North America

This region includes lots of strong institutions — from government agencies to universities — but curtailed funding raises concerns for the future.

ARTICLE COUNT (AC): 28,378
FRACTIONAL COUNT (FC): 21,430
WEIGHTED FRACTIONAL COUNT (WFC): 19,425

North America remains the world's most dominant region for high-quality scientific output in the Nature Index, with a weighted fractional count (WFC) of nearly 19,500. The gap is getting narrower, however, between North America and East & Southeast Asia thanks to China, which is a distant second to the United States but with a rapidly increasing number of publications. Although the two countries that make up the North America region — the United States and Canada — enjoy substantial federal funding for scientific research, that source has been constrained in recent years and is not expected to grow significantly in the foreseeable future.

Almost half the region's output in the Index is in the life sciences, representing a greater share of total science output than in the rest of the world. In the United States, much life science research is financed by the National Institutes of Health (NIH), a government-funded agency. The NIH is the country's largest non-defence funder of research and the largest biomedical research agency in the world. The agency, however, has seen a reduction in purchasing power by a fifth over the last dozen years as budget increases have failed to keep pace with inflation. Canada, meanwhile, continues to place emphasis on life sciences through the Canadian Institute of Health Research. The government's most recent strategy for science and technology innovation put life sciences and health as one of five priority areas, with particular focuses on neuroscience, ageing, regenerative medicine and biomedical engineering.

North America is one of the most self-sufficient regions when it comes to published papers, and its rates of collaboration are lower than the global aggregate in every subject area. Of all the North American articles that include researchers from more than one country, 11% are within the region, stemming from cooperation between the United States and Canada.

> "WE'RE LEAVING GREAT STUFF ON THE CUTTING ROOM FLOOR, BECAUSE WE HAVE TO PRIORITIZE."

The United States is the collaboration partner of choice for most of the world's countries. Both China and South Korea partner with US researchers for half of all their international collaborations. The United States is also the number one collaborator for Canada, as well as for several countries from every region.

Of the total WFC for North America, 4.5% came from articles published in either *Nature* or *Science*, a higher percentage than any other region except for Africa — but that continent's 4.7% arises from a WFC in those journals of only 6, while for North America the total is 870.

INTERNATIONAL CHALLENGER

The United States' WFC in the Nature Index is 17,936, a drop of 3.5% from the previous year. Although with only two years of data it's difficult to assess the significance of that change, its position as the lead country for high-quality research could soon be in jeopardy. The country with the second largest output in the Index is China, whose WFC of 6,037 is roughly a third of the US count. That number, however, is a 16% climb for China from 2013.

US National Science Foundation (NSF) senior analyst Carol Robbins says China is not the only contender experiencing meteoric growth. "The article output of developing countries has been growing faster than the European Union and the US since at least 2000," Robbins says. But she cautions, "Growth in the developing world is going to look more rapid than growth in the developed world, because they're starting from a lower base."

The United States is most productive in life sciences, which represents 44% of its 2014 output. But it is in chemistry and physical sciences, each accounting for nearly 30% of output, where the scientific giant enjoyed most international acclaim last year. The 2014 Nobel Prize in Chemistry, for example, for developing a super-resolution fluorescent microscope,

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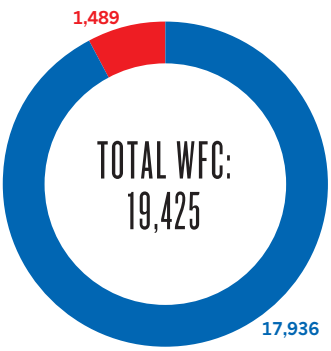
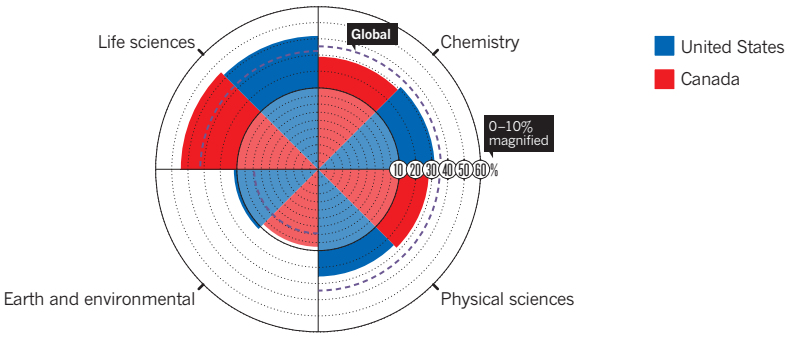
Countries' weighted fractional count (WFC)
Canada accounted for less than 8% of the region's WFC, leaving a lopsided advantage to the United States.



