

Teacher's Guide

April 2026

<u>April Teacher's Guide Introduction</u>	2
<u>Fireflies</u>	4
<u>Illegal Logging</u>	13
<u>Natural Products</u>	22
<u>Black Walnuts</u>	31



April Teacher's Guide Introduction

The April 2026 issue of ChemMatters includes articles relating to the chemicals and chemistry of forests and natural environments. These articles will help students understand that science is interdisciplinary, appealing to many different interests. Students may also think about how a scientific career might be interesting to them since most articles feature real scientists who have genuine curiosity about the natural world. For all articles, encourage students to think about how science is done, how we know what we know, and how chemistry connects to their lives.

Teaching Ideas for this issue:

1. "Open for Discussion" on pages 3 and 4 describes what students can learn about chemistry from camping in a forest for several days and nights and asks the question of where do others find chemistry.
2. "Quick Read: Dinner to Soil" on page 21 and 22 describes the chemistry of composting and may appeal to general science students as well as chemists. The differences between different types of compostable materials and the three phases of composting are discussed.
3. "Nano Reads" on page 19 describes three interesting areas of chemical research that may appeal to a variety of student interests. In this issue we are in search of daVinci's DNA, social media flops and what moss tells us about microparticles.
4. The "Chemistry in Person" column on page 23 is an interview with a person who struggled with STEM subjects in high school, but she followed her interests and now works in science communication. The article will help students learn that science is done by real people with curiosity and passion.
5. Consider assigning a team of students to read one of the feature articles, then present what they learned in a podcast, PowerPoint or similar presentation, poster or brochure, or some other engaging format.
 - Prior to reading the article, give students the Anticipation Guide for the article along with the graphic organizer and links to other information provided.
 - Be sure to ask students to include information providing evidence for the claims made in the article.
6. Alternatively, students can create concept maps about the important chemistry concepts in the feature article they choose.

5E Lesson Ideas for individual articles:

Engage	Provide the Anticipation Guide or ask a thoughtful question (see the individual Teacher's Guide for each article) to engage students in the reading. Students should record their initial ideas individually, in pen, so they can't be erased. Students can then discuss their initial ideas in small groups or as a whole class.
Explore	Students read the article to discover more about the concepts in the article. During this phase, students will revisit their beginning ideas and record how the information in the article supports or refutes their initial ideas, providing evidence from the article.
Explain	Students answer questions and/or complete the graphic organizer provided for each article, then discuss their learning with their classmates. Students should recognize the evidence for the claims made in the articles, and how the evidence supports the claims.
Elaborate	Students can pose questions for further study. For some articles, there are related ACS Reactions videos students can watch to learn more about the concepts presented. See the individual Teacher's Guide for each article to learn more.
Evaluate	Students write a short summary of what they learned that describes how it connects to their lives. Students may also present their learning to their classmates or others. Here is a template for an exit slip: <ul style="list-style-type: none">● I used to think...● But now I know...● And this is how I learned it...

Teacher's Guide

Fireflies

April 2026

Table of Contents

<u><i>Anticipation Guide</i></u>	5
Activate students' prior knowledge and engage them before they read the article.	
<u><i>Reading Comprehension Questions</i></u>	6
These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You'll find the questions ordered in increasing difficulty.	
<u><i>Graphic Organizer</i></u>	7
This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
<u><i>Answers</i></u>	8
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u><i>Additional Resources</i></u>	11
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u><i>Chemistry Concepts and Standards</i></u>	12

