Highly Cited Researchers 2021

Highly Cited Researchers™ have demonstrated significant and broad influence reflected in their publication of multiple highly cited papers over the last decade.

These highly cited papers rank in the top 1% by citations for a field or fields and publication year in the Web of Science™.

Of the world's population of scientists and social scientists, Highly Cited Researchers are 1 in 1,000.

The Highly Cited Researchers list is produced each year by the **Institute for Scientific Information (ISI)™** at Clarivate. ISI has pioneered the organization of the world's research information for more than half a century. Today it remains committed to promoting integrity in research whilst improving the retrieval, interpretation and utility of scientific information. It maintains the knowledge corpus upon which the Web of Science™ index and related information and analytical content and services are built. It disseminates that knowledge externally through events, conferences and publications whilst conducting primary research to sustain, extend and improve the knowledge base. For more information, please visit clarivate.com.

The Web of Science™ organizes the world's research information to enable academia, corporations, publishers and governments to accelerate the pace of research. It is powered by the world's largest publisher-neutral citation index and research intelligence platform. Learn more.

Overview

The list of Highly Cited Researchers 2021 from Clarivate™ identifies scientists and social scientists who have demonstrated significant and broad influence, reflected in the publication of multiple papers frequently cited by their peers during the last decade.

Researchers are selected for their exceptional influence and performance in one or more of 21 fields (those used in Essential Science Indicators™ or ESI) or across several fields.

6,602 researchers are named Highly Cited Researchers in 2021 – 3,774 in specific fields and 2,828 for cross-field performance. This is the fourth year that we have identified researchers with cross-field impact.

The number of researchers selected in each field is based on the square root of the population of authors listed on the field's highly cited papers. The number of those with cross-field influence is determined by finding those who have influence equivalent to those identified in the 21 fields.

For the Highly Cited Researchers 2021 analysis, the papers surveyed were the most recent papers available to us – those published and cited during 2010 to 2020 and which at the end of 2020 ranked in the top 1% by citations for their ESI field and year (the definition of a highly cited paper).

The threshold number of highly cited papers for selection differs by field, with Clinical Medicine requiring the most and Pharmacology/Toxicology the fewest.

6,602

Highly Cited Researchers in 2021

A second criterion for selection is a citation count to highly cited papers that ranks the individual in the top 1% by total citations in an ESI field for the period surveyed.

The **Essential Science Indicators™** database reveals emerging science trends as well as influential individuals, institutions, papers, journals and countries in a field of research. With science trend statistics drawn from more than 12 million articles from over 12,000 global journals, Essential Science Indicators delivers the in-depth coverage needed to effectively analyze and benchmark research performance, identify significant trends, rank top performers, and evaluate potential employees and collaborators. Learn more.

Incites Benchmarking and Analytics™ provides objective and reliable indicators needed to make confident, data-driven decisions – to help research organizations understand their impact and how they compare to peers across a range of multi-disciplinary fields. It enables them to quickly gain the context needed to accurately evaluate funding outcomes, assess collaborations, identify subject matter experts, benchmark against peers and more. Learn more.

There is no universally agreed concept of what constitutes extraordinary research performance

To identify researchers with cross-field impact, highly cited paper and citation counts are normalized through fractional counting according to the thresholds required for each field (thus, each Clinical Medicine paper has a smaller unit fraction, or counts less, than one in Pharmacology/Toxicology). Citation counts are treated in a similar manner. If the sum of the fractional publication counts and the sum of the fractional citation counts for a researcher equals 1.0 or more, the individual exhibits influence equivalent to a researcher selected in one or more ESI-defined fields and is therefore selected as a Highly Cited Researcher for exceptional cross-field performance.

There is no universally agreed concept of what constitutes extraordinary research performance and elite status in the sciences and social sciences. Consequently, no quantitative indicators will produce a list that satisfies all expectations or requirements. Moreover, a different basis or formula for selection would generate a different – though likely overlapping – list of names. Thus, the absence of a name on our list cannot be interpreted as inferior performance or stature in comparison to those selected. To understand both the meaning and the inevitable limitations of our analytical approach, a careful reading of the methodology is required.

An outstanding faculty is the lifeblood of every notable research institution, and this year our Highly Cited Researchers are based at more than 1,300 institutions all over the world. Here we showcase some institutions that excel in a competitive global environment to support their Highly Cited Researchers in a way that encourages collaboration, facilitates career growth and accelerates highly innovative research.

Case study:
The National University of Singapore

The National University of Singapore (NUS) is home to 32 Highly Cited Researchers in 2021. NUS researchers have been featured in the annual list of Highly Cited Researchers since 2014. This recognition is testament to the talent of the research community, and the resources invested in research from the university, its partners and the Singapore government.

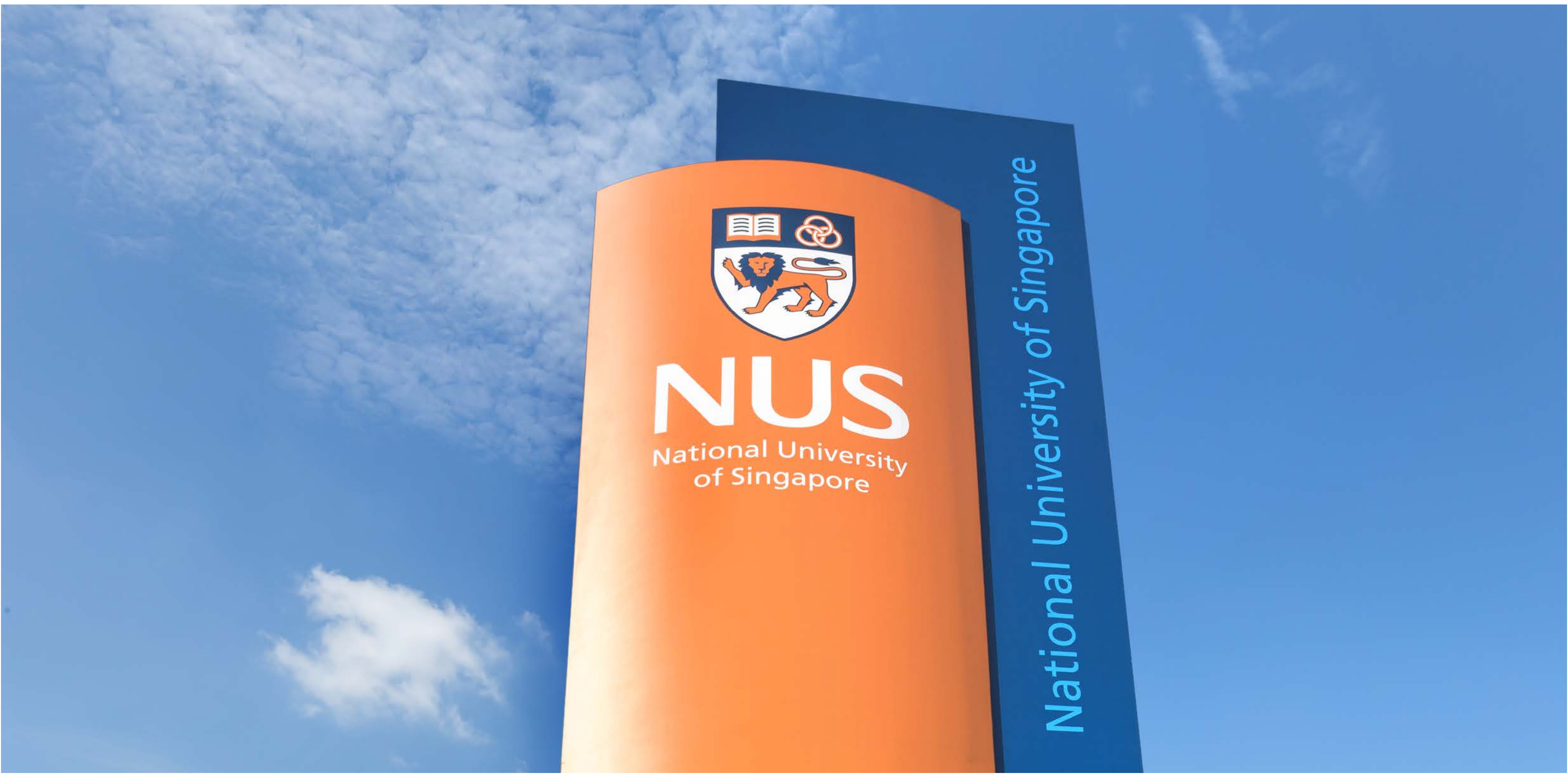
NUS has invested heavily in cutting-edge research capabilities that span multiple disciplines. It has also established numerous interdisciplinary platforms where researchers of varying levels of expertise are brought together to approach their ideas collaboratively.

