A CLOSER LOOK AT DINOSAURS

Gull eggs buried by Mount St. Helens' eruption.

Sunday, May 18, 1980, began pleasantly enough on the small island in eastern Washington state where I was studying a nesting colony of ring-billed gulls.[1] Before long, however, a bank of dark clouds closed in from the southwest, and by noon, covered the island. Fearing a serious storm, I returned to the safety of the mainland. There I discovered that a "sonic boom" I'd heard that morning was in reality the eruption of Mount St. Helens, and that the dark cloud above was composed of volcanic ash.

The next day, I returned to the island to examine the impact of the ashfall on the gulls. To my surprise, they were alive and well, standing like little sentinels on their territories. Most of their nests, however, were completely buried by a blanket of volcanic ash. The only unburied eggs were those that had been excavated by their parents.[2]

During the late 1970s, I recalled, a trove of fossil dinosaur eggs and babies had been discovered several hundred miles away, near Choteau, Montana. The sediments there contained ancient volcanic ash layers.[3] I wondered what I could learn about dinosaur egg fossilization from my ashfall experience. So one year later, I returned to my study island. Within minutes, I uncovered three gull nests with eggs. The eggs had dried out, but the eggshells were still intact.[4]

The discovery of those ash-buried eggs has kept my students, colleagues, and me busy for more than two decades. Our central question has been, *What can dinosaur eggs and eggshell fragments tell us about how and where dinosaurs lived?*[5]

What can dinosaur eggs and eggshell fragments tell us about how and where these animals lived?

To answer that question, we've spent lots of time examining fossil eggs in museum collections, talking with other scientists, exploring dinosaur egg sites, and participating in excavations. We've also learned a great deal about these fossils from reading the scientific literature and from the many experiments we've carried out with eggs. I'd like to pass along some of what we've learned about dinosaur eggs and related topics in hopes that it will inspire you and your students to dig deeper into this topic on your own.

Earlier articles in Adventist publications have dealt with questions concerning the origin and demise of dinosaurs, and how these animals fit into the history of life on Earth.[6] These are intriguing questions that merit further exploration. As a biologist, how-

BY JAMES L. HAYWARD

California gulls (avian dinosaurs!) on May 19, 1980, one day after Mount St. Helens' ashfall. The colony surface looks like a moonscape. Note the dirty feathers around the eye of the gull in the foreground. Many of these birds developed temporary conjunctivitis due to irritation from the ash.

ever, my purpose in this article is to consider how dinosaurs *lived* and *behaved*, especially in relation to reproduction. My reason for this is that in our rush to try to answer these other questions, we have overlooked some fascinating information about the day-to-day lives of some very interesting animals!

When Were Dinosaur Eggs First Discovered?

Archaeologists tell us that, long before the time of Christ, people who lived in the region of present-day Mongolia wore jewelry made from dinosaur eggshells. It's unlikely, however, that these people knew anything about the source of their

The author inspects the site of a ring-billed gull nest on an eastern Washington breeding colony on May 19, 1980, one day after the Mount St. Helens' eruption. The nest, which contains three eggs, is completely covered by volcanic ash.

Archaeologists tell us that, long before the time of Christ, people who lived in the region of present-day Mongolia wore jewelry made from dinosaur eggshells.

baubles. It's impossible to know whether they found any bones of adult or baby dinosaurs in the same area.[7]

The first dinosaur fossils known to science were described in the 1820s, but it wasn't until 1859 that Jean-Jacques Pouech, a French priest and amateur geologist, discovered the first dinosaur eggshell. Pouech guessed from the curvature of the fragments that the original eggs were about 18 centimeters (seven inches) in diameter. He mistakenly believed the fragments were from a giant prehistoric bird. It took another 10 years for the true identity of these fossils to become known.[8]

The most famous early dinosaur eggshell discovery occurred in 1923. In that year, Roy Chapman Andrews from New York's American Museum led an expedition to Mongolia looking for traces of the first humans. He never achieved his objective, but his team did collect some nicely preserved dinosaur eggs from the Flaming Cliffs in Mongolia. Andrews was a consummate publicist, so word of this discovery—incorrectly billed as the first of its kind—quickly spread throughout the world.[9]

One might wonder how paleontologists can tell the difference between dinosaur eggshells and the eggshells of other animals. Well, sometimes they can't! In most cases, however, microscopic features of the eggshell and close proximity of the eggshell to dinosaur bones provide a link. The best way to be certain, however, is to find the bones of baby

dinosaurs inside whole eggs!

