

**October/November 2016 Teacher's Guide for**

***How SUE Became a Rock Star***

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# About the Guide

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Articles from past issues of *ChemMatters* and related Teacher’s Guides can be accessed from a DVD that is available from the American Chemical Society for $42. The DVD contains the entire 30-year publication of *ChemMatters* issues, from February 1983 to April 2013, along with all the related Teacher’s Guides since they were first created with the February 1990 issue of *ChemMatters*.

The DVD also includes Article, Title, and Keyword Indexes that cover all issues from February 1983 to April 2013. A search function (similar to a Google search of keywords) is also available on the DVD.

The *ChemMatters* DVD can be purchased by calling 1-800-227-5558. Purchase information can also be found online at <http://tinyurl.com/o37s9x2>.

# Student Questions

**How SUE Became a Rock Star**

* 1. Is a fossil the actual bones of the skeleton of an animal that died many years ago? Explain.
	2. How did SUE get her name?
	3. Who is SUE and why is she important?
	4. Why are more fossils formed in the ocean than on land?
	5. Name three types of body cells and what they release soon after death.
	6. Why are bacteria important to the decomposition process and the formation of fossils?
	7. Describe the construction of living bone.
	8. After death, what happened to the spaces left by the loss of organic material from *T. rex* bones?
	9. From the given chemical formula for a unit of hydroxyapatite, name the ions that are present.
	10. Since small dinosaur bones are usually washed away, why is the fossil of SUE remarkable?
	11. Give at least three examples of things that we can learn about the past from fossilsof animals that died millions of years ago.
	12. What can we learn by studying protein preserved in fossils?

# Answers to Student Questions

**(taken from the article)**

**How SUE Became a Rock Star**

* + 1. **Is a fossil the actual bones of the skeleton of an animal that died many years ago? Explain.**

*A fossil is not the actual bones of an animal, but the rocks that formed in and around the bones as they decayed.*

* + 1. **How did SUE get her name?**

*SUE was named for Sue Hendrickson, the paleontologist who discovered her in 1990.*

* + 1. **Who is SUE and why is she important?**

*To date, SUE is the largest and most complete fossil of a* Tyrannosaurus rex *ever found.*

* + 1. **Why are more fossils formed in the ocean than on land?**

*Most fossils form in the ocean because decomposition occurs slowly when the organism is covered in sand or mud in the ocean.*

* + 1. **Name three types of body cells and what they release soon after death.**

*Soon after death:*

* + - 1. *red blood cells release iron,*
			2. *digestive cells release enzymes, and*
			3. *muscle cells release calcium.*
		1. **Why are bacteria important to the decomposition process and the formation of fossils?**

*Bacteria are important to the decomposition process because they produce putrescine and cadaverine that attract insects and larger scavengers.*

* + 1. **Describe the construction of living bone.**

*Living bone is composed of a porous collagen protein embedded in a mineral and permeated with living cells, blood vessels and nerves.*

* + 1. **After death, what happened to the spaces left by the loss of organic material from *T. rex* bones?**

*After death, the spaces left by the loss of organic material from* T. rex *bones were filled by minerals.*

* + 1. **From the given formula for a unit of hydroxyapatite, name the ions that are present.** *The given chemical formula for a unit of hydroxyapatite shows calcium ions, phosphate ions and hydroxide ions.*
		2. **Since small dinosaur bones are usually washed away, why is the fossil of SUE so remarkable?**

*The fossil of SUE is remarkable because SUE’s tiny ear bones have been recovered.*

* + 1. **Give at least three examples of things we can learn about the past from fossils of animals that died millions of years ago.**

*Accept student responses that show at least three of these five answers.*

*Fossils of animals that died millions of years ago may be able to tell us about:*

1. *how animals changed over time*
2. *whether animals disappeared due to mass extinctions*
3. *migration patterns of animals*
4. *climate change and*
5. *continental plate movements.*
	* 1. **What can we learn by studying protein preserved in fossils?**

*Studying protein preserved in fossils reveals information about when and how animal traits evolved.*

# Anticipation Guide

Anticipation guides help engage students by activating prior knowledge and stimulating student interest before reading. If class time permits, discuss students’ responses to each statement before reading each article. As they read, students should look for evidence supporting or refuting their initial responses.