The university has also invested in the recruitment of top researchers from around the world to lead research programs and mentor young up-and-coming researchers. This has created a rich research ecosystem that enables researchers to make significant impact within their fields.

NUS is a research-intensive university that works closely with government and industry partners to conduct research addressing real-world needs, through knowledge generation and innovative solutions. The university's reputation as a high-impact, research-intensive and innovation-driven university is built on the recognition given to its researchers for their contributions to their respective fields.

When the annual list of Highly Cited Researchers is released, NUS recognizes the achievements of its researchers through its university channels. It also works with local media to celebrate this achievement.

"We appreciate the role the annual list of Highly Cited Researchers plays in promoting top researchers of the university."

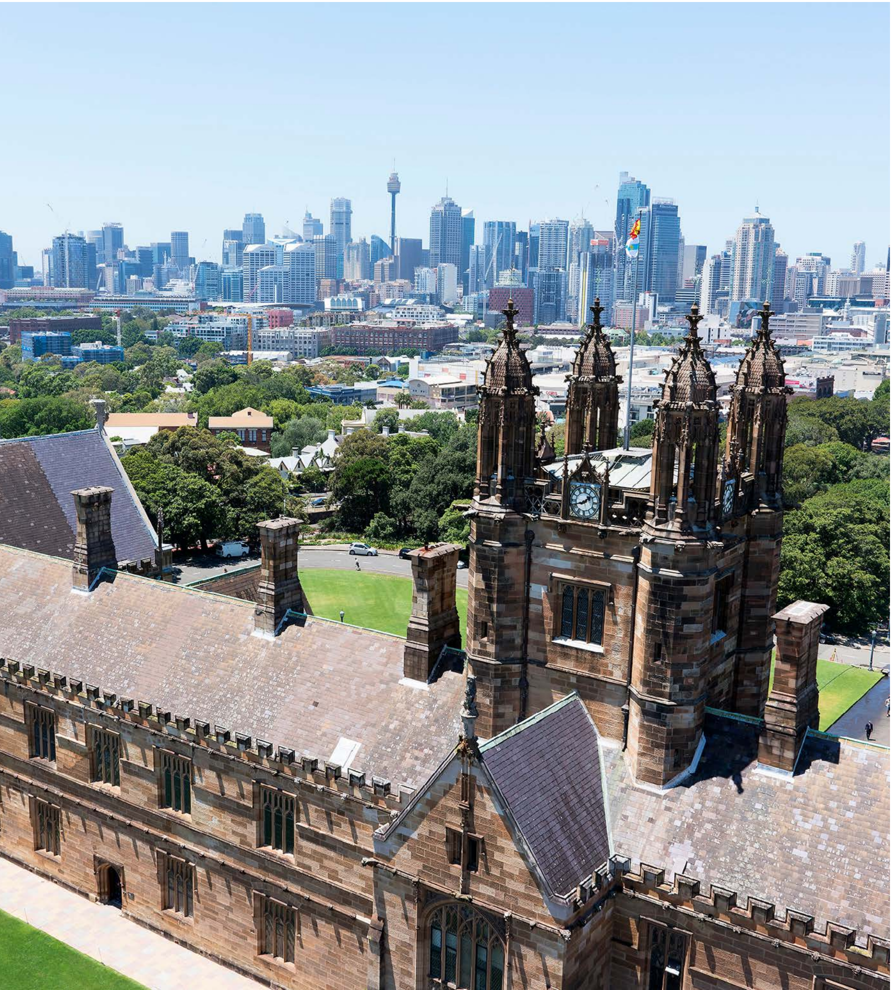


Case study:
The University of Sydney, Australia

The University of Sydney is home to 30 Highly Cited Researchers in 2021. The Highly Cited Researchers based at Sydney are making exceptional contributions to their research fields, and the university is proud to recognize and support their research which is advancing knowledge and addressing key global issues.

The university invests significantly in its researchers, supporting them through career development, project funding and world-class research facilities. The university has committed to harnessing the depth and breadth of its research in innovative ways to address some of the biggest challenges facing the world today, in partnership with government, industry and community.

Specialist teams at the University of Sydney help secure competitive national funding and internal funding schemes, mentor up-and-coming researchers, provide project funding for innovative research, and facilitate collaborations on campus and with industry.



The university has invested in world-class research facilities that provide its researchers with the infrastructure, tools and technical support to drive both fundamental and translational research for the benefit of Australia and the world. The facilities bring together world-class instrumentation, outstanding people and excellent user-focused processes.

As one of Australia's premier research universities with more than 150 research centers and institutes, the University of Sydney also has six whole-of-university multidisciplinary initiatives focused on bringing together expertise from across disciplines to address some of the world's most complex and pressing issues alongside a wide range of external partners.

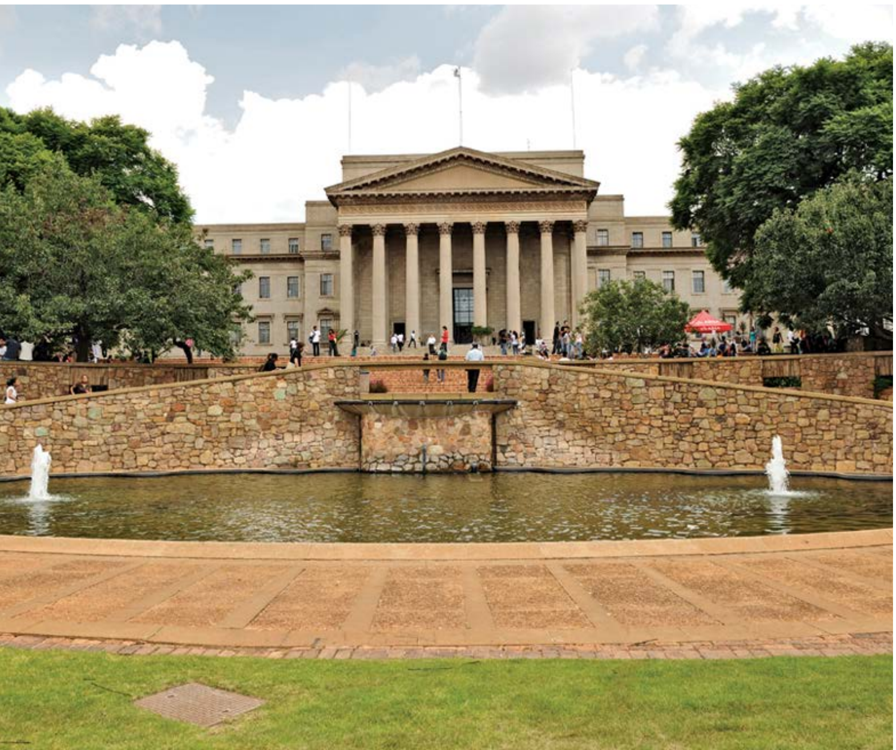
When the annual list of Highly Cited Researchers is released, demonstrating the breadth and depth of research excellence at Sydney, the university acknowledges their achievement via their university channels. Citations are one indication of the quality and reach of their research. The Clarivate list is one way of identifying and recognizing researchers who are undertaking globally significant research, which is benefiting the community.

