The American Chestnut
Life, Death, and Rebirth

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Activities

OVERVIEW
Introduces students to the story of the American chestnut tree with emphasis on Pennsylvania, the tree's demise in the early 20th century, and how humans are trying to bring back the "Mighty Giant" to the eastern forests of the United States.

OBJECTIVES

Students will be able to:

- Identify the uses and importance of the American chestnut tree.
- Explain Pennsylvania's role in helping to slow the spread of the blight and cite examples of the importance of the tree to Pennsylvanians.
- Express the importance of the American Chestnut Foundation and how the organization is helping to restore the American chestnut tree.

PENNSYLVANIA CORE STANDARDS

Science & Technical Subjects: CC.3.5.6-8.D; History & Social Studies: CC.8.5, CC.8.5.6-8G, CC.8.6.6-8.F (Extension); English Language Arts: CC.1.2.6.G.

PENNSYLVANIA STANDARDS

Environment and Ecology: 4.3.7.A, 4.4.7.C, 4.5.6.D, 4.5.8.A; Geography: 7.1.6.B, 7.1.7.B, 7.1.8.B; Reading, Writing, Speaking and Listening: 1.6.6.A,1.6.7.A, 1.6.8.A; History: 8.2.7.B

LEVEL: Grades 6-8

5Es: Engage, Explore, Explain

TIME CONSIDERATIONS:
Part A: One or 2 50-minute periods depending on video choice.
Part B: One 50-minute period.

MATERIALS NEEDED:
For the class: Schedule presenter from the PA Chapter of the American Chestnut Foundation to come and speak to the class OR secure enough computers with microphones and video cameras to Skype with presenter; one computer and one projector, "American Chestnut Blight-Greatest Forest Loss in History" video (27:36) OR depending on time, the first chapter "Historical Background" of "The American Chestnut" video (3:00), CD with slide show of historical Pennsylvania photographs.
For each student: Copies of Student Pages "American Chestnut in Pennsylvania" and corresponding black and white map "Percent American Chestnut by County, 1911," and "The American Chestnut Story." Copies of full color map "Percent American Chestnut by County, 1911" (from CD); multiple red, green, yellow, blue, and orange colored pencils, crayons or markers (if used as an in-class activity).

BACKGROUND

The American Chestnut Story

Those who know the story can never forget it, but the tragedy happened long enough ago that many, now, have never heard of the tree's demise.

The American chestnut tree was once one of the most important trees in Pennsylvania and in our eastern hardwood forests. It ranged from Maine to Georgia, and west to the prairies of Indiana and Illinois. It grew mixed with other species, often making up to 25 percent of the forest. In Pennsylvania, approximately one in three trees (33%) was American chestnut. In early summer, when the trees were covered with their long, creamy flowers, the mountains looked as if their crests were covered with snow. In the virgin forests, where large chestnuts were commonplace, mature trees could be more than 600 years old. They averaged 1.5 meters (4 to 5 feet) in diameter and 28 to 35 meters (80 to 100 feet) tall. Many specimens 3.1 meters (8 to 10 feet) in diameter were recorded, and there are rumors of trees bigger still. Here in Pennsylvania, a champion American chestnut tree with a diameter of about 8 feet was measured on January 1, 1889 in Chester County!

Wildlife depended extensively on the nuts as well: deer, wild turkey, squirrels and once, the huge flocks of passenger pigeons (now extinct)--all stored fat for the winter in the chestnut forests. The tree was also one of the best for timber. It grew straight and tall, often branch-free for 18 meters (50 feet). Loggers tell of loading entire railroad cars with boards cut from just one tree. Straight-grained, lighter in weight than oak and more

easily worked, it was as rot-resistant as redwood. It was used for everything--telegraph poles, railroad ties, heavy construction, shingles, paneling, fine furniture, musical instruments, pulp and plywood. The chestnut was also the country's major source of tannin for tanning leather.

Disaster Strikes

Unfortunately, the American chestnut was tragically susceptible to the deadly chestnut blight fungus imported in the mid- to late- 19th Century on Oriental chestnut trees planted in New York City. These trees were brought into the country before passage of plant quarantine laws. It wasn't until 1906 that the chestnut blight fungus was isolated and classified. The blight rampaged through the forests, spreading 30 to 80 kilometers (20 to 50 miles) per year, killing nearly every chestnut in its path. Within decades, an estimated four billion trees were killed by the blight as it spread throughout the eastern United States. By 1950, the American chestnut was nearly eliminated as a forest tree. The blight effectively removed 25% of the eastern forest cover, impacting ecosystem diversity, forest species composition, and wildlife. However, since the root system is protected from the blight fungus by the surrounding soil, some American chestnut trees continue to survive, though now as shrubby sprouts, where giants once stood.

Pennsylvania Fights Back

Pennsylvania made a determined, well planned effort to combat the blight. The initiative came, not from the government, but from an affluent group of citizens known as "The Mainliners," who resided on estates along the main railroad line extending north into Montgomery County to and from their business offices in Philadelphia. The Main Line Citizen's Association recognized that a serious problem existed and asked the State Forestry Department for help. It was soon evident that the overall prevalence of the blight required more than a local effort. Governor John K. Tener gave full support and on April 10, 1911 sent a message to both houses of the Legislature, "…calling direct attention to the situation, and asking the help of the General Assembly to combat the disease." A bill creating the Pennsylvania Chestnut Tree Blight Commission was passed by the assembly and signed into law by the Governor, June 14, 1911. The Pennsylvania Department of Forestry was directed to work in collaboration with the

Commission. Crews were organized and the state was scouted to locate and treat areas where blighted trees were found. The procedure was to cut and peel all diseased parts of the trees and to burn what was taken. This was a slow, precarious and necessarily costly procedure, but the only one known and approved at this time. By 1912 reports from the field were very discouraging and all in charge of the work agreed the task of even curtailing the rapid spread of the disease was apparently hopeless.

The American Chestnut Foundation

In 1983, a group of prominent scientists established the American Chestnut Foundation as a non-profit organization. The organization's only goal is to reestablish the American chestnut, magnificent king of the eastern forests, as part of our natural heritage. The American Chestnut Foundation opened its first research farm in April 1989, where researchers in genetics and plant pathology are working to produce a blight resistant strain of American chestnut. The organization advocates a multi-pronged attack on the fungus, using research in biological control, hypovirulence, genetic breeding, and bioengineering. This farm, located near Meadowview, VA, serves as the focus of a specialized breeding program. Tens of thousands of chestnut trees are planted on over 150 acres. The public is invited to visit the site and learn more about the latest research.

As part of a larger effort to restore the American chestnut tree, the Pennsylvania Chapter of the American Chestnut Foundation began breeding chestnuts in 1994. Since then, over 50,000 chestnuts have been planted in Pennsylvania, New Jersey, Maryland and Delaware.

"*Where there be mountains, there be chestnuts*"
--a member of DeSoto's expedition, 1520

PART A:
GETTING READY

- Retrieve "American Chestnut Blight - Greatest Forest Loss in History" OR the shorter "The American Chestnut" video from the CD and secure the proper audio/visual equipment to show the video.

- Copy Student Page: "American Chestnut Story" for each student.

- Copy Student Page: "The American Chestnut, Reading/Focus Questions" for each student.

- Copy map "Percent American Chestnut by County, 1911" (enclosed on CD). *Note: Two versions of this map are enclosed, one with county names and one without. This lesson can be expanded to include learning Pennsylvania County names.*

- Copy Student Page: "American Chestnut in Pennsylvania" and corresponding black-and-white map, "Percent of American Chestnut by County, 1911," for each student. *Note: Two versions of this map are enclosed, one with county names and one without. This lesson can be expanded to include learning Pennsylvania County names.*

DOING THE ACTIVITY

1. Ask the students if they have ever seen an American chestnut tree or if they have heard the story of the American chestnut. Give them time to share what they know or if they are unaware of how an introduced fungus infected and killed the American chestnuts of the eastern United States.

1. View the "American Chestnut Blight - Greatest Forest Loss in History" OR "The American Chestnut" video.

2. To reinforce the video information, handout copies of "American Chestnut Story" to each student to silently read. Students could also take turns reading aloud.

3. Discuss the video and have students use the "American Chestnut Story" to answer questions from Student Pages "The American Chestnut, Reading/Focus Questions."

4. Ask the students how many chestnuts they think grew in Pennsylvania compared to other tree species? What about the county they live in?

5. If there is time, show the class some of the historical Pennsylvania photos (slide show on CD).

- Most of the photos were taken in counties or portions of the Commonwealth where the percentage of American chestnut was higher. Some follow-up questions could be asked in conjunction with viewing the photos at the completion

of the map activity or as part of the introduction to the next days lesson.

6. Either for homework or for an in-class activity, handout copies of full color map "Percent American Chestnut by County, 1911" and Student Page "American Chestnut in Pennsylvania" and corresponding black-and-white map "Percent American Chestnut by County, 1911." Have each student work on coloring-in the black-and-white map and answering questions on Student Page "American Chestnut in Pennsylvania," while referencing the full color map.

- Students will have to use the percent of American chestnut listed in each county on the black-and-white "Percent American Chestnut by County" map and corresponding legend on the full color map to color-in each county and answer a few questions.

- *Note: data were unavailable for Greene, Allegheny and Philadelphia Counties.*

7. In addition to the questions listed on Student Page "American Chestnut in Pennsylvania," a few follow-up questions could be asked:

- Example: *How do you think the loss of the chestnut tree has affected humans? Animals? Cite examples of how important the American chestnut tree was to Pennsylvanians.*

PART B:
GETTING READY

- Pre-schedule a representative of the PA Chapter of the American Chestnut Foundation to come to your classroom for a day to discover what the organization is doing about American chestnut tree reforestation. A 20- to 30-minute presentation should be sufficient to include time for questions and debriefing. If scheduling a guest speaker to physically come to your classroom is not feasible, schedule several Skype sessions with the speaker to cover all class periods.

- Set-up any necessary audio-visual needs that the presenter has requested OR set-up enough computers with speakers and video cameras for students to participate in a Skype session with the speaker.

DOING THE ACTIVITY

1. Introduce the guest speaker and explain that he/

she is going to be talking about what the American Chestnut Foundation is doing about American chestnut tree reforestation.

2. Remind the students that they will be quizzed on the content of the presentation.

3. Have each student formulate one question for the guest speaker as they listen to the presentation.

4. For homework, have the students interview their parents, grandparents or senior citizens to determine their knowledge of the American chestnut tree. As new generations of students pass through your classroom and older generations pass on, we lose our oral history. Discuss this with your students. Have them teach their parents and grandparents what they have learned about the American chestnut tree.

EXTENSION

- Complete library research on how trees are used. Illustrate the uses on a tree silhouette.

- Have students read the New York Times article "Mysterious Blight Kills Chestnut Trees by the Thousands," on the enclosed CD and answer associated questions.

- Have students create an anthology of material that references the chestnut to help them understand the importance of the chestnut tree. Using the Internet, library or other resources collect three different artifacts that include the chestnut tree. These should be historical references and not information from the restoration process. You can use poems, stories, music, recipes, or other similar information. All material should be cited and copies should be included in the report. The report will discuss how the artifacts the collected show the importance of the chestnut trees.

SUGGESTED WORDS TO LEARN:

Bioengineering	Fungus
Biological control	Genetic breeding
Blight	Hypovirulence
Blight resistance	Quarantine laws
Ecosystem	

ANSWER KEY

Student Page: "The American Chestnut Tree Video/Reading Focus Questions:"

1. The American chestnut ranged from Maine to Georgia, and west to the prairies of Indiana and Illinois.

2. 33%

3. The American chestnut grew straight and tall, it was branch-free, lighter weight than oak, and rot-resistant.

4. The American chestnut was used for telegraph poles, railroad ties, heavy construction, shingles, paneling, fine furniture, musical instruments, pulp and plywood. The chestnut was also the country's major source of tannin for tanning leather.

5. 1904

6. The chestnut blight impacted ecosystem diversity, forest species composition, and wildlife.

7. The "Mainliners" or The Main Line Citizen's Association were an affluent group of citizens who resided on estates along the main railroad line extending north into Montgomery County to and from their business offices in Philadelphia. They recognized that a serious problem existed and asked the State Forestry Department for help.

8. The American Chestnut Foundation as a non-profit organization whose goal is to reestablish the American chestnut as part of our natural heritage.

Student Page: "American Chestnut in Pennsylvania:"

1. Answer depends on the county you live in.

2. Lebanon, Cameron, Union, Chester and Cumberland

3. Erie, Wayne, Tioga, Washington

REFERENCES

Carroll County Public Schools. 2010. Restoration of the American Chestnut Tree Curriculum. Carroll County, Maryland.

Commonwealth of PA. 1913. The Publications of the Pennsylvania Chestnut Tree Blight Commission,

1911-1913. Harrisburg, PA.

Dutlinger, Forrest H. 1974. After 60-plus Years- A Saga of the Pennsylvania 1912 Chestnut Tree Blight. Pennsylvania Forests. 64(4): 110-113.

The American Chestnut Foundation. nd. Meadowview Research Farms. Accessed online March 4, 2014: http://www.acf.org/meadowview.php.

The American Chestnut Foundation. 1999. A Tree on the Rebound: Featuring Charlie Chestnut, Star of "The Life and Times of Charlie Chestnut." American Chestnut Foundation New York State Chapter, Buffalo, NY.

The American Chestnut Tree
Video/Reading Focus Questions

1. Where did the American chestnut tree grow?

2. In Pennsylvania, approximately what percentage of trees was American chestnut?

3. List two properties that made the American chestnut tree a good tree to use for timber?

    1. _____ 2. _____

4. What are four ways people used the American chestnut tree?

    1. _____ 3. _____

    2. _____ 4. _____

5. In what year was the chestnut blight fungus isolated and classified?

6. How has the loss of the American chestnut tree affected the environment?

    1._____ 3. _____

    2. _____

The American Chestnut Tree
Video/Reading Focus Questions

7.   Who were "The Mainliners" and what was their involvement in helping to stop the spread of the blight?

8.   Who is The American Chestnut Foundation®? What do they do?

The American Chestnut Story

"Those who know the story can never forget it, but the tragedy happened long enough ago that many, now, have never heard of the tree's demise."

The American chestnut tree was once one of the most important trees in Pennsylvania and in our eastern hardwood forests. **It ranged from Maine to Georgia, and west to the prairies of Indiana and Illinois.** It grew mixed with other species, often making up to 25 percent of the forest. **In Pennsylvania, approximately one in three trees (33%) was American chestnut.** In early summer, when the trees were covered with their long, creamy flowers, the mountains looked as if their crests were covered with snow. In the virgin forests, where large chestnuts were commonplace, mature trees could be more than 600 years old. They averaged 1.5 meters (4 to 5 feet) in diameter and 28 to 35 meters (80 to 100 feet) tall. Many specimens 3.1 meters (8 to 10 feet) in diameter were recorded, and there are rumors of trees bigger still. Here in Pennsylvania, a champion American chestnut tree with a diameter of about 8 feet was measured on January 1, 1889 in Chester County!

Wildlife depended extensively on the nuts as well: deer, wild turkey, squirrels and once, the huge flocks of passenger pigeons (now extinct)--all stored fat for the winter in the chestnut forests. **The tree was also one of the best for timber. It grew straight and tall, often branch-free for 18 meters (50 feet).** Loggers tell of loading entire railroad cars with boards cut from just one tree. **Straight-grained, lighter in weight than oak and more easily worked, it was as rot-resistant as redwood. It was used for everything--telegraph poles, railroad ties, heavy construction, shingles, paneling, fine furniture, musical instruments, pulp and plywood. The chestnut was also the country's major source of tannin for tanning leather.**

Disaster Strikes

Unfortunately, the American chestnut was tragically susceptible to the deadly chestnut blight fungus imported in the mid- to late- 19th Century on Oriental chestnut trees planted in New York City. These trees were brought into the country before passage of plant quarantine laws. **It wasn't until 1906 that the chestnut blight fungus was isolated and classified.** The blight rampaged through the forests, spreading 30 to 80 kilometers (20 to 50 miles) per year, killing nearly every chestnut in its path. Within decades, an estimated four billion trees were killed by the blight as it spread throughout the eastern United States. By 1950, the American chestnut was nearly eliminated as a forest tree. **The blight effectively removed 25% of the eastern forest cover, impacting ecosystem diversity, forest species composition, and wildlife.** However, since the root system is protected from the blight fungus by the surrounding soil, some American chestnut trees continue to survive, though now as shrubby sprouts, where giants once stood.

The American Chestnut Story cont.

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Pennsylvania made a determined, well planned effort to combat the blight. **The initiative came, not from the government, but from an affluent group of citizens known as "The Mainliners," who resided on estates along the main railroad line extending north into Montgomery County to and from their business offices in Philadelphia. The Main Line Citizen's Association recognized that a serious problem existed and asked the State Forestry Department for help.** It was soon evident that the overall prevalence of the blight required more than a local effort. Governor John K. Tener gave full support and on April 10, 1911 sent a message to both houses of the Legislature, "…calling direct attention to the situation, and asking the help of the General Assembly to combat the disease." A bill creating the Pennsylvania Chestnut Tree Blight Commission was passed by the assembly and signed into law by the Governor, June 14, 1911. The Pennsylvania Department of Forestry was directed to work in collaboration with the Commission. Crews were organized and the state was scouted to locate and treat areas where blighted trees were found. The procedure was to cut and peel all diseased parts of the trees and to burn what was taken. This was a slow, precarious and necessarily costly procedure, but the only one known and approved at this time. By 1912 reports from the field were very discouraging and all in charge of the work agreed the task of even curtailing the rapid spread of the disease was apparently hopeless.

