Engaging K-12 Students in
Integrated STEM via
3D Digitization, 3D Printing
and Paleontology

LESSON TITLE
Trends and Changes: Feeding Evolution of Horse Teeth

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GRADE LEVEL
Middle grades 6-8

TIMEFRAME
1- 90 minute session

DRIVING QUESTION
How can Carbon Isotopes determine the change in Equine teeth evolution?

LEARNING GOALS
- Use mathematical representation to measure size and analyze structure change within species of horse teeth.
- Use decoder analysis to interpret scientific text of Equine teeth evolution.
- Analyze and interpret data to categorize C_3 and C_4 plants photosynthesis cycles.
- Explain the difference between carbon isotopes of horse teeth and emphasis the relationship of food diet over time.

ANCHORING EVENT
Elicit Prior Knowledge:
Option 1: Write sentences, draw, or use a graphic organizer to share what you know about Carbon Isotopes.
or
Option 2: Watch the background video below and write a 5 sentence summary of the uses of Carbon Isotopes.

Background Video on Carbon Isotopes

(click above link)

Isotopes

COLLABORATIONS

In this lesson, students will collaborate by sharing their responses using a cooperative learning structure similar to Think-Pair-Share. Students will also work in small groups to share their response to challenge prompts from their escape classroom lesson. At the end of the lesson, students will collaborate as a whole class by sharing their ideas of the relationship of Equine teeth and Carbon Isotopes.

STEM INTEGRATION

In this lesson, students will measure size of horse teeth and analyze structure change within species using 3D scans and prints. Using that knowledge, students will expand their focus of carbon isotopes and determine the relationship of the teeth structure and food diet.

ASSESSMENT

Formative assessment:
1. Positive charge atoms are responsible for an element to differ between isotopes. True or False
2. Carbon has 3 naturally occurring isotopes. True or False
3. Carbon Isotopes can be used to determine the type of diet the Equine species ate in the past. True or False
4. 3D printing only makes items out of plastic materials. True or False
5. 3D printing was invented in 2010. True or False
6. 3D printing reduces the cost of making a living. True or False

Summative assessment:
Students will record an online forum discussion to the driving question- "How can Carbon Isotopes determine the change in Equine teeth evolution?" and/or How can 3D printing benefit your understanding of fossils from the past? The discussion can be conducted using Google Classroom or Nearpod. Students will respond to the responses of their peers by sharing their claim and evidence gained from the escape classroom activity.

Rubric for Communicating Information

EXPERT (4)	PROFICIENT (3)	APPROACHING PROFICIENCY (2)	NOT MEETING (1)
All the questions are answered and the ideas are communicated in a **clear, coherent and detailed** way and **make connections** to other topics learned in class, real life situations or other subject areas.	All the questions are answered and the ideas are communicated in a **clear, coherent and detailed** way.	Student responses are **incomplete** and the communication of ideas is **not coherent or clear**.	The responses are **not** related to the question.

PROCEDURE

Begin the lesson by asking student to complete option 1 or 2 to activate prior knowledge.

Day 1:

ENGAGE
During the first 10 minutes of class, students will be engaged n the topic of carbon isotopes and Equine teeth evolution by completing the anchoring activity as described above.

EXPLORE
After completing the anchoring activity, students will be divided into two groups: each group of about 11 students. Students will be given a brief introduction to their escape room mission and an envelope with puzzles to solve related to horse teeth and carbon isotopes.   **(refer to handouts below)**

EXPLAIN
Students will explain the difference between the two types of isotopes mentioned in their classroom escape room challenge

Graphic Organizer

Carbon Isotope _____	Carbon Isotope _____

EVALUTATE
Nearpod Lesson Formative and Summative Assessment of 3D printing and its uses (attached separately-adapted from previous Nearpod lesson)

OR

[Gallery Walk](#)
Students will walk around to [3-3D printed horse teeth](#) positioned around the room and provide feedback and evidence of the type of diet each tooth represented.
STL files chosen below:
Predominantly C3 diet include *Sifrhippus sandrae* (refer to MacFadden, 2000)
Mixed C3/C4 diet would be *Dinohippus mexicanus* (refer to MacFadden et al., 1999)
C4 dominated diet would be *Neohipparion eurystyle* (refer to MacFadden et al., 1999)

