Science News

IN HIGH SCHOOLS | EDUCATOR GUIDE

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Dino Doomsday

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Dino Doomsday

About this Issue

In a geologic instant 66 million years ago, dinosaurs largely disappeared from the planet, along with many other plant and animal species. But researchers don't know what exactly caused the mass extinction. The article "Devastation detectives" describes the current state of evidence for whether a space rock impact, massive volcanic eruptions or some combination of both was responsible for the apocalypse. Dinosaurs didn't disappear entirely, though. A lineage had evolved into birds, some of which survived the extinction event, as described in an infographic titled "The lucky ones." These survivors gave rise to all modern bird species. Students can focus on details in the articles, follow connections to earlier articles about paleontology and extinction events, explore cross-curricular connections to other major science topics, and study real fossils and meteorite samples. For additional articles about the dinosaur extinction event and fossilized remains written at slightly lower Lexile levels, see the following *Science News for Students* articles: "Dino double whammy" (8.3 readability score) and "Reviving dinosaurs" (8.1 readability score). Also, *Science News for Students* describes "How a fossil forms" in a brief explainer (6.5 readability score). To access the lower Lexile version of "Devastation detectives," use this Science News for Students link.

Connections to Curricula

- History of the Earth
- Evolution
- Fossils
- Climate change
- Geology
- Extinction
- Paleontology
- Phylogeny
- Kinetic energy

What's in this Guide?

- Article-Based Observation: These questions focus on reading and content comprehension by drawing on information found in the article "Devastation detectives." Questions focus on what might have caused the mass extinction that largely wiped out the dinosaurs.
- Quest Through the Archives: With Internet access and your school's digital access to *Science News*, your students can use this short section to explore the traits of ancient birds and dinosaurs as reported by *Science News* since 1922.
- Cross-Curricular Discussion: These questions and extension prompts connect to the articles "Devastation detectives" and "The lucky ones" and encourage students to think in more detail about scientific areas related to the articles. The section is divided roughly by science subdiscipline for educators who would like to focus on a specific topic area. The extension prompts are either more topic-specific or more conceptually advanced. **Biological Sciences** questions involve the topic of evolution and extinction. **Earth Sciences** questions address types of rocks and minerals relevant to the articles. **Physical Sciences/Mathematical Problem Solving** questions concern the energies involved in meteorite impacts. **Engineering and Experimental Design** questions focus on possible methods of averting future large meteorite impacts.

- Activities: **Geology of Dino Doomsday** is a hands-on geologic activity for students to study the Cretaceous-Paleogene, also known as the Cretaceous-Tertiary or K-T, boundary. It suggests ways to have students examine real meteorites, meteorite impact material, fossils and rocks from relatively inexpensive sources to understand that geology can provide insight into the Earth's history. **Build a Bird** encourages students to explore "The lucky ones" infographic. Students will analyze the traits of ancient birds and design a hypothetical bird that might survive in a particular ecosystem.

Standards Alignment

Next Generation Science	Common Core
Biological Evolution: HS-LS4-1, HS-LS4-4, HS-LS4-5	ELA Standards: Reading Informational Text (RI): 1, 2, 7
Earth's Systems: HS-ESS2-4, HS-ESS2-7	ELA Standards: Writing (W): 2, 3, 6, 9
Energy: HS-PS3-1, HS-PS3-2	ELA Standards: Speaking and Listening (SL): 1, 6
Engineering Design: HS-ETS1-2, HS-ETS1-3	ELA Standards: Reading for Literacy in Science and Technical Subjects (RST): 1, 2, 4, 8, 9
	ELA Standards: Writing Literacy in History/Social Studies and Science and Technical Subjects (WHST): 2, 4, 6, 7, 9

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Article-Based Questions

Directions: After reading the article "Devastation detectives," answer these questions:

1. **Scientists have evidence that an extraterrestrial event changed the landscape of Earth about 66 million years ago. Explain the event and its effects.**

2. **What other landscape-changing event may have contributed to the dinosaur extinction? How did it impact the environment?**

3. **What element has been found in the layers of earth that mark the boundary between the Cretaceous and Paleogene periods? Why is that element significant?**