These researchers are at the very top of their fields, conducting important work ranging from understanding the emergence and spread of viruses, to developing new technology for renewable energy and advancing artificial intelligence. The university is proud of their success and grateful for their dedication to conducting world-class research which makes our society better.

Case study:
The University of the Witwatersrand, Johannesburg (Wits), South Africa

Being a Highly Cited Researcher means that an academic's published research is making an impact in the peer community. This is a powerful validation of high quality. Dr. Robin Drennan, Director: Research and Innovation at the University of the Witwatersrand says: "At Wits we strive to advance our research intensity through impact and quality, i.e., We strive to achieve impact through quality research. Thus, sharing information about our Highly Cited Researchers encourages others to strive for greater quality and impact."

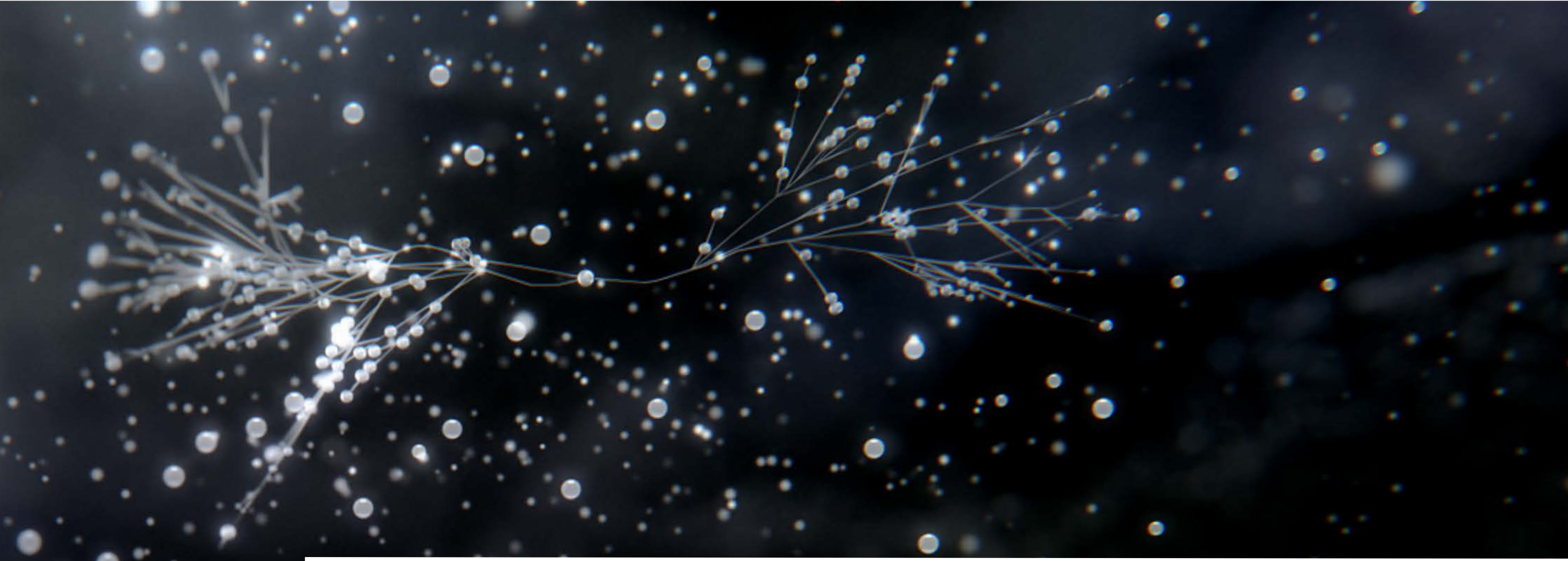
There are multiple reasons that an institution attracts great talent, which makes it difficult to distill to just one or two matters. However, some factors that make Wits University appealing include their 100-year history of top scholarship (they celebrate their centenary in 2022) – a history filled with leading scholars who have been brave enough to speak truth to power, even when it was not convenient to do so, and research that has global impact, such as that of Wits alumnus and Nobel Laureate, Sydney Brenner. Similarly, Wits' Highly Cited Researcher for 2021, Professor Frederick Raal, is world renowned and a game-changer in advancing lifesaving treatments for familial hypercholesterolaemia. Talent begets talent and at Wits, people begin to collaborate in an environment that encourages and expects and delivers quality.



"Talent begets talent"

Wits University has a range of mechanisms to support research excellence. Examples include recognition, prizes and seed funding based on previous publications. Other support programs are connected to the South African system of rating the impact individual researchers have on their academic field. This system of rating is managed by the National Research Foundation and categorizes researchers as ‘established,' ‘internationally recognized' and ‘leading international' researchers. Highly Cited Researchers most often fall into the last two categories. In terms of advancing a public profile of these researchers, Wits University also undertakes strategic communications that include promotion in the newsletter of the Deputy Vice-Chancellor: Research and Innovation, leveraging traditional media and Wits' social media platforms, stories online on Wits' research news page, and featuring researchers in official university publications such as the annual research report and, where relevant, in the university's research magazine, *Curios.ty*.

The academic research career is developed around the process of building of a reputation of excellence in a coherent field of knowledge. This road to recognition can be long and bumpy. However, the pursuit of excellence as seen through the eyes of one's peers should remain the guiding principle. Highly Cited Researchers know this and never waver from this path.



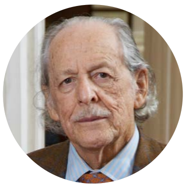
Who would contest that in the race for knowledge it is human capital that is fundamental?

Talent – including intelligence, creativity, ambition and social competence – outpaces other capacities such as access to funding and facilities, although these are typically also needed for success.

Recognition and support of the scientific elite, both fully formed and incipient, is important for a nation or an institution's plans for efficient and accelerated advancement.

The Highly Cited Researchers 2021 list from Clarivate helps identify that small fraction of the researcher population that contributes disproportionately to extending the frontiers of knowledge and gaining for society innovations that make the world healthier, richer, more sustainable and more secure.

Citations: Pellets of peer recognition



Eugene Garfield
Founder of the Institute for Scientific Information (ISI), pioneer in the field of scientometrics

When Eugene Garfield produced the first *Science Citation Index* in 1964, he did so to make searching the literature more efficient and effective. He called his creation an "association-of-ideas index."[1] The connections he captured between topics, concepts or methods discussed in indexed papers could be trusted, he argued, because they were based on the informed judgments of researchers themselves, as recorded in the references they appended to their papers.

Thus, the network of citations linking items in the Web of Science offers a cognitive road map for those seeking to follow the progression of a finding or advancement – a map sometimes leading to unexpected regions that can turn research in a new, promising direction.

The raison d'être of the Web of Science is and always has been to help researchers find the information they need to carry out their investigations. And today Clarivate continues Garfield's work by providing trusted insights and analytics to enable researchers to accelerate discovery.

A secondary use of a citation index for science evolved in the decade after its introduction: analysis of research performance. Citations, when tallied and especially at high frequency, reveal influence and utility (determining importance and quality, however, requires expert judgment). In 1972, the U.S. National Science Foundation included publication and citation data in its first *Science Indicators* report, which permitted comparisons of national research activity, focus, performance and growth. In the 1980s, and in Europe particularly, publication and citation data were harvested and deployed for analysis of universities' research performance.

