South Korea

Working to build a 'creative economy', the country has boosted its significant science spending with researchers particularly focusing on nanotechnology, nuclear fusion and stem-cell research.

ARTICLE COUNT (AC): 1,966
FRACTIONAL COUNT (FC): 1,232.24
WEIGHTED FRACTIONAL COUNT (WFC): 1,167.49

South Korea is often called the world's most innovative country. Last year, for example, it beat Sweden and the United States to claim first place in Bloomberg's 2014 Global Innovation Index. If its endeavours are measured by financial commitment, South Korea is shining. The Organization for Economic Cooperation and Development's (OECD's) Science, Technology and Industry Outlook 2014 shows the country spent 4.4% of its GDP on R&D in 2012, leading the world. The Battelle Institute's estimates have South Korea's total R&D spending at about US$63 billion in 2014. The lion's share of these funds goes into industrial work led by giants, such as Hyundai and Samsung. But South Korean researchers also are making increasingly important contributions in basic and applied research, in fields ranging from nanotechnology to nuclear fusion and from stem cells to space science, and boosting efforts to transfer their advances to industry.

An educated workforce is key to achieving scientific and technological success, and this is Korea's greatest strength, according to Sung-Mo Kang, president of the Korea Advanced Institute of Science and Technology (KAIST) in Daejeon. He points out that more than 65% of young people graduate from college — compared to only about 40% of the entire US population.

However, observers inside and outside South Korea advise that getting the most from this well-educated workforce will require more ambitious basic research programmes; Korean scientists historically have published relatively few papers in leading scientific journals. "Today, Korea faces a new challenge in the field of basic research: the country has attained a goal in terms of growth, but it needs to improve its quality of research," researchers from Chungnam National University and the National Research Foundation of Korea noted in a 2014 paper. "Korean researchers need to demonstrate excellence, a far more critical issue than the number of papers published." In 2014, for example, only 0.6% — compared to a global average of 3.1% — of its papers were published in *Nature* or *Science*.

> "SOUTH KOREAN SCIENCE HAS MOSTLY BEEN A FAST FOLLOWER RATHER THAN A FIRST MOVER."

TAKING IT FROM THE TOP

Enhancing basic science capabilities and goals is a key part of the national initiatives that President Park Geun-hye prioritized when she was elected in 2013 and outlined a vision of a "creative economy". This effort is supposed to push the country's strengths in R&D — especially in information and communications technologies (ICT) — towards industrial application and help generate innovative products and services. To promote this, the Park government merged three agencies to establish the Ministry of Science, ICT and Future Planning, a new ministry designed to ease coordination within the government and overcome bureaucratic barriers. However, Sean Connell, an expert on South Korean research and development, who analysed the quest for a creative economy on behalf of the Washington-based Korea Economic Institute of America, says the restructuring was the third such reorganization of governance for South Korean science, technology and innovation in a decade and that its effectiveness is yet to be seen.

Supporting such reorganization and deriving results requires funding. To this end, in February 2014, President Park announced plans to increase Korea's R&D investments to represent 5% of its GDP by 2017, to further support the establishment of a creative economy. In recent years, the government has boosted its own R&D spending by an impressive average of 11% a year. This year's federal R&D expenditures are pegged at US$19 billion, up 5.9% from 2014. Within these expanding budgets, spending on basic research also will rise, to 40% of the total by 2017.

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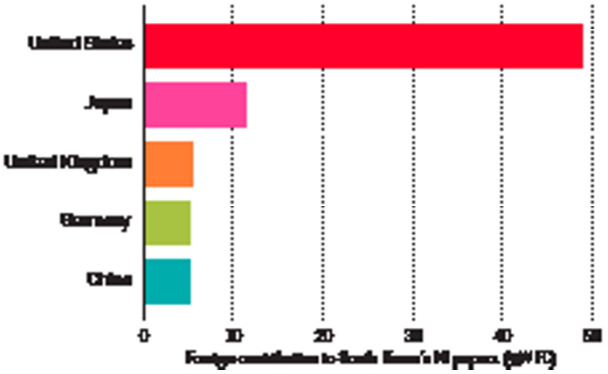
Top ten institutions
South Korea's leading institutions publish — in the Nature Index (NI) WFC — less than those in China and Japan, but with more of a balance across the top ten.

RANK	INSTITUTION	WFC 2014	AC 2014
1	Seoul National University (SNU)	160.24	424.00
2	Korea Advanced Institute of Science & Technology (KAIST)	116.33	222.00
3	Yonsei University	71.00	200.00
4	Pohang University of Science & Technology (POSTECH)	70.33	150.00
5	Korea University (KU)	61.21	210.00
6	Sungkyunkwan University (SKKU)	58.83	240.00
7	Hanyang University (HYU)	49.74	127.00
8	Ulsan National Institute of Science &Technology (UNIST)	38.28	87.00
9	Kyung Hee University (KHU)	30.98	122.00
10	Institute for Basic Science (IBS)	29.03	116.00

Top five collaborators
Of the roughly 40% of South Korea's NI WFC papers with international authors, Japan and China rank in the top five, but far below the rate of collaboration with US authorities.



