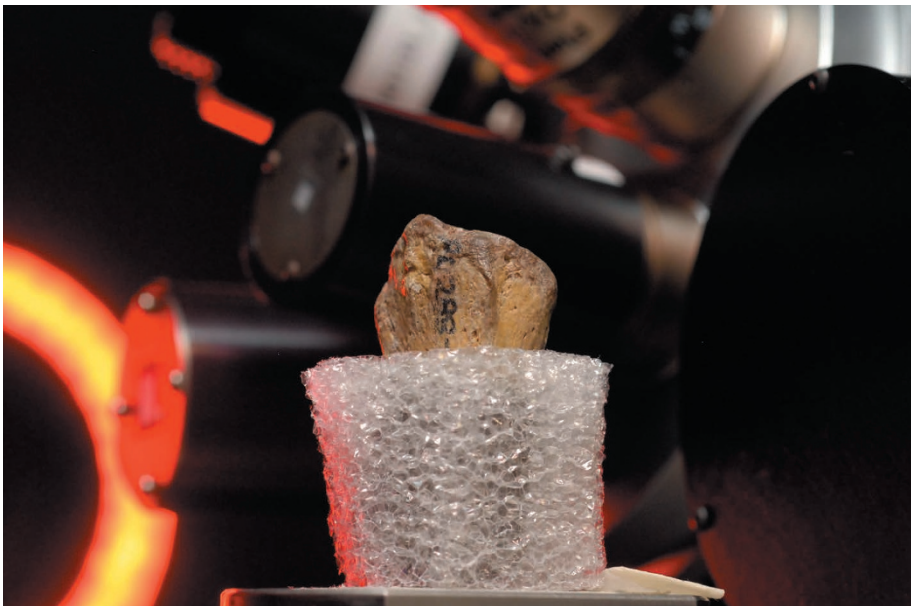
ANTHROPOLOGY

Print your own 3D hominin to work out how Lucy died

Digital scans will help to test whether the famous australopithecine fell out of a tree.

BY EWEN CALLAWAY



MARSHA MILLER/UT AUSTIN

Lucy's arm bone undergoes a computed-tomography scan.

The world's most famous fossil is now open source. 3D scans of Lucy — a 3.18-million-year-old hominin found in Ethiopia — were released on 29 August, allowing anyone to examine her arm, shoulder and knee bones and even make their own 3D-printed copies.

The scans accompany a *Nature* paper that argues that Lucy, a human relative belonging to the species *Australopithecus afarensis*, died after falling from a tree (J. Kappelman *et al. Nature* http://dx.doi.org/10.1038/nature19332; 2016). The team behind the paper also made the scans available to the public and is eager for other researchers to test the hypothesis by printing out the bones.

"It's one thing for me to describe it in detail in paper, but it's another thing to hold these things, to be able to print them out, look at them and put them together," says team leader John Kappelman, a palaeoanthropologist at the University of Texas at Austin.

His team received approval from the National Museum of Ethiopia and the country's government to make the models of Lucy public. "My sense from the Ethiopians is that Lucy is not only their national treasure, but they see her as a treasure for humankind," says Kappelman, who hopes that the country will soon release digital scans of the rest of Lucy and that other countries may follow suit with other hominin fossils.

"Coming from Ethiopia, it really is a positive step, because other countries that are hesitant may be willing to do the same thing," says Louise Leakey, a palaeontologist at Stony Brook University in New York.

But Kappelman and others say that such a move could threaten cash-strapped museums — many of them in Africa — that rely on income generated from casts of their fossil collections to help them survive.

Lucy's digital debut was eight years in the making. Her 40%-complete remains spent 10 days in Kappelman's lab in August 2008 during a US tour. His team worked day and night to scan every one of several hundred bone fragments using a computed-tomography (CT) imager.

Close examination revealed unusual fractures: the end of her right humerus that connected to her shoulder had a series of clean breaks and compressions similar to those that orthopaedic surgeons often see in people who attempt to break a fall with an outstretched arm. Damage to Lucy's pelvis, left shoulder and knee and right ankle was also consistent with a fall from a great height. Kappelman's team estimates that Lucy fell from a tree taller than 10 metres and died from her injuries, reaching a speed of up to 60 kilometres per hour at impact.

ARBOREAL ORIGINS

It's unclear how suited Lucy was to arboreal life. She walked upright, but she may have held onto adaptations that helped her ancestors cope in trees — although that idea is hotly debated. Kappelman's team proposes that Lucy would have slept in trees to avoid predators, yet was not as adroit there as her more-ape-like ancestors. "Here's the most famous fossil on the planet, the centre of the debate over arborealism in human evolution, and we think it's most likely she died from a fall out of tree," he says. ▶

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But Marc Meyer, a palaeoanthropologist at Chaffey College in Rancho Cucamonga, California, who recently examined Lucy in Addis Ababa, is sceptical. Chimpanzees tend to break their spines when they fall from trees, says Meyer, and "Lucy's spine does not come close to the amount of damage we would expect to see in a fatal fall".

Lucy's discoverers noticed her broken bones when they found her, but proposed that this had occurred after she died. Donald Johanson, the palaeoanthropologist at Arizona State University in Tempe who found Lucy in 1974, still stands by that interpretation. Broken bones such as Lucy's are common in other nearby remains, he notes.