Relative subject area distribution
Both Canada and the United States focus on the life sciences, generating more than 40% of their outputs in this area.*



*Each slice represents the proportion each subject area contributes to a country's overall WFC. Subject areas can overlap, so the total percentage may exceed 100%.

went to Eric Betzig of Howard Hughes Medical Institute and William Moerner of Stanford University, along with Stefan Hell from Germany's Max Planck Society.

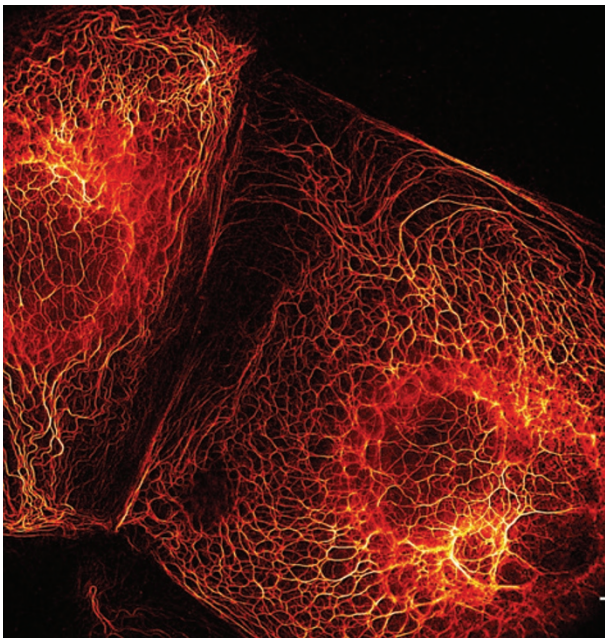
Even as its scientists produce award-winning results, US research spending continues to be curtailed, with steady erosion in federal funding for science since 2004, according to Matt Hourihan, director of the R&D Budget and Policy Program for the American Association for the Advancement of Science. Between 2010 and 2015, non-defence spending for research dropped by 5%, adjusted for inflation. And although President Barack Obama has proposed a 7% rise in spending for 2016, "that is a much bigger increase than Congress is likely to grant this year," Hourihan says.

Since the federal sequester cuts in March 2013, which imposed comprehensive reductions in federal spending, there's been a modest recovery in such expenditures, Hourihan says. He adds that spending is expected to grow only moderately until 2021. "The pool of funding from which science can draw is going to remain very tight for the next few years, unless Congress acts to change it," he says.

The NIH has had a turbulent couple of decades financially. Its budget doubled between 1998 and 2003 but has dropped by a fifth since then — though it bounced back from a 2013 low. With a little more money in its budget, the percentage of grant applications the agency approved rose somewhat to 18.1% in 2014 from 16.8% in 2013, according to NIH deputy director for extramural research Sally Rockey, although that doesn't compare to rates above 30% in the late 1990s and early 2000s. "We're leaving great stuff on the cutting room floor, because we have to prioritize," adds NIH principal deputy director Lawrence Tabak.

The long-term consequences of this budget uncertainty are worrying, warns Shirley Tilghman, former president of Princeton University and a past participant in NIH advisory groups. The growth in NIH funding until 2003 encouraged many young people to enter the biomedical field, she says, but now there's not enough funding to support their research careers. "There are too many people chasing too little money in the US," she says.