**Directions:**  *Before reading*, in the first column, write “A” or “D,” indicating your agreement or disagreement with each statement. 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. Fossils are bones of animals that lived a long time ago.
 |
|  |  | 1. The dinosaur SUE was named after the paleontologist who discovered it.
 |
|  |  | 1. The process of decomposition is accelerated when an organism is buried under sand or mud.
 |
|  |  | 1. When an organism dies, iron, digestive enzymes, and calcium leak, causing the body to stiffen.
 |
|  |  | 1. The compounds produced in the gut of a dead organism attract scavengers.
 |
|  |  | 1. Bone minerals contain phosphate.
 |
|  |  | 1. Bone mineral reacts with chemicals in the environment when an organism dies.
 |
|  |  | 1. Some fossils show signs of the behavior and activity of ancient organisms, not the organism itself.
 |
|  |  | 1. Some atoms in your body right now probably came from a dinosaur’s body.
 |
|  |  | 1. SUE’s ear structure is much different from human ear structure.
 |

# Reading Strategies

These graphic organizers are provided to help students locate and analyze information from the articles. Student understanding will be enhanced when they explore and evaluate the information themselves, with input from the teacher if students are struggling. Encourage students to use their own words and avoid copying entire sentences from the articles. The use of bullets helps them do this. If you use these reading strategies 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 |

***Teaching Strategies (for entire October/November 2016 issue):***

* Links to **Common Core Standards for Reading**:
	+ ELA-Literacy.RST.9-10.1:Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.
	+ ELA-Literacy.RST.9-10.5: Analyze the structure of the relationships among concepts in a text, including relationships among key terms (e.g., force, friction, reaction force, energy).
	+ ELA-Literacy.RST.11-12.1:Cite specific textual evidence to support analysis of science and technical texts, attending to important distinctions the author makes and to any gaps or inconsistencies in the account.
	+ ELA-Literacy.RST.11-12.4: Determine the meaning of symbols, key terms, and other domain-specific words and phrases as they are used in a specific scientific or technical context relevant to grades 11-12 texts and topics.
* Links to **Common Core Standards for Writing**:
	+ ELA-Literacy.WHST.9-10.2F: Provide a concluding statement or section that follows from and supports the information or explanation presented (e.g., articulating implications or the significance of the topic).
	+ ELA-Literacy.WHST.11-12.1E: Provide a concluding statement or section that follows from or supports the argument presented.
* **Vocabulary** and **concepts** that are reinforced in this issue:
	+ Forensic science
	+ Molecular structures
	+ Polar and nonpolar molecules
	+ Wavelengths of light
	+ Chemical reactions
	+ Personal and community health
	+ Heavy metals
	+ Conservation of matter
	+ Consumer choices
* Some of the articles in this issue provide opportunities for students to consider how understanding chemistry can help them make informed choices as consumers.
* To help students engage with the text, ask students which article **engaged** them most and why, or what **questions** they still have about the articles. The Background Information in the *ChemMatters* Teachers Guide has suggestions for further research and activities.
* In addition to the writing standards above, consider asking students to debate issues addressed in some of the articles. Standards addressed:
	+ **WHST.9-10.1B** Develop claim(s) and counterclaims fairly, supplying data and evidence for each while pointing out the strengths and limitations of both claim(s) and **counterclaims** in a discipline-appropriate form and in a manner that anticipates the audience’s knowledge level and concerns.
	+ **WHST.11-12.1.A** Introduce precise, knowledgeable claim(s), establish the significance of the claim(s), distinguish the claim(s) from alternate or opposing claims, and create an organization that logically sequences the claim(s), counterclaims, reasons, and evidence.

**Directions:** As you read the article, complete the graphic organizer below to describe the steps in fossil formation.

|  |  |  |
| --- | --- | --- |
|  | **What happens, including time each process takes** | **Chemicals involved** |
| **Organism dies** |  |  |
| **Minerals replace bone** |  |  |
| **More minerals replace blood vessels** |  |  |
| **Rocks form around fossils** |  |  |