4. **Imagine that you were a dinosaur standing on Earth during the Chicxulub impact. Assuming you weren't close enough to be immediately physically injured, describe what aftereffects you might have experienced.**

5. **Clay Tabor and his colleagues at the National Center for Atmospheric Research in Boulder, Colo., assembled a computer simulation of the climatic consequences associated with the Chicxulub impact. What did the simulation show?**

6. **Paleontologist Gerta Keller said that "Deccan volcanism is vastly more dangerous to life on Earth than an impact." What evidence could be used to support this statement?**

7. **Based on the evidence presented, what do you think caused the mass extinction of the dinosaurs? Explain your answer.**

Responses to Article-Based Observation

1. **Scientists have evidence that an extraterrestrial event changed the landscape of Earth about 66 million years ago. Explain the event and its effects.** Possible student response: A space rock crashed into Earth and created the Chicxulub crater (approximately 180 kilometers wide) near what is currently the country of Mexico. Scientists believe that this impact caused mountains to form within minutes and tsunami waves to bury plants and animals in rubble.

2. **What other landscape-changing event may have contributed to the dinosaur extinction? How did it impact the environment?** Possible student response: Evidence suggests that super-volcanic eruptions near what is now India may have acidified the oceans and destabilized ecosystems. The impact of Chicxulub may have boosted the eruptions.

3. **What element has been found in the layers of earth that mark the boundary between the Cretaceous and Paleogene periods? Why is that element significant?** Possible student response: Luis and Walter Alvarez discovered iridium along this boundary in 1980. Iridium is rare in the Earth's crust but abundant in space rocks. This discovery fostered the idea that a significant impact from an asteroid or comet occurred between the Cretaceous and Paleogene periods and may have contributed to a mass extinction around that time.

4. **Imagine that you were a dinosaur standing on Earth during the Chicxulub impact. Assuming you weren't close enough to be immediately physically injured, describe what aftereffects you might have experienced.** Possible student response: The ground would be shaking under my feet. Rocks start to pop up as the ground churns. There are ashes and soot flying everywhere causing fires to start when hot ash hits grasses. The sky grows darker and darker, and soon I can't see anything around me. I see a wave of water the height of a tall mountain.

5. **Clay Tabor and his colleagues at the National Center for Atmospheric Research in Boulder, Colo., assembled a computer simulation of the climatic consequences associated with the Chicxulub impact. What did the simulation show?** Possible student response: The simulation showed that no light reached any part of Earth's surface for two years causing average temperatures to drop by some 16 degrees Celsius. Areas around the equatorial Pacific experienced bigger drops than polar regions and coastal areas felt less impact than inland areas. It took about six years for sunlight levels to return to normal. For about two years after that, temperatures continued to rise above pre-impact levels, probably because the carbon dioxide levels in the atmosphere were higher and created a "warming blanket" around the planet.

6. **Paleontologist Gerta Keller said that "Deccan volcanism is vastly more dangerous to life on Earth than an impact." What evidence could be used to support this statement?**
Possible student response: Deccan volcanic eruptions near India spewed more than 1.3 million cubic kilometers of molten rock and debris. The volcanic activity started 250,000 years before the impact and continued for about 500,000 years after. Volcanic activity releases mercury into the environment that weakens the plankton population, which is the foundation of marine food chains. Carbon dioxide levels in the atmosphere also increased due to volcanic eruption, contributing to climate change and ocean acidification.

7. **Based on the evidence presented, what do you think caused the mass extinction of the dinosaurs? Explain your answer.** Possible student response: The "double doomsday" or combination of the Chicxulub impact and Deccan volcanism is supported by some researchers. Sierra Petersen, a geochemist at the University of Michigan, argues that either event alone would have caused some extinction, but a mass extinction was likely caused by a combination. The physics does not readily support the "double doomsday" scenario, so some scientists support the impact scenario alone.