Tilghman, along with three other luminaries — Bruce Alberts, former president of the National Academy of Sciences, Marc Kirschner of the Harvard Medical School, and former director of the National Cancer Institute Harold Varmus — wrote a perspective in the *Proceedings of the National Academy of Sciences* last year calling on the country to revamp its biomedical research system. Tilghman argues in the paper that, for some years, graduate students and postdocs have been treated as a source of cheap labour for biomedical research, Tilghman says many of them don't manage to start their own lab until their late 30s. And the competition for scarce funding can make scientists more conservative in their thinking, she says, because they want to give funding agencies what they're expecting rather than propose a new idea whose outcome is uncertain. "Over time, the quality of science is going to go down because people are too scared to take big risks," she says.



ANDRIY CHMYROV/STEFAN HELL/MAX PLANCK INSTITUTE FOR BIOPHYSICAL CHEMISTRY

Parallelized RESOLFT nanoscopy reveals the protein keratin in living cancer cells in amazing detail.

CANADA'S EYE ON COMPETITION

Canada's WFC (1,489) is essentially unchanged from last year. That maintains its place as the country with the 7th largest WFC in the Index, way above its 37th place ranking in terms of population, according to data from the United Nations. Like the United States, Canada's output in the Nature Index is strongest in the life sciences, which accounts for about 40% of the country's total WFC. The nation's WFC of 33 in either *Nature* or *Science* is 2% of its WFC in 2014. Yet in Canada too there are worries about the nation's future competitiveness in the global research landscape, says Paul Dufour, an adjunct professor at the University of Ottawa's Institute for Science, Society, and Policy. "The state of science and technology innovation in this country is in decline," he says. Among his concerns is a fall in research investment. According to the Organization for Economic Co-Operation and Development (OECD), Canada's gross domestic expenditure on research and development dropped as a percentage of GDP from 2.0% in 2001 to 1.6% in 2013, which is below the OECD average of 2.4%. "We're one of the lowest in the OECD and it's still dropping, so it's not a good picture over all," Dufour says.

Canada weathered the recession of 2008–2009 fairly well due to a strong banking system,

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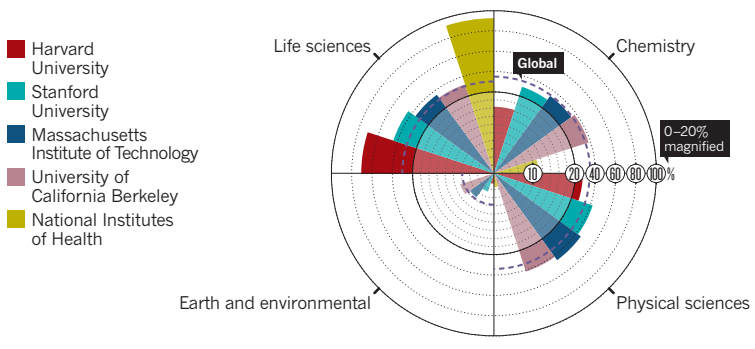
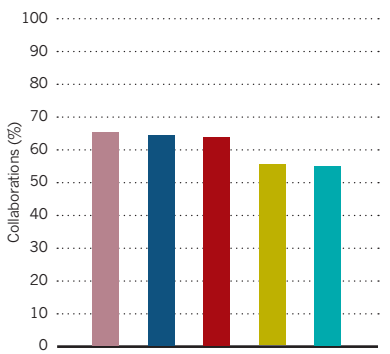
Top 5 institutions' relative subject area distribution
Harvard University, the region's leader by WFC, publishes about 70% of its output in the Index in life sciences.*



*Each slice represents the proportion each subject area contributes to an institution's overall WFC. Subject areas can overlap, so the total percentage may exceed 100%.

Top 5 institutions' collaborativeness
Over half of the work from researchers at the top institutions in North America stems from collaborative efforts with domestic and global counterparts.*



*Each bar represents the proportion of an institution's overall output in the index (AC) stemming from domestic and international collaborations.