Anticipation Guide

Name: _____

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Both young and adult fireflies emit light for the same reasons.
		2. Fireflies are found on all continents except Antarctica
		3. Luciferase is an enzyme that catalyzes the reaction to produce “cold light” from fireflies.
		4. Nitric oxide is a very stable compound.
		5. Luciferase from fireflies has important medicinal uses.
		6. Most of a firefly’s life is spent underground.
		7. Firefly harvesting by schoolchildren stopped in the 1960s
		8. Luciferase is now made by genetic engineering using bacteria.
		9. There are only about 14 species of fireflies.
		10. Firefly decline is due to habitat loss, light pollution, and commercial harvesting.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What chemical reaction produces light in fireflies?
2. What are the main chemical components involved in firefly bioluminescence?
3. What is the first chemical step in the bioluminescent reaction?
4. What happens after luciferyl adenylate forms?
5. Why does light get emitted in this reaction?
6. Why is firefly light extremely efficient compared with light bulbs?
7. What color light do most fireflies emit?
8. How does oxygen availability control flashing?
9. What role does nitric oxide play in firefly flashing?
10. Why did scientists once collect fireflies for research?
11. How was luciferase used in laboratory chemistry?
12. How did biotechnology eliminate the need to harvest fireflies?
13. Why is luciferase still widely used in modern research?

Additional Questions

14. How can luciferase help track biological processes in living cells?
15. What modern applications use the luciferase reaction today?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the importance of luciferase and why firefly populations have declined.

	Importance	How it works
Luciferase in fireflies		
Luciferase in medicine		
Luciferase harvesting		
Luciferase production today		
Firefly decline		

Summary: On the bottom or back of this sheet, write a one-sentence summary (18 words or less) of the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What chemical reaction produces light in fireflies?
Firefly light is produced by the oxidation of a molecule called luciferin which is catalyzed by the enzyme luciferase in the presence of ATP, oxygen, and magnesium ions.
2. What are the main chemical components involved in firefly bioluminescence?
The reaction involves luciferin (substrate), luciferase (enzyme), ATP (energy carrier), molecular oxygen, and Mg^{2+} ions.
3. What is the first chemical step in the bioluminescent reaction?
Luciferin reacts with ATP to form luciferyl adenylate, an activated intermediate.
4. What happens after luciferyl adenylate forms?
Oxygen reacts with luciferyl adenylate to form an unstable dioxetanone intermediate that quickly decomposes, producing oxyluciferin in an excited electronic state.
5. Why does light get emitted in this reaction?
When excited oxyluciferin returns to its ground state, the excess energy is released as a photon of visible light.
6. Why is firefly light extremely efficient compared with light bulbs?
Nearly 90–98% of the reaction energy becomes light rather than heat, making it one of the most efficient light-producing reactions known.
7. What color light do most fireflies emit?
Most fireflies emit yellow-green light (around 560 nm), although color varies slightly by species.
8. How does oxygen availability control flashing?
Fireflies regulate oxygen flow to light-producing cells. When oxygen reaches the luciferin reaction, the light flash occurs.
9. What role does nitric oxide play in firefly flashing?
Nitric oxide temporarily inhibits mitochondria in light cells so oxygen becomes available for the luciferin reaction.

10. Why did scientists once collect fireflies for research?

Fireflies were harvested because luciferase was needed for biochemical experiments and diagnostic assays.

11. How was luciferase used in laboratory chemistry?

Because the reaction requires ATP, luciferase assays were used to measure cell viability and ATP concentration in biological samples.

12. How did biotechnology eliminate the need to harvest fireflies?

Scientists cloned the luciferase gene and inserted it into bacteria and yeast so the enzyme could be produced industrially.

13. Why is luciferase still widely used in modern research?

Luciferase is commonly used as a reporter gene in molecular biology to monitor gene expression.

Additional Questions

14. How can luciferase help track biological processes in living cells?

Researchers attach the luciferase gene to DNA sequences of interest. When the gene is expressed, the cells glow.

15. What modern applications use the luciferase reaction today?

Applications include drug discovery, cancer research, food safety testing, and environmental monitoring.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Classroom Demonstrations and Activities

Glow Stick Chemiluminescence Demonstration (Royal Society of Chemistry)

Students investigate how temperature affects the brightness of glow sticks and relate this to reaction rate and chemiluminescence.

<https://edu.rsc.org/exhibition-chemistry/the-glow-stick-reaction/3010386.article>

Luminol Chemiluminescence Demonstration (Royal Society of Chemistry)

A classic “cold light” reaction that demonstrates chemiluminescence similar to biological light production.

