Background information for teaching about 3 million year old shell fossils[1]

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You do not need any special knowledge of fossils or the geologic past to use these activities. These activities simply take advantage of the interest students often have in shells and in fossils to teach science topics in your existing curriculum. The descriptions that follow may help you know a little more about fossils and shells, for running the activity or answering student questions.

What is a fossil?

Fossils are preserved evidence of past life. The most typical fossils are the remains of mineralized hard parts of organisms (e.g., bones or shells), imprints of those remains, or traces of activities of organisms (such as footprints). The most common fossils are shells preserved in sediment (such as sand and mud) in aquatic settings (which is where sand and mud normally accumulate). This is because to become preserved, objects must be resistant to decay and local environmental forces, and even such hard parts must ultimately be protected from too much weathering and other destructive forces.

Objects made by people such as arrowheads are not considered fossils. Contrary to common perception, remains of organisms do not *need* to have been altered chemically (though many have been) to be considered fossils. Conventionally many definitions say that an object must be 10,000 years old to be a fossil, but that particular number is chosen just for convenience and is arbitrary (much younger specimens are often studied in the same manner as older fossils).

You can learn more about how fossils are formed and preserved on the "Nature of the Fossil Record" chapter of the Digital Encyclopedia of Ancient Life: http://www.digitalatlasofancientlife.org/learn/nature-fossil-record/.

What is a formation?

A formation is a layer of rock or sediments that formed in a particular time and area and has certain characteristics (such as mineral content and grain size, color, and fossils). Geologists have long used such names for practical purposes, since they needed to describe and communicate about layers that could be mined for sand, fossil fuels, or other resources. We also use characteristics of formations to study ancient environments and how the environment changed in successive formations.

To imagine a formation physically, consider if sand was weathered from a local mountain range and then deposited in the sea at about 50 m depth, forming a layer about 30 m thick over an area of some thousands of square kilometers (which might take a few tens of thousands of years to be deposited). That layer would look rather similar throughout that

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[1] This information was developed to accompany the activity sets "Species Diversity and Classification" and "Species Across Time and Terrain," though may be generally applicable to other activities that use fossils.

area, and, if it became exposed at the surface (if sea level declined or the land rose), we might be able to show on a map all the places where it is weathering out at the surface. Formations typically have distinctive and consistent sets of fossils within them – such data are used in this activity.

There are, by the way, larger and smaller units of rocks and sediments. Sequences of formations consistent over an area are called a "group." Formations are often subdivided into "members" that are physically homogenous. "Beds" are thinner, distinctive layers within a formation.

What is a species?
The data for these sets of activities are mostly species of bivalves and gastropods (the singular and plural are both "species"). Species are generally described among zoologists as groups of organisms that can interbreed and have fertile offspring. Most people have a sense of what species are and colloquially might call them "kinds" of animals. Most familiar animals are, however, actually two or more related species. For example, elephants are three species: Asian elephants and two species of African elephant – the familiar savannah elephant and the African forest elephant. Chimps are two species: the "common" chimpanzee and bonobo. Groups of closely related species have traditionally been grouped into "genera" (singular: genus), families, and larger groups.

It may have occurred to you that if members of a species are defined by the ability to mate with each other, then how can we distinguish among fossil species, or even among extant (still living) species if we don't observe them mating? Generally, members of the same living species--supported by genetic data--have very similar forms, though there is always some natural variation. Thus, we can use shell shape as an approximation for determining what is a species in the fossil record.

Your students may be only vaguely familiar with the idea that shells are made by animals, and that different shell shapes are generally made by different species. Thus, if your students sort shells from a beach, they are, at least in part, sorting them into different species. Some species may look similar to each other (they might be from the same genus or family), and it may be difficult to tell if shells are from different, related species or from one species that has some variation. One kind of within-species variation is growth, but clams and snails of the same species can also vary slightly in color or other features. This is one reason it can be helpful to look at numerous specimens to try to distinguish variation *among* species from variation *within* species.

