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The Case of Dinosaur Metabolism

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Publication Information

Llewellyn, Douglas and Ullock, Caitlin (2017). "The Case of Dinosaur Metabolism." *The Science Teacher* 84.6, 31-36.
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The Case of Dinosaur Metabolism

Abstract
In lieu of an abstract, here is the article's first paragraph:

To learn the critical skill of scientific argumentation, students need learning experiences that involve constructing evidence-based explanations. Students often struggle to propose, support, critique, refine, justify, and defend a scientific position (Llewellyn 2013). This article describes a lesson in which biology students are challenged to support their claims with evidence-based reasoning as they research the thermoregulation of dinosaurs.

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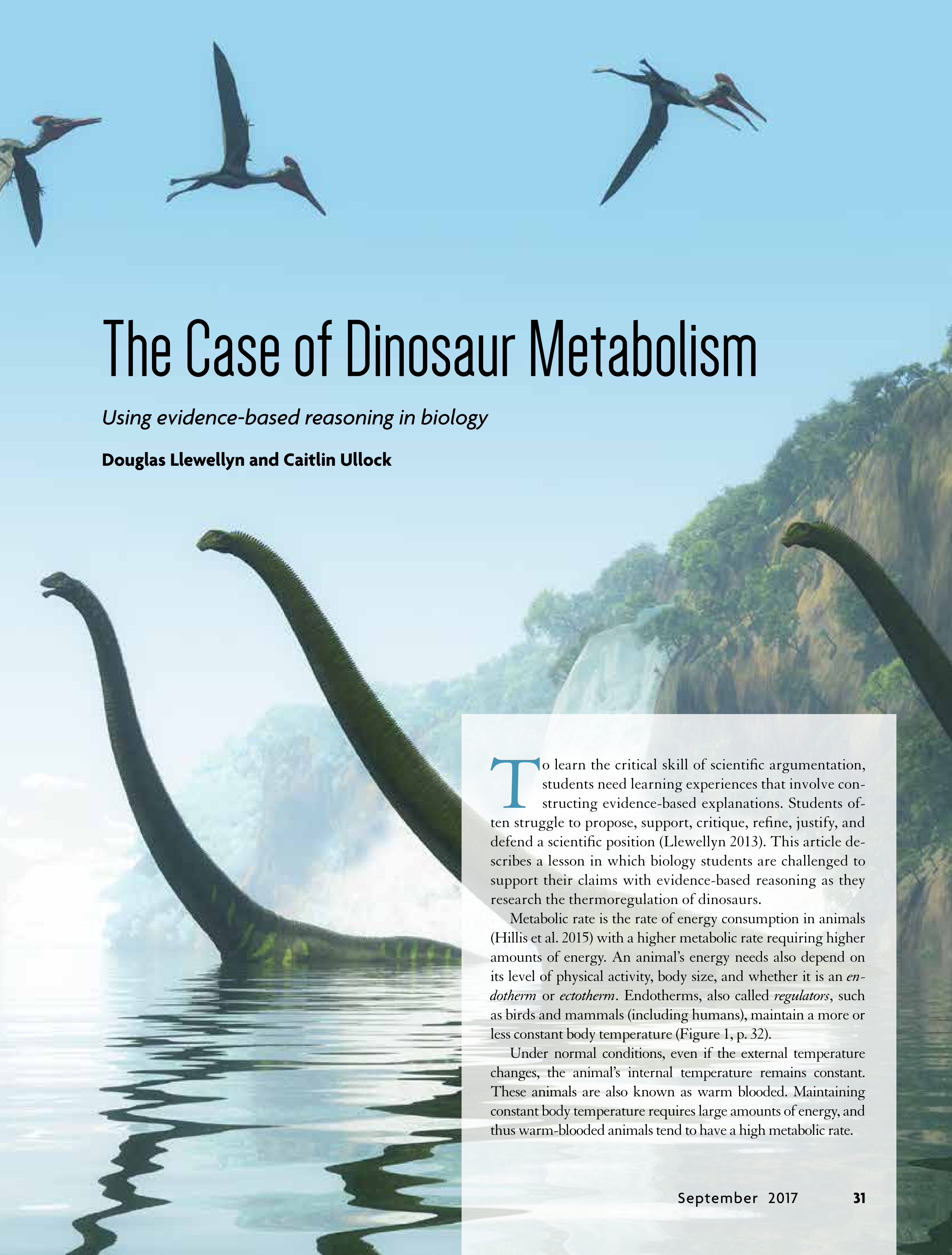

