TEACHING GUIDE
GRADES 9–12

SCHOLASTIC

Explore the Mystery of Blood

Inside You'll Find:

- A comprehensive education program
- Student worksheets, lessons, and laboratory assignments
- Connections to *Blood Detectives* DVD

Supports National Standards for Science, Technology, Life Skills, and Literacy in Science

About the

American Society of Hematology

The American Society of Hematology's (ASH) mission is to further the understanding, diagnosis, treatment, and prevention of disorders affecting the blood, bone marrow, and the immunologic, hemostatic, and vascular systems, by promoting research, clinical care, education, training, and advocacy in hematology.

ASH celebrated its 50th anniversary in 2008 and is continuing to mark this milestone by helping the public make the connection between blood health and total health.

About the

Blood Detectives DVD

Blood Detectives is a documentary produced by award-winning filmmaker Joseph Lovett. The documentary details the secrets and mysteries of human blood and the highly specialized medical professionals—hematologists—who unravel these medical mysteries to save lives. The film delves deeply into the lives of patients who are affected by some of the most common, and sometimes the deadliest, blood disorders. The cameras track the best in the field as they race against time to find treatments for a number of conditions, including leukemia, bleeding disorders, and several others.

Explore the Mystery of Blood

The American Society of Hematology, in partnership with Scholastic, is pleased to share Explore the Mystery of Blood, a resource-filled, national standards-based and Common Core–ready teaching guide that will capture your students' attention.

Starting with the enclosed *Blood Detectives* DVD, students will see real hematologists in action working with patients, performing experiments in laboratories, and making discoveries that will lead to better treatments for blood diseases.

From there, use the lesson plans and student worksheets in this teaching guide to support the content in the DVD and provide rich research-based and hands-on assignments for students to perform their own experiments and make their own discoveries.

Through this exciting material, we hope that your students will take this sense of excitement and exploration with them through their high school years and beyond.

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Education Standards & Benchmarks for Grades 9–12

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Science	Understands biological evolution and the diversity of life									
	Knows that heritable characteristics, which can be biochemical and anatomical, largely determine what capabilities an organism will have, how it will behave, and how likely it is to survive and reproduce					◖				
	Understands the concept of natural selection					◖				
	Understands the nature of scientific knowledge									
	Knows ways in which science distinguishes itself from other ways of knowing and from other bodies of knowledge			◖	◖					
	Understands the nature of scientific inquiry									
	Designs and conducts scientific investigations	◖	◖	◖	◖	◖	◖	◖	◖	◖
	Evaluates the results of scientific investigations, experiments, observations, theoretical and mathematical models, and explanations proposed by other scientists	◖	◖	◖	◖	◖	◖	◖	◖	◖
	Uses technology to perform accurate scientific investigations and communications	◖		◖	◖		◖	◖	◖	◖

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Technology	Understands the relationships among science, technology, society, and the individual									
	Knows examples of advanced and emerging technologies and how they could impact society		◖			◖		◖		
	Knows that technology can benefit the environment by providing scientific information, providing new solutions to older problems, and reducing the negative consequences of existing technology	◖		◖	◖	◖		◖	◖	
	Knows the role of technology in a variety of careers	◖	◖		◖	◖				

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Language Arts	Writing: Gathers and uses information for research purposes									
	Uses appropriate research methodology	◖	◖	◖	◖			◖	◖	◖
	Uses a variety of print and electronic sources to gather information for research topics	◖	◖	◖	◖	◖	◖	◖	◖	◖
	Writes expository compositions					◖	◖	◖	◖	◖
	Synthesizes information from multiple research studies to draw conclusions that go beyond those found in any of the individual studies			◖	◖			◖		
	Writes research papers		◖					◖		
	Reading: Uses reading skills and strategies to understand and interpret a variety of informational texts									
	Uses reading skills and strategies to understand a variety of informational texts	◖	◖	◖	◖	◖	◖	◖	◖	◖
	Listening and Speaking: Uses listening and speaking strategies for different purposes									
	Makes multimedia presentations using text, images, and sound		◖		◖		◖			

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Life Work	Makes general preparation for entering the work force									
	Establishes an explicit career action plan, including short- and long-term goals						◖			
	Evaluates potential career choices in relation to personal interests, strengths, and values			◖			◖			
	Analyzes information associated with careers of interest			◖			◖			

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Self-Regulation	Performs self-appraisal									
	Determines personal career goals and establishes a plan to meet them						◖		◖	

		Lesson 1	Lesson 2	Lesson 3	Lesson 4	Lesson 5	Lesson 6	Lesson 7	Lesson 8	Lesson 9
Health	Knows the availability and effective use of health services, products, and information									
	Knows situations that require professional health services in the areas of prevention, treatment, and rehabilitation		◖	◖			◖	◖	◖	◖
	Knows essential concepts about the prevention and control of disease									
	Understands the social, economic, and political effects of disease on individuals, families, and communities		◖					◖	◖	

Sources: McREL (Mid-continent Research for Education and Learning)

Common Core State Standards

Skills Supporting the COMMON CORE Learning Standards for English Language Arts & Literacy in Science

SKILLS: Grades 9–12	Lesson 10
Analysis of science and technical texts	✓
Follow procedure for experiments, measurements, tasks	✓
Translate quantitative or technical text visually, translate visuals to text	✓
Write informative/explanatory texts	✓
Effective use of advanced searches in gathering data	✓

Source: http://www.corestandards.org/ela-literacy

Lesson 1

A normal blood smear.

What Runs Through My Veins

Objectives:

- Become familiar with the components of blood
- Understand the roles of the cellular components of blood
- Use a compound light microscope to observe blood smears
- Understand the role of stem cells in the production of RBCs (red blood cells)

Directions:

1. If students are not familiar with how to use a compound light microscope, conduct a pre-lesson in which students learn the parts of the microscope and observe microscope slides. Alternatively, guide them through a brief online demonstration at **www.udel.edu/biology/ketcham/microscope/**.
2. Instruct students on the components of blood and how blood cells form (hematopoiesis).
3. Use visuals to show the cellular components of blood, and ask students to compare and contrast their appearance and functions.
4. Observe blood smears using the 10X and 40X objective lenses of the compound light microscope.
5. Sketch observations and answer all questions on the student worksheet.

Materials:

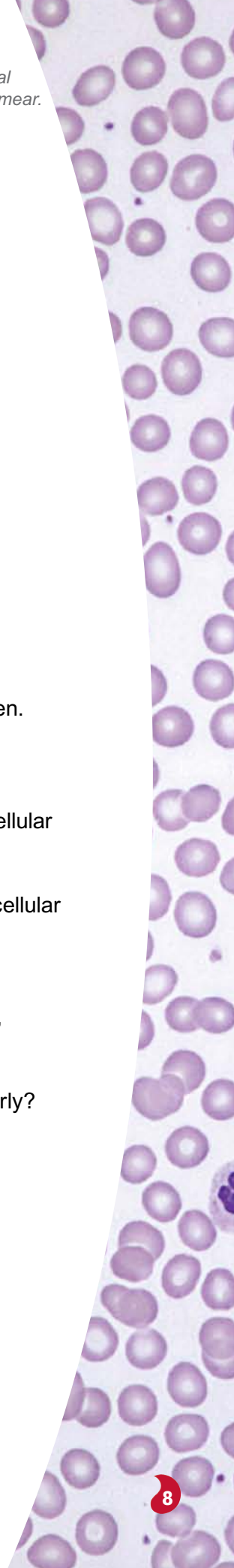
- ***What Runs Through My Veins*** *Student Worksheet 1*
- *pen*
- *paper*
- *prepared microscope slides of blood smears (or high-quality color photos)*
- *compound light microscope (one for every one to two students)*

Time Required:

one to two class periods (approximately 45 minutes each)

Extension Activities:

- Show a film segment from the movie *Osmosis Jones* to supplement instruction on the immune response **(www.imdb.com/title/tt0181739/plotsummary)**.
- Have students complete all or part of *The Case of Eric, Lou Gehrig's Disease, and Stem Cell Research* from the National Center for Case Study Teaching in Science, University at Buffalo, State University of New York **(www.sciencecases.org/gehrigs_disease/gehrigs_disease.asp)**. Teachers can create an account for free to view the answer keys and teaching notes.



A normal blood smear.

Worksheet 1

What Runs Through My Veins

Name: _____

Class/Period: _____

Materials:

- Compound light microscope
- Prepared slides of normal blood smears

Procedure:

1. Place the prepared slide on the stage of the compound light microscope. Turn the light on, or adjust the mirror so that light is reflected up toward the specimen.
2. Turn the nosepiece so that the 10X objective lens is in place over the slide.
3. Adjust the focus by turning the coarse adjustment knob until the image of the blood smear is clear.
4. Sketch your observations under low power on the back of this sheet. Which cellular components are visible?
5. Turn the nosepiece so that the 40X objective lens is in place over the slide.
6. Sketch your observations under high power on the back of this sheet. Which cellular components are visible?

Analysis Questions:

1. Describe the appearance of red blood cells (RBCs), white blood cells (WBCs), and platelets.
2. Describe the function of RBCs, WBCs, and platelets.
3. What would happen to a person if his or her RBCs were not functioning properly? His or her WBCs? His or her platelets?
4. If you know of a disease/disorder in which any of these cells fail to function properly, name and describe it on another sheet of paper.

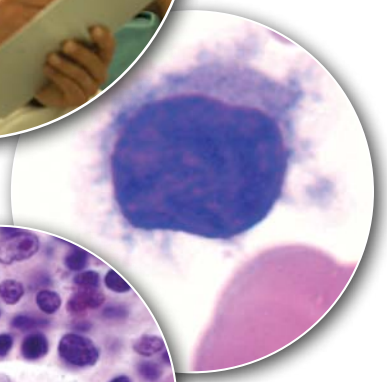
Lesson 2

Common Blood Disorders

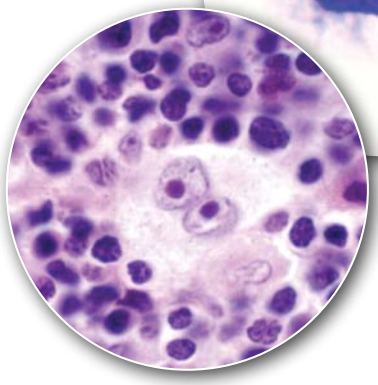
Objectives:

- Become familiar with common blood disorders
- Understand the pathology and symptoms of some common disorders
- Distinguish among the three categories of blood disorders

Paler, abnormally small red blood cells indicate iron-deficiency anemia.



Hairy-cell leukemia



A Reed-Sternberg cell (owl-like appearance) indicates Hodgkin lymphoma

Directions:

1. Play video segments from the *Blood Detectives* DVD showing patients being treated by hematologists at NewYork-Presbyterian hospital. Show segments for three to six of the patients, depending on how many class periods will be devoted to this activity. Show at least one segment for anemia, one for a clotting disorder, and one for lymphoma/leukemia.
2. While watching the video segments, students should answer questions and fill out the table on the accompanying worksheet.

Extension Activities:

- Give students a list of blood disorders not included in the video segment. Have the students work in teams of two to four to research their assigned disorder, including the symptoms of the disease, the changes that take place in the blood, available treatments, and current research that is being carried out on the disorder. Students can complete a research paper on their topic or give a presentation to the class.