In How Many Places Have Dinosaur Eggs Been Found?

A recent publication lists 237 localities where fossilized dinosaur eggs, eggshell fragments, or babies have been found. Such sites occur on every continent except Antarctica, and paleontologists think that eventually they will be found there as well.[10]

At some localities, dinosaur eggshell is the most abundant type of fossil. In *Walking on Eggs*, Louis Chiappe and Lowell Dingus describe their 1997 discovery of a huge dinosaur egg site in Patagonia: "Eggs were everywhere. . . . In many places the fragments of eggs were so abundant that we couldn't walk without stepping on pieces of fossil eggshell." Some of these eggs contained the bones and even fossilized skin of baby sauropods, which as adults, grew very large![11]

Sign in Warner, Alberta, which directs visitors to the Devil's Coulee egg site where many fossilized dinosaur eggs and babies have been found.

The author maps the locations and orientations of dinosaur eggshell fragments at a site just east of the Front Range of the Rocky Mountains, visible in the background. Numerous fossilized dinosaur eggs, eggshell fragments, and babies have been found in this region.

The Patagonian site is hardly unique. A large and virtually unstudied deposit of dinosaur eggshell is located on the Blackfoot Indian Reservation in northern Montana. Thousands more dinosaur eggs, many with embryos, have been found in the Laiyang Province in northeastern China; hundreds of these eggs were sold overseas before the Chinese government halted the practice. Thousands more eggs have been found in the Deccan Traps volcanic region of north-central India. In Tremp Basin, Spain, an estimated 300,000 eggs are preserved in what appear to be nests of up to seven eggs each. The richest eggshell site found to date, however, is located in Kyrgyzstan, where sediments containing fragments from millions of eggs extend for nine miles![12]

How Many Kinds of Dinosaur Eggs Are There?

Hundreds of species of dinosaurs have been described. Clearly, these creatures represent a very large and diverse group of animals. Assuming that all dinosaurs laid eggs, the diversity of dinosaur eggs should equal the diversity of dinosaur bones. But bones are much more likely to fossilize than eggs, so scientists have not found as many kinds of dinosaur eggs as bones.

The first dinosaur fossils known to science were described in the 1820s, but it wasn't until 1859 that Jean-Jacques Pouech, a French priest and amateur geologist, discovered the first dinosaur eggshell.

Despite this limitation, more than 70 types of dinosaur eggshell have been described. A handful of paleontologists around the world have built their scientific careers around classifying them. Eggshell classification is based, not just on macroscopic characteristics like egg size, shape, and texture, but also on distinctive microscopic features.[13]