**Summary:** On the back of this paper, write a one-sentence summary (20 words or less) describing fossil formation.

# Connections to Chemistry Concepts

**(for correlation to course curriculum)**

1. **Ionic structure**—Figure 1 in the Emilsson/Tinnesand SUE article shows a single unit of an ionic mineral crystal and provides possible changes in the unit formula due to ion migration.
2. **Balancing the ionic charge in compounds**—When working on balancing ionic charges in a formula, ask students to make the possible replacements given in Figure 1 in the Emilsson/Tinnesand SUE article noting that the replaced ionic charge may differ from the charge of the ion in hydroxyapaptite. Students will have to balance the charges.
3. **Ion replacement**—As shown in Figure 1 of the Emilsson/Tinnesand SUE article, ions in the original hydoxyapaptite unit crystal can often be replaced by others with stronger affinity located in moist ground or bodies of water.
4. **Catalysis**—Digestive enzymes are organic catalysts that speed the decomposition of living material. This leads to the breakdown of blood and tissues.
5. **Periodicity**—Figure 1 in the Emilsson/Tinnesand SUE article provides the opportunity to discuss that the possible replacement of mono and polyatomic ions in hydroxyapatite is determined by their periodic relationship to the original ion in the crystal.
6. **Nomenclature of ionic formulas**—Refer to Figure 1 in the Emilsson/Tinnesand SUE article while naming and writing formulas for ionic structures. Naming the unit cells in hydroxyapatite substitutions can be shown by focusing first on the back end of the molecular formula. This becomes the beginning of the name. For example: When the end is a hydroxyl (OH–) unit, the name will begin with “hydroxy” (e.g., hydroxyapatite). If F– has been substituted for OH–, the name will become fluorapatite and a Cl– replacement is chlorapatite.
7. **Nomenclature of organic molecules**—The structures of putrescine (NH2(CH2)4NH2) and cadaverine (NH2(CH2)5NH2) present good opportunities to connect students’ prior knowledge of the nomenclature of amino compounds such as amino acids studied in biology with the alkane series.
8. **Crystal packing**—When students study ionic crystals and crystal packing, the unit cell of hydoxyapatite provides a good example of the complexity of mineral structures, which suggests the value of the study of single unit cells.
9. **Chemical changes**—Initial phases of fossil formation involve many chemical changes. As bacteria decompose living tissue, cadaverine and putrescine, as well as many other chemicals, are formed.
10. **Physical changes**—Fossil formation also involves physical changes as ions migrate from the ground water or bodies of water to fill pores in the bone.
11. **Conservation of matter**—The sidebar in the Emilsson/Tinnesand SUE article describes how nature recycles. This provides an opportunity to reinforce conservation of matter over millions of years.

# Possible Student Misconceptions

**(to aid teacher in addressing misconceptions)**

1. **“This *T. Rex* is female, of course; she is named SUE.”** *SUE was named for Sue Hendrickson, a female paleontologist. Researchers say that too few specimens of T. rex have been found to speculate about their gender.*
2. **“I’ve heard that fossils are simply bones that have turned into stone.”** *Although fossils may look like stone on the outside, they are actually bones that still contain some of their original calcium and phosphate material in bone mineral similar to the hydoxyapatite formula given in the Emilsson/Tinnesand SUE article.*
3. **“Dinosaurs were really a failed species, because they died out completely.”** *Actually dinosaurs were quite successful and adapted well. They ruled the earth for over 150 million years (compared to man’s approximate six million, or our civilization of only about 6,000 years)! And, many dinosaur species led to the evolution of birds.*
4. **“I’m really confused. Some people say that the dinosaurs were still on Earth when early humans were here.”** *Scientific data shows that the last dinosaurs died 62 million years before humans arrived.*
5. **“I’ve heard that archeologists dig up dinosaurs.”** *Archeologists deal with humans who lived during the last 3-4 million years; paleontologists study fossils left during the last 3.5 billion years.*
6. **“In a film, I saw a *T. rex* chasing a jeep at a scary 45 miles an hour.”** *T. rex was a massive animal. To run at this speed, SUE would need 86% of its muscle content located in its legs. Paleontologists say that this impossible.*
7. **“I guess that we can just use carbon dating to determine the age of *T. rex* fossils.”** *Carbon dating requires the presence of organic (carbon containing) compounds that are no longer present in fossils. Besides, carbon dating only extends back about 56,000 years, about 10 half-lives of C-14. See “fossil dating” in the “Background Information” section, above.*

# Anticipating Student Questions

**(answers to questions students might ask in class)**

1. **“If *T. rex* fossils are buried under many layers of sediment, how can we find them?”** *Over millions of years, the earth’s tectonic plates have continually shifted. The uplifts that result from plate collisions, bring lower sediment layers that contain fossils to the surface. Here, wind and rain can erode the sediment material leaving the fossils exposed.*
2. **“How will I know when I find a fossil and not just a bone?** *A fossil looks and feels different from a bone. A bone is often white from the calcium in the bone mineral. As calcium ions leave, the fossil is left with a brownish color. Bone is also porous and light-weight compared to a solid fossil.*
3. **“Can you tell the difference between a fossil and an ordinary rock?”** *Yes, but this is difficult. If the object is broken, look inside. If it is the same inside and out, it is a rock. A fossil will show tiny spaces inside like the ones seen in bone. When in doubt you will need to ask a paleontologist.*
4. **“How long does it take to make a fossil?”** *Fossils are defined as remains of animals that died more than 10,000 years ago. So, the minimum time to make a fossil is considered to be 10,000 years.*
5. **“How quickly did *T. rex* grow as a teenager?”** *Between the ages of 14 and 18,* T. rex *probably gained five pounds per day!*
6. **“When did the dinosaurs inhabit the earth?”** *This depends upon the species of dinosaur. For example, there were 65 million years between the times that Apatosaurus and* T. rex *inhabited the earth.*
7. **“Can we determine the exact age of SUE?”** *No, uranium dating will only provide an approximate age of a dinosaur.*

