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.

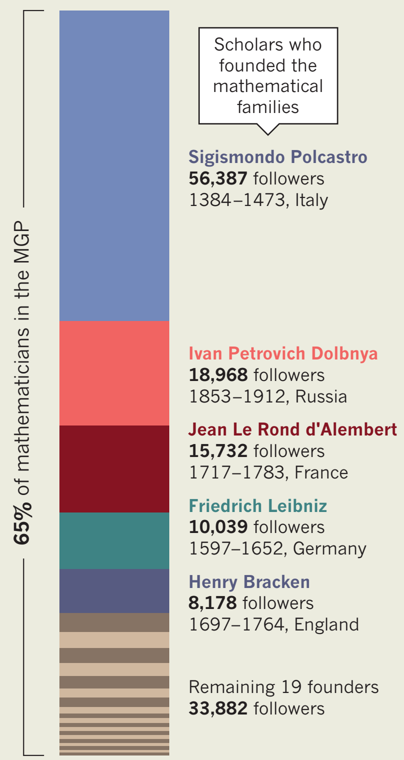
This revealed 84 distinct family trees with two-thirds of the world's mathematicians concentrated in just 24 of them. The high degree of clustering arises in part because the algorithms assigned each mathematician just one academic parent: when an individual had more than one adviser, they were assigned 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

in the late nineteenth century.

The authors also tracked mathematical activity by country, which seemed to pinpoint major historical events. Around the time of the dissolution of the Austro-Hungarian Empire, there is a decline in mathematics PhDs awarded in the region, notes Gargiulo. Between 1920 and 1940, the United States took over from Germany as the country producing the largest number of mathematics PhDs each year (see 'Mathematics in flux'). And the ascendancy of the Soviet Union is marked by a peak of PhDs in the 1960s, followed by a relative fall after the break-up of the union in 1991.

Gargiulo's team also looked at the dominance of mathematical subfields relative to each other. The researchers found that dominance shifted from mathematical physics to pure maths during the first half of the twentieth century, and later to statistics and other applied disciplines, such as computer science.

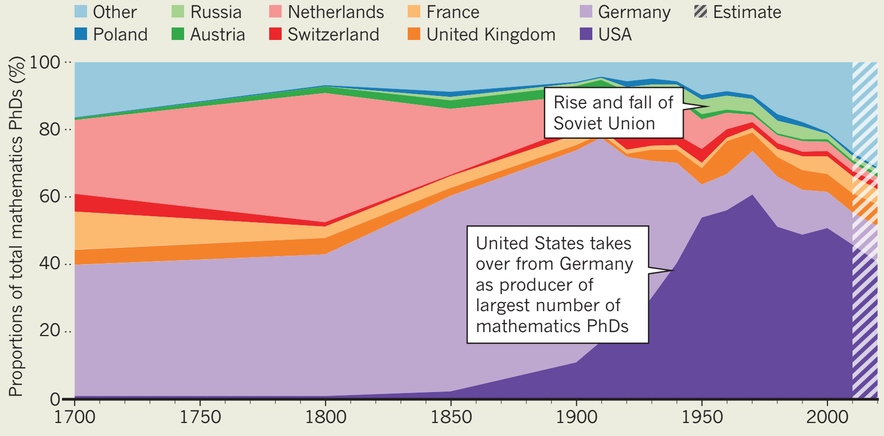
Idiosyncrasies in the field of mathematics could explain why it has the most comprehensive genealogy database of any discipline. "Mathematicians are a bit of a world apart," says Roberta Sinatra, a network and data scientist at Central European University in Budapest who led a 2015 study that mapped the evolution of the subdisciplines of physics by mining data from papers on the Web of Science[2].

Mathematicians tend to publish less than other researchers, and they establish their academic reputation not so much on how frequently they publish or on their number of citations, but on who they have collaborated with, including their mentors, she says. "I think it's not a coincidence that they have this genealogy project."

At least one discipline is trying to catch up. Historian of astronomy Joseph Tenn of Sonoma State University in California plans by 2017 to launch the AstroGen project to record the PhD advisers and students of astronomers. "I started it," he says, "because so many of my colleagues in astronomy admired and enjoyed perusing the Mathematics Genealogy Project." ■

MATHEMATICS IN FLUX

The proportion of mathematics PhDs produced by various countries changes over the centuries, tracing geopolitical trends.



SOURCE: GARGIULO *ET AL.*/MGP

1. Gargiulo, F. *et al. EPJ Data Sci.* **5,** 26 (2016).
2. Sinatra, R. *et al. Nature Phys.* **11,** 791–796 (2015).