<https://edu.rsc.org/resources/chemiluminescence-of-luminol-a-cold-light-experiment/823.article>

Videos

Bioluminescence – HHMI BioInteractive Video

Explains how living organisms produce light and how the chemistry works.

<https://www.biointeractive.org/classroom-resources/symbiotic-bioluminescence>

Glowing Bacteria in a Flask – HHMI BioInteractive

Shows real bioluminescent bacteria glowing in a laboratory culture.

<https://www.biointeractive.org/classroom-resources/glowing-bacteria-flask>

Data and Citizen Science

Firefly Atlas Project

Students can explore real firefly sightings and contribute observations.

<https://www.fireflyatlas.org>

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students if they have ever seen lightning bugs (fireflies), and what they know about them. Ask how they might produce light. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about how fireflies create “cold light.” Ask why firefly populations might be declining. Ask how genetic engineering has played a role in protecting fireflies.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Enzymes
- Molecular Structure
- Chemical and Biochemical engineering
- Sustainability

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- PS1.A: Structure and properties of matter
- ETS1.A: Defining and delimiting engineering problems
- ETS1.B: Developing possible solutions

Crosscutting Concepts:

- Scale, proportion, and quantity
- Structure and function

Science and Engineering Practices:

- Asking questions (for science) and defining problems (for engineering)
- Planning and carrying out investigations

Nature of Science:

- Scientific investigations use a variety of methods.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

Teacher's Guide

Illegal Logging

April 2026

Table of Contents

<u>Anticipation Guide</u>	14
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	15
These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You'll find the questions ordered in increasing difficulty.	
<u>Graphic Organizer</u>	16
This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
<u>Answers</u>	17
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	20
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	21

Name: _____

Anticipation Guide

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Illegal logging is extremely profitable.
		2. There are at least 70,000 tree species worldwide.
		3. Cellulose and lignin polymers are different for each tree species.
		4. The DART-MS mass spectrometer can be used outside the lab.
		5. Prior to using the DART-MS, a chemical sample must be separated into its components.
		6. All species of rosewood are endangered.
		7. The harvesting location can be determined by analyzing isotopes of Oxygen-16 and Oxygen-18 in the wood sample.
		8. Illegal logging can disrupt entire ecosystems.
		9. Illegal logging contributes to climate change.
		10. Wood forensics is interdisciplinary, involving scientists from many different disciplines.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What is illegal logging?
2. Why is illegal logging considered a major environmental crime?
3. What is wood forensics?
4. What two main questions do forensic scientists try to answer about wood samples?
5. Why is it difficult to identify processed wood visually?
6. What are metabolites?
7. What is metabolomics?
8. How can metabolomics help identify wood species?
9. What analytical technique is commonly used in wood forensics?
10. What does a mass spectrum show?
11. What is DART-MS?
12. Why is illegal logging harmful to ecosystems?
13. What example species discussed in the article illustrates ecosystem impact?
14. How can stable isotope analysis help identify where a tree grew?
15. Why is wood forensics considered interdisciplinary science?

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe two important tools used by forensic scientists.

	Dart-MS	Metabolomics
What is it? How does it work?		
What does it identify?		
What are some limitations?		
How has it been used to catch illegal loggers? Give examples from the article. Include why the wood in your example is valuable.		

Summary: On the back of this paper, describe three challenges faced by scientists who study wood forensics.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What is illegal logging?

Illegal logging occurs when trees are harvested, transported, or sold in violation of laws protecting forests or regulating timber trade.

2. Why is illegal logging considered a major environmental crime?

The illegal timber trade generates billions of dollars each year and contributes to deforestation, habitat destruction, and organized crime.

3. What is wood forensics?

Wood forensics is the scientific study used to identify wood species and sometimes determine where the tree grew.

4. What two main questions do forensic scientists try to answer about wood samples?

They determine what species the wood is and where the tree grew.

5. Why is it difficult to identify processed wood visually?

Once trees are cut and processed, features such as leaves, bark, and growth patterns are removed.

6. What are metabolites?

Metabolites are small molecules produced by living organisms as part of their normal metabolism.

7. What is metabolomics?

Metabolomics is the study of the complete set of metabolites produced by an organism.