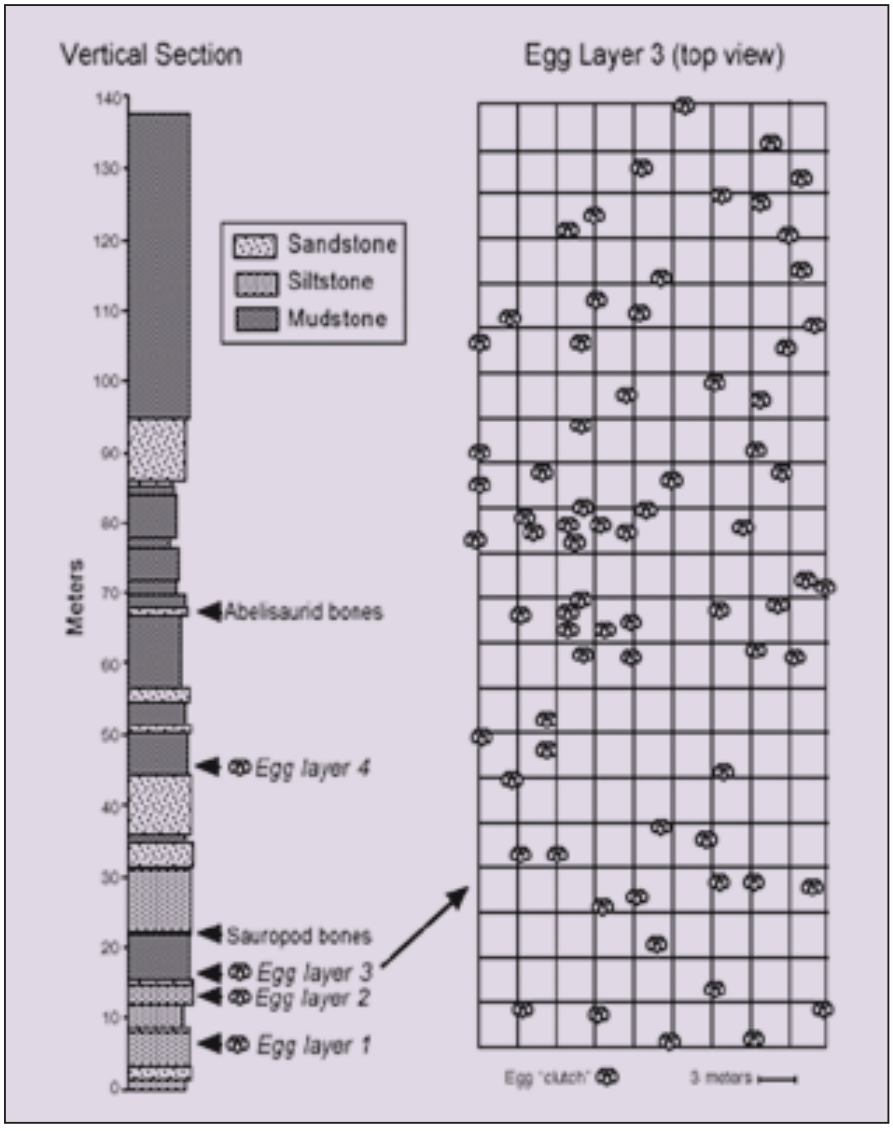
Did Some Dinosaurs Nest in Colonies?

This question is intriguing, because if dinosaurs nested in colonies, they must have maintained fairly complex social systems. All social sys-

Three large dinosaur eggs from China, on display at a Dinofest Conference at Indiana University.

tems exhibit intricate patterns of communication and behavior. If some dinosaurs did nest in colonies, they could not have been the stupid, lumbering creatures they once were depicted as!

So what evidence do we have? The most obvious clue concerns the large concentrations of eggs and eggshell already described. Barring colonial nesting, it's difficult to imagine how all these concentrations of eggs and fragments could have come into existence. Also, within these areas, dinosaur eggs often are clumped together, much like eggs within nests of modern birds. In some clumps, the eggs are merely bunched together, whereas in others, they form circles. Sometimes the eggs lie horizontally, while in others, they stand upright. Not all clumps represent nests, but some probably do. Randomly spaced eggs and some clumps may have resulted from movement and jostling during the sedimentation process.[14]



Diagrams showing the distribution of sauropod eggs and bones at a Patagonian site discovered by Luis Chiappe and his team during the late 1990s. The diagram on the left shows the vertical distribution of rock strata containing the eggs and bones. Four egg layers are indicated in the lower part of the diagram. The diagram on the right shows the horizontal distribution of egg "clutches," many of which seem to represent actual nest sites. The clutches are too close together, however, to represent a nesting colony that featured parental care. In this case, it is more likely that the mothers laid their eggs in the sediment, then left them to hatch on their own. (Redrawn from Chiappe et al., "Sauropod Eggs and Embryos From the Late Cretaceous of Patagonia," Extended Abstracts, First International Symposium on Dinosaur Eggs and Babies [2000], pp. 23-29.)

Further evidence of colonial nesting can be found in the multiple levels of eggs and eggshell fragments found in vertical sequences of rock layers. These areas seem to have been used repeatedly, with nesting events interrupted by catastrophes such as massive dust storms, floods, sand avalanches, and volcanic ashfalls. Interestingly, this is exactly what happened at the gull colony in Washington. The year after Mount St. Helens' ashfall, the gulls returned, building their nests on top of the ash layer containing the previous year's nests. Every year, new sediment accumulates, so today's nesting level is somewhat higher than in 1980, when the volcano erupted. Many modern colonial nesters use the same breeding sites for hundreds of years. This type of behavior may account for the large concentrations of eggshell fragments found at some fossil sites.[15]

How Much Alike Were Dinosaurs and Modern Birds?