Materials:

- ***Common Blood Disorders*** *Student Worksheet 2*
- *pen*
- *paper*
- ***Blood Detectives*** *DVD*

Time Required:

one to two class periods (approximately 45 minutes each), depending on how many disorders are profiled

Paler, abnormally small red blood cells indicate iron-deficiency anemia.

Worksheet 2

Common Blood Disorders

Name: _____

Class/Period: _____

Instructions:

1. Watch the video segments selected by your teacher.
2. For each patient profiled in the video, take notes on each of the topics in the chart below. Your notes should include the name of the disease, the type of disorder (anemia, clotting disorder, or cancer of the blood), the physical symptoms, the molecular/cellular changes that take place, and the available treatments.

Disease	Type of Disorder	Physical Symptoms	Molecular/ Cellular Changes	Treatments

Analysis Question:

Compare and contrast the symptoms and causes of each type of blood disorder.

Lesson 3

A sickle cell blood smear.

Analyze a Case Study

Objectives:

- Understand science as a process
- Understand how the results of one experiment can lead to additional studies
- Describe and interpret scientific data
- Learn about the history of hematology via case study analysis

Directions:

1. Students should be familiar with cell organelles and their functions.
2. Have students complete the case study *Sickle Cell Anemia* from the National Center for Case Study Teaching in Science, University at Buffalo, State University of New York **(http://ublib.buffalo.edu/libraries/projects/cases/sickle_cell1.html)**. Students should work in cooperative groups of three to four and use a course textbook as reference.
3. Students should read section 1 of the case study prior to class. Have students reiterate the main points in the reading at the start of class. Students should then work in cooperative groups to identify and list each piece of experimental evidence described in the reading. For each piece of evidence, students should explain its significance. Share answers as a group, then have students answer the case study questions for section 1.
4. Students should read section 2A of the case study prior to class. Have students reiterate the main points in the reading at the start of class. Use the course textbook as a reference to see the difference in shape between normal RBCs and those of an individual with sickle cell anemia. In Campbell, Reece, and Mitchell's *Biology* (5th edition), use figure 5.19 on page 72. Students should answer all questions for part 2A of the case study in cooperative groups.
5. Students should read section 2B of the case study prior to class. Have students reiterate the main points in the reading at the start of class, then answer all questions for the section in cooperative groups. Share answers as a whole class, then distribute section 2C of the case study. Students should read section 2C in class and answer the analysis questions in cooperative groups.

Materials:

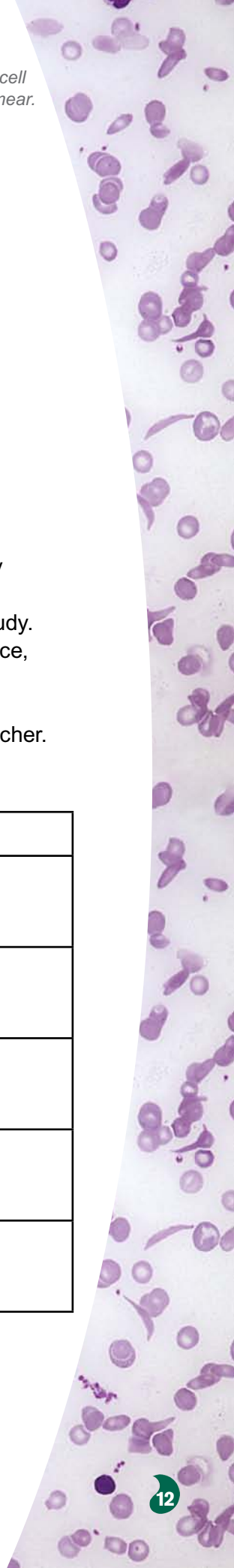
- ***Analyze a Case Study*** *Student Worksheet 3*
- *pen*
- *paper*
- *copy of case study*
- ***Biology*** *(5th edition), Campbell, Reece, and Mitchell*

Time Required:

3 class periods (approximately 45 minutes each)

Extension Activities:

- For a more advanced course, such as Advanced Placement Biology, section 3 of the case study can be completed. This section requires more in-depth knowledge of cellular functions.
- Assign students to research a well-known hematologist and create a scrapbook based on that person's life. Students should include biographical information, career information, and a one-page reflection on the hematologist's life.



A sickle cell blood smear.

Worksheet 3

Analyze a Case Study

Name: _____

Class/Period: _____

Instructions:

1. Read section 1 of *Sickle Cell Anemia* from the National Center for Case Study Teaching in Science, University at Buffalo, State University of New York.
2. Work in groups to identify the experimental evidence described in the case study.
3. List all experimental evidence in the chart below, and for each piece of evidence, describe its significance.
4. Answer analysis questions at the end of section 1 of the case study.
5. Complete sections 2A, 2B, and 2C of the case study as instructed by your teacher.

Experimental Evidence	Significance

Lesson 4

A chronic myelogenous leukemia patient's blood smear shows an increased number of neutrophils, a type of white blood cell.

Blood Detectives

Objectives:

- Use a compound light microscope to observe blood smears from individuals with blood disorders
- Distinguish between blood smears of healthy and unhealthy individuals
- Correlate changes in the blood with disease symptoms
- Diagnose diseases based on blood smear observations

Directions:

1. Review categories of blood disorders and examples of each.
2. Observe blood smears from individuals with blood disorders at 10X and 40X magnification under the compound light microscope.
3. Sketch observations and answer all questions on the student worksheet.
4. Students should use their previous sketches of normal blood smears as a basis of comparison. You may also make the normal blood smears or color photos available for students to look at again.
5. Group students into teams of two to four. Distribute the history, physical symptoms, and microscope slides with blood smears of patients who have not yet been diagnosed ("unknown" samples). Teachers should use the ASH Web site to create accurate descriptions of the symptoms of specific diseases for which you have obtained blood smears. If you cannot obtain blood smears for all of the diseases you want students to diagnose, use color photographs instead.
6. Have students make observations and predict which disease the patient has based on the blood smears and the physical symptoms. The diagnosis has to be justified on their direct observations and information from previous lessons and/or the ASH Web site. Students should specifically cite the symptoms and changes in the blood smear that led to their diagnosis.

Extension Activities:

- Students can present their findings to the class in the form of a PowerPoint presentation. Have them include background information on the blood disorder they diagnosed, specific observations that led them to that diagnosis, and their recommendations for treatment.
- Assign students to research a well-known hematologist and create a scrapbook based on that person's life. Students should include biographical information, career information, and a one-page reflection on the hematologist's life.

Materials:

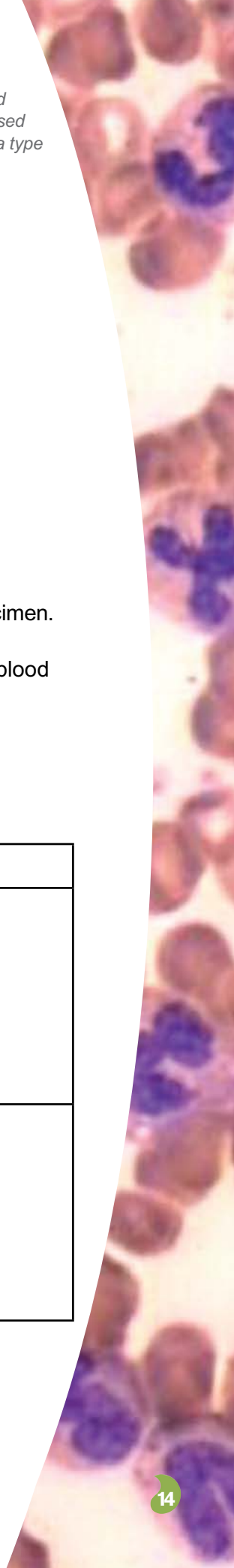
- ***Blood Detectives*** *Student Worksheets 4A and 4B*
- *pen*
- *paper*
- *prepared slides of blood smears from individuals with blood disorders (or high-quality color photos)*
- *compound light microscope (one for every one to two students)*

Time Required:

two to three class periods (approximately 45 minutes each), depending on how many disorders are observed/assigned

Worksheet 4A

Blood Detectives



A chronic myelogenous leukemia patient's blood smear shows an increased number of neutrophils, a type of white blood cell.

Name: _____

Class/Period: _____

Materials:

- Compound light microscope
- Prepared slides of blood smears from patients with blood disorders

Procedure:

1. Place the prepared slide on the stage of the compound light microscope.
2. Turn the light on, or adjust the mirror so that light is reflected up toward the specimen.
3. Turn the nosepiece so that the 10X objective lens is in place over the slide.
4. Adjust the focus by turning the coarse adjustment knob until the image of the blood smear is clear.
5. Sketch your observations under low power in the space below.
6. Turn the nosepiece so that the 40X objective lens is in place over the slide.
7. Sketch your observations under high power in the space below.

Name of Disease	Observations/Sketches

Analysis Questions:

1. For each disease you observed, contrast the corresponding blood smear with sketches of a normal blood smear.
2. How do these changes in the cellular components of the blood result in symptoms of the disease?

A chronic myelogenous leukemia patient's blood smear shows an increased number of neutrophils, a type of white blood cell.

Worksheet 4B

Blood Detectives

Name: _____

Class/Period: _____

Materials:

- Compound light microscope
- Prepared slides of blood smears from patients with blood disorders

Instructions:

1. Work in teams of two to four students.
2. Obtain the blood smear, history, and physical symptoms of your assigned patient.
3. Observe the blood smear with the 10X and 40X objective lenses, and note/sketch observations in the space below.
4. Using **www.hematology.org/Training/Students/5591.aspx#PowerPoint** as a reference, diagnose the disease of the patient your group was assigned. Be prepared to justify your determination based on your observations and notes from reference materials.

Summary/Description of Symptoms:

Observations/Sketches of Blood Smear:

Analysis Questions:

1. Contrast the blood smear you observed today with a normal blood smear. What differences did you observe?
2. Which symptoms gave a clue to the patient's possible diagnosis? How did you narrow down the possibilities?
3. What treatments would you recommend for your patient?

Lesson 5

Advances in Hematology

Zebrafish is a popular laboratory animal choice for genetic studies, developmental biology, and disease modeling.

