Science & Literacy Activity

GRADES 9-12

OVERVIEW

This activity, which is aligned to the Common Core State Standards (CCSS) for English Language Arts, introduces students to scientific knowledge and language related to the evidence for evolution and diversity in pterosaurs. Students will read content-rich texts, visit the *Pterosaurs: Flight in the Age of Dinosaurs* exhibition, and use what they have learned to complete a CCSS-aligned writing task, creating an illustrated text about how the fossil record provides evidence of pterosaur evolution and diversity.

Materials in this activity include:
- Teacher instructions for:
  - o Pre-visit student reading
  - o Visit to *Pterosaurs* and Student Worksheet
  - o Post-visit writing task
- Text for student reading: "Unearthing Pterosaurs"
- Student Worksheet for the *Pterosaurs* visit
- Student Writing Guidelines
- Teacher rubric for writing assessment

Common Core State Standards:
WHST.9-12.2, WHST.9-12.8, WHST.9-12.9, RST.9-12.1, RST.9-12.2, RST.9-12.7, RST.9-12.10

NYS Science Standards:
LE 3.1E

Next Generation Science Standards:
PE HS-LS4-1
DCI LS4.A: **Evidence of Common Ancestry and Diversity.** Genetic information, like the fossil record, provides evidence of evolution. DNA sequences vary among species, but there are many overlaps; in fact, the ongoing branching that produces multiple lines of descent can be inferred by comparing the DNA sequences of different organisms. Such information is also derivable from the similarities and differences in amino acid sequences and from anatomical and embryological evidence.

SUPPORTS FOR DIVERSE LEARNERS: An Overview
This resource has been designed to engage all learners with the principles of Universal Design for Learning in mind. It presents multiple ways for your students to engage with scientific concepts through reading, observing, discussing, and writing. While certain tasks may challenge individual students, we suggest that all learners participate in each part of the experience. In the paragraphs labeled "Supports for Diverse Learners" that supplement this activity, we have provided suggestions for how to adapt each section for students with different skill-levels. If any students have an Individualized Education Program (IEP), consult it for additional accommodations or modifications.

1. BEFORE YOUR VISIT

This part of the activity engages students in reading a non-fiction text about how paleontologists hunt for and study pterosaur fossils to better understand these extinct reptiles. The reading will prepare students for their visit by introducing them to the topic and framing their investigation.

Student Reading
Have students read "Unearthing Pterosaurs" and make notes in the right-hand margin. For example, they could underline key passages, paraphrase important information, or write down questions.

Then, have students partner up. Each should have three pieces of paper:

- Explain that you will ask a question, and they will have two minutes to silently respond. (e.g. What struck you about the reading?)
- Have students swap their papers. Give them two or three minutes to read and respond to their partners' answers. Remind them that no conversation is allowed.
- Repeat with two additional questions. (e.g. What was hard to understand? What important ideas did the reading contain?)

After the three exchanges are completed, give students a few minutes to discuss the questions. Remind them to use specific examples and evidence from the text to explain their thinking. Then, for further class discussion, ask each pair to share one highlight or thread from their conversation with the entire group.

SUPPORTS FOR DIVERSE LEARNERS: Student Reading
- "Chunking" the reading can help keep them from becoming overwhelmed by the length of the text. Present them with only a few sentences or a single paragraph to read and discuss before moving on to the next "chunk."
- Provide "wait-time" for students after you ask a question. This will allow time for students to search for textual evidence or to more clearly formulate their thinking before they speak.

2. DURING YOUR VISIT

This part of the activity engages students in exploring *Pterosaurs: Flight in the Age of Dinosaurs*.

Museum Visit & Student Worksheet

Explain to students that they will be using worksheets to gather all the necessary information about pterosaur evolution and diversity. Tell students that back in the classroom they will refer to these notes when completing the writing assignment.

SUPPORTS FOR DIVERSE LEARNERS: Museum Visit
- Review the Student Worksheet with students, clarifying what information they should collect during the visit.
- Have students explore the exhibition in pairs, with each student completing their own Student Worksheet.
- Encourage student pairs to ask you or their peers for help locating sources of information. Tell students they may not share answers with other pairs, but they may point each other to places in the exhibition where answers may be found.

3. BACK IN THE CLASSROOM

This part of the activity engages students in an informational writing task that draws on the pre-visit reading and on observations made at the Museum.