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"Where there be mountains, there be chestnuts"

--a member of DeSoto's expedition, 1520

American Chestnut In Pennsylvania

Directions: Use this black-and-white map worksheet and the map of the "Percent American Chestnut by County, 1911" and corresponding legend to color each county the appropriate color. Then, answer the following questions about the map. Note: three counties do not have any data associated with them. These do not need to be colored.

What was the percent of American chestnut trees growing in the county where your school is located in 1911?

Which five counties had the highest percentage of American chestnut compared to other tree species in 1911?

1. _____   4. _____

2. _____   5. _____

3. _____

Which four counties had the lowest percentage of American chestnut compared to other tree species in 1911?

1. _____   3. _____

2. _____   4. _____

Percent American Chestnut by County, 1911

Erie 4

Pike 29
Wayne 7

Susquehanna 10

Bradford 10

Tioga 8

Potter 14

McKean 14

Warren 16

Forest 10

Venango 17

Crawford 15

Mercer 17

Lawrence 10

Beaver 10

Butler 10

Clarion 10

Jefferson 22

Elk 15

Cameron 50

Clinton 32

Lycoming 31

Sullivan 12

Wyoming 13

Lackawanna 10

Luzerne 20

Columbia 22

Montour 22

Northumberland 30

Snyder 17

Union 46

Centre 28

Clearfield 21

Indiana 18

Armstrong 17

Allegheny

Washington 9

Greene

Fayette 26

Somerset 27

Westmoreland 30

Cambria 15

Blair 28

Bedford 25

Huntingdon 28

Mifflin 31

Juniata 27

Perry 25

Dauphin 34

Cumberland 41

Franklin 32

Fulton 20

Adams 15

York 36

Lebanon 50

Lancaster 34

Berks 40

Schuylkill 23

Carbon 31

Monroe 31

Northampton 22

Lehigh 37

Bucks 24

Montgomery 10

Philadelphia

Chester 46

Delaware 40

Data extracted from: *Commonwealth of PA. 1913. Report of the Pennsylvania Chestnut tree Blight Commission: July 1 to December 31, 1912.* pp. 35-39. *In The Publications of the Pennsylvania Chestnut Tree Blight Commission, 1911-1913. Harrisburg, PA.*

0 5 10 20 30 40 Miles

sff. 2/17/14

Introduction to the American Chestnut Tree

Percent American Chestnut by County, 1911

Data extracted from: *Commonwealth of PA. 1913. Report of the Pennsylvania Chestnut tree Blight Commission: July 1 to December 31, 1912. pp. 35-39. In The Publications of the Pennsylvania Chestnut Tree Blight Commission, 1911-1913. Harrisburg, PA.*

sf. 2/17/14

OVERVIEW

Introduces students to the basics of measuring trees using circumference and height and why professional foresters measure trees.
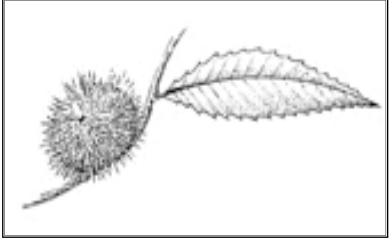
OBJECTIVES

Students will be able to:

- Determine the height and circumference of trees using a variety of methods.
- Demonstrate the size difference between an American chestnut tree and other species of trees.
- Explain why we measure trees.

PENNSYLVANIA CORE STANDARDS

Science & Technical Subjects: CC.3.5.6-8.C, CC.3.5.6-8.D; Mathematics: CC.2.1.6.D.1, CC.2.1.6.E.2, and CC.2.3.7.A.1.

PENNSYLVANIA STANDARDS

Environment and Ecology: 4.3.6.C, 4.3.7.C; Mathematics: 2.3.7.A, 2.3.7.F; Reading, Writing, Speaking and Listening: 1.6.6.A,1.6.7.A, 1.6.8.A; Career Education and Work: 13.1.8.A.

LEVEL: Grades 6-8

5Es: Engage, Explore, Explain, Evaluate

TIME CONSIDERATIONS:
Part A: One 50-minute period

Part B: One 50-minute period

MATERIALS:
Part A:

For the class: interactive whiteboard, white board, chalk board or overhead projector; "American chestnut historical photo" presentation (on CD); one computer and one projector.

For each student: Copies of Student Page "Circumference."

Part B:
For the class: balls of string, meter sticks, several pairs of scissors, and tape measures.

For each student: Copies of Student Pages "Size It Up" and "Who's the Tallest of Them All."

BACKGROUND

The American Chestnut

During the American chestnut's prime, trees averaged 1.5 meters (4 to 5 feet) in diameter and 28 to 35 meters (80 to 100 feet) tall. Many specimens 3.1 meters (8 to 10 feet) in diameter were recorded, and there are rumors of trees bigger still. In Pennsylvania, a champion American chestnut tree with circumference of over 7.5 meters (25 feet 2 inches) and almost 1.5 meters (8 feet) in diameter, was measured on January 1, 1889 in Chester County!

Measurements

Trees are different than grasses and flowers. Trees, shrubs and vines all have one thing that separates them from the rest of the plant world -- a woody stem that lives for many years.

Grasses and other herbaceous plants may have long lives, but they die back and regrow year after year. Although trees, shrubs, and vines are woody, the biggest difference between trees and shrubs and vines is their size, both in height and in circumference (girth). Some trees here in Pennsylvania may range from 15 to 30 meters (50 to 100 feet).

Two easy ways to measure height of a tree include the Native American method and the meter stick method. To measure the circumference of a tree, (distance around the trunk), place the tape 1.5 meters (4.5 feet) above the ground. This is called diameter at breast height (DBH) and is the standard height used to measure tree circumference.

Circumference of a Circle

The circumference of a circle is the

edge or rim of a circle itself. It is the equivalent of 'perimeter' for a circle. In other words, if you took a circle and unrolled it, you would have its circumference. The radius of a circle is the distance from the center of a circle to any point on the circle. If you place two radii (plural of radius) end-to-end in a circle, you would have the same length as one diameter. Thus, the diameter of a circle is twice as long as the radius. You can use either of the formulas below to find the circumference. One formula uses the radius of a circle; the other formula uses the diameter.

$$Circumference = \pi \; x \; diameter$$
$$or$$
$$Circumference = 2\pi \; x \; radius$$

Circumference, diameter and radii are measured in linear units, such as inches and centimeters. A circle has many different radii and many different diameters, each passing through the center. A real-life example of a radius is the spoke of a bicycle wheel. A 12 in pizza is an example of a diameter - when one makes the first cut to slice a round pizza pie in half, this cut is the diameter of the pizza. So a 12 in pizza has a 12 in diameter.

Why Do We Measure Trees?

Tree diameter and tree height are important measures of tree growth, especially when combined with additional measurements such as the age of a tree. A forester is someone who practices planting, managing, and caring for forests and frequently measures the diameter and height of trees to help solve forest management issues like assisting a landowner with selling timber. Knowing how much timber a landowner has to sell can mean additional dollars earned from a timber sale. A forester decides which trees are ready for market, then measures them and marks them with paint spots at breast height and below stump height. If the trees are already cut, he or she can scale or measure the logs before they are sent to the mill. Imagine how much money could be made if we still had American chestnuts growing in Pennsylvania forests!

PART A:
GETTING READY

• Make copies of Student Pages: "Circumference"

for each student.

• Obtain a clean interactive white board, white board, chalk board or overhead projector to present circumference materials.

DOING THE ACTIVITY

1. Ask the students some review questions regarding their knowledge of the American chestnut tree.

• Where could the American chestnut tree be found?

• Why do we not have American chestnut trees today?

• Ask the students to think about why it might be important to measure the circumference and height of trees.

2. Explain to the students that they are going to find the height and circumference of trees and why a person might want to measure a tree.

3. What is circumference? Describe circumference and related terms using a chalk board or overhead projector to draw examples. Use the pizza and bicycle wheel examples to explain radius and diameter and do a few sample circumference problems.

4. What is a forester? Describe what a forester does for a living and why it is important to measure trees.

5. Hand out Student Page "Circumference" worksheet with practice problems and have students complete each problem.

PART B:
GETTING READY

• Make copies of Student Page: "Size It Up" for each student.

• Make a copy of Student Page: "Who's the Tallest of Them All?" for each student.

• Gather several balls of string, pairs of scissors, meter sticks, and tape measures. The number of each will determine if the activity is completed by the class as a whole or by groups of students.

• Scope-out your school grounds and choose at least two large trees or several large trees to measure. The number of each will determine if

the activity is completed by the class as a whole or by groups of students.

- Retrieve "American Chestnut Historical Photos" presentation from the CD and secure a computer and projector to view the photos.

DOING THE ACTIVITY

1. Using the background information, discuss the different ways of measuring the height and circumference of a tree.

2. Model measuring the height of a tree using the Native American method. Use the directions from the "Size It Up" activity.

3. Divide the class into several groups (this can vary depending on the materials and the number of large trees available).

4. Allow each group to measure the height of a different tree.

5. Model measuring the circumference of the original tree using the string method using the directions from the "Size It Up" activity.

6. Allow each group to measure the circumference of a different tree.

7. Have the students estimate a length of 8 meters (approximately 26 feet) using a ball of string. Have the students check their estimates by measuring the string and cutting the string at 8 meters (approximately 26 feet). Tell the students the American chestnut tree had a circumference of 8 to 10 meters (approximately 26 to 33 feet).

8. Compare the length of the circumference string from the original trees to that of the American chestnut tree.

9. Make a circle around the original tree with the American chestnut tree circumference string.

10. Complete the activity pages "Size It Up"and "Who's the Tallest of Them All?"

11. If there is time, show the class some historical photos of American chestnut trees.

- Follow-up questions could include: *How did the size of an American chestnut compare to the trees we measured today? Why do you think American chestnuts were able to grow so big?*

- This questioning could segue into a brief explanation (or another lesson) of Pennsylvania forest history, the loss of Pennsylvania's forests, and how we have professionals to help manage our forests today.

EXTENSION

- Invite a local Service Forester from the Pennsylvania Department of Conservation and Natural Resources (DCNR) Bureau of Forestry to visit or Skype with your class to demonstrate the tools he/she uses to measure trees on a daily basis. This is a great career connection opportunity to learn what a forester does.

SUGGESTED "WORDS TO LEARN:"

Circumference	Girth
DBH	Native American
Diameter	Radius
Forester	

ANSWER KEY

Student Page: "Circumference"

1. 204 in or 17 ft

2. 640.6 in or 53.383 ft

3. 37.7 in

4. 75.4 in

5. 266.9 in OR 22.242 ft

6. 3.981 ft

REFERENCES

Carroll County Public Schools. 2010. Restoration of the American Chestnut Tree Curriculum. Carroll County, Maryland.

Math Warehouse. nd. Circumference of a Circle. Accessed online February 26, 2014: http://www.mathwarehouse.com/geometry/circle/circumference-of-circle.php.

The American Chestnut Foundation. 1999. A Tree on the Rebound: Featuring Charlie Chestnut, Star of "The Life and Times of Charlie Chestnut." American Chestnut Foundation New York State Chapter, Buffalo, NY.

Directions: Use the information and diagrams below to determine various calculations on the size of an American Chestnut tree.

1) The American chestnut tree could have a radius of up to 102 inches! What would be the diameter of the tree given the formula?
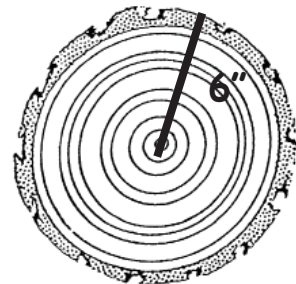
$$Diameter = 2r$$

Diameter = _____ inches   OR   _____ feet

2) Given the same radius length in question 1, what would the circumference (the perimeter) of the tree be given the formula? Round your answer to the nearest tenth.

$$Circumference = 2 \pi r \text{ where } \pi = 3.14$$

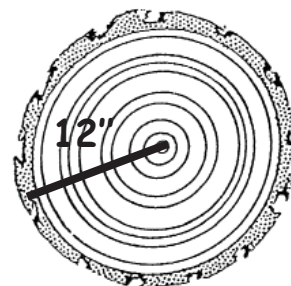Circumference = _____ inches   OR   _____ feet

3) Given a radius of 6 inches, what is the circumference of the American chestnut tree cross section below. Round your answer to the nearest tenth.

4) Given a radius of 12 inches, what is the circumference of the American chestnut tree cross section? Round your answer to the nearest tenth.

12"

5) Given a diameter length of 85 inches, what would the circumference of the tree cross section be given the formula? (A mature American Chestnut tree could have reached a diameter of 7 feet, though diameters as large as 12 feet have been found.) Convert your answer to feet and round to the nearest thousandth.

Circumference = π d

85"
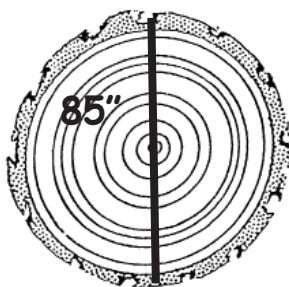
_____ inches OR _____ feet

6) Given a circumference of 25 feet, what would be the radius of an American chestnut tree? Round your answer to the nearest thousandth.

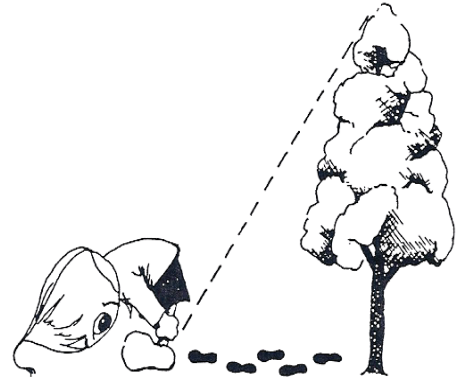## Size It Up

How to measure the height of a tree:

Some Native Americans measured the height of a tree this way. Holding your ankles, walk away from a tree until you see the top of that tree between your legs. Measure the distance you are from the tree. That distance is approximately the height of the tree.

How to measure the circumference of a tree:

Using a piece of string, have one person hold the end of the string on the tree trunk 1.5 meters (4.5 feet) above the ground. A second person should wrap the string around the trunk until it meets the starting point. Cut the string. Take the string down and measure it.

1. What is the height of your tree?
   _____ meters

2. What is the circumference of your tree? _____ meters

3. Describe how your tree's circumference compares to that of the American chestnut tree's circumference.

_____

_____

_____

_____

How does Charlie's Tree Size Up?

Complete the graph of the height of Charlie's American chestnut tree.

Directions:

Charlie is using the Native American method to measure the height of an American chestnut tree. Charlie is 28 meters from his tree. Draw the height of the tree Charlie saw on the scale below.

Use this symbol:

35

30

25

20

Meters

15

10

5

0
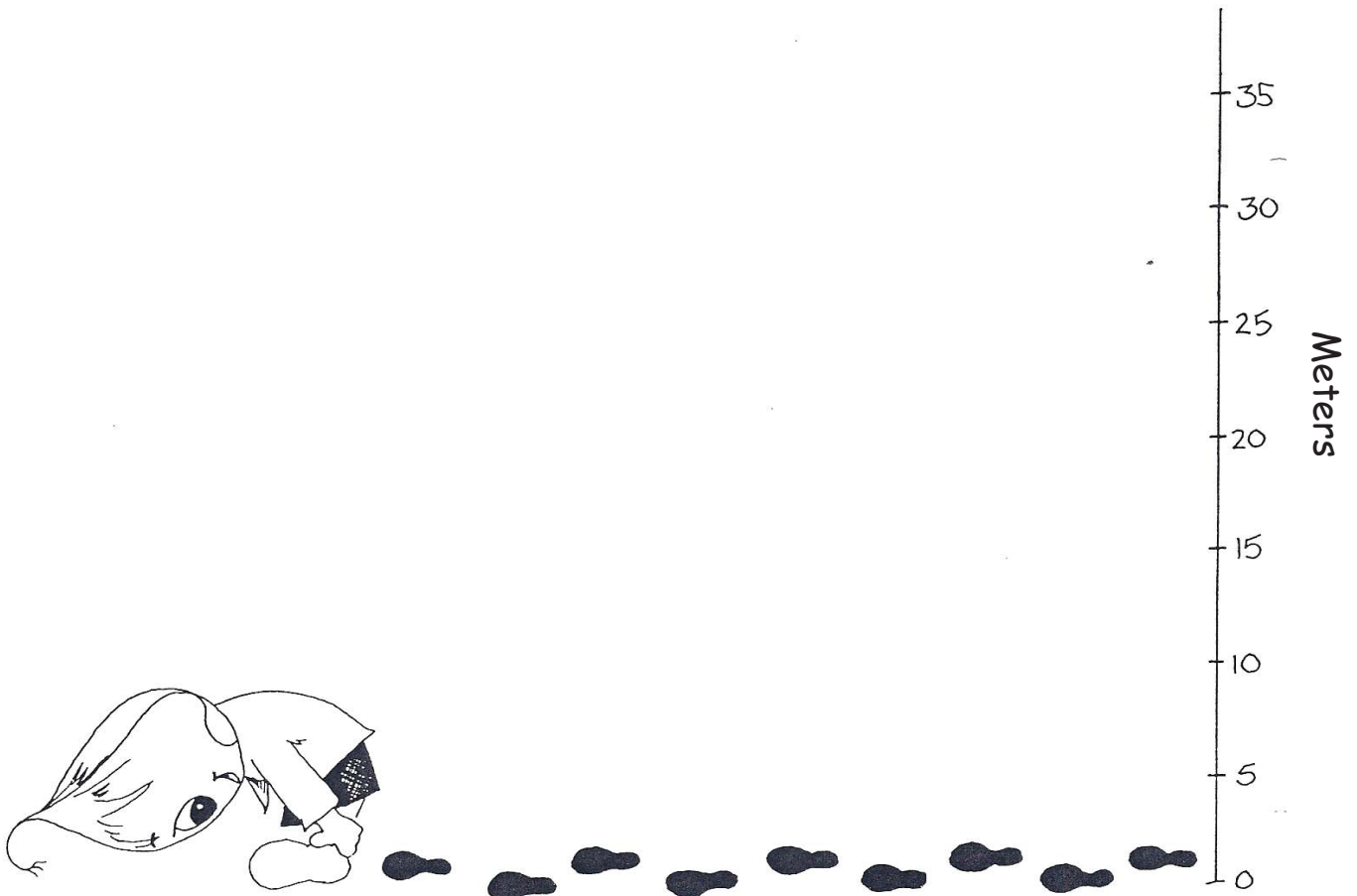
Who's the Tallest of Them All?