Objectives:

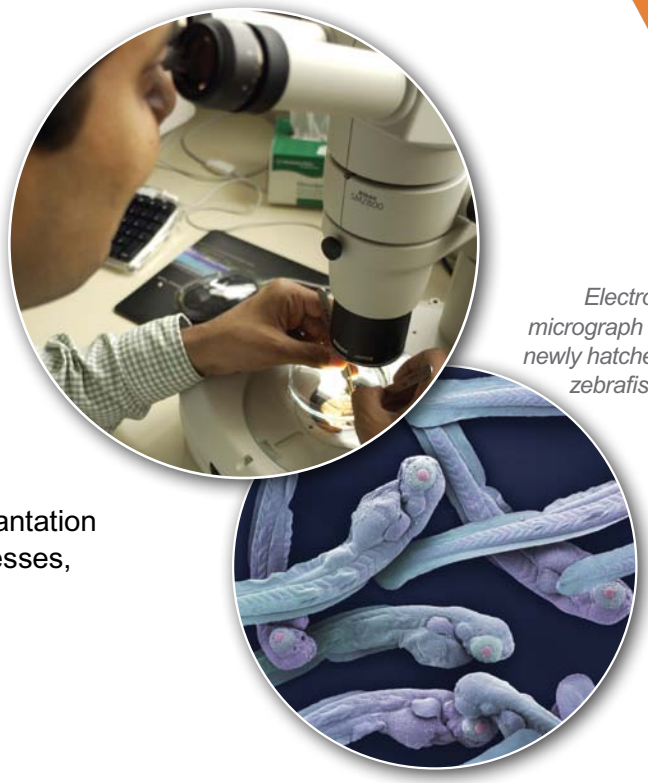
- Understand how the use of model organisms has contributed to research in biology
- Describe the ideal attributes of a model organism
- Describe similarities in structure and function between humans and some common model organisms, such as the zebrafish
- Be introduced to the concept of evolutionary developmental biology

Directions:

1. Have students watch the video segment from the *Blood Detectives* DVD where zebrafish research is described.
2. Instruct students to conduct research on model organisms in biology (two references are listed below) and answer all questions on the student worksheet.

Extension Activities:

- Research the history of hematopoietic stem cell transplantation (HCT). Have students describe the procedure, its successes, and obstacles to its use.
- Allow students to observe, analyze, and record data on the embryonic development of zebrafish.



Electron micrograph of newly hatched zebrafish.

For information on model organisms:
www.bio.miami.edu/~cmallery/150/special/model_organisms.htm

www.bio.miami.edu/~cmallery/150/special/scientist.models.pdf

For information on HCT (extension activity):
www.hematology.org/Publications/50-Years-in-Hematology/4735.aspx

For information on zebrafish development (extension activity):
www.the-aps.org/education/k12curric/activities/pdfs/krenz.pdf

Materials:

- ***Advances in Hematology*** *Student Worksheet 5*
- *pen*
- *paper*
- ***Blood Detectives*** *DVD*

Time Required:

one to two class periods (approximately 45 minutes each)

Zebrafish is a popular laboratory animal choice for genetic studies, developmental biology, and disease modeling.

Worksheet 5

Advances in Hematology

Name: _____

Class/Period: _____

Instructions:

1. Conduct research on the use of model organisms in biology. Use the suggested references below, your course textbook, and any additional resources you find.
2. Answer the questions below based on your research.

Analysis Questions:

1. What is a model organism?
2. What characteristics are most useful in a model organism?
3. For what processes do scientists specifically use zebrafish as models?
4. What processes are similar between humans and zebrafish?
5. What model organisms are used most commonly for studies of human immunity? Why?
6. How is it possible for organisms as diverse as yeast, zebrafish, worms, and mice to be used as models of human functions and diseases? Explain.

Suggested References:

www.bio.miami.edu/~cmallery/150/special/model_organisms.htm
www.bio.miami.edu/~cmallery/150/special/scientist.models.pdf

Do I Have What It Takes to Be a Hematologist?

The appearance of normal circulating blood offers little variation in cell size and shape.

Objectives:

- Become familiar with the field of hematology
- Understand the educational and training requirements to become a hematologist
- Become aware of available resources

Directions:

1. Have students watch a *Blood Detectives* DVD segment profiling the hematologists at NewYork-Presbyterian hospital.
2. Instruct students to answer questions on Student Worksheet 6. Students should conduct research as necessary using **www.hematology.org/Training/Students/5593.aspx**. Read interview responses at **www.hematology.org/Training/Students/5595.aspx** and watch the video *Why Choose Hematology?* at **www.hematology.org/Publications/Videos/3908.aspx**.

Extension Activity:

- Instruct students on how to conduct a journal club presentation, using **www.hematology.org/Publications/Hematologist/2006/945.aspx** as a guideline. Assign each student (or each group of two to three students if it is a larger class) to read and interpret one article from **www.hematology.org/Patients/Other-Resources/Education-Book/5244.aspx**. Each student or group should prepare a journal club presentation using PowerPoint and present their findings to the class.

Materials:

- ***Do I Have What It Takes to Be a Hematologist?*** *Student Worksheet 6*
- *pen*
- *paper*
- ***Blood Detectives*** *DVD*

Time Required:

two class periods (approximately 45 minutes each)

The appearance of normal circulating blood offers little variation in cell size and shape.

Worksheet 6

Do I Have What It Takes to Be a Hematologist?

Name: _____

Class/Period: _____

Instructions:

1. Conduct research using **www.hematology.org/Training/Students/5593.aspx**. Read the interviews with Dr. Ginna G. Laport (below) and with Dr. George Buchanan online at **http://www.hematology.org/Training/Students/5611.aspx**. Watch the video *Why Choose Hematology*? at **www.hematology.org/Publications/Videos/3908.aspx**.
2. Answer the analysis questions below using information from your research.

Ginna G. Laport, M.D.
Associate Professor of Medicine
Division of Blood and Marrow Transplantation
Stanford University Medical Center (Stanford, CA)

Q **How did you become interested in the field of hematology? Clinical research, in particular?**

A Hematology is a dynamic field with exciting breakthroughs in diagnosis and treatment occurring on a regular basis. Clinical research interested me because I wanted a career that finds better ways to diagnose and treat blood diseases and, at the same time, be able to maintain direct patient contact.

Q **Why do you think it's important for people to get involved in this field?**

A The study of blood and blood diseases is absolutely fascinating as blood is an organ that literally touches, affects, and connects every organ in the body. Hematology is a specialty that requires a large amount of intellectual investigative work. There are vast numbers of malignant [cancers] and non-malignant diseases related to hematology that I always feel intellectually challenged in a positive way.

Photo courtesy of Ginna G. Laport, M.D.

Q **In your experience, what is the most difficult or challenging aspect of becoming a hematologist in the United States?**

A In today's medical reimbursement environment, it is difficult to solely practice hematology. Thus, many private practice hematologists must also incorporate primary care into their practice. Unfortunately, it seems possible to only practice pure hematology if one works at a large academic center.

Q **How do you feel advances in technology (recent or past) have helped you along the way, be it in your studies or in general practice?**

A Hematology has seen revolutionary changes in the way we treat hematologic malignancies in the last 10 years. The advent of drugs such as imatinib for chronic myelogenous leukemia and lenalidomide for multiple myeloma has revolutionized the way we treat these blood cancers. Both drugs are pills that help patients avoid other toxic treatments, which were the only available options until recently. Advances such as these stimulate and remind me why I chose the dynamic field of hematology.

Q **What do you find to be most rewarding about a career in hematology research?**

A I am on the forefront of the medical field, and I hope that I am making a difference. I primarily work in the field of blood and bone marrow transplantation. This is a treatment that offers a cure to patients with cancers, such as leukemia, that weren't curable 20-30 years ago.

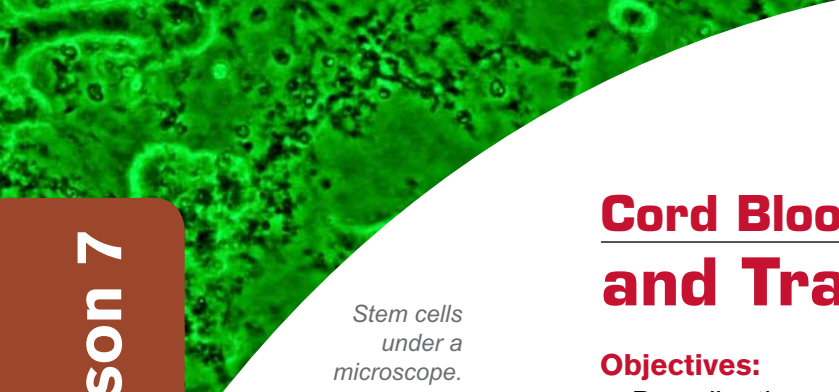
Q **Finally, what advice might you have for a younger person who will be pursuing a career in this field?**

A Try to decide as early as possible if you choose to pursue a hematology career in private practice, academia, or industry. Knowing early will help you best tailor your training to be highly competitive and well trained when seeking your first job. However, at the same time, be open to all possibilities and don't overly restrict yourself so that you will always have options should your career path unexpectedly change. Fortunately, hematology is such a diverse, all-encompassing specialty that hematologists will always have options, whether in a big city or small town.

Analysis Questions:

1. What are the educational and training requirements in order to become a hematologist?
2. Why did the hematologists featured in the video clip and interviews choose to enter this field?
3. Are you interested in becoming a hematologist? Why or why not?

Lesson 7



Stem cells under a microscope.

Cord Blood Banking and Transplantation

Objectives:

- Describe the possible lineages of stem cells
- Define "hematopoietic stem cell"
- Describe possible uses of cord blood stem cells in disease treatment and prevention
- Distinguish between embryonic and cord blood stem cells
- Describe the issues that have arisen relating to public versus private banking of cord blood
- Formulate and express an opinion on the banking and use of cord blood

Directions, Lesson 7A:

1. Ask the class the following motivating question (do now): *What comes to mind when you hear the words "stem cells"?* Then ask students to list at least three topics or phrases.
2. Have students discuss their answers with a partner (pair share), then as a whole class.
3. Explain to students that hematopoietic stem cells can be found in umbilical cord blood, or "cord blood" for short. Instruct them on the importance of stem cells, the different types of stem cells, where they can be found, and the lineages of stem cells.
4. Ask students to research possible uses of cord blood stem cells and share their answers with a partner (pair share). Follow this activity with a whole class discussion.

Materials:

- ***Cord Blood Banking and Transplantation*** *Student Worksheet 7*
- *pen*
- *computers with Internet access and library databases*

Time Required:

two to three class periods (depending on the length of class discussions, approximately 45 minutes per lesson)

Directions, Lesson 7B:

1. Have students work in groups to complete ***Cord Blood Banking and Transplantation*** *Student Worksheet 7*.
2. Groups will conduct research using articles and Web pages (see References on page 21) about cord blood banking and possible uses of cord blood. Alternatively, students can conduct the background research as homework and come to class prepared to begin the discussion. *Note: Students should already be familiar with the different types of stem cells*.
3. Students should use the following guiding questions for their background research:
   - Why does cord blood contain hematopoietic stem cells?
   - What are some diseases that cord blood stem cells could possibly be used to treat?
   - What research is currently under way with regard to the use of cord blood stem cells? What have been some successes and failures?

Stem cells under a microscope.

- What is the value of donating a baby's cord blood to a public blood bank versus storing it at a private bank for one's own use?

4. After completing its research, each group should present its findings on one or more of the topics addressed in the guiding questions. Ask students to express their own opinions on the banking and use of cord blood.

Extension Activities:

- Conduct an in-class debate or trial in which each group of students represents a person or group involved with cord blood banking, research, or treatment.
- Groups could represent physicians who research and/or treat life-threatening diseases, stem cell researchers, parents of newborns, or presidents of public or private cord blood banks.
- Have the students debate the pros and cons of public versus private cord blood banks and potential issues regarding research using cord blood stem cells.

Homework:

- Have students write a one-page description of their opinions on the banking and use of cord blood. Students should be required to be specific in their description and to use supporting facts from their research with in-text citations.