A large and famous group of dinosaurs called theropods included animals such as *Oviraptor*, *Velociraptor*, *Albertosaurus*, and *Tyrannosaurus*. Theropods shared a number of common features, including hollow limb bones, a moon-shaped wrist bone (semilunate carpal) that allowed wrist flexure, a wishbone (furcula), a strap-like fibula attached to the tibia (shin bone), brittle eggshells, and bipedal ground locomotion.[16]

Interestingly, modern birds exhibit these same characteristics. In fact, the similarities are so striking that fossil birds have sometimes been mistaken as theropod dinosaurs, and vice versa. Although the similarities were recognized as early as the 1860s, for a long time, scientists rejected the notion that birds and theropods belonged to the same group of animals. After all, as everyone knows, only birds have feathers . . . or so we thought.[16]

Several amazing discoveries in northeastern China during the late 1990s falsified this conclusion: Small theropods with names like *Sinosaur-*

opteryx, *Protarchaeopteryx*, and *Caudipteryx* were found with well-preserved feathers! I've seen these fossils for myself, and they are truly remarkable. The feathers stand out clearly and look just like those of birds. Yet the associated bones are not those of birds. Because of these finds, most biologists agree that modern birds and extinct theropod dinosaurs should be classified within the same group. In fact, paleontologists now refer to modern birds as "avian dinosaurs" and to their non-bird look-alikes as "non-avian dinosaurs."[17]

Keep in mind that classification systems are to some degree artificial and constantly undergo change. But this particular grouping seems here to stay. The implications are significant. Instead of dividing vertebrates into the traditional fish, amphibian, reptile, bird, and mammal categories, the new system contains only fish, amphibians, reptiles, and mammals, with birds classified as reptiles. It also suggests that dinosaurs never went extinct, but that members of this group continue to forage on our backyard feeders! Finally, it strengthens the assertion that observing modern-day birds can help us understand the lives of extinct dinosaurs.[18]

A recent publication lists 237 localities where fossilized dinosaur eggs, eggshell fragments, or babies have been found.

What possible function would feathers serve in these animals, most of which probably couldn't fly? We can't answer this question for certain, but it's intriguing to hypothesize that at least some theropods, even non-avian ones, were at least somewhat "warm-blooded" and needed a way to retain body heat. As any cold-weather backpacker can attest, nothing keeps you warm better than feathers.[19]

Feathers have been found only on small dinosaurs. This makes sense in view of the warm-blooded hypothesis. Large-bodied dinosaurs would be able to retain heat much easier than small dinosaurs. In fact, large dinosaurs may have faced the opposite problem—overheating. Small dinosaurs, including the babies of large dinosaurs, could stay warm if they were covered with feathers. Recently, in northeastern China, a duck-sized theropod was discovered curled up in the same sleeping posture used by birds. This fossil was named *Mei long*, which in Chinese means "soundly sleeping dragon." Apparently, this animal had been buried alive by a volcanic ashfall, like the residents of Pompeii. Modern birds use this type of posture to retain body heat. No feathers were preserved with this little dinosaur, but paleontologists wouldn't be surprised to find other specimens of the same species sporting a coat of warm feathers.[20]

In 1981, one year after the Mount St. Helens' ashfall, an ash-buried ring-billed gull nest is uncovered, and then removed from the ash layer.

Did Dinosaurs Care for Their Young?

Have you ever watched a bird incubate its eggs, feed its young, or protect its nest? Except for cowbirds, cuckoos, and a few other anomalies, birds provide some of the best care for their young in the animal world. Given their many similarities to modern birds, is it possible that at least some non-avian dinosaurs also cared for their young? Intriguing evidence suggests that the answer is Yes.