8. How can metabolomics help identify wood species?

Different species produce different mixtures of metabolites, creating chemical fingerprints that can identify the tree species.

9. What analytical technique is commonly used in wood forensics?

Mass spectrometry is used to measure molecular masses and detect chemical fingerprints.

10. What does a mass spectrum show?

A mass spectrum is a graph of peaks representing molecules with specific masses detected during analysis.

11. What is DART-MS?

Direct Analysis in Real Time Mass Spectrometry is a method that allows scientists to analyze samples quickly with minimal preparation.

12. Why is illegal logging harmful to ecosystems?

Removing key tree species disrupts food webs and can cause population declines in animals that depend on those trees.

13. What example species discussed in the article illustrates ecosystem impact?

Mongolian oak trees support Siberian boars, which are prey for endangered Amur tigers.

14. How can stable isotope analysis help identify where a tree grew?

Isotope ratios vary by geography and climate, allowing scientists to trace wood to specific regions.

15. Why is wood forensics considered interdisciplinary science?

It combines chemistry, biology, genetics, statistics, and environmental science.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

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0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Classroom Activities

Wood Identification Resources – U.S. Forest Service

Explains how scientists identify tree species using wood structure and chemistry.

<https://research.fs.usda.gov/fpl/identification>

The Wood Database – Wood Identification Guide

A student-friendly guide explaining how wood species are identified using grain patterns and structure.

<https://www.wood-database.com/wood-articles/wood-identification-guide/>

Videos

Mass Spectrometry Explained (Introductory Chemistry Video)

Animation explaining how molecules are ionized and separated by mass-to-charge ratio.

<https://www.youtube.com/watch?v=myoIF-h1kKI>

How Technology Tracks Illegal Logging – Global Forest Watch

Shows how scientists monitor forests and detect illegal logging using satellite data.

<https://www.youtube.com/watch?v=fjp0IkW3gNQ>

Interactive Data

Global Forest Watch Map (Real Deforestation Data)

Students can explore satellite data showing forest loss around the world.

<https://www.globalforestwatch.org/map>

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students how they might use chemistry to find wood that was logged illegally. Ask why it is important to find illegal logging activities. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about how chemistry is important in wood forensics.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Forensics
- Instrumentation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-LS2-2. Use mathematical representations to support and revise explanations based on evidence about factors affecting biodiversity and populations in ecosystems of different scales.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- LS2.A: Interdependent relations in ecosystems
- ETS1.B: Developing possible solutions

Crosscutting Concepts:

- Patterns
- Cause and effect
- Systems and system models

Science and Engineering Practices:

- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data

Nature of Science:

- Scientific knowledge is based on empirical evidence.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

Teacher's Guide

Natural Products

April 2026

Table of Contents

<u><i>Anticipation Guide</i></u>	23
Activate students' prior knowledge and engage them before they read the article.	
<u><i>Reading Comprehension Questions</i></u>	24
These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You'll find the questions ordered in increasing difficulty.	
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Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u><i>Chemistry Concepts and Standards</i></u>	30

Name: _____

Anticipation Guide

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Before a chemical can be synthesized, it must be isolated and its structure determined using spectroscopy.
		2. Malaria is transmitted by all species of mosquitoes.
		3. Obtaining desirable chemicals from trees always means killing the tree.
		4. Some chemicals obtained from natural products were synthesized in the 1800s.
		5. The chemicals from both birch and beech trees are used for treating wounds.
		6. Foxglove is a source of both a poison and a beneficial heart drug.
		7. Heroin is produced from morphine which comes from poppy seeds.
		8. Cacao seeds are used to produce chocolate as well as a chemical used as a heart stimulator and diuretic.
		9. Caffeine, morphine, taxol, and quinine all contain nitrogen in addition to carbon, hydrogen, and oxygen.
		10. Fiction writers have referred to the use of real chemicals from plants to murder people.