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Quest through the Archives

Directions: After reading the infographic "The lucky ones," use the archives at www.sciencenews.org to answer these questions:

1. **Search for an article about birds in the Cretaceous Period. Describe what new information scientists learned about birds from that time period.**

2. **Search for an article about a dinosaur trait that scientists tried to simulate in a modern bird. Summarize what the scientists did.**

3. **Find an article about an "oldest known" relative of modern birds. Where did the bird live and what do scientists think it looked like?**

Responses to Quest Through the Archives

1. **Search for an article about birds in the Cretaceous Period. Describe what new information scientists learned about birds from that time period.** Possible student response: https://www.sciencenews.org/article/birds'-honks-filled-late-cretaceous-air. The article discusses the discovery of a fossilized voice box or syrinx from the Late Cretaceous. The discovery allowed scientists to predict what prehistoric birds might have sounded like.

2. **Search for an article about a dinosaur trait that scientists tried to simulate in a modern bird. Summarize what the scientists did.** Possible student response: https://www.sciencenews.org/blog/scicurious/weighted-butt-gives-chickens-dinosaur-strut. Chickens walk on two legs like many dinosaurs. By giving a chicken a makeshift weighted tail, scientists tried to model a dinosaur walk.

3. **Find an article about an "oldest known" relative of modern birds. Where did the bird live and what do scientists think it looked like?** Possible student response: https://www.sciencenews.org/article/oldest-known-avian-relative-today's-birds-found-china. The remains of an *Archaeornithura meemannae*, which lived 130.7 million years ago, were found in northeastern China. It is thought to have been the size of a hummingbird with stubby feathers, and it may have waded in the water.

Cross-Curricular Discussion

After students have had a chance to review the articles "Devastation detectives" and "The lucky ones," lead a classroom discussion based on the questions that follow. You can copy and paste only the questions that apply to your classroom into a different document for your students. Before starting the discussion, you may want to show this Howard Hughes Medical Institute educational video titled "The day the Mesozoic died." This video is approximately 33 minutes, but shorter clips may be useful for geologic visuals. The video highlights the asteroid impact hypothesis and does not mention the potential impact Deccan volcanism had on Earth or the dinosaurs. NASA has also released images of the Chicxulub crater in "A 'smoking gun' for dinosaur extinction."

BIOLOGICAL SCIENCES

Discussion Questions:

1. What set of features distinguishes modern birds from dinosaurs like *Tyrannosaurus rex*? [*Wings, loss of wing claws, loss of teeth, etc.*]
2. How might those features have arisen, hypothetically speaking? [*Feathers might have offered insulation, provided cushion against injury, attracted mates, served as camouflage, etc. Small wings might have been useful for trapping prey, swimming, mating displays, etc. Once birds could fly, it might have been less important to maintain defense features such as teeth.*]
3. What types of animals went extinct 66 million years ago? [*Non-avian dinosaurs, some branches of the bird family tree, many other vertebrates (fish/amphibians/reptiles/mammals), ammonites, belemnites, etc.*]

Extension Prompts:

4. What factors might have determined which animals went extinct and which survived? [*Larger animals would have found it hard to find enough food during the several-year-long winter that killed most plants, so there was strong selection for animals that were smaller at the time. Warm-blooded animals including mammals and birds did better in the cold. Depending on where they lived, animals may have been more or less affected by the impact event, the following climate change or atmospheric and ocean changes caused by volcanic eruptions.*]
5. How did the extinction lead to new diversity? [*Once the planet recovered, there was a lot of room and resources, but the surviving species were much fewer and smaller. Thus, there was plenty of opportunity for them to grow to larger sizes, become more numerous and diversify to fill ecological niches that had been previously filled by other species now extinct.*]

Biological Sciences Question Bank

What set of features distinguishes modern birds from dinosaurs like *Tyrannosaurus rex*?

How might those features have arisen, hypothetically speaking?

What types of animals went extinct 66 million years ago?

What factors determined which animals went extinct and which survived?

How did the extinction lead to new diversity?