In 1923, the team led by Roy Chapman Andrews discovered an *Oviraptor* (a theropod whose name means "egg robber") skeleton over a group of eggs thought to have been laid by a small vegetarian dinosaur called *Protoceratops*. The assumption that the eggs were those of *Protoceratops* was logical—lots of *Protoceratops* bones had been found in the same sediments. It looked to Chapman as if the *Oviraptor* had been caught preying on the *Protoceratops* eggs.[21]

In the early 1990s, however, a team of scientists from the American Museum of Natural History found one of these same types of eggs with an excellently preserved skeleton of an embryonic dinosaur inside. But the skeleton was clearly that of an *Oviraptor*, not of *Protoceratops*! It now appeared more likely that the *Oviraptor* found by Chapman's group was a parent to, not a predator of,

the eggs. At least two additional examples have now been found of *Oviraptor* skeletons over sets of eggs. In one case, it was poised in what appeared to be a brooding posture similar to that used by birds. It seems very possible that *Oviraptor* engaged in parental care for its eggs.[22]

The most dramatic evidence for parental care by dinosaurs was reported in late 2004. In the Liaoning province of China, paleontologists uncovered the skeleton of a small vegetarian dinosaur, *Psittacosaurus*, over a tight cluster of 34 juvenile members of the same species. The juveniles, all the same age, had well-formed bones, indicating post-hatch-

In 1987, seven years after the ashfall that buried an eastern Washington gull colony, the 1980 ash layer that contained buried nests and eggs appears as a light band 2-3 centimeters deep. Approximately 4 centimeters of material have been deposited on top of the ash layer since the ashfall. The gulls now nest on top of the new material.

ing growth and development. They were situated in a basin-like structure (nest?), with the animals around the perimeter situated a little higher than those at the center. Both the juveniles and adult were preserved in an upright posture, indicating very quick burial. This remarkable find strongly suggests parental care of juveniles in this species.[23]

Hundreds of species of dinosaurs have been described. . . . But bones are much more likely to fossilize than eggs, so scientists have not found as many kinds of dinosaur eggs as bones.

Conclusion

The term *dinosaur*, coined by Richard Owen in 1842, means "terrible lizard." Indeed, dinosaurs continue to appear "terrible" to many people, perhaps in part because of how artists depict them. Some Christians still deny that dinosaurs existed because these creatures don't seem to fit neatly into one of the categories described in Genesis 1 or into God's assessment of everything He made as being "very good."[24] As is so often the case, people tend to fear what they don't understand.

My encounter with Mount St. Helens opened for me a window to a past filled with one surprise after another. More than two decades later, I continue to be amazed by each new discovery. Imagining and reconstructing the past is an intriguing way to exercise the mind. Indeed, this is what makes the historical sciences such as archaeology and paleontology so exciting and appealing.

There is still much we don't understand about dinosaurs. But we know enough to realize that these creatures were truly remarkable. In this respect, they were no different than any other animal group, such as mollusks, insects, fish, and mammals, all of which we accept as members of God's great creation.

As teachers, we can use recent findings about dinosaurs to spark enthusiasm for science among our students. We can persuade students to examine evidence about dinosaurs for themselves, and, in so doing, encourage them to learn how to separate evidence from interpretation. Finally, as the accompanying sidebar suggests, we can help students carry out simple but informative experiments from which they can learn firsthand about factors leading to fossilization.

Dinosaurs provide teachers with one of the most intriguing topics available to inspire students to explore the amazing pageant of life on Earth and to celebrate the diversity of creation!

James L. Hayward, Ph.D., *is a Professor of Biology at Andrews University in Berrien Springs, Michigan. In addition to dinosaur egg research, he co-directs the Seabird Ecology Team (SET), a National Science Foundation-funded group of biologists and mathematicians from Andrews University, Walla Walla College, and the University of Arizona, which is developing ways to predict habitat occupancies and behaviors among marine animals. In 2002, he served as Coordinator of a special issue of the* JOURNAL *on Science. Dr. Hayward can be reached by e-mail at hayward@andrews.edu.*

NOTES AND REFERENCES

1. James L. Hayward, "Nest-Site Selection and Reproductive Success of Ring-Billed Gulls at Sprague Lake, Washington," *Northwestern Naturalist* 74 (1993), pp. 67-76.

