world-leading scientific powerhouse by 2050.

In 1990, the government began investing in nanoscience via schemes such as the State Science and Technology Commission's Climbing Up project on nanomaterials. In 1999, the Ministry of Science and Technology began a basic research project, Nanomaterial and Nanostructure, and by 2006 the field had become one of the four pillars of basic research that received targeted funding from central government. Last year, the Suzhou Institute of Nano-Tech and Nano-Bionics announced a US$200-million plan to build the world's largest multifunctional nanoscience research facility for computer and robot technologies.

China's nano-related output has grown from 820 papers in 1997 to more than 52,000 papers in 2016 in the Science Citation Index. Four of the top 10 institutions for high-quality nanotechnology output are in China, according to the index.

The most popular area of the country's nanoscience papers is in catalysis research, according to the number of articles listed in *Nature*'s Nano database, a web platform that examines the quantity and impact of nano-related research papers published globally. Experts predict this area of nanoscience research will continue to flourish. A team of scientists led by Bao Xinhe at the Dalian Institute of Chemical Physics has developed a catalyst that enables the direct conversion of synthetic fuel gas to light olefins, the basic building blocks of plastics.

MODEST RETURNS

Chinese researchers have also contributed to nanomedicine applications, such as improved methods for treating cancer. Despite such developments, Dai Qing, who returned to China in 2012 to launch a nanophotonics laboratory at the National Center for Nanoscience and Technology, is among those who believe Chinese scientists should push for stronger returns on investment. "We need to find a stand-out application to demonstrate that it is beneficial to the country to spend this money, not just talk about the possibilities," he says.

Dai says that the grants structure has changed to reflect a push for tangible outcomes. "If you want a flagship grant you definitely need to find an industry partner." Examples of change include developing interdisciplinary teams within Chinese institutes, taking a stronger lead in international projects, and working more closely with industry partners. For example, in May 2018, a minimally invasive cancer therapy was trialled in Shanghai. The 'nano gun' is a device loaded with anti-cancer agents that is injected into tumours. It was developed by a Chinese team working with Algerian researchers, based in France. If trials are successful, it will be developed for application in China.

As a young scientist Zhang, whose drive impressed Leigh, broke with tradition by initiating a conversation with his former professor, Hai-Bo Yang, from ECNU's Department of Chemistry about starting a lab, which is now open. "Historically, respected Chinese academics court international talent to create collaborations. I realized young starters could do it with the help of senior local professors," Zhang says. "To succeed in academia you need to learn to make connections."

In 2018, China established its first private research institute, Westlake University in Hangzhou. It is backed by some of the country's wealthiest industrialists, including Ma Huateng (Pony), founder and CEO of Internet giant Tencent, and Wang Jianlin, founder and chairman of the Dalian Wanda Group.

Many agree that while China has a bright future, cultural factors can hinder its ability to compete. On Zhang's new team are four postdocs, two from China, and two from the UK and Germany. All were invited to Manchester for training. During that period Zhang noticed how culture and language influence research styles. "Discoveries often come from conflict or argument. But Chinese people can be culturally averse to this," he says. "Also, when you're working in your second language, it can be hard to argue your point."

Zhang believes the country will become a nanotech world leader. Certainly, Leigh believes that his days of being revered in China are numbered. ■

NANOTECHNOLOGY

TOP INSTITUTIONS 2015–2017:
1. Tsinghua University (Fractional count: 29.16)
2. Peking University (FC: 28.45)
3. Soochow University (FC: 24.23)

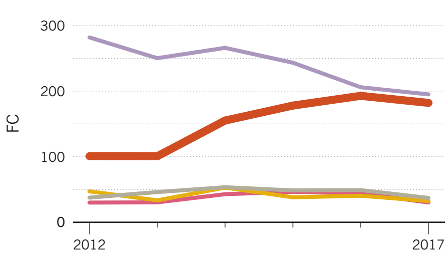
CHINESE INSTITUTIONS IN SUBJECT'S GLOBAL TOP 20: 7