References:

- "Whose Blood Is It Anyway?" *Scientific American*, April 2001, pages 42–49.
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- **www.hematology.org/Publications/Hematologist/2010/5151.aspx**
- **www.hematology.org/Publications/Legends/3803.aspx**
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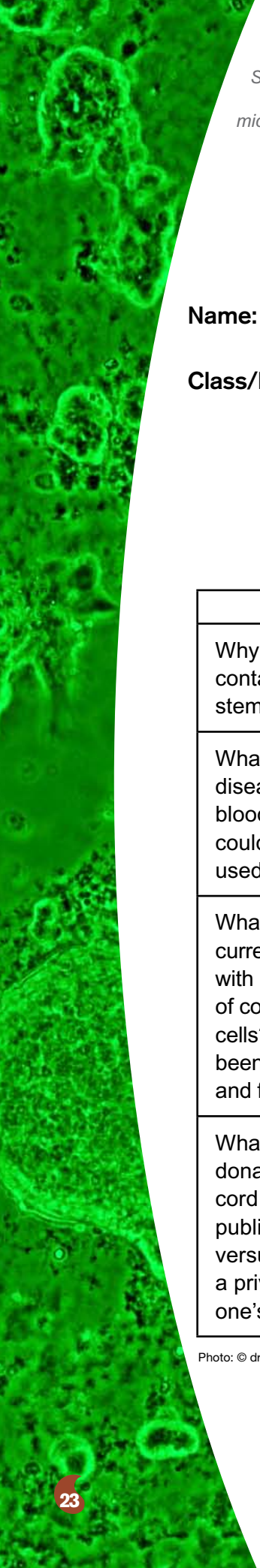
- **http://latimesblogs.latimes.com/booster_shots/2009/09/banking-umbilical-cord-blood-costs-1374246-per-life-year-gained.html**



Stem cells under a microscope.

Worksheet 7

Cord Blood Banking and Transplantation

Name: _____

Class/Period: _____

Instructions:

Fill in the following chart while completing the background research. Be sure to record a full MLA citation for each source used. See **www.easybib.com** for a description of MLA format citations.

Questions	Answers/Notes	Sources
Why does cord blood contain hematopoietic stem cells?		
What are some diseases that cord blood stem cells could possibly be used to treat?		
What research is currently under way with regard to the use of cord blood stem cells? What have been some successes and failures?		
What is the value of donating a baby's cord blood to a public blood bank versus storing it at a private bank for one's own use?		

A chronic myeloid leukemia patient's blood smear.

Worksheet 8

The Case of the Tired Grandma

Name: _____

Class/Period: _____

Instructions:

Read the passage and answer the questions that follow based on the content of the readings. Conduct additional background research as needed.

PART 1:
A Hectic Day

"OK, let's get started on your homework while I make dinner. John Jr., can you help Mary with those math problems she has due tomorrow?"

"Sure. What's for dinner, Grandma?"

"I'm making some chicken and vegetables. I already prepared it earlier so it won't take long," replied Susan.

John Jr. and Mary sat down on the living room floor, still wearing their jerseys, shorts, and high socks. It had been two years since their mother passed away from breast cancer, and they were still trying to adjust. Their father works at the local airport and has been on the night shift for the past five months. He was hoping to be back on days by next month so he didn't have to rely on his mother to help out with the kids so much. It really seemed to be taking a toll on her. She was exhausted all the time now.

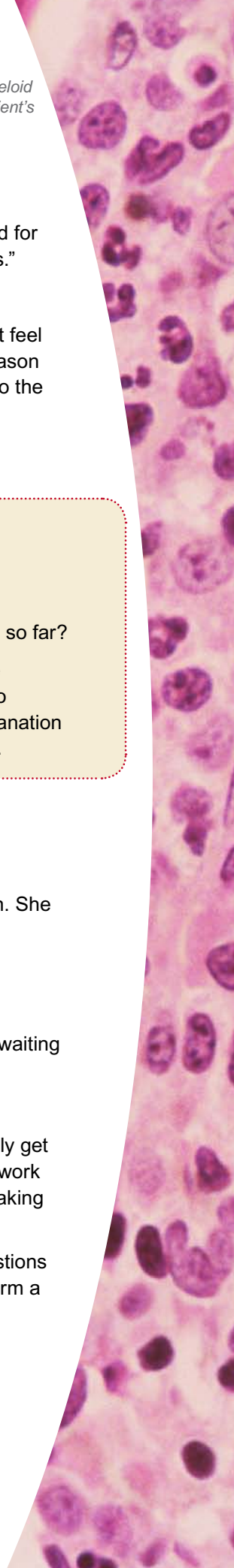
Susan sat down at the kitchen table after placing the chicken and vegetables in the oven to roast. She felt out of breath, even after just walking in from the car, helping the kids carry their school bags, and putting dinner in the oven. She used to walk three miles a day, but her job and personal life had become so hectic lately that she didn't have the time or energy to exercise anymore. She had just turned 67, and felt that her age was finally catching up with her.

After checking the children's homework and tucking them in, Susan washed the dishes, cleaned up the kitchen, and waited for her son to return from work. He walked in at about 11:30 p.m. and found her asleep on the couch. He nudged her awake.

"How'd it go today?" John asked.

"Fine. Mary hates fractions a little less than she did yesterday. John Jr. is still pretending to like my cooking, which is nice of him. They both had fun at their soccer practices."

"Thanks for helping out so much. Hopefully I'll be back on days soon so you won't have this



A chronic myeloid leukemia patient's blood smear.

ridiculous schedule. How are you feeling? Do you still have that cold?" he asked.

"I just feel run down. But I'm not feverish anymore and I'm not sneezing or coughing. And for the last couple of weeks or so I've been waking up during the night with aches and pains."

"That doesn't sound good, Ma. Maybe you should see the doctor," John suggested.

"I have an appointment with Dr. Owen next week, but I'm not sure what to tell him. I don't feel well but I don't really feel sick, either. I've been working longer hours because it's tax season and you've been on nights. He's probably going to tell me to get more rest. But I can't. So the visit seems pointless." Susan rubbed her eyes and yawned.

"Still, it's better to get checked out. I'll take the day off and go to the doctor with you."

PART 1: Questions

Answer the following questions on a separate sheet of paper.

1. Describe the main characters in this case study. What do you know about this family so far?
2. Describe Susan's symptoms. Conduct background research and give some possible explanations (at least three) for what could be causing Susan's symptoms. Be sure to include a description of the ailments you think Susan may be suffering from, an explanation of your reason for choosing those particular ailments, and a list of sources you used.

PART 2: A Visit to the Doctor

Susan sat nervously in Dr. Owen's office. "I hate going to the doctor," she said to her son. She fidgeted in her chair. "And I feel so silly coming in when I'm not even that sick."

"It can't hurt to have him examine you, Mom. Just relax," replied John.

"Susan Forest?" the nurse asked.

Susan followed the nurse into the small exam room and sat on the crunchy white paper waiting for Dr. Owen. He walked in and shook her hand.

"What brings you here today, Mrs. Forest?"

"I haven't been feeling well lately. I had a cold for a while that never seemed to completely get better, and I've been feeling tired and achy for a while. I've also been extremely busy at work and watching my grandchildren, so I think it's just lack of sleep. But recently I've been waking up at night with pain."

"OK, Mrs. Forest. I'm going to do a history and physical right now. I'll ask you some questions about your symptoms, your general medical history, and your lifestyle, and then I'll perform a physical exam to try to determine what is causing your symptoms. How old are you, Mrs. Forest?"

"Sixty-seven," she replied.

"And how long ago did you begin having symptoms?"

A chronic myeloid leukemia patient's blood smear.

"About three months ago, in February, I caught a cold that I couldn't seem to get rid of."

"Are you still producing mucus when you cough or sneeze? Are you blowing your nose a lot?"

"Not anymore."

"Did you take any over-the-counter medications?"

"Yes, for about two weeks I took an over-the-counter decongestant and pain reliever."

"So at that point you weren't really having the cold symptoms anymore?"

"Right."

"What about fevers? Did you take your temperature?"

"No, but I felt feverish once in a while even after the cold symptoms stopped. I don't think it was a very high fever, though."

"And you said you are feeling tired a lot. How much sleep do you usually get each night?"

"About five or six hours every night, which I don't feel is enough."

"Why do you think you aren't getting enough sleep?"

"Well, I work in an accountant's office, so tax season is our busiest time. In early March I started working about 60 hours per week. Also, my son started working the night shift a little after that, and that's when I began picking up my grandchildren after their sports practices and watching them until their father gets home."

"Any shortness of breath after activities?"

"As a matter of fact, yes. I've been exercising a lot less than usual because I become out of breath. Even after just cleaning..."

"Have you been around anyone who was sick with the flu or any other contagious illness?"

"I don't think so. No one at work or in my family has been sick."

"Have you had any nausea or diarrhea or stomach upset in general?"

"No."

"Have you been urinating more frequently or had blood or pain with urination?"

"No."

"You said you've been having pain at night? Is this only at night, or do you feel pain upon waking up in the morning?"

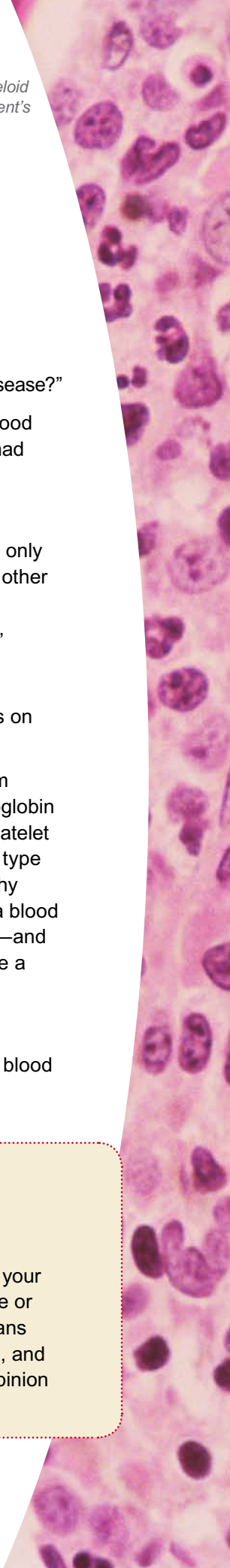
"Only during the night."

"Does the pain wake you from sleep?"

"Yes, sometimes."

"Is the pain localized in one specific place?"

"No, it's just general achiness, almost like my bones hurt. Sometimes it's in my upper legs,



A chronic myeloid leukemia patient's blood smear.

sometimes my back hurts. But I can't pinpoint it to one location."

"Do you find that the pain increases with more activity?"

"No, not really."

"Have you lost any weight?"

"No."

"Do you or any close family members have high blood pressure, diabetes, cancer, or heart disease?"

Susan shook her head. "No. My daughter-in-law died of breast cancer, but none of my blood relatives have had it. My grandmother had diabetes, but no one else who I know of has had anything else you mentioned."

"Do you smoke or drink alcohol? Are you taking any drugs or prescription medications?"

"No, I don't smoke or drink. I have a prescription medication for migraine headaches, but only take it when I get a migraine, which is usually about once a month or so. I don't take any other medicines, and I don't use any illegal drugs for heaven's sake."