2. James L. Hayward, "Mount St. Helens Ash: Its Impact on Breeding Ring-Billed and California Gulls," *The Auk* 99 (1982), pp. 623-631; _____, "Breath of Vulcan," *The Living Bird Quarterly* 4:1 (1985), pp. 4-8.

3. John R. Horner and James Gorman, *Digging Dinosaurs: The Search That Unraveled the Mystery of Baby Dinosaurs* (New York: Workman, 1988).

4. James L. Hayward, Charles J. Amlaner, and Karen A. Young, "Turning Eggs to Fossils: A Natural Experiment in Taphonomy," *Journal of Vertebrate Paleontology* 9 (1989), pp. 196-200.

5. James L. Hayward, Karl F. Hirsch, and Theodore C. Robertson, "Rapid Dissolution of

USING EGGS TO TEST HYPOTHESES ABOUT THE PAST

Eggshells of dinosaurs and modern birds share virtually identical characteristics. Unlike most reptile eggs, which have leathery shells, dinosaur and bird eggshells are brittle. Also, the microscopic structures of bird and theropod dinosaur eggshells closely resemble one another. These and other similarities allow us to test hypotheses about ancient dinosaur eggs by doing experiments on the eggs of modern birds, such as chickens and ostriches.

Experiments with chicken eggs are simple to do, cost very little, and can be designed for any grade level. Begin by encouraging each student to imagine a particular set of environmental conditions to which dinosaur eggs might be exposed. Then help the students (1) pose a simple hypothesis about the effect of those conditions on the eggs, (2) design an experiment to test this hypothesis, (3) perform the experiment, (4) examine the results, and (5) report on what they found.

I've listed three suggested hypotheses below, along with brief instructions for testing each hypothesis. Teachers can adapt the complexity of the assignment to the abilities of their classes. Elementary students can be asked to verbally describe or graph their results, whereas university students should compare results using formal statistical tests. Remember that it's always best to do a trial run before attempting the actual experiment.

Hypothesis I: Eggshell fracture patterns differ, depending on egg contents. Dinosaur eggshells often fracture following compression by overlying sediment. Fracture patterns provide information about the condition of the eggs when they were crushed.

Experiment: (1) Carefully poke small holes in both ends of a fresh egg; then cover the holes with small pieces of duct tape or other heavy tape. (2) Poke similar holes in a second egg. Use a pipette or straw to blow out the contents; then cover the holes with tape. (3) Hard-boil a third egg, then carefully poke a small hole in each end and cover the holes with tape. (Though the second and third eggs do not need to be taped to prevent their contents from leaking, all of the eggs are prepared in the same way to ensure that comparisons between them are valid.)

From top to bottom, cut down through the four corners of a topless cardboard box so that each of the sides lies flat with the bottom. After making the cuts, return the sides to their original positions to again form a box. Keep the sides in place using large rubber bands that stretch around the entire box. Fill the box with sand. Bury each of the eggs beneath the sand, and place a piece of plywood on top of the sand. Carefully stand on the plywood to partially crush the eggs. The flexible sides of the box should push outward as the sand is compressed. Carefully uncover the eggs.

Results and analysis: Compare the fracture patterns of the three eggs.

Hypothesis II: Eggshell fragment orientations depend on events that occur before burial. Eggshell fragment orientation (proportions of fragments whose concave surface faces up or down) depends on if and how the fragments were transported before burial. To prepare for Experiments A and B below, break and empty the contents of several dozen brown eggs. (You can cook the contents for lunch!) Let the empty eggshells dry overnight. Crush the dry eggshells into fragments that measure roughly 0.5 to 1.0 centimeter in diameter.

Experiment A: Make a wind chute by placing a layer of sand on a flat surface between two parallel boards at least 2.5 meters (about 8 feet) long. Set a window fan (or better yet, a "squirrel-cage" fan) at one end of the chute. Drop a handful of eggshell fragments on the sand close to the fan. Turn on the fan to blow the fragments to the other end of the chute. Shut off the fan. Determine the relative percentages of fragments that are concave (white surface up) and convex (brown surface up).