# Activities

**Labs and Demos**

1. **Chemistry lab, “Effect of pH on Precipitation of Hydroxyapatite**”: This investigation is appropriate high school students and best scheduled late in the school year. Allow about 40 minutes of class time; 20 minutes of teacher preparation time.Students will review chemical equations, solutions, pH and Le Châtelier’s Principle as they study the effects of varying the concentration of hydrochloric acid on the precipitation of hydroxyapatite. Complete lesson plans are given in Appendix B, along with suggested data and student questions with answers. The experimental procedure is prefaced by extensive background information on fossilization. (<https://answersingenesis.org/fossils/how-are-fossils-formed/soft-tissue-fossilization/>)
2. **A lab: “Make your Own Fossil”:**  Note: The material must sit for 1 hour or be left overnight to dry. Students can make their own Plaster of Paris fossils. After practice in the high school classroom, this lab activity would be an excellent choice to share with local elementary students during National Chemistry Week and/or through a ChemClub at your school.

The chemistry is simple: the mineral gypsum is heated to 150 oC to drive the water from the hydrate

 heat

2 CaSO4 • 2 H2O 🡪 2 CaSO4 • ½ H2O + 3 H2O

 Gypsum Plaster of Paris (powder)

In lab, the powdered Plaster of Paris is rehydrated with water to form a slurry, then the fossil is left to dry (dehydrating again):

 2 CaSO4 • ½ H2O + 3 H2O 🡪 2 CaSO4 • 2 H2O + heat

Note that forming Plaster of Paris requires heat energy; reconstituting releases energy.

Complete lab instructions are located on this website: (<http://www.chemicalformula.org/plaster-of-paris>)

**Simulations**

1. **“Collagen Synthesis” flash movie:** This site from the *National Center for Biotechnology Information* contains a short flash movie showing collagen synthesis. Just keep pressing “continue” to forward to the next stage. (<https://depts.washington.edu/bonebio/ASBMRed/matrix.html>)

**Media**

1. **YouTube video (3:00), “Dinosaur 13 Official Trailer (2014) HD**”**:** This is the official trailer of the documentary, “Dinosaur 13”. Show this as a dramatic introduction to the drama behind the discovery of SUE. (<https://www.youtube.com/watch?v=XZywsT8Sy-c>)
2. **YouTube video (15:32) Outdoor labs to study human decomposition:** Students will find this TED Talk video, “Dr. Arpad Vass—Forensics”, on forensic anthropology interesting. Dr. Vass, University of Tennessee, set up outdoor labs to study human decomposition. He encountered legal problems securing human cadaver donations. The 480 different volatile compounds (biomarkers) that are released during this process help determine the date and time of death. Cadaver dogs are important in crime solving because, “You can’t do post mortem until you find the body.” (<https://www.youtube.com/watch?v=l0Qd2nxMC2Y>)
3. **YouTube video “Radiometric Dating” (7:08):** This New Zealand video describes the use of radiometric dating to determine fossil age using adjacent rock. A piece of rock is pulverized, uranium in the minerals is extracted using a mass spectrometer and the age is determined from the rate of decay of uranium. Credit for the genesis of this procedure is given to Einstein and Rutherford. (<https://www.youtube.com/watch?v=1920gi3swe4>)
4. ***Discovery Channel* film (56:21), “Last Day of Dinosaurs”:** This is a very dramatic presentation that shows the hypothesized effects on dinosaurs of an asteroid hitting the earth. (<https://www.youtube.com/watch?v=9f5HehQovx8>)
5. **YouTube video (1:36) “Fossilization”:** This video provides an introduction to the process of fossilization. Animation is used to clearly describe four steps to becoming a fossil. (<https://www.youtube.com/watch?v=4-dTz416rYg>)
6. **Four YouTube video lessons on *measuring age on earth*:** There are four Kahn lessons on radioactive dating in this series. Although they do not cover uranium/lead dating, they cover the basic theory of half-life and take students through mathematical calculations:
7. “Carbon 14 dating 1” (10:03)
8. “Carbon 14 dating video 2” (4:14)
9. “Potassium-argon (K-Ar) dating” (10:35)
10. “K-Ar dating calculation” (11:07)

