disease involving defective hemoglobin synthesis. The disease is called thalassemia or Mediterranean anemia (compare with porphyria). The article presents a good "color-coded" picture of normal hemoglobin's structure (alpha and beta chain positions).

- McPherson, E. What Is Thalassemia?. *Scientific American*, Jan 18, 1999: http://www.sciam.com/article.cfm?id=what-is-thalassemia