Directions:

Using a bar or a tree shape, show the height of each tree in the graph below:

1. The class model tree
2. The student measured tree
3. Charlie's American chestnut tree

Note: you should have three separate tree drawings when you are finished.

Meters

55
50
45
40
35
30
25
20
15
10
5
0

Whole class model   2ⁿᵈ tree   Charlie's American chestnut tree
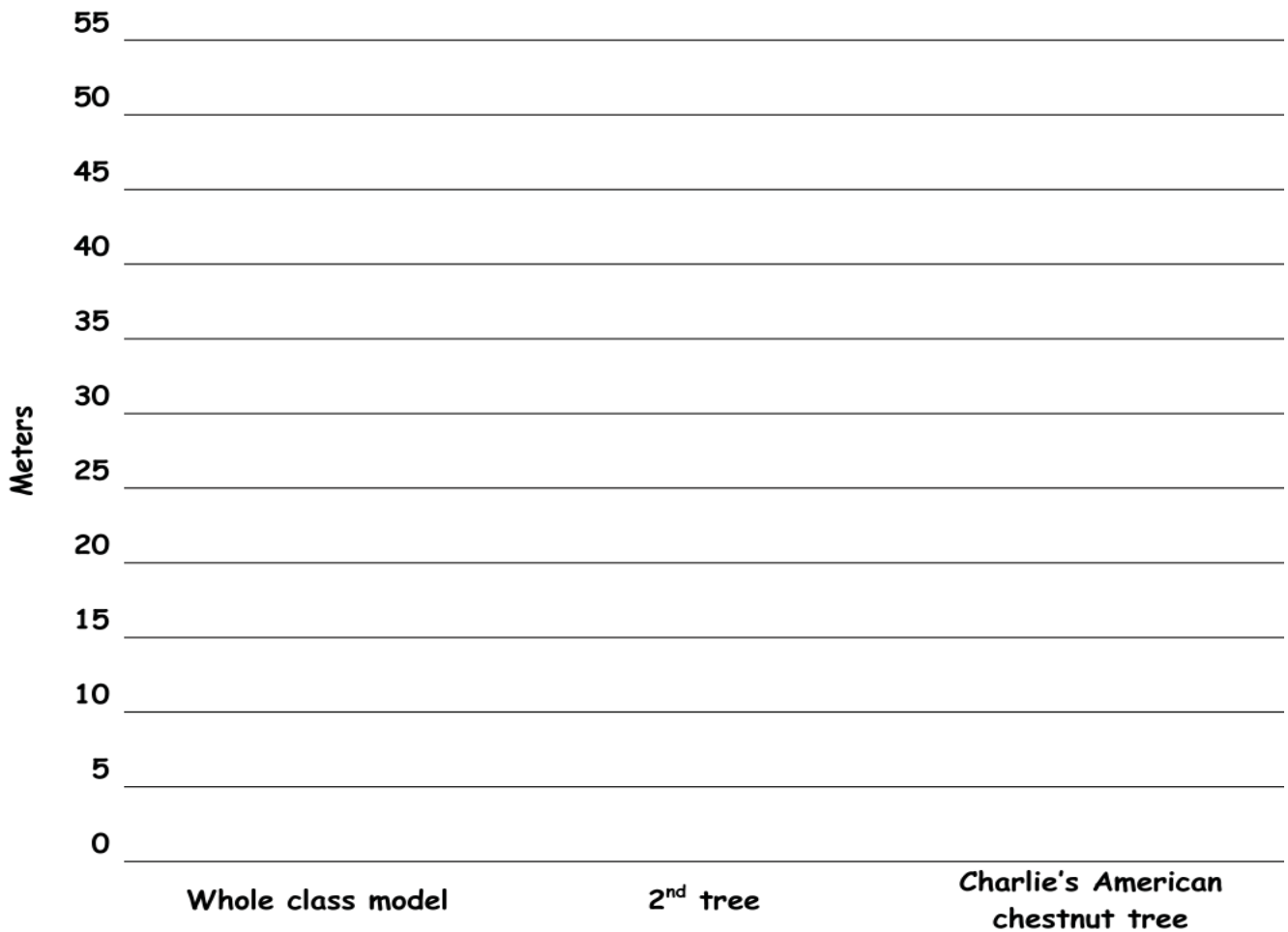
4. Describe how the height of these trees compare to the American chestnut tree.

_____
_____
_____

OVERVIEW

Introduces students to the concept of capillary action and how it relates to chestnut blight cankers.

OBJECTIVES

Students will be able to:

- Explain how capillary action provides nutrients for chestnut trees.
- Recognize that chestnut blight cankers prevent the process of capillary action.
- Define a series of words related to capillary action and the chestnut blight.

PENNSYLVANIA CORE STANDARDS

Science & Technical Subjects: CC.3.5.6-8.C, CC.3.5.6-8.D; History & Social Studies: CC.8.5.6-8.G; English Language Arts: CC.1.2.6.G.

PENNSYLVANIA STANDARDS

Environment and Ecology: 3.1.7.A1, 4.3.6.C, 4.3.7.C; Reading, Writing, Speaking and Listening: 1.1.6.C, 1.1.7.B, 1.1.8.B, 1.6.6.A, 1.6.7.A, 1.6.8.A

LEVEL: Grades 6-8

5Es: Engage, Explain, Elaborate, Evaluate

TIME CONSIDERATIONS: 2 50-minute periods.

MATERIALS:

For the class: One computer, a projector, CD with slide show of canker photographs, markers, crayons or colored pencils, food coloring, beaker with small amount of water, and a paper towel.

For each group: 4 beakers or jars, 4 celery stalks, blue food coloring, masking tape, sharp knives or scalpels, and plasticine or modeling clay.

For each student: Copies of Student Pages "Disease of an American Chestnut Tree," "Up, Up and Away: Lab Sheet," "Up, Up and Away Worksheet," "Capillary Action and Chestnut Blight Review Questions," and optional pages "Capillary Action and Chestnut Blight Vocabulary Match" and/or "American Chestnut Disease Word Search."

BACKGROUND

Capillary Action

Even if you've never heard of capillary action, it is still important in your life. Capillary action is important for moving water (and all of the things that are dissolved in it) around. It is defined as the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

Capillary action occurs because water is sticky, thanks to the forces of cohesion (water molecules like to stay close together) and adhesion (water molecules are attracted and stick to other substances). Adhesion of water to the walls of a vessel will cause an upward force on the liquid at the edges and result in a meniscus which turns upward. The surface tension acts to hold the surface intact. Capillary action occurs when the adhesion to the walls is stronger than the cohesive forces between the liquid molecules. The height to which capillary action will take water in a uniform circular tube is limited by surface tension and, of course, gravity.

Not only does water tend to stick together in a drop, it sticks to glass, cloth, organic tissues, soil, and to the fibers in a paper towel. Dip a paper towel into a glass of water and the water will "climb" onto the paper towel. In fact, it will keep going up the towel until the pull of gravity is too much for it to overcome.

Capillary Action is All Around Us Every Day

When you spill your glass of juice on the kitchen table you rush to get a paper towel to wipe it up. First, you can thank surface tension, which keeps the liquid in a nice puddle on the table, instead of a thin film of sugary

liquid that spreads out onto the floor. When you put the paper towel onto your mess the liquid adheres itself to the paper fibers and the liquid moves to the spaces between and inside of the fibers.

Plants and trees couldn't thrive without capillary action. Plants put down roots into the soil, which are capable of carrying water from the soil up into the plant. Water, which contains dissolved nutrients, gets inside the roots and starts climbing up the plant tissue. As water molecule #1 starts climbing, it pulls along water molecule #2, which is dragging water molecule #3, and so on.

Capillary action is also essential for the drainage of constantly produced tear fluid from the eye. Two tiny-diameter tubes, the tear or lacrimal ducts, are present in the inner corner of the eyelid; these ducts secrete tears into the eye.

The American Chestnut Story

Diseases are caused by bacteria, viruses, fungi, and other agents. The chestnut blight is caused by a fungus. A fungus is an organism that feeds on other living or dead organisms and reproduces via spores. The fungal spores are transferred from tree to tree by birds, insects, water and the wind. Once the fungus begins to grow in the cracks of the bark, it forms an orange colored canker (blister) on the surface. Below the bark surface, thread-like strings called hyphae penetrate the vascular tissue. Similar to plant roots, fungi grow hyphae to acquire nutrients from plants and dead animals. The vascular tissue is what allows water and mineral nutrients to move from roots to leaves and transfer manufactured food to other parts of the tree. When the hyphae plug the vascular tissue, the tree begins to die. Girdling is the process by which the living connection between the roots and the leaves is severed. Usually this occurs by cutting or chopping away the outer bark and the inner bark or cambium (growing layer). However, in this case, the blight fungus encircles a portion of a tree and plugs the vascular tissue with hyphae. *Note: depending on grade level, the terms xylem and phloem may be introduced when talking about vascular tissue. A great way demonstrate the presence of xylem tubes is to blow bubbles in a bowl of soapy water using a pice of wood approximately 10 cm in length.* At first, only a few small branches show the effect of this choking process; eventually the entire tree dies.

Because the fungus is prevented from growing below ground by other organisms growing in the soil, American chestnut tree roots continue to send up new stem growth each year, even after it has been attacked. As a result of learning this, tree scientists cover small cankers above ground with mud. This process to prevent the spread of the disease is called mudpacking. However, to cover an entire tree with mud packs is not practical. Breeding and other methods are currently being researched by The American Chestnut Foundation® to give the American chestnut tree the tools it needs to defend itself from the chestnut blight. We will explore one of these, backcrossing, in Lesson #5: Chestnut Genetics.

GETTING READY

Day 1:

• Retrieve the following items for each group of students for the "Up, Up and Away" experiment: 4 beakers or jars, 4 celery stalks, blue food coloring, plasticine or modeling clay, and one sharp knife or scalpel. *Note: Celery stalks with the leaves still attached are most desirable since the leaves almost completely turn blue after a 24-hour soak.. This better illustrates how plants transport water and nutrients to their leaves. Using the thickest and outermost stalks of celery will help prevent wilting. A dull knife will not make a clean cut through the vascular bundles and may contribute to color leaking.*

• Copy Student Page: "Up, Up and Away: Lab Sheet" for each student.

• Copy Student Page: "Disease of an American Chestnut Tree" for each student.

• Mix a small amount of water and 4 or 5 drops of food coloring in a beaker to use for the capillary action demonstration. *Note: The food coloring is for a better visual effect.*

• Retrieve a paper towel for the capillary action demonstration.

Day 2:

• Set-up a computer and projector for showing photos of cankers.

• Copy Student Page: "Up, Up and Away Worksheet" for each student.

• Copy Student Page: "Capillary Action and

Chestnut Blight Vocabulary Match" for each student.

- Copy Student Page: "American Chestnut Disease Word Search" for each student if additional homework or class work is desired.

DOING THE ACTIVITY

Day 1

1. Begin class by discussing capillary action. Grab the students attention by spilling a small puddle of colored water on a counter or desk and dipping the end of a paper towel in the water. Ask the students to describe what they see. Explain capillary action and how it relates to plants and trees like the American chestnut.

2. Discuss what a fungus is and how it affects the American chestnut tree. Use the background information provided to assist you.

3. Explain to the students that they are going to conduct an experiment to see how capillary action works. Set-up the celery experiment "Up, Up and Away" using the Student Page "Up, Up and Away Lab Sheet."

- Beaker/jar preparation-- Add 100 mL of water and 10 drops of blue food coloring to each jar/beaker. Label each jar/beaker with masking tape (Control, Test 1, Test 2, and Test 3).

- Control - Set up a control experiment. Cut one inch off of the bottom of a piece of celery and place it in the jar/beaker of blue water labeled "Control."

- Test 1-- Cut 2 1/2 cm (about 1 in) off of the bottom of a second stalk of celery. Also cut a notch about 16 cm (6 in) up the stem (see illustration). *Note: Make sure each notch successfully severs some of the vascular bundles in the celery stalk. You may want to inspect each groups celery before the class period is over.* Using modeling clay to represent the blight canker, cover the notch. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar/beaker of blue water labeled "Test 1."

- Test 2 - Cut 2 1/2 cm (about 1 in) off of the bottom of a third stalk of celery. On this stalk cut three notches, 2 notches on one side 5 cm apart (about 2 in) and one notch on the other side. Cut the lowest of the three notches about 16 cm (6 in) up the stem. Cover each with a clay blight canker. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar or beaker of blue water labeled "Test 2."

- Test 3--Cut 2 1/2 cm (about 1 in) off of the bottom of a fourth stalk of celery. On this stalk, girdle the entire outer surface by cutting a 1 to 1 1/2 cm (~1/2 in) wide strip of celery away from the rest of the stalk about 16 cm (6 in) up the stem (see illustration). This cut should be deep enough to remove all or most of the vascular bundles, but not deep enough to cut through the stalk. Ask your teacher for assistance if you are having trouble. Cover the girdle with a clay blight canker. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar/beaker of blue water labeled "Test 3." *Note: Make sure most if not all of the vascular bundles are removed from the entire surface (including edges). You may want to inspect each groups celery before the end of the class period.*

- For best results, set up several of these in early morning and make observations throughout the day. Observe one the next day.

- Have each student write down a hypothesis on his/her "Up, Up and Away Lab Sheet." You may want to briefly explain that a hypothesis is a statement of prediction, proposed explanation or educated guess that scientists use to predict the outcome of an experiment. Ask them "What do you think is going to happen to each stalk of celery." Explain that tomorrow we will make some observations.

Day 2

1. Have the students complete the activity page as they observe the experiment.

2. Discuss the spread of the blight from the background information. Show the students pictures of cankers via the projector and reference the lab and notched celery--cankers halt capillary action in trees.

- Follow-up questions could include: *How does the chestnut blight fungus kill chestnut trees? Explain girdling? Why might someone inten-*

tionally girdle a tree? What do you think the American Chestnut Foundation is doing to bring back the American chestnut tree? These last few questions can be used to segue into a field trip to a chestnut breeding orchard. Note: Chestnut trees can be partially girdled to increase fruit production. Undesirable trees can be girdled to kill them for management purposes or to create wildlife habitat (snags).

3. Have the students complete Student Page: "Capillary Action and Chestnut Blight Review Questions." These can be completed in class or for homework depending on time.

4. Have the students complete the optional Student Page: "Capillary Action and Chestnut Blight Vocabulary Match" for homework. Student Page: "American Chestnut Disease Word Search" can be completed by the students in class or for homework if additional practice materials are needed.

EXTENSION

• Schedule a field trip to one of the Pennsylvania Chapter of the American Chestnut Foundation's many chestnut breeding orchards. Students will be able to see first-hand what a canker looks like! PA-TACF has been breeding chestnut trees since 1994. Since then over 50,000 chestnut trees have been planted in Pennsylvania, New Jersey, Maryland, and Delaware. A map of the chestnut breeding orchards is included on the CD and additional information regarding this map and chestnut breeding can be found in Lesson 5: Chestnut Genetics and associated supplemental materials (also on the CD).

SUGGESTED "WORDS TO LEARN:"

Adhesion	Hyphae
Blight	Hypothesis
Canker	Meniscus
Capillary action	Mudpacking
Cohesion	Spore
Fungus	Surface tension
Girdling	Vascular tissue/bundles

ANSWER KEY

Student Page: "Up, Up and Away Lab Results"

Control -- Students should see each colored vascu-

lar bundle after cleanly slicing through the stalk of celery. If leaves are present and the celery has sat in the blue water overnight, the leaves should be blue.

Test 1 -- Students should see blue vascular bundles on the lower portion of the notch. The upper portion should still be green. After cleanly slicing the end off of the celery stalk, only the vascular bundles on the non-notched side of the celery should be blue.

Test 2 -- Students should see blue vascular bundles on the lower portion of the lowest two notches. The upper portions of each notch should have green vascular bundles. After cleanly slicing the end off of the celery stalk, only green vascular bundles should be visible unless the notching process did not successfully "girdle" all vascular bundles.

Test 3 -- Students should be able to see blue vascular bundles on the lower portion of the girdle. The upper portion of the girdle should have green vascular bundles. After cleanly slicing the end off of the celery stalk, only green vascular bundles should be visible unless the girdling process did not successfully remove all of the vascular bundles.

Student Page: "Capillary Action and Chestnut Blight Review Questions"

1. Movement of water within spaces of porous material due to forces of adhesion, cohesion, and surface tension. Examples include: paper towel soaking-up liquid, tear ducts, moisture-wicking synthetic fabric clothing, and plant roots transporting water and nutrients.

