Lesson Nine

Causal Hypotheses of Dinosaur Extinction

Summary

What caused the extinction of the dinosaurs? Was it a massive meteor? Was it the result of tremendous volcanic activity that covered the globe in volcanic ash? Was it the effects of gradual climate change? Was it the result of plate tectonics? Students are given a set of evidence cards that state scientific discoveries about rocks from 66 million years ago and prediction cards that discuss the predicted effects of different events such as a meteor impact, a rise in carbon dioxide levels, and plate tectonics. Teams of students are charged with assembling this information into an overarching hypothesis that best explains the evidence at hand. At the end of the period or the following period, teams present their hypotheses to the whole group and enter into a debate about the cause or causes of the great dinosaur extinction.

(*This plan is slightly adapted and updated from a lesson created by Irene Salter. www.mysciencebox.org*)

Objectives

Students will be able to:

1. Describe the different hypotheses for how dinosaurs and other plants and animals went extinct 66 million years ago.
2. Sort through evidence and come up with a scientific hypothesis that best fits the data.
3. Recognize whether evidence is consistent with a scientific hypothesis.

Estimated teaching time

5 minutes introduction
40–50 minutes to come up with hypotheses
45–55 minutes to present hypotheses and discuss alternative hypotheses

Groups

Groups of 3 students

Materials

- 1 set of evidence cards per team
- 1 envelope per team
- 1 “Dinosaur Extinction” worksheet per team

Teacher background

There have been five mass extinctions throughout the history of the Earth. A mass extinction may be defined as an episode in geologic history where over half of the species in existence become extinct in a relatively short amount of time (just a few million years). The worst mass extinction came at the end of the Paleozoic Era 251 million years ago when nearly 95% of plant and animal life in the seas disappeared. Another mass extinction may be happening today. Some estimates show that current rates of extinction are as high as 27,000 species per year, which is significantly higher than the 10–100 species extinctions (also known as 'background extinction') per year indicated by the fossil record.

Probably the most famous mass extinction happened ~66 million years ago, when all of the dinosaurs but birds (referred to as non-avian dinosaurs) disappeared. This is generally called the K-T, or K-Pg, extinction. Until recently geologists used the term K-T to refer to the boundary between the Cretaceous (K) and Tertiary (T) periods. Now, however, geologists have eliminated the Tertiary and replaced it with two periods, known as the Paleogene and Neogene, so that the K-Pg refers to the Cretaceous-Paleogene boundary. You will still see both K-T and K-Pg. To keep up with the science, we are using K-Pg.

Whatever triggered the extinction of the dinosaurs also caused the death of nearly 60-70% of all the other species on Earth. Interestingly, not all groups of organisms were affected equally. Marine species were hit harder than land species, with 90% of marine species becoming extinct. Birds were the only survivors of the dinosaur lineage. Interestingly, some mammals, lizards, snakes, salamanders, and frogs that would seem to be vulnerable to such an event were less affected. Some groups even benefited from the event. For example, ferns actually expanded and thrived immediately after the event, and mammals underwent a long-term diversification.

So what caused the dinosaur extinction? Clues to the cause of this mass extinction event can be found in the rocks that date from ~66 million years ago. Some pieces of evidence are accepted by nearly all scientists:

1. Around the time of the K-Pg extinctions, there was global climate change. What was once a warm, mild climate changed to one that was more varied (sometimes very hot, sometimes very cold).
2. In India, there was extensive volcanic activity, known as the Deccan Traps. Rocks that date from 67–64 million years ago in southern India are almost entirely igneous (volcanic). Almost 200,000 square miles was covered in lava over a period of 3 million years (an area equivalent to the entire mid-western United States). In some places, the lava beds are a mile deep.
3. Geologist Alan Hildebrand found evidence of what is most likely an enormous asteroid impact site in the Yucatan region of Mexico. He named the 110 mile-wide crater after a nearby town, Chicxulub, which means devil's tail. The crater has been dated and is coincident with the K-Pg boundary (~66 million years ago). The size of the crater has been used to estimate the size of the asteroid. Estimates vary but the asteroid may have been as large as 6 miles wide.
4. High levels of the rare earth element iridium have been found in a thin ~ 2 cm-thick layer dated to around 66 million years ago. This iridium anomaly has been found in many places around the world at the same rock level. The iridium levels contained in the rocks from this time period are up to 30 times the normal levels on Earth. The most likely sources of high levels of iridium are from:
   - ⇒ outer space in the form of cosmic dust from a nearby exploding supernova
   - ⇒ outer space carried to Earth by an asteroid or meteor
   - ⇒ eruptions of massive volcanoes.
5. Shocked quartz and glassy spherules have been found associated in the same layer with the iridium anomaly. The shocked quartz grains are metamorphically transformed quartz

with crosshatch patterning that resulted from intense shock waves produced from a high-energy impact event. The glassy spherules are small droplets of melted rock. Both were produced at the impact site and thrown up into the atmosphere and circulated globally before falling to Earth as impact debris and forming a sedimentary layer that we can analyze in the geologic record.