"OK. I have to ask these questions just so I can get a clear picture of your overall health."

Upon physical examination, Dr. Owen noticed that Susan's spleen, located under the ribs on the left side of the abdomen, was swollen.

"I think that we should run some tests, so I'm going to take a blood sample from you. I am requesting a CBC (complete blood count) with differential. This will determine your hemoglobin and hematocrit levels, which are proteins present in the blood. It will also give me your platelet count, red blood cell count, and white blood cell count (including the percentage of each type of white blood count). All of these cells are present at specific levels in the blood of healthy individuals but can increase or be reduced when someone is sick. I am also requesting a blood smear—meaning the lab technicians will look at your blood sample under a microscope—and a chest X-ray. I should have the results in a few days. My office will call you to schedule a follow-up appointment as soon as we have the results."

"Thank you, Dr. Owen. Do you think this is something serious?"

"I can't really say until I have more information. Let's wait and see what the results of the blood work tell us."

PART 2:
Questions (CONDUCT ADDITIONAL RESEARCH IF NECESSARY)

Answer the following questions on a separate sheet of paper.

1. Look back at your original list of possible causes of Susan's symptoms. Discuss with your group members whether the ailments you originally thought Susan had were accurate or inaccurate, based on the information in the history and physical. This is what physicians refer to as a differential diagnosis. Discuss the possibilities with your group members, and narrow down the possible diagnoses based on the information you have. Has your opinion changed now that you have more information? Why or why not?

A chronic myeloid leukemia patient's blood smear.

2. What are the functions of each type of blood cell? Why do you think Dr. Owen requested a CBC?
3. What results to you expect to see in the CBC if Susan has an infection?
4. Why do you think Dr. Owen requested a blood smear? A chest X-ray?

PART 3:
Results and Additional Testing

Note: Additional materials are required for this part of the case study: normal, chronic myeloid leukemia (CML), and multiple myeloma blood smears; normal and CML karyotypes showing the Philadelphia chromosome.

The following week, Susan waited in the exam room for Dr. Owen to come in with her test results.

"Hello, Mrs. Forest. I've been looking over your test results. The blood count did come back abnormal. Your white blood cell count was elevated. This is something that can occur when someone has an infection, since these cells are involved in fighting disease. In addition, your red blood cell count was below normal. That would probably explain the shortness of breath you've been experiencing, since those cells are responsible for carrying oxygen around the body. However, it is your blood smear that concerns me. In addition to an elevated white blood cell count, many of your white blood cells are in the early stages of development—an immature state, if you will. This is something that occurs in cancers of the blood."

"Oh my God! Are you saying you think I have cancer?" Susan gasped.

"Given your age and your symptoms, I believe that you have one of two types of blood cancer—either multiple myeloma or chronic myeloid leukemia. Both of these are very treatable if detected early. I'll need to perform some additional testing to determine your final diagnosis and treatment plan. In order to do this, I have to collect another blood sample and perform a bone marrow biopsy. This additional testing will also help to rule out an infection or other causes for the abnormal CBC."

"So it might not be cancer?"

"We still can't be sure, but you have to prepare yourself for that news. I can give you some general information about these diseases, and we'll also set up an appointment for you to have the bone marrow biopsy done at the hospital."

"What is a bone marrow biopsy?"

"This is a test that is used to obtain a sample of bone marrow, the soft tissue in the center of the bones. We use a needle to remove a small sample of those cells. You'll receive an injection to the area to numb you."

"Will the removal of the cells hurt?"

"The initial injection of the numbing agent causes a sharp sting. Once the larger needle is inserted, the center of it is removed and a core of bone marrow is collected. Some patients report feeling a dull pain during the collection, since the numbing agent is not injected into the bone. However, not all patients report pain during the procedure."

"Why do you need bone marrow if I am giving another blood sample anyway?"

A chronic myeloid leukemia patient's blood smear.

"Well, in chronic myeloid leukemia a very specific mutation is present in the DNA of the bone marrow cells. This mutation, or change in the DNA, is usually detectable in the blood also."

"What is this mutation?"

"It is generally referred to as the Philadelphia chromosome. The DNA in your cells is organized into smaller 'pieces' called chromosomes. Humans have 23 pairs of chromosomes. In CML, chromosome 9 and chromosome 22 exchange pieces, resulting in an abnormal gene. This gene produces the protein BCR-ABL tyrosine kinase."

"What the heck is that?"

"Tyrosine kinases are involved in regulating the cell cycle and often cause cells to proliferate, or make more cells. The normal form of the protein has no harmful effects, but this abnormal form caused by the chromosomal translocation results in higher rates of cell proliferation, which leads to cancer. I am going to perform two tests on the bone marrow. One, called karyotyping, involves examining the chromosomes present in the bone marrow cells to determine whether the Philadelphia chromosome is present. Another test, called Real-time Quantitative PCR (RQ-PCR), determines whether this abnormal form of the gene is producing the BCR-ABL tyrosine kinase. This will help us in deciding what course of treatment to take if you do, in fact, have CML."

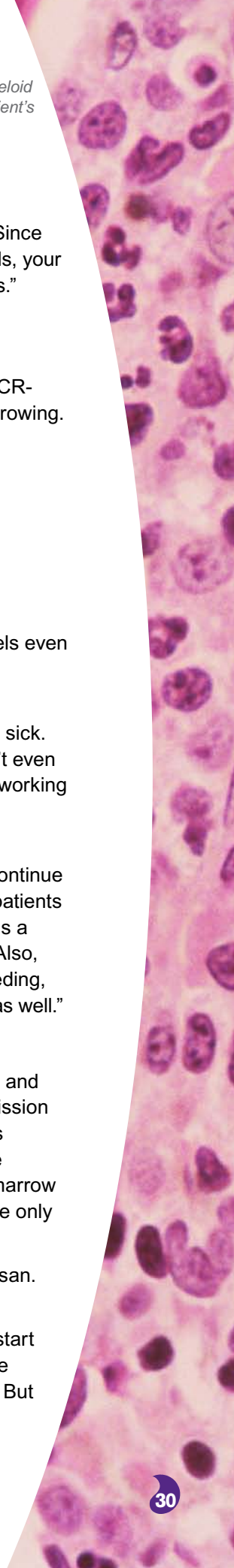
PART 3:
Questions (CONDUCT ADDITIONAL RESEARCH IF NECESSARY)

Answer the following questions on a separate sheet of paper.

1. Conduct background research on multiple myeloma and chronic myeloid leukemia (CML). What are the signs and symptoms of each? What changes occur in the blood composition of individuals with these diseases?
2. Examine the blood smears from the normal individual, the individual with CML, and the individual with multiple myeloma. Then examine Susan's blood smear. What conclusions can you draw about Susan's diagnosis?
3. Describe the Philadelphia chromosome. How does this mutation come about? Does CML run in families?
4. Describe PCR. What is this procedure used for? How is RQ-PCR used in the diagnosis of CML?
5. What do you think is the emotional impact of this news for Susan? What adjustments will Susan have to make to her lifestyle if she is diagnosed with cancer?

PART 4:
Final Diagnosis and Treatment Options

"Well, Mrs. Forest, I've examined all of your test results and concluded that you are suffering from chronic myeloid leukemia. I'm sorry to have to bring you this news. However, I will reassure you that this particular type of cancer is very treatable due to recent advances in leukemia research," Dr. Owen reported.



A chronic myeloid leukemia patient's blood smear.

"Do I have to go for radiation treatment?"

"That is generally not the recommended first course of treatment for this type of cancer. Since we know that the abnormal BCR-ABL tyrosine kinase is present in your bone marrow cells, your treatment will focus on disabling this protein in order to stop the growth of the cancer cells."

"I don't understand how the treatment can just target one thing."

"Well, the standard treatment for CML involves taking a drug called imatinib. This is a substance that inhibits that mutant protein we spoke about last time, BCR-ABL. Since BCR-ABL causes increased cell growth, when imatinib binds to and inhibits it, the cells stop growing. This markedly reduces the cancer growth and leads to remission in the vast majority of patients. Obviously nothing is guaranteed, but your prognosis is quite good."

"How long do I have to take the drug? Are there side effects?"

"You will likely need to remain on the drug even after you are in remission. It seems that interruption of treatment usually results in a relapse."

"I have to take this drug for the rest of my life?"

"It's possible, and we'll have to continue to monitor your blood counts and BCR-ABL levels even while you are being treated, to make sure the drug is working."

"What about side effects?" Susan was particularly concerned about this, since she had witnessed the side effects of chemotherapy and radiation when her daughter-in-law was sick. "My daughter-in-law lost her hair and had terrible nausea, to the point where she couldn't even take care of the kids. It was awful," Susan continued, "and I need to be able to continue working and helping my son..."

"Well, the side effects of imatinib are not as severe as what you see with traditional chemotherapy and radiation. In fact, most patients find the side effects mild enough to continue using imatinib. The benefit of reducing CML cells outweighs the risks. Most commonly, patients report edema, or fluid retention. This is particularly common in patients over 65, so that is a concern for you. We have to continue regular blood counts to monitor you for anemias. Also, it is common for patients to experience some nausea, joint pain, or muscle cramps. Bleeding, hypothyroidism, and hepatotoxicity (damage to the liver) are less common but can occur as well."

"So this type of cancer—it seems like it never really goes away?"

"CML is what is referred to as a chronic form of leukemia. It is not an aggressive cancer, and most people respond very well to treatment, as I said. But even when a patient is in remission we have to keep monitoring you and treating you because small numbers of cancer cells can still be present in the cells of the bone marrow. The only real cure for CML is a bone marrow transplant, but if you respond well to imatinib we won't have to do that. A bone marrow transplant is much more invasive than taking a pill, and it is difficult to find a donor. So we only do that if the patient does not respond to drug treatment."

"If I don't respond to the imatinib, I'll have to get a bone marrow transplant?" inquired Susan.

"No, not necessarily. There are other drugs besides imatinib that act as tyrosine kinase inhibitors. They are not as effective as imatinib and may have more side effects. So we start first with imatinib, then move on to other tyrosine kinase inhibitors if necessary. The bone marrow transplant is a last resort for patients who don't respond to any drug treatments. But let's not get ahead of ourselves—we should see if the imatinib works for you first."

A chronic myeloid leukemia patient's blood smear.

"What about my job? And my grandchildren?"

"You'll have to make some adjustments to your lifestyle, particularly during your treatment. Until you return to feeling well, you'll need to reduce your activity levels for a while. Though I encourage you to stay physically active if you are feeling up to it, since that is generally beneficial."

"Should my son or my grandchildren be tested to see if they are at risk for CML? Does this mean cancer runs in our family now?"

"CML is caused by a random mutation in the bone marrow later in life and is considered sporadic. It's not like other forms of cancer that run in families, so you don't have to worry about that."

"OK. I don't think I have any more questions right now. So what do I do next? I feel like I should get a second opinion for something this serious."

"I'll send you to a CML specialist to get a second opinion. After you see him, we'll meet again to discuss the start of your treatment."

"Thank you, Dr. Owen."

"And they also have some information at the front desk on support groups for patients with CML. Sometimes it can be helpful to speak with others who are going through the same thing."

PART 4: Questions

Answer the following questions on a separate sheet of paper.