Dufour says. Nevertheless, the Canadian government has emphasized austerity and has cut spending in all areas. The country's national statistical agency, Statistics Canada, estimated federal spending on science and technology would decline 5.4% in the fiscal year 2014–2015 to about US$8.5 billion, continuing a downward slide since it peaked in 2010–2011. Prime Minister Stephen Harper's office, however, prefers to focus on a total of about US$8.75 billion in new investments in science, technology and innovation since 2006. Its priority areas, besides health and life sciences, are environment and agriculture, energy and natural resources, information and communications technologies, and advanced manufacturing, ranging from aerospace and robotics to three-dimensional printing and nanotechnology.

One major government initiative is the Canadian High Arctic Research Station, costing around US$113 million and billed to open in 2017. The country hopes that the station — above the Arctic Circle in Cambridge Bay, Nunavut — will attract international scientists and strengthen Canada's position in polar research.

In 2014, the government created the Canada First Research Excellence Fund. Starting with almost US$40 million this year, the fund proposes to provide about US$1.2 billion over the next decade to fund university research that creates "long-term economic advantages for Canada", according to its mission statement. This funding effort has been controversial, however. In a December 2014 editorial, the *Toronto Star* suggested, "It's a significant investment fully undermined by a disastrous caveat: to access the funding, applicants will have to show that they have private-sector co-funders." Such a focus on research with commercial applications means sacrificing the basic research that leads to future innovations, undermining Canadian science in the long run, the paper argued. And this is not the only sign that Canada's government wants closer ties between research and industry. The

MICHELLE JOHNSTON/NATIONAL RESEARCH COUNCIL OF CANADA

This Canadian icebreaker takes scientists to study the polar environment, and in 2017 the country's High Arctic Research Station should open.

previous year, Canada's National Research Council had its mission refocused to support research that would help Canadian business be more competitive.

> "YOU MUST DEMONSTRATE THAT YOU HAVE A WELL-KNOWN OR WELL-DEFINED MARKET OUTCOME."

"You have to demonstrate that you have a well-known or well defined market outcome," Dufour says of the new emphasis. "Some of the grass roots science community are quite vocal on the problems this may create." For example, Evidence for Democracy is a non-profit group that formed in response to funding cuts, and is urging the government to return to a focus on more basic science.

TOP SCHOOL IMPACTS

US universities are well represented among the world's leading research institutions in the Index, with Harvard, Stanford, the Massachusetts Institute of Technology (MIT) and the University of California, Berkeley all among the top 10 institutions by WFC. Canada's top school, the University of Toronto, is 21st.

Top US institution Harvard University, with a WFC of 865, has the second largest output overall in the Index — behind the Chinese Academy of Sciences, which has a WFC of 1,308. While the Chinese Academy's output improved by 8% over 2013, Harvard was up only 1.4% on the previous year. Nevertheless, this was in the face of declining income: Harvard's sponsored research budget dropped to US$812 million in 2014, down US$9 million from the year before. The decline was due to a 5% cut in federal awards, to US$605 million, though that was partly offset by a 12% rise in contributions from foundations and businesses. The university has about 2,400 faculty members, plus 10,400 academic appointments in its affiliated teaching hospitals. There are approximately 6,700 undergraduates and 14,500 graduate and professional students.

The school's greatest strength is in the life sciences, which accounted for nearly three-quarters of its output. In fact, it's the Index's world leader in that field, with a WFC of 610, nearly double the 320 of the second-placed NIH. Harvard's life sciences output is boosted through its affiliation with more than a dozen leading research and teaching hospitals in the Boston area, including the Dana-Farber Cancer Institute and the Joslin Diabetes Center, as well as with independent research organizations such as the Whitehead Institute for Biomedical Research. For instance, researchers at the Broad Institute of MIT and Harvard contributed to Harvard's total with a December paper in *Nature Genetics*, "Comprehensive Variation Discovery in Single Human Genomes."