One project exemplifying the push into basic research is the Institute for Basic Science (IBS), which was launched in 2012. IBS focuses on big and sometimes risky research, historically not a particular strength of Korean science. Now 24 IBS research centres are up and running. In 2014, the government also pushed forward with plans to build a rare-ion accelerator — managed by IBS and funded at around US$2.1 billion through 2021 — for work in nuclear physics, materials science and biomedicine.

STRENGTHS IN SCIENCE

Short of domestic energy sources, South Korea is playing a significant role in nuclear-fusion research, especially as a major player in the International Thermonuclear Experimental Reactor (ITER) project. In 2014, researchers celebrated the 10,000th plasma-generation experiment of its Korea Superconducting Tokamak Advanced Research device, which began operating in 2008. Researchers also began conceptual designs for a fusion demonstration reactor (K-DEMO) in 2012 and hope an upgraded version of the reactor will go into operation around 2037. If this ambition is realized, K-DEMO will be the first nuclear-fusion device to contribute to a power grid.

Nanotechnology is a focus and the government has invested several billion US dollars in nanotechnology since 2001. Research into the discipline receives big industrial support. Results in 2014 ranged from developing graphene for flexible electronics to gelatin-based nanoparticles for delivering drugs to the brain. Unsurprisingly, nearly half of South Korea's published articles are in physical sciences.

In space science, 2013 marked the first success for a South Korean launch vehicle putting a satellite into Earth orbit. Aiming to move from Earth monitoring to Moon monitoring, the Korea Aerospace Research Institute is leading an effort to build a lunar orbiter and lunar module, for take-off in 2020.

In life sciences, South Korea's fame and notoriety has been in stem-cell research — both for genuine advances, such as the first cloned dog,

EPA/ALAMY

Researchers at KAIST interact though this transwall, a two-sided touchscreen, which could be used in classrooms or laboratories.

and for a fraudulent claim a decade ago to have isolated the first human embryonic stem-cell line using somatic cell nuclear transfer (SCNT, in which a nucleus is removed from an egg and replaced with a donor nucleus). Both projects came from the lab of Woo Suk Hwang, formerly of Seoul National University, who now runs a startup that clones pet dogs.

In the wake of the Hwang scandal in 2009, the government stopped funding embryonic stem-cell research, a moratorium that has now ended. The government is again encouraging such work — much of it led by CHA University in Seoul. In 2011 South Korea became the first country to award medical approval to stem cell-based therapies for solid tissues, giving a go-ahead for treating myocardial infarction with a patient's own mesenchymal stem cells. Among laboratory advances in 2014, CHA researchers, working with US scientists and using SCNT, generated human embryonic stem cells using skin cells from two adult males, a promising step in regenerative medicine.

Strengthening research in a less visible field, in December 2014 the government announced it was necessary by 2023 for the nation to invest US$18.1 billion for developing clean energy technologies. Of that total, the government would provide US$10.9 billion and industry would come up with the remainder.

In an ambitious move to boost the scope and quality of university research, in 2014 President Park introduced a Korea Research Fellowship programme, which aims to bring 300 top scientists from around the world to the country's universities. The programme joins a wave of new centres targeting promising areas of research reflecting societal challenges. For example, in 2014, Seoul National University opened an agricultural sciences campus in Pyeongchang and launched a Big Data Institute to conduct interdisciplinary research across a very broad range of fields, while KAIST began to work with partners to create a medical campus in Sejong City.

KAIST president, Kang, also highlights the institute's rapid approach to implementing an "Education 3.0" initiative, with a "flipped classroom" approach, which eschews traditional big-lecture classes, integrates online and classroom education, and offers the potential for more engaging and effective learning. "Students watch video lectures provided by professors prior to class, and go to class to meet their professors and classmates for in-depth discussions, problem solving, group assignments and Q&A sessions," explains Kang. While leading universities worldwide dabble with the approach, KAIST plans to deliver no less than 30% of all its classes this way by 2017, with 65 newly-designed classrooms.

Such initiatives exemplify a push to broaden and strengthen research efforts, says Heeyoon Lee, a KAIST professor of organic chemistry. "With the rapid expansion of output in Korea, the country is looking into two areas for expansion of its research strength," Lee adds. One is creating new fields in basic research, he says. "Korean science has mostly been a fast follower rather than a first mover and pioneer. Korea is now looking to see many first movers." Secondly, Lee says, "Korean science has focused mostly on pure academic research fields and thus provided little or remote impact on industries." Achieving these goals will go hand in hand with a successful implementation of Park's creative economy. ■

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