The Case of Dinosaur Metabolism

Using evidence-based reasoning in biology

Douglas Llewellyn and Caitlin Ullock

To learn the critical skill of scientific argumentation, students need learning experiences that involve constructing evidence-based explanations. Students often struggle to propose, support, critique, refine, justify, and defend a scientific position (Llewellyn 2013). This article describes a lesson in which biology students are challenged to support their claims with evidence-based reasoning as they research the thermoregulation of dinosaurs.

Metabolic rate is the rate of energy consumption in animals (Hillis et al. 2015) with a higher metabolic rate requiring higher amounts of energy. An animal's energy needs also depend on its level of physical activity, body size, and whether it is an *endotherm* or *ectotherm*. Endotherms, also called *regulators*, such as birds and mammals (including humans), maintain a more or less constant body temperature (Figure 1, p. 32).

Under normal conditions, even if the external temperature changes, the animal's internal temperature remains constant. These animals are also known as warm blooded. Maintaining constant body temperature requires large amounts of energy, and thus warm-blooded animals tend to have a high metabolic rate.

In contrast, the body temperatures of ectotherms, or *conformers*, such as reptiles, fish, and amphibians, change in response to the external environment. These animals are commonly known as cold blooded. Their metabolic rates change with changes in the external temperature. Comparing the metabolic rates of various organisms can provide evidence as to which method of thermoregulation an organism uses.

The Case of Dinosaur Metabolism

This lesson on dinosaur thermoregulation, which aligns with the *Next Generation Science Standards* (NGSS Lead States 2013; see box, p. 36), took one double period and two single periods in an advanced biology class.

Day 1

The lesson begins by introducing the term *thermoregulation*. Students pair up to share their prior knowledge of the term, then the teacher asks: "What happens to your body when you have a fever?" One student, Nathan, recovering from a recent bout with the flu, says "you sweat, shiver, and become disoriented." The teacher then asks what happens when you have a low body temperature, citing a recent report of boaters whose canoe capsized in a cold lake.

Students watch a video (see "On the web") that compares

FIGURE 1

Temperature graph.

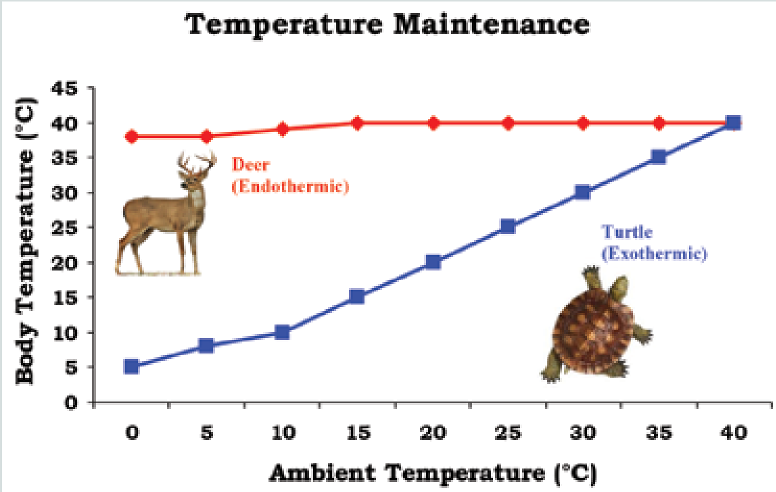

FIGURE 2

Comparison chart.