1. How do you think Susan's diagnosis will affect her lifestyle? What changes will she have to make?
2. Conduct some research on other tyrosine kinase inhibitors used to treat CML. How effective are these treatments compared to imatinib?
3. What are the advantages and disadvantages of having a bone marrow transplant to treat CML?
4. What type of testing will Susan have to undergo in order to monitor her treatment? Conduct additional background research if necessary.
5. If you were Susan, what concerns and questions would you have at this point?
6. CML has been referred to as the "poster child" for translational medicine, i.e., the use of molecular biology research results to determine treatment for a disease. Do you agree with this statement? Explain why or why not.

Lesson 9

A blood clot.

Silvia's New Knees

Objectives:

- Conduct background research on deep vein thrombosis (DVT), osteoarthritis, and joint replacement surgery
- Become familiarized with risk factors for DVT
- Understand the inherent risks of major surgery, such as DVT, pulmonary embolism (PE), and infection
- Describe the procedures used to diagnose, monitor, and treat DVT
- Discuss the issues to be considered by the patient and physician regarding joint replacement surgery

Directions:

This case study is meant to familiarize students with the risk factors, symptoms, diagnosis, and treatment of deep vein thrombosis (DVT). It is geared toward students taking a high school biology course, and it is recommended that students have a general familiarity with the circulatory system, specifically blood flow and the major types of blood vessels and their functions. The case study reinforces the concepts of blood flow in arteries and veins, and the health risks of blood clots. These lessons use a case-based approach (mostly via dialogue) to deepen students' understanding of these concepts in the context of a real-life scenario. Students are given the patient's description of her symptoms and are asked to conduct additional background research as necessary to determine a possible diagnosis.

Materials:

- ***Silvia's New Knees Worksheet 9***
- ***Internet access and library databases***

There are four parts to this case study, which should be distributed one part at a time. Each part of the case study should take approximately one 50-minute class period, though students may have to finish some questions as homework, depending on the library resources available during class. It is recommended that part 4 be spread over two days, to allow students enough time to conduct background research, answer all questions, and discuss the coagulation cascade. This case study can also be extended to allow students to discuss risks and benefits of having joint replacement surgery. Points of discussion may include putting oneself in the patient's position and trying to decide whether to have the surgery versus alternative treatments, such as taking anti-inflammatory medication or receiving cortisone injections. With a wrap-up day at the end of the case, the entire lesson should take four 50-minute class periods.

Extension activities for more advanced students, in an AP Biology class for example, may also include conducting more detailed research on the mechanism of the drug treatments (heparin and warfarin) for DVT. Discussion of the coagulation cascade in part 4 of the case study also provides an opportunity to review enzyme activity. As a closing activity, students can also work in groups to design an informational pamphlet for patients at risk for DVT.

A blood clot.

Worksheet 9

Silvia's New Knees

Name: _____

Class/Period: _____

Instructions:

Read the passage and then answer the questions that follow, based on what you've learned from the reading. Conduct additional background research as needed.

PART 1:
Post-Op Day 3

"Wow, this hurts!" said Silvia, as she stepped out of her hospital bed. It was the first time she was standing up with her full weight on her new knees without the physical therapist's assistance. At 60 years old, after some wrangling with her health insurance company, she had finally been able to go through with the double knee replacement she had needed for years. Silvia had suffered with osteoarthritis for as long as she could remember, and Dr. Avery had informed her that both of her knees were almost devoid of cartilage at the joint—"bone on bone" was the term he had used—which was causing her excruciating pain. Her doctor had insisted that she lose at least 30 pounds prior to the surgery (she lost 35), so she would be in the best shape possible when facing the intense physical therapy required for her postoperative recovery.

"I'll assist you as necessary, but I want you to try using the walker on your own. Julius and I will be right beside you and he's bringing the wheelchair in case you need it," said Sam, the physical therapist at the hospital.

Silvia made it down the hospital hallway, about 50 feet, before needing a rest. The therapists seemed pleased.

"That was excellent," said Julius, "I'm sure Dr. Avery will want you to transfer to the rehabilitation center right away."

Silvia let out a sigh of relief. The sooner she went to the rehab center, the sooner she could go home. At this point, she would definitely miss Christmas dinner with the family, but she was hoping to make it back home for New Year's Eve. She was mostly looking forward to an end to her postoperative pain. The doctor had prescribed morphine after her surgery, but it made her nauseous so she tried to avoid taking it all the time.

A blood clot.

Just as Silvia was being wheeled back to her room, Dr. Avery came in to check on her. “How did it go with the walker today?” he asked.

Julius and Sam both showed their approval. “Excellent. She made it down the hallway with it on her own.”

After asking Silvia how she was feeling, and discussing alternative pain medications, Dr. Avery informed her that she was being transferred to the rehab center today to continue with her postoperative physical therapy.

PART 1:
Questions (Conduct additional research if necessary.)

Answer the following questions on a separate sheet of paper.

1. What is osteoarthritis?
2. What is joint replacement surgery? What are some risks associated with having this type of surgery?
3. Are there things that can be done to minimize these risks?
4. Why did the patient need a double knee replacement?

PART 2:
Post-Op Day 8

Silvia had been in the rehab center for about five days, and she was feeling exhausted. The physical therapy was intense by itself, and even while she was sleeping her legs were in compression stockings put on by the nurses. The sequential compression device squeezed and released her legs during the night, which the nurses informed her was to keep the blood flowing properly even when she was not moving her leg muscles. Silvia found it hard to sleep with them on, and today she was feeling more tired than usual. She also noticed that her calf hurt and was swollen and red. She wondered why that was happening. *I’m falling apart*, she thought.

The nurse walked in to take Silvia’s vital signs, and asked how she was feeling. “Not great today, actually. My calf is hurting a lot and looks swollen and red.”

“Let’s see what your temperature is,” replied the nurse.

The digital thermometer beeped and the nurse said, “Normal. Are you having any difficulty breathing?” Silvia shook her head, and the nurse said she would call the doctor regardless. About 10 minutes later, Silvia was told that she would be transported to the emergency room where Dr. Avery would meet her.

A blood clot.

PART 2:
Questions (Conduct additional research if necessary.)

Answer the following questions on a separate sheet of paper.

1. What symptoms did Silvia develop that concerned Dr. Avery?
2. Given the patient's medical history, what condition(s) could be causing these symptoms?
3. Why do you think the nurse asked if Silvia was having difficulty breathing?

PART 3:
Differential Diagnosis

Dr. Avery greeted Silvia and began his examination.

"Let me know if this hurts at all," said Dr. Avery. He squeezed her calf, and Silvia winced.

"Yes," she replied. "What's going on? Why am I having pain in my calf now?"

Dr. Avery flexed her foot for her, and she winced again at the intense pain in her calf.

"We'll have to do a Doppler test to confirm this, but I think you may have DVT, or deep vein thrombosis."

"I remember you talking about this before I had the surgery. What is it again?"

"DVT is a blood clot that forms in a deep vein, usually in the legs. It is a risk following any surgery, but especially joint replacements."

"And what is this Doppler test you're talking about? It sounds like a weather prediction."

Dr. Avery smiled. "Not exactly. We are going to perform a test, basically the same as the ultrasound they do to view unborn babies, but we'll be looking at the blood flow in your veins to see if there is a clot."

PART 3:
Questions (Conduct additional research if necessary.)

Answer the following questions on a separate sheet of paper.

1. Has the physical exam changed your differential diagnosis?
2. Are there other tests that Dr. Avery might want to perform besides the Doppler ultrasound? Describe at least one more test that could be conducted.
3. Besides the sequential compression device, is there anything else Silvia could have done to help prevent a clot?

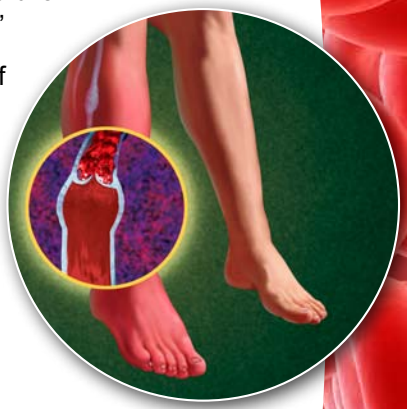
A blood clot.

PART 4:
Diagnosis and Treatment

Dr. Avery returns with the results of Silvia's tests. "Your CBC, or complete blood count, is normal, which reassures me that you don't have an infection, but the ultrasound did confirm a clot in your posterior tibial vein, essentially a big vein behind your knee. Now that we know there is a clot we'll have to get you started on heparin therapy right away."

"What's that?"

"It's a blood thinner. When a patient has acute DVT, we initially give heparin intravenously. Blood thinners prevent blood clot formation, and keep existing clots from getting bigger. While you are on heparin, we will need to monitor your PTT, or partial thromboplastin time, to make sure your dose is keeping your level within therapeutic range. It is a test that essentially measures how long it takes your blood to clot. You'll be on the IV drugs for a few days while we get the warfarin, an oral blood thinner, therapeutic. Warfarin is monitored with a different clotting time called PT/INR, or prothrombin time and international normalized ratio. This is a medication that you can continue to take at the rehab center, and after you are discharged home. You will probably need treatment for about three months."



"Didn't you say that if a clot forms it could break off and travel to other parts of the body?"

"Yes, that's true. That is called an embolism. There isn't any reason to think that's happened in your case. But in some cases, the clot can break off and lodge in the lungs, making it difficult to breathe. This is called a pulmonary embolism, and it can be very serious. As I said, you are not showing any signs of that, and it is quite unusual for a blood clot in the lower leg to embolize at all."

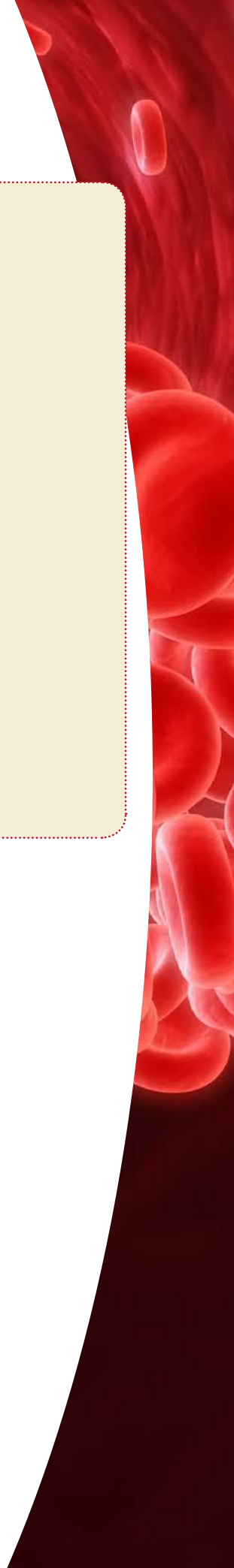
"Why do clots form?"

"Some people are at risk for DVT because they have a blood clotting disorder, which can run in families. Clots can form anytime a blood vessel is damaged in any way, which can happen during surgery. This is especially true during joint replacement surgery because a tourniquet is used to prevent blood loss. Clots are also more likely to form when a patient is lying still for long periods of time, such as during and after any surgery. That's why we do things to prevent DVT in patients having joint replacement surgery, such as using sequential compression devices and giving low molecular weight heparin, another type of blood thinner, prior to the surgery."