This URL will take you to the first lesson. On the left margin you will see links to the other three. (<https://www.khanacademy.org/science/cosmology-and-astronomy/life-earth-universe/measuring-age-tutorial/v/carbon-14-dating-1>)

**Lessons and Lesson Plans**

1. **Lesson on writing formulas of ionic compounds:** While studying ionic compounds, ask students to write formulas for substituted hydroxyapatite unit crystals using the ions given in Figure 1 of the Emilsson/Tinnesand SUE article. For example: If Ca2+ is replaced by Sr2+ the new formula for the unit crystal will be Sr10(PO4)6(OH)2 because strontium has the same charge as calcium. But if Na+ is substituted, the formula will be Na20(PO4)6(OH)2.
2. **Students develop a geologic time line:** These sites provide detailed information on the presentation of a lesson to illustrate the concept of time from the beginning of the earth to human habitation.
3. This site shows a 5E lesson plan for a high school student activity: <https://www.cwu.edu/waters/sites/cts.cwu.edu.waters/files/documents/5E_investigating_geological_time_building_timescale.doc>.
4. Here is a simple lesson plan for a similar activity: <http://www2.mbusd.org/staff/pware/pdf/GeologicalTimeline.pdf>.
5. Students may find this timeline activity a bit juvenile, but it could be readily adapted to the level of high school students. (<http://www.dynamicearth.co.uk/media/1514/geological-timeline-pack.pdf>)

**Projects and Extension Activities**

1. **Debate ethical questions that surround for-profit paleontology:** Provide students with a prompt and ask teams to prepare for a debate. For example:
2. Should a piece of our natural history be sold?
3. Consider the “pros” and “cons” of the for-profit fossil sale business in the USA and/or internationally. The following URLs contain useful information for group debates. Note: you may want to review these before assigning/giving them to students for research.
4. **“Con” group arguments** against the for-profit sellers featured in the “Dinosaur 13” movie:
5. (<http://www.slate.com/articles/health_and_science/science/2013/01/tarbosaurus_bataar_smuggling_case_dinosaur_fossil_dealers_steal_bones_from.single.html>)
6. (<http://www.slate.com/blogs/browbeat/2014/08/22/dinosaur_13_review_movie_about_peter_larson_spins_a_bogus_tale.html>)
7. (<http://www.chicagoreader.com/chicago/dinosaur-13-review-todd-douglas-miller-peter-larson-tyrannosaurus-rex-fossil-sue-field-museum-of-natural-history/Content?oid=14690513>)
8. (<https://www.washingtonpost.com/local/the-t-rex-that-got-away-smithsonians-quest-for-sue-ends-with-different-dinosaur/2014/04/05/7da9a73c-b9a6-11e3-9a05-c739f29ccb08_story.html>)

See “Dinosaur 13” in “Web Sites for Additional Information” below for more information on these links.

Students may use arguments such as:

* For-profit sellers save researchers time and money but they sometimes deal in stolen property.
* For-profit sellers may try to increase the value to their specimens by adding teeth from one fossil to another.
* A fossil sold to the public may disappear and never be displayed in museums.
1. **“Pro” group arguments** in favor of the for-profit sellers featured in the “Dinosaur 13” movie:
2. 3 minute film trailer: (<https://www.youtube.com/watch?v=XZywsT8Sy-c>)
3. The movie (1:35:00): available through ITunes and other movie distributors. (<https://itunes.apple.com/us/movie/dinosaur-13/id889020430>)

Students may use arguments such as:

* For-profit sellers help scientists who lack the time and resources to find fossils.
* For-profit sellers travel throughout the world to collect, clean and repair fossils for museums and academic researchers.
1. **Research and presentation:** Ask student groups to research the conditions optimal for fossil formation. Use this information to complete and explain the following statements for a classroom presentation or skit:

You might be a fossil if …

1. you were lower on the food chain.
2. you were small and weak, rather than big and strong.
3. you were slow, lacked eyes, were attached to the sea floor and thus immobile.
4. you lived in or near a marine or aquatic environment, as opposed to on land.
5. you were crunchy rather than soft.
6. you expired in water or fell in some water after you expired.

Complete extensions to the “You might be a fossil if…” are located at <http://www.collectingfossils.org/fossilrecord.htm>.