INTERNATIONALLY COLLABORATIVE ARTICLES 2015–2017: 49.9%

TOP CHINESE–INTERNATIONAL COLLABORATIVE PAIR 2015–2017:
Soochow University – Monash University, Australia (CS*: 3.92, Article count: 6)

ATTAINS WORLD NUMBER ONE: 2018**

TOP 5 COUNTRIES (2012–2017):
China, United States, South Korea, Germany, Japan



*Bilateral collaboration score **Extrapolation only

SOURCE: NATURE INDEX/DIMENSIONS FROM DIGITAL SCIENCE

ENGINEERING A BIOMEDICAL REVOLUTION

A permissive regulatory climate and a pragmatic approach has seen China's bioscience sector soar.

BY SMRITI MALLAPATY

For the past 20 years, French neuroscientist Erwan Bezard has spent at least one week every two months in Beijing. Bezard makes the long journey from France to visit the primates bred in Chinese labs.

China has become the top destination for research involving these animals, which are invaluable models for studying human disease. Other countries do not breed the primates in such large numbers or to the standard produced in China.

"Some 95% of papers using transgenic monkeys come from China," says Bezard, director of the Institute of Neurodegenerative Diseases at the University of Bordeaux, and manager of his own lab at the Institute of Laboratory Animal Sciences, Chinese Academy of Medical Sciences. Among recent breakthroughs, researchers at the Chinese Academy of Sciences (CAS) have genetically modified cynomolgus monkeys so they exhibit autistic-like behaviours, to better understand what causes the disorder, and how to treat it. CAS scientists have also cloned primates using a technique similar to the one that produced Dolly the sheep. Bezard has used rhesus monkeys to show how brain–computer interfaces can restore leg movement after spinal cord injury.

These developments have coincided with improvements in the regulation and enforcement of international standards in the biosciences in China. Two events were critical to the process: the 2003 SARS outbreak, which put a spotlight on the issue of wildlife and lab animal management, and the creation in China of the world's first human–rabbit embryos in 2001, which provoked an international public relations crisis for the country.

The Chinese government recognizes that bioscience will play a major role in its global competitiveness. Biomedicine, synthetic biology and regenerative medical techniques are listed as strategic fields and industries in China's 13th Five-Year Plan. "China doesn't want to miss the life-science biotech revolution," says Cao Cong, an innovation studies researcher at the University of Nottingham Ningbo China.

Scientists have also realized that to gain

Genetically identical cloned monkeys Zhong Zhong and Hua Hua are the first primates to emerge from the method that produced Dolly the sheep.

JIN LIWANG/XINHUA/EYEVINE

global recognition for their achievements, they must play by internationally accepted rules, says Du Yanan, a biomedical engineer at Tsinghua University, who returned to China in 2010 after three years at Harvard-MIT Health Sciences and Technology.

Chinese life scientists have used advanced medical imaging technology to better detect malignant nodules in the lungs, created the first monkeys using the CRISPR–Cas9 gene-editing technique, and discovered that fetal DNA flows through the mother's bloodstream. That advance led to the development of a non-invasive test for Down's syndrome during pregnancy, which is used around the world.

In the Nature Index, China is the second leading contributor to biomedical engineering articles after the United States, measured by its contribution to the authorship of papers in 82 high-quality research journals in 2015–17.

CROSS-EXAMINED

In 2001, such advances were unthinkable. In September of that year, Chinese newspapers reported that Chen Xigu, a scientist at Sun Yat-sen University in Guangzhou, had successfully grown rabbit embryos injected with skin-cell nuclei taken from a seven-year-old boy.

"At that time, no one thought that China could make such a breakthrough," says Joy Zhang, a sociologist at the University of Kent in the United Kingdom. The resulting hybrids could be used to derive human embryonic stem cells, useful for regenerative medicine.

The national response was buoyant, but brief. Within days, there was international outcry over the research and China was being called the 'Wild East' of biology. Startled by the furore, the government effectively banned all hybrid embryonic stem cell research, says Zhang. Chen's hybrid research came to an abrupt end, though he remained on the Sun Yat-sen faculty and continued to supervise students, particularly on somatic (non-reproductive) stem cells.

China's bioethics landscape has evolved since the incident. In 2003, the Ministry of Science and Technology and the then Ministry of Health (MoH) issued guidelines for human embryonic stem cell research. Between 2009 and 2013, the MoH introduced administrative measures and regulations governing the clinical application of medical technology and stem cells. A national standard for lab animal institutions came into effect in 2014.

Zhang describes the government's regulatory approach as pragmatic, in which it "copy-pastes" international regulations, largely following the relatively permissive stance of the UK. By clearing the regulatory route for research, says Zhang, China has attracted many overseas-Chinese scientists and non-Chinese collaborators. "Permissive regulation has helped China's quick ascent," says Zhang.

INFORMED CONSENT

On his return to Beijing in 2010, Du experienced lab-culture shock. Researchers were raising lab animals under varying conditions and killing them without humane procedures. Doctors were handing over patient samples to researchers without patient consent.

These practices, although expedient, come with serious risks. Unscrupulous behaviour opens science to criticism, and can make research ineligible for publication in top journals. And, the failure to follow procedures undermines the reproducibility of the results.

Submissions to many reputable journals must be accompanied by approvals from ethics committees. In the years since his return, Du — who has co-authored several recent papers on methods for introducing stem cells into the body — has witnessed great progress in biomedical research ethics.

For example, the first accreditation of a Chinese facility by the Association for Assessment and Accreditation of Laboratory Animal Care International (AAALAC International) was in 2006; by 2016 around 60 Chinese programmes were accredited by this organization, a non-profit promoting the responsible care and use of animals in science under a voluntary certification framework. China has also begun to take more initiative in global policy debates and set standards in emerging fields, such as stem cells and synthetic biology.

When in 2015, Chinese researchers became the first to use CRISPR on nonviable human embryos, sparking another global ethics debate, the government's response was much more measured than it had been in the recent past, says Zhang. The government clarified its position and regulatory procedures, specifying that embryo gene editing is permitted in China for basic and preclinical research, but prohibited for clinical or reproductive use.

VAST BACKYARD

But, in ethical practice, Chinese science remains highly variable. Decisions about how to implement broad-brush guidelines are left to the discretion of institutions and researchers. The recent claims of genome-edited twins by He Jiankui at the Southern University of Science and Technology of China (SUSTech), which SUSTech has distanced itself from and more than 100 Chinese biomedical researchers have strongly condemned, is a case in point.

Implementation remains patchy, says Du, especially in universities and hospitals in remote regions. When it comes to enforcing standard practices across the whole of China, he says, "we still have a long way to go."

Part of the problem, says Zhang, is one of communication. Good enforcement, she says, requires not just top-down monitoring, but also engagement with the public about "what they should expect and what they are, by law, entitled to." A failure to interact with public interest groups about the rules facilitates the spread of rumours, misconceptions and distrust in science, says Zhang. ■

BIOMEDICAL ENGINEERING

TOP INSTITUTIONS 2015–2017:

1. Soochow University (Fractional count: 11.39)
2. Nanjing University (FC: 10.07)
3. Xi'an Jiaotong University (FC: 7.71)

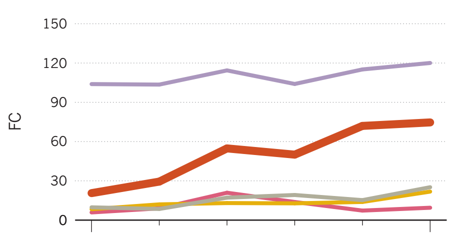
CHINESE INSTITUTIONS IN SUBJECT'S GLOBAL TOP 20: 5

INTERNATIONALLY COLLABORATIVE ARTICLES 2015–2017: 51.7%

TOP CHINESE-INTERNATIONAL COLLABORATIVE PAIR 2015–2017:
Beijing Institute of Nanoenergy and Nanosystems, CAS – Georgia Institute of Technology, United States
(CS: 6.27, Article count: 12)

ATTAINS WORLD NUMBER ONE: 2022*

TOP 5 COUNTRIES (2012–2017):
China, United States, South Korea, Germany, Japan



*Bilateral collaboration score **Extrapolation only

NATURE INDEX/DIMENSIONS FROM DIGITAL SCIENCE

STRONG SPENDING COMPOUNDS CHEMISTRY PROWESS

The discipline's historic prominence in China is underpinned by its crucial value to industrial processes. Committed funding sees it leading the way in emerging areas, such as nanomaterials.

BY HEPENG JIA

There were no research labs and no chemical testing devices when Lu Wei and colleagues joined the chemistry department of the new Southern University of Science and Technology (SUSTech) in Shenzhen in 2012. Their only teaching demonstration labs were in a makeshift building; equipment had to be set up and dismantled for each class. "Our graduate students had to cycle for several kilometres to test our samples in partner labs nearby," says Lu, founding head of the department.

As their labs took shape around them, lively discussions stretching into the evenings, sometimes with beer, sparked ideas between young faculty members, recalls Lu. Teams rearranged themselves in new combinations to stretch limited resources further by simplifying logistics.

When state-of-the-art labs were built two years later, with generous funding from the Shenzhen municipal government, the young chemists at SUSTech quickly made breakthroughs, rising to be among the top 50 in China for high-quality chemistry research with a fractional count (FC) of 83.41 for 2015–17 in the Nature Index.

One recent study in *Science*, lead by SUSTech chemist, Tan Bin, identified a catalyst that improves the efficiency of the chemical reaction known as Ugi, which has been widely used to synthesize compounds, especially in the search for new pharmaceuticals.

From 2012 to 2017, China's FC in the Nature Index for chemistry grew by 84% from 2,712 to 4,993, ranking it as the world's second after the United States. By contrast, the US saw a decline of 10% from 6,026 to 5,451.

Among the chemistry sub-disciplines, China surpassed the US for top position in organic chemistry in 2015. It has run second to the US in most other chemistry sub-disciplines in recent years.

"The solid scientific foundation built by Chinese chemists over many years, the nurturing of young talent, and the state's surging investment in research have combined to contribute to this significant growth," says Chen Xiaoming, a chemist at Guangzhou-based Sun Yat-sen University (SYSU), who is also a member of the Chinese Academy of Sciences (CAS).

Chemistry has long been China's top-performing discipline in terms of international research publications. Its crucial importance to many industrial processes has guaranteed it sustained attention since modern science was introduced to the country, says Lu.

ORGANIC GROWTH

Organic chemistry, which studies compounds and materials containing carbon, is the strongest sub-discipline, due to its "wide application, easier operation and huge number of researchers," says Lu, adding that it is very cheap and quick to set up an organic chemistry lab.

There has been rapid growth in studies on organic synthesis methods, nano-catalysts, synthetic organofluorine chemistry, visible-light-driven organic reactions, and natural product chemistry. So said a May 2017 special edition dedicated to organic chemistry of China's most prestigious multidisciplinary journal, *National Science Review*.

Ma Shengming, guest editor of the edition and a leading chemist at CAS Shanghai Institute of Organic Chemistry (SIOC), pointed out the great industrial and environmental benefits of many of these studies which involved interdisciplinary collaboration with emerging areas such as nanomaterials.

For example, according to Hu Jinbo of SIOC, which topped the Nature Index in organic chemistry with an FC of 139.17 for 2015–17, Chinese chemists have made significant progress in improving synthetic organofluorine chemistry, which can reduce chemical pollution. In another example, visible-light-driven organic reactions greatly lower the energy needed for industrial organic chemical synthesis, wrote Wu Lizhu of the CAS Technical Institute of Physics and Chemistry in the special issue.

The large recruitment of chemists particularly through the Young Thousand Talents Plan has provided a fresh boost to the booming study of chemistry in China, says Zhao Dongbing, a chemist at Tianjin-based Nankai University, who was enrolled as a scholar under the plan after completing his postdoctoral research at Cornell University and the University of Washington in Seattle. China launched the plan in 2008 to attract established scientists and high-tech entrepreneurs to return to China. In 2011, the programme was extended to young scholars, mostly