"Right, I remember you telling me that you were giving me that. Do you think this is going to delay my recovery at all?"

"I'm afraid you'll have to be in the hospital for a few days, so we can be assured that the symptoms and signs from your clot are resolving and you've reached the proper therapeutic level on the anticoagulant. I want to monitor you more before sending you back to the rehab facility."

So much for New Year's Eve, thought Silvia. She thanked the doctor and sighed as she waited to be readmitted to the hospital for appropriate treatment of her DVT.



A blood clot.

PART 4:
Questions (Conduct additional research if necessary.)

Answer the following questions on a separate sheet of paper.

1. What is deep vein thrombosis (DVT)?
2. What are some risk factors for DVT development? What put Silvia at risk for getting DVT?
3. What blood tests have proven useful to screen patients for the presence of acute DVT?
4. What is a pulmonary embolism (PE)? Why is a PE a potentially life-threatening condition?
5. What drug treatments are used for patients who develop DVT or PE?
6. Describe the coagulation cascade. At what point do heparin and warfarin work?

Use the following sources as a reference to answer question 6:

http://themedicalbiochemistrypage.org/blood-coagulation.php

http://medical-dictionary.thefreedictionary.com/coagulation+cascade

http://theblooddoctor.wordpress.com/2007/11/16/coagulation-cascade-animated/

http://www.med.illinois.edu/hematology/medications.htm

http://almostadoctor.co.uk/content/systems/haematology/clotting/physiology-clotting

Photo: blood clot, © Media Bakery.

Sources (also see above):
Brandon, Mark L., M.D., personal communication
Casaretti, Wanda, personal communication
http://www.nlm.nih.gov/medlineplus/druginfo/meds/a682826.html
http://www.medicinenet.com/deep_vein_thrombosis/article.htm
http://www.mayoclinic.com/health/deep-vein-thrombosis/DS01005
http://orthoinfo.aaos.org/topic.cfm?topic=a00219#top
http://www.nlm.nih.gov/medlineplus/deepveinthrombosis.html
http://www.nhlbi.nih.gov/health/health-topics/topics/dvt/
http://themedicalbiochemistrypage.org/blood-coagulation.php

NEW! Lesson 10

Sickled red blood cells, drawing (above). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

Materials:

- ***Sickle Cell Trait | Case and Research*** *Worksheet 10*
- *Internet access and library databases*
- *Gel electrophoresis equipment for eight groups of four students, including:*
  - *electrophoresis gel box and power supplies*
  - *one gel tray with six-tooth comb*
  - *50-ml beaker or graduated cylinder*
  - *disposable plastic pipette*
  - *250-ml beaker*
  - *20-µl micropipette with tips or 10-µl fixed volume micropipette*
  - *gloves*
  - *safety glasses*
  - *0.8% agarose solution (enough for 25 ml per team)*
  - *plastic carboy with TAE buffer (1X)*
  - *distilled water*

Time Required:

- *One to two class periods (approximately 45 minutes each)*

Sickle Cell Trait
Case and Research

Objectives:

- conduct background research on sickle cell trait
- distinguish between sickle cell trait and sickle cell disease (also called sickle cell anemia)
- describe the risk factors and diagnostic criteria for sickle cell trait

Standards Connections:

- **CCSS.ELA-Literacy.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.
- **CCSS.ELA-Literacy.RST.9-10.3** Follow precisely a complex multistep procedure when carrying out experiments, taking measurements, or performing technical tasks, attending to special cases or exceptions defined in the text.
- **CCSS.ELA-Literacy.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.
- **CCSS.ELA-Literacy.WHST.9-10.2** Write informative/explanatory texts, including the narration of historical events, scientific procedures/experiments, or technical processes.
- **CCSS.ELA-Literacy.W.9-10.8** Gather relevant information from multiple authoritative print and digital sources, using advanced searches effectively; assess the usefulness of each source in answering the research question; integrate information into the text selectively to maintain the flow of ideas, avoiding plagiarism and following a standard format for citation.

Directions:

This lesson has two parts and is meant to familiarize students with the symptoms, risk factors, and diagnostic criteria for sickle cell trait. On day one, students are first given a brief case study to read, in which a high school football player is discussing his collapse at an August practice with his family and doctor. It comes up in discussion that the athlete may have sickle cell trait. After reading the case study, students should generate questions they have about sickle cell trait and sickle cell disease. These questions can be shared either on a whiteboard or chart paper, or electronically using an interactive software program such as Socrative (www.socrative.com). Students should then organize their questions into specific categories. Teachers may give students the question categories, which may include:

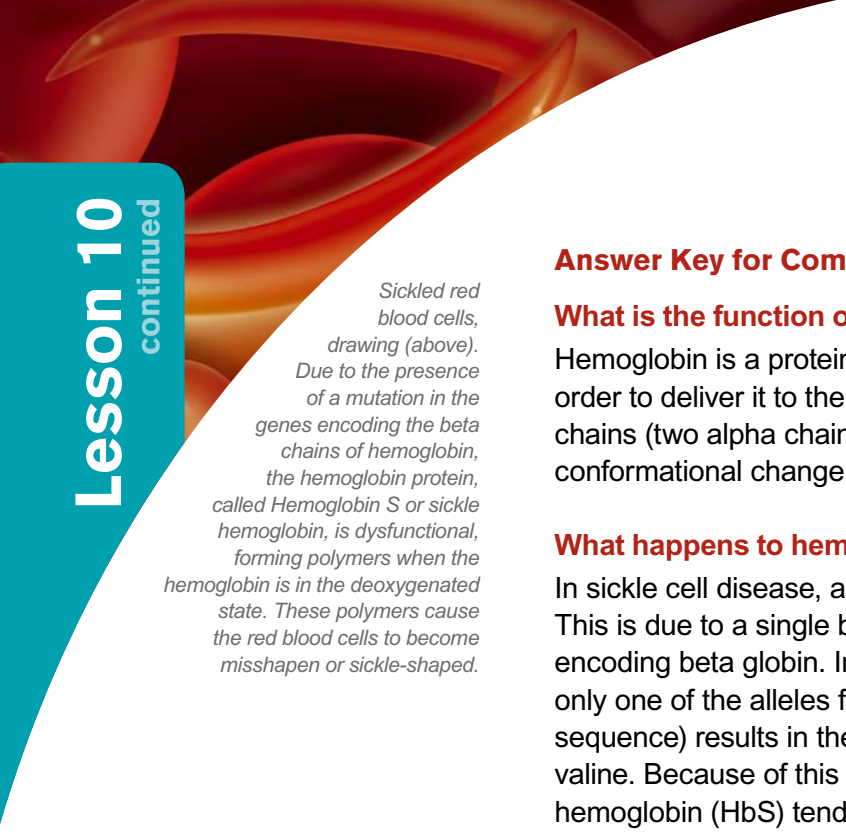
- symptoms or health risks
- diagnostic criteria or testing
- inheritance patterns or risk factors

Alternatively, teachers may ask students to create their own categories in groups, then collectively agree on the categories as a whole class. However, the above listed categories should be included and students should be guided in that direction if they are not asking appropriate questions. Students should then conduct background research (see suggested references below) to answer their own questions. Questions should be split equally among group members, but each group member should research and answer at least two questions, listing all references on the attached research worksheet.

On day two, groups should present their research findings to the whole class and discuss the case scenario again. Students should then work in groups to conduct gel electrophoresis to determine whether Garrett Anderson has sickle cell trait (is a carrier for one copy of the gene that causes sickle cell disease). Standard gel electrophoresis protocols using 1% agarose mini-gels should be used. The samples given to students are simply a mix of dyes: blue dye No. 1 for the normal hemoglobin (negative control), blue dye No. 2 for the sickle hemoglobin, also known as hemoglobin S (positive control), and a mix of the same two dyes for Garrett (sickle cell trait-positive). The gels can be run for 20 minutes using 1X TAE buffer at 100 volts. The voltage can be modified to adjust the time it takes for the dyes to separate. See reference list for gel electrophoresis instructions and available kits or equipment. If gel electrophoresis equipment is not available, an alternative is to give students a sketch or diagram of the results and have them interpret the gel in order to make a diagnosis. The sickle (abnormal) hemoglobin "band" should be closer to the positive electrode, since it has a neutral amino acid (valine) in place of the normal negatively charged amino acid (glutamic acid). Students then complete a genetic testing report (see worksheet) summarizing their observations and the clinical diagnosis for Garrett Anderson. This final assignment can be completed in class or as homework. If the genetic testing report is completed in class, students should be given at least 20 minutes to complete their reports.

The following answer key includes some frequently asked questions students may pose, along with the answers. If students fail to pose most of these questions, the teacher should guide them in that direction during small-group or whole-class discussions. For example, if a student simply asks "What is sickle cell disease?" based on the reading, the teacher may pose the question "Does Garrett actually have this disease?"

Sickled red blood cells, drawing (above). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.



Sickled red blood cells, drawing (above). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

Answer Key for Common Student Questions:

What is the function of hemoglobin in the body?

Hemoglobin is a protein present in red blood cells that binds to oxygen in order to deliver it to the tissues. It is a tetramer made up of four polypeptide chains (two alpha chains and two beta chains). Oxygen binding results in a conformational change (or change in shape) in the protein.

What happens to hemoglobin in sickle cell disease?

In sickle cell disease, a single amino acid in the beta chain is incorrect. This is due to a single base substitution in both alleles of the gene encoding beta globin. Individuals with sickle cell trait have this mutation in only one of the alleles for beta globin. This mutation (or change in the DNA sequence) results in the replacement of the amino acid glutamic acid with valine. Because of this change in the amino acid sequence, the abnormal hemoglobin (HbS) tends to polymerize when it is in the deoxygenated state, thereby deforming the red blood cell in which it resides, forming so-called “sickle-shaped” cells. Though the cells usually can return to their normal shape when oxygen levels increase and the sickle hemoglobin polymers resolve, the continual changes in conformation damage the red blood cells and decrease their life span. Note: Some cells may sustain such significant damage that they become irreversibly “sickled.”

What is the difference between sickle cell disease and sickle cell trait?

Sickle cell disease is an inherited blood disorder in which the red blood cells, due to abnormalities in the hemoglobin molecule, become misshapen. Individuals with this disease inherit TWO abnormal alleles for the gene encoding the beta chain of the hemoglobin protein. Individuals with sickle cell trait inherit ONE abnormal allele and are considered “carriers” of the disease. Though some of the hemoglobin in each of their red blood cells is abnormal, enough normal hemoglobin is present in the red blood cells to prevent the health problems associated with sickle cell disease.

How is sickle cell disease inherited?

Sickle cell disease is an inherited disorder. All of us have two copies of every gene (except for some genes on the X and Y chromosomes). If both copies of the gene encoding the beta chain of hemoglobin are abnormal, then all of the individual’s hemoglobin will be the abnormal HbS, or sickle hemoglobin. This person is considered to have sickle cell disease (or sickle cell anemia), and will experience its symptoms. (It is important to note that mutations in the genes encoding the alpha chains of hemoglobin can also result in a variety of other genetic disorders.)