STANDARDS: NEXT GENERATION SCIENCE STANDARDS (NGSS)

Performance Expectation: Analyze and interpret data on the properties of substances before and after the substances interact to determine if a chemical reaction has occurred. MS-PS1-2	
Science Practices	Connection to the Lesson
Analyzing and Interpreting Data Analyzing data in 6-8 builds on K-5 experiences and progresses to extending quantitative analysis to investigations, distinguishing between correlation and causation, and basic statistical techniques of data and error analysis. Analyze and interpret data to determine similarities and differences in findings (MS-PS1-2) Science Knowledge is Based on Empirical Evidence Science knowledge is based upon logical and conceptual connections between evidence and explanations. (MS-PS1-2).	Students analyze and interpret data from a past event.
Disciplinary Core Ideas	Connection to the Lesson
PS1.A: Structure and Properties of Matter Each pure substance has characteristic physical and chemical properties (for any bulk quantity under given conditions) that can be used to identify it. (MS-PS1-2)	Students analyze and interpret data from a past event.

PS1.B: Chemical Reactions
Substances react chemically in characteristic ways. In a chemical process, the atoms that make up the original substances are regrouped into different molecules, and these new substances have different properties from those of the reactants.

Crosscutting Concepts	Connection to the Lesson
Patterns Macroscopic patterns are related to the nature of microscopic and atomic-level structure.	Students identify similarities and differences of past events.

OTHER STANDARDS

Connections to other DCIs in this grade-band:
MS.PS3.D ; MS.LS1.C ; MS.ESS2.A

Articulation of DCIs across grade-bands:
5.PS1.B ; HS.PS1.B

Common Core State Standards Connections:
ELA/Literacy -
RST.6-8.1 Cite specific textual evidence to support analysis of science and technical texts, attending to the precise details of explanations or descriptions.(MS-PS1-2)
RST.6-8.7 Integrate quantitative or technical information expressed in words in a text with a version of that information expressed visually (e.g., in a flowchart, diagram, model, graph, or table). (MS-PS1-2)
Mathematics -
MP.2 Reason abstractly and quantitatively. (MS-PS1-2)
6.RP.A.3 Use ratio and rate reasoning to solve real-world and mathematical problems. (MS-PS1-2)
6.SP.B.4 Display numerical data in plots on a number line, including dot plots, histograms, and box plots. (MS-PS1-2)
6.SP.B.5 Summarize numerical data sets in relation to their context. (MS-PS1-2)

ISTE STANDARDS

Student Standard	Description
1. Creativity and innovation	Students use models and simulations to explore complex systems and issues.
2. Communication and collaboration	Students interact, collaborate, and publish with peers, experts, or others employing a variety of digital environments and media.
3. Research and information fluency	Students locate, organize, analyze, evaluate, synthesize, and ethically use information from a variety of sources and media.
4. Critical thinking, problem solving and decision making	Students plan and manage activities to develop a solution or complete a project.

5. Digital citizenship	-Students advocate and practice safe, legal, and responsible use of information and technology. -Students exhibit positive attitude toward using technology that supports collaboration, learning and productivity. -Students demonstrate personal responsibility for lifelong learning. -Students exhibit leadership for digital citizenship.
6. Technology operations and concepts	-Students understand and use technology systems. -Students select and use applications effectively and productively.