Student Reading Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What is the role of a "Natural Products Chemist"?
2. What is the benefit of synthesizing these chemicals that come from plants?
3. Name some pharmaceuticals that could also be detrimental to one's health. What are these negative effects?
4. What was done to salicylic acid to make it less irritating? What was the name given to this improved compound?
5. What is the name of the types of compounds that work as fever-reducers? What is the most common of these compounds, and what is it used to treat?
6. If some chemicals are too hard to synthesize, what are some options? Give an example in the reading to support your answer.
7. Look at the molecular structures for each of the featured chemicals. What are a few of the most common features of all the molecules?
8. What was the original reason for Xylitol? What is the common reason for its use presently?

Making Connections

9. Looking at the effects of the chemicals found in the cacao tree, why do you think chocolate is so widely popular, especially during special times like Valentine's Day or other holidays?
10. Explain how there needs to be collaboration between biologists, chemists, and medical professionals when it comes to developing medicines from plant-based chemicals.

Short Answer

State and explain some benefits, both environmentally and medicinally, of the practice of replicating natural forming molecules in the lab. Can you think of any possible complications or drawbacks? Explain.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe the chemicals found in each product, along with the use and when synthesized.

Natural product	Chemical(s)	Use(s)	First synthesized	Interesting fact(s)
Yew				
Willow				
Cinchona				
Madagascar Periwinkle				
Birch				
Beech				
Foxglove				
Poppy				
Cacao trees				
Deadly nightshade				

Summary: On the back of this paper, write a one-sentence summary (18 words or less) of the article.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What is the role of a "Natural Products Chemist"?
They extract the chemicals from plants and isolate the useful ingredients, and identify their structures.
2. What is the benefit of synthesizing these chemicals that come from plants?
To make sure the natural source is not depleted or destroyed.
3. Name some pharmaceuticals that could also be detrimental to one's health. What are these negative effects?
Poppy contains morphine and heroin, which when used by medical professionals can help with pain relief in their patients. However, these are also very popular and dangerous and illegal recreational drugs. Digoxin is used to treat heart conditions, but can also cause nausea, loss of appetite and blurry yellow vision. Additionally, it was once used by a nurse to poison and kill many people. Nightshade can also cause paralysis and death.
4. What was done to salicylic acid to make it less irritating? What was the name given to this improved compound?
Chemists added a CH_3 group (Methyl group) to the molecule which made it gentler on the stomach. The new name given was "aspirin".
5. What is the name of the types of compounds that work as fever-reducers? What is the most common of these compounds, and what is it used to treat?
Antipyretics is the group of molecules that reduce fever. Quinine is the most common; it is used to help treat malaria.
6. If some chemicals are too hard to synthesize, what are some options? Give an example in the reading to support your answer.
In the Pacific Yew Tree, the molecules are very hard to make in mass quantities because of the complicated ring structures. However, scientists can use the pine needles to extract chemicals without harming the tree and have now found a way to make it using cellular fermentation reactions.
7. Look at the molecular structures for each of the featured chemicals. What are a few of the most common features of all the molecules?
All molecules are organic, containing carbon, hydrogen, and oxygen. A few also contain nitrogen. Also, all but one molecule contains one or more rings in the structures.

8. What was the original reason for Xylitol? What is the common reason for its use presently?

During WWII, there was rationing of sugar in America. Scientists found a way to make a sugar substitute to keep up with demand. Presently, Xylitol is used to create artificial sweeteners for many diet drinks and foods to help combat obesity and other health problems related to too much sugar intake.

Making Connections

9. Looking at the effects of the chemicals found in the cacao tree, why do you think chocolate is so widely popular, especially during special times like Valentine's Day or other holidays?

The molecule theobromine is the molecule produced from caffeine. These two molecules are stimulants, which help increase heart rates in people. This effect, including the sugar content making chocolate so sweet, makes it a very appetizing treat. The Greeks called it "food of the Gods". This reputation makes chocolate a very popular choice for celebrations, holidays, and sweet rewards.

10. Explain how there needs to be collaboration between biologists, chemists, and medical professionals when it comes to developing medicines from plant-based chemicals.

