



## ARCHAEOLOGY

# Pot residues show how ancient Egyptians made a mummy

Analysis reveals the chemicals applied to corpses in a 2700-year-old mummification workshop

By **Andrew Curry**

**F**or the ancient Egyptians, mummification was a spiritual process imbued with deep meaning. Ancient texts show it took 70 days, with carefully defined rituals and invocations, to prepare the deceased for an eternal afterlife. It also required specialized skills, long lists of ingredients, and a professional class of embalmers steeped in religious and chemical knowledge.

But what went into—or was smeared on, brushed over, and wrapped around—the mummified bodies themselves has been mostly guesswork on the part of modern scholars. “There’s almost no textual evidence,” says Philipp Stockhammer, an archaeologist at the Ludwig Maximilian University of Munich. “How this worked, how the substances were mixed, how they were named—this wasn’t known.”

That changes with a study Stockhammer and his colleagues published this week in *Nature*. By identifying residues from labeled jars

found in an ancient Egyptian mummification workshop, the researchers were able to show the process involved complex chemistry and exotic ingredients, including resins sourced from a continent away. “You can actually look into the vessels and see what’s still inside,” says Barbara Huber, an archaeological scientist at the Max Planck Institute for Geoanthropology who was not involved with the research.

The new evidence emerged from a 2700-year-old (664 B.C.E.–525 B.C.E.) burial complex south of Cairo called Saqqara. In 2016, University of Tübingen archaeologist Ramadan Hussein, who died in the spring of 2022, identified shallow aboveground

pits where the dead would have been covered in natron, a salt mixture used to dry out the body after death. Partway down a nearby shaft was an underground chamber outfitted with flat stone niches for corpses—a workshop for mummifiers. “It’s the first physical evidence for the places where they worked,” says University of York archaeochemist Stephen Buckley. At the very



The label on a jar from a mummification workshop read “to be put upon his head.”

Embalming a body in ancient Egypt combined ritual, chemistry, and ingredients from distant sources.

bottom of the shaft, 30 meters down, were burial chambers.

A body that began the mummification process at the top of the “funeral home” could have been buried directly below, presumably after spending a few weeks being prepared in the underground chamber. “It was a protoindustrial mummification workshop for the upper class,” Stockhammer says.

The shaft had been carefully filled with sand, rocks—and dozens of embalming vessels that seemed to have been ritually disposed of after workers had used them. “They turned it into a hiding place for the tools,” Hussein said in an interview before his death. “We found cups, bowls, plates, and incense burners inscribed with the names of oils and substances used for embalming.”

The researchers used a dentist’s drill to remove coin-size fragments a few millimeters thick from the inside of the containers, then analyzed their chemical makeup using gas chromatography-mass spectrometry. Earlier studies had analyzed mummies from museum collections and identified embalming chemicals including tree resins and bitumen. But this is the first to examine vessels found in the context of a mummification workshop.

The analysis revealed traces of animal fats, beeswax, vegetable oils, and bitumen along with multiple plant resins—ingredients that were probably mixed and heated to form ointments. Their properties made them particularly easy to recover from pottery vessels, even after thousands of years. “The more fatty and sticky a residue is, the better results you get,” Stockhammer says. “We had good organic preservation, and we had residues that preserve well.”

After being immersed in natron, corpses were treated with the sticky mixtures to seal the skin, blocking decay and decomposition by bacteria. “The materials we found have an antibacterial function,” Stockhammer says. “It’s the most complicated part of the process, where the chemistry really starts.” Some ointments may have been smeared directly on the corpses; others were probably applied to the linen bandages, which may have been dipped directly into wide-mouthed “goldfish bowl” vessels.

Some of the bowls still had stains on the outside from spills and dripping mummy wrappings. Many also bore labels naming specific ingredients—*antiu* or *sefet*—or giving more general descriptions, like “to make his odor pleasant” and “treatment of the head.” “For the first time, you have a direct correlation between text and a spe-

cific residue,” Huber says. “I don’t know if there’s a better case study than having them all together.”

The finds may require reassessment of ancient Egyptian texts. The word *antiu*, for example, appears thousands of times in Egyptian sources, and for more than a century Egyptologists have thought it referred to myrrh, the resin of a particular thorn tree. But vessels labeled *antiu* at the mummification workshop contained other substances—most notably cedar, sourced at the time from the mountains of Lebanon. “Possibly *antiu* is just a generic word for resin,” Hussein said before his death. *Sefet*, described as one of the “seven sacred oils” in many ancient texts, turned out to be a mixture of cypress or juniper resin and animal fat.

The researchers also identified more exotic ingredients, including dammar and elemi, resins extracted from hardwoods native to Southeast Asian rainforests thousands of kilometers from ancient Egypt. Cedar and pistachio, meanwhile, were sourced from around the Mediterranean, and pitch from the Dead Sea. “Almost all the things embalmers needed came from outside Egypt,” Stockhammer says. “And you need a lot of this to mummify and embalm, not just a few grams. Even if it’s just a few thousand individuals a year who are high-status enough to be mummified, it’s still a lot of material. Mummification drove globalization.”

The substances themselves may have been selected precisely because they were hard to get. “Some of the materials may have been used not because they were more effective, but because they were exotic—‘Look at the size of my world, that I can get something from so far away,’” Buckley says.

Some scientists caution that the mummification compounds could have degraded and changed over time, throwing off the analysis. “They may have gone a little too far in the interpretation,” says Kate Fulcher, a heritage scientist at the British Museum. “No one’s done a controlled experiment where we’ve aged resin for 3000 years and seen how it’s deteriorated—we don’t know how these [chemical compounds] look after all this time.”

But the chemical artistry behind the pot residues is unmistakable, reflecting precise knowledge of ingredients, temperatures, and cooking times won over hundreds, if not thousands, of years. Ancient Egyptians “spent more than 2000 years trying to perfect the preservation of the human body—that’s 2000 years trying to perfect their workflow,” Stockhammer says. “The chemical knowledge they must have had in this workshop was amazing.” ■

## COVID-19

# New COVID-19 vaccine strategy would mimic flu’s annual shots

Scientists and regulators seek new course amid uncertainty

By Jennifer Couzin-Frankel

**C** COVID-19 vaccination in the United States is set to change this year. The Food and Drug Administration (FDA) is planning a shift toward a single booster shot, administered in the fall, like the strategy used for influenza. Members of an FDA vaccine advisory panel meeting last week generally endorsed the idea and also said all COVID-19 vaccines should have the same composition going forward. Today, the initial shots are based on the virus that emerged in Wuhan, China, in 2019, whereas most boosters also target the Omicron variant.

Yet many important questions remain. It’s not clear whether a COVID-19 booster can protect for a full year, whether some vaccinated people who have also been infected with COVID-19 could wait longer, or which variants the annual shot should target. Nor is it clear how many people would embrace another booster. “Where are we headed?” Jerry Weir of FDA’s Office of Vaccines Research and Review asked at the 26 January meeting. “I don’t know, but we just follow the data we have.”

*Science* asked researchers to weigh in on some of the most urgent questions.

### Q: What are the pros and cons of an annual booster—the influenza strategy?

**A:** The influenza vaccine consists of an annual dose tailored to flu strains expected to circulate next winter. FDA officials say they anticipate something similar for COVID-19: assessing strains “at least annually” and conferring with advisers in early June to settle on the makeup of a fall vaccine. (Executives at vaccinemakers Pfizer and Moderna said that schedule would pose no problem; Novavax would want to know the strain around March, a company official said.) Many researchers agree the regimen is less cumbersome and confusing than multiple boosters per year, and it makes sense to “vaccinate with the circulating variants,” says immunologist Rafi Ahmed, director of the Emory Vaccine Center.

But flu is seasonal, Ahmed and others note, whereas the coronavirus circulates year-round. People who contract COVID-19 in August—which is vanishingly rare for flu—would have to decide whether to also take a shot in the fall, when their immunity may still be robust. It’s also unclear whether an annual booster offers everyone enough protection for a whole year. The durability question “is a big one,” says immunologist Jennifer Gommerman of the University of Toronto. FDA indicated it might recommend two doses for the elderly, the immunocompromised, and children who’ve had fewer than two doses.

More data could help bolster—or weaken—the case for a once-a-year vaccine.

Because the current vaccines are especially protective against severe disease, it’s crucial for the U.S. Centers for Disease Control and Prevention (CDC) “to tell us exactly who’s getting hospitalized and dying from the virus,” panel member Paul Offit, an infectious disease specialist at the Children’s Hospital of Philadelphia, said at the meeting. Offit craves details on patients’ ages, whether and how their immune system is compromised, and whether they received antiviral medications. “Only then can we make the decision about who gets vaccinated, with what, and when.” Bruce Gellin, a global public health specialist at the Rockefeller Foundation, added a caveat as well: “This is not influenza, and we need to keep paying attention to that to make sure we don’t just follow that dogma.”

### Q: How should the annual vaccine recipe be picked?

**A:** The FDA panel voted to give all of the vaccines the same composition, which for now means the current boosters’ “bivalent” formulation, evenly split between vaccine targeting the Wuhan strain and Omicron subvariants BA.4 and BA.5.

When the plan for a bivalent booster was agreed on in June 2022, it was something of a hedge: Although the original Wuhan variant was long gone, FDA advisers worried an Omicron-only vaccine would be less effective against an entirely new SARS-CoV-2 variant that might emerge. The advisers also hesitated then