Writing Task

Distribute the Student Writing Guidelines handout, which includes the following prompt for the writing task:

> Based on your reading "Unearthing Pterosaurs," your visit to *Pterosaurs: Flight in the Age of Dinosaurs*, and your discussions, write an essay in which you describe how the fossil record provides evidence of pterosaur evolution and diversity.
>
> Be sure to include:
> - Labeled illustrations showing the evolution of traits for flight in the ancestors of pterosaurs
> - Labeled illustrations of three pterosaur crests
> - Labeled illustrations of three pterosaur teeth and/or feeding mechanisms
>
> Support your discussion with evidence from the reading and your visit to the *Pterosaurs* exhibition.

Go over the handout with students. Tell them that they will use it while writing, and afterwards, to evaluate and revise their essays.

Have students work in pairs, small groups, or as a class. First have them use the prompt and guidelines to discuss the information that they gathered in the *Pterosaurs* exhibition, and to compare and exchange their findings.

Referring to the writing prompt, have students underline or highlight all relevant passages and information from the reading and their notes from the exhibition. Drawing on these sources, students should write individual essays.

SUPPORTS FOR DIVERSE LEARNERS: Writing Task
- Re-read the "Before Your Visit" assignment with students. Ask what they saw in the exhibition that helps them understand pterosaur evolution and diversity.
- Allow time for students to read their essay drafts to a peer and receive feedback based on the Student Writing Guidelines.

Student Reading
Unearthing Pterosaurs

There is a place called the Araripe Basin in a remote, sparsely populated region of northeastern Brazil. Arid but beautiful, it can be a difficult place for farmers to grow crops. But the earth provides another bounty: fossils. And among the bevy of bones are some rare finds — including 23 species of extinct flying reptiles called pterosaurs.

More than three decades ago, a local there found some large pterosaur bones. He delivered them to the Museu Nacional in Rio de Janeiro, where they were tucked away in a drawer. As it happens, many natural history museums have a trove of unexamined fossils awaiting study in their collections — there are just too many to go through. But a few years ago, paleontologist Alexander Kellner, a research associate at the American Museum of Natural History who as a doctoral student trained with Curators John Maisey and Malcolm McKenna, found the time to examine the 30-plus-year-old fossil finds at the Rio museum, where he is now a curator.


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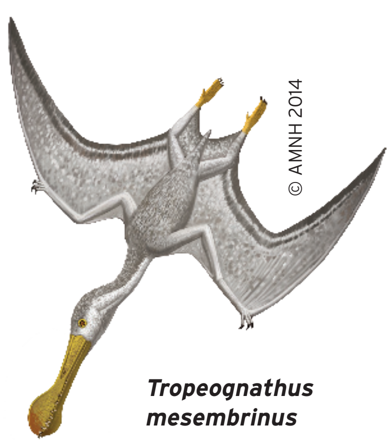
One especially rich layer, the Romualdo Formation, produced distinctive round nodules. Here, calcium collected around dead plants and animals that sank into the soupy mud. Sometimes, a hard shell, or calcareous nodule, formed around them. These rocky coverings preserved fish, plants, even entire pterosaurs, in three dimensions.

Before studying the bones, Kellner had to dissolve the calcereous "nodules" of rock in which the bones were entombed by sinking the fossils into buckets of formic acid. Using a pneumatic hammer, specialists at the museum gradually freed a partial skeleton of the animal from its stony home.

It included part of the animal's skull, complete with a bony crest at the tip of its nose, vertebrae, pelvis — and, perhaps most dramatically, arm and wing-bones. The wingspan of this pterosaur was, the research team concluded, nearly 27 feet — the largest pterosaur discovered so far in the Southern Hemisphere. A model of this recently described giant specimen, from the species *Tropeognathus mesembrinus*, flies overhead at the entrance to the special exhibition *Pterosaurs: Flight in the Age of Dinosaurs*, overseen by Curator Mark Norell with Kellner as co-curator.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Tropeognathus mesembrinus