2. An organism that feeds on other living or dead organisms and reproduces via spores. In the case of the chestnut blight, the fungus gets its food from the trees and kills the tree in the process.

3. Fungi reproduce via spores. Spores are microscopic sized, typically one-celled reproductive units produced by fungi that spread through the air; like a seed, a spore allows a new organisms to begin developing when it reaches proper growing conditions.

4. The fungal spores are transferred from tree to tree by birds, insects, water and the wind.

5. The fungus forms an orange colored canker

(blister) on the surface of the tree. Girdling is the process by which the living connection between the roots and the leaves is severed. The blight fungus encircles a portion of a tree and plugs the vascular tissue or cambium with hyphae, thus girdling the tree.

6. Answer wording will vary.

Student Page: "Capillary Action and Chestnut Blight Vocabulary Match"

1. c

2. j

3. f

4. m

5. e

6. l

7. b

8. k

9. a

10. h

11. d

12. g

13. i

Student Page: "American Chestnut Disease Word Search"

See Appendix B for answer key.

REFERENCES

American Forest Foundation. nd. Project Learning Tree: Exploring Environmental Issues -- Focus on Risk. Biotechnology Supplement.

Carroll County Public Schools. 2010. Restoration of the American Chestnut Tree Curriculum. Carroll County, Maryland.

The American Chestnut Foundation. 1999. A Tree on the Rebound: Featuring Charlie Chestnut, Star of "The Life and Times of Charlie Chestnut." American Chestnut Foundation New York State Chapter, Buffalo, NY.

United States Geological Survey (USGS). nd. Capillary Action. Accessed online February, 27, 2014: http://water.usgs.gov/edu/capillaryaction.html.
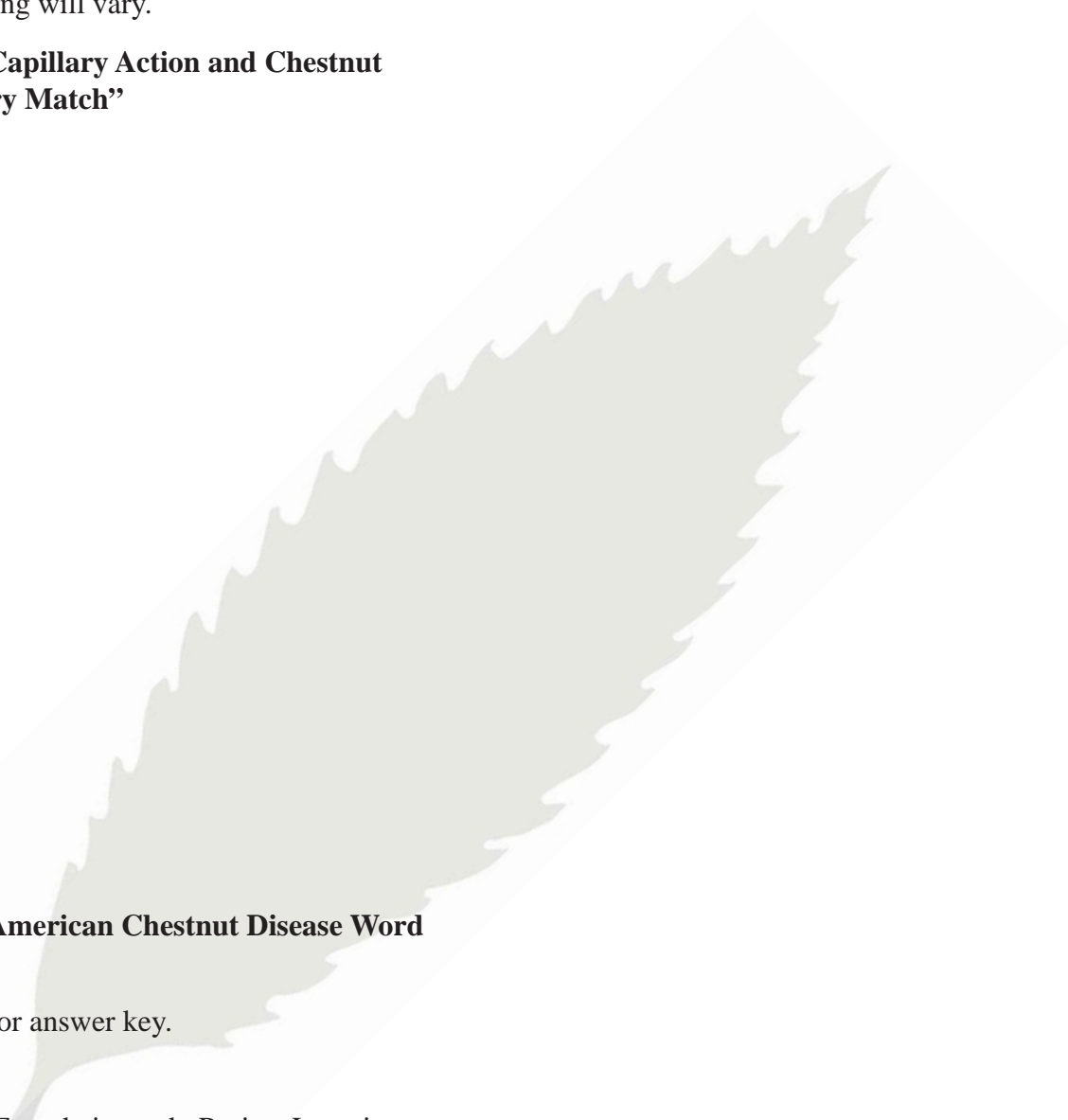
Disease of an American Chestnut Tree

Diseases are caused by bacteria, viruses, fungi, and other agents. The chestnut blight is caused by a fungus. A **fungus** is an organism that feeds on other living or dead organisms and reproduces via spores. The fungal **spores** are transferred from tree to tree by birds, insects, and the wind. Once the fungus begins to grow in the cracks of the bark, it forms an orange colored **canker** (blister) on the surface. Below the bark surface, thread-like strings called **hyphae** penetrate the vascular tissue. Similar to plant roots, fungi grow hyphae to acquire nutrients from plants and dead animals. The **vascular tissue** is what allows water and mineral nutrients to move from roots to leaves and transfer manufactured food to other parts of the tree. When the hyphae plug the vascular tissue, the tree begins to die. **Girdling** is the process by which the living connection between the roots and the leaves is severed. Usually this occurs by cutting or chopping away the outer bark and the inner bark or cambium (growing layer). However, in this case, the blight fungus encircles a portion of a tree and plugs the vascular tissue with hyphae. At first, only a few small branches show the effect of this choking process; eventually the entire tree dies.

Because the fungus is prevented from growing below ground by other organisms growing in the soil, American chestnut tree roots continue to send up new stem growth each year, even after it has been attacked. As a result of learning this, tree scientists cover small cankers above ground with mud. This process to prevent the spread of the disease is called **mudpacking**. However, to cover an entire tree with mudpacks is not practical. Breeding and other methods are currently being researched by The American Chestnut Foundation® to give the American chestnut tree the tools to defend itself from the chestnut blight.

Up, Up and Away: Lab Sheet

What to use:

- Four beakers or jars
  Four stalks of celery
- Blue food coloring
- Plasticine or modeling clay
- Paper towel

- Masking tape
- Pen or marker
- Sharp knife or scalpel
- Colored pencils or markers

1. Beaker/jar preparation-- Add 100 mL of water and 10 drops of blue food coloring to each jar/beaker. Label each jar/beaker with masking tape and a pen or marker (Control, Test 1, Test 2, and Test 3).

2. Control - Set up a control experiment. Cut 2 1/2 cm (about 1 in) off of the bottom of a piece of celery and place it in the jar/beaker of blue water labeled "Control."

3. Test 1 - Cut 2 1/2 cm (about 1 in) off of the bottom of a second stalk of celery. Also cut a notch about 16 cm (6 in) up the stem (see illustration). Make sure each notch successfully severs some of the vascular bundles in the celery stalk. Using modeling clay to represent the blight canker, cover the notch. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar/beaker of blue water labeled "Test 1."
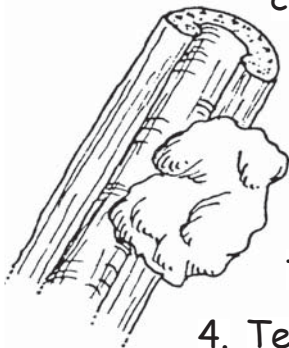
4. Test 2 - Cut 2 1/2 cm (about 1 in) off of the bottom of a third stalk of celery. On this stalk cut three notches, 2 notches on one side 5 cm apart (about 2 in) and one notch on the other side. Cut the lowest of the three notches about 16 cm (6 in) up the stem. Cover each with a clay blight canker. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar or beaker of blue water labeled "Test 2."

5. Test 3 - Cut 2 1/2 cm (about 1 in) off of the bottom of a fourth stalk of celery. On this stalk, girdle the entire outer surface by cutting a 1 to 1 1/2 cm (about 1/2 in) wide strip of celery away from the rest of the stalk about 16 cm (6 in) up the stem (see illustration on the next page). This cut should be deep enough

Up, Up and Away: Lab Sheet cont.

to remove all or most of the vascular bundles, but not deep enough to cut through the stalk. Ask your teacher for assistance if you are having trouble. Cover the girdle with a clay blight canker. If the clay does not stick, you may need to dry that portion of the celery with a paper towel. Place the stalk in the jar/beaker of blue water labeled "Test 3."
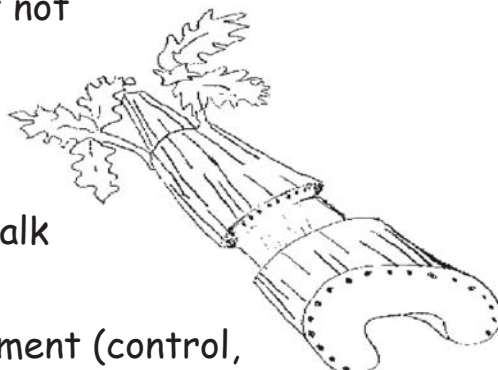
1. Write a hypothesis for each part of the experiment (control, Test 1, Test 2, and Test 3) below. What do you expect to happen to each part of the experiment?

Control:

Test 1:

Test 2:

Test 3:

Up, Up and Away Worksheet

The "strings" in celery are called vascular bundles. **Vascular bundles** are specialized strands of vascular tissue. They carry water and nutrients up the stem to the leaves. This same process happens in trees. The purpose of this experiment is to observe the flow of water up the stem when the stem is damaged (notched or girdled). This damage is the model of how the blight damages American chestnut trees. Try it for yourself and see what happens.

Directions:

1.   The day after you set up the experiment, draw how the celery looks in each beaker. Be sure to color your drawings.
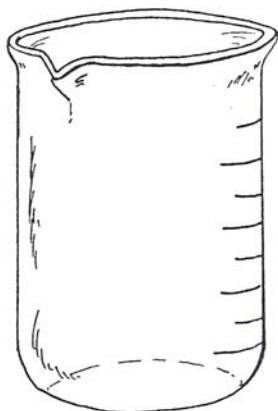
| Control | Test 1 | Test 2 | Test 3 |
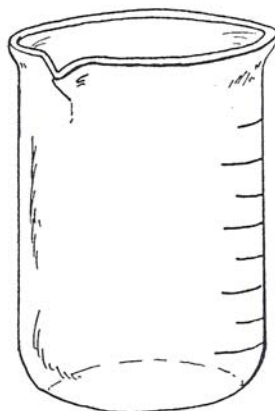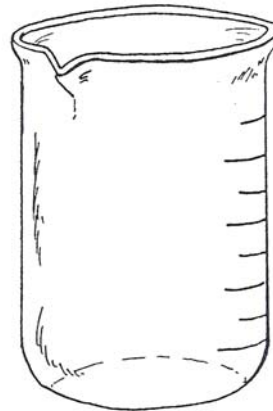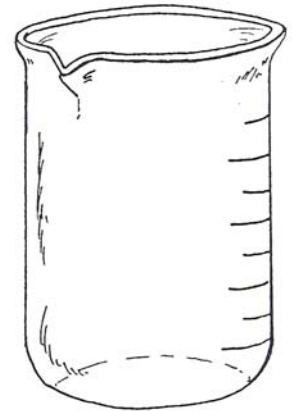
Up, Up and Away Worksheet cont.

Directions:

2.   Carefully remove one stalk of celery at a time. Observe how the blue liquid has traveled up the stem.

Control -- Make a slice at 16 cm (6 in) up the stem. Using colors, draw what you see on the celery cut surfaces.
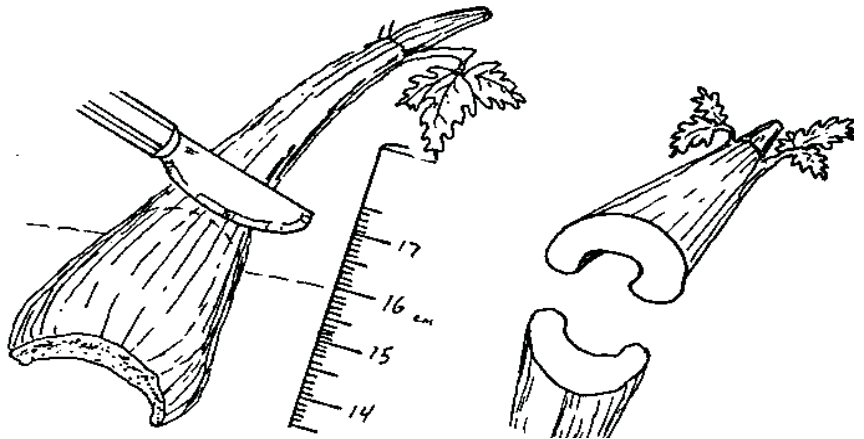
Test 1 -- Remove the clay.
Slice the celery 1 cm below and above the notch. Record your observations by drawing what you see on the cut celery surfaces. What do you think happened?
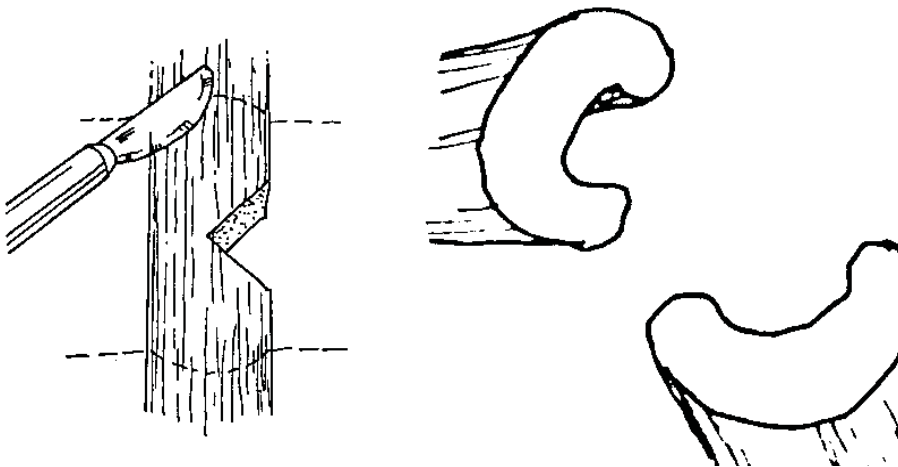
Test 2 -- Remove the clay. Slice the celery 1 cm above and below the notches. Record your observations by drawing what you see in the chart on the next page.

Up, Up and Away Worksheet cont.

Test 3 -- Remove the clay. Slice the celery 1 cm above the girdled area. Record your observations by drawing what you see in the chart below.

Three Notches	Girdle
Below notches Above notches	

Capillary Action and Chestnut Blight Review Questions

1. Explain capillary action and give one everyday example of it.

2. What is a fungus?

3. How does the chestnut blight fungus reproduce?

4. Name four ways that the chestnut blight fungus spreads to other trees?

    1. _____   2. _____

    3. _____   4. _____

Capillary Action and Chestnut Blight Review Questions cont.

1. How does the chestnut blight fungus kill chestnut trees? Be sure to explain the canker and girdling.

2. Complete the following concept circle with what you have learned. Use all four words in two sentences or less to define the words and show that you understand what they mean.

Capillary Action and Chestnut Blight Vocabulary Match

Directions: Match the words with their definitions.

1. Adhesion   _____   a. The curved upper surface of a liquid in a tube.

2. Blight   _____   b. Cutting off the transportation of nutrients from the roots to the canopy of a tree.

3. Canker   _____   c. The attractive forces between unlike molecules (of different substances).
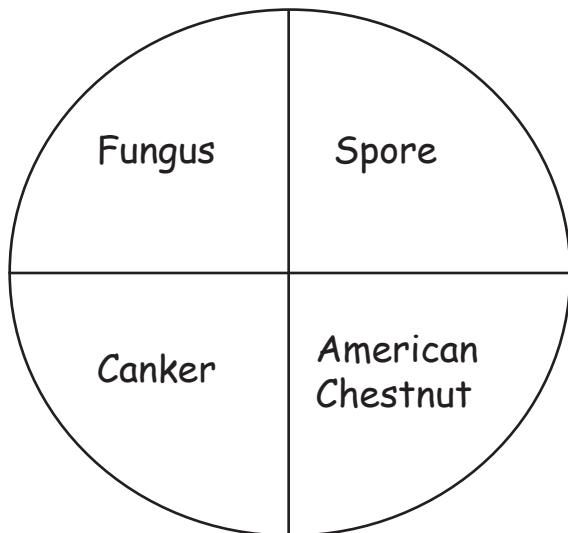
4. Capillary action _____   d. A microscopic-sized, typically one-celled reproductive unit produced by fungi that spread through the air.