EARTH SCIENCES

Discussion Questions:

1. What is the difference between a mineral and a rock? [*Minerals are pure elements or compounds, whereas rocks are mixtures of two or more minerals.*]
2. What type of rock forms the foundation of continents, and what minerals are in it? What type of rock forms the foundation of the ocean floor, and what are some of the major minerals in it? [*Continental plate is made mostly of granite, which contains feldspar, quartz and mica. Oceanic plate is made mostly of basalt, which contains augite, feldspar and other minerals.*]
3. What is the major type of rock in Earth's mantle, and what is the primary mineral in it? [*Peridotite, composed largely of olivine.*]
4. How does limestone form? What is the main mineral or compound in limestone? What is limestone mined to produce? [*Limestone forms from sedimentary deposition and compression of tiny seashells that accumulate at the bottom of the ocean. The main compound in limestone is calcite, or calcium carbonate. Limestone is mined for the stone for buildings, and pure calcium carbonate for chalk and antacids like Tums.*]

Extension Prompts:

5. How resistant is limestone to erosion? [*Limestone is partially soluble in water and can erode over time from water. Limestone is even more soluble in acidic conditions, such as acid rain.]*
6. What is a cenote? [*A sinkhole or natural well through limestone, generally leading from the surface down to water*.]
7. As discussed in the article "Devastation detectives," the Chicxulub impact churned a lot of material together. Based on the colors of the multicolor core samples mentioned in the article, as well as other information in the article, what minerals might be in the core samples? [*Black could be black biotite mica and/or black basalt. White could be white feldspar, white quartz and/or white limestone. Green could be olivine or peridotite. Red could be pinkish-red feldspar or iron originally from basalt or olivine/peridotite that has melted and come out and rusted to form hematite.*]
8. What would those minerals tell you about the original locations of rocks that were mixed together by the impact? [*Granite would have likely come from the continental crust, basalt from the seafloor crust and peridotite from the upper mantle.*]

9. Look at a map of cenotes in the Yucatán Peninsula, such as [this one from NASA](). Do you see any patterns? What do you think might have caused that pattern? [*Many of the cenotes form a semicircle. The edge of the Chicxulub impact crater may have caused this formation by damaging the limestone and making it more susceptible to the formation of cenotes. Since the actual crater is located under the ocean and 66 million years of deposits, the map of the cenotes might be a good way for students to visualize the crater.*]

Earth Sciences Question Bank

What is the difference between a mineral and a rock?

What type of rock forms the foundation of continents, and what minerals are in it? What type of rock forms the foundation of the ocean floor, and what are some of the major minerals in it?

What is the major type of rock in Earth's mantle, and what is the primary mineral in it?

How does limestone form? What is the main mineral or compound in limestone? What is limestone mined to produce?

How resistant is limestone to erosion?

What is a cenote?

As discussed in the article "Devastation detectives," the Chicxulub impact churned a lot of material together. Based on the colors of the multicolor core samples mentioned in the article, as well as other information in the article, what minerals might be in the core samples?

What would those minerals tell you about the original locations of rocks that were mixed together by the impact?

Look at a map of cenotes in the Yucatán Peninsula provided by your teacher. Do you see any patterns? What do you think might have caused that pattern?

PHYSICAL SCIENCES/MATHEMATICAL PROBLEM SOLVING

Discussion Questions:

1. Using Blackline Master 3 or the diagram titled "Ringing true" on Page 18 of "Devastation detectives," describe how the Chicxulub crater formed. [*The "space rock" made a deep crater impacting both the upper crust and lower crust. Rocks from deep within the surface quickly fill the voided space, forming an unstable central column. The column collapses and a peak ring forms.*]

2. Explosive energies are often measured in terms of the equivalent tons of TNT that would produce the same explosion. 1 ton of TNT = 4.184×10^9 Joules (J) of energy, or 1 kiloton (kT, thousand tons) = 4.184×10^{12} Joules. Determine the explosive energy of the nuclear bomb dropped on Hiroshima in tons of TNT and Joules. [*15,000 tons = 6.28×10^{13} Joules*]

3. If the Chicxulub impact released about 10 billion times as much energy as the Hiroshima bomb, what was its explosive energy in tons of TNT and Joules? [*1.5×10^{14} tons ≈ 6.28×10^{23} Joules*]

Extension Prompts:

4. The exact size, density and velocity of the Chicxulub impactor (asteroid, comet or terribly clueless Star Destroyer) are still somewhat uncertain. Assuming that the impactor was round with a radius of 6 km (12 km diameter), what was its volume? [*$V = (4/3)\pi r^3 \approx 9.05 \times 10^{11}\ m^3$*]
5. Assuming that the Chicxulub impactor had that volume and was a stony asteroid with a density of 3000 kg/m^3 (specific gravity of 3), what was its mass? [*$m = pV \approx 2.71 \times 10^{15}\ kg$*]
6. Assuming that the Chicxulub impactor had that mass and that its velocity immediately before impact was 17,000 m/sec (17 km/sec, approximately 50 times the speed of sound), what was its kinetic energy in Joules or tons? [*$K.E. = mv^2/2 = 3.92 \times 10^{23}\ J = 9.37 \times 10^{13}$ tons*]
7. The impactor's kinetic energy became the explosive energy that was released upon impact. How much does your estimate of the kinetic energy differ from the earlier estimate of 10 billion Hiroshima bombs? [*10 billion Hiroshima bombs would be approximately 1.6 times the kinetic energy just calculated*.]
8. What factors might account for the different numbers? [*The 10 billion Hiroshima bombs estimate itself might be somewhat off, or the impactor might have been somewhat larger, had a higher density (iron meteorites have a density of 7000–8000 kg/m^3) or may have had a higher velocity (perhaps closer to 20 km/sec).*]

Physical Sciences/Mathematical Problem Solving Question Bank

Using Blackline Master 3 or the diagram titled "Ringing true" on Page 18 of "Devastation detectives," describe how the Chicxulub crater formed.

Explosive energies are often measured in terms of the equivalent tons of TNT that would produce the same explosion. 1 ton of TNT = 4.184×10^9 Joules (J) of energy, or 1 kiloton (kT, thousand tons) = 4.184×10^{12} Joules. Determine the explosive energy of the nuclear bomb dropped on Hiroshima in tons of TNT and Joules?

If the Chicxulub impact released 10 billion times as much energy as the Hiroshima bomb, as stated in the article, what was its explosive energy in tons of TNT and Joules?

The exact size, density and velocity of the Chicxulub impactor (asteroid, comet or terribly clueless Star Destroyer) are still somewhat uncertain. Assuming that the impactor was round with a radius of 6 km (12 km diameter), what was its volume?

Assuming that the Chicxulub impactor had that volume and was a stony asteroid with a density of 3000 kg/m^3 (specific gravity of 3), what was its mass?

Assuming that the Chicxulub impactor had that mass and that its velocity immediately before impact was 17,000 m/sec (17 km/sec, approximately 50 times the speed of sound), what was its kinetic energy in Joules or tons?

The impactor's kinetic energy became the explosive energy that was released upon impact. How much does your estimate of the kinetic energy differ from the earlier estimate of 10 billion Hiroshima bombs?

What factors might account for the different numbers?

ENGINEERING AND EXPERIMENTAL DESIGN

Discussion Questions:

1. How could you spot unknown asteroids or comets in space that might collide with Earth? [*Photographing the same region of stars at different times, then comparing them to look for objects that have changed their position relative to the stars. Of those objects that have changed position, one can eliminate those that are known planets, asteroids or comets, and then—with enough images—determine the orbits of any newly discovered objects that remain.*]

Extension Prompts:

2. How could you potentially prevent a future impact that might cause a mass extinction? *[An object might be nudged by using rockets to push it, or by detonating nuclear bombs near it. The farther away and longer the time before an object hits Earth, the smaller change in the object's trajectory is required to make it miss Earth. If you shatter it with nuclear bombs, one or more of the pieces might still be on a collision course.]*

3. If another Chicxulub-type impact could not be prevented, how could some humans survive the impact and its aftermath? *[Send an "ark" with some humans, animals and plants into orbit. They could later return to restart civilization. Or, equip shelters with protection against the blast/tsunamis, enough food and nuclear power to survive the long winter and enough animals and plants to restart civilization afterward. Or just give up and hold the biggest "going out of business" sale of all time.]*

Engineering and Experimental Design Question Bank

How could you spot unknown asteroids or comets in space that might collide with Earth?