Not a Bird, Not a Dinosaur


© AMNH/C.Chesek

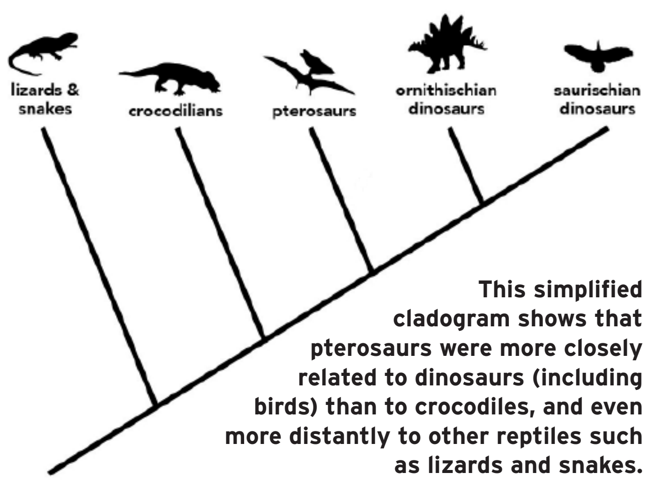
This fossil animal's long forelimbs perplexed early naturalists. In 1809, it was finally identified as a flying reptile and named *ptéro-dactyle*, meaning "wing finger."

What is a pterosaur? It sounds like such a simple question. But the answer was by no means obvious when the first pterosaur skeleton was discovered in the mid-1700s, in the Solnhofen limestone quarry in Germany. Perhaps, early observers theorized, that specimen's long skinny arm-and-finger bones were for swimming? Or was it some kind of toothed, clawed, winged bird? Or even a mammal? Debates raged, even after 1801, when the great French anatomist Georges Cuvier analyzed drawings of the skeleton and determined the animal to be something new to science: a flying reptile that Cuvier later named ptero-dactyle (wing finger in Greek), whose wings were composed of a shortened upper arm bone, along with a dramatically elongated fourth finger that likely supported a wing membrane.

Since Cuvier's time, the fossil record has revealed much more about these extinct reptiles, which lived from about 220 million years ago to the end of the late Cretaceous period 66 million years ago, disappearing at the same time as large dinosaurs in a mass extinction event.

Still, although pterosaurs may often be grouped with dinosaurs in children's picture books, they are not dinosaurs.

"Dinosaurs are characterized by a set of anatomical features pterosaurs don't have," explains Norell, including a hole in the hip socket. Today's scientific consensus is that pterosaurs are nonetheless more closely related to dinosaurs, whose living descendants are birds, than to any other group, including the next-closest, crocodiles.



This simplified cladogram shows that pterosaurs were more closely related to dinosaurs (including birds) than to crocodiles, and even more distantly to other reptiles such as lizards and snakes.

What is also clear is that pterosaurs were the first vertebrates to fly — an amazing feat. Tiny, invertebrate insects had long since taken to the air, but nothing as large as a four-legged vertebrate had attempted such a thing.

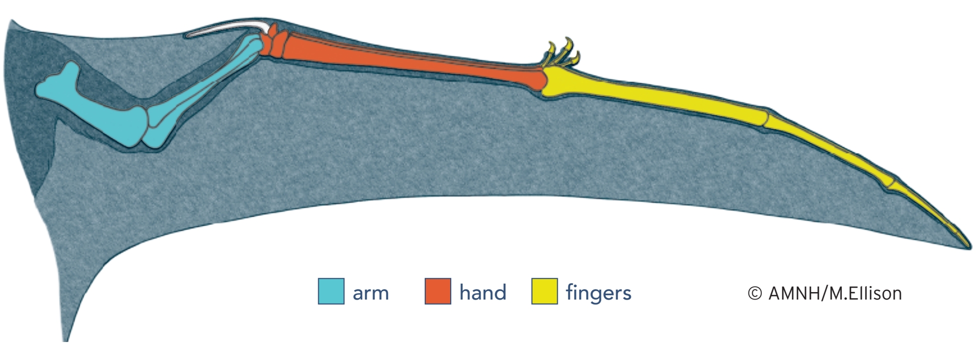
"They are the most fabulous creatures that ever existed! I am not exaggerating," says Kellner. "They made the first attempts among vertebrates to conquer the air — they were the first to develop powered flight," that is, the type of sustained flight that evolved, later and independently, in birds and bats.

Still, many mysteries remain. What type of material covered their skin? Was it hair, or feathers, or something in between? What did they eat, and how did they hunt? Many pterosaurs had flesh-and-bone crests atop their skulls — dramatic anatomical characteristics whose purpose is still debated by paleontologists.

Unlike dinosaurs, whose living descendants are modern birds, pterosaurs left no heirs when they disappeared from Earth. That means paleontologists have no living analogs to draw from as they make inferences about pterosaur behavior. Nonetheless, in the past decade or two, there has been a resurgence of pterosaur research and synthesis, as new methods of examining fossils, such as computed tomography (CT) scanning and UV lighting to discern heretofore invisible details, have become commonplace; as researchers share data digitally; and as researchers begin to find new fossils in previously unexplored locales, including China and Brazil.