Experiment B: Place a handful of eggshell fragments in a creek. After several hours, return to the creek and determine the relative percentages of fragments facing up (concave) and down (convex) that have been transported downstream.

Experiment C: Hatch your own chicks or schedule a field trip to a poultry farm. After a batch of chicks hatches, determine the relative percentages of eggshell fragments whose concave surfaces face up and down.

Results and analysis: Compare the relative percentages from each experiment. (Note: Results from our hatching experiments, as well as examination of eggshells at a gull colony and two dinosaur eggshell sites, show virtually the same outcome: 60 percent concave [facing up] versus 40 percent convex [facing down]. If you cannot perform Experiment C, you can compare the results of Experiments A and B with our 60:40 pattern).

Hypothesis III: Eggshell fossilization will occur more readily in alkaline sediments than in acidic sediments. Dinosaur and bird eggshells consist of calcium carbonate crystals deposited within a protein

matrix. Because calcium carbonate is dissolved by acids, acidic sediments lessen the likelihood of eggshells becoming fossilized. Students can demonstrate this for themselves by performing the following experiment.

Experiment: Prepare three solutions, and pour each into a different 1-liter container:

- Container 1: a mixture of water and vinegar (or another acid) to create a pH of 5.0-6.0 (use pH paper to check).
- Container 2: a mixture of household bleach (sodium hypchorite) and water to create a pH of 8.0-9.0.
- Container 3: only pure water (pH=7.0).

Fill three small flowerpots with soil, and bury eggshell fragments (approximately 1 centimeter diameter) 1 centimeter beneath the top of the soil in each pot. Each day for two weeks, water the first pot with the acidic solution, the second pot with the alkaline solution, and the third pot with pure water. At the end of a two-week period, remove the eggshell fragments from each pot, rinse off the soil particles, and let the fragments dry.

Results and analysis: Use a magnifying glass or dissecting microscope to compare the experimental fragments with the untreated fragments. Describe any changes that have occurred in the experimental fragments.

To explore a dinosaur dig in which Adventists are involved, go to "Dinosaur Project" at http://dinodig.swau.edu/.

—Eds.

Avian Eggshells Buried by Mount St. Helens Ash," *Palaios* 6 (1991), pp. 174-178; James L. Hayward et al., "Experiments on the Taphonomy of Amniote Eggs in Marine Environments," *Palaios* 12 (1997), pp. 482-488; James L. Hayward et al., "Eggshell Taphonomy at Modern Gull Colonies and a Dinosaur Clutch Site," *Palaios* 15 (2000), pp. 343-355; Jere K. Clayburn, Denise L. Smith, and James L. Hayward, "Taphonomic Effects of pH and Temperature on Extant Avian Dinosaur Eggshell," *Palaios* 19 (2004), pp. 170-177.

6. Harold G. Coffin, *Creation—Accident or Design?* (Washington, D.C.: Review and Herald Publ. Assn., 1983), pp. 184-192; James L. Hayward, "Dinosaurs," *Adventist Review* 170:32 (August 12, 1993), pp. 12-14; _____, "Noah's Ark or 'Jurassic Park'?" *Spectrum* 23:2 (1993), pp. 6-14; M. Elaine Kennedy, "The Intriguing Dinosaur," *Dialogue* 5:2 (1993), pp. 9-11, 34.

7. Kenneth Carpenter, *Eggs, Nests, and Baby Dinosaurs: A Look at Dinosaur Reproduction* (Bloomington: Indiana University Press, 1999), p. 4.

8. Eric Buffetaut and Jean le Loeuff, "The Discovery of Dinosaur Eggshells in 19th-Century France." In Kenneth Carpenter, Karl F. Hirsch, and John R. Horner, eds., *Dinosaur Eggs and Babies* (Cambridge, U.K.: Cambridge University Press, 1994), pp. 31-34.

9. Carpenter, *Eggs, Nests, and Baby Dinosaurs*, pp. 1-5.

10. Ibid., pp. 8-30, 259-270.

11. Luis M. Chiappe and Lowell Dingus, *Walking on Eggs: The Astonishing Discovery of Thousands of Dinosaur Eggs in the Badlands of Patagonia* (New York: Scribner, 2001), pp. 23, 50, 89-103.