Biologists study the plants to identify which ones have medicinal properties. Chemists analyze and isolate the compounds in those plants and then find a way to synthesize them in the lab to preserve the plants. Medical researchers would then test these compounds in new medicines to see how effective they are in treating diseases.

Short Answer

State and explain some benefits, both environmentally and medicinally, of the practice of replicating natural forming molecules in the lab. Can you think of any possible complications or drawbacks? Explain.

Environmentally, replicating these natural forming molecules will save the plants and trees that we used to extract these compounds from. With a larger population on the planet, and more diseases being discovered, making these compounds in the lab is better for the environment. Medicinally, scientists can make the compounds with higher purity and sometimes can tweak the structures to make them more effective compared to their natural counterparts. This would make the healing effects more effective with less side effects.

One complication is the fact that we cannot perfectly replicate some of these compounds. If we try to make similar substitutes, they may not be as effective as the actual chemicals. Also, as seen in some of the examples in the article, some of these lab-made chemicals can be too strong and lead to harm or death.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
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0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Laboratories

Making Aspirin

<https://teachchemistry.org/classroom-resources/aspirin-synthesis-and-spectroscopy-analysis>

Make a simple medicine from herbs

<https://www.diy.org/challenges/make-medicine>

Leaf chromatography

<https://edu.rsc.org/experiments/leaf-chromatography/389.article>

Lesson Plans

Different labs and activities about chocolate

<https://www.hersheyland.com/stories/chocolate-science-facts-tricks-and-learning-activities.html>

Activities

Medicines and drugs from plants – ‘trumps’ card game

<https://www.saps.org.uk/teaching-resources/resources/871/medicines-and-drugs-from-plants-trumps-card-game/>

Videos

The Power of Medicinal Plants & The Science Behind Them

https://youtu.be/K7x826mK6yI?si=DmszyCEcWAniJ_kS

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students if they know of any plants that are used medicinally, and what they are used for. Ask what problems might arise when we depend on a natural product for important drugs. Their initial ideas can be collected electronically via digital whiteboards or similar technology. As they read, students can find information to confirm or refute their original ideas.
- After students have read and discussed the article, ask students what they learned about the importance of synthesizing chemicals derived from natural products. Also ask what problems are encountered when trying to synthesize new chemicals.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Structural formulas
- Organic chemistry
- Instrumentation

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-6. Refine the design of a chemical system by specifying a change in conditions that would produce increased amounts of products at equilibrium.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ETS1.B: Developing possible solutions

Crosscutting Concepts:

- Patterns
- Cause and effect
- Structure and function

Science and Engineering Practices:

- Asking questions and defining problems
- Planning and carrying out investigations
- Analyzing and interpreting data

Nature of Science:

- Scientific knowledge assumes an order and consistency in natural systems.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).

Teacher's Guide

Black Walnuts

April 2026

Table of Contents

<u>Anticipation Guide</u>	32
Activate students' prior knowledge and engage them before they read the article.	
<u>Reading Comprehension Questions</u>	33
These questions are designed to help students read the article (and graphics) carefully. They can help the teacher assess how well students understand the content and help direct the need for follow-up discussions and/or activities. You'll find the questions ordered in increasing difficulty.	
<u>Graphic Organizer</u>	34
This helps students locate and analyze information from the article. Students should use their own words and not copy entire sentences from the article. Encourage the use of bullet points.	
<u>Answers</u>	35
Access the answers to reading comprehension questions and a rubric to assess the graphic organizer.	
<u>Additional Resources</u>	38
Here you will find additional labs, simulations, lessons, and project ideas that you can use with your students alongside this article.	
<u>Chemistry Concepts and Standards</u>	39

Name: _____

Anticipation Guide

Directions: *Before reading the article*, in the first column, write “A” or “D,” indicating your Agreement or Disagreement with each statement. Complete the activity in the box.

As you read, compare your opinions with information from the article. In the space under each statement, cite information from the article that supports or refutes your original ideas.