MATERIALS
- ❖ Computer/Ipad
- ❖ 3D printer
- ❖ Fossil samples: https://www.morphosource.org/Detail/ProjectDetail/Show/project_id/144
- ❖ 3D printing material (PLA-Polymaker)
- ❖ Rulers or calipers
- ❖ Sticky Notes
- ❖ Poster Paper
- ❖ Paper fastener (decoder)

REFERENCES

MacFadden, B. J., Solounias, N., & Cerling, T. E. (1999, February 05). Ancient Diets, Ecology, and Extinction of 5-Million-Year-Old Horses from Florida. Retrieved from http://science.sciencemag.org/content/283/5403/824

MacFadden, B. J. (2000). Cenozoic Mammalian Herbivores From the Americas: Reconstructing Ancient Diets and Terrestrial Communities. Annual Review of Ecology and Systematics, 31(1), 33-59. doi:10.1146/annurev.ecolsys.31.1.33

KEY ACADEMIC AND/OR SCIENTIFIC LANGUAGE
List the terms used in the lesson and definitions (e.g., deep time, brachiopod etc.).
Some of the many paleontology glossaries:
- Fossil- any preserved living or nonliving specimen from a past geological age.
- Photosynthesis- the process by which plants and other organisms transform a light energy into chemical energy.
- C3 Plants- plants that are most common and efficient at photosynthesis in cool, wet climates.
- C4 Plants- plants that are most efficient at photosynthesis in hot, sunny climates.
- Isotopes-a form of a chemical element whose atomic nucleus houses a specific number of neutrons.
- Paleontology-study of fossil animals and plants.

- Taxonomy- study of classifying organisms.

PRIOR KNOWLEDGE
N/A

FOSSIL HORSE
Equus complicatus

The Challenge
FOSSIL RECORD ESCAPE DIRECTIONS

You will have the class period to solve this challenge and free yourself from the evil villains. Your job is to solve all the puzzles as a group. You will also be given 2 Hint Passes to use in case you get stuck on an answer. Once your Hint Passes are used up, you will not be able to receive more. Be careful how you use them!
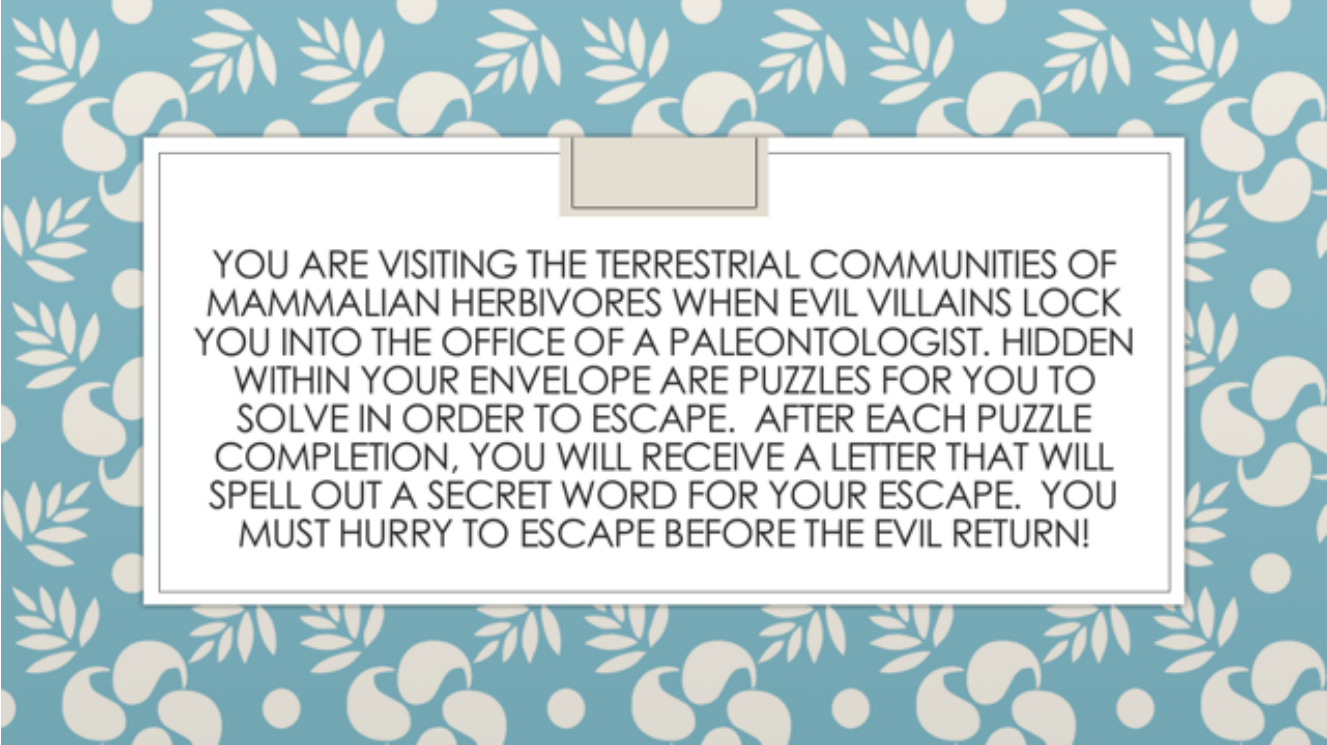
You may start on any puzzle, but in order to get the keys which are needed to solve the final code, you need to turn in Puzzles 1 and 2 for 2 keys, Puzzles 3 and 4 for 2 keys, and Puzzle 5 for yet another key.