How could you potentially prevent a future impact that might cause a mass extinction?

If another Chicxulub-type impact could not be prevented, how could some humans survive the impact and its aftermath?

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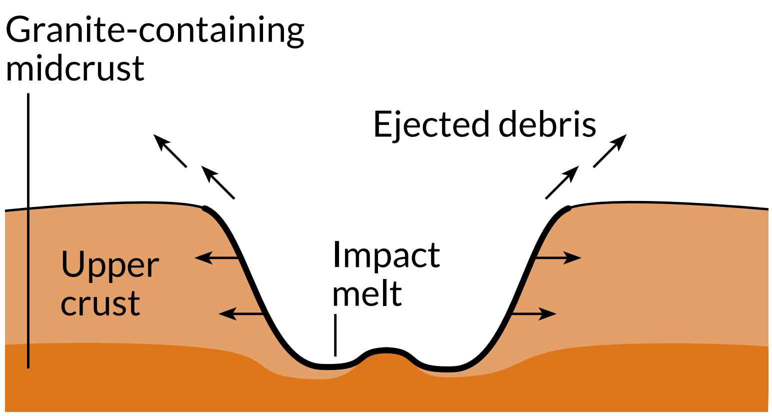
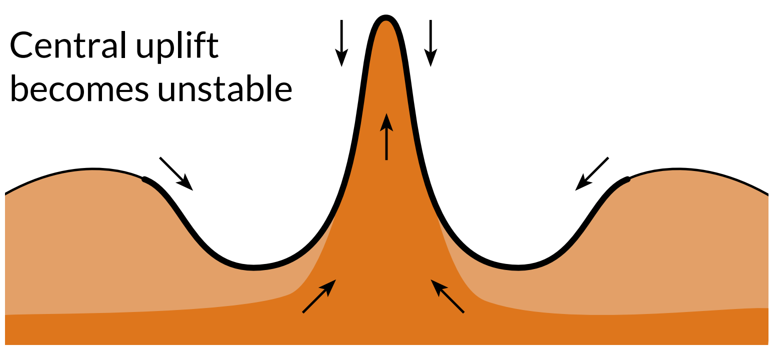
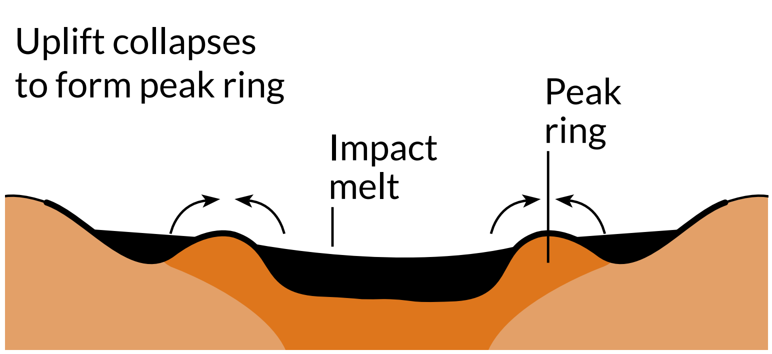
Cross-Curricular Discussion

Directions: Use the diagram from “Devastation detectives” to answer the related discussion questions assigned by your teacher.







Teacher's Guide for Geology of Dino Doomsday Activity

Class time: 30-60 minutes

Purpose: Students can examine real meteorites, meteorite impact samples, fossils and rocks relevant to "Devastation detectives."

Notes to the teacher: You can adapt this activity based on what materials you are able to buy, borrow or find. Museums are sometimes willing to loan specimens for educational purposes. It may be worth checking with a local museum. Ammonites, belemnites and small dinosaur fossils are inexpensive to buy.