5. Cohesion   _____   e. The attractive forces between like molecules (of the same substance).

6. Fungus   _____   f. Dead area or blister on the bark, branch or trunk of an infected tree caused by a fungus.

7. Girdling   _____   g. Property of the surface of a liquid that allows it to resist an external force.

8. Hyphae   _____   h. Covering a canker with mud.

9. Meniscus   _____   i. Allows water and mineral nutrients to move from roots to leaves and transfer manufactured food to other parts of the tree.

10. Mudpacking   _____   j. A plant disease generally caused by fungi.

11. Spore   _____   k. Thread-like fungal strands; similar to plant roots, fungi grow these structures to acquire nutrients from plants and dead animals.

12. Surface tension   _____   l. An organism that feeds on other living or dead organisms and reproduces via spores.

13. Vascular tissue   _____   m. The movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

American Chestnut Disease Word Search

Directions: Look at the word list provided. Find each word in the letter box. Each word may go up, down, and diagonal; or it may read forward or backward.

```
I Q X O K J S C I V X V F U N D E T
L F G F C F S N O I S E H D A O R N
C O H E S I O N E D O I B V M J O A
D W X R A E C Z M T C N L K I A P S
K N O I T C A Y R A L L I P A C S I
C A N K E R H M Q C G F A E X E D S
F H R I C H L K A N E P V E P T E E
A U A M C P D C I Z Y M C A Y W K H
T J N X R F W L X C P Y I H Q T U T
X H U G B I D F O D G J V P G V N O
O M I U U R Z B Q H C M I Y C Z I P
N L U V I S S H Q E Q S C H D Z V Y
B L I G H T Y I V F K Q C M P K V H
G N I K C A P D U M Y P P P X R K N
S U R F A C E T E N S I O N A R W D
Y M E V H T O S B J I U I Y Z I N L
```

Words to find:

SURFACE TENSION	ADHESION
MENISCUS	BLIGHT
CAPILLARY ACTION	GIRDLING
HYPHAE	MUDPACKING
CANKER	FUNGUS
HYPOTHESIS	SPORE

OVERVIEW

This lesson looks at the spread and speed of the chestnut blight in the eastern United States and Pennsylvania. It also answers the question: how and why do some American chestnut trees survive longer than others?

OBJECTIVES

Students will be able to:
• Calculate speed in relation to how fast the chestnut blight spread.
• Explain why some American chestnut trees survive longer than others.
• Define speed and American chestnut survival vocabulary words.

PENNSYLVANIA CORE STANDARDS

Science & Technical Subjects: CC.3.5.6-8.D; English Language Arts: CC.1.2.6.G; Mathematics: CC.2.1.6.D.1, CC.2.1.6.E.2

PENNSYLVANIA STANDARDS

Environment and Ecology: 4.3.6.C, 4.3.7.C; Mathematics: 2.1.8.C, 2.2.6.B; Geography: 7.1.6.B, 7.1.7.B, 7.1.8.B; Reading, Writing, Speaking and Listening: 1.6.6.A, 1.6.7.A, 1.6.8.A

LEVEL: Grades 6-8

5Es: Engage, Explore, Explain, Evaluate

TIME CONSIDERATIONS:
Part A: Two 50-minute periods.
Part B: One 50-minute period.

MATERIALS:
For the class: One computer, a projector, an overhead transparency projector; CD with "Spread of the Chestnut Blight Fungus" map and "Pennsylvania Chestnut Blight Spread" map and photos (CD Presentation).

For each group: Copies of Student Pages "Description of American Chestnut Distribution" (numbers 1-5), 5 transparencies containing Student Page "Map of the Central and Eastern United States" and one colored marker. Yellow, orange, red, green, and blue are recommended.

For each student: Copies of Student Pages "Why Do Some American Chestnuts Survive?" "American Chestnut Survival Reading Questions," "Finding the Speed of the Blight," and "Speed of the Blight Crossword Puzzle;" Copies of "Spread of the Chestnut Blight Fungus" map (on CD) if not using computer projector.

BACKGROUND

Definition of Speed

Speed is an expression of the rate at which an object moves relative to a frame of reference. When you are calculating an average speed of something, you are assuming that the object is moving at a rate relative to a stationary place.

For example, the speed of a car is the rate at which the car is moving assuming that the road is stationary (not moving), even though technically the road is moving with the Earth.

Physics Formula for Speed

The math formula for speed is distance divided by time. In other words, the average speed or how fast something is moving is the distance it has travelled divided by the time it takes to travel.

$$AVERAGE\ SPEED = \frac{DISTANCE}{TIME}$$

For example, the average speed at which a girl swims is given by the distance she swam divided by the time it took her to swim that distance. If the girl swims 100 meters in 62 seconds, her average speed is 1.61 m/s.

Speed is scalar

When calculating average speed, note that speed is a scalar quantity and not a vector quantity. Scalars are quantities that are fully described by a magnitude (or numerical value) alone and are non-directional. Vectors are quantities that are fully described by both a magnitude and a direction. For example, the speed at which a car is moving East at 8 meters per second is the same as the speed at which the same car is moving West at 8 meters per second.

Examples: 5 m/s = scalar; 5 m/s East = vector

What is the SI Unit for speed?

The standard international unit for

speed is meter per second or m/s. That means when calculating average speed, measure the distance travelled in meters and measure the time taken to travel that distance in seconds then divide the distance travelled in meters by the time taken to travel that distance in seconds and there you have the average speed.

Spread of the Blight

The chestnut tree fungus first arrived in the United States in the mid- to late- 19th Century. By 1950, the blight had spread across the natural growing range of the tree. The blight rampaged through the forests, spreading 30 to 80 kilometers (20 to 50 miles) per year, killing nearly every chestnut in its path. Within decades, an estimated four billion trees were killed by the blight as it spread throughout the eastern United States.

In southeastern Pennsylvania, by 1911, the disease affected a very high percentage of the chestnut trees, large and small. In Bucks, Montgomery, Chester, Delaware, and Philadelphia Counties alone, an estimated 80% of American chestnuts were infected by the blight fungus. The documented extent of blight infection in Pennsylvania in 1911 can be viewed on the Pennsylvania Blight Progress Map (on CD). The boundary can be approximately shown by drawing a line across the state from Susquehanna, in Susquehanna County, southwest to Waterville, in Lycoming County, then to Orbisonia, in Huntingdon County, and southward along the Tuscarora Mountains in Fulton County. West of this line there were a few isolated infections. By 1930, the chestnut blight had encompassed all of Pennsylvania.

Why Do Some American Chestnuts Survive?

The American chestnut grew to be a large tree before the chestnut blight devastated the extensive natural stands in the Appalachian region. Today, only a few large trees remain in scattered locations throughout the region and most other American chestnuts only survive as shrubby sprouts. Typically these sprouts are extensively infected with the chestnut blight and show various degrees of dieback in the crown and bole due to this infection. American chestnut survivors that grow large enough to produce nuts/seed are called 'Parent trees.' These trees provide a source of native germplasm (living tissue from which new plants can be grown). Scientists can preserve this germplasm to help guarantee that the genetic background (mostly adaptability and genetic diversity) of trees currently living in our forests, will be conserved for future generations.

Research is ongoing to determine why a few of these trees survive to maturity, while many others succumb to the chestnut blight and die at a younger age. Topography (arrangement of the natural and artificial physical features of an area), moisture, temperature, wind speed, presence and density of the host (an organism that harbors a parasite), and people transporting infected American chestnut material all play roles in how fast the blight spreads or doesn't. Primarily, there are three main reasons why some infected American chestnut trees survive for longer periods of time: luck or random chance, genetic resistance, and hypovirulence.

Luck is the predominant reason why some of these trees have survived. The longer a tree lives and is exposed to the fungal spores of the blight fungus, the higher the probability (the relative frequency with which an event occurs or is likely to occur) that the tree will become infected.

Secondly, genetic resistance is some type of genetic predisposition that would make an organism less likely to die from a condition. Genetic resistance to chestnut blight occurs naturally in populations of chestnut trees.

Finally, a naturally existing form of biological control called hypovirulence is helping to keep some of the trees alive longer. Hypovirulence is a phenomenon where the chestnut blight fungus is attacked naturally in the field and weakened by a virus. Think of it as the chestnut blight getting sick -- just like viruses attack humans and make us sick. This virus weakens and slows down chestnut blight disease by reducing the pathogenicity (virulence or aggressiveness) of the fungus. Scientists are currently researching natural genetic resistance and hypovirulence as means to restore the American chestnut. This phenomenon has also inspired great poetry:

Evil Tendencies Cancel

Will the blight end the chestnut?

The farmers rather guess not.

It keeps smoldering at the roots

And sending up new shoots

Till another parasite

Shall come to end the blight.

 - *Robert Frost, 1936*

PART A:

GETTING READY

Day 1

- Set-up a computer and projector to show the "Spread of the Chestnut Blight Fungus" and "Pennsylvania Chestnut Blight Spread" maps (from CD) OR make color copies for each student or group of students.

- Retrieve five transparency markers. Yellow, orange, red, green and blue are recommended.

- Print 5 copies of the Student Page "Map of the Central and Eastern United States" on transparency sheets.

- Print one copy per group of Student Pages "Description of American Chestnut Distribution" (numbers 1-5).

Day 2

- Set-up a computer and projector to reference the "Spread of the Chestnut Blight Fungus" map (from CD) OR make color copies for each student or group of students. *Note: carryover from Day 1.*

- Set-up an overhead projector.

- Copy Student Page "Why Do Some American Chestnuts Survive?" for each student.

- Copy Student Page "American Chestnut Survival Reading Questions" for each student.

DOING THE ACTIVITY

Day 1

1. Review what the chestnut blight is by asking students to recall details from the previous lesson: *What is a blight? Where did it originate? How did it affect the American chestnut?*

- Discuss the blight and where it was first discovered: The disease was first discovered in 1904 in the Bronx Zoological Gardens in New York City. You may use the "Spread of the Chestnut Blight Fungus" map (file on CD) as well as the "Pennsylvania Chestnut Blight Spread map" (presentation on CD) to help explain the disease progression.

1. Divide the class into five groups. Explain that each group will create an overhead transparency about the distribution of the American chestnut population at a different point in history.

2. Give each group a transparency copy of Student Page "Map of the Central and Eastern United States," and a copy of Student Page "Description of American Chestnut Distribution (numbers 1-5) to record onto their transparency map.

3. Display the "Spread of the Chestnut Blight Fungus" map (enclosed on CD) for students to refer to during the activity. After students have completed their paper map, they will transfer the outline of the American chestnut range and distribution onto an overhead transparency containing a pre-printed map of the United States.

4. Members of the group with the oldest data set should color in their distribution range with the lightest color of overhead marker. The marker colors for each group should get progressively darker with more recent data sets so that the distribution range will show up clearly when the transparencies are laid one on the other.

5. When all five groups are finished making their transparencies, explain that tomorrow we will introduce and show the progression of the fungal infection.

Day 2

1. Yesterday we created overhead transparencies to model the distribution of the American chestnut at different points in history. Introduce and show the progression of the fungal infection that decimated the American chestnut population by laying the oldest transparency on the projector and then covering it with a more recent set of data until the current distribution is laid on the stack. Have the last group explain what happened by 1950. *Note: Group 5's activity sheet and observations will help segue into a short discussion on why some trees survive the blight.*

2. Engage the students in a conversation to discuss the speed of this population's decline to see if they understand the contributing factors. *How fast did the blight travel? Are there areas that survived the blight? Why do you think some trees survived?* This is a great time to briefly introduce the concepts of genetic resistance and

hypovirulence and show some photos of Parent trees.

3. To reinforce the discussion information, handout copies of "Why Do Some Chestnuts Survive?" to each student to silently read. Students could also take turns reading aloud.

4. Discuss the reading and have students use the "Why Do Some Chestnuts Survive?" to answer questions from Student Pages "American chestnut Survival Reading Questions." This handout could also be completed for homework.

5. Tomorrow we will learn about speed and how to calculate how fast the chestnut blight spread.

PART B:

GETTING READY

- Secure a whiteboard, chalk board or interactive white board to use for presenting speed material.
- Copy Student Pages "Finding the Speed of the Blight" and "American Chestnut Tree Disease Word Search" for each student.

DOING THE ACTIVITY

1. Yesterday we looked at the chestnut blight progression in the eastern United States and posed the question "how fast did the blight travel?"

2. Explain that we will use the speed formula to find the speed and the average speed of the blight. "Before we begin, let's learn more about speed."

3. Show the students the formula for calculating speed and use the background materials to explain speed, scalar vs. vector and the standard international unit for speed.

4. Have the students complete some practice problems as a class. Tell them that they may use a calculator. Below are some examples:

- *If you drive a distance of 400 miles in 8 hours, what is your speed? Answer = 50 miles/hour*

- *If you have walked 2 miles in 20 minutes, how fast were you walking in miles/minute? Answer = .1 miles/minute*

- *Try converting both of the answers to SI units. 1 mile = 1609.34 meters; 1 hour = 3600 seconds.*

5. Using the measurements for the spread of the blight, calculate the speed at which the blight

spread. Students can complete questions using the speed formula on the Student Page "Finding the Speed of the Blight."

- *Note: Due to climate differences, topography, and smaller more isolated populations of American chestnut in New England, this activity is based on rough average distances to the south and west of the blight origin location.*

6. Wrap-up by reviewing blight and speed. Have the students complete the Speed of the Blight Crossword Puzzle or use the exercise as a homework assignment.

EXTENSION

- Write to the Pennsylvania Chapter of the American Chestnut Foundation to find out what kinds of research they are conducting to bring the American chestnut back to Pennsylvania forests.

- Talk with your class about the spread of disease and how a virus or other disease can spread through a population. Use the popular Sodium Hydroxide and Phenolphthalein Solution experiment to demonstrate this. This experiment can be found by Googling these terms online.

SUGGESTED "WORDS TO LEARN:"

Adaptability	Parent tree
Blight	Pathogenicity
Bole	Probability
Crown	Scalar
Genetic diversity	Speed
Genetic resistance	Standard International
Host	Unit
Hypovirulence	Topography
Germplasm	Vector

ANSWER KEY

Student Page: "Why Do Some Large American Chestnuts Survive?"

1. American chestnut survivors that grow large enough to produce nuts/seed.

2. Germplasm; Scientists can preserve germplasm to help guarantee that the genetic background (adaptability and genetic diversity) of trees currently living in our forests, will be conserved for future generations.

3. Pathogenicity

4. Luck, genetic resistance and hypovirulence; Luck is the predominant reason why some of these trees have survived; Genetic resistance is a type of genetic predisposition that makes the American chestnut less likely to die from a condition like the chestnut blight. Hypovirulence is a phenomenon where the chestnut blight fungus is attacked and weakened by a virus. This virus weakens and slows down chestnut blight disease by reducing the pathogenicity (virulence or aggressiveness) of the fungus.

Student Page: "Finding the Speed of the Blight"

1. 53/5 = 10.6 miles/year

2. 188/10 = 18.8 miles/year

3. 394/26 = 15.154 miles/year

4. 761/36 = 21.139 miles/year

5. 956/46 = 20.783 miles/year

Student Page: "Speed of the Blight Crossword Puzzle"

See Appendix B for answer key..

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Map of the Central and Eastern United States

Group #1 Description of American Chestnut Distribution

Data set for chestnut distribution in 1880:

The areas of the eastern United States where the American chestnut could be found free of blight in 1880 are listed below. Use these data to create a yellow-colored distribution map. Label the map "American Chestnut Distribution before 1880."

Maine--southern quarter of the state

New Hampshire--southern quarter of the state

Vermont--southern quarter of the state

Massachusetts--entire state

Connecticut--entire state

Rhode Island--entire state

New York--southern two-thirds of the state

Pennsylvania--entire state

New Jersey--entire state

Delaware--entire state

Maryland--northern three-quarters of the state

Virginia--western third of the state

West Virginia--entire state

Ohio--eastern half of the state

Indiana--southeastern fifth of the state

Kentucky--eastern half of the state

Tennessee--eastern three-quarters of the state

North Carolina--western third of the state

South Carolina--western quarter of the state

Georgia--northern quarter of the state

Alabama--northern third of the state

Mississippi--northeastern quarter of the state

Group #2 Description of American Chestnut Distribution

Data set for chestnut distribution in 1909:

The areas of the eastern United States where the American chestnut could be found free of blight in 1909 are listed below. Use these data to create an orange-colored distribution map. Label the map "American Chestnut Distribution in 1909."

Maine--southern quarter of the state

New Hampshire--southern quarter of the state

Vermont--southern quarter of the state

Massachusetts--entire state

Connecticut--eastern three-quarters of the state

Rhode Island--entire state

New York--southwestern third of the state

Pennsylvania--entire state

New Jersey--north western quarter and southern half of the state

Delaware--entire state

Maryland--northern three-quarters of the state

Virginia--western third of the state

West Virginia--entire state

Ohio--eastern half of the state

Indiana--southeastern fifth of the state

Kentucky--eastern half of the state

Tennessee--eastern three-quarters of the state

North Carolina--western third of the state

South Carolina--western quarter of the state

Georgia--northern quarter of the state

Alabama--northern third of the state

Mississippi--northeastern quarter of the state

Group #3 Description of American Chestnut Distribution

Data set for chestnut distribution in 1914:

The areas of the eastern United States where the American chestnut could be found free of blight in 1914 are listed below. Use these data to create a red-colored distribution map. Label the map "American Chestnut Distribution in 1914."