Puzzles 3 and 4 will require extra materials which are scattered around the classroom. It will be up to you to find the materials to solve these two puzzles. There will not be enough materials for everyone to use and must be shared by all groups, so it will be important to figure out how to use your time to make sure all puzzles get completed. Remember puzzles do not have to be completed in order.

Once the puzzles have all been turned in and you have received your keys, decipher the code by determining what fossil record they spell. Be sure to record this on your Final Key Code Sheet to escape.

Introduction

YOU ARE VISITING THE TERRESTRIAL COMMUNITIES OF MAMMALIAN HERBIVORES WHEN EVIL VILLAINS LOCK YOU INTO THE OFFICE OF A PALEONTOLOGIST. HIDDEN WITHIN YOUR ENVELOPE ARE PUZZLES FOR YOU TO SOLVE IN ORDER TO ESCAPE. AFTER EACH PUZZLE COMPLETION, YOU WILL RECEIVE A LETTER THAT WILL SPELL OUT A SECRET WORD FOR YOUR ESCAPE. YOU MUST HURRY TO ESCAPE BEFORE THE EVIL RETURN!

Puzzle 1

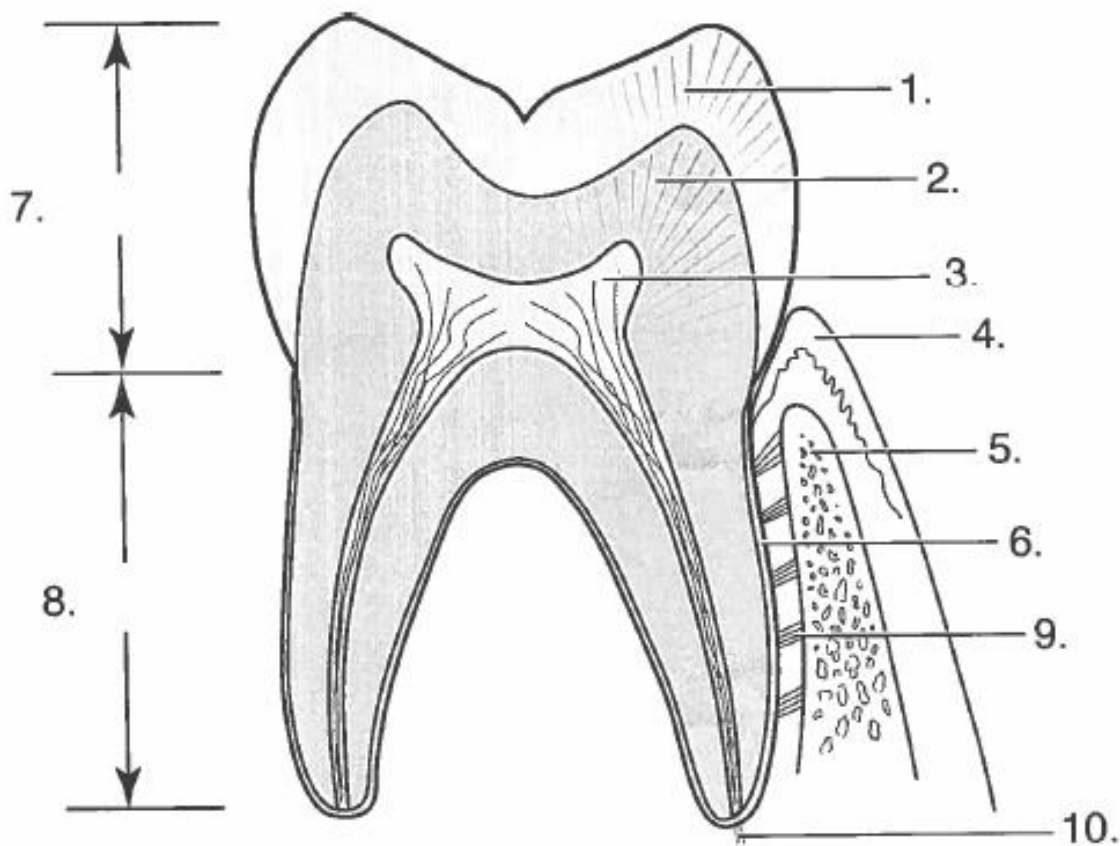Directions: Match the appropriate vocabulary term with definition.