Harvard's WFC of 75 is also the highest of contributions to *Nature* and *Science*. The university is also in the top 10 for output in both physical sciences and chemistry, but comes in at 35th for earth and environmental sciences.

Stanford, with the second-highest output in

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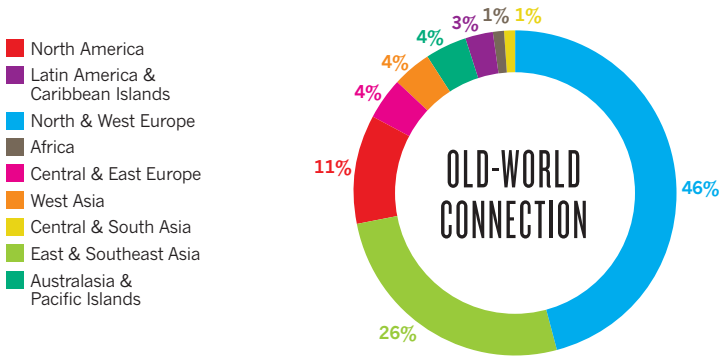
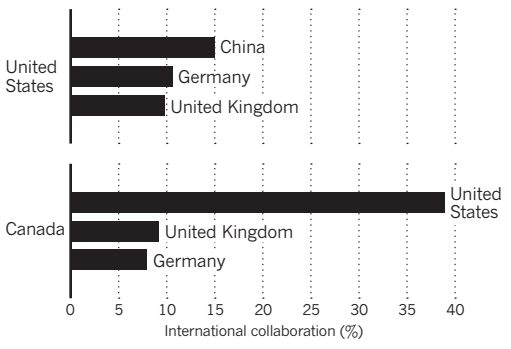
International collaborations
Scientists in North & West Europe make up nearly half of the collaborators with North American researchers.



Top 3 country collaborations
When Canadian scientists collaborate outside the country, it is with researchers from North America nearly 40% of the time.*



*Bars represent international collaboration rates between countries as a proportion of the total output (WFC) stemming from international collaborative efforts.

SLAC

Stanford's SLAC relies on 284 microwave pulse generators in its particle accelerator, which is more than three kilometres long.

North America and fifth globally, had a WFC of 539, a drop of 2% from 2013. The school's sponsored research budget was US$1.33 billion, down US$21 million from the previous year. Approximately 82% of that support comes from the federal government, which actually increased its funding for most of the university's research; the major drop was caused by a $37 million cut in funds for the SLAC National Accelerator Laboratory.

Despite its larger budget — mostly attributable to SLAC — Stanford is similarly sized to Harvard, with 2,118 faculty members in 2015, 7,018 undergraduates and 9,118 graduate students. At Stanford, life sciences and physical sciences each represent about 40% of its contributions, with chemistry covering about 30% and earth and environmental science 5%. (Nature Index assigns some articles to more than one field of science, so the totals don't come to 100%.) Stanford contributes heavily to the *Journal of High Energy Physics*, in part because of its work on the ATLAS detector at the Large Hadron Collider (LHC) in Switzerland. This journal published upwards of two dozen Stanford-authored papers on ATLAS-related work in 2014. But, despite its funding cut, SLAC shines as well. In a November paper in *Nature*, "High-Efficiency Acceleration of an Electron Beam in a Plasma Wakefield Accelerator," SLAC researchers showed how they might build a cheaper, more compact particle accelerator than the kilometres-long LHC. The paper garnered quite a bit of attention in news media, blogs and Twitter, according to Altmetric, which looks at the social-media impact of journal papers.

With the third highest WFC in the United States and sixth globally, MIT also made a splash in particle physics at the LHC. More than 50 MIT researchers and students were involved in a different LHC instrument, the compact muon solenoid, and helped confirm the discovery of the long-sought Higgs boson, which underpins why objects have mass. A June 22, 2014 paper, "Evidence for the Direct Decay of the 125 GeV Higgs Boson to Fermions," attributed to hundreds of researchers, including 31 at MIT, scored higher for public attention than any other paper ever in *Nature Physics*, according to Altmetric data.