Kappelman is keen for others to test their theory. Digital models of portions of Lucy's left knee and right shoulder and arm are available at eLucy.org.

But although printed bones and virtual models can be helpful, Meyer says there is no substitute for seeing a fossil in person. He found stark differences between *Ardipithecus ramidus*, a 4.4-million-year-old hominin also found in Ethiopia, and a physical cast that he studied, including several deformities not captured in the cast.

DIGITAL DOWNLOADS

Digital models of hominin fossils are rare, but a few are available. About 100 of the 1,500 remains ascribed to *Homo naledi*, uncovered in 2013 in a South African cave system, can be downloaded at MorphoSource.org, as can models of the 2-million-year-old *Australopithecus sediba* found by the same team in 2008.

AfricanFossils.org, which distributes digital models of hominin fossils for education and is headed by Leakey, contains numerous important specimens from Kenya. But the website's models, although sufficient for 3D printing in many cases, are purposefully low in resolution, so as not to cut into income generated from making physical replicas.

"The days of keeping this content squirrelled away are gone."

Kappelman would like to see such revenue streams maintained, for instance by making lower-quality models free while charging researchers for good digital reproductions. "What has to be done is to put together a good business model that allows these museums to be able to have some sort of revenue stream off of these data," he says.

Leakey, however, thinks that charging researchers will further limit access. She also points out that digital models can easily be pirated. "The days of keeping this content squirrelled away are gone," she says. "Once you make a 3D model available, to control it is impossible." ■

GENEALOGY

The 'family trees' of mathematics

Academic relationships hint at science, and world, history.

BY DAVIDE CASTELVECCHI

Most of the world's mathematicians fall into just 24 scientific 'families', one of which dates back to the fifteenth century. The insight comes from an analysis of the Mathematics Genealogy Project (MGP), which aims to connect all mathematicians, living and dead, into family trees on the basis of teacher–pupil lineages, in particular who an individual's doctoral adviser was[1].

The analysis also uses the MGP — the most complete such project — to trace trends in the history of science, including the emergence of the United States as a scientific power in the 1920s and the rise to dominance of different mathematical subfields.

"You can see how mathematics has evolved in time," says Floriana Gargiulo, who studies networks dynamics at the University of Namur, Belgium, and who led the analysis.

The MGP is hosted by North Dakota State University in Fargo and co-sponsored by the American Mathematical Society. Since the early 1990s, its organizers have mined information from university departments and from individuals who make submissions regarding themselves or people they know about. As of 25 August, the MGP contained 201,618 entries. As well as doctoral advisers and pupils of mathematicians, the MGP contains details such as the university that awarded the doctorate.

Previously, researchers had used the MGP to reconstruct their own PhD-family trees, or to see how many 'descendants' a researcher has. Gargiulo's team wanted to make a comprehensive analysis of the entire database and divide it into distinct families, rather than just looking at how many descendants any one person has.

After downloading the database, Gargiulo and her colleagues wrote machine-learning algorithms that cross-checked and complemented the MGP data with information from Wikipedia and from scientists' profiles in the Scopus bibliographic database.

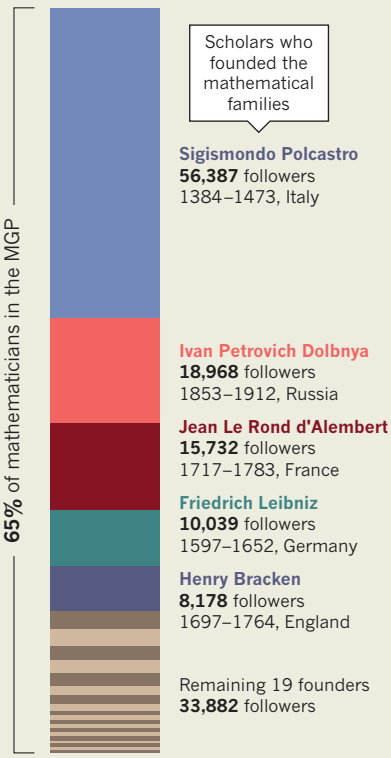
This revealed 84 distinct family trees with two-thirds of the world's mathematicians concentrated in just 24 of them. The high degree of clustering arises in part because the algorithms assigned each mathematician just one academic parent: when an individual had more than one adviser, they were assigned the one with the bigger network. But the phenomenon chimes with anecdotal reports from those who research their own mathematical ancestry, says MGP director Mitchel Keller, a mathematician at Washington and Lee University in Lexington, Virginia. "Most of them run into Euler, or Gauss or some other big name," he says.

Although the MGP is still somewhat US-centric, the goal is for it to become as international as possible, Keller says.

Peculiarly, the progenitor of the largest family tree is not a mathematician but a physician: Sigismondo Polcastro, who taught medicine at the University of Padua in Italy in the early fifteenth century. He has 56,387 descendants according to the analysis (see 'Mathematical clans'). The second-largest tree is one started by a Russian called Ivan Dolbnya

MATHEMATICAL CLANS

Two-thirds of mathematicians in the Mathematics Genealogy Project (MGP) belong to just 24 distinct academic families, according to an analysis that assigns 'parenthood' based on teacher–pupil relationships.



SOURCE: GARGIULO *ET AL.*/MGP