New Public Management, introduced in universities in the United States, the United Kingdom and Australia in the 1980s and 1990s, applied business management methods to academia and emphasized performance indicators and benchmarks. Academic scientists and social scientists, who previously rejected evaluation by outsiders and insisted on traditional peer review, have gradually accepted bibliometric assessments because opportunities and rewards tied to such assessments have become institutionalized. Some researchers now list citation data on their CVs and websites, such as a total citation count or an h-index.

[1] Eugene Garfield, "Citation indexes for science: A new dimension in documentation through association of ideas," *Science*, 122 (3159): 108-111, July 15, 1955. DOI: 10.1126/science.122.3159.108)

The practice of citing another researcher's work and the interpretation of citation statistics has been debated for many years.[2] Some assert that citations convey impact or visibility; others say they function largely as rhetorical devices and collectively create a socially constructed reality.

The late Robert K. Merton, the 20th century's leading sociologist of science, called the citation "a pellet of peer recognition."[3] Citations, he said, were repayments of an intellectual debt to others. He emphasized that citation was an essential part of normative behavior among researchers, that it was a considered, formal and obligatory activity, one that included a moral imperative to cite others when appropriate. It is largely this perspective that supports citation analysis to identify research influence. In most fields, there is a moderate positive correlation between peer esteem and citation frequency of papers and people, shown in a variety of so-called validation studies.

Evaluating the research performance of individuals is the most contentious application of publication and citation data. Apart from being an emotionally charged exercise, difficulties include finding comparable researchers or research publications to enable fair comparisons, expecting that influence and impact can be detected quickly when it may require many years, and selecting appropriate indicators, ones in alignment with the agreed priorities and values of a research program. A specific hazard is false precision – making distinctions without any meaningful differences – which frequently arises in dealing with small numbers so often encountered in analyzing the work of an individual rather than that of an institution or nation.

When, however, a researcher's record exhibits top-tier status quantitatively, demonstrated by the production of papers in the top 1%, top 0.1% or even top 0.01% of a citation distribution, one can be more certain of having positive and reliable evidence that the individual under review has contributed something of utility and influence. Having multiple contributions of this type increases confidence in attributing substantial influence to a researcher's oeuvre.

The raison d'être of the Web of Science is and always has been to help researchers find the information they need to carry out their investigations.

Still, the application of the data (or of the designation 'Highly Cited') – for example in the context of appointment or promotion decisions or in awarding research funds – demands informed interpretation.

This perspective is consistent with two of the recommendations of the Leiden Manifesto (2015): that "quantitative evaluation should support qualitative, expert assessment," and that "assessment of individual researchers [should be based] on a qualitative judgement of their portfolio."[4]

One should never rely on publication and citation data as a substitute for reading and assessing a researcher's publications – that is, for human judgment.

[2] Dag W. Aksnes, Liv Langfeldt, and Paul Wouters, "Citations, citation indicators, and research quality: An overview of basic concepts and theories," *Sage Open,* 9 (1): article number 2158244019829575, February 7, 2019. DOI: 10.1177/2158244019829575

[3] Robert K. Merton, "The Matthew Effect in science, II: Cumulative advantage and the symbolism of intellectual property," *Isis,* 79 (4): 606-623, December 1988. DOI: 10.1086/354848

[4] Diana Hicks, Paul Wouters, Ludo Waltman, Sarah de Rijcke, and Ismael Rafols, "The Leiden Manifesto for research metrics," *Nature,* 520 (7548), 429–431, April 23, 2015. DOI: 10.1038/520429a

Beyond questions of evaluation, Garfield was fascinated by the power of citations to discriminate the typical from the truly exceptional researcher. The power-law nature of the citation distribution allows one to rapidly focus on a small number of top-end 'events,' both papers and people. Over the years he produced many lists of most-cited researchers in almost every field of inquiry. And he took special interest in using citation data to forecast Nobel laureates by identifying a group of researchers he termed 'of Nobel class.'[5]

The Highly Cited Researchers list extends Garfield's work in recognizing investigators whose citation records position them in the top strata of influence and impact. This year's list includes 24 Nobel laureates, including five announced this year: David Julius, University of California San Francisco, San Francisco, C.A., U.S. (Physiology or Medicine); Ardem Patapoutian, Scripps Research, La Jolla, C.A., U.S. (Physiology or Medicine); David W. C. MacMillan, Princeton University, Princeton, N.J., U.S. (Chemistry); David Card, University of California Berkeley, Berkeley, C.A., U.S. (Economics); and, Guido Imbens, Stanford University, Stanford, C.A., U.S. (Economics).

Also included in this year's list of Highly Cited Researchers are 77 Citation Laureates: individuals recognized by Clarivate, through citation analysis, as 'of Nobel class' and potential Nobel Prize recipients.

Figure 1: Nobel laureates identified as Highly Cited Researchers 2021

Name	Category and year
James P. Allison	Physiology or Medicine 2018
David Baltimore	Physiology or Medicine 1975
David Card	Economics 2021
Emmanuelle Charpentier	Chemistry 2020
Jennifer A. Doudna	Chemistry 2020
Esther Duflo	Economics 2019
Eugene Fama	Economics 2013
Ben L. Feringa	Chemistry 2016
Andre K. Geim	Physics 2010
Reinhard Genzel	Physics 2020
John B. Goodenough	Chemistry 2019
Alan J. Heeger	Chemistry 2000
Guido Imbens	Economics 2021
David Julius	Physiology or Medicine 2021
Brian K. Kobilka	Chemistry 2012
Robert J. Lefkowitz	Chemistry 2012
David W. C. MacMillan	Chemistry 2021
Konstantin Novoselov	Physics 2010
Ardem Patapoutian	Physiology or Medicine 2021
Gregg L. Semenza	Physiology or Medicine 2019
Phillip A. Sharp	Physiology or Medicine 1993
Fraser Stoddart	Chemistry 2016
Thomas C. Südhof	Physiology or Medicine 2013
Susumu Tonegawa	Physiology or Medicine 1987

[5] Eugene Garfield and Alfred Welljams-Dorof, "Of Nobel class: A citation perspective on high-impact research authors," *Theoretical Medicine*, 13 (2): 117-135, June 1992. DOI: 10.1007/BF02163625

Highly Cited Researchers and 2021 Nobel Laureates

David Julius and Ardem Patapoutian
2021 Nobel laureates in Physiology or Medicine

David W. C. MacMillan and Benjamin List
2021 Nobel laureates in Chemistry

Joshua Angrist, David Card and Guido Imbens
2021 Nobel laureates in Economics

David Julius and Ardem Patapoutian

2021 Nobel laureates in Physiology or Medicine

David Julius

Photo credit: Scripps Research/Noah Berger

Ardem Patapoutian

Photo credit: Scripps Research/Noah Berger

The 2021 Nobel Prize in Physiology or Medicine was awarded for the "discovery of receptors for temperature and touch." As such, this Nobel Prize recognizes fundamental physiological mechanisms in vertebrates that allow us to interact with our environment.

David Julius of the University of California, San Francisco identified a novel ion channel protein sensitive to capsaicin, the molecule in chili papers that produces the sensation of heat. Patapoutian of Scripps Research, La Jolla, California, revealed a different class of protein gateways that respond to mechanical stimuli and convey body position and motion. Ion channels allow electrical signals to travel through nerve cells and eventually to the brain, where we perceive heat, cold, pressure and pain.