Me	Text	Statement
		1. Black walnut husks are red.
		2. The importance of black walnut trees to humans has been known for only about 500 years.
		3. Black walnuts have a very sweet taste.
		4. Natural product chemists identify chemicals found in trees and plants that may help cure human diseases.
		5. Volatile compounds have a low boiling point.
		6. Esters contain oxygen.
		7. Wood from black walnut trees is very dark and valuable.
		8. Juglone dye made from black walnuts was used to sign the Declaration of Independence.
		9. Juglone dye fades easily.
		10. Native Americans used juglone to treat skin infections and parasites.

Student Reading

Comprehension Questions

Name: _____

Directions: Use the article to answer the questions below.

1. What do natural product chemists and synthetic chemists do and how do they work together?
2. How has the black walnut tree species survived for thousands of years?
3. What are the uses of some of the compounds produced by the black walnut tree?
4. Explain the two places in the body where taste occurs.
5. Study the image of the juglone molecule shown in the article.
 - a. How many carbon atoms are in the molecule?
 - b. How many oxygen atoms are in the molecule?
 - c. How many double-bonded oxygens?
 - d. How many hydrogen atoms are there?
 - e. How many double bonds are there?
6. Why would someone want to steal a black walnut tree?
7. List three additional natural dye sources and the colors associated with each.
8. Describe how juglone is extracted from the black walnut tree.
9. Why doesn't pigment from juglone fade?

Questions for Further Learning

10. The article states that esters have the general formula: $\text{RCO(O)R}'$.
 - a. What do R and R' represent?
 - b. Many esters taste fruity. Research and draw a small poster that shows the structure of several fruity esters. Be sure to highlight the common feature in all esters which is the fact that one oxygen is single-bonded and the other is double-bonded.

<https://jameskennedymonash.wordpress.com/2013/12/13/infographic-table-of-esters-and-their-smells/>

11. Research allelopathy, the property of the black walnut that causes it to kill surrounding plants.

Graphic Organizer

Name: _____

Directions: As you read, complete the graphic organizer below to describe products from the black walnut tree.

Black Walnut Products	Examples & Why Valuable	Chemicals Involved
Food		
Inks & Dyes		
Wood		
Disease treatment		

Summary: On the back of this sheet, write three new things you learned about black walnuts.

Answers to Reading Comprehension Questions & Graphic Organizer Rubric

1. What do natural product chemists and synthetic chemists do and how do they work together?
Natural product chemists investigate chemical compounds found in plants and animals that may be used to cure diseases in humans. Once an active ingredient—a molecule that sparks a biological response—is identified, natural product chemists use spectroscopy to identify the structure of the molecule. Then they work with synthetic chemists to devise methods to make these compounds in the laboratory to preserve the natural sources but make large enough amounts of the compounds for therapeutic use.
2. How has the black walnut tree species survived for thousands of years?
The black walnut tree (*Juglans nigra*) has evolved over time to produce chemicals that allow it to successfully compete for space and light amid other trees in North America. They also produce a chemical, juglone, that kills most plants that come in contact with it.
3. What are the uses of some of the compounds produced by the black walnut tree?
The black walnut tree produces food (the walnuts themselves) along with chemical compounds used as inks and dyes. Native Americans used compounds in the tree to treat skin infections and parasites.
4. Explain the two places in the body where taste occurs.
Taste is a combination of receptors in the mouth interacting with molecules in your food. Additionally, receptors in the nose detect gas molecules from volatile compounds in the food.
5. Study the image of the juglone molecule shown in the article.
 - a. How many carbon atoms are in the molecule? 10
 - b. How many oxygen atoms are in the molecule? 3
 - c. How many double-bonded oxygens? 2
 - d. How many hydrogen atoms are there? 6
 - e. How many double bonds are there? 6
6. Why would someone want to steal a black walnut tree?
Black walnut trees have uses beyond baking with the nuts. The dark wood is easy to work with and the distinctive dark color makes it very coveted for furniture. In addition, dark ink and dye are made from these trees.
7. List three additional natural dye sources and the colors associated with each.
Indigo plant leaves are used to make a blue dye.
Hematite produces red, brown, and black dyes.
Crushed cochineal insects make bright red dye.
8. Describe how juglone is extracted from the black walnut tree.
Juglone is extracted from the black walnut tree by taking crushed fruit husks and boiling them in water. The colorless compound, hydrojuglone, is produced. Hydrojuglone converts to juglone when exposed to air. Juglone is brownish-yellow and turns black upon oxidation.