Maine--southern quarter of the state

New York--western quarter of the state

Pennsylvania--western third of the state

Delaware--southern half of the state

Virginia--western third of the state

West Virginia--entire state

Ohio--eastern half of the state

Indiana--southeastern fifth of the state

Kentucky--eastern half of the state

Tennessee--eastern three-quarters of the state

North Carolina--western third of the state

South Carolina--western quarter of the state

Georgia--northern quarter of the state

Alabama--northern third of the state

Mississippi--northeastern quarter of the state

Group #4 Description of American Chestnut Distribution

Data set for chestnut distribution in 1930:

The areas of the eastern United States where the American chestnut could be found free of blight in 1930 are listed below. Use these data to create a green-colored distribution map. Label the map "American Chestnut Distribution in 1930."

Virginia--southwestern quarter of the state

West Virginia--western two-thirds of the state

Ohio--most of eastern half of the state minus a small section along the entire border of Pennsylvania

Indiana--southeastern fifth of the state

Kentucky--eastern half of the state

Tennessee--eastern three-quarters of the state

North Carolina--western third of the state

South Carolina--western quarter of the state

Georgia--northern quarter of the state

Alabama--northern third of the state

Mississippi--northeastern quarter of the state

Group #5 Description of American Chestnut Distribution

Data set for chestnut distribution in 1940:

The areas of the eastern United States where the American chestnut could be found free of blight in 1940 are listed below. Use these data to create a blue-colored distribution map. Label the map "American Chestnut Distribution in 1940."

Tennessee--Split the state in half and of the western half, the eastern quarter of that half of the state

Alabama--northern third minus a small area in the northeastern corner of the state

Mississippi--northeastern quarter of the state

Data set for chestnut distribution before 1950:

The progression of the chestnut blight in the eastern United States in 1950 is shown on the "Spread of the Chestnut Blight Fungus" map. By observing the map, what happened by 1950? Be prepared to explain to the class what happened. What do the black dots on the map mean? How do you think these trees survived?

Why Do Some American Chestnuts Survive?

The American chestnut grew to be a large tree before the chestnut blight devastated the extensive natural stands in the Appalachian region. Today, only a few large trees remain in scattered locations throughout the region and most other American chestnuts only survive as shrubby sprouts. Typically these sprouts are extensively infected with the chestnut blight and show various degrees of dieback in the crown and bole due to this infection. **American chestnut survivors that grow large enough to produce nuts/seed are called 'Parent trees.' These trees provide a source of native germplasm (living tissue from which new plants can be grown). Scientists can preserve this germplasm to help guarantee that the genetic background (mostly adaptability and genetic diversity) of trees currently living in our forests, will be conserved for future generations.**

Research is ongoing to determine why a few of these trees survive to maturity, while many others succumb to the chestnut blight and die at a younger age. **Topography (arrangement of the natural and artificial physical features of an area), moisture, temperature, wind speed, presence and density of the host (an organism that harbors a parasite), and people transporting infected American chestnut material all play roles in how fast the blight spreads or doesn't. Primarily, there are three main reasons why some infected American chestnut trees survive for longer periods of time: luck, genetic resistance, and hypovirulence.**

Luck is the predominant reason why some of these trees have survived. The longer a tree lives and is exposed to the fungal spores of the blight fungus, the higher the probability (the relative frequency with which an event occurs or is likely to occur) that the tree will become infected.

Secondly, **genetic resistance is some type of genetic predisposition that would make an organism less likely to die from a condition. Genetic resistance to chestnut blight occurs naturally in populations of chestnut trees.**

Finally, a naturally existing form of biological control called hypovirulence is helping to keep some of the trees alive longer. **Hypovirulence is a phenomenon where the chestnut blight fungus is attacked**

Why Do Some American Chestnuts Survive? cont.

naturally in the field and weakened by a virus. Think of it as the chestnut blight getting sick -- just like viruses attack humans and make us sick. This virus weakens and slows down chestnut blight disease by reducing the **patho-genicity (virulence or aggressiveness)** of the fungus. Scientists are currently researching natural genetic resistance and hypovirulence as means to restore the American chestnut. This phenomenon has also inspired great poetry:

Evil Tendencies Cancel

Will the blight end the chestnut?

The farmers rather guess not.

It keeps smoldering at the roots

And sending up new shoots

Till another parasite

Shall come to end the blight.

- Robert Frost, 1936

American Chestnut Survival Reading Questions

1. What is a Parent tree?

2. Parent trees provide a source of hereditary material called
   _____. What is the significance of this hereditary
   material?

3. _____ describes the virulence or aggressiveness
   of the fungus.

4. List three main reasons why some chestnut trees survive for longer periods
   of time.

   a. _____   b. _____

   c. _____

5. What factors might affect how fast the blight spreads? List 5. If you
   need more space, use the back of this sheet.

Finding the Speed of the Blight

Directions: Using the speed formula, calculate the rate of speed for each question. Show your work. Use the blight lines found on the Flight of the Blight map. Round any decimals to the nearest thousandth if possible.

1. What was the speed of the blight by 1909? The distance from the starting point to the blight line is 53 miles. The blight started in 1904.

2. What was the speed of the blight by 1914? The distance from the starting point to the blight line is 188 miles. The blight started in 1904.

3. What was the speed of the blight by 1930? The distance from the starting point to the blight line is 394 miles. The blight started in 1904.

4. What was the speed of the blight by 1940? The distance from the starting point to the blight line is 761 miles. The blight started in 1904. Round your answer to the nearest thousandth.

5. What was the speed of the blight by 1950? The distance from the starting point to the blight line is 956 miles. The blight started in 1904. Round your answer to the nearest thousandth.

Speed of the Blight Crossword Puzzle
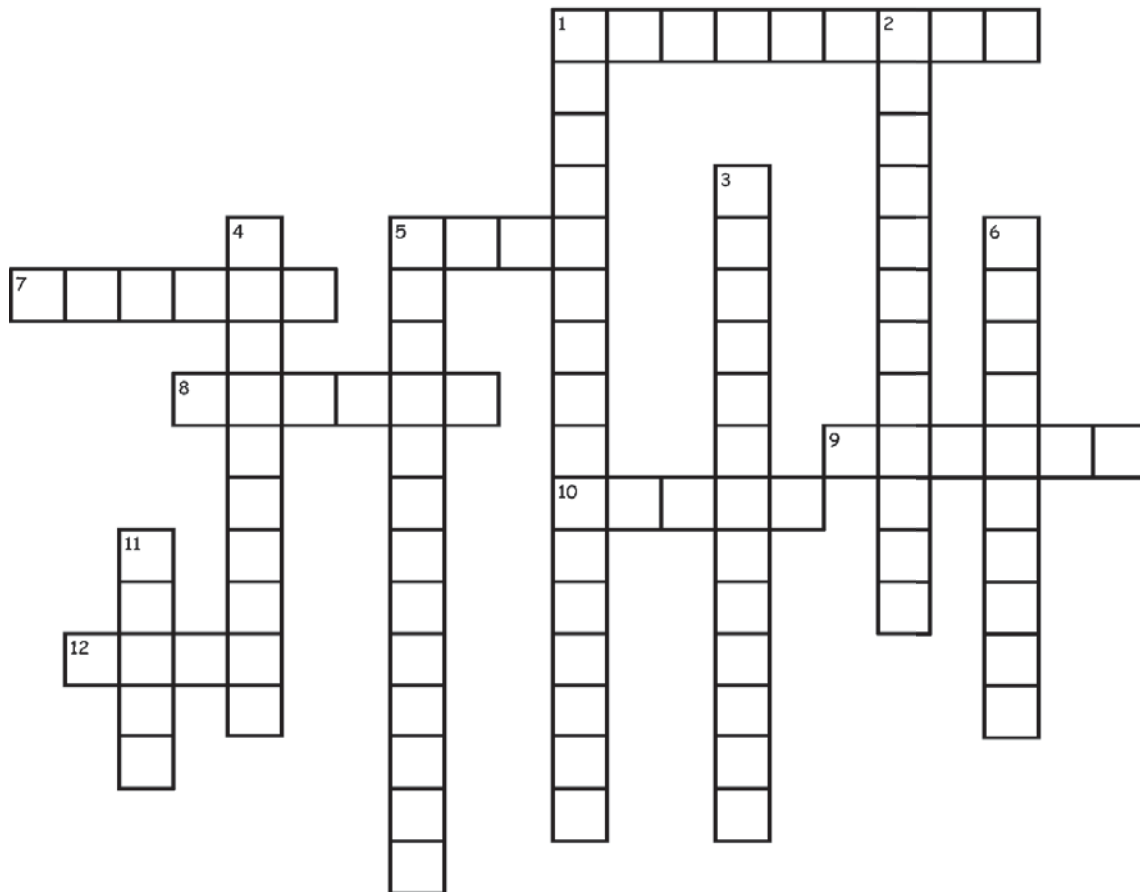
Across

1. Living tissue from which new plants can be grown.

5. An organism that harbors a parasite.

7. A one-dimensional or non-directional physical quantity that can be described with a magnitude or single number (e.g., 50 miles/hour).

8. Quantities that are fully described by both magnitude or single number and a direction (e.g. 25 meters/second, South).

9. A plant disease generally caused by fungi.

10. Distance divided by time.

12. Trunk of a tree.

Down

1. Some type of genetic predisposition that would make an organism less likely to die from a condition.

2. The ability to change (or be changed) to fit changed circumstances.

3. The virulence or aggressiveness of the fungus.

4. An American chestnut tree that grows large enough to produce nuts/seed.

5. A naturally existing form of biological control; virus disease of chestnut blight that weakens and slows down the chestnut blight disease by reducing the pathogenicity.

6. Arrangement of the natural and artificial physical features of an area.

11. Branches, leaves, and reproductive structures extending from the trunk or main stems of woody plants.

OVERVIEW

This lesson reviews Mendelian genetics and looks at a traditional breeding program employed to restore the American chestnut with a focus on the backcross breeding method.

OBJECTIVES

Students will be able to:
- Demonstrate and illustrate backcrossing by performing a mock genetic backcross.
- Complete Punnett Squares for single gene crosses.
- Predict phenotypic and genotypic probabilities and ratios for single gene crosses based on the Punnett Square.
- Explain how the backcross breeding method works and is helping to develop blight-resistant populations of American chestnut trees.
- Demonstrate how to graphically represent data collected in an experiment.

PENNSYLVANIA CORE STANDARDS

Science & Technical Subjects: CC.3.5.6-8.C, CC.3.5.6-8.D; Mathematics: CC.2.4.7.B.3

PENNSYLVANIA STANDARDS

Environment and Ecology: 4.3.6.C, 4.3.7.C; Science and Technology and Engineering Education: 3.1.7.B1, 3.1.7.B4; Mathematics: 2.1.8.C, 2.2.6.B; Reading, Writing, Speaking and Listening: 1.6.6.A, 1.6.7.A, 1.6.8.A

LEVEL: Grades 6-8

5Es: Engage, Explore, Explain, Extend, Evaluate

TIME CONSIDERATIONS:
Part A: 1 to 2 50-minute periods depending on the students' prior knowledge of basic Mendelian genetics.
Part B: 1 to 2 50-minute periods.

MATERIALS:
For the class: Interactive white board, white board, chalk board or overhead projector, one computer and projector, CD with "Backcross Breeding Program" chart and "An Introduction to the Backcross Breeding Method" presentation.

For each group: 50 to 100 mL beakers or containers (5 for each group); 1 large beaker or container for discarded beans; 2 kinds of dried beans; 1 paper plate.

For each student: Copies of Student Pages: "Punnett Square Problems," "Backcrossing of the American Chestnut Tree," "Bean There Done That -- Genetic Backcrossing of the American Chestnut," "Bean There Done That -- Genetic Backcrossing of the American Chestnut Review Questions," and optional "Genetics Vocabulary Match."

BACKGROUND

Genetics is the study of heredity or how traits are inherited (passed on) from parents to their children. Just as children inherit specific traits from their biological parents, trees also inherit genes from their parents. Examples of human traits include hair color, eye color, natural talents, and genetic disorders. Examples of tree traits include leaf shape, tree height, and risk for disease. A trait may not be observable, but its gene can be passed to the next generation. Traits are expressed by genes, which are small sections of DNA found on chromosomes. Humans have two sets of 23 chromosomes -- one set from each parent. Both American and Chinese chestnut have two sets of 12 chromosomes.

Mendelian Inheritance

In the 1800s, Gregor Mendel, known as "the father of genetics," discovered laws that govern how traits are passed from parents to offspring. Although Mendel studied heredity in plants, the basic underlying principles he discovered also apply to people and other animals.

As mentioned earlier, inherited traits are determined by genes that are passed from parents to children. A child inherits two sets of genes --one from each parent. Each gene comes in different variations, known as alleles, that express different traits. For example, a child inherits two genes for freckles, one from mom and one from dad.

- Allele from mom -- has freckles

(F)
- Allele from dad -- no freckles (f)
- Child has inherited the gene pair of alleles (Ff) -- has freckles since the freckles allele (F) is completely dominant over the no freckles allele (f).

Punnett Square

By studying genetics we can predict the likelihood of inheriting particular traits. Plant and animal breeders can use this knowledge to develop varieties that have desirable qualities, like blight-resistance in an American chestnut tree. It can also help people explain and predict patterns of inheritance in family lines.

To calculate the probability of inheriting a specific trait, we use a Punnett Square. The Punnett Square was invented by an early 20th century English geneticist named Reginald Punnett. This is a simple, graphical way of discovering all of the potential combinations of genotypes that can occur in offspring, given the genotypes of their parents.

Punnett Squares Example Problem and Steps

Complete Dominance

Complete dominance is a type of genetic relationship where the dominant gene completely masks the effect of the recessive gene in heterozygous condition. Heterozygous means having dissimilar pairs of genes for any hereditary characteristic (different). In pea plants, the gene for tall pea plants (T) is dominant over the gene for short pea plants (t). Capital letters represent dominant traits, and lowercase letters represent recessive traits.

$$T = tall \quad t = short$$

Using Punnett Squares, we can predict the genotypes and phenotypes of the offspring of a cross between a homozygous tall pea plant (TT) and a homozygous short pea plant (tt). Homozygous means having identical pairs of genes for any given pair of hereditary characteristics (same).

Step 1. Write down the genotypes of each parent.

$$TT \ X \ tt$$

Step 2. Draw a Punnett square - 4 small squares in the shape of a window. Write the alleles of one parent across the top and the alleles of the other parent along the side of the Punnett square.

	T	T
t		
t		

Step 3. Fill in each box of the Punnett square by transferring the letter above and in front of each box into each appropriate box. As a general rule, the capital letter goes first and a lowercase letter follows.

	T	T
t	Tt Tall	Tt Tall
t	Tt Tall	Tt Tall

Step 4. List the possible genotypes and phenotypes of the offspring for this cross. The letters inside the boxes indicate probable genotypes (genetic makeup) of offspring. There are 4 boxes, and the genotypic results can be written either as fractions or percents. In this case, all 4 boxes are showing the heterozygous (different) Tt genotype. Therefore, 100% or 4/4 have the Tt genotype. We have also written the phenotype (physical appearance) in each box under the genotype. Remember, T = tall and t = short. Since a capital letter indicates a dominant gene, T (tall) is dominant over t (short). Therefore, 100% or 4/4 of the offspring are tall.

Incomplete Dominance

Incomplete dominance is a form of intermediate inheritance in which one allele for a specific trait is not completely dominant over the other allele. This results in a third phenotype in which the expressed physical trait is a blending of the dominant and recessive phenotypes. An example of incomplete

dominance is the color of snapdragon flowers. One of the genes for flower color in snapdragons has two alleles, one for red flowers and one for white flowers. A plant that is homozygous for the red allele will have red flowers, while a plant that is homozygous for the white allele will have white flowers. On the other hand, the heterozygote will have pink flowers. Neither the red nor the white allele is dominant, so the phenotype of the offspring is a blend of the two parents.

$$R = red$$
$$W = white$$
$$RW = Pink$$

The following Punnett Square is an example of incomplete dominance. It shows the possible results of crossing two pink snapdragons, each with one red gene (R) and one with one white gene (W). Each parent snapdragon passes along only one gene for color to its offspring.

For example, the probability of a red snapdragon offspring will be 1/4 or 25%, a pink offspring will be 1/2 or 50%, and a white offspring will be 1/4 or 25%.

	R	W
R	RR (red)	RW (pink)
W	RW (pink)	WW (white)

Backcrossing and the American Chestnut Tree

Backcrossing is the crossing of a hybrid with one of its parents or an individual genetically similar to its parent, in order to achieve offspring with a genetic identity that is closer to that of the parent. It is the standard method for transferring a single trait into an otherwise acceptable plant. In the case of the American chestnut, The American Chestnut Foundation is transferring into the American chestnut the genes responsible for the blight-resistance of the Chinese tree and, at the same time, preserve the height, majesty, and suitability to the eastern forest of the American species. The process begins by hybridizing or crossing an American chestnut (blight-susceptible) and a Chinese chestnut (blight-resistant). A hybrid is any offspring resulting from the mating of two genetically distinct individuals. The resulting seeds are planted and grown into small trees. Each small tree is tested to measure its resistance to blight. The most resistant trees are crossed to susceptible American trees. This is called the first backcross. As before, the resulting seeds are planted, grown into small trees, and tested for blight-resistance. Once again, the most resistant trees are backcrossed to susceptible American trees. At each step in the process, the trees become more and more like the original American chestnuts, except that they are moderately resistant to blight.

Between each breeding step, the trees are inoculated with the blight fungus. The purpose of inoculation is to determine the rate at which cankers grow, by measuring their size, so that the most blight-resistant trees can be identified. Only those trees showing strong blight-resistance and American chestnut morphological characteristics are chosen to breed additional generations. The process continues until blight-resistant, American-type trees are produced. It takes at least six years to grow and test each set of trees.