6. Major changes in the oceans and landscape were occurring around 66 million years ago due to plate tectonics. There is evidence that the oceans were receding. For example, a shallow sea once covered what is now the mid-western United States, which ran from the Gulf of Mexico up through Canada, and separated North America in two. This seaway drained away over several million years around the time of the dinosaur extinctions, as the Colorado Plateau rose.

Although there is an abundance of evidence detailing the environmental disturbances that occurred at this time, there is no consensus among scientists whether one or all of these caused the mass extinction. Generally speaking, scientists are divided into two camps:

Single Cause (Asteroid impact) – These scientists argue that the fossil record indicates that ecosystems were "healthy" in the millions of years leading up to the K-Pg boundary until a sudden catastrophic event, namely the asteroid impact, caused massive extinctions. This hypothesis was first proposed in 1980 by Walter Alvarez, a geologist, and his physicist father, Luis Alvarez, and is often referred to as the "Alvarez Theory". Although there is ample evidence in the form of high iridium levels and presence of shocked quartz and glassy spherules in the rocks of that age, it is unclear what the outcome of this impact would have been and how it would have affected the biota. Some have hypothesized that the resulting blast would have destroyed everything within 250–300 miles, including the impact object itself. Trillions of tons of debris (like dust, smoke, and steam) would have been thrown into the atmosphere when the object vaporized, darkening the sky around the globe in just a few weeks. The darkness may have only persisted for a few years but the effects on plant life would have been devastating and caused a chain reaction through the ecosystem. Earthquakes would almost certainly have been triggered, and so might have tsunamis and wildfires.

Multiple Causes – These scientists argue that the fossil record indicates that ecosystems were of declining "health" in the last few millions of years before the K-Pg boundary as the result of accumulating environmental disturbances, culminating in the asteroid impact at the Cretaceous-Paleogene boundary. The time frame is consistent with several major long-term events such as dropping sea level, massive volcanic activity, and climate change. For example, these scientists argue that extensive volcanic activity in India (called the Deccan Traps) would have released massive amounts of sulfuric acid and carbon dioxide into the atmosphere, resulting in climate changes and possibly acid rain, that would have strongly affected ecosystems.

This ongoing debate offers an exciting opportunity for students to sort through the clues and propose a hypothesis to explain the extinction of the dinosaurs. The key to this activity is for students to begin by organizing the evidence into sets of related information and then use the evidence to support a logical theory. Since there is no right answer students have an opportunity to engage in a true scientific debate over the same set of data that paleontologists, geologists, and physicists argue over. Furthermore, there are endless directions in which the debate may travel, opening endless opportunities for further exploration.

Student background

Students should have an understanding of how fossils form and have experience with the geologic time scale. It is helpful to have a good foundation in the rock cycle and stratigraphy so as to better understand how the evidence provided may have been gathered.

Set up

Classroom

1. Make a copy of the "Dinosaur Extinction" handout for each team of students.
2. Copy and cut out a set of extinction cards for each team of students. Putting the cards on cardstock paper allows you to use the same cards year after year.
3. Put a set of extinction cards into each envelope.

Introducing the activity

1. Rather than start class with any warm-up or initial discussion, begin by dividing the class into teams and giving each team a copy of the handout. It is important to keep kids from thinking about what they might have heard previously about the dinosaur extinction 66 million years ago. Many have heard about the catastrophic meteor/asteroid/comet theory and are likely to use evidence to justify their previous beliefs than to use evidence to arrive at a reasoned hypothesis.

2. Read through the first page of the handout together, stopping to answer any questions and define any vocabulary the students may be unfamiliar with (mass extinction, hypothesis, etc.) using the glossary.

3. Emphasize that a hypothesis must be supportable by evidence. Encourage students to temporarily ignore anything they **think** they know about the dinosaur extinction and instead seriously consider **ANY** possible explanation that is suggested by the evidence. The evidence is not equal in importance, so it is not the number of evidence cards that matters but the conclusiveness of the evidence that matters. Thus, discourage students from using the strategy of the hypothesis with the most number of evidence cards must be true.