Fossil	any preserved living or nonliving specimen from a past geological age.
Photosynthesis	the process by which plants and other organisms transform a light energy into chemical energy.
C3	plants that are most common and efficient at photosynthesis in cool, wet climates.
C4	plants that are most efficient at photosynthesis in hot, sunny climates.
Isotopes	a form of a chemical element whose atomic nucleus houses a specific number of neutrons.
Paleontology	study of fossil animals and plants.
Taxonomy	study of classifying organisms.

Puzzle 2

Directions: Label the following tooth structures.

ENAMEL   CEMENTUM
DENTIN   CROWN
PULP   ROOT
GINGIVA (GUM)   PERIODONTAL LIGAMENT—
ALVEOLAR BONE   NERVE AND BLOOD VESSELS

7.

8.

1.

2.

3.

4.

5.

6.

9.

10.

UNIT 9

Puzzle 3

Horses

Adapted from "Cenozoic Mammalian Herbivores from The Americas: Reconstructing Ancient Diets and Terrestrial Communities, (pg. 34)" by Bruce MacFadden

Puzzle 4
Ancient Diets, Ecology, and Extinction of 5-Million-Year-Old Horses from Florida
Journal Article by Dr. Bruce McFadden
Journal Article Excerpt (Fill-In)

Answer Key

"Our study indicates that the Bone Valley horses partitioned their available food resources across a broad spectrum from almost pure C_4 grazers to principally C_3 browsers. The Bone Valley horses remained hypsodont, even though they were not all grazers, because of phylogenetic constraints and the irreversibility of macroevolution. The ancestral clades from which Bone Valley horses descended probably evolved high-crowned teeth adapted for grazing. Once hypsodonty evolved, it was impossible to return to being short-crowned browsers, even though the descendent Bone Valley horses had markedly changed their diets."

Puzzle 4
Ancient Diets, Ecology, and Extinction of 5-Million-Year-Old Horses from Florida by Dr. Bruce McFadden
Journal Article Excerpt (Fill-In)

"Our study indicates that the Bone Valley horses partitioned their available _____ resources across a broad spectrum from almost pure C_4 _____ to principally C_3 browsers. The Bone Valley horses remained hypsodont, even though they were not all grazers, because of _____ constraints and the irreversibility of _____. The ancestral clades from which Bone Valley horses descended probably evolved high-crowned _____adapted for grazing. Once _____evolved, it was impossible to return to being _____-crowned browsers, even though the descendent Bone Valley horses had markedly changed their diets."

Puzzle 5

Directions: Match the food type and name to the appropriate plant column.

C3 plants	C4 plants

Woody Plants

Potatoes

Wheat

Beans

Rice

(C3 plants)

Corn

Amaranth

Grass

Sugarcane

(C4 plants)