Materials:

- Rocks, minerals, fossils, meteorites and/or meteorite impact materials (depending on what you have or can obtain—see suggestions below)
- Gloves (if the samples are sharp or messy)
- 10–30x stereo dissection microscopes with top illumination*
  *If you do not have these microscopes but do have regular higher-power microscopes, then students can use those with the lowest power setting (40x), the sample resting on a glass slide covering the hole in the stage, the below-stage light off, a flashlight or task lamp for top illumination and strict instructions not to bump the objectives into the samples.
- Hand magnifiers
- Directions for student groups (using the directions below, decide what questions to ask your students based on the samples you obtain)
- Books or websites to help students identify the samples (see suggested resources below)

Sample Identification Resources:

- For very concise identification guides for rocks, minerals and fossils, as well as other related activities, see Pages 12–14 and 20–22 of the MIT Lincoln Laboratory Mini Science Kit guide
- For a more extensive identification guide to rocks and minerals, see: Shaffer & Zim, *Rocks, Gems and Minerals* (St. Martin's Press Golden Guide, 2001); Chris Pellant, *Smithsonian Handbooks: Rocks and Minerals* (DK, 2002); or Prinz, Harlow, & Peters, *Simon & Schuster's Guide to Rocks and Minerals* (1978)
- For a more extensive identification guide to fossils, see: Rhodes, Zim, & Shaffer, *Fossils* (St. Martin's Press Golden Guide, 2001) or Cyril Walker & David Ward, *Fossils* (DK, 2002)
- For a good guide to meteorites, see: Norton and Chitwood, *Field Guide to Meteors and Meteorites* (Springer, 2008)

Sample Resources:

- For a very good quantity, quality and variety of fossils at a relatively low price (50 fossils for $67, including K-T boundary layer material or a 1 lb bag of K-T boundary material for $20), see Two Guys Fossils 2
- For a very large selection of minerals and rocks (plus some fossils and other items) at competitive prices, go to Geosource
- For a very large selection of meteorites at competitive prices, go to The Meteorite Market
- For small but inexpensive tektites (terrestrial black glass formed by a meteorite impact), go to American Science & Surplus

Microscope Suggestions:

- For good-quality stereo dissection microscopes at a good price, go to Home Science Tools
- For inexpensive 2x/6x hand magnifiers, go to American Science & Surplus
- To find out what rocks, minerals and fossils you can collect in your area and where to find them, consult books in the Roadside Geology of... series, which are available for most states

Directions:

1. Set up several lab stations with microscopes and/or hand magnifiers.
2. Distribute the rocks, minerals, fossils, meteorites and/or meteorite impact materials. If you only have one or two of each type, you can ask the students to swap samples as they finish with each one.
3. Have the students identify and study each sample and write down their findings. You might provide them with access to identification sheets, books or websites (as previously mentioned).

   a. **For meteorites and impact materials**, ask students to notice the differences in density among iron meteorites, stony meteorites and tektites, and to study those plus K-T boundary material under the microscope.

   b. **For rocks and minerals**, ask students to identify rocks related to the article (limestone, basalt, granite, peridotite) and minerals related to the article (calcite, augite, feldspar, mica, quartz, olivine, hematite).

   c. **For fossils**, ask students to identify what creature it comes from, and to estimate the oldest and youngest possible ages based on the range of times during which such organisms lived. Which organisms went extinct during the K-T event?

Teacher's Guide for Build a Bird Activity

Class time: Approximately 60 minutes

Purpose: Students look at traits that connect species over time and theorize about the way adaptations affect survival.

Notes to the teacher: "The lucky ones" presents three ancient bird species, including *Vegavis iaai*, which may be an ancient relative of modern ducks. There is also a feathered dinosaur for comparison. Each species depicted had specific features that had advantages or disadvantages for survival.

There are many sources that discuss the relationship between dinosaurs and birds. For more background information beyond the infographic, see the related information on this University of California Museum of Paleontology page.

Materials:

- Blackline Master 4
- Online access or printed copies of the infographic "The lucky ones"
- Materials for illustrating hypothetical birds

Procedure:

1. Show students this short Melbourne Museum video on the link between dinosaurs and birds. Discuss why scientists think dinosaurs and modern birds are closely related. Discuss similarities and differences between dinosaurs and modern birds.
2. Ask students to read "The lucky ones." Discuss the science of phylogeny and how it helps us classify and relate organisms based on shared characteristics.
3. Tell students that they will be looking at the examples of ancient birds and one dinosaur and hypothesizing about which traits could have been most beneficial to survival.
4. Give students Blackline Master 4. Tell them to work through the following parts:
   a. Catalog the features discussed in the infographic and describe ways the feature could have enhanced and would not have enhanced survival (see chart for possible student responses).
   b. Design a bird that you think would have the best chance of survival in a particular ecosystem. Your design should incorporate a combination of the cataloged features.
   c. Answer the discussion questions about birds and dinosaurs.