	Regulator	Conformer
Also known as		
Regulation of Metabolism		
Adaptations to regulate heat loss		
Adaptations to regulate heat gain		
Examples		

FIGURE 3

Poster supporting mesothermy.

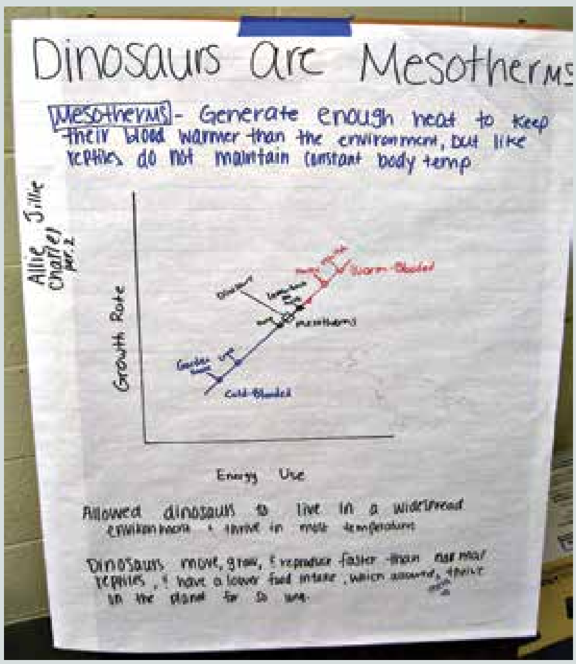

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FIGURE 4

Poster supporting endothermy.

regulators (endotherms) and conformers (ectotherms), then work in pairs to complete a comparison chart (Figure 2) and construct a graph depicting the differences between regulators and conformers.

Students use the chart and graph to answer the question: How does metabolic rate change for conformers and regulators with a change in ambient temperature? Students discover such thermoregulatory adaptations as panting, sweating, reduced blood flow to the skin through vasoconstriction, and others. One group was fascinated by how elephants use their huge ears like car radiators, flapping them when necessary to cool the blood flowing through vessels close to the skin.

The teacher directs the class to work in pairs to research the question online, make a claim based on the information found, and be prepared to justify their answers with evidence-based reasoning with specific examples. Twenty minutes later, each group, one at a time, shares its findings. During the reporting-out session, several students offer rebuttals and counterclaims to other groups' positions. Day 1 ends with a summary about the connection between metabolic rate and thermoregulation.

Day 2

The double-period Day 2 begins with two questions:

- What thermoregulation strategy did the dinosaurs most likely use?
- Were dinosaurs more like regulators or conformers?

Students are told to choose one side, form groups of three, research their choice, and provide a scientific argument based on their findings. The questions are followed by instructions for a group performance task engaging students in four areas:

1. Generate questions to gather additional information from various sources (primary sources, classroom textbooks, online databases, and reliable scientific websites).
2. Assign group members roles to conduct research to collect evidence that will help support a claim about dinosaur thermoregulation.
3. Develop an explanation to support a claim about the thermoregulation in dinosaurs using evidence collected and science concepts discussed in class.
4. Create a poster to clearly display the claim, evidence, and reasoning with a written explanation.

During the fact-finding segment of the task, the teacher overhears several additional questions students raise, such as, "Did the size of the dinosaur determine whether it was an endotherm or exotherm?" and "Could the dinosaur's environment affect whether it was an endotherm or exotherm?" Throughout this time students are researching their claims, collecting and discussing their evidence-based reasoning, and designing the layout for their poster presentations on Day 3.

Day 3

The student groups take 10 minutes to put the final touches on their posters (examples, Figures 3 and 4) and tape them to the classroom wall. Then, during a "gallery walk," each group rotates among the posters, one by one, discussing the merits of the poster's claim and supporting evidence. The groups use color-coded (pink or blue) sticky notes to place "warm," or positive,

FIGURE 5

Evidence chart.

