While Mom is talking with a couple of potters, she keeps her son busy with a little clay pig.

Rattle Finds at Ur

To be a part of this scene, you would have to travel back in time more than 4,000 years to the land of Mesopotamia (present-day Iraq). See the rectangular structure in the background? It’s what we call a ziggurat, a stepped tower that was often crowned with a temple.

Archaeologists have uncovered a great variety of clay objects, including one in the shape of a pig, that date back to the time when high-ranking individuals were being buried in the Royal Cemetery at Ur. Research shows that pigs definitely were domesticated by then—so the potters above might easily have fashioned a variety of clay objects in that shape.

Was this clay pig fashioned to be a rattle? Turn to pages 48 and 49 to find out.
When we think about archaeology, we usually think about excavation, but, in reality, most archaeological work takes place in the laboratory! Archaeologists spend countless hours examining and studying uncovered remains (see photo at right), even when the actual excavations took place years, even decades, earlier. Why? Archaeological remains have much to tell about ancient people.

A close look at these remains can offer clues as to who the people involved were, what they ate, what their environment was like, and what kinds of tools they made. The goal at the Center for the Analysis of Archaeological Materials (CAAM) is to answer these important questions. To do this, CAAM experts work with students in a variety of ways—through coursework, research, and projects.

CAAM is located in the University of Pennsylvania Museum of Archaeology and Anthropology, also known as the Penn Museum. Housed there are roughly one million objects that were excavated largely by scholars associated with the museum. With its laboratories, instruments, and team of experts, CAAM’s mission is to train college students in a range of scientific methods crucial to archaeological discovery. High school students are also involved in the life of the Center through afterschool internships and summer courses in archaeological science.

For more information about CAAM, please click on: www.penn.museum/caam
Behind the Scenes with CAAM

One Axe—Many Answers
In the 1920s, British archaeologist Sir Leonard Woolley led an archaeological expedition at Ur that had been organized jointly by the British Museum and the Penn Museum. Located along the Euphrates River, in what is present-day southern Iraq, Ur had once been a very important city. Occupied from around 5500 to 400 B.C., it is best known for its amazing third-millennium B.C. Royal Cemetery. Although excavations ended decades ago, the research on the finds continues.

Among the artifacts uncovered was an axe (see page 46). Originally, it had had a wooden handle, but, over time, its metal axehead began to corrode. This metal corrosion gradually spread over the entire artifact. Even the axe’s wooden handle came to be covered with metal corrosion. While the wood did not survive, we can still see its traces, called pseudomorphs. This corrosion did have one positive effect—it filled in the plant cells and actually preserved their structures. CAAM’s researchers used a high-powered microscope to look more closely at the cells, and their findings suggest that the axe handle was made from Syrian ash. Ash is a species of tree that produces strong wood.

A pseudomorph is a mineral that replaces another while keeping the original size and shape.
with good shock-resistance. Because of these properties, many axe handles today are still made from ash.

**A Call to Archaeobotanists**

The researchers who identified the wood species were archaeobotanists Naomi Miller and Chantel White. But just what exactly do archaeobotanists do? The clue to the answer lies in the word used to describe them: *archai* is Greek for “ancient,” and *botane* is Greek for “plant.”

Plants were used as food, medicine, cloth, and tools in the ancient world. Sometimes, traces of preserved plants are found at archaeological sites. Such finds are known as ecofacts. Archaeobotanists carefully extract these ecofacts and take them back to the lab where they can be examined under a microscope. When seeds are found among the ecofacts, archaeobotanists compare them to modern seeds to identify the ancient plant of origin. When wood is found, the species can be identified by studying the unique cells that make up the wood’s tree rings.

**Questions for Archaeometallurgists**

But what about the axehead itself? Who can tell us more about it? Well, that’s the job of archaeometallurgists. These scientists study ancient metals and try to figure out how and where excavated metal was produced and how the objects were made. Archaeometallurgist Moritz Jansen uses a variety of scientific techniques to understand the structure of an object and the chemical composition of the metal. For example, x-radiography can help scientists look under the surface of a corroded artifact.

This imaging technique is also non-invasive—that is, it does no harm to the object. It gathers its information by using the differences in the way x-rays are absorbed to detect variation in the structure of the object. So, just as doctors look at bone x-rays to determine whether a

The technique known as x-ray imaging was used on the uncovered axe (above) to “see” under the corroded surface (left).
person has suffered a fracture, so archaeologists look at objects to understand their internal structure. In the radiographic image of the axe from Ur shown at left, the original shape of the corroded axe is visible. See how the lighter areas on the radiographic images are denser than the darker areas.

The metal used to make the axehead was identified as a copper alloy. However, ancient Ur was particularly known for its silver and gold metal objects. If archaeometallurgists want to know the region from which the gold originated, they look to the dirt particles found within the object. For example, some dirt comes from rivers where the gold was panned in ancient times. When the gold objects were created, tiny dirt particles were partly melted and contaminated with bitumen, a sticky but hard form of asphalt. Figuring out the composition of these pendants was easy; the more difficult question was: What animals do they represent?

**A Need for Zooarchaeologists**

Katherine Moore, a zooarchaeologist, took a close look at the features of the tiny animals and then compared them with the features of living animals. It is the job of

An *alloy* is a mixture of two or more metals. Bronze, for example, is an alloy of copper and tin.
zooarchaeologists to study both animal bones found at archaeological sites and the various ways people have used and thought about animals. Some of the animals represented—gazelles, for example—are easy to identify.

The ancient people of Mesopotamia might have seen deer in the marshy area along the river, but such sightings would have been rare. And the bull? Look closely at the bull head at left, and you can see that it is wearing a false beard. What story does this odd combination tell? It may be that, when included in a royal tomb, a bull with a beard represented the sun-god figure and offered an important message about life. (See also page 57.)

At Ur, representations of animals were also made out of clay—the little pig at right (opposite), for instance. Archaeologists have found a great quantity of clay around the site, as it was constantly being deposited there during the frequent flooding of the Euphrates River.

Clay, which becomes ceramic when fired, is a readily available raw material that could easily be shaped in various ways to make pots, bricks, drain pipes, tablets, tools, jewelry, and small objects such as incense burners, figurines, children’s toys, and rattles. Rattles? Yes! We are still not quite sure how these rattles were used. They may have been musical instruments. They were hollow, and this little pig, for example, produces a sound when shaken. The radiographic image to the right of the ceramic pig (opposite) shows that the sound this pig makes when shaken is due to three small clay balls moving about inside its body.

This magnificent bearded bull’s head is from the Royal Tombs at Ur. It adorned what is known today as the Great Lyre. The bull is believed to represent the sun god Shamash, the god of judgment and destiny. The figures in the panel below tells the story of the funeral ritual.

Call in the Ceramic Experts

Of all the ceramic objects found on archaeological sites, pots of different shapes and sizes are the most abundant. These vessels were used as containers for storage, transport, and food preparation. While they break easily, their fragments, known as sherds, last for thousands of years and are packed with information just waiting to be discovered.

Where pots were made is a very important question for archaeologists. Most of those excavated at Ur were probably produced by local potters. Some, however, may have been transported and brought from other places, both near and far.

To figure out where the objects
were made, ceramic experts—Marie-Claude Boileau among them—rely on an analytical technique called “ceramic petrography.” It uses a special type of microscope to examine the mineral composition of thin sections of ceramics. This method can be described as one that “fingerprints” ceramic objects. By matching the mineral and rock fragments in the clay to specific geological areas, it can identify the area where a ceramic object was made. Using this data, we can study trade and contact between groups of people.

Whose Bones? Ask the Physical Anthropologists
Perhaps you are now wondering about the people who lived and were buried at ancient Ur. Human skeletons offer us many clues about the lives of peoples who lived in the distant past. At Ur, people were buried in a way that made them look as if they were sleeping. They had been positioned on their backs with their hands on their chests or lying on their sides, all curled up in a small ball.

When skeletal remains are brought to the lab, physical anthropologist Janet Monge and her colleagues go to work. An analysis of excavated bones and teeth offers clues to the age of a person and to whether the skeleton is that of a male or female. Physical anthropologists can sometimes even tell the kind
of work a person did when alive and even if a person suffered from any diseases.

Teeth are especially revealing. They can offer clues that will lead to figuring out the kinds of foods people in the past chewed. At Ur, people wore their teeth down flat, almost to the roots if they lived 50 or more years. We know that the foods they ate everyday were full of grit, particularly wheat that was ground into flour for bread. As it was similar to sandpaper, it wore away the projections, or cusps, on the teeth.

Teeth offer many clues as to the age of a person at the time of death. Children have teeth that are replaced, beginning with a full set of baby teeth that emerges by the age of two and then begins to fall out by the age of six. New adult teeth come in up to about 20 or so years of age. Analysis of one skeleton uncovered at Ur revealed that the person died just as her last adult tooth was forming. She would have been about 18 years of age.

Marie-Claude Boileau, the lab coordinator and ceramic specialist in CAAM, works on ancient ceramic technology, trade, and exchange in the Near East and Aegean. Tessa de Alarcon, a project conservator, is currently working on the Ur Digitization Project, a joint initiative between the Penn Museum and the British Museum to digitize material from excavations at Ur. Moritz Jansen, an archaeometallurgist in CAAM, focuses his research on Near Eastern metal production and processing. Megan Kassabaum, a professor and archaeologist in the Department of Anthropology and a curator at the Museum, takes students to Smith Creek every summer. Janet Monge, a keeper and curator of the human skeletal collections at the Museum, focuses her interests on bioarchaeology, forensic anthropology, and human evolutionary studies. Katherine Moore, a zooarchaeologist in CAAM, works on early hunters and herding peoples in South America and Asia. Chantel White, an archaeobotanist in CAAM, analyzes ancient plants to identify the diet of humans from archaeological sites in Greece, Italy, Israel, and Jordan.

Above are photos of two skeletons uncovered at Ur. The inset is a skull with elaborate headdress that was found in the Royal Tomb of the King and Queen. The full skeleton at top was found in deeper deposits at Ur and is probably the remains of an older man.
Analytical work at CAAM is conducted not only on materials that were excavated many years ago, but also on materials uncovered at archaeological sites that are active today. In fact, projects directed by Penn’s faculty and museum staff are ongoing every year in different countries. Leading one such project is assistant professor of anthropology Megan Kassabaum.

Yesterday’s Highways
Before there were cars and roads, the rivers of North America were the interstate highways for Native American people who lived in what is now the United States. The biggest highway, the Mississippi River, allowed those living near its shores to travel, trade, and communicate with many people beyond their communities.

More than 1,300 years ago, a group known as the Coles Creek culture lived along the southern part of the Mississippi. Most of the time, they lived in small villages scattered in the river’s bluffs and floodplains. On special occasions, they would gather at sacred sites marked by large mounds, some of which have survived. Archaeologists are now excavating these mounds, hoping to learn more about the people who built them.

Up Close at Smith Creek
In 2015, Kassabaum’s team excavated at a mound site called Smith Creek. Here, three large mounds surround an open space called a plaza. The team determined that one mound was used as a cemetery, while the other two had flat tops that probably served as foundations for buildings or stages for ritual activities.

On the largest mound, they found a midden, the technical name for a large deposit of trash. It included broken pottery, animal bones, and shells. These finds offered answers to many questions about what happened there.

Using a special technique called

Mounds were built by hand, one basketful of dirt at a time. Most mounds were built in stages, with dirt that was dug from large pits nearby.
flotation (see above), team members were able to recover thousands of tiny burned fragments of plants. Analysis of these finds revealed that the people had prepared and eaten food on top of the mound, perhaps as part of a feast or other celebration.

After the team finished excavating at Smith Creek, they brought the uncovered materials back to CAAM for cleaning and analysis. They started by washing each artifact carefully with a toothbrush. They then sorted the artifacts according to the type of material that had been used to make them—clay, stone, bone, shell, or charcoal. With those tasks completed, they then counted and weighed every piece. All the artifacts are now being analyzed individually, using special techniques for each material type.

Report from Zooarchaeologists

What animals did the people using the Smith Creek mounds hunt and fish? Zooarchaeologist Kate Moore has been working with graduate student Stacey Espenlaub to find out. Study of the animal bones found at the site has shown that the people ate mostly white-tailed deer, rabbits, and fish.

Several unusually shaped bones popped up in samples from the mounds. These had a different story to tell. Careful matching of bone shapes with the bones of black bear paws in the museum’s collection shows that Smith Creek people had killed several bears. Examination under the microscope further proved that the bears had been carefully skinned, possibly to make a garment or ceremonial object.

What Archaeobotany Reveals

Another method used to help understand the prehistoric activities at Smith Creek is archaeobotany. Kassabaum and undergraduate student Ally Mitchem separated the flotation samples into different fractions based on size: 2mm, 1.4mm (this is about the size of the head of a pin!), and .71mm. They then looked at each fraction under the microscope to identify the plants that are contained in the sample.

The team members working on the Smith Creek archaeobotanical

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**On site at Smith Creek:** Team member Ally Mitchem uses the technique known as flotation to recover tiny plant fragments in excavated soil.

**Flotation** uses water to recover tiny artifacts from the soil. Water is gently pushed through the soil from the bottom. Seeds, charcoal, and other light materials float to the top where they can be collected; heavy materials are left behind and also collected.

**2mm** stands for 2 millimeters, which is equal to approximately 1/12 of an inch.
samples have made two major discoveries thus far. First, five burned corn kernels indicate that the Smith Creek people might have been some of the earliest people in the Lower Mississippi Valley to grow corn. Second, the Smith Creek people burned lots of sweetgum balls in a small pit in the plaza. Right now, the answer to why they did this is still unknown, but more excavation and more archaeobotanical analysis may help solve this mystery!