1. **A Debate: what killed the dinosaurs:** Ask students to investigate possible explanations for the mass extinction of large animals that occurred at the K-T boundary (between the Cretaceous and Tertiary geologic Periods). Ask student groups to select one hypothesis supported by scientific evidence for a classroom debate. Much information about various theories is located on this site from the Smithsonian Museum of Natural History (7 pages). (<http://paleobiology.si.edu/dinosaurs/info/everything/why.html>)

# References

**(non-Web-based information sources)**

**The references below can be found on the
*ChemMatters* 30-year DVD, which includes all articles
published from the magazine’s inception in October 1983 through April 2013, all available Teacher’s Guides, beginning February 1990, and 12 *ChemMatters* videos. The DVD is available from the American Chemical Society for $42 (or $135 for a site/school license) at this site:** [**http://ww.acs.org/chemmatters**](http://www.acs.org/chemmatters)**. Click on the “Teacher’s Guide” tab directly under the *ChemMattersonline* logo and, on the new page, click on “Get the past 30 Years of *ChemMatters* on DVD!” (the icon on the right of the screen).**

**Selected articles and the complete set of
Teacher’s Guides for all issues from the past three
years are available free online at the same Web site, above. Click on the “Issues” tab just below the logo, *“ChemMattersonline”*.**

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Iridium is rarely found on earth but is more common in asteroids. This article describes how the concentration of iridium at the K/T Boundary provides evidence for the impact of the Chicxulub meteorite at the time of dinosaur extinction. (Withgott, J. Dinosaurs and Iridium—Traces of an Impact. *ChemMatters*, 2001, *19* (1), pp 12–13)

This article provides details including molecular and structural formulas and chemical reactions as tooth decay is discussed. Also shown is how hydroxyapatite is broken down by bacteria and how fluorine forms fluorapatite. (Rohrig, B. Demystifying Gross Stuff. *ChemMatters*, 2001, *19* (3), pp 12–14)

The structure of bone including osteocytes is pictured and described in this article. Hydroxyapatite is introduced as a calcium phosphate compound. (Stone, C. Bones—The Living Skeleton. *ChemMatters*, 2000, *18* (3), pp. 12–13)

\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_\_

Hendrickson, S. *Hunt for the Past: My Life as an Explorer;* Scholastic, Inc.: New York, NY, 2001. Hendrickson’s autobiography contains many references to her self-taught accomplishments from painting boats to diving for ship wrecks to paleontology. She leads an exciting adventurous life of nonconformity. This will probably appeal to students.

# Web Sites for Additional Information

**(Web-based information sources)**

**Sue Hendrickson**

This site provides some information about the life of Sue Hendrickson, the high school dropout, after she found SUE. (<http://articles.chicagotribune.com/2000-05-08/news/0005080126_1_specimen-dinosaur-high-school-diploma>)

**“Dinosaur 13”**

The film critique was published by the *Chicago Reader*. It goes beyond “Dinosaur 13” to discuss the deep problems involved in the commercialization of fossil recovery. (<http://www.chicagoreader.com/chicago/dinosaur-13-review-todd-douglas-miller-peter-larson-tyrannosaurus-rex-fossil-sue-field-museum-of-natural-history/Content?oid=14690513>)

 The documentary “Dinosaur 13” (1:35:00) is available for rent or purchase. (<https://itunes.apple.com/us/movie/dinosaur-13/id889020430>) This YouTube video (38:39) includes clips and a trailer of the film. (<https://www.youtube.com/watch?v=K66ja5WJurk>) The 3:00 minute official trailer can be found at <https://www.youtube.com/watch?v=XZywsT8Sy-c>.

Film critics gave positive responses to the film:

* Dennis Harvey, [*Variety*](https://en.wikipedia.org/wiki/Variety_%28magazine%29): "engrossing"
* Duane Byrge, [*The Hollywood Reporter*](https://en.wikipedia.org/wiki/The_Hollywood_Reporter)*,* "story of scientific discovery and petty politics"
* Eric Kohn, [Indiewire](https://en.wikipedia.org/wiki/Indiewire), "A subset of the recent scientific-documentary-as-thriller tradition epitomized by [*The Cove*](https://en.wikipedia.org/wiki/The_Cove_%28film%29) and [*Blackfish*](https://en.wikipedia.org/wiki/Blackfish_%28film%29)”
* Todd Douglas Miller, “both awe-inspiring and tragic”

(<https://en.wikipedia.org/wiki/Dinosaur_13>)

Others in the scientific community call ”Dinosaur 13” a very slanted anti-government approach that ignores U.S. Federal laws written to protect fossils on public land.