Regulators/endoderms	Mesoderms	Conformers/ectoderms
• Metabolism much faster • Lived in environment with varying temperatures • Had many layers of skin • Similar to birds, which are warm-blooded • Varied in size from as small as a chicken to as large as a 70-ton titanosaur	• Middle point resembling characteristics of both • Generated heat to maintain a range of internal temperature • Lived in various environments, had to adapt to different areas • Can regulate internal temperature somewhat • Mesoderms live today	• Similar to modern-day reptiles, which are cold-blooded • Originally smaller dinosaurs were possibly ectoderms with larger ones evolving into endoderms

comments, or "cool" suggestions for improvement. Afterward, groups return to their own posters to read and discuss the posted comments. Interestingly, of the eight groups in this class, four claimed that dinosaurs were like regulators, two claimed they were like conformers, and two uncovered a separate category in between called *mesothermy* from a BBC article (Webb 2014).

The final phase of the lesson is the Dino Convention, in which the eight student groups (four endothermy, two ectothermy, and two mesothermy groups) come together to synthesize their findings into a list of evidence and write a collective explanation statement. As each group reports out, students record the evidence in a three-section format in their individual science notebooks (Figure 5). One at a time, "delegates" representing each of the three sections recite their evidence and explanation statement to the rest of the class. After the three presentations, the delegates vote on which claim, supporting evidence, and reasoning appear most credible. In this class, 13 delegates vote for regulators, 11 for mesotherms, and none for conformers (not even the two original conformer groups).

The teacher then summarizes the lesson and reflects on how the delegates were swayed by the preponderance of presented evidence. This, she said, mirrors what happens in the scientific community. As more information is revealed, ideas about many scientific topics change, ranging from the metabolism of dinosaurs to the effects of global warming.

Conclusion

Students reported that they found the topic engaging, thought-provoking, and relevant. They appreciated doing their own research and determining whether a source was verifiable and reliable. Note that the method of dinosaur thermoregulation is still an open question. Considering that most students already knew that modern reptiles are ectothermic, the idea that the question of dinosaur thermoregulation might have more than one possible answer challenged them to consider alternative evidence and points of view. The lesson affirmed that science knowledge changes with new evidence.

The purpose of this activity is for students to

- gain skills in online research,
- assess the validity of argument-based literature,
- develop appropriate claims,
- cite supporting evidence,
- enhance their speaking and listening skills by explaining their reasoning, and
- gain an understanding of scientific inquiry and the importance of evidence-based reasoning.

The lesson can be modified to fit students' learning needs. For example, students new to the Claim-Evidence-Reasoning (CER) model can be provided a template and rubric (Figure 6). A printed list of online resources of the appropriate reading level can be handed out during the lesson.

This teacher's biology class has opportunities throughout the school year to weigh evidence and evaluate scientific claims and explanations. Other topics students address include climate change, fracking, genetically modified organisms, conservation issues, and herbal medicines. The scientific reasoning skills these students develop prepare them to become engaged citizens and thoughtful decision makers—able to use scientific, evidence-based reasoning to analyze claims and supporting evidence. ■

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FIGURE 6

Claim, evidence, reasoning rubric.

