Sarah E. Reisman, Division of Chemistry & Chemical Engineering, California Institute of Technology, is the 2019 recipient of the Cottrell Frontiers in Research Excellence and Discovery (FRED) Award from Research Corporation for Science Advancement. Her work uses machine learning methods to predict new, efficient structures for nickel-catalyzed cross-coupling reactions. Her goal is to develop a computational tool that dramatically accelerates the rate of discovery and optimization of new nickel catalysts.

The Cottrell FRED Award supports early stages of exceptional, high-risk/high-reward research that may potentially transform a field of scientific inquiry. It is presented to highly creative Cottrell Scholars whose ideas and potential solutions, though not readily funded by conventional grant programs, address major current challenges in the recipients’ areas of research expertise. By developing unique perspectives for solving key challenges, Cottrell FRED awardees create new approaches that accelerate basic science research for the benefit of society.

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Celebrating old and new: Nankai University turns 100

Nankai University's 100th anniversary highlights its strong vision for scientific endeavor. Here, a look at six prominent departments at Nankai—chemistry, life sciences, mathematics, environmental science and engineering, physics, and computer science—shows how far the university has come and how bright its future appears.

A future for materials chemistry

Nankai's chemistry team, formed in 1919, has an impressive standing in the scientific community and is ranked in the top 0.1% worldwide for its research, according to the Essential Science Indicators (ESI) database. However, the department has no intention of resting on its laurels. According to Chen Jun, the university's vice president, the resource, energy, and environmental challenges that face China and the rest of the globe fuel the ambitions of chemistry researchers at Nankai.

"It is imperative to shift from combustion-engine propulsion to electrified transportation, for example," Chen says. "However, for technologies such as electric-vehicle batteries, the gap between theory and practice needs to be narrowed, and for that we need progress in scientific research on the rational design and synthesis of key materials." His team is currently developing low-cost batteries that have a high-energy density and longer life spans.

At the same time, Nankai chemist Zhou Qilin, a catalyst scientist, is working on a project to transform CO₂ into a more useful material.

"It’s extremely challenging to find the catalyst that will convert carbon dioxide into organic compounds. We’ve been exploring the subject for several years. It will take a long time, but it is important work, as we need to find alternative sources to synthesize materials before fossil fuels run out," says Zhou.

In 2018, Zhou won China’s top science prize, the Future Science Prize for physical sciences, for his previous work on chiral catalysts, which are now used by international pharmaceutical and chemical companies to make drugs, reagents, and pesticides.

Throughout its history, the team has had many firsts. During the 1980s, the first prototype nickel–metal hydride battery (a type of rechargeable battery) was developed by Nankai’s chemists. In 1987, Zhang Yunshi led one of China’s first groups to perform basic and applied basic research on high-energy batteries. Then in 1992, the department set up the country’s first university-based institute of new energy materials chemistry. "Nankai has a fascinating academic atmosphere," says Chen. "My colleagues inspire me to work with passion every day."

One of the department’s top talents is Chen Yongsheng, one of the world’s most-cited scientists according to Clarivate Analytics. His research focuses on developing high-performance materials, devices, and technologies that can convert sunlight to electricity, and electricity to other energy formats, such as chemical energy in batteries. Recent breakthroughs include achieving high efficiency when converting sunlight to electricity using organic photovoltaic technology, which he believes brings its commercial application one step closer. He is also hopeful for the possibilities of 3D graphene, a new material that has the potential to be used in next-generation batteries for storing electrical energy more efficiently and for longer periods of time. "Using energy in an efficient and environmentally friendly manner is the greatest challenge for the sustainable development of the world," he says. "If human beings want to survive the next hundred years, then the most promising solution is to use sunlight."

Bu Xianhe, a professor of chemistry at Nankai, researches the design and construction of materials that are well suited to optical, electronic, or magnetic applications. He notes that after several decades of development, the chemistry and materials team now has cutting-edge faculties, outstanding students, and strong financial support, all of which keep its research moving forward. "Materials research at Nankai has flourished into a multidisciplinary platform that includes solid-state chemistry, materials physics and chemistry, computational chemistry, and the life sciences. All these fields are on the frontiers of science development in China," says Bu.

Getting to the heart of life sciences

As Nankai comes to celebrate its 100-year anniversary, there is one department that is definitely looking ahead. Under the leadership of leading biologist Chen Quan, Nankai’s College of Life Sciences is working on pioneering research in the field of biomedicine. This Chen
is best known for his work on mitochondria and its relationship to aging-related diseases. He became the dean in 2019 and has ambitious plans for the department's development. "I hope to attract more of the brightest minds in China. I believe that Nankai is the perfect place for young scientists to start their careers," he says.