Fossils Reveal Diversity

Pterosaur bones have been found on every continent including Antarctica. Although all pterosaurs share the wing anatomy in which the upper-arm bone (humerus) and elongated fourth digit form the truss of the wing membrane, the wing shapes are quite diverse: from long, thin soaring wings like those of an albatross to short, stubby wings that might have allowed for more frequent flapping flight, like that of a cardinal. Some early pterosaurs had peg-like teeth seen in living reptiles, while many others were toothless. Early pterosaurs often had long tails that they might have used as airborne rudders, while later species have a short tail or no tail at all.



A number of adaptations made flight possible: a greatly elongated fourth finger of the hand that evolved to support a wing; flexible, hollow bones; and membranes between different parts of the body.

The above text is excerpted from the article "Unearthing Pterosaurs," which appeared in the Spring 2014 issue of Rotunda*, the American Museum of Natural History's member magazine.*

Crazy Crests

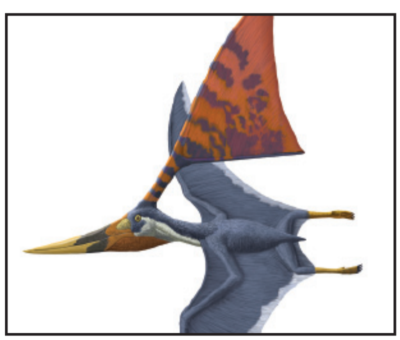
The incredible diversity of pterosaurs is perhaps best expressed in one of the prehistoric flying reptile's most intriguing and mysterious features: the head crest.

Akin to a rooster's comb, peacock's crown, or the frill on some lizards' necks, pterosaur crests were prominent anatomical features found across many species. But rather than flesh or feathers, these reptiles' crests were made at least in part of bone — a boon to paleontologists, as hard bone tends to be preserved as a fossil. Recent research also indicates that other horn-like material comprised part or even most of some pterosaur crests, with the thin, underlying bony structure supporting sometimes expansive membranes. Pterosaurs crests are thought to have been fairly ubiquitous, appearing in many groups of pterosaurs from the Triassic (252–201 million years ago) through the Jurassic (201–145 million years ago) and Cretaceous (145–66 million years ago) periods. In terms of size and dramatic effect, crests peaked in the Late Cretaceous, when the biggest pterosaurs also evolved.

Among pterosaur species known to have had crests, there is an amazing range of shapes and sizes. *Pteranodon sternbergi*, for example, had a high upright crest on its skull; *Pteranodon longiceps*, dagger-shaped blades at the back of its head; and *Nyctosaurus*, a fan-like structure at the rear of its head. *Dsungaripterus weii* had two: a long, low crest on its snout and a short crest rising above the back of the head. The *Anhanguera* species had rounded disk shapes on both upper and lower jaws, while *Gnathosaurus* pterosaurs had long, low ridges running down the middle of their heads. *Tupandactylus* imperator had huge sail-like extensions that dwarfed the rest of its head.

Dsungaripterus weii

Nyctosaurus gracilis



Tupandactylus imperator

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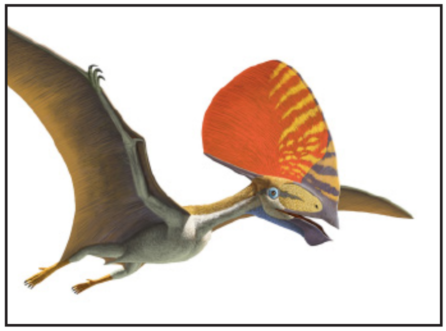

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Could something so flashy be all form and no function? The heavier crests cost the reptiles a lot in energy to grow and carry around. Reason suggests if they weren't useful, they would have disappeared over millions of years of evolution. But just what that use was is a question that puzzles pterosaurologists to this day.

There are competing theories, chief among them that crests serve as a form of species identification. Other possibilities include a role in sexual selection, heat regulation, as a rudder in flight, or as a keel in the water, stabilizing the reptile as it dove or skimmed for food. The discovery in Brazil of wildly different crests among closely related species lends credibility to the theory of species identification: like a Mesozoic mohawk, a distinct crest would allow ready recognition of one's own kind and, equally important, rule out others.