Some individuals have two different forms (alleles) of the gene encoding the beta chain of hemoglobin (i.e., one normal and one mutated). Individuals who carry one abnormal allele have “sickle cell trait.” In

this case, about half of the individual's hemoglobin is normal and functions properly while the remainder is the HbS form. The carrier's red blood cells typically function normally though they can become sickle shaped under extremely low oxygen conditions, such as might be encountered in an unpressurized airplane or with very extreme exertion such as in the case described of the football player. This person is considered a carrier since enough normal hemoglobin is present to prevent the symptoms of the disease.

Sickled red blood cells, drawing (above). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

However, a carrier can pass the abnormal allele to his or her children. If two people with sickle cell trait have a child, there is a 25% chance that the child will have sickle cell disease. The gene encoding the beta chain of hemoglobin is inherited in an autosomal recessive fashion. In other words, the gene is not located on a sex chromosome (X or Y), and one normal copy of the gene is enough to prevent the symptoms of the disease. Only individuals with two abnormal alleles have the disease.

For a helpful diagram depicting the inheritance of sickle cell disease, see: **www.cdc.gov/ncbddd/sicklecell/documents/sicklecelltraitfactsheet_english.pdf**.

What are the signs and symptoms of sickle cell disease? Sickle cell trait?

Due to the presence of an abnormal form of the protein hemoglobin, the red blood cells of individuals with sickle cell disease become misshapen and sticky when the HbS within them is not bound to oxygen. These cells have a shorter life span, resulting in a constant shortage of red blood cells and decreased oxygen delivery to the tissues. In addition, the cells can clump together and block small blood vessels, causing blockage of blood flow and pain. Patients may experience acute pain crises, an infarcted spleen (since the RBCs get stuck in the spleen); stroke, reduced kidney function (due to the "clumping" of the abnormal RBCs, which can reduce or completely block blood flow); and increased risk of infections (due to reduced immune function). For more advanced students (in an honors or advanced placement course), this is an opportunity to distinguish between signs of a disease versus symptoms of a disease. Signs are objective manifestations of a disease (e.g., sickled red blood cells on a blood smear) perceived by an examiner, while symptoms (pain, shortness of breath) are subjective indications of disease or changes perceived by a patient. Because individuals with sickle cell trait are considered "carriers," they do not usually show any symptoms of sickle cell disease.

Sickled red blood cells, drawing (above). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

What does it mean to be a carrier for sickle cell disease?

Carriers for sickle cell disease have one abnormal and one normal copy of the hemoglobin gene. Such individuals are often said to have sickle cell trait. This condition is not a disease, and the person generally does not have any symptoms of sickle cell disease. However, a carrier can pass the abnormal gene to his or her children. Therefore, if both parents are at risk for being carriers, it is a good idea to be screened and receive genetic counseling.

Who is affected by sickle cell disease?

Sickle cell disease only occurs in individuals who have two abnormal copies of the hemoglobin gene. According to the Centers for Disease Control and Prevention (CDC), sickle cell disease affects between 90,000 and 100,000 Americans and occurs in 1 in 500 African-American births and 1 in 36,000 Hispanic-American births. **(http://www.cdc.gov/ncbddd/sicklecell/documents/scd-factsheet_what-is-scd.pdf)**

How common is sickle cell trait?

Sickle cell trait can occur in individuals of any race or ethnicity though it is much more common in individuals of African descent. According to the Centers for Disease Control and Prevention, approximately 1 in 12 African Americans in the United States have sickle cell trait (**http://www.cdc.gov/ncbddd/sicklecell/documents/scd-factsheet_what-is-scd.pdf** and **www.cdc.gov/ncbddd/sicklecell/data.html**).

How are individuals tested for sickle cell trait?

The individual gives a blood sample, which is screened for the presence of abnormal hemoglobin. This screening is performed at birth in all 50 states and the District of Columbia. If the person has sickle cell trait, a small percentage of the hemoglobin will be abnormal. A negative test indicates the sickle cell gene is not present. People with two copies of the abnormal gene show a much higher percentage of abnormal hemoglobin in the screening test (and have sickle cell disease). Though one can examine the individual's blood smear under the microscope for the presence of sickled red blood cells, this is not a definitive way to distinguish between a person who has sickle cell disease and someone who has sickle cell trait (since either individual could have some normal and some sickled red blood cells). Hemoglobin electrophoresis (to detect the presence of the HbS form of hemoglobin) is the most commonly used confirmatory test.

Worksheet 10 Sickle Cell Trait | Case and Research

Name: _____

Class/Period: _____

Instructions:

Read the following passage *actively* (underline and annotate while reading). Discuss the content of the reading and generate questions about the reading. Conduct background research online using references suggested by your teacher and fill out the research log below. For each source, list a full MLA format citation, and, in your own words, describe what you learned from that source.

PART 1:
"Play Ball!"

Garrett Anderson gazed at the sky as he was rolled toward the ambulance. The lights flashed as he struggled to comprehend what was happening. It had been a hot day and his preseason football practice had been grueling. Garrett was starting at wide receiver for the first time this year at his high school. When he started to feel dizzy, he figured he was just dehydrated or overheated, so he drank more water and tried to cool off. He didn't want to stop practicing and make a bad impression on the coaching staff.

He awoke the next morning in a hospital room, feeling better but still tired. His parents were sitting by his bed. His mother, Shirley, looked exhausted.

"Hi, baby. Are you feeling better? We were so worried." Her voice was shaking.

"I'm okay. What happened?"

"The doctor thinks you overdid it at practice. You passed out."

Dr. Ortiz walked in. "Well, look who's awake. You look much better. We've been giving you plenty of fluids. I need to ask you a few questions. Have you ever had a fainting spell before? At practice or otherwise?"

"A couple times," Garrett replied. "I passed out during a soccer game at summer camp when I was 12, but I came to right away. It was really hot that day."

"The pediatrician told us Garrett had heat exhaustion," his mother chimed in.

"Any other episodes?"

Sickled red blood cells, drawing (right). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

“Once at my football practice two years ago. It was a hot day in August, and we were doing drills for over an hour that afternoon. I felt fine once I cooled off. I had stopped to rest, but the coach said I had to finish the last drill before I left. That’s when I passed out.”

“That man was a lunatic,” Mrs. Anderson stated emphatically.

“Do you have low blood pressure? Hypoglycemia? Or any other chronic illnesses?”

“No,” Garrett replied.

“My sister had sickle cell disease, and so did Shirley’s brother,” Garrett’s father said. “Is it possible Garrett has sickle cell disease?”

“Has he ever had episodes where he had severe pains in his bones or abdomen, or does he frequently get short of breath or fatigued?”

“I don’t think so,” said Garrett.

“No,” said Mrs. Anderson, “I would have known right away if he did—after seeing what my brother went through all our lives.”

“It is possible that Garrett has sickle cell trait, meaning he is a carrier for sickle cell disease. This condition is not a disease, and the person generally does not have any symptoms of sickle cell disease. But overexertion can sometimes have a greater effect on someone with sickle cell trait.”

“He was screened for sickle cell trait when he was born,” Garrett’s mother stated, “but I’m not sure what the results were.”

“We can have him screened again. But I have to warn you, practicing football when it’s over 90 degrees is potentially harmful to anyone, not just a person with sickle cell trait. We really need to get the word out to the coaches about how to prevent these types of problems in the first place. They should be putting the health and safety of the athletes first, before pushing them to the limit in practices and conditioning.”

Sickled red blood cells, drawing (right). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

PART 2:
Using the questions you have generated based on the below categories, outline what you have learned regarding each. Properly list a full MLA source citation:

- symptoms or health risks
- diagnostic criteria or testing
- inheritance patterns or risk factors

Analysis

Source: _____

What I learned: _____

_____

_____

_____

_____

Source: _____

What I learned: _____

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Source: _____

What I learned: _____

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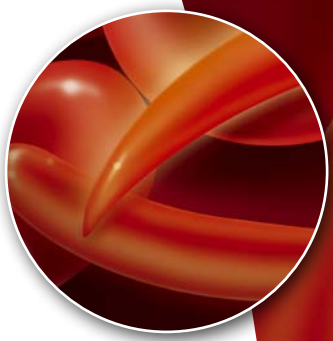
Sickled red blood cells, drawing (right). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.



Genetic Testing Report for Garrett Anderson

Lab Technicians (group members):

_____

_____

_____

Class/Period: _____

Patient Name: Garrett Anderson **Date of Test:** _____

Description of Testing Procedure

_____

_____

_____

_____

_____

_____

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_____

_____

_____

Test Results

Sketch results on the picture of the gel below. Be sure to label each with the name of the sample: positive control (sickle Hb), negative control (normal Hb), patient (Garrett Anderson).

Picture Reference: **http://www.apsnet.org/edcenter/K-12/TeachersGuide/PlantBiotechnology/Pages/Activity2.aspx**

Sickled red blood cells, drawing (right). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

Analysis of Testing Results or Diagnosis:

Laboratory Technician Signature

Date

Sources:

http://www.cdc.gov/ncbddd/sicklecell/freematerials.html

http://www.cdc.gov/ncbddd/sicklecell/documents/scd-factsheet_what-is-scd.pdf

http://www.cdc.gov/ncbddd/sicklecell/documents/sicklecelltraitfactsheet_english.pdf

http://www.scholastic.com/browse/collection.jsp?id=689

http://www.hematology.org/Patients/Blood-Disorders/Anemia/5228.aspx

http://www.hematology.org/news/2012/7703.aspx

http://www.mayoclinic.com/health/sickle-cell-anemia/DS00324/DSECTION=tests-and-diagnosis

http://www.cdc.gov/extremeheat/athletes.html

Gel Electrophoresis References:

http://www.clarion.edu/158986.pdf

http://ceprap.ucdavis.edu/index.php?option=com_content&view=article&id=56&Itemid=138 (Click on “Gel Electrophoresis of Dyes”)

http://teachingbioinformatics.fandm.edu/activities/gel-electrophoresis-dyes

http://allnurses.com/general-nursing-student/signs-vs-symptoms-342501.html

Sickled red blood cells, drawing (right). Due to the presence of a mutation in the genes encoding the beta chains of hemoglobin, the hemoglobin protein, called Hemoglobin S or sickle hemoglobin, is dysfunctional, forming polymers when the hemoglobin is in the deoxygenated state. These polymers cause the red blood cells to become misshapen or sickle-shaped.

SCHOLASTIC

ADDITIONAL RESOURCES

online

Hematology.org is an information resource center for teachers, students, and consumers who want **easy-to-understand** information about blood, advances in hematology, career resources, and patient stories. Not everyone is a doctor or a researcher, but it is important for everyone to be knowledgeable about their health and how to initiate conversations with their doctors.

- **www.hematology.org/patients**
- **www.hematology.org/Training/Students/5591.aspx**

more sites

Additionally, the following sites provide important information about clinical trials, blood diseases, and other disorders:

- National Heart, Lung, and Blood Institute: **www.nhlbi.nih.gov**
- National Institute of Diabetes and Digestive and Kidney Diseases: **www2.niddk.nih.gov**
- National Cancer Institute: **www.cancer.gov**
- National Center for Research Resources: **www.nih.gov/about/almanac/organization/NCRR.htm**

AMERICAN SOCIETY OF HEMATOLOGY