Part A: Use the chart below to catalog the features of the ancient birds described in the infographic.

Feature	Example ancient bird that possessed the feature	Hypothesize: Why might this enhance survival?	Hypothesize: Why might this harm survival?
Small size	*Protopteryx fengningensis*	Allow the bird to hide and nest in small spaces, decrease its need for nutrition	Can't catch bigger prey, heat loss in the cold
Flight capable wings	*Protopteryx fengningensis* *Vegavis iaai*	Allow the bird to migrate, find food, escape danger	Flight can limit weight
Teeth	*Protopteryx fengningensis*	Greater range of diet, defense	Might sap nutrients that could be used for forming other body parts
Short tail	*Vegavis iaai*	Harder for predators to catch, helps wading capability	Changes center of gravity when walking
Long tail	*Confuciusornis sanctus* *Protopteryx fengningensis*	Enhances	Would hurt wading capability
Wings with claws	*Confuciusornis sanctus*	Help with grip	Might affect flying capability
Syrinx	*Vegavis iaai*	Greater range of communication with members of species	

Part B: Design your bird

Describe your bird. Consider the following when writing your description:

1. The ecosystem that your bird will be adapted for.

2. The features your bird will have and how they will enhance its survival.

Draw your bird

Part C: Answer these questions:

1. **Biologists generally accept birds as a kind of dinosaur. What are examples of features of modern birds that are similar to features that we believe at least some dinosaurs possessed?** Possible student response: Bipedal stance, wishbones, feathers, hinged ankles and wings are features shared by birds and some dinosaurs.
2. ***Vegavis iaai* is the only example given in the infographic with a short tail and is also the example most closely related to a modern bird. Can you think of a possible way that a short tail might enhance survival?** Possible student response: A short tail would have been more beneficial to wading birds, since the feathers on the tail would not have gotten weighed down in water the way a long tail might have. In wetter ecosystems, this would have made movement easier.
3. **How do the diagram and the features that emerged with each species mentioned in the infographic help you hypothesize about what might have been happening to the landscape of the planet?** Possible student response: Adaptations that improve survival under given conditions would be passed on to the next generation. Features that didn't enhance survival might slowly be weeded out. The traits that help an organism survive would depend on the climate and conditions in which it lived and reproduced.

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Dino Doomsday

Student Worksheet for Build a Bird

Directions: “The lucky ones” presents three ancient bird species, including *Vegavis iaai*, which may be an ancient relative of modern ducks. There is also a feathered dinosaur for comparison. Each species depicted had specific features that had advantages or disadvantages for survival.

Part A: Catalog the features and describe ways the features might enhance or not enhance survival.

Part B: Design a bird that would have the best chance of survival in a selected ecosystem. Your design will incorporate a combination of the cataloged features.

Part C: Answer the discussion questions about birds and dinosaurs.

Part A: Use the information from “The lucky ones” to fill in the following chart

Feature	Example ancient bird that possessed the feature	Hypothesize: Why might this enhance survival?	Hypothesize: Why might this harm survival?

Part B: Design your bird

Describe your bird. Consider the following when writing your description:

1. The ecosystem that your bird will be best adapted for.

2. The features your bird will have and how they will enhance its survival.

Draw your bird

Part C: Answer these questions before discussing your answers with your class.

3. Biologists generally accept birds as a kind of dinosaur. What are examples of features of modern birds that are similar to features that we believe at least some dinosaurs possessed?

4. The *Vegavis iaai* is the only example given in the infographic with a short tail and is also the example most closely related to a modern bird. Can you think of a possible way that a short tail might enhance survival?

5. How do the diagram and the features that emerged with each species mentioned in the infographic help you hypothesize about what might have been happening to the landscape of the planet?