on his site frequently complained to senior officials at his institution.

Last June, a scholarly-services firm called Cabell's International in Beaumont, Texas, launched a pay-to-view blacklist of journals it deems 'deceptive', listing criteria for deciding whether titles should be added. Kathleen Berryman, a project manager at the firm, says that a lack of clear explanations for why journals are on the anonymously maintained blacklists is a problem. Ideally, every entry on the list would state reasons for its inclusion, agrees the anonymous site manager. "I'm not sure if I will ever have time to do that myself," they say.

Berryman says that around 200 institutions have subscribed to Cabell's blacklist since its launch. The list contains about 8,000 journals, including some that aren't open access. (The firm also maintains a whitelist; some journals aren't on either list, Berryman says.)

Rick Anderson, an associate dean in the library at the University of Utah in Salt Lake City, says that the scholarly community does need a good list of predatory publishers (Anderson did paid consulting work for Cabell's when it was planning its blacklist). But it should include clear criteria and justifications for inclusion, explanations for removed entries and an appeal system, he says. "To do it well is going to be expensive and difficult." ■

PEOPLE

World's scientists pay tribute to Stephen Hawking

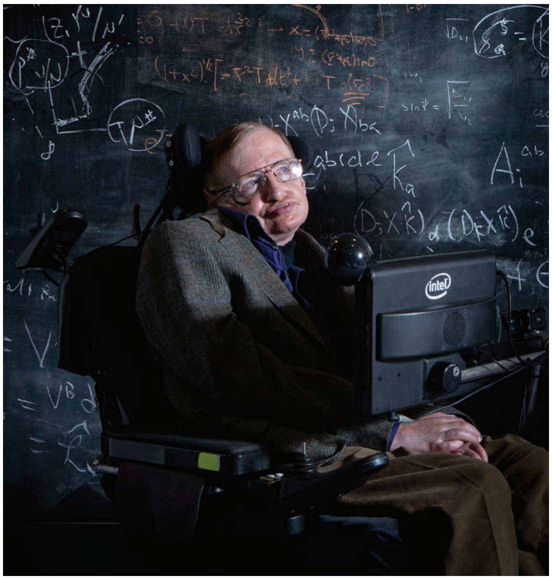
The physicist and science icon died at his home in Cambridge, UK, aged 76.

BY DAVIDE CASTELVECCHI

Stephen Hawking, one of the most influential physicists of the twentieth century and perhaps the most celebrated icon of contemporary science, died on 14 March at the age of 76.

Since his early twenties, Hawking had lived with amyotrophic lateral sclerosis (ALS), a disease in which motor neurons die, leaving the brain incapable of controlling muscles. His health had reportedly been deteriorating.

Hawking's death was marked by tributes from scientists worldwide. "The reaction among physicists is just profound shock and sadness," says Malcolm Perry, a theoretical physicist at the University of Cambridge, UK, and a student of Hawking's in the early 1970s. "He was a truly extraordinary man," says Roger Penrose, a theoretical physicist at the University of Oxford, UK, who in 1970 co-authored a seminal paper with Hawking on black holes.



TOM PILSTON/PANOS

Stephen Hawking, giant of cosmology, in 2013.

Another former student, theoretical physicist Raphael Bousso at the University of California, Berkeley, told *Nature* that his teacher was a brilliant physicist who also excelled at communicating science to the public. "Stephen was a joyful and light-hearted person, not to be burdened by excessively respectful and convoluted interactions," he says.

The British physicist was born in Oxford in 1942. He was diagnosed with ALS when he was 21, while a doctoral student in cosmology at the University of Cambridge. Physicians gave him just a few years to live, but his disease advanced more slowly than expected. He had an active career for decades, both as a theoretical physicist and as a popularizer of science. Hawking became one of the most recognized names in contemporary science. His books, particularly *A Brief History of Time* (1988), became blockbuster successes. He relished making cameo appearances on television shows such as *Star Trek: The Next Generation* and *The Simpsons*.

Scientifically, his name is most closely associated with the physics of black holes, which he began to study when they were considered mere mathematical curiosities in Albert Einstein's general theory of relativity. In the early 1970s, he began to investigate what quantum physics could reveal about the event horizon, a black hole's surface of no return. Hawking shocked the physics world when he calculated that this surface should slowly emit radiation (soon to become known as Hawking radiation). Black holes were not truly black.

This emission, he reasoned, should ultimately lead a black hole to shrink and disappear (S. W. Hawking *Nature* **248,** 30–31; 1974). Even more shocking to researchers was Hawking's realization in 1976 that Hawking radiation should erase information from the Universe, in apparent contradiction to some of the basic tenets of quantum theory (S. W. Hawking *Phys. Rev. D* **14,** 2460–2473; 1976). "The importance of this work was not so much the effect itself, but that he was able to provide the one clear-cut physical implication that we know of which brings together the two great revolutions of twentieth-century physics, namely, general relativity and quantum mechanics," says Penrose.

Two years ago, together with Perry and Andrew Strominger at Harvard University in Cambridge, Massachusetts, Hawking began to sketch a possible way out of the black-hole information paradox. The three of them, along with Strominger's student Sasha Haco, had been working on a follow-up paper, which Perry says is in its final stages and will have Hawking's name on it.

Perhaps because most of his work was of a speculative nature and difficult to test, Hawking never won a Nobel prize. In 2016, some wondered whether he might finally win one, when Jeff Steinhauer, a physicist at the Technion–Israel Institute of Technology in Haifa, announced that he had found convincing evidence of Hawking radiation — not in an actual black hole, but in a laboratory analogue made of ultra-cold atoms. However, some experts still consider those results inconclusive.

A more direct test of some of Hawking's findings might yet come from the study of ▶

astrophysical black holes through gravitational waves, initiated by the US-based Laser Interferometer Gravitational-wave Observatory (LIGO). Hawking and others have linked the surface area of a black hole's event horizon to its entropy, a measure of disorder. When interviewed by *Nature*'s news team in 2016 about LIGO's first detection of gravitational waves from merging black holes, Hawking said that he hoped future detections would be sensitive enough to confirm a prediction he had made in the 1970s: that the surface area of a post-merger black hole should exceed the combined surface areas of the original objects that formed it.

Together with cosmologist Thomas Hertog, another of his former students, Hawking had also explored cosmic inflation — a brief period of rapid expansion in the first moments of the Big Bang — and how it could spawn several universes, a 'multiverse'. The pair set out to transform the idea of a multiverse into a testable scientific framework, says Hertog. "This was Hawking: to boldly go where *Star Trek* fears to tread." ■ SEE OBITUARY P.444

PALAEOANTHROPOLOGY

Surprise roots for human culture

Technology developments linked to climate turbulence.

BY JEFF TOLLEFSON

Early humans in eastern Africa crafted advanced tools and displayed other complex behaviours tens of thousands of years earlier than previously thought, according to a trio of papers published on 15 March in *Science*[1–3]. Those advances coincided with — and may have been driven by — major climate and landscape changes.

The latest evidence comes from the Olorgesailie Basin in southern Kenya, where researchers have previously found traces of ancient relatives of modern human as far back as 1.2 million years ago (see 'Complex lives'). Evidence collected at sites in the basin suggests that early humans underwent a series of profound changes at some point before roughly 320,000 years ago. They abandoned simple hand axes in favour of smaller and more advanced blades made from obsidian and other materials obtained from distant sources. That shift suggests the early people living there had developed a trade network — evidence of growing sophistication in behaviour. The researchers also found gouges on black and red rocks and minerals, which indicate that early Olorgesailie residents used those materials to create pigments and possibly communicate ideas.

A TIME OF CHANGE

All of these changes in human behaviour occurred during an extended period of environmental upheaval, punctuated by strong earthquakes and a shift towards a more variable and arid climate. These changes occurred at the same time as larger animals disappeared from the site and were replaced by smaller creatures. "It's a one-two punch combining tectonic shifts and climate shifts," says Rick Potts, who led the work as director of the human origins programme at the Smithsonian Institution in Washington DC. "That's the kind of stuff out of which evolution arises."

The studies push back the timeline for such behaviour by around 100,000 years, adding to a growing body of evidence suggesting that the roots of human culture are deeper and more extensive than once thought.

The latest evidence is "probably not enough to put the question to rest as to what effect the climate variability had on human behaviour", says Nick Blegen, an anthropologist at the Max Planck Institute for the Science of Human History in Jena, Germany. But he says that the findings from Olorgesailie provide solid evidence for a shift towards sophisticated behaviour that predates the earliest evidence for *Homo sapiens*. Researchers have traditionally thought that *H. sapiens* emerged around 200,000 years ago, but fossils discovered in Morocco could push that date to more than 300,000 years ago[4].

Blagen has documented the transport of obsidian in central Kenya roughly 200,000 years ago[5], and he is preparing another study that would push that record back to 396,000 years ago at the same site. The record for such complex behaviour is likely to extend back even further, he says, but it is not clear whether the environment is shaping human behaviour, or whether advances in human behaviour are enabling them to inhabit riskier environments.

HUMAN ORIGINS PROGRAMME, SMITHSONIAN

Simpler tools (left) gave way to smaller and more complex versions (right) in Kenya's Olorgesailie Basin.

COMPLEX TOOLS

Excavations in the Olorgesailie Basin have been turning up Stone Age artefacts ever since Louis and Mary Leakey pioneered work there in the 1940s. But this is the first time that scientists have documented evidence of more advanced tools and behaviours typically associated with the Middle Stone Age, which lasted until 25,000–50,000 years ago, says Alison Brooks, an anthropologist at George Washington University in Washington DC, who led the dating and analysis of the latest artefacts.

Isotopic dating techniques helped the team to pin down the age of the stone tools, and the researchers traced the obsidian back to its sources, which were mostly located 25–50 kilometres away in multiple directions. "It's the best evidence yet for the exchange of raw materials" so early in time, Brooks says.

Curtis Marean, a palaeoanthropologist at the