 Writing for *Slate*, Don Lessem provides a thorough review of the documentary “Dinosaur 13” from his perspective: “Don’t Believe the Anti-Government Tale Spun by This New Dinosaur Documentary”. This may provide information useful if your students are gathering material for a debate on the ethics of for-profit fossil hunting or to present an alternative view if you show the film. (<http://www.slate.com/blogs/browbeat/2014/08/22/dinosaur_13_review_movie_about_peter_larson_spins_a_bogus_tale.html>)

 The *Chicago Reader* critique of the documentary reviews the film and speaks about the frustration of academic paleontologists when excavations become commercial. (<http://www.chicagoreader.com/chicago/dinosaur-13-review-todd-douglas-miller-peter-larson-tyrannosaurus-rex-fossil-sue-field-museum-of-natural-history/Content?oid=14690513>)

**The Field Museum purchase of SUE**

This *Washington Post* story: “The *T. rex* that Got Away” describes the drama and secret bidding involved in the purchase of SUE. (<https://www.washingtonpost.com/local/the-t-rex-that-got-away-smithsonians-quest-for-sue-ends-with-different-dinosaur/2014/04/05/7da9a73c-b9a6-11e3-9a05-c739f29ccb08_story.html>)

 On March 21, 2014, Christina Rose published an article in the tribal newsletter, *The Indian Country Today*, titled, “After T-Rex Troubles, Dinosaurs Stay on the Rez”. The judge’s decision favoring Maurice Williams in the SUE case was based on the premise that, “… fossils are actually part of the ground, which meant the dinosaur was tribal land.”

(<http://indiancountrytodaymedianetwork.com/2014/03/21/after-t-rex-troubles-dinosaurs-stay-rez-154111>)

**The anatomy of *T. rex***

 This site gives “Fast Facts on *T. rex*” and provides many details of the assumed physical anatomy, physiology and behavior of *T. rex*. The information may help answer student questions about theories regarding the life style of huge dinosaurs. (<http://www.fossilguy.com/gallery/vert/dinosaur/tyrannosaurus/tyrannosaurus.htm>)

***T. rex* growth and behavior**

 George Erickson, Florida State University questioned how dinosaurs became gigantic so quickly. His research attributes enormous growth rates for *T. rex* between 14 and 18 years due to voracious eating habits. (<http://news.nationalgeographic.com/news/2004/08/0811_040811_trex.html>)

 *Wikipedia* provides detailed information and references on the feeding and predatory behavior of T-rex. (<https://en.wikipedia.org/wiki/Feeding_behaviour_of_Tyrannosaurus>)

**Scientific evidence of *T. rex* predation**

 *PLOS* is an open access journal of the *Public Library of Science*. This article describes and shows photos of teeth marks that suggest the cannibalistic behavior of *T. rex.* (<http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0013419>)

**Types of animal preservation**

 The *Virtual Fossil Museum* Web site posting, “Fossilization - How Fossils Form”, lists and explains fossil formation under different environmental conditions. This informative site includes some of the chemistry involved in processes including drying, freezing and immersion in tar that leave evidence such as fossils, molds and casts of ancient animal habitation. (<http://www.fossilmuseum.net/fossilrecord/fossilization/fossilization.htm>)

 Paleosol is the type of soil that was preserved many years ago through burial under sediments. This soil, conducive to fossil formation, is discussed in a soil science blog from the University of Oregon. (<http://blogs.uoregon.edu/gregr/files/2013/07/Retallack-1997-dinosaurs-and-dirt-17ef2dj.pdf>)

**Steps to fossil formation**

This site contains a concise step by step, easy to follow procedure for the formation of a fossilized animal. (<https://www.papertrell.com/apps/preview/The-Handy-Dinosaur-Answer-Book/handy%20answer%20book/How-likely-is-it-that-an-organism-becomes-a-fossil/001137014/content/SC/52cafef582fad14abfa5c2e0_Default.html>)

 The Australia Museum in Sydney shows pictures with a description of the four stages of fossil development in “How fossils are formed”. There are links to sedimentary processes and the types of fossils found in the Sydney Basin.

(<http://australianmuseum.net.au/how-are-fossils-formed>)

**Cadaver dog training**

 This article describes the training of cadaver dogs and the situations that they must experience in their work. (<https://www.theguardian.com/lifeandstyle/2015/sep/08/cadaver-dogs-trained-to-smell-death>)

**Bone mineral**

 Smithsonian Institute researchers describe the reactivity of bone mineral and how its formula changes over time. The high surface area of the crystal readily lends itself to cation exchange.