Professors Julius and Patapoutian are 2021 Highly Cited Researchers, as they have been over the last several years. Both were selected in the cross-field category because – as might be anticipated from the nature of this research – their multiple highly cited papers are categorized in several fields. The highly cited papers of Julius are classified as biochemistry, molecular biology and neurosciences, whereas those of Patapoutian as biochemistry, clinical medicine and neurosciences.

The 1997 discovery account of the capsaicin receptor by Julius and colleagues[6] is a citation classic even among the small population of already exceptional highly cited papers. With more than 6,100 citations to date, this report ranks in the top 500 of some 18 million regular and proceedings papers in the biological and biomedical sciences indexed in the Web of Science since 1970. Thus, it ranks in the top .003% of papers in the last 50 years. For this and other qualitative considerations, Clarivate named Julius a Citation Laureate in 2009, a designation for researchers "of Nobel class." Since 2002, 64 Citation Laureates have gone on to receive Nobel recognition, now including Julius.

"Intensive ongoing research originating from this year's Nobel Prize awarded discoveries focusses on elucidating their functions in a variety of physiological processes," noted the press release of the Nobel Assembly at the Karolinska Institutet. "This knowledge is being used to develop treatments for a wide range of disease conditions, including chronic pain."[7]

[6] Michael J. Caterina, Mark A. Schumacher, Makoto Tominaga, Tobias A. Rosen, Jon D. Levine, and David Julius, "The capsaicin receptor: a heat-activated ion channel in the pain pathway," *Nature*, 389(6653): 816-824, October 23, 1997. DOI: 10.1038/39807

[7] Press release: The Nobel Prize in Physiology or Medicine 2021. NobelPrize.org. Nobel Prize Outreach AB 2021. Wed. 27 Oct 2021

David W. C. MacMillan and Benjamin List
2021 Nobel laureates in Chemistry

David W. C. MacMillan

Benjamin List

The Nobel Assembly named David W. C. MacMillan of Princeton University and Benjamin List of the Max-Planck-Institut für Kohlenforschung, Mülheim an der Ruhr, Germany, as recipients of the 2021 Prize for Chemistry. The pair were recognized "for the development of asymmetric organocatalysis." In 2000, MacMillan and List independently introduced a novel approach for building important compounds that depended on neither metals nor enzymes as catalysts but rather harnessed small organic molecules to drive chemical reactions. Their approach has been transformative for the pharmaceutical industry and, being an efficient production method, has advanced green chemistry.

The two groundbreaking papers of 2000[8] were published in March and May, both in the *Journal of the American Chemical Society*. The report of List and colleagues, describing enamine catalysis, came first and has been cited more than 2,200 times in the Web of Science. That of MacMillan and colleagues, describing iminium ion catalysis, has been cited about half as much, perhaps reflecting a 'first-mover advantage' in attention for List's paper. It was MacMillan, however, who coined the term organocatalysis. MacMillan is a Highly Cited Researcher for 2021 in chemistry, as he has been each year since 2014. List was selected as a Highly Cited Researcher in chemistry from 2014 through 2017. List was also selected in 2009 as a Citation Laureate, a designation for researchers "of Nobel class." Since 2002, 64 Citation Laureates have gone on to receive Nobel recognition, now including List.

The sociologist of science Robert K. Merton studied the phenomenon of independent multiple discovery in science and noted that such instances are more common than typically acknowledged. Well known examples include the invention of calculus by Newton and Leibniz and the theory of evolution of species by Darwin and Wallace. A more contemporary example, honored with the Nobel Prize in Physics last year, was the finding of the existence of a supermassive black hole at the center of the Milky Way, revealed by independent research of Reinhard Genzel and of Andrea Ghez. While the specific techniques that Professors MacMillan and List introduced differ, the idea of organocatalysis surfaced at the same moment or nearly so.[9]

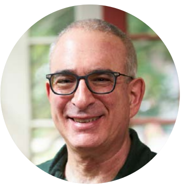
"The discovery being awarded the Nobel Prize in Chemistry 2021 has taken molecular construction to an entirely new level. It has not only made chemistry greener, but also made it much easier to produce asymmetric molecules. During chemical construction a situation often arises in which two molecules can form, which – just like our hands – are each other's mirror image. Chemists often just want one of these mirror images, particularly when producing pharmaceuticals, but it has been difficult to find efficient methods for doing this. The concept developed by Benjamin List and David MacMillan – asymmetric organocatalysis – is as simple as it is brilliant. The fact is that many people have wondered why we didn't think of it earlier."[10]

[8] Benjamin List, Richard A. Lerner, and Carlos F. Barbas, "Proline-catalyzed direct asymmetric aldol reactions," *Journal of the American Chemical Society*, 122(10): 2395-2396, March 15, 2000 DOI: 10.1021/ja994280y; and, Kateri A. Ahrendt, Christopher J. Borths, and David W.C. MacMillan, "New strategies for organic catalysis: The first highly enantioselective organocatalytic Diels-Alder reaction," *Journal of the American Chemical Society*, 122(17): 4243-4344, May 3, 2000 DOI: 10.1021/ja000092s

[9] Eugene Garfield, Multiple independent discovery and creativity in science, *Essays of an information scientist*, Vol. 4, 660-665, 1981.

[10] Popular information. NobelPrize.org. Nobel Prize Outreach AB 2021. Thu. 28 Oct 2021.

Joshua Angrist, David Card and Guido Imbens
2021 Nobel laureates in Economics



Joshua Angrist
Photo credit: Lillie Paquette

David Card

Guido Imbens
Photo credit: Andrew Brodhead

The three new Nobel laureates in Economics – Joshua Angrist of MIT, David Card of the University of California Berkeley, and Guido Imbens of Stanford – pioneered the use and interpretation of so-called natural experiments.

One half of the Prize was awarded to Card "for his empirical contributions to labour economics" and the other half to Angrist and Imbens "for their methodological contributions to the analysis of causal relationships."

Card and Imbens are Highly Cited Researchers, Card since 2019 and Imbens every year since 2014. In 2013 Clarivate named Angrist, Card and the late Alan B. Krueger, who authored key studies with Angrist and Card in the 1990s, as Citation Laureates "for their advancement of empirical microeconomics."

A natural experiment in economics, which draws upon observational data rather than those generated in a randomized controlled trial, tests a hypothesis about a market phenomenon by interrogating data that nonetheless permits the use of controls. An example is Card and Krueger's 1994 paper[11] examining how raising the minimum wage affects employment. When the U.S. state of New Jersey raised its minimum wage and the bordering state of Pennsylvania did not, Card and Krueger studied the labor market of the fast-food industry. Contrary to expectation that a higher minimum wage would reduce levels of employment in New Jersey, it did not relative to Pennsylvania which served as the control in the experiment. The finding was controversial and vigorously debated, but the study is a model of carefully chosen methods deployed on appropriate data to illustrate a labor market issue of practical concern for policymakers and the public.

Meanwhile Angrist and Imbens, also in the 1990s, published a method for estimating cause and effect in a natural experiment to understand the impact of a policy implementation in changing individuals' behavior. This paper[12] has received about 2,500 citations according to the Web of Science. The citations come not only from economics journals but also those in public, environmental and occupational health, social sciences methods, computational biology, education, political science, sociology and demography, among many others, reflecting significant interdisciplinary influence.

The range of topics that Angrist, Card and Imbens have studied (along with Krueger) is remarkable: unemployment, wages, unions, immigration, education, health insurance, terrorism, income distribution, regulation, methods. Their common approach to answering fundamental questions about how markets work has plainly had great impact – not only deep but broad as well.