Score	Claim An assertion or conclusion that addresses the original question and attempts to construct a tentative answer or a possible solution to the question.	Evidence A subset of the findings collected during an investigation that supports or refutes the claim.	Reasoning A summary of the assertion that provides an interpretation of the newly acquired knowledge and the reasoning about how the claim and evidence are linked.
3	Based on the data collected, the student draws a clear and detailed conclusion to the inquiry. The claim is a statement derived from an analysis of the data and includes patterns and relationships among the variables of the investigation.	The evidence is derived from the data that either supports or refutes the claim. The evidence is empirically based information, free from opinion or personal interpretation.	The explanation and reasoning are clear and concise. They show cause and effect and link the supportive evidence directly to the claim. The explanation also connects the student's prior knowledge with the new knowledge gained from the investigation.
2	Based on the data collected, the student draws a reasonable conclusion to the inquiry. The claim is a statement derived from an analysis of the data but does not include patterns or relationships among the variables of the investigation.	The evidence is derived from the data that either supports or refutes the claim. The evidence is somewhat empirically based but includes evidence that is circumstantial in nature.	The explanation and reasoning are clear and generally to the point. They link the evidence to the claim. The explanation relates the student's prior knowledge with the new knowledge gained from the investigation.
1	Because the data collected are questionable, the student does not draw a conclusion to the inquiry, draws an inaccurate claim, or fails to state a claim. The claim is not derived from an analysis of the data and does not include patterns or relationships among the variables of the investigation.	The evidence is loosely derived from the data and does not either support or refute the claim. The evidence is unclear, opinion-based, or circumstantial in nature.	The explanation and reasoning are unclear and rambling. They do not link the evidence to the claim. The explanation does not connect the student's prior knowledge with the knowledge gained from the investigation.

On the web

Current topics concerning dinosaurs, "hot-blooded or cold-blooded": *www.ucmp.berkeley.edu/diapsids/metabolism.html*

"Evidence for Mesothermy in Dinosaurs": *http://bit.ly/2ucdxsU*

Video comparing endo and ectotherms: *http://bit.ly/2rmNroZ*

"Were Dinosaurs Warm-Blooded? New Study Fuels Debate": *www.livescience.com/51162-dinosaurs-warm-blooded-growth-rates.html*

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Connecting to the *Next Generation Science Standards* (NGSS Lead States 2013).

Standard
HS-LS4 Biological Evolution: Unity and Diversity

Performance Expectation
The chart below makes one set of connections between the instruction outlined in this article and the *NGSS*. Other valid connections are likely; however, space restrictions prevent us from listing all possibilities. The materials/lessons/activities outlined in this article are just one step toward reaching the performance expectation listed below.

HS-LS4-2 Construct an explanation based on evidence that the process of evolution primarily results from the proliferation of those organisms that are better able to survive and reproduce in the environment.

Dimension	*NGSS* code/citation	Specific connections to classroom activity
Science and Engineering Practices	**Engaging in argument from evidence** • Evaluate the evidence behind currently accepted explanations to determine the merits of arguments. **Obtaining, evaluating, and communicating information** • Communicate scientific information in multiple formats	Students will research and analyze reliable online sources to make claims based upon dinosaurs' means of thermoregulation and communicate those claims using scientific reasoning.
Disciplinary Core Idea	**LS4.C: Adaptation** • Evolution is a consequence of the interaction of factors—including ensuring the proliferations of those organisms that are better able to survive and reproduce in that environment. (HS-LS4-2)	Students will understand that the external environment of pre-historic periods influenced the metabolism of dinosaurs, which could have contributed, in part, to their survival and/or extinction.
Crosscutting Concept	**Stability and Change** • Much of science deals with constructing explanations of how things change and how they remain stable.	Students will understand that changes in the physical environment may cause changes in a species' metabolism and ultimately its traits.

Connections to the Nature of Science.

Scientific Knowledge Is Open to Revision in Light of New Evidence

- Most scientific knowledge is quite durable, but is, in principle, subject to change based on new evidence and/or reinterpretation of existing evidence.
- Scientific argumentation is a mode of logical discourse used to clarify the strength of relationships between ideas and evidence that may result in revision of the explanation.

Connections to the *Common Core State Standards* (NGAC and CCSSO 2010).

Language Arts: Reading: Evaluate various explanations for actions or events and determine which explanation best accords with textual evidence, acknowledging where the text leaves matters uncertain.

Language Arts: Writing: Develop claim(s) and counterclaims fairly and thoroughly, supplying the most relevant data and evidence for each while pointing out the strengths and limitations of both claim(s) and counterclaims in a discipline-appropriate form that anticipates the audience's knowledge level, concerns, values, and possible biases.

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