Left: Here, Ally Mitchem is working to identify seeds in a paleobotanical sample from Smith Creek.

Far left: A close-up of a branch of a sweetgum tree, with two leaves and seven spiky green fruit balls.
At CAAM, archaeological scientists work closely with conservators, who are responsible for the preservation and care of these objects so that they can be studied and displayed, not just now but in the future as well. Objects in the museum are often brought to the conservation lab for a condition check—much like your regular check-up at the doctor’s office. Once in the lab, they are examined, and each observation is documented. The goal is to track the condition of each artifact and to flag any that have problems.
Salt—the Good and the Bad
A key problem facing conservators who work with archaeological material is salt. It is true that there are many types of salt, including the kind we use on food. Regardless of type, many common salts dissolve in water. As a result, salt is found not only on the dinner table but also in groundwater.

When ceramics and metals are underground before they are excavated, they are exposed to ground water and can absorb the water much as a sponge does. But it is not only water that they are absorbing; the salts are also being absorbed. As long as an artifact stays wet, with the salts dissolved in the water, there is no problem. But, once the objects are excavated, the exposure to air causes problems for both metals and ceramics.

For ceramics, the problem happens as the object dries out. As the water evaporates out of the ceramic, the salts stay behind, forming crystals. These crystals can form harmlessly on the surface, or they can crystallize inside the ceramic, breaking it apart as the salt crystallizes. For an example, see the photos above of a camel figurine that was uncovered at Ur. The cracking and fragmentation seen on the camel at left were both caused by the crystallization of salts. It is the job of conservators to treat these objects. They often do so by soaking them in water that has no salts in order to dissolve the salts in the ceramic and remove them.

When Air Meets Salt
Metal reacts quickly when it is excavated and then exposed to air and water. For example, the copper in pennies goes from shiny to red-brown as the coins react with the air. Copper artifacts do the same, and the corrosion can be red or green, depending on the amount of water and air that an object met while it was buried in the ground. All usually stabilizes once an object is excavated.

If, however, there are salts in the groundwater, then their effect on the metal is to create pustules, or small bumps, on the surface of the object. These can burst open after the object is excavated, exposing bright green powdery corrosion. The corrosion on the
The Raven Pipe

In the digital age, it is still important to see actual objects. I saw pictures of the raven pipe when I was a student at Southern Illinois University-Carbondale and a graduate student at Northwestern University. The raven usually was pictured in profile, with its beak on the pipe’s platform. “Raven pecking the head or the profile of a human face” was the usual description. In Hopewell culture, ravens are associated with the dead and related rituals.

As a new curator at the Gilcrease Museum in 2010, I held the beautiful raven pipe in my hands for the first time. The body of the raven is finely shaped and polished. Feathers of the wings and tail are artfully carved. The eyes are freshwater pearls. I thought about the description that I had read so many times and how it was interpreted. Looking closely now at the actual artifact, I realized that my perception was totally wrong! I saw now that the raven’s beak touched the head behind the eye and in front of the ear of the human head. A single curled line was engraved into the side of the head. The location of the beak and the curl suggests that the raven is whispering to the man. Could this curl be a speech scroll, an illustrated device that is used to denote a speech, song, or even a sound? This raven is not pecking at the man’s face; he speaks to the man. Perhaps this is a spirit that is passing on knowledge. The pipe itself is a ritual item, smoked by its owner for spiritual purposes. Very likely, the pipe was an important item in its owner’s personal ritual possessions.

As we move into the digital age, this pipe offers a lesson that needs to be remembered: Seeing the actual object still has the power to excite and educate in a way that images of that object do not.

The Hopewell culture flourished in Ohio and other parts of eastern North America during the Middle Woodland Period, possibly as early as 100 B.C.E.
This tiny golden bull is actually a bead that was part of an ornament buried with a Sumerian queen named Pu-abi around 2500 B.C. It is just over three-quarters of an inch wide. British archaeologist Sir Leonard Woolley uncovered it in 1927 at the site of Ur in present-day Iraq. The bull is shown with a false beard tied over his nose, suggesting that he represents an image of the Mesopotamian sun god, who sometimes was shown as a bearded bull. In addition to this bull and another of similar size, the ornament had pairs of gold beads in the shape of rams, deer, and gazelle. Also part of the ornament are almost 10,000 tiny beads made of blue lapis lazuli, an imported semi-precious gemstone. Today, the jewelry and many other items from the site are on display at the University of Pennsylvania Museum of Archaeology and Anthropology in Philadelphia.