[11] David Card and Alan B. Kruger, "Minimum wages and employment: A case study of the fast-food industry in New Jersey and Pennsylvania", *American Economic Review*, 84 (4): 772-93, 1994 (1,055 citations)

[12] Joshua D. Angrist and Guido W. Imbens, "Identification of causal effects using instrumental variables", *Journal of the American Statistical Association*, 91 (434): 444-455, 1996 (2,491 citations)

Highly Cited Researchers 2021

Highly Cited Researchers from Clarivate is an annual list recognizing influential researchers in the sciences and social sciences from around the world.

The 2021 list contains about 6,600 Highly Cited Researchers, some 3,800 in 21 fields of the sciences and social sciences and about 2,800 Highly Cited Researchers identified as having exceptional performance across several fields.[13] The list focuses on contemporary research achievement: only highly cited papers in science and social sciences journals indexed in the Web of Science Core Collection during the 11-year period 2010 to 2020 were surveyed. Highly cited papers are defined as those that rank in the top 1% by citations for field and publication year. This percentile-based selection method removes the citation advantage of older papers relative to recently published ones, since papers are weighed against others in the same annual cohort.

Using our InCites analytics tool, the data are derived from the ESI database, which reveals emerging science trends as well as influential individuals, institutions, papers, journals and countries. The fields are also those employed in ESI – 21 broad fields defined by sets of journals and exceptionally, in the case of multidisciplinary journals such as *Nature* and *Science*, by a paper-by-paper assignment to a field based on an analysis of the cited references in the papers.

Essential Science Indicators fields

- Agricultural Sciences
- Biology and Biochemistry
- Chemistry
- Clinical Medicine
- Computer Science
- Economics and Business
- Engineering
- Environment/Ecology
- Geosciences
- Immunology
- Materials Science
- Mathematics
- Microbiology
- Molecular Biology and Genetics
- Neuroscience and Behavior
- Pharmacology and Toxicology
- Physics
- Plant and Animal Sciences
- Psychiatry/Psychology
- Social Sciences
- Space Science

Researchers who, within an ESI-defined field, publish papers that are highly cited by their peers are judged to be influential, so the production of multiple top 1% papers is interpreted as a mark of exceptional influence. Relatively young and early career researchers are more likely to emerge in such an analysis than in one dependent on total citations over many years.

[13] The number of unique Highly Cited Researchers is 6,331, including 3,503 in the ESI fields and 2,828 in the cross-field category. The analysis reported here is based on appearances of Highly Cited Researchers in specific fields, and a small number are selected in more than one ESI field.

Recognizing early and mid-career as well as senior researchers is one of our goals in generating Highly Cited Researchers lists. The determination of how many researchers to include in the list for each field is based on the population of each field, as represented by the number of disambiguated author names on all highly cited papers in that field, 2010 to 2020. The ESI fields vary greatly in size, with Clinical Medicine being the largest in terms of highly cited papers and Space Science the smallest; likewise, Clinical Medicine is largest in terms of researchers whereas Mathematics is smallest. The square root of the number of authors in each field indicated how many individuals should be selected.

One of two criteria for selection is that the researcher must have enough citations to their highly cited papers to rank among all authors in the top 1% by total citations in the ESI field in which that person is considered. Authors of highly cited papers who meet this criterion in a field are ranked by number of such papers, and the threshold for inclusion is determined, as mentioned, using the square root of the population represented by the number of disambiguated authors names on the highly cited papers in a field. All who published highly cited papers at the threshold level are admitted to the list, even if the final list then exceeds the number given by the square root calculation.

In addition, and as a concession to the somewhat arbitrary cut-off, any researcher with one fewer highly cited paper than the threshold number is also admitted to the list if total citations to their highly cited papers rank that individual in the top 50% by total citations of those at the threshold level or higher. The justification for this adjustment is that it seems to work well in identifying influential researchers, in the judgment of the Web of Science citation analysts.

Of course, there are many highly accomplished and influential researchers who are not recognized by the method described above and whose names do not appear in the 2021 list. This outcome would hold no matter what specific method were chosen for selection. Each measure or set of indicators, whether total citations, h-index, relative citation impact, mean percentile score, etc., accentuates different types of performance and achievement. Here we confront what many expect from such lists but what is unobtainable: that there is some optimal or ultimate method of measuring performance.

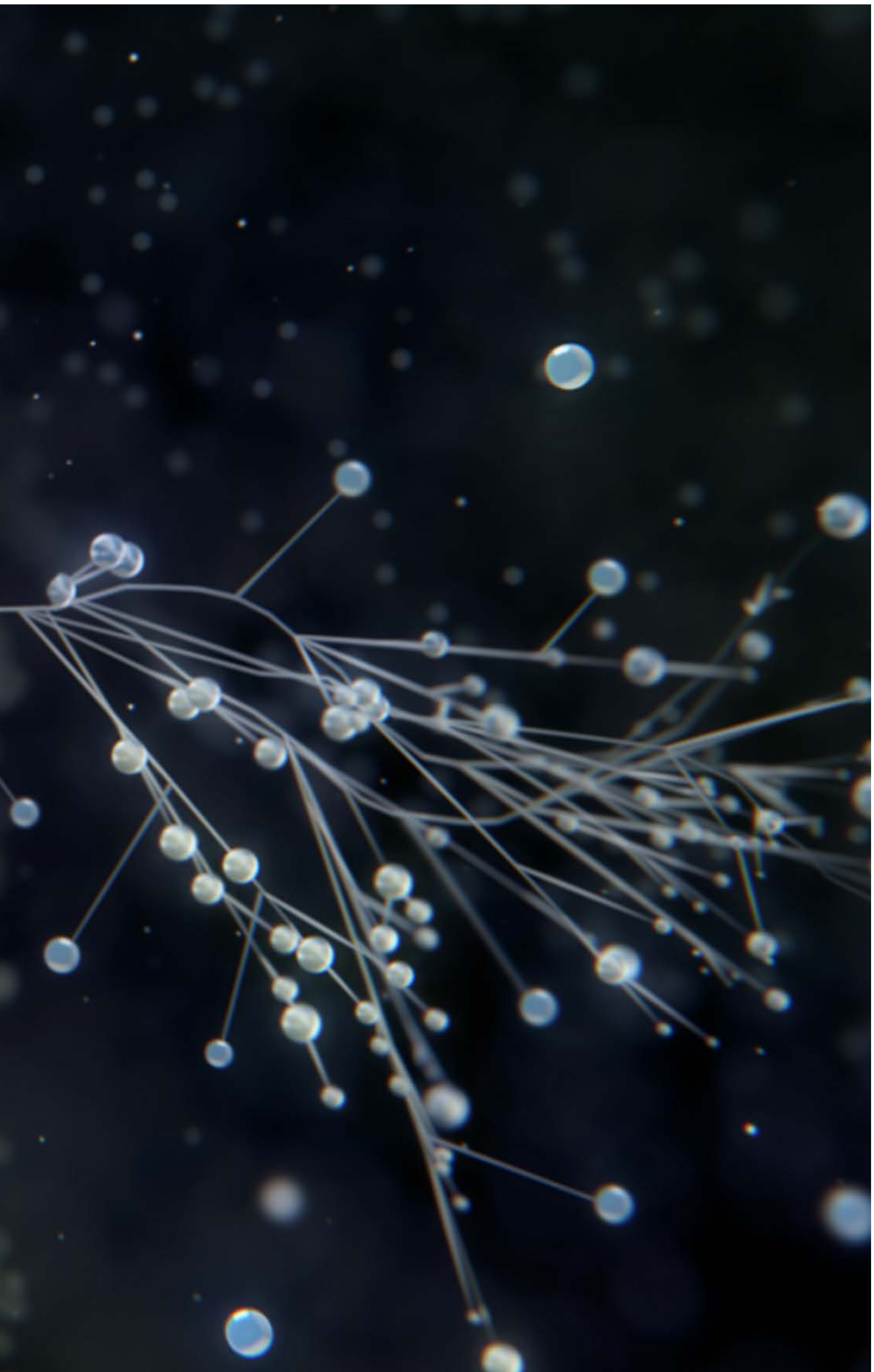
The only reasonable approach to interpreting a list of top researchers such as ours is to fully understand the method behind the data and results, and why the method is used. With that knowledge, in the end, the results may be judged by readers as relevant or irrelevant to their needs or interests.