4. Students may need an example of what a hypothesis looks like, particularly, the way a hypothesis is composed of a series of logically linked statements. For instance, a hypothesis might say "If a new virus evolved and caused the extinction of all non-avian dinosaurs, then we might expect to see evidence of viral disease/infection in the cellular structure of dinosaur bones but not in the bones of those animals that survived the K-Pg extinction."

Facilitating the activity

1. Once students understand the overall goal of this exercise, give them their cards and allow them to begin. Circulate around the room and help groups that get stuck or cannot

agree. Make sure that students do not let their previous assumptions interfere with the process and keep students focused on the evidence cards.

2. If teams finish early, force them to make their hypothesis as clear as possible and challenge them by pointing out flaws in their logic or evidence that does not fit their ideas. For instance, if they hypothesize that the wildfires caused the extinction require that they have evidence in the form of soot layers to support their hypothesis. Force students to think their ideas through completely and explain why they favor some evidence more than others.

3. The following class period, or when all groups have finished, give each group a chance to present their hypothesis, and their supporting evidence, to the rest of the class. Allow a question and answer period following each group's presentation. Make sure that questions from other students are also grounded in the evidence and not personal attacks.

4. When all groups have finished, allow an open debate about the causes of the dinosaur extinction. If necessary, clarify the various theories by writing them up on the board. Use this opportunity to discuss what pieces of evidence are stronger than others and why. If it appears that all teams favor one explanation (as happened in one of my classes), play the devil's advocate and challenge students with evidence supporting an opposing viewpoint. Always come back to the evidence cards and keep the discussion focused on looking for a hypothesis that best explains the evidence at hand.

5. 10 minutes before the end of class, close the debate and describe the current state of affairs is in the scientific community – that scientists are still very divided into the single cause and multiple cause camps. Allow students to suggest areas of research that could help settle the debate: more conclusive information about how quickly or slowly the extinctions occurred, more clear evidence of asteroid or meteor impacts, more detailed radioactive dating information, fossil evidence from different parts of the world, etc.

Assessment
NA

Going further
1. Have students research other mass extinctions and compare them to the rate of extinction today. Have students write a position paper arguing whether we are currently in a period of mass extinction or not.
2. Have students investigate the conflicting hypotheses explaining the end-Permian (also called Permo-Triassic) extinction, the largest mass extinction known. As they did in this activity, have them summarize one theory about the causes of the Permian extinction and the evidence that supports that idea.

References
There are many excellent websites that discuss the K-Pg extinction:
- The UC Museum of Paleontology has a superb discussion of the ongoing scientific debate. (http://www.ucmp.berkeley.edu/diapsids/extinction.html)

- Wikipedia offers a great deal of information about both of the major theories and the evidence in favor of each. (http://en.wikipedia.org/wiki/K-T_extinction)
- PBS also provides a balanced discussion of the major theories. (http://www.pbs.org/wgbh/evolution/extinction/dinosaurs/asteroid.html)
- Finally, the BBC has a good article about the dating of the Chicxulub crater. http://news.bbc.co.uk/2/hi/science/nature/3520837.stm

Teaching standards

Grade 7, Earth and Life History (Earth Sciences)

4. Evidence from rocks allows us to understand the evolution of life on Earth. As a basis for understanding this concept:

a. Students know Earth processes today are similar to those that occurred in the past and slow geologic processes have large cumulative effects over long periods of time.

b. Students know the history of life on Earth has been disrupted by major catastrophic events, such as major volcanic eruptions or the impacts of asteroids.

e. Students know fossils provide evidence of how life and environmental conditions have changed.

g. Students know how to explain significant developments and extinctions of plant and animal life on the geologic time scale.

Glossary

- Extinction – The total disappearance of a species or higher taxon, so that it no longer exists anywhere.*
- Iridium – A naturally occurring chemical element with the atomic number 77. Iridium is found in much higher concentrations in meteorites than in the Earth's crust.
- K-Pg boundary – Sixty-six million years ago. This boundary marks the end of the Mesozoic and beginning of the Cenozoic eras. The boundary is when one of five mass extinction events in Earth's history took place. Groups that went extinct at the K-Pg boundary include mosasaurs, plesiosaurs, ammonites, pterosaurs, and non-avian dinosaurs.
- Mass extinction – The worldwide extinction of a large number of species.
- Theory – A concept or proposition, developed from an hypothesis, that is supported by experimental or factual evidence but is not so conclusively proved as to be accepted as a law.*

* = Definition directly from Dictionary of Geological Terms, prepared by the American Geological Institute