You can learn more about the practice of taxonomy in the "Systematics" chapter of the Digitial Encyclopedia of Ancient Life:
http://www.digitalatlasofancientlife.org/learn/systematics/.

What does (bio)diversity mean when we discuss organisms?
Biodiversity is, most simply, the number of kinds of living things – that is, the number of species. Although many factors influence biodiversity, we often find that it is a good summary measure of the state of an environment. On average, environments that are

"stressful" in some way on organisms tend to have lower diversity. The highest diversity environments are generally found in the tropics – on land we find the highest diversity in rain forests, and in the ocean the highest diversity is on and near coral reefs. In both cases, higher diversity is associated with higher temperatures.

What's the difference between a fossil shell and a shell on the beach?
In the case of marine shells that are "only" a few million years old (as opposed to a few hundred million years old), there actually is not much difference between fossil and modern shells except for color. Shells are made of calcium carbonate ($CaCO_3$), and in many fossils shells it has not changed since the animals made them. On the other hand, shell color--which is made through organic molecules that decay--has been lost in most fossils. Thus, the fossil shells are more-or-less white. The head of the research project connected to this activity, Dr. Jon Hendricks, has been working on using ultraviolet light to reveal ancient color patterns in cone shells! Organic matter associated with pigment remains in some fossil shells. This matter fluoresces when it is illuminated by ultraviolet light, causing the original coloration pattern of the shell to be revealed. You can see some examples here: http://neogeneatlas.net/species/conus-adversarius/.

How did the shells get into the formation? (That is, how did they end up as fossils?)
Most fossils form in places where organisms are buried by sand or mud ("sediment") not long after they died, before the powerful forces of weathering have destroyed all evidence of them, including their hard shells. By far the most common place for fossils to form is in the ocean: sediment is continually added to the sea bottom from streams and rivers that carry weathered particles of rock from the land. Marine creatures with shells are in an especially good position to be fossilized, since their hard mineralized shells may be covered by sediments within a few years or decades. The layers of sediment that pile up in the ocean become covered by additional layers and so on, and eventually become part of a geological formation. If at some later time, sea level falls or the land is uplifted, then the sedimentary formations that were below the sea may become land. If weathering removes the upper layers, we can find older layers with their enclosed fossil shells eroding at the surface.

What kind of animals made the shells?
Shells are made by living animals that used the shells for support of their "soft parts" (somewhat like we use our internal skeleton for support of our soft tissues such as muscles and organs) and for protection from predators and the environment. A very wide variety of animals make shells, often in very different ways, but nearly all use calcium carbonate, $CaCO_3$ (vertebrate skeletons use calcium phosphate). Most of the shells in these activities are from snails (technically known as "gastropods") and clams (known as "bivalves"). Though clams and snails look very different, they are actually relatively closely related (they are both "mollusks") to each other (both have a specialized organ called the "mantle" that they use to build their shells). By comparison, skeletons of animals such as corals and sand dollars are very distant relatives of clams and snails.

Where and when did they live?

The animals that made the shells used in these sets of activities lived off the coast of the southeastern US over the past several million years. They lived in shallow sea water up to about 50 meters in depth.

What can we learn from fossils? Why study them?

We use fossils as tools to understand the history of life, which we study for some of the same reasons we study human history. If we know what happened when life was faced with changing environments in the past, we might be able to plan for changes we would expect to accompany current environmental changes. We can't do experiments on whole ecosystems, but in a sense the Earth has done those experiments for us. We also study fossils simply because it's interesting to know about the Earth's past and to understand broadly how the Earth works.

What can we not know from fossils?

Fossils are clues about the past, but most details about ancient animals are not preserved. For example, the soft tissues of organisms normally rot away (are eaten by bacteria and other organisms), so that we have only the shell to tell us about what the soft-bodied organism was like in life. For the most part, we are not able to see how these past organisms behaved (though we can look for clues, such as traces they left behind when moving). Many organisms have no shells at all (for example, jellyfish, many marine worms, and others), and therefore we cannot know any details about these other organisms. We can sometimes make estimates of ancient temperatures, but we cannot measure in detail ocean chemistry or temperature variations as we would when studying modern living organisms. Thus, an important part of doing paleontology is trying to ask good questions that can be answered with the geological data available, and inventing clever new methods to use clues in the fossil record that give us new information about past life.

What does it mean that the fossil record is incomplete?

Just as information about past human cultures is often lost, most information about past nature is not preserved. The fossil record is incomplete in at least two important ways. Firstly, in many places sediments did not accumulate for some (possibly most) intervals of time. Secondly, even when fossil shells are being preserved in sediment, many organisms are not preserved, either because they have no shells (or skeletons), the shells were too fragile to preserve, or the shells were dissolved before they were buried. Therefore, the fossil record is "incomplete," and we must ask questions that can be usefully answered with the fossil record that we have.

For more information, visit the "Completeness of the Fossil Record" page on the Digital Encyclopedia of Ancient Life: http://www.digitalatlasofancientlife.org/learn/nature-fossil-record/completeness-of-the-fossil-record/.

Are the fossils in museum collections representative of the things that lived in the past?

When paleontologists study fossils, they often collect them in the field and bring them back to their lab at a university or museum, where they can study them further. In addition, collecting the fossils preserves them from weathering away at the surface, which is inevitable over a period of years or decades, or from being lost due to construction of roads, parking lots, and buildings.

Fossils collected for research ideally are eventually donated to a natural history museum, where they become available for any future researchers to use them to solve additional scientific problems. The fossils in museum collections are just a tiny sample of what exists in nature, but the collection and curation of fossils by dozens of researchers over many years can create large collections that are representative of what exists in nature at some important localities. The data for this activity comes from such museum collections.

How do paleontologists study fossils? What do they do?
Paleontologists are people who study the history of life using fossils. Paleontologists try to understand how life came to be the way it is today, and what are the most important processes that cause life to change through time. One thing they often do is collect the kind of data used in these sets of activities -- they collect fossils in nature, categorize them, and then plot where they occur through time and space. They also work with other scientists to collect data about the rocks that tells them about past environments and climates, to better understand the context of the changes in organisms they see. And they do much more – they try to understand sizes and shapes of past organisms, the evolutionary relationships among the various groups, the way the organisms may have interacted with each other, and the influence of large extinctions that have occurred.

How do we know how old the fossils are?
During the 1800s when geology and paleontology first described much of what we know about the distribution of rocks and fossils at the surface of the world, we knew how old the rocks were relative to each other, but we didn't know numerically how old they were. "Relative" dating allows us to put in order past events by comparing the unique sequences of fossils and certain geological features that are found consistently around the world. This field of relative dating ("stratigraphy") was driven by the desire to understand the strata in order to look for natural resources, especially fossil fuels.

In the early 1900s radioactivity was discovered and became a tool for dating certain kinds of rocks. For the most part, to date rocks radiometrically we need to use radioactive elements within minerals of igneous rocks (rocks that form from molten magma or lava). Thus, mostly, we cannot date sedimentary rocks and fossils directly. But we can integrate the numerical dates where can get them with the relative time scale developed for geological strata.

There are a variety of other methods for numerically dating relatively young rocks and sediments that are "just" a few million years old or younger. For example, carbon-14 – perhaps the most familiar method with the general public -- can be used to date the carbon in very (geologically) young samples of less than about 50,000 years old. Another method uses degradation of amino acids preserved in well-preserved shells to date shells up to a few million years old.

The shells and formations used in this study were mostly dated relatively, with numerical dates from rocks of approximately equivalent age (relatively) in other places. One formation in one of the activities used radiometric dating using uranium that had been integrated into the calcium carbon skeleton of corals.

You can learn more about relative and radioactive (or, absolute) age dating on the Digital Encyclopedia of Ancient Life chapter on "Geological Time": http://www.digitalatlasofancientlife.org/learn/geological-time/.