(<http://rimg.geoscienceworld.org/content/48/1/489>)

**Bone repair**

This paper, **“**Collagen-Hydroxyapatite Composites for Hard Tissue Repair (bone repair)”, describes the work of researchers at Oxford University, UK. Their work involves the use of a bioresorbable collagen-hydroxyapatite composite for bone repair. (<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.655.1594&rep=rep1&type=pdf> )

**Bone marrow transplants**

 The U.S. National Library of Medicine published this description of three types of transplants to replace bone marrow damaged by chemotherapy or radiation. Hopefully, healthy donor white blood cells may continue the process of eradicating cancer cells. (<https://www.nlm.nih.gov/medlineplus/ency/article/003009.htm>)

**Permineralization**

 This technical paper describes studies of the chemical analysis of bone mineral and synthetic hydroxyapatite, including discussion of the crystalline structure and the Ca:P ratio in these compounds. (<http://www.ncbi.nlm.nih.gov/pmc/articles/PMC2760485/>)

**Dinosaur extinction**

 This article, “After asteroid hit, a giant cloud of smoke led to dinosaur’s demise.” from the July 23, 2016 *Los Angeles Times* reports data from the release of Professor Kaiho’s research. The newspaper report is clear and very readable.

(<http://www.latimes.com/science/sciencenow/la-sci-sn-dinosaurs-asteroid-soot-20160714-snap-story.html>)

 The *Scientific American* article, “A Theory Set in Stone: An Asteroid Killed the Dinosaurs, After All” contains additional information about Chicxulub and Kaiho’s research and how the impact led to destruction of the food chain. And, it discusses the less plausible explanation that multiple volcanic eruptions caused the extinction. (<http://www.scientificamerican.com/article/asteroid-killed-dinosaurs/>)

 The Smithsonian National Museum of Natural History site lists several references and two URLs that discuss, “Why did they go extinct?” (<http://paleobiology.si.edu/dinosaurs/info/everything/why_7.html>)

**Fossil dating**

 Studies by geologists at the University of California, Berkeley Geochronology Center present how uranium/lead (U/Pb) ratios can be used to date geological events up to 100 million years ago with a precision of within 250,000 years (1 in 400, or 0.25%). This article also discusses the advantages of using uranium decay as compared to argon (Ar/Ar) dating. (<http://www.berkeley.edu/news/media/releases/2004/09/16_uranium.shtml>)

 When U–Pb dating techniques were used on fossil bone, the data caused scientists to question previous proposed dates of dinosaur extinction. This article, “Uranium technique raises dinosaur question” describes the collection of this data and the controversy surrounding it. (<http://www.world-nuclear-news.org/EE-Uranium_technique_raises_dinosaur_question-0202117.html>)

 These are “class notes” on a lesson on radioactive dating, including an explanation of half-life. There are questions for students and they are asked to graphically analyze data. I don’t see this as a lesson in itself, but there is some material (particularly the problems) that could be used to challenge students. (<http://eas2.unl.edu/~tfrank/History%20on%20the%20Rocks/Teachers/Plan%20files/Planansky_geochronology.pdf>)

**Dinosaur** **protein**

Additional information is given on the molecular analysis by Mary Schweitzer on the soft tissue found in a *T. rex* bone. This article provides details of analyses and findings using mass spectrometry techniques to sequence the amino acids in dinosaur protein. Protein antibody bonding is discussed, as well as the data from tests that show a strong similarity between the dinosaur tissue and that of modern birds. (<http://www.nature.com/news/molecular-analysis-supports-controversial-claim-for-dinosaur-cells-1.11637>)

# More Web Sites on Teacher Information and Lesson Plans

**(sites geared specifically to teachers)**

 These are “Teacher Resource Activities for Education and Fun”, including Earth Science lessons, that include details on how to build a volcano model. Many links are shown on each margin that take you to general information as well as lessons to use for studying the formation of fossils. (<http://www.fossils-facts-and-finds.com/how_are_fossils_formed.html>)

The Emilsson/Tinnesand SUE article contains a sidebar, “Types of Fossils”, with brief explanations of different types of fossil evidence. Supported by the National Science Foundation (NSF), the University of California, Berkeley, Museum of Paleontology has produced an extensive Web page on this subject. In conjunction with *PBS Learning Media*, they present pictures (in series) of the different types of fossils, a NOVA video on the Grand Canyon, questions for students and links to the specific *Benchmarks for Science Literacy* (National Standards). This site is rich with possibilities for student lessons. (<http://www.pbslearningmedia.org/resource/ess05.sci.ess.earthsys.fossiltype/types-of-fossils/>)