TACF has begun harvesting nuts expected to be highly blight-resistant and American in character. Many of these seeds, known as BC_3F_3, have been planted throughout the eastern United States to restore the American chestnut.

Use the The American Chestnut Foundation's "Backcross Breeding Program Presentation" and the "Backcross Breeding Program Chart" (on CD) for a more in-depth explanation of this process.

PART A:

GETTING READY

- Obtain a clean interactive white board, white board, chalk board or overhead projector to present genetics materials.
- Copy Student Page: "Punnett Square Problems" for each student.

DOING THE ACTIVITY

1. Explain to the students that they are going to be learning about genetics and how traits are passed

from parents to children. Break the class up into several groups of two to three students each and ask the students why they do and do not look like their parents. Have them discuss in small groups and share a few of their answers with the class. Jump into the lesson with a discussion on inheritance.

2. Introduce genetics and key terms (phenotype, genotype, trait, dominant vs. recessive, dominance (incomplete and complete), homozygous, heterozygous, etc.).

3. Introduce the Punnett Square and work through the pea and snapdragon problems with the class.

4. Give each student a copy of Student Page "Punnett Square Problems" and have the class work on the questions for the remaining class period.

5. Explain to the class that tomorrow they are going to learn how genetics is being used to bring back the American chestnut tree.

PART B:

GETTING READY

- Set-up a computer and projector with Microsoft PowerPoint capability to show the "Introduction to the Backcross Breeding Method" presentation and "Backcross Breeding Program" chart.

- Obtain 1 paper plate for each group. *Note: An even number of groups is important since the last step of the activity involves pairing-up with another group.*

- Obtain 5 small beakers (50 mL - 100 mL), 3-ounce cups, or other small scoops or containers for each group. Each container should be able to hold 100 beans.

- Obtain 1 large beaker or container for each group to discard their beans.

- Prepare containers of beans. Each group will need 4 beakers or containers with equal numbers of beans that represent American chestnut and 1 beaker full of beans that represent Chinese chestnut. Pre-count 100 beans per container. *Note: Try to use beans that are similar in size, but that contrast each other in color (e.g., red kidney beans and white cannellini beans). The actual number of beans is not important. What is important is that the beginning number in each*

container is the same. If the chosen container only holds 75 beans, then make sure all containers contain 75 beans each.

- *Note: If you have the class time, have the students count their own beans*

- Copy Student Page: "Bean There Done That -- Genetic Backcrossing of the American Chestnut."

- Copy Student Page: "Bean There Done That -- Genetic Backcrossing of the American Chestnut Review Questions."

DOING THE ACTIVITY

1. Break-up the students into an even number of groups.

2. Handout copies of Student Page "Bean There Done That -- Genetic Backcrossing of the American Chestnut."

3. Have each group follow the directions on Student Page "Bean There Done That -- Genetic Backcrossing of the American Chestnut" to complete the activity.

4. Designate which groups will work with one another on step #13.

5. Walk around the classroom as the students are completing the activity to make sure they understand the experiment. You may want to give examples of some types of graphs that can be used.

6. When all groups have completed the activity, handout copies of Student Page: "Bean There Done That Genetic Backcrossing of the American Chestnut Review Questions." Ask some follow-up questions:

- *How does this activity simulate what the American Chestnut Foundation is currently doing with genetic backcrossing?*

- *Based on what you have observed, will there ever be a pure American Chestnut again?*

7. Have the students complete the worksheet in class or for homework. You may also handout Student Page: "Genetics Vocabulary Match" for additional homework or class work.

EXTENSION

- Have students conduct research using the library and internet to write a report on the use of genetic traits/genetic engineering and the impact or benefits they have on American society. For example, cross breeding crops for better food production.

- Discuss the importance of native species with your class. What makes a species native? Native organisms create an intricate web of life. This is an incredible natural orchestration with each species' life cycle highly dependent on others. Discussions and activities that relate to biodiversity and non-native and invasive species could also be included.

SUGGESTED "WORDS TO LEARN:"

Allele	Heredity
Backcrossing	Heterozygous
Chromosome	Homozygous
Complete dominance	Hybrid
DNA	Incomplete dominance
Gene	Phenotype
Genetic resistance	Punnett Square
Genetics	Trait
Genotype	

ANSWER KEY

Student Page: "Punnett Square Problems"

1a. Phenotypes: One is brown, one is white, and two are orange.

1b. Genotypes: One is BB, one is WW, and two are BW.

1c. White = 25%; Black = 25%; Orange = 50%

	B	W
B	BB (brown)	BW (orange)
W	BW (orange)	WW (white)

2. B. 50%

3. D. 50%

4. A. 1/2

5. B. 0%

6. Both parents are heterozygous dominant for the tongue rolling gene (Rr). Their son is homozygous recessive (rr).

Student Page: "Bean There Done That Genetic Backcrossing of the American Chestnut Review Questions"

1. Backcrossing

2. Hybrid

3. Chestnut blight resistance

4. F_1=1/2; BC_1: 3/4; BC_2: 7/8; BC_3: 15/16; BC_3F_2: 15/16; BC_3F_3: 15/16

5. Inoculated

6. To determine the rate at which cankers grow (by measuring their size) so that the most blight-resistant trees can be identified.

7. No. There will always be a small amount of Chinese genetic material present.

Student Page: "Genetics Vocabulary Match"

1. g
2. p
3. f
4. m
5. h
6. o
7. l
8. b
9. e
10. q
11. k
12. c
13. d
14. a
15. j
16. i
17. n

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Punnett Square Probelms

1. Complete the following Punnett Square. In this situation you are crossing 2 orange-haired cats (genotype = BW). In cats, the fur colors are codominant and the traits will blend. B = brown fur and W = white fur

	B	**W**
B		
W		

a. Describe the phenotype of the offspring?

b. What are the genotypes of the offspring?

c. What percent of the offspring will have:

White fur _____   Black fur _____   Orange fur _____

2. One flower is heterozygous red (Rr) and it is crossed with a homozygous white (rr) plant. Use a Punnett square to determine the probability of one of their offspring having a white color. Circle your answer below.

   A. 100%
   B. 50%
   C. 75%
   D. 25%

3. One cat carries heterozygous, long-haired traits (Ss), and its mate carries homozygous short-haired traits (ss). Use a Punnett square to determine the probability of one of their offspring having long hair. Circle your answer below.

   A. 100%
   B. 25%
   C. 75%
   D. 50%

Punnett Square Probelms cont.

1. In humans, curly hair (CC) and straight hair (SS) are codominant. According to the Punnett Square, what is the genotypic ratio of offspring having wavy hair (CS) if both parents have wavy hair? Circle your answer below.

	C	S
C	CC	CS
S	CS	SS

A. 1/2
B. 7/8
C. 3/4
D. 1/4

2. In a certain species of pine trees, short needles (S) are dominant to long needles (s). According to the Punnett square, what is the probability of an offspring having long needles? Circle your answer below.

	S	S
S	SS	SS
s	Ss	Ss

A. 50%
B. 0%
C. 75%
D. 100%

3. The ability to roll the tongue (R) is determined by a dominant gene while the recessive gene results in the inability to roll the tongue (r). A man and his wife can both roll their tongues and are surprised to find that their son can-not. Explain this by showing the genotypes of all three persons. (Note: you do not need to do a Punnett Square for this problem).

Backcrossing and the American Chestnut Tree

Backcrossing is the crossing of a hybrid with one of its parents or an individual genetically similar to its parent, in order to achieve off-spring with a genetic identity that is closer to that of the parent. It is also the standard method for transferring a single trait into an otherwise acceptable plant. In the case of the American chestnut, The American Chestnut Foundation is transferring into the American chestnut the genes responsible for the **blight-resistance** of the Chinese tree and, at the same time, preserve the height, majesty, and suitability to the eastern forest of the American species. The process begins by hybridizing or crossing an American chestnut (blight-susceptible) and a Chinese chestnut (blight-resistant). **A hybrid is any offspring resulting from the mating of two genetically distinct individuals.** The resulting seeds are planted and grown into small trees. Each small tree is tested to measure its resistance to blight. The most resistant trees are crossed to susceptible American trees. This is called the first backcross. As before, the resulting seeds are planted, grown into small trees, and tested for blight-resistance. Once again, the most resistant trees are backcrossed to susceptible American trees. At each step in the process, the trees become more and more like the original American chestnuts, except that they are moderately resistant to blight.

Between each breeding step, the trees are inoculated with the blight fungus. The purpose of inoculation is to determine the rate at which cankers grow, by measuring their size, so that the most blight-resistant trees can be identified. Only those trees showing strong blight-resistance and American chestnut morphological characteristics are chosen to breed additional generations. The process continues until blight-resistant, American-type trees are produced. It takes at least six years to grow and test each set of trees.

TACF has begun harvesting nuts expected to be highly blight-resistant and American in character. Many of these seeds, known as BC_3F_3, have been planted throughout the eastern United States to restore the American chestnut.

Bean There Done That
Genetic Backcrossing of the American Chestnut

Remember that the **genotype** refers to the genes that make up the trait. The **phenotype** is the physical characteristics that result from the genes. For example, dimples would be the phenotype, but Dd would be the genotype. The American chestnut has a different genotype than the Chinese chestnut and thus a different phenotype. The important thing to understand is that the Chinese chestnut has the gene to resist the blight, but the American chestnut does not. The goal of The American Chestnut Foundation is to reestablish the once flourishing American chestnut tree in eastern forests. In order to do this, scientists are trying to breed American chestnuts with the Chinese blight resistant gene. They are using a process called **genetic backcrossing**. You will now complete a simulation of such backcrossing, but with beans!

Materials:

o   Two different types of beans
o   1 Paper plate
o   50 to 100 mL beaker (or small scooplike container)
o   1 large beaker for discarded beans
o   Pen or pencil

What to do:

1. Identify each set of beans. Depending on the type and color of beans, your teacher will tell you what beans to identify as American chestnut and what beans to identify as Chinese chestnut.

2. Take a beakerful of American beans and a beakerful of Chinese beans and mix them on the paper plate—this represents F_1 generation.

Bean There Done That cont.

3. Create a graph to represent the findings on your paper plate. Label the graph F_1.

4. Remove a beakerful of the mixed F_1 generation and put them into another container.

5. Add another beakerful of American beans and mix with the F_1 generation on the paper plate. This represents the BC_1 generation (BC stands for backcross).

6. Create a graph to represent the findings on your paper plate. Label the graph BC_1.

Bean There Done That cont.

7. Remove a beakerful of the mixed BC_1 generation and put them into a separate container.

8. Add another beakerful of American beans and mix with the BC_1 generation on the paper plate. This represents the BC_2 generation.

9. Create a graph to represent the findings on your paper plate. Label the graph BC_2.

10. Remove a beakerful of the mixed BC_2 generation and put them into a separate container.

11. Add another beakerful of American beans and mix with the BC_2 generation on the paper plate. This represents the BC_3 generation.

12. Create a graph to represent the findings on your plate. Label the graph BC_3.

Bean There Done That cont.

13. Now… Remove a beakerful of the mixed BC_3 generation and mix them with another group's beakerful of BC_3 generation. This is considered the BC_3F_2 generation. This is referred to as the first intercross.

14. Create a graph to represent the findings on your paper plate. Label the graph BC_3F_2.

15. At this point, please stop and wait for the teacher's directions.

Bean There Done That
Genetic Backcrossing of the American Chestnut
Review Questions

1. _____ is the crossing of a hybrid with one of its parents or an individual genetically similar to its parent, in order to achieve offspring with a genetic identity that is closer to that of the parent. It is also the standard method for transferring a single trait into an otherwise acceptable plant.

2. A _____ is any offspring resulting from the mating of two genetically distinct individuals.

3. What characteristic was trying to be obtained with each cross?

4. The Backcross Method lasts for many generations of taking the initial American Chestnut Chinese Chestnut Cross and then back crossing it with the American genes again. What fraction of the American Chestnut genes are in each cross generation? Hint: Use the Backcross Breeding Chart for help.

   F_1 _____ BC_3 _____

   BC_1 _____ BC_3F_2 _____

   BC_2 _____ BC_3F_3 _____

5. Between each breeding step, the trees are _____ with the blight fungus and only those trees showing strong blight resistance and American chestnut characteristics are chosen to breed additional generations.

Bean There Done That
Genetic Backcrossing of the American Chestnut
Review Questions cont.

1. What is the purpose of inoculation?

2. Based on what you have observed, will there ever be a pure American Chestnut again? Why?

Genetics Vocabulary Match

Directions: Match the words with their definitions.

1. Traits _____

2. Hybrid _____

3. Allele _____

4. DNA _____

5. Chromosome _____

6. Homozygous _____

7. Punnett Square _____

8. Heredity _____

9. Genotype _____

10. Heterozygous _____

11. Phenotype _____

12. Backcrossing _____

13. Gene _____

14. Genetics _____

15. Genetic resistance _____

16. Incomplete dominance _____

17. Complete dominance _____

a. The study of heredity.

b. The transmission of genetic characters from parents to offspring.

c. The crossing of a hybrid with one of its parents or an individual genetically similar to its parent, in order to achieve offspring with a genetic identity that is closer to that of the parent.

d. Small section of DNA that is coded for specific traits.

e. Genetic makeup of an organism.

f. An alternative form of a gene (one member of a pair) that is located at a specific position on a specific chromosome.

g. Distinct variant of a phenotypic character of an organism that may be inherited, be environmentally determined or be a combination of the two.

h. Thread-like structure of DNA that carries genes.

i. A form of intermediate inheritance in which one allele for a specific trait is not completely dominant over the other allele.

j. Some type of genetic predisposition that would make an organism less likely to die from a condition.

k. An organisms observable characteristics or traits.

l. Diagram that is used to predict an outcome of a particular cross or breeding experiment.

m. Also known as deoxyribonucleic acid, the hereditary material in humans and almost all other organisms.

n. Type of dominance where the dominant gene completely masks the effect of the recessive gene in heterozygous condition.

o. Having identical pairs of genes for any given pair of hereditary characteristics (same).

p. Any offspring resulting from the mating of two genetically distinct individuals.

q. Having dissimilar pairs of genes for any hereditary characteristic (different).

Appendices

Appendix A. Glossary

Adaptability: the ability to change (or be changed) to fit changed circumstances.

Adhesion: the attractive forces between unlike molecules (of different substances).

Allele: an alternative form of a gene (one member of a pair) that is located at a specific position on a specific chromosome.

Annual ring/Growth ring: each of a number of concentric rings in the cross section of a tree trunk, representing a single year's growth.

Backcrossing: the standard method for transferring a single trait into an otherwise acceptable plant.

Bark: outermost covering of stems and roots of woody plants; usually rough on older tissue and smooth on young growth; outside of cambium layer.

Biological control: the control of a pest by the introduction of a natural enemy or predator.

Bioengineering: the process of manually adding new DNA to an organism. The goal is to add one or more new traits that are not already found in that organism.

Blight: a plant disease generally caused by fungi; in the case of the American chestnut tree, the blight fungus plugs water- and food-carrying vessels causing the tree to die.

Botanist: a person who studies trees and plants.

Cambium: layer of cells between the wood and the bark; it produces both of these tissues.

Canker: dead area or blister on the bark, branch or trunk of an infected tree; caused by fungi like the Chestnut blight fungus that enter the tree through wounded or injured bark tissue.

Capillary action: the movement of water within the spaces of a porous material due to the forces of adhesion, cohesion, and surface tension.

Chromosome: thread-like structure of DNA that carries genes.

Circumference: the linear distance around the edge of a closed curve or circular object; π x diameter OR 2π x radius.

Cohesion: the attractive force between like molecules (of the same substance).

Complete Dominance: type of dominance where the dominant gene completely masks the effect of the reces-

sive gene in heterozygous condition.

Crown: branches, leaves, and reproductive structures extending from the trunk or main stems of woody plants.

DBH (Diameter at breast height): standard method of expressing the diameter of the trunk or bole of a standing tree; the measurement is taken 1.5 meters (4.5 feet) above the ground.

Dendrochronologist: scientist who uses tree rings to answer questions about climate change and past events.

Dendrochronology: the dating and study of annual rings in trees.

Diameter: a straight line passing from side to side through the center of a body or figure, especially a circle or sphere.

DNA: deoxyribonucleic acid, the hereditary material in humans and almost all other organisms.

Earlywood: the part of the wood in a growth ring that is produced at the beginning of the growing season; these light-colored rings are generally wider and less dense as a result of better growing conditions.

Ecosystem: the interactions of all living things with their environment within a community.

Forester: a person who practices planting, managing, and caring for forests.

Fungus: (fungi = plural) an organism that feeds on other living or dead organisms and reproduces via spores;

in the chestnut blight, the fungus gets its food from the trees and kills the tree in the process.

Gene: small section of DNA that is coded for specific traits.

Genetics: the study of heredity; how traits such as hair color, eye color, and risk for disease are passed ("inherited") from parents to their children.

Genetic breeding: mixing the character of two breeds by gene transfer (e.g. Chinese chestnut is 'mixed' with American chestnut).

Genetic resistance: some type of genetic predisposition that would make an organism less likely to die from a condition.

Genotype: genetic makeup of an organism.

Germplasm: living tissue from which new plants can be grown

Girdling: cutting off the transportation of nutrients from the roots to the canopy of the tree.

Girth: the distance around a trunk of a tree (circumference).

Heredity: the transmission of genetic characters from parents to offspring.

Heterozygous: having dissimilar pairs of genes for any hereditary characteristic.