Were the crests as brightly colored as shown in artists' renderings? While scientists cannot know for certain, light and dark bands of color on the rare preserved tissue of a *Pterorhynchus wellnhoferi* crest found in China led to speculation that crests might indeed have been highly colored, especially if they served to communicate identity or attract mates.

Still, without living descendants for comparison and the relative scarcity of fossils, definitive proof has been elusive — so far.

The above text is excerpted from the article "Flying Colors," which appeared in the Spring 2014 issue of Rotunda, *the American Museum of Natural History's member magazine.*

Student Worksheet

Explore each section of the exhibition to investigate pterosaur evolution and diversity.

Section 1: Introduction

Watch the video and explore the fossils. What is a pterosaur?

Section 2: From the Ground Up

Explore the pterosaur family tree 3D mobile.

What are some of the theories for how pterosaurs evolved flight? What do scientists base these theories on?

Beneath the mobile you'll see this illustration of how the ancestors of pterosaurs developed traits that were helpful for gliding, which gradually evolved into wings.

Label the illustration.

Use the information from the pterosaur family tree and the iPad interactives in the next section of the exhibition to fill in the chart below.

	Triassic (252-201 MYA)	Jurassic (201-145MYA)	Cretaceous (145-66 MYA)
Body Size		longer hand bones/larger body size	
Tail Length			short or no tail
Neck Size			
Teeth Present		various types	
Crest Size	no/small Crest	small, bony crests common	

Compare the information you've collected from the three time periods. What do you think it tells us about pterosaur evolution and diversity?

Section 3: Into the Air

Explore the display of pterosaur crests. Draw and label three crests.

Name:	Name:	Name:

How does the presence of crests in the fossil record help support the idea of pterosaur diversity?

Section 4: A Watery World

Explore the display of pterosaur teeth and feeding mechanisms. Draw and label three examples.

Name:	Name:	Name:

Compare the teeth and feeding mechanisms. Do they support the idea of pterosaur diversity? Explain your answer using evidence from the fossil record.

ANSWER KEY

Student Worksheet

Explore each section of the exhibition to investigate pterosaur evolution and diversity.

Section 1: Introduction

Watch the video and explore the fossils. What is a pterosaur?

(Answers may include: Pterosaurs are flying reptiles that lived from about 220 to 66 million years ago. They are related to dinosaurs but evolved on a separate branch of the family tree. Pterosaurs were the first animals after insects to evolve powered flight.)

Section 2: From the Ground Up

Explore the pterosaur family tree 3D mobile.

What are some of the theories for how pterosaurs evolved flight? What do scientists base these theories on?

(Answers may include: One theory is that pterosaurs may have evolved from a reptile that ran around on its hind legs and generated lift by flapping its arms. Another theory is that tree-dwelling reptiles may have jumped to the ground to catch prey or flee predators. Flaps of skin would have helped it glide farther and later evolved into flapping wings. Still another theory speculates that pterosaurs may have leapt from branch to branch in the woods; leaping evolved into gliding and eventually into flight. Scientists based these theories on the anatomy of pterosaurs and other gliding and flying animals.)

Beneath the mobile you'll see this illustration of how the ancestors of pterosaurs developed traits that were helpful for gliding, which gradually evolved into wings.

Label the illustration.

Use the information from the pterosaur family tree and the iPad interactives in the next section of the exhibition to fill in the chart below.

	Triassic (252-201 MYA)	Jurassic (201-145MYA)	Cretaceous (145-66 MYA)
Body Size	*(A: small/robust)*	longer hand bones/larger body size	*(A: largest known)*
Tail Length	*(A: long tail)*	*(A: shorter tail)*	short or no tail
Neck Size	*(A: short neck)*	*(A: Longer neck)*	*(A: very long necks)*
Teeth Present	*(A: jaws lined with teeth)*	various types	*(A: various types but often toothless jaws)*
Crest Size	no/small Crest	small, bony crests common	*(A: large, bony crests)*

ANSWER KEY

Compare the information you've collected from the three time periods. What do you think it tells us about pterosaur evolution and diversity?

(Answers may include: The chart shows that pterosaurs evolved and became more diverse over time in various aspects: they became larger, they evolved crests and those crests became larger over time, they lost tails and developed various feeding mechanisms. These characteristics support the idea that pterosaurs were a diverse group.)

Section 3: Into the Air

Explore the display of pterosaur crests. Draw and label three crests.

Name:	Name:	Name:

How does the presence of crests in the fossil record help support the idea of pterosaur diversity?