MIT distributes its contributions fairly evenly — 42% in physical sciences, 37% in life sciences, and 34% in chemistry, though only 7% in earth and environmental sciences. That makes it much stronger than the country as a whole in physical sciences and chemistry. Its sponsored research budget of US$1.28 billion includes US$739 million in Department of Defense funds for its defense research arm, Lincoln Laboratory.

The University of Toronto — with about 7,000 full-time faculty, 2,700 postdocs and research associates, 15,000 graduate students and a science budget of almost US$1 billion — is Canada's largest research institution. Its WFC for 2014 rose 5% to 269.The country has two other schools in the top 100: McGill at 68 and the University of British Columbia at 70. Like Harvard, the University of Toronto has an affiliated network of several local hospitals, and its largest contribution is in life sciences, where it comes 9th worldwide.

SHARING SCIENCE, GOING BIG

Sharing the cost of research and working across disciplines is becoming common, as expansive and expensive projects such as the LHC draw on resources. "There's generally more collaboration, because of technology, because science is so complex," says the NSF's Hill.

The NIH announced two large initiatives in 2014, both of which will bring together large numbers of people from different institutions. The Accelerating Medicines Partnership, which aims to develop new treatments for Alzheimer's disease, diabetes and autoimmune disorders, has a budget of US$230 million over five years and will entail partnerships between NIH, pharmaceutical companies and non-profit groups. The Brain Research through Advancing Innovative Neurotechnologies (BRAIN) initiative seeks to derive a more complete understanding of the human brain. It received US$46 million in 2014 to start a 12-year project that will involve more than 100 researchers from several countries.

Despite the promise of these bold projects, the NIH's Rockey still has worries over continued budgetary constraints. "At some point there's going to be diminishing returns, simply because we don't have the funds to keep up," she says. "We have every reason to be optimistic about the future scientifically. We just have to get our house in order." ■

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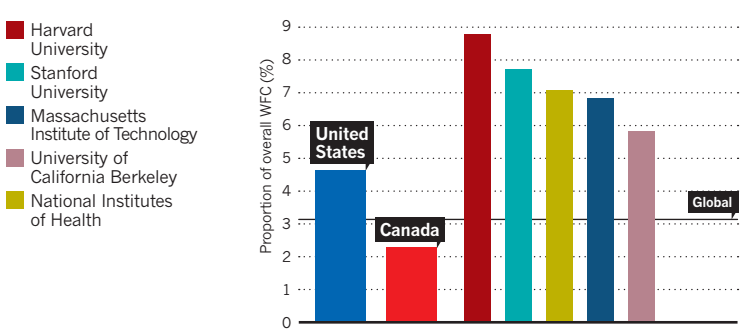
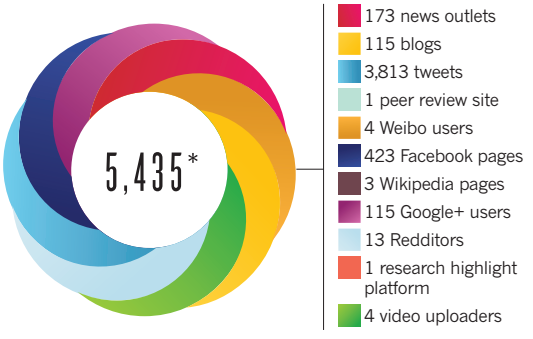
Contributions to *Nature* and *Science*
Harvard University surpasses the global level by more than 2.5 times in this metric of high-profile publishing.*



*Each bar represents an institution's or country's relative contribution to publications in *Nature* and *Science*, given as a proportion of its overall WFC.

Social impact
Not surprisingly, the world's number one Altmetric score in 2014 came from an article about social networking.*



*Altmetric score correct as of 21 May 2015. Experimental evidence of massive-scale emotional contagion through social networks. *Proceedings of the National Academy of Sciences*. DOI: 10.1073/pnas.1320040111.