Researchers with cross-field impact

In 2018 we introduced a new cross-field category to identify researchers with substantial influence across several fields during the data census period. As mentioned above, 2,828 researchers with cross-field impact now join some 3,774 who have been selected in one or more of 21 broad ESI fields. The addition of cross-field selectees yielded a substantial increase from those chosen in the 21 ESI fields only, but the current 6,602 still represent a very small fraction of all scientists and social scientists actively publishing today.

Since introducing Highly Cited Researchers in 2014, Clarivate analysts have received the suggestion from many that limiting the methodology for selection to only those with a required number of highly cited papers in a single field, as defined in ESI, discriminates against researchers who publish highly cited papers in several fields but not enough in any one field to be chosen.

We responded to this concern. In line with recommendations on best practice, we wanted to ensure that any metrics or analyses that we produce are structured and presented in a responsible manner. Extending the identification of Highly Cited Researchers to cross-disciplinary work fulfills that goal.



3,774

Highly Cited Researchers in specific field

2,828

Highly Cited Researchers for cross-field performance

Figure 2: Method for identifying Highly Cited Researchers in the cross-field category

ESI field	First name	Last name	Number of HCPs	Citation to HCPs	Field citation threshold	Field paper threshold	Field paper score	Field citation score
Field 3	Joseph	Savant	1	98	1857	22	0.045	0.053
Field 6	Joseph	Savant	7	2937	946	8	0.875	3.105
Field 14	Joseph	Savant	3	663	676	6	0.500	0.981
Field 16	Joseph	Savant	4	3397	2223	16	0.250	1.528
Cross-field	**Joseph**	**Savant**					**1.670**	**5.667**

The challenge for us was finding a method that took account of the different threshold number of highly cited papers in each field so that those contributing papers in several fields could be compared in an equal manner with those selected in one or more ESI fields. The solution chosen was to fractionally count the credit for each highly cited paper such that a paper in a field with a high threshold number of papers was weighted less than a paper in a field with a lower threshold number of papers. The example at the top of this page illustrates the method.

The fictional researcher Joseph Savant published 15 highly cited papers in four ESI fields. Seven papers in Field 6, with a threshold number of eight for selection, earned Savant a credit of 0.875 (or 7/8ths). Three papers in Field 14, with a threshold number of six for selection, were worth 0.5. The sum of the fractional paper counts in each field yielded a total cross-field paper score of 1.67. A score of 1 or more indicates that the individual achieved equivalent impact to a researcher chosen in a specific ESI field.

The second criterion for selection as a Highly Cited Researcher is enough citations to rank in the top 1% by citations for a field. Again, citations in different fields were fractionated in a similar manner to the treatment of papers. In the example above, Professor Savant earned more than five times the number of citations needed for selection as an influential cross-field researcher. Both criteria had to be met for selection as a cross-field Highly Cited Researcher, just as required for selection in one or more ESI fields.

Traditional field definitions are useful in some contexts but less so in others. Today, an immunologist may identify himself as a biochemist and a molecular biologist. Another researcher may be hard pressed to say whether she is a chemist, materials scientist or engineer. Breaking through the artificial walls of conventional disciplinary categories helps to keep our Highly Cited Researcher list contemporary and relevant.

Moreover, as frontier areas of research are frequently interdisciplinary, it is even more important to identify scientists and social scientists working and contributing substantially at the cross-field leading edge.

"The Clarivate list is one way of identifying and recognizing researchers who are undertaking globally significant research, which is benefiting our community."

University of Sydney, Australia

The 6,602 Highly Cited Researchers of 2021 are unevenly distributed by field, in accordance with the size of each. The table below summarizes the number of researchers in each ESI field and in the cross-field category.

Figure 3: Highly Cited Researchers by ESI field and cross-field category

ESI field	Number of Highly Cited Researchers
Agricultural Sciences	125
Biology and Biochemistry	206
Chemistry	240
Clinical Medicine	453
Computer Science	110
Economics and Business	81
Engineering	169
Environment/Ecology	202
Geosciences	143
Immunology	161
Materials Science	219
Mathematics	74
Microbiology	126
Molecular Biology and Genetics	177
Neuroscience and Behavior	179
Pharmacology/Toxicology	159
Physics	198
Plant and Animal Science	202
Psychiatry/Psychology	183
Social Sciences, General	263
Space Science	104
Total	**3774**
Cross-field	**2828**
Grand total	**6602**

The following analysis is based on primary researcher affiliations, as specified by the Highly Cited Researchers themselves.

The United States is the institutional home for 2,622 of the Highly Cited Researchers in 2021, which amounts to 39.7% of the group, down from 41.5% in 2020, 44.0% in 2019, and 43.3% in 2018, as the table shows. By contrast, of all papers indexed in Web of Science for 2010 to 2020 the percentage with a U.S. author was 24.7%. Mainland China is second this year, with 935 Highly Cited Researchers, or 14.2%, up from 12.1% in 2020, 10.2% in 2019, and 7.9% in 2018. In other words, in four years Mainland China has nearly doubled its share of the Highly Cited Researchers population. The United Kingdom, with 492 researchers or 7.5%, is third. Rounding out the top 10, all with 100 or more Highly Cited Researchers, are Australia (332), Germany (331),The Netherlands (207), Canada (196), France (146), Spain (109), and Switzerland (102). These figures do not include the few cases in which a Highly Cited Researcher opted to list a primary affiliation that represented a Research Fellowship rather than a permanent home base.

The Highly Cited Researchers in 2021 work in some 70 countries/regions, but 82.9% are from these 10 and 71.4% from the first five, a remarkable concentration of top talent.

As mentioned, Mainland China has increased its share of Highly Cited Researchers significantly in recent years. Of course, world share is a zero-sum game so as Mainland China increases its stable of Highly Cited Researchers other countries/ regions decline. This year we observe a significant 1.8% loss in Highly Cited Researchers for the United States, and 3.6% since 2018. This contrasts with an increase of 6.3% for Mainland China since 2018. The United Kingdom exhibits a decline of .5% since last year and 1.5% since 2018. Germany has lost .9% share since 2018. Meanwhile, Australia is gaining share, moving from 4.0% in 2018 to a 5.0% share this year, overtaking Germany to rank in fourth place. For the first time, researchers from Bangladesh, Kuwait, Mauritius, Morocco and the Republic of Georgia are included on the list.

The sharp decline of .7% for Switzerland since last year is anomalous and reflects a change in our methodology: Papers with more than 30 institutional addresses were removed from our analysis in past years, but this year we eliminated papers with more than 30 authors or group authorship. The change, which we judged an improvement in reasonably crediting individual authors – the previous use of institutional addresses was a heuristic – happened to impact Switzerland heavily and especially researchers at the Swiss Institute of Bioinformatics, which produces a significant number highly cited papers with many authors but few institutional addresses.

The headline story then, as it has been lately, is one of sizeable gains for Mainland China and large losses for the United States, which reflects a transformational rebalancing of scientific and scholarly contributions at the top level through the globalization of the research enterprise.