Chen has a long history with Nankai that goes back more than 10 years. He is keen to establish new strategies to raise the quality of research and to experiment with new ways of investigating the causes of the world's most prevalent diseases, such as cancers and degenerative disorders. Chen has worked closely with the university's president, Cao Xuetao, an immunologist, to establish interdisciplinary centers that will encourage innovative research. "I will be heading a center to promote interdisciplinary research between life sciences, physics, chemistry, and medicine. This new initiative will hugely benefit our college and university as a whole," he says. Chen is also hoping to attract more international talent among the faculty and students, and to create global partnerships. He recently recruited a professor from the United States, for example.

One of Nankai's leading biomedical researchers and the university's vice president, Wang Lei, says that forging international research partnerships is vital to ensuring long-term, high-quality research. Alongside president Cao, Wang has been working hard to develop new working relationships with academics from the University of Oxford. "We recently signed a collaborative memo with Oxford, and some of their experts will become adjunct professors in the life sciences at Nankai. During the initial phase, we will be focusing on biomedical research, among other areas," he says. "Through this type of collaboration, we will reach the highest standards in terms of education and research." He agrees that partnerships are key to research, particularly to his work on disease-causing bacteria.

In 2001, Wang established China's first microbial, genomics, proteomics, and bioinformatics research platform, and more recently an interdisciplinary group to find more about how microbes adapt and escape attacks by our immune system. "Infectious diseases caused by pathogenic bacteria are our most deadly threat and cause millions of deaths each year. Our work is essential for establishing effective prevention and control strategies against them," he says. Wang's team is also working on a system to better classify strains of bacteria. "China is a big country and some areas still have poor sanitation. The bacterial molecular serotyping techniques we have developed will greatly benefit Chinese public health, economic development, and social stability," he says.

At present, the College of Life Sciences has more than 170 staff members, including one academician of the Chinese Academy of Engineering, one academician of the Chinese Academy of Sciences, and more than 10 Changjiang Scholars and Distinguished Young Scholars of the National Natural Science Foundation (NSFC), respectively. There are also visiting professors from universities all over the world. Since 2002, the faculty have published more than 2,000 papers in international peer-reviewed Science Citation Index journals, including Science, Nature, and PNAS, and certain disciplines at Nankai, such as animal sciences, molecular biology, and genetics, are ranked in the top 1% of all universities by ESI. Currently, there are more than 500 undergraduate students and more than 700 graduate students pursuing their education in the life sciences.

Wang believes that highly collaborative, cross-disciplinary investigation is the future of life sciences research, and the department's greatest challenge will be to integrate the ideas, knowledge, and efforts of scientists from different research backgrounds. He explains, "To tackle these difficulties, we are going to
build a culture of academic exchange. We will invite specialists from all related research areas to set up routine forums. During these forums, we will explain our own research projects in depth and inspire each other with creative ideas and with the hope of finding emerging fields of research."

**Calculating the future**

When Long Yiming joined the faculty of the Chern Institute of Mathematics as an associate professor in 1988, he knew he was being given a unique opportunity. The newly founded institute, which opened in 1985, was under the leadership of Chern Shiing-Shen (1911–2004), a leading Chinese mathematician whose seven-decade research career helped shape the world’s understanding of differential geometry and topology. Now called the Chern Institute of Mathematics, the research hub continues to rank highly in its field. In 2018, it was ranked No. 39 in the world by U.S. News and World Report’s Best Global Universities annual survey and is regularly ranked among the top five mathematics schools in China.

Thirty years after joining the mathematics team at Nankai, which also includes the School of Mathematical Sciences, the Center for Combinatorics, and the School of Statistics and Data Science, Long still appreciates the atmosphere of free exploration that was fostered by Chern and his successors. "Chern invited world-leading mathematicians to give courses and lectures to students and teachers at Nankai," says Long. "I believe that Professor Chern was the person who had the most crucial role and made the most important contribution to the renaissance of [Chinese] mathematics after the reform and opening up of our country in 1978."

Long researches dynamical systems—a set of variables that evolve over time, such as the movement of the planets. "When one looks at the night sky, one can see many planets and objects moving along their own orbits and appearing periodically. This kind of research can be traced back to the famous Italian scientist, Galileo Galilei," he says.

Fast forward to the present day and you’ll come to the work of Nankai mathematician Wang Zhaojun, vice-dean of the School of Mathematical Sciences and a professor at the recently established School of Statistics and Data Science. “Our aim is to develop new fundamental theories of statistics and core algorithms for big data analysis. We want to furnish big data industries with scientific support and generic technologies,” says Wang. He is aware of the importance of his team’s work in China. The government has asked scientists to prioritize the use of big data in their research and develop analysis techniques that enable scientific breakthroughs. “At present, the main issue that slows us down is weaknesses in the fundamental theories of statistics, analysis methods, and computational algorithms. In the area of big data, traditional statistical theories have been found to be seriously inadequate,” he says.