9. Why doesn't pigment from juglone fade?

The structure is unique in that it binds to proteins in paper and fabric. Oxidation also locks molecules onto surfaces – it is great for coloring fabric, but be careful because it will also stain your skin.

Questions for Further Learning

10. The article states that esters have the general formula: $\text{RCO(O)R}'$.

a. What do R and R' represent?

R and R' are used as general terms for hydrocarbon chains of any length.

b. Many esters taste fruity. Research and draw a small poster that shows the structure of several fruity esters. Be sure to highlight the common feature in all esters which is the fact that one oxygen is single-bonded and the other is double-bonded.

Some esters taste like banana, peach, or cherry and so many more! Study this infographic for more information and examples.

Source:

<https://jameskennedymonash.wordpress.com/2013/12/13/infographic-table-of-esters-and-their-smells/>

11. Research allelopathy, the property of the black walnut that causes it to kill surrounding plants.

Answers will vary. This property in juglone causes energy production in surrounding sensitive plants to cease. Roots of the black walnut tree release the chemical into the ground so the issue persists even if the tree is removed. Some plants that are affected include lilacs, tomatoes, and peppers. Resistant plants include hostas and forsythia.

Graphic Organizer Rubric

If you use the Graphic Organizer to evaluate student performance, you may want to develop a grading rubric such as the one below.

Score	Description	Evidence
4	Excellent	Complete; details provided; demonstrates deep understanding.
3	Good	Complete; few details provided; demonstrates some understanding.
2	Fair	Incomplete; few details provided; some misconceptions evident.
1	Poor	Very incomplete; no details provided; many misconceptions evident.
0	Not acceptable	So incomplete that no judgment can be made about student understanding

Additional Resources and Teaching Strategies

Additional Resources

Video:

Khan Academy: Fischer Esterification

Learn how esters are made and see examples of how to name some organic acids and alcohols.

https://www.youtube.com/watch?v=-Jzk_P9jTL8

Article:

Juglone

Read more about juglone in ACS Molecule of the Week.

<https://www.acs.org/molecule-of-the-week/archive/j/juglone.html>

Career Connection:

Explore the Environmental Education and Interpretation undergraduate program at SUNY.

<https://www.esf.edu/academics/undergraduate/environmental-interpretation.php>

Teaching Strategies

Consider the following tips and strategies for incorporating this article into your classroom:

- **Alternative to Anticipation Guide:** Before reading, ask students if they have ever eaten black walnuts, or foods made with black walnuts. Ask if black walnuts might have any uses other than food.
 - As they read, students can find information to confirm or refute their original ideas.
 - After they read, ask students what they learned about black walnuts and why they are valued by indigenous people. Ask them what we may use black walnuts for in the future.

Chemistry Concepts and Standards

Connections to Chemistry Concepts

The following chemistry concepts are highlighted in this article:

- Molecular structure
- Structural formulas
- Intermolecular forces
- Environmental chemistry

Correlations to Next Generation Science Standards

This article relates to the following performance expectations and dimensions of the NGSS:

HS-PS1-3. Plan and conduct an investigation to gather evidence to compare the structure of substances at the bulk scale to infer the strength of electrical forces between particles.

HS-ETS1-3. Evaluate a solution to a complex real-world problem based on prioritized criteria and tradeoffs that account for a range of constraints, including cost, safety, reliability, and aesthetics, as well as possible social, cultural, and environmental impacts.

Disciplinary Core Ideas:

- PS1.A: Structure and Properties of Matter
- ETS1.C: Optimizing the Design Solution

Crosscutting Concepts:

- Structure and function
- Stability and change

Science and Engineering Practices:

- Planning and carrying out investigations
- Constructing explanations (for science) and designing solutions (for engineering)

Nature of Science:

- Science is a human endeavor.

See how *ChemMatters* correlates to the [Common Core State Standards online](#).