Figure 4: Highly Cited Researchers by country or region

Rank	Country/region	Number HCRs 2021	2018%	2019%	2020%	2021%	Change % Share 2018 to 2021
1	United States	2622	43.3	44	41.5	39.7	-3.6
2	China, Mainland	935	7.9	10.2	12.1	14.2	6.3
3	United Kingdom	492	9	8.3	8	7.5	-1.5
4	Australia	332	4	4.4	4.8	5	1
5	Germany	331	5.9	5.3	5.4	5	-0.9
6	The Netherlands	207	3.1	2.6	2.8	3.1	0
7	Canada	196	2.7	2.9	3.1	3	0.3
8	France	146	2.6	2.5	2.5	2.2	-0.4
9	Spain	109	1.9	1.9	1.6	1.7	-0.2
10	Switzerland	102	2.2	2.5	2.4	1.5	-0.7

Figure 5: Highly Cited Researchers by institutions

Institutions	Country/ region	Numbers HCRs
Harvard University	U.S.	214
Chinese Academy of Sciences	China, Mainland	194
Stanford University	U.S.	122
National Institutes of Health (NIH)	U.S.	93
Max Planck Society	Germany	70
Massachusetts Institute of Technology (MIT)	U.S.	64
University of California Berkeley	U.S.	62
Tsinghua University,	China, Mainland	58
University of California San Diego	U.S.	56
University of Oxford	U.K.	51
Memorial Sloan Kettering Cancer Center	U.S.	50
Johns Hopkins University	U.S.	49
University of California Los Angeles	U.S.	49
University of California San Francisco	U.S.	49
Yale University	U.S.	48
Columbia University	U.S.	47
University of Pennsylvania	U.S.	47
Washington University (WUSTL)	U.S.	46
Cornell University	U.S.	45
University of Queensland	Australia	44
University of Cambridge	U.K.	43
University of North Carolina Chapel Hill	U.S.	41
University of Science and Technology of China	China, Mainland	41
University of Washington Seattle	U.S.	41
Nanyang Technological University	Singapore	38

Institutions	Country/ region	Numbers HCRs
University College London	U.K.	38
Duke University	U.S.	37
King Saud University	Saudi Arabia	36
University of Melbourne	Australia	36
University of New South Wales Sydney	Australia	36
University of Hong Kong	Hong Kong	33
Icahn School of Medicine at Mount Sinai	U.S.	32
King Abdulaziz University	Saudi Arabia	32
Mayo Clinic	U.S.	32
National University of Singapore	Singapore	32
University of Texas MD Anderson Cancer Center	U.S.	32
Broad Institute	U.S.	31
King's College London	U.K.	31
Northwestern University	U.S.	31
University of Chicago	U.S.	31
University of Sydney	Australia	30
University of Toronto	Canada	29
Utrecht University	Netherlands	29
Zhejiang University	China, Mainland	29
Ghent University	Belgium	28
New York University	U.S.	28
Peking University	China, Mainland	28
University of Texas Austin	U.S.	28
University of Edinburgh	U.K.	27
University of Minnesota Twin Cities	U.S.	27

In the 2021 ranking of institutions, with 27 or more Highly Cited Researchers, 50 organizations – whether universities, government agencies, or other entities – are listed.

The university with the greatest number of Highly Cited Researchers is Harvard, as it has been in past years. Its 214 Highly Cited Researchers for 2021 places it well ahead of third ranked Stanford University, with 122.

Among governmental and other types of research organizations, the Chinese Academy of Sciences heads the list (194), followed by the U.S. National Institutes of Health (93), the Max Planck Society (70), Memorial Sloan Kettering Cancer Center (50), and the Broad Institute (31). This year we have counted the University of Science and Technology of China (USTC) as part of the Chinese Academy of Sciences, an association also indicated in the Organization-Enhanced data of Web of Science (Chinese Academy of Sciences: University of Science and Technology of China, CAS). USTC is also listed separately in the table to provide insight on its contribution to the CAS total.

Figure 6: Highly Cited Researchers recognized across three ESI fields

Name	Primary affiliation	ESI fields
Zhenan Bao	Stanford University, U.S.	Chemistry; Engineering; Materials Science
Jinde Cao	Southeast University – China, China, Mainland	Computer Sciences; Engineering; Mathematics
Xiaoyuan Chen	NIH National Institute of Biomedical Imaging and Bioengineering (NIBIB), U.S.	Chemistry; Materials Science; Pharmacology/Toxicology
Yi Cui	Stanford University, U.S.	Chemistry; Engineering; Materials Science
Richard H. Friend	University of Cambridge, U.K.	Chemistry; Materials Science; Physics
Lorenzo Galluzzi	Cornell Medical Center, U.S.	Immunology; Molecular Biology and Genetics; Pharmacology/Toxicology
Michael Graetzel	Ecole Polytechnique Federale de Lausanne, Switzerland	Chemistry; Engineering; Materials Science
Wei Huang	Nanjing Tech University, China, Mainland	Chemistry; Materials Science; Physics
Curtis Huttenhower	Harvard University, U.S.	Biology and Biochemistry; Microbiology; Molecular Biology and Genetics
Mercouri G. Kanatzidis	Northwestern University, U.S.	Chemistry; Materials Science; Physics
Ali Khademhosseini	Terasaki Institute for Biomedical Innovation, U.S.	Biology and Biochemistry; Materials Science; Pharmacology/Toxicology
Rob Knight	University of California San Diego, U.S.	Biology and Biochemistry; Environment/Ecology; Microbiology; Molecular Biology and Genetics;
Guido Kroemer	Universite de Paris, France	Immunology; Molecular Biology and Genetics; Pharmacology/Toxicology
Robert Langer	Massachusetts Institute of Technology (MIT), U.S.	Biology and Biochemsitry; Materials Science; Pharmacology/Toxicology
Jun Liu	Pacific Northwest National Laboratory, U.S.	Chemistry; Engineering; Materials Science
Xiong Wen (David) Lou	Nanyang Technological University, Singapore	Chemistry; Materials Science; Physics
Ju H. Park	Yeungnam University, South Korea	Computer Sciences; Engineering; Mathematics
Keywan Riahi	International Institute for Applied Systems Analysis (IIASA), Austria	Environment/Ecology; Geosciences; Social Sciences
Edward H. Sargent	University of Toronto, Canada	Chemistry; Materials Science; Physics
Muhammad Shahbaz	Beijing Institute of Technology, China, Mainland	Economics and Business; Engineering; Social Sciences
Detlef P. van Vuuren	Utrecht University, Netherlands	Environment/Ecology; Geosciences; Social Sciences
Ian A. Wilson	Scripps Research, U.S.	Biology and Biochemistry; Immnuology; Microbiology
Ramnik J. Xavier	Broad Institute, U.S.	Immunology; Microbiology; Molecular Biology and Genetics

The top ranked institutions show little change in position compared to last year, including the same order for the first five. Those increasing more than 10 places in rank are: University of California Los Angeles, University of Queensland, University of Science and Technology of China, National University of Singapore, Northwestern University and Zhejiang University. University of Hong Kong, University of Sydney, University of Texas Austin and University of Edinburgh are new to the Top 50 ranking. Among the 3,774 researchers named as Highly Cited in the 21 ESI fields, 248, or 6.6%, appear in two ESI fields and only 23 (listed above), or .6%, appear in three or more fields. (Cross-field researchers, of which there are 2,828, qualify in only one category, or else they would have been chosen in one or more ESI fields.)

It is important to understand the difference between selection as a Highly Cited Researcher in the cross-field category and selection in more than one ESI field. Both classes of individuals have demonstrated significant research influence across fields. Cross-field researchers, however, qualify for selection based on the sum of their highly cited papers and citations that meets a normalized threshold equivalent to selection in any one field whereas those named in multiple fields qualify outright in each field.

Finally, and again this year as in the last two years, a filter was applied to remove researchers whose level of self-citation exceeded, by far, the typical patