NATURE | NEWS

Linnaeus's Asian elephant was wrong species

Molecular sleuths crack 300-year-old mystery over the identity of the Asian elephant type specimen.

Ewen Callaway

04 November 2013

The story of Linnaeus's pickled elephant
In this special production by the *Nature Podcast* team, Ewen Callaway digs into the story of how Linnaeus got one Asian elephant specimen wrong — but another one right.

Natural history museums don't usually tell their visitors, but they are riddled with wrongly identified specimens. Such errors even occur with important holdings, including plants and animals that serve as the archetypes, or type specimens, for their species — the ones that biologists described when they officially named them.

Taxonomy, the science of species organization, started with Carl Linnaeus, and his species descriptions serve as the basis for all other plant and animal classifications. Linnaeus has been proved correct more often than not, but questions hover over some of the species he classified, including the Asian elephant.

Could the pickled fetus he used as its archetype actually have been a different species?

A team in Copenhagen decided to find out, unaware they were about to add the final chapter to a centuries old saga.

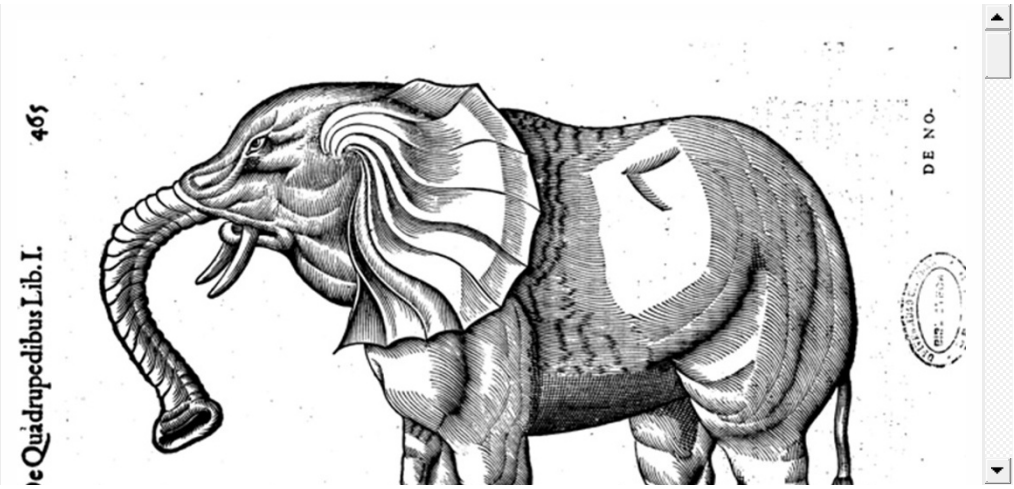
Uppsala, Sweden, 1753
Carl Linnaeus could hardly contain his excitement over his latest acquisition. “I am pleased that the little elephant has arrived. If he costs a lot, he was worth it. Certainly, he is as rare as a diamond,” the founding father of modern taxonomy wrote in a letter to a friend on 18 May 1753.

At Linnaeus’s urging, King Adolf Frederick of Sweden had bought a fetal elephant preserved in alcohol for his already immense natural history collection. Few Europeans had ever laid eyes on an elephant, and Linnaeus was eager to include the beast in his life’s work, *Systema Naturae*.

Published in 1735 and updated regularly thereafter, *Systema Naturae* was a naively audacious index of all known life, organized according to the binomial classification system that Linnaeus formalized. He grouped organisms hierarchically, each described with genus and species names in Latin. Linnaeus's system hinged on the concept of types — individuals that serves as the archetypes for a species, in much the same way that a platinum–iridium cylinder outside Paris defines the kilogram. And because Linnaeus was the one who came up with this system, which is still used by scientists today, he got to pick the type specimens.

Linnaeus may have been thinking of himself when he described *Homo sapiens sapiens* (he was formally designated the type in 1959). But for the more than 10,000 other plants and animals he classified, Linnaeus relied on collections such as the king's. The fetal elephant, the size of a well-fed cat, became the elephant's type specimen, included in *Systema Naturae*.

