kicks in when they reach an age two to five times their age of sexual maturity.

But not naked mole rats. After they reached sexual maturity at 6 months of age, each animal's daily chance of dying was a little more than one in 10,000, Buffenstein found, and it stayed roughly the same, and even went down a little, throughout their lives—even after they reached 25 times the age of sexual maturity. Dying, for naked mole rats, is "stochastic," Buffenstein says. "It's like radioactive decay."

Caleb Finch, a biogerontologist at the University of Southern California in Los Angeles, agrees that the animals' mortality is "remarkably low." "At advanced ages, their mortality rate remains lower than any other mammal that has been documented," he says. But more data on older naked mole rats are needed to be sure that their risk of dying really is flat, he says. Fewer than 50 in the study lived past 15 years of age, because many of the animals were killed or moved to other labs.

Buffenstein says her data are enough to show that the animals don't age. "If you look at any rodent aging study, 100 animals is all you need to see Gompertz aging. Here we have 3000 data points and we're not seeing it," she says. "To me it says that these animals really have figured out a way to slow aging."

Still, the oldest animal currently living in Buffenstein's lab is 35, and few are older than 30. Matthias Platzer, a biologist at the Leibniz Institute on Aging in Jena, Germany, says it's still not clear what happens when naked mole rats age beyond 30 years. "Maybe aging happens really fast then? Even Rochelle Buffenstein does not have the data on this," he says.

The big question is how naked mole rats stay so young. Their low body temperature of about 32°C may help them avoid accumulating cellular and molecular damage, says Magalhães, and there is evidence that, compared with other mammals, they have better DNA damage repair and are more efficient at getting rid of misfolded proteins. Buffenstein says she hopes to identify a master switch controlling all these antiaging measures. "We're pretty certain that with so many things being different there has to be something upstream regulating the whole process."

Although the naked mole rat is a special case, it could end up being the key to understanding aging in other mammals, including people, says Buffenstein, just as studying squid giant axons helped neuroscientists fathom how nerve cells work. "I would argue," she says, "that most of our biggest discoveries in biology have been made using freak animals." ■

PHYSICS

Accelerator boom hones China's engineering expertise

Bevy of particle accelerators could pave the way for future collider that would be world's largest

By **Dennis Normile**, *in Dongguan, China*

Aiming a stream of protons at a target to produce neutrons for experiments is "so hard to do," says Andrew Taylor, former director of the ISIS Neutron and Muon Source near Oxford, U.K. Most accelerators generate electron beams; accelerating and controlling protons, which are 2000 times as heavy, is far more complex and requires higher magnetic fields. The targets themselves pose challenges, too. In raising the curtain on the China Spallation Neutron Source (CSNS) here, China has joined just four other nations in having mastered the technology. The $277 million facility, set to open to users this spring, is expected to yield big dividends in materials science, chemistry, and biology.

More world class machines are on the way. China is starting construction on four more major accelerator facilities this year (see table, below). The building boom is prompting a scramble to find enough engineers and technicians to finish the projects. But if they all come off as planned, the facilities collectively will put China "on par with or leading the world in the design, construction, and exploitation of accelerator-based research and applications," says Wu-Tsung Weng, an accelerator physicist at Brookhaven National Laboratory in Upton, New York.

That would position China to tackle the next global megaproject: a giant accelerator that would pick up where Europe's Large Hadron Collider (LHC) leaves off. With a $6 billion price tag and a planned circumference of at least 50 kilometers, the Circular Electron Positron Collider (CEPC) would study the Higgs boson in detail. A possible future upgrade that would cost billions of dollars more, the Super Proton-Proton Collider, would search for physics beyond the standard model at several times the LHC's energy levels. The CEPC, which backers hope to see built by 2030, would "put China in a dominant position in fundamental physics in the world in the 21st century," says Shing-Tung Yau, a mathematician at Harvard University. Many high-energy physicists in China and abroad think the CEPC is an obvious next step, though researchers in other disciplines worry it will monopolize available resources.

The current construction binge reflects a late start and pent-up demand. The Institute of High Energy Physics (IHEP) in Beijing inaugurated China's first particle accelerator, the Beijing Electron Positron Collider, in 1989; it was followed 2 years later by the Hefei Light Source, a facility designed to

Accelerating Chinese science

China is ramping up its capacity in accelerator physics with several machines nearing completion or coming online in the next decade. Particle physicists hope the buildup will climax with the Circular Electron Positron Collider.

FACILITY (LOCATION)	RESEARCH TARGET	COST	STATUS/SCHEDULE
China Spallation Neutron Source (Dongguan)	Materials science, physics, chemistry, and life sciences	$277 million	Opening to users in spring
Shanghai Soft X-ray Free-Electron Laser (FEL), Hard X-ray FEL (Shanghai)	Materials science and life sciences	$110 million	Soft x-ray FEL opening to users in mid-2019 Hard x-ray FEL online in 2025
High-Energy Photon Source (Beijing)	Materials science, chemistry, and biomedicine	$730 million	Mid-2025
China Initiative Accelerator Driven System (Huizhou)	Nuclear waste transmutation and future energy technologies	$280 million	2024
High-Intensity Heavy ion Accelerator Facility (Huizhou)	Atomic and nuclear physics	$240 million	2024
Circular Electron Positron Collider (site TBD)	Particle physics	$6 billion	Under study

produce synchrotron radiation for studies of molecules and materials. The next major accelerator—another effort to catch up with other countries—was the Shanghai Synchrotron Radiation Facility, completed in 2009.

By then, China's physicists were thinking bigger. Next on the wish list was a powerful spallation neutron source. By the early 2000s, the United Kingdom and Switzerland had such machines in operation, and the United States, Japan, and a European consortium were either building or planning comparable facilities. It was clear that "neutron scattering would be very important for many fields," says Chen Hesheng, CSNS project manager. Neutrons interact weakly with other particles, making them better than synchrotron x-rays at probing cells or substances without damaging them. Just as the CSNS was getting underway, China's physicists got a windfall. In 2010, the National Development and Reform Commission (NDRC), China's primary funder of big science projects, agreed to build several more accelerators; four won funding under China's 13th 5-year plan, starting in 2016.

Technological development for the new facilities is ambitious, Taylor says. A hard x-ray free-electron laser, being built by the Shanghai Institute of Applied Physics (SINAP) and ShanghaiTech University, employs superconducting cavities to accelerate electrons that shed x-rays. That approach, used in only three other facilities in the world, yields higher energies, says Wang Dong, an accelerator physicist at SINAP. A heavy-ion accelerator now rising at a new complex in Huizhou, China, will have a higher beam intensity than comparable machines elsewhere, providing advantages in studying atomic and nuclear structures and the origin of heavy elements, explains Chen Xurong, a nuclear physicist heading the project for the Institute of Modern Physics in Lanzhou, China. The Huizhou complex will also host an accelerator-driven system that will experiment in nuclear waste transmutation and energy production.

Groundbreaking is slated this year for what would become one of the world's brightest x-ray sources, IHEP's High-Energy Photon Source in Beijing. It owes its intense brightness to a beam bending angle that cuts energy losses, says project manager Qin Qing. It, too, relies on superconducting cavities.

The CEPC likely would rely on similar cavities, says Lou Xinchou, an IHEP deputy director in charge of planning the mega-accelerator. The High-Energy Photon Source, he notes, also requires know-how in cooling and control technologies that will pay off for the CEPC.

IHEP is now working on a conceptual design for the CEPC, due out in April. But some physicists wonder whether the scientific payoff will be worth the investment, even though China anticipates that international partners will bear a hefty share of the machine's cost. In 2016, NDRC rejected IHEP's request for $100 million for R&D on the megacollider during China's current 5-year plan, forcing the institute to scrape together funds from other sources. "This is a great project for China and the world," Yau argues. He notes that 300 scientists from nine countries contributed to the preliminary design report.

In the meantime, the flurry of activity in planning and completing the approved accelerator projects has left IHEP staff "overloaded," says the CSNS's Chen Hesheng. His institute and others are recruiting from the Chinese diaspora to get the job done. Lou is one example. Mainland-born, he took a leave from a tenured position at the University of Texas in Austin to work on the CEPC. Adequate funding is another challenge, as construction spending squeezes budgets for operating the new facilities. The CSNS, for example, planned for five experimental instruments, but is starting with three because construction costs rose more than anticipated.

Still, as IHEP's Wang Sheng puts it: "It's a good time to be an accelerator physicist in China." ■

The new China Spallation Neutron Source is one of just a handful of comparable facilities worldwide.

PHOTO: INSTITUTE OF HIGH ENERGY PHYSICS

ECOLOGY

Dams nudge Amazon's ecosystems off-kilter

Decline of giant catfish emblematic of habitat fragmentation

By **Barbara Fraser**, *in Lima*

Once upon a time, thousands of dorados, a giant among catfish, would swim more than 3000 kilometers from the mouth of the Amazon River to spawn during the austral autumn in Bolivia's Mamoré River, in the foothills of the Andes. But the dorado, which can grow to more than 2 meters in length, is disappearing from those waters, and scientists blame two hydropower dams that Brazil erected a decade ago on the Madeira River.

"The dams are blocking the fish," says Michael Goulding, a Wildlife Conservation Society aquatic ecologist in Gainesville, Florida, who has been studying the dorado since the 1970s. They are "probably on their way to extinction" in Peru and Bolivia.

Most Amazon dams are in Brazil, where scientists have raised concerns about the displacement of local communities and emissions of greenhouse gases such as carbon dioxide and methane from large reservoirs. But as countries seek new energy sources to drive economic growth, a surge in dam construction on the eastern flank of the Andes could further threaten fish migration and sediment flows, Elizabeth Anderson, a conservation ecologist at Florida International University in Miami, and colleagues warn this week in *Science Advances*.

For the ecology of the western Amazon Basin, where the mountains meet the lowlands, the main consequence of proliferating dams is habitat fragmentation (see map, p. 509). Interference with spawning is one facet. Another is that dams hold back sediments and nutrients that nourish the Amazon Basin, Anderson says. Her team documented 142 hydropower dams that are operating or under construction on headwaters in the western Amazon Basin, and another 160 that are under consideration. If even a fraction of the planned projects

Science

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