12. Kenneth Carpenter and Karen Alf, "Global Distribution of Dinosaur Eggs, Nests, and Babies." In Carpenter, Hirsch, and Horner, *Dinosaur Eggs and Babies*, pp. 15-30.

13. Konstantin E. Mikhailov, Emily S. Bray, and Karl F. Hirsch, "Parataxonomy of Fossil Egg Remains (*Veterovata*): Principles and Applications," *Journal of Vertebrate Paleontology* 16 (1996), pp. 763-769; Carpenter, et al., *Eggs, Nests, and Baby Dinosaurs*, pp. 271-301; Chiappe and Dingus, *Walking on Eggs*, pp. 79-87.

14. Konstantin Mikhailov, Karol Sabath, and Sergey Kurzanov, "Eggs and Nests From the Cretaceous of Mongolia." In Carpenter, Hirsch, and Horner, *Dinosaur Eggs and Babies*, pp. 88-115. J. J. Moratalla and J. E. Powell, "Dinosaur Nesting Patterns." In ibid., pp. 37-46; Carpenter, *Eggs, Nests, and Baby Dinosaurs*, pp. 152-178; Luis Chiappe et al., "Sauropod Eggs and Embryos From the Late Cretaceous of Patagonia," Extended Abstracts, First International Symposium on Dinosaur Eggs and Babies (2000), pp. 23-29; Chiappe and Dingus, *Walking on Eggs*, pp. 151-175.

15. Rémi Cousin et al., "Dinosaur Egglaying and Nesting in France." In Carpenter, Hirsch, and Horner, *Dinosaur Eggs and Babies*, pp. 56-74; Chiappe et al. "Sauropod Eggs and Embryos From the Late Cretaceous of Patagonia"; Chiappe and Dingus, *Walking on Eggs*, pp. 161-175; Hayward, Amlaner, and Young, "Turning Eggs to Fossils: A Natural Experiment in Taphonomy."

16. Kevin Padian and Luis M. Chiappe, "Bird Origins." In Philip J. Currie and Kevin Padian, eds., *Encyclopedia of Dinosaurs* (San Diego, Calif.: Academic Press, 1997), pp. 71-79; Philip J. Currie, "Theropoda." In Currie and Padian, *Encyclopedia of Dinosaurs*, pp. 731-737.

17. Kevin Padian, "When Is a Bird Not a Bird?" *Nature* 393 (1998), pp. 729-730; J. Qiang et al., "Two Feathered Dinosaurs From Northeastern China," *Nature* 393 (1998), pp. 753-761; Hayward et al., "Eggshell Taphonomy at Modern Gull Colonies and a Dinosaur Clutch Site."

18. Kevin Padian, "Dinosauria: Definition." In Currie and Padian, *Encyclopedia of Dinosaurs*, pp. 175-179. It should be emphasized that the classification of birds in relation to theropod dinosaurs and other reptiles is still in flux. However, theropods, which now include modern birds, are still classified as reptiles.

19. Kevin Padian, "Physiology." In Currie and Padian, *Encyclopedia of Dinosaurs*, pp. 552-557.

20. Xing Xu and Mark A. Norell, "A New Troodontid Dinosaur From China With Avian-Like Sleeping Posture," *Nature* 431 (2004), pp. 838-841.

21. Mark A. Norell et al., "A Theropod Dinosaur Embryo and the Affinities of the Flaming Cliffs Dinosaur Eggs," *Science* 266 (1995), pp. 779-782.

22. Mark A. Norell et al., "A Nesting Dinosaur," *Nature* 378 (1995), pp. 774-776; Z. Dong and P. J. Currie, "On the Discovery of an Oviraptorid Skeleton on a Nest of Eggs at Bayan Mandahu, Inner Mongolia, People's Republic of China," *Canadian Journal of Earth Sciences* 4 (1996), pp. 631-636.

23. Qingjin Meng et al., "Parental Care in an Ornithischian Dinosaur," *Nature* 431 (2004), pp. 145-146.

24. Spencer G. Lucas, *Dinosaurs: The Textbook* (Dubuque, Iowa: William C. Brown, 1994), p. 1; Hayward, "Noah's Ark or 'Jurassic Park'?"