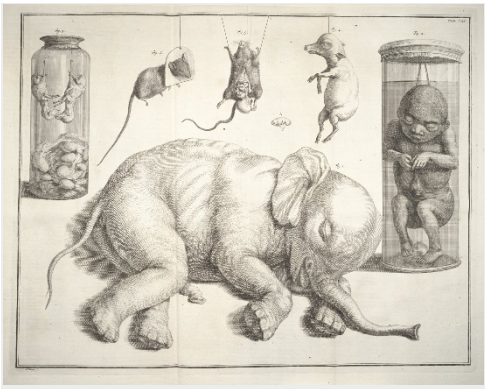
Linnaeus dubbed the species *Elephas maximus*, which is now commonly known as the Asian elephant. He recognized just one species of elephant in the world, and this would be its archetype. Linnaeus was also aware of other specimens — including some teeth and an elephant skeleton that had been described in Florence by an English scholar named John Ray — and noted old artistic renderings of short-legged beasts with unnatural-looking trunks (see slideshow below). All of this which were part of his description of the elephant, a list referred to as the type series. He listed the elephant's origin, or locality, as *Zeylonae paludosis*, or Ceylon, the island now called Sri Lanka.



Although Linnaeus believed elephants originated from south Asia, it is likely that he knew that elephants also lived in Africa. For example, he would probably have learned about the campaigns by the Carthaginian leader Hannibal against the Romans in the third century bc, which were led by dozens of war elephants decked in armour. But there is debate as to whether he knew that his pickled exemplar came from Africa by way of a Dutch collector.

Amsterdam, 1735

Albertus Seba made enough money as owner of a pharmacy to indulge his true passion — natural history. His voluminous collections included most of the world's known mammals, amphibians, snakes, insects and even plants and minerals. After selling a large hoard to Tsar Peter the Great of Russia in 1717, Seba amassed another collection, which was catalogued and illustrated in a four-volume work called *Thesaurus*. The first volume was issued in the mid-1730s.


Albertus Seba

Among Seba's final acquisitions was the elephant fetus, which was either sold or given to him by the Dutch West India Company. Seba died in 1736, and his collection was put up for sale in 1752 to pay for the costs of publishing the final two volumes of Seba's *Thesaurus*. The auction prospectus included a brief description of the elephant that Linnaeus would soon get his hands on: "An extra fine uncommon elephant fetus from Africa."

Europe, various locations, late 1700s

Whether or not Linnaeus knew its origin, his pickled pachyderm was cemented as the archetype for the Asian elephant. Near the end of the eighteenth century, scholars recognized the African elephant as a distinct species and named it *Elephas africanus*. A century later, African elephants were split into two species on the basis of their habitats: forest and savannah. Both species were later given a

genus distinct from *Elephas* — *Loxodonta*, from the Greek word for oblique-sided tooth.

It's easy to tell a grown Asian elephant from its African kin: the longer ears of *Loxodonta* are one of many giveaways. But their fetal forms can be difficult to discern. Beginning in the 1800s, after the fetus was moved from the royal palace outside Stockholm to the building that became the Swedish Natural History Museum, curators there began to wonder whether their prized holding was mislabelled. In some ways, the specimen looked more like an African elephant, two curators suggested in unpublished notes and at academic meetings. Questions about the fetus still lingered when the museum's current science director, Per Ericson, joined in the 1990s as an ornithology curator.

London, early 2000s

In the early 2000s, Anthea Gentry, a mammal curator at the London Natural History Museum (NHM) was also starting to have the same doubts.

Gentry, an expert on birds and mammals, first saw the fetus in 1999. She had heard that the Stockholm museum held a couple of specimens that Linnaeus had described, and she wanted to see them. She nearly gasped when the keeper of the museum's wet collection wheeled out three carts crammed with jars containing dozens of birds, squirrels, bats and other animals. "This was an absolute eye opener," says Gentry. "Nobody's ever looked through this material to see what Linnaeus had."

Gentry set about describing the material, expecting that some of Linnaeus's descriptions would not match up with modern species designations. She won a European Union grant to catalogue the collection, and photographed the specimens extensively for later study. In 2004, on vacation with her husband, a mammal palaeontologist, Gentry pulled out a photograph of the elephant fetus."I said to him 'I don't think this is an Asian elephant,'" she recalls. "He said 'you're right — it's an African elephant,'" Its ears looked too big for an Asian elephant, and its domed head looked like that of an African elephant.

In the hope of confirming her hunch, in 2006 Gentry decided to analyse the specimen's DNA. By then, scientists had become adept at coaxing DNA sequences out of 2,000-year-old mummies and still-older Neanderthal fossils, and Gentry and her NHM colleagues hoped that the much younger elephant fetus would contain enough genetic material to reveal whether it came from Africa or Asia. But pure alcohol is unkind to DNA, and the sequencing efforts were inconclusive. The researchers enlisted Tom Gilbert, an ancient-DNA expert at the University of Copenhagen, and he too failed, even using what was then the world's most advanced DNA sequencing technology.

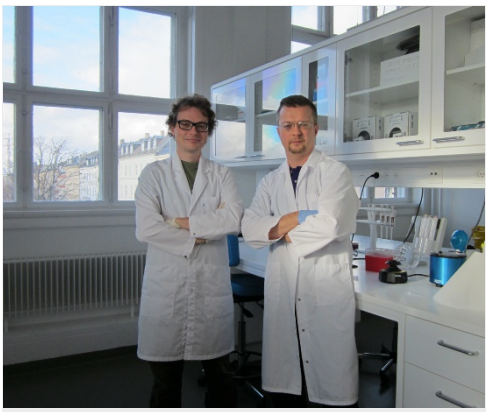
Copenhagen, 2009

But Gilbert kept thinking about the elephant. He bought a reissued edition of Seba's illustrated *Thesaurus*, which is currently in print under the title of *Cabinet of Natural Curiosities* (TASCHEN, see slideshow below), and told anyone who would listen about the fetus and the mystery over its identity.

Enrico Cappellini was befuddled when Gilbert began telling him about the elephant, flipping through the Seba catalogue. Cappellini, a protein chemist, had joined Gilbert's laboratory as a postdoctoral researcher in 2009 to study cereal-crop domestication. "Why is he talking about elephants?" Cappellini wondered.

Gilbert had an idea for cracking the case, but he needed his new postdoc's help to pull it off. Three hundred years in a bath of alcohol

may have destroyed most of the elephant's DNA, but he reasoned that other biomolecules, such as proteins, had to be intact — otherwise the specimen would have been liquefied. "Clearly it's got protein, because the damn thing still exists," he says. Cappellini's prior project had involved analysing collagen, the main protein in bone and connective tissue, to identify species from small and cryptic remains. Gilbert hoped that Cappellini could extract proteins from Linnaeus's elephant and find one that differed between Asian and African elephants.



Kim Magnussen/University of Copenhagen

Tom Gilbert and Enrico Cappellini determined that Linnaeus's specimen was an African, not Asian, elephant.

Cappellini, whose physical resemblance to Gilbert has often amused conference-goers, was intrigued. The study of ancient DNA had been revolutionized by 'next-generation' DNA sequencers that rapidly read short stretches of DNA — a technology particularly well-suited to reading centuries-old DNA, which comes shredded to pieces. But techniques to rapidly decode numerous proteins at once were also gaining power. In 2012, Cappellini and Gilbert published a paper identifying 126 proteins from the femur of a 43,000-year-old woolly mammoth, an experiment that revealed the potential of ancient proteomics[1].

In theory, Cappellini needed to isolate just a single protein that differed between African and Asian elephants. But his earlier approach would not do the trick — collagen, which is also abundant in skin and in blood vessels, does not differ between elephant species. Identifying one distinguishing protein was also hindered by the scarcity of genetic information available for elephants, particularly Asian.

From a bit of oesophagus, Cappellini and Gilbert detected one protein that differed, by a single amino acid, between the two species. The protein was a portion of the haemoglobin complex that carries oxygen in red blood cells. In Asian elephants, the amino acid is aspartate, whereas in African elephants it is glutamate. Cappellini's tests confirmed that Linnaeus's elephant encoded glutamate. Mystery solved: the fetus that Linnaeus had taken as the archetype of the Asian elephant was, in fact, an African elephant.

After knocking Linnaeus's elephant off its perch, Gilbert wondered whether his team's discovery would wreak havoc on the small world of elephant taxonomy. "I was imagining the chaos we were about to unleash on the systematists when they find out their type specimen is the wrong thing," he says. Would *Elephas maximus* become the new Latin name for the African elephant, forcing taxonomists to come up with a new name for the Asian variety? Could they designate any Asian elephant as the new type?

"Unfortunately, they're wily creatures, taxonomists, and they've always got loopholes," Gilbert says. Rules issued by the International Commission on Zoological Nomenclature, the arbiter of all animal species, state that a new type specimen should first be drawn from any other examples listed in *Systema Naturae* or seen by Linnaeus. The candidates were John Ray's description of a skeleton and a partial tooth that Linnaeus had noted. If neither of those were suitable, only then would the commission consider another Asian elephant as the archetype for *E. maximus*.

The obvious candidate was the tooth, now housed at a museum in Uppsala, Sweden. "It wasn't a very satisfying type specimen, having half of a molar," Gilbert says. They were just getting used to that idea, when Cappellini received an e-mail from a palaeontologist at NHM who specializes in elephants. The short note included a document from the travels of John Ray.

Europe, 1663–67

In the spring of 1663, at the age of 35, Ray embarked on a 4-year tour of Europe. He had just quit his post at Trinity College in Cambridge, UK, where he had taught Greek and mathematics, preached the occasional sermon and pursued his own interests in natural history. After passing through northern Europe, Ray reached Florence in the summer of 1664, where he came across the remains of an elephant in the palace of Duke Ferdinand II. "We saw…the skin and skeleton of an elephant which was shown in Florence some 8 or 10 years ago and died there," Ray wrote.

Ray was a thinker in the mould of the British philosopher Francis Bacon, who had emphasized direct observation. Ray therefore paid close attention to the anatomical details of the elephant skeleton, in which some missing bones had been replaced with wooden replicas. "There are 20 pairs of false and true ribs altogether, but I could not discern how many were false and how may were true because the breast-bone and cartilages were missing from the skeleton which I saw in Florence," Ray noted.

Copenhagen, 2012

Enrico Cappellini et al.

English naturalist John Ray.

The travelogue was written in the scholarly Latin used by seventeenth-century European scientists, so Cappellini had to resort to what classical Latin he could remember from secondary school — and some help from Google — to make his way through the text. Cappellini had done his PhD in Florence nearly a decade earlier, and something clicked when he read about Ray's elephant. "I thought when I saw this, if it is still around it must be in the zoological section of the Natural History Museum at the University of Florence," Cappellini says. "I knew there was an elephant skeleton, because that was my department."

With that clue, Cappellini set out to determine whether the skeleton he remembered from his graduate days matched the description Ray wrote, and which Linnaeus referenced alongside the now-relegated fetus. Tracing Ray's account through digitally archived texts, Cappellini learned that the elephant was named Hansken.

Hansken was given as a gift to the Dutch royal family in the 1630s after having been imported by the Dutch East India Company — a fact that already pointed to a probable Asian origin — and was later sketched by the Dutch master Rembrandt (see picture at right). The animal became an inconvenience, and was later sold to a showman who taught it tricks, such as pulling a sword out of holster, and charged people to see it. After touring Holland, Germany and Italy, Hansken died in Florence on 9 November 1655. It had been dead for only a few years when Ray saw it in 1664.

Enrico Cappellini et al.

A sketch of Hansken by Rembrandt.

Cappellini contacted the Florence museum and told them about his hunch. The skeleton he remembered was indeed still in its collection. It was clearly Asian, and the proportions were nearly identical to those of Hansken as Ray and others had described them. But what sealed the deal were the skeleton's wooden ribs, which corresponded to the false ribs that Ray had noted 350 years earlier.

Saulo Bambi/University of Florence

Hansken's skeleton.

"It's perfectly preserved. You can clearly see that the sternum is not there but is replaced by a wood replica," Cappellini says. "I think we were in a good position to designate the Florence elephant as the lectotype, or the new type, for the species *Elephas maximus*." That designation was announced today, with the publication of the team's efforts in *Zoological Journal of the Linnean Society*[2].

Epilogue

"This is first and foremost a really cool science detective story," says Kris Helgen, a mammal curator at the Smithsonian Institution in Washington DC. Even though no one has trouble distinguishing Asian and African elephants now, he says "part of the importance of this work is 200 years from now we don't want any confusion to be in place in the way these names are applied." Gilbert believes that his team's work has potential implications for other fields, such as paleontology and conservation. New species or sub-species of living or extinct Asian elephant are defined in reference to type specimens. Such comparisons ought to be done using an accurate frame of reference, he says.

Ericson, the Stockholm museum's science director, is thrilled to have the mystery solved, even if it means downgrading his museum's celebrated artefact. "This is how it should be with these questionable specimens," he says.

Gilbert and Cappellini think that protein analysis will set straight other species records held in natural history museums. For instance, they are trying to clarify how *Toxodon*, an extinct South American mammal resembling a hippopotamus, relates to other mammals, and they are working on extracting protein from other ambiguous specimens at the NHM.

Linnaeus's record may soon be corrected even further. Gentry plans to soon publish a catalogue of Linnaeus's birds and mammals. In addition to the elephant, she has discovered several other less ambiguosly misidentified type specimens, including bat and rodent species. "I think it's a shame we have to set aside these specimens," she says, "but it's what we have to do."

References

1. Cappellini, E. *et al*. *J. Proteome Res.* **11**, 917–926 (2011).
2. Cappellini, E. *et al*. *Zool. J. Linn. Soc.* http://dx.doi.org/10.1111/zoj.12084 (2013).