(Answers may include: The fossil evidence shows that crests came in many shapes and sizes and were not confined to one single group of pterosaurs; they evolved in many groups and became larger and more prevalent in later pterosaurs. Some fossil evidence shows that several species with very different crests lived in the same time and place in Brazil and China.)

Section 4: A Watery World

Explore the display of pterosaur teeth and feeding mechanisms. Draw and label three examples.

Name:	Name:	Name:

Compare the teeth and feeding mechanisms. Do they support the idea of pterosaur diversity? Explain your answer using evidence from the fossil record.

(Answers may include: The fossil record shows an incredible diversity of teeth and feeding adaptations in pterosaurs. Some had beaks designed for crushing fruit and seeds, others had teeth that resembled the bristles of a brush for straining food out of water and some had sharp, dagger-like teeth for spearing fish.)

Student Writing Guidelines

Based on your reading "Unearthing Pterosaurs," your visit to *Pterosaurs: Flight in the Age of Dinosaurs*, and your discussions, write an essay in which you describe how the fossil record provides evidence of pterosaur evolution and diversity.

Be sure to include:
- labeled illustrations showing the evolution of traits for flight in the ancestors of pterosaurs
- labeled illustrations of three pterosaur crests
- labeled illustrations of three pterosaur teeth and/or feeding mechanisms

Support your discussion with evidence from the reading and your visit to the *Pterosaurs* exhibition.

Use this checklist to ensure that you have included all of the required elements in your essay.

- ☐ I introduced pterosaurs.
- ☐ I clearly describe how the fossil record provides evidence of pterosaur evolution and diversity.
- ☐ I only included relevant information about pterosaur evolution and diversity.
- ☐ I used information from "Unearthing Pterosaurs" to explain the topic in detail.
- ☐ I used information from the *Pterosaurs* exhibition to explain the topic in detail.
- ☐ I used academic, non-conversational tone and language.
- ☐ I included a conclusion at the end.
- ☐ I proofread my essay for grammar and spelling errors.

Assessment Rubric

	Scoring Elements	1 Below Expectations	2 Approaches Expectations	3 Meets Expectations	4 Exceeds Expectations
RESEARCH	**Reading**	Attempts to present information in response to the prompt, but lacks connections to the texts or relevance to the purpose of the prompt.	Presents information from the text relevant to the purpose of the prompt with minor lapses in accuracy or completeness.	Presents information from the text relevant to the prompt with accuracy and sufficient detail.	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the text.
RESEARCH	**AMNH Exhibit**	Attempts to present information in response to the prompt, but lacks connections to the Museum exhibit content or relevance to the purpose of the prompt.	Presents information from the Museum exhibit relevant to the purpose of the prompt with minor lapses in accuracy or completeness.	Presents information from the Museum exhibit relevant to the prompt with accuracy and sufficient detail.	Accurately presents information relevant to all parts of the prompt with effective paraphrased details from the Museum exhibit.
WRITING	**Focus**	Attempts to address the prompt, but lacks focus or is off-task.	Addresses the prompt appropriately, but with a weak or uneven focus.	Addresses the prompt appropriately and maintains a clear, steady focus.	Addresses all aspects of the prompt appropriately and maintains a strongly developed focus.
WRITING	**Development**	Attempts to provide details in response to the prompt, including retelling, but lacks sufficient development or relevancy.	Presents appropriate details to support the focus and controlling idea.	Presents appropriate and sufficient details to support the focus and controlling idea.	Presents thorough and detailed information to strongly support the focus and controlling idea.
WRITING	**Conventions**	Attempts to demonstrate standard English conventions, but lacks cohesion and control of grammar, usage, and mechanics.	Demonstrates an uneven command of standard English conventions and cohesion. Uses language and tone with some inaccurate, inappropriate, or uneven features.	Demonstrates a command of standard English conventions and cohesion, with few errors. Response includes language and tone appropriate to the purpose and specific requirements of the prompt.	Demonstrates and maintains a well-developed command of standard English conventions and cohesion, with few errors. Response includes language and tone consistently appropriate to the purpose and specific requirements of the prompt.
SCIENCE	**Content Understanding**	Attempts to include science content in explanations, but understanding of the topic is weak; content is irrelevant, inappropriate, or inaccurate.	Briefly notes science content relevant to the prompt; shows basic or uneven understanding of the topic; minor errors in explanation.	Accurately presents science content relevant to the prompt with sufficient explanations that demonstrate understanding of the topic.	Integrates relevant and accurate science content with thorough explanations that demonstrate in-depth understanding of the topic.