Homozygous: having identical pairs of genes for any given pair of hereditary characteristics.

Host: an organism that harbors a parasite.

Hybrid: any offspring resulting from the mating of two genetically distinct individuals.

Hyphae: thread-like fungal strands; similar to plant roots, fungi grow hyphae to acquire nutrients from plants and dead animals.

Hypothesis: a statement of prediction, proposed explanation or educated guess that scientists use to predict the outcome of an experiment.

Hypovirulence: (hypo = low or less than normal, virulence = disease-causing) refers to an infection of the blight that is less virulent, or less damaging to the tree; basically, the fungus that infects the tree is weakened when it itself is infected by a virus.

Incomplete dominance: a form of intermediate inheritance in which one allele for a specific trait is not completely dominant over the other allele.

Latewood: the part of the wood in a growth ring of a tree that is produced later in the growing season; these dark rings are narrower and more dense due to less favorable summer growing conditions.

Meniscus: the curved upper surface of a liquid in a tube.

Mudpacking: covering the canker with mud; bacteria and other microorganisms found in the mud attack and kill the American chestnut blight fungus; not a practical way to destroy the blight fungus on every tree.

Native American: an individual who has his/her origins in North America.

Phenotype: an organisms observable characteristics or traits.

Phloem: system of cells that transport food and other nutrients like sugar from stems to growing and storage tissues.

Probability: the relative frequency with which an event occurs or is likely to occur.

Punnett Square: diagram that is used to predict an outcome of a particular cross or breeding experiment; way to calculate the mathematical probability of inheriting a specific trait.

Quarantine laws: Federal laws to prevent the importation and exportation of contaminated soil, plants, planted containers and products made using plant material to prevent infestations from spreading.

Radius: the distance from the center to the edge of a circle; half of the circle's diameter.

Scalar: in physics, a one-dimensional or non-directional physical quantity that can be described with a magnitude or single number (i.e., speed and temperature).

Speed: distance divided by time.

Spore: a microscopic sized, typically one-celled reproductive unit produced by fungi that spread through the air; like a seed, a spore allows a new organisms to begin developing when it reaches proper growing conditions.

Surface tension: property of the surface of a liquid that allows it to resist an external force.

Topography: arrangement of the natural and artificial physical features of an area.

Traits: distinct variant of a phenotypic character of an organism that may be inherited, be environmentally determined or be a combination of the two.

Tree cookie: cross section of tree trunks that can be used to illustrate how trees grow.

Vascular bundle: a strand of specialized vascular tissue.

Vascular tissue: allows water and mineral nutrients to move from roots to leaves and transfer manufactured food to other parts of the tree.

Vector: in physics, quantities that are fully described by both a magnitude or single number AND a direction (e.g., 10 miles, North and 50 m/sec South).

Xylem: the system of tubes and transport cells that circulate water and dissolved minerals from the roots to aerial parts of the plant.

American Chestnut Disease Word Search Answer Key

```
I Q X O K J S C I V X V F U N D E T
L F G F C F S N O I S E H D A O R N
C O H E S I O N E D O I B V M J O A
D W X R A E C Z M T C N L K I A P S
K N O I T C A Y R A L L I P A C S I
C A N K E R H M Q C G F A E X E D S
F H R I C H L K A N E P V E P T E H
A U A M C P D C I Z Y M C A Y W K E
T J N X R F W L X C P Y I H Q T U T
X H U G B I D F O D G J V P G V N O
O M I U U R Z B Q H C M I Y C Z I P
N L U V I S S H Q E Q S C H D Z V Y
B L I G H T Y I V F K Q C M P K V H
G N I K C A P D U M Y P P P X R K N
S U R F A C E T E N S I O N A R W D
Y M E V H T O S B J I U I Y Z I N L
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Speed of the Blight Crossword Puzzle Answer Key

```
                              G E R M P L A S M
                              E           D
                              N           A
                              E       P   P
            P       H O S T   T   P   A   T       T
  S C A L A R       Y       I   A   B   O
            R       P       C   T   B   P
      V E C T O R   R       R   H   I   O
            N       V       E   O   B L I G H T
            T       I       S P E E D   I   R
        C   T       R       I   E   T   A
        R   R       U       S   N   Y   P
    B O L E         L       T   I       H
        W   E       E       A   C       Y
        N           N       N   I
                    C       C   T
                    E           Y
```
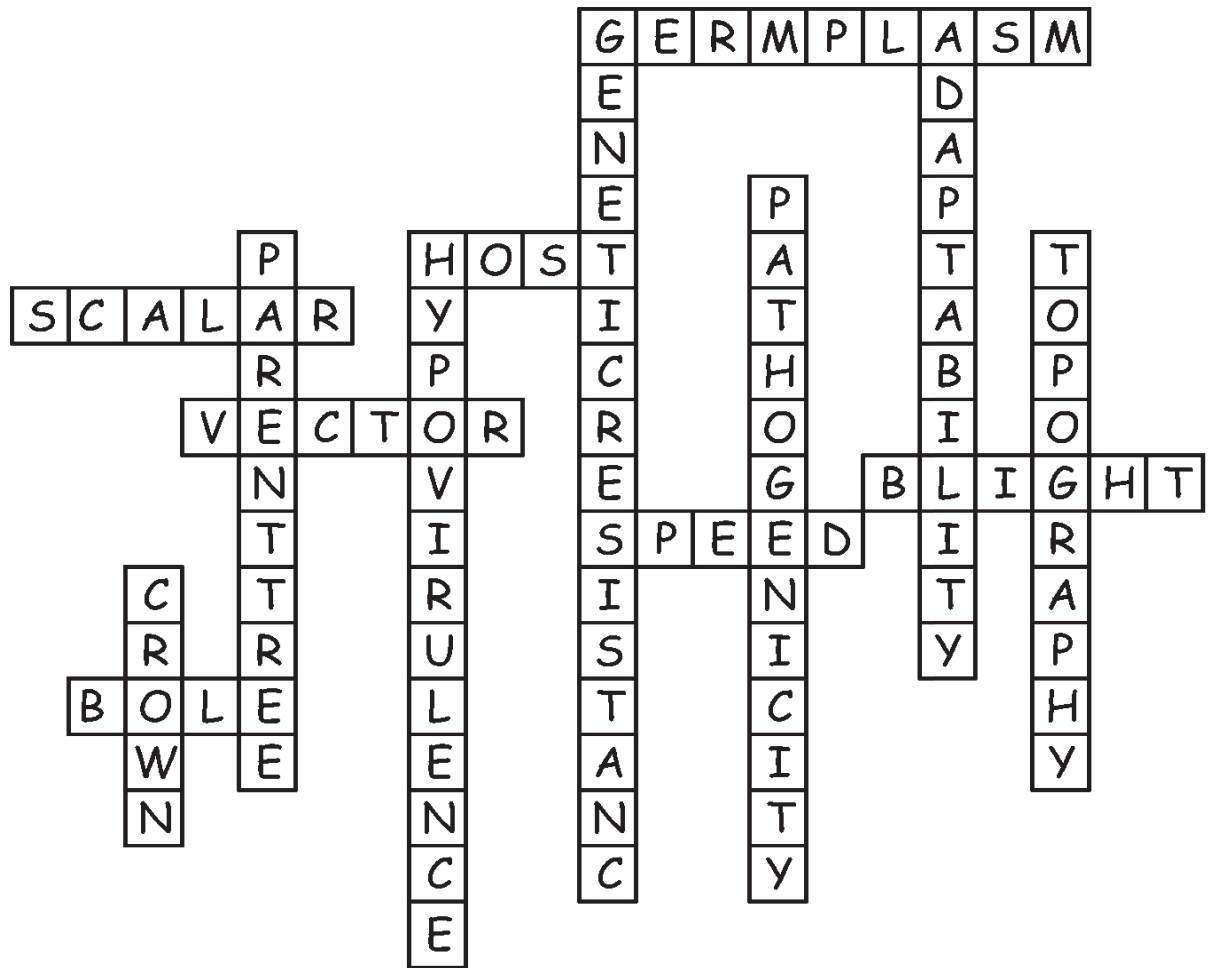
Appendix C.
Correlations to Pennsylvania Core Curriculum Standards

Pennsylvania Core Standards

Pennsylvania Core Standards	Lesson 1: Intro	Lesson 2: Size	Lesson 3: Disease	Lesson 4: Speed	Lesson 5: Genetics
Science & Technical Subjects					
CC.3.5.6-8.C: Follow precisely a multistep procedure when carrying out experiments, taking measurements, or performing technical tasks.		X	X	X	X
CC.3.5.6-8.D: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 6–8 texts and topics.	X	X	X	X	X
CC.3.6.6-8.G: Gather relevant information from multiple print and digital sources, using search terms effectively; assess the credibility and accuracy of each source; and quote or paraphrase the data and conclusions of others while avoiding plagiarism and following a standard format for citation.	Extension		Extension		
English Language Arts					
CC.1.2.6.G: Integrate information presented in different media or formats (e.g. visually, quantitatively) as well as in words to develop a coherent understanding of a topic or issue.	X		X	X	
History & Social Studies					
CC.8.5: Students read, understand, and respond to informational text – with emphasis on comprehension, making connections among ideas and between texts with focus on textual evidence.	X				
CC.8.5.6-8.G: Integrate visual information (e.g., in charts, graphs, photographs, videos, or maps) with other information in print and digital texts.	X		X		
CC.8.6.6-8.F: Conduct short research projects to answer a question (including a self-generated question), drawing on several sources and generating additional related, focused questions that allow for multiple avenues of exploration. (Extension)	Extension				
Mathematics					
CC.2.1.6.D.1: Understand ratio concepts and use ratio reasoning to solve problems.		X		X	
CC.2.1.6.E.2: Identify and choose appropriate processes to compute fluently with multi-digit numbers.		X		X	
CC.2.3.7.A.1: Solve real-world and mathematical problems involving angle measure, area, surface area, circumference, and volume.		X			
CC.2.4.7.B.3: Investigate chance processes and develop, use, and evaluate probability models.					X

Appendix D.
Correlations to Pennsylvania Curriculum Standards

Pennsylvania State Standards

Environment and Ecology

Pennsylvania State Standards	Lesson 1: Intro	Lesson 2: Size	Lesson 3: Disease	Lesson 4: Speed	Lesson 5: Genetic
3.1.7.A1: Describe the similarities and differences of physical characteristics in diverse organisms			X		
4.3.6.C: Understand how theories are developed. Identify questions that can be answered through scientific investigations and evaluate the appropriateness of questions. Design and conduct a scientific investigation and understand that current scientific knowledge guides scientific investigations. Describe relationships using inference and prediction. Use appropriate tools and technologies to gather, analyze, and interpret data and understand that it enhances accuracy and allows scientists to analyze and quantify results of investigations. Develop descriptions, explanations, and models using evidence and understand that these emphasize evidence, have logically consistent arguments and are based on scientific principles, models, and theories. Analyze alternative explanations and understanding that science advances through legitimate skepticism. Use mathematics in all aspects of scientific inquiry. Understand that scientific investigations may result in new ideas for study, new methods or procedures for an investigation, or new technologies to improve data collection.		X		X	X
4.3.7.A: Explain how products are derived from natural resources.	X				
4.3.7.C: Understand how theories are developed. Identify questions that can be answered through scientific investigations and evaluate the appropriateness of questions. Design and conduct a scientific investigation and understand that current scientific knowledge guides scientific investigations. Describe relationships using inference and prediction. Use appropriate tools and technologies to gather, analyze, and interpret data and understand that it enhances accuracy and allows scientists to analyze and quantify results of investigations. Develop descriptions, explanations, and models using evidence and understand that these emphasize evidence, have logically consistent arguments and are based on scientific principles, models, and theories. Analyze alternative explanations and understanding that science advances through legitimate skepticism. Use mathematics in all aspects of scientific inquiry. Understand that scientific investigations may result in new ideas for study, new methods or procedures for an investigation, or new technologies to improve data collection.		X		X	X
4.4.7.C: Investigate resources, their relation to land use, and their impact on the food and fiber system.	X				
4.5.6.D: Identify reasons why organisms become threatened, endangered, and extinct.	X				
4.5.8.A: Explain how Best Management Practices (BMP) can be used to mitigate environmental problems.	X				

Pennsylvania State Standards

Pennsylvania State Standards	Lesson 1: Intro	Lesson 2: Size	Lesson 3: Disease	Lesson 4: Speed	Lesson 5: Genetic
Science and Technology and Engineering Education					
3.1.7.B1: Explain how genetic instructions influence inherited traits. Identify Mendelian patterns of inheritance.					X
3.1.7.B4: Describe how selective breeding and biotechnology can alter the genetic composition of organisms.					X
Mathematics					
2.1.8.C: Use ratio and proportion to model relationships between quantities.				X	
2.2.6.B: Add, subtract, multiply, and divide whole numbers, decimals, fractions, and mixed numbers.				X	
2.3.7.A: Demonstrate an understanding of measurable attributes and the units, systems, and processes of measurement.		X			
2.3.7.F: Estimate and verify measurements of length, perimeter, area, volume, capacity, temperature, time, weight, and angles.		X			
Geography					
7.1.6.B: Describe and locate places and regions as defined by physical and human features.	X			X	
7.1.7.B: Explain and locate places and regions as defined by physical and human features.	X			X	
7.1.8.B: Explain and locate places and regions as defined by physical and human features.	X			X	
Reading, Writing, Speaking and Listening					
1.1.6.C: Use meaning and knowledge of words (e.g., root words, literal meanings, idioms, common foreign words) across content areas to expand reading vocabulary.			X		
1.1.7.B: Use word analysis skills, context clues, knowledge of root words as well as a dictionary/thesaurus or glossary to decode and understand specialized vocabulary in content areas during reading.			X		
1.1.8.B: Use context clues, knowledge of root words as well as a dictionary or glossary to decode and understand specialized vocabulary in the content areas during reading.			X		
1.6.6.A: Listen critically and respond to others in small and large group situations.	X	X	X	X	X
1.6.7.A: Listen critically and respond to others in small and large group situations.	X	X	X	X	X

Pennsylvania State Standards

Pennsylvania State Standards	Lesson 1: Intro	Lesson 2: Size	Lesson 3: Disease	Lesson 4: Speed	Lesson 5: Genetic
1.6.8.A: Listen critically and respond to others in small and large group situations.	X	X	X	X	X
Career Education and Work					
13.1.8.A: Relate careers to individual interests, abilities, and aptitudes.		X			
History					
8.2.7.B: Identify the role of local communities as related to significant historical documents, artifacts, and places critical to Pennsylvania history.	X				

Appendix E.
The 5E Instructional Model

The 5E Instructional Model

The 5E instructional model, developed by Rodger W. Bybee in the 1980s, was designed specifically to provide a model that promotes a constructivist approach to science education while incorporating aspects of behaviorism and cognitivism. Developed and tested over 18 months, it is a reference point for school leaders and teachers to develop a deeper understanding of what constitutes high quality teacher practice in the classroom. There are five phases in the model:

1. Engage

The goal of this phase is to capture the students' attention and interest. Get the students focused on a situation, event, demonstration, or problem that involves the content and abilities that are the aims of instruction. From a teaching point of view, asking a question, posing a problem, or presenting a discrepant event are all examples of strategies to engage learners.

- Develops shared norms
- Determines readiness for learning
- Establishes learning goals
- Develops metacognitive capacity

2. Explore

In the exploration phase, students have activities with time and opportunities to resolve the disequilibrium of the engagement experience. The exploration lesson or lessons provide concrete, hands-on experiences where students express their current conceptions and demonstrate their abilities as they try to clarify puzzling elements of the engage phase.

Exploration experiences should be designed for later introduction and description of the concepts, practices, and skills of the instructional sequence. Students should have experiences and the occasion to formulate explanations, investigate phenomena, observe patterns, and develop their cogni-

tive and physical abilities.

The teacher's role in the exploration phase is to initiate the activity, describe appropriate background, provide adequate materials and equipment, and to counter any misconceptions. After this, the teacher steps back and becomes a coach with the tasks of listening, observing, and guiding students as they clarify their understanding and begin reconstructing scientific concepts and developing their abilities.

- Prompts inquiry
- Structures inquiry
- Maintains session momentum

3.   Explain

The scientific explanation for phenomena is prominent in this phase. The concepts, practices, and abilities with which students were originally engaged and subsequently explored, now are made clear and comprehensible. The teacher directs students' attention to key aspects of the prior phases and first asks students for their explanations.

- Presents new content
- Develops language and literacy
- Strengthens connections

4.   Extend (or Elaborate)

The students are involved in learning experiences that extend, expand, and enrich the concepts and abilities developed in the prior phases. The intention is to facilitate the transfer of concepts and abilities to related, but new situations. A key point for this phase—use activities that are a challenge but achievable by the students.

In the elaboration phase, the teacher challenges students with a new situation and encourages interactions among students and with other sources such as written material, databases, simulations, and web-based searches.

- Facilitates substantive conversation
- Cultivates higher order thinking
- Monitors progress

5.   Evaluate

In the evaluate phase, the teacher should involve students in experiences that are understandable and consistent with those of prior phases and congruent with the explanations. The teacher should determine the evidence for student learning and means of obtaining that evidence, as part of the evaluate phase.

- Assesses performance against standards
- Facilitates student self assessment

Adapted from:

Bybee, Rodger W. 2014. The BSCS 5E Instructional Model: Personal Reflections and Contemporary Implications. Science and Children. 51(8): 10-13.

Victoria Department of Education and Early Childhood Development. 2013. The e5 Instructional Model. Accessed online June 25, 2013: http://www. education.vic.gov.au/school/teachers/support/pages/e5.aspx.