The new school, founded in May 2018, grew out of the original Institute of Statistics at Nankai University. It intends to develop collaborative research programs with researchers from economics, finance, biology, insurance, and other disciplines across the university. Because the school is a part of Nankai’s Double First-Class program, Wang is keen to see his team achieve its goals and contribute to the university’s success. Statistics research at Nankai University grew from pioneering work in probability theory and mathematical statistics done by Wang Zikun Wang and Hu Guoding in the 1950s, he explains. “Nankai’s statistics program was ranked the third best in China in 2017 by the Ministry of Education,” says Wang. The faculty is made up of experts in the field who are all highly influential in their research areas, he adds. Those areas include experiment design, statistical process control, machine learning, mathematical finance, FinTech, functional data analysis, biostatistics, and bioinformatics.

**Meeting environmental challenges**

During her 30-year career at Nankai University, the work of Sun Hongwen, the Dean of the College of Environmental Science and Engineering, and her faculty have become increasingly significant to China and the wider world. As China's industrial output has swiftly grown, so have the levels of harmful by-products and waste released into the environment. Sun’s research focuses on how contaminants change in air, water, and soil, and how chemical exposure is linked to the development of human diseases, such as diabetes, for example, and to conditions that cause infertility. She and her team are also developing technologies that can remediate the contamination of hazardous chemicals (both heavy metals and organic pollutants) in farmland soil or discarded industrial sites, in order to prevent disease.

Sun is acutely aware of the size of the challenge facing her department. "We come into contact with more than 100,000 chemicals during our lifetime. Each day, more and more new chemicals emerge, and it has been revealed that most chronic human diseases are
related to chemical exposure," she says. "We need more evidence to understand how these mechanisms work." Sun points out that while China produces and uses a very large quantity of chemicals, they are not as well-regulated there as in Western countries, which means that the risk posed by exposure to chemicals could be very high.

Nankai’s College of Environmental Science and Engineering was the first of its kind in China when it was established in 1983. It comprises eight laboratories focusing on areas such as environmental chemistry and toxicology, atmospheric pollution control, water pollution control, risk assessment and remediation, and biomass recycling. In the past five years, Sun’s team has been awarded six scientific prizes from bodies such as the Ministry of Education (MOE) and Tianjin’s city government, for projects including work on human exposure to emerging contaminants, water treatment technology, and recycling technology for biomass solid waste.

In addition to a high publication rate—around 400 papers yearly—the team are involved in a range of collaborative academic platforms, support by the Ministry of Science and Technology (MOST), MOE, and an international partnership with Canada on water and environment safety. Sun has also successfully applied for 10 patents. She says the greatest difficulty she faces in her research is dealing with the complexity of the natural environment. "For example, chemicals change over time both in their structures and in associated forms after they enter our environment, so a result obtained based on short-term experiments may lead to a wrong conclusion," she says. "We need to conduct long-term experiments to determine what happens to chemicals that sit in the soil for many years. What are the potential risks to humans who encounter them?"

Another challenge, Sun says, is to understand how pollutants interact. "The main environmental concern for a complex agent like EDTA [ethylenediaminetetraacetic acid] is not the toxicity of the acid itself, but that it may combine with heavy metals and increase their mobility and toxicity," she says.

Sun has worked at Nankai University for her entire career, receiving her Ph.D. in environmental chemistry in 1994, and publishing over 360 papers, 1 monograph, and numerous chapters in monographs and textbooks. She has also led over 40 research projects, including one MOST project on soil remediation and an NSFC project for outstanding young scholars on emerging chemicals. "As a professor, my first priority is teaching," she says. "I have a responsibility to be a model for the next generation of faculty and students."

A vision for physics

Established in 1922, the School of Physics at Nankai University has a record for academic excellence in optics and photonics. The discipline was first established at Nankai by professor Rao Yutai, one of China’s earliest modern physicists, whose efforts were developed by his successors Shen Shouchun, Mu Guoguang, Zhang Guangyin, and Xu Jingjun. According to Zhang, current dean of the School of Physics, optics research at Nankai focuses on areas such as nonlinear optics, quantum optics, optical information processing, nanophotonics, and optical materials. The department also has a key laboratory established by the MOE for research into weak-light nonlinear photonics.

Zhang’s current research focuses on the development of new light sources, such as superbunching light sources and narrow-band single-photon sources, and ways to optimize lithium niobite crystal as a material platform for integrated photonics applications. "These are research topics with both fundamental importance and practical application. Historically, every invention of a new light source will not only give rise to new physics but also spur development of novel technology," he says. "For example, the narrow-band single-photon source is a very useful resource for quantum information processing"
and computing, and is also an important tool to verify fundamental quantum physics.”

Nankai also has a thriving photovoltaic research team, which was founded in 1978. Zhang Xiaodan is one of the university’s leading researchers at the Institute of Photoelectronic Thin Film Devices and Technology, and won China’s 15th Young Women Scientist Award in early 2019 for her work fabricating highly efficient solar cells, a renewable energy source that will become more important to China in the years to come.

“The energy structure in the next 20 years will contribute to national energy security and the quality of life of all Chinese citizens,” says Zhang. “Of course, to achieve this goal, many scientific problems need to be solved, especially how to improve the efficiency of solar cells while reducing costs.”

Zhang is now working on how to use a semiconductor material called metal halide hybrid perovskite to fabricate highly efficient solar cells. “There is no single material or semiconductor that can absorb most of the light in the solar spectrum without physical loss, so it can be difficult to achieve high efficiency in solar cells. Fortunately, this material can be used to boost their efficiency,” she says. According to the ESI database, the research performance of Nankai’s physics department is ranked in the top 1% of global institutions.

Zhang Guoquan notes that for complicated research projects, it is almost impossible to solve all problems within his own research group, thus internal and international cooperation is necessary. “We are always seeking appropriate internal and international groups to work with,” he says. “The School of Physics has established stable, international cooperation with more than 50 departments and institutes around the world, not only in research but also in the area of student training.”

Both researchers recognize the importance of creating a supportive environment for research. Nankai University offers its students academic freedom, high-quality facilities, and strong financial support, explains Zhang Guoquan.

“My team and I have been strongly supported by the university, which enables us to overcome scientific problems,” adds Zhang Xiaodan.

Science with a mind of its own

From futuristic cyber challenges, such as developing enhanced computer vision, to practical industrial applications of computer science, Nankai’s scientists are keen to find solutions to a range of issues. The university is blessed with an innovative research team who hit the headlines in 2015 when they unveiled the first brain-powered car.

Fang Yongchun is the head of the university’s College of Artificial Intelligence (AI), and a robotics researcher. He credits the college’s success to a hard-working team that collaborates closely and has enough funding to support their research. “We don’t have too much pressure and enjoy the freedom to implement research based on our ideas, which is important for innovation and creation,” he says.

Nankai took an early lead in the field of information and communications technology (ICT), setting up a laboratory dedicated to AI and control theory as early as 1985. These were followed by the Research Lab of AI and Robotics and the Institute of Machine Intelligence (IMI) in 1986 and 1990, respectively. The university now hires the brightest young minds, such as Fang, who has received a stream of honors, including being named the Changjiang Distinguished Professor of the Chinese Ministry of Education in 2017.

Fang is working on robotics theory that will enable cranes to perform tasks automatically. He works closely with industry partners to take his research from the bench to real-world situations, such as the Tianjin harbor. “We recently worked together with a local crane company to invent a 32-ton automatic crane that’s highly efficient and safe. It’s been operating [at the harbor] for three years now,” he says. “We need to learn more about industrial systems, as well as the laboratory environment in the

Real-time mapping system for vehicle pollution testing in Environmental Science and Engineering College
are working on very different problems with equally valuable applications. Cheng’s area of research is computer vision, an area that aims to give computers the ability to "see" and understand their visual environment. "Since 80% of sensory information the brain receives comes from our eyes, being able to understand every pixel is crucial for computers to accomplish a wide variety of tasks, such as image enhancement, autonomous driving, and aerial surveillance," says Cheng.

His research goal is to develop robust computer vision systems that can learn to identify images from a few examples, or even directly from the Internet without explicit human supervision, in the way that humans can. "A small child can easily learn to recognize a panda without their parents showing them thousands of pixels of accurately labeled examples against all possible backgrounds. They use their intuitive visual ability to do this. We want to train computers to do this," Cheng says. The research of Cheng and his colleagues has already been put into practice: Their algorithms underpin visual software that runs on Huawei mobile phones.

Since Cheng joined Nankai University in 2014, he and his students have published more than 40 research papers in top journals and conference proceedings in computer vision, such as *IEEE Transactions on Pattern Analysis and Machine Intelligence* and the *IEEE Conference on Computer Vision and Pattern Recognition (CVPR)*. They have also worked with top academic institutions and companies in different fields to develop computer vision methods that can be used in several applications, including smartphone cameras, wind power plants, skin disease screening, and pest identification for agriculture. Although his research team has an impressive publication record, Cheng is more motivated by how his work can help the public. "China needs lots of machines to help humans do tasks, as the population ages and technology advances. Machines are stronger and faster than humans, and highly stable," says Cheng. "If we can improve their ability to understand their environment and interact with it, China can create a sustainable workforce for future generations."

**Come see what’s new**

The work of Nankai University will play a key part in China’s future and contribute to the global advancement of scientific research and development. For more information about the university please go to www.nankai.edu.cn or contact the Office of Science and Technology at keyanbu@nankai.edu.cn.
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