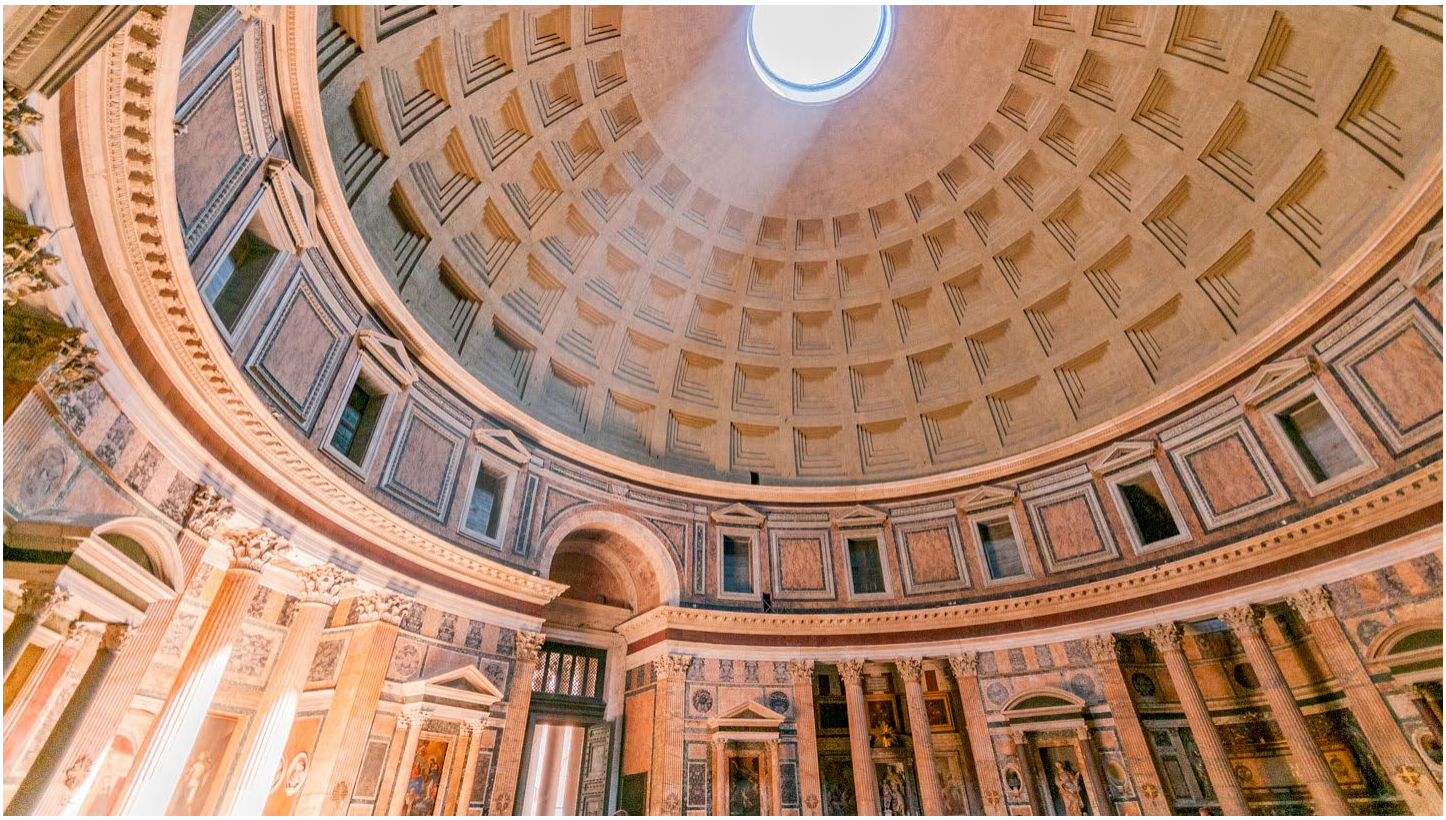
ScienceNews
EDUCATOR GUIDE



STEPHEN KNOWLES PHOTOGRAPHY/MOMENT/GETTY IMAGES PLUS

February 11, 2023

Chemists Crack the Code to Ancient Roman Concrete

SOCIETY FOR SCIENCE

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Chemists Crack the Code to Ancient Roman Concrete

About this Guide

The ancient Romans built concrete structures that have stood for thousands of years. In this Guide, students will learn how scientists experimented to make Roman-style concrete — without causing explosions!

This Guide includes:

Article-based Comprehension Q&A — Students will answer questions about the online *Science News* article "These chemists cracked the code to long-lasting Roman concrete," which explains the process scientists used to re-create the Romans' superb building material. A version of the article "Chemists Crack the Code to Ancient Roman Concrete" appears in the February 11, 2023 issue of *Science News*. Related standards include NGSS-DCI: MS-PS1; HS-PS3.

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

Cross-curricular Discussion Q&A — Use a real-life example to have students gain a deeper understanding of physical and chemical changes and properties of substances. Learning Outcomes: Gain an understanding of physical and chemical changes and properties and apply the knowledge to real-world examples. Related standards include NGSS-DCI: MS-PS1; HS-PS3.

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

Science Bite Activity — In this quick activity, students will write a scientific question to learn more about a historical artifact. Learning Outcomes: Asking scientific questions.

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

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Article-based Comprehension, Q&A

Directions for teachers: Ask students to read the online *Science News* article "These chemists cracked the code to long-lasting Roman concrete" and have them answer the following questions. A version of the article "Chemists Crack the Code to Ancient Roman Concrete" appears in the February 11, 2023 issue of *Science News*.

1. What components are in modern concrete?

Cement, gravel, sand and water are common ingredients in concrete.

2. Why do chemists want to understand how the ancient Romans made concrete?

Chemists want to improve modern concrete production. The concrete made by the ancient Romans has lasted much longer than concrete made nowadays.

3. Whose writings did the scientists read to learn how the Romans made concrete? What pieces of information did those early Roman writers provide?

The scientists read works by the historian Pliny and the architect Vitruvius. From the writings, the scientists learned that quicklime used to make concrete should be made from high-quality limestone and that heat is produced when quicklime, volcanic ash and water are combined.

4. What is the chemical name for quicklime, and what element in the chemical name also appears in Roman concrete?

Calcium oxide is the chemical name for quicklime. One of the elements in quicklime is calcium. Roman concrete contains lots of small calcium-rich rocks.

5. How might the presence of calcium-rich rocks improve the quality of Roman concrete? Explain the interaction between the calcium and the concrete that might make the concrete last longer.

The scientists think the presence of calcium-rich rocks allows the concrete to heal itself when it cracks. It's like the concrete has a built-in repair kit. The calcium can dissolve when it gets wet and then it moves into cracks and hardens (or re-crystallizes), and thereby fixes the concrete.

6. How did chemist Admir Masic and his team go about making their version of Roman concrete? What is the name of the method they used?

The scientists had to use "hot mixing" to make concrete that was high in calcium. In hot mixing, calcium oxide and ash are mixed, and then water is added.

7. How did the team test its version of the Roman concrete?

After the scientists made their concrete, they tested it to see whether it behaved like Roman concrete. The researchers did this by breaking the concrete, dripping water between the pieces and verifying that the breaks did heal.

8. What is the environmental cost of modern concrete manufacturing, and what would be the environmental benefit of making concrete that is more like Roman concrete?

Manufacturing concrete contributes significantly to greenhouse gas emissions every year. Approximately 8 percent of annual carbon dioxide emissions are a result of concrete manufacturing. Making concrete with the long-lasting properties of Roman concrete would reduce the need to replace structures and would decrease the need to produce as much of the building material.

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Student Comprehension Worksheet

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Cross-curricular Discussion, Q&A

Directions for teachers: This discussion activity can be used to help students better understand the difference between physical and chemical changes. Before beginning this work, students should understand that substances are made up of atoms, elements and molecules. Have students discuss the first set of questions with a partner, then read the *Science News* article "These chemists cracked the code to long-lasting Roman concrete" and answer the second set of questions. A version of the article, "Chemists Crack the Code to Ancient Roman Concrete," appears in the February 11, 2023 issue of *Science News*.

Want to make it a virtual lesson? Post the online *Science News* article to your virtual classroom. Discuss the article and questions with your class on your virtual platform.

Changes in matter

1. When matter goes through a change, the process is either classified as chemical or physical. Look at the examples given below and discuss which group of examples you think show physical changes and which show chemical changes.

Crumbling paper, dissolving sugar, melting ice, bending a metal earring and diluting orange juice with water

A piece of paper burning, a car door rusting, food digesting, a banana ripening and a leaf photosynthesizing

The objects listed in the first example are going through physical changes, and the objects in the second set are going through chemical changes.

2. What happens to matter when it goes through a physical change? What about a chemical change? Using your answers, write your own definition of physical change and chemical change.

Physical changes do not change the chemical composition of a substance. The same substance is present before and after the physical change. Also, these changes are often reversible. Chemical changes alter the chemical makeup of a substance, creating new substances when chemical bonds are broken and new chemical bonds form.

3. Using the examples given, discuss what indicators you can use to determine whether a physical or chemical change has taken place.

Physical changes can be indicated by changes in a substance's texture, shape, temperature or amount. Phase changes — for example, when a solid becomes a liquid or a liquid becomes a gas — also indicate a physical change.

Some common indicators of chemical changes include the production or consumption of heat or energy, changes in color and composition, the combustion of a substance, and the formation of new solids or gases.

4. Can observation always tell you whether a change in matter has occurred? Discuss why or why not.

You cannot always see whether a change in matter has occurred. Sometimes chemical changes occur, and the products don't appear to be different from the reactants.

5. Every substance has physical and chemical properties. Physical properties of a substance can be observed without changing the chemical makeup of the substance, such as density. Chemical properties of a substance describe how it can react with other substances. Describe some of the chemical and physical properties of at least three of the substances in the examples listed in question 1.

A physical characteristic of paper is that it is flexible, so it can be crumbled and bent, and yet it remains paper. A chemical characteristic of paper is that it is flammable. When you burn paper, it reacts with oxygen to create new substances, including ashes, water and carbon dioxide. A physical property of the metal earring is malleability. However, no matter how much you mash the earring, it remains the same metal. You can change the earring's chemical properties by combining it with a reactive acid. Water's chemical formula is H_2O. Its chemical makeup stays the same whether it is solid, liquid or gas.

6. If a physical change occurs to a substance, do its physical and chemical properties change? What if a chemical change occurs?

If a physical change occurs to a substance, the resulting substance will have the exact same chemical and physical properties. If a chemical change occurs, the physical and chemical properties will likely be different, because a new substance is created.

Concrete creations and changes

1. The article mentions the Pantheon, an impressive Roman structure that is made of concrete. What other uses of concrete do you know about and see all the time? Name some physical and chemical properties of concrete based on your examples.

Concrete is used in bridges and to make sidewalks. It also is used to make foundations and subfloors in many houses and buildings. A physical property of concrete is that it is strong but can crack under pressure. A chemical property of concrete is that it reacts and degrades with acid rain.

2. As the article highlights, many chemical and physical changes occur when concrete is made. Give examples of chemical and physical changes mentioned in the article. Discuss with your partner why you think they are physical or chemical changes. If you'd like to, look up additional information about the science around cement and concrete.

"Hot mixing" and the reaction of quicklime with water cause chemical changes; the article says the reaction is highly exothermic and possibly explosive. The change also produces a completely different material with different physical properties, which indicates a chemical change has occurred. Breaking the pieces of concrete and placing them a distance apart were physical changes that the scientists made.

3. Are there any changes mentioned in the article that you cannot classify as physical or chemical? Discuss why you can't and note what additional information you will need to determine whether the changes are physical or chemical.

When "mixing" is mentioned in the article, the writer does not say specifically what is changing or being created, so we're not able to determine exactly what type of change is occurring. We think the dissolving of the calcium-rich stones and their re-crystallization is likely a physical change. The article does not indicate that a new substance is formed when re-crystallization occurs, but if a new substance crystalizes, then the change would be chemical.

4. How did studying the physical and chemical properties of Roman concrete help researchers understand its "healing power?"

The researchers figured out how to recreate the "ubiquitous calcium-rich rocks" found in Roman concrete. They hypothesized that the rocks they made would interact with water and dissolve to fill cracks and fissures in concrete. The scientists tested their concrete and found that it could heal cracks. If the scientists had not known the composition and properties of the calcium-rich rocks, they might not have been able to recreate them in the concrete.

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Student Discussion Worksheet

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Science Bite Activity: Write a Scientific Question Based in History

Directions for teachers: Use this short activity as a warm-up or an exit ticket in class. After students read the article "These chemists cracked the code to long-lasting Roman concrete," ask them to follow the prompts below to write their own scientific question about a historical artifact. For guidance on writing scientific questions, check out the lesson plan "Why ask scientific questions?"

Tapping history for clues

Think of a historical artifact or structure that you've studied. It could be anything from a clay pot found in an archaeological dig to the pyramids of Giza.

1. What artifact or structure did you choose? What about your object makes you curious? What questions do you have?

2. How could you use science to answer one of your questions?

3. Write a scientific question about your chosen historical artifact. Because your object might be quite old and not have a written record, there will be limits to what you can discover. Consider those limitations when developing your question. Scientific questions should lead to measurable results, and the variables under consideration need to be controllable. Investigation using observation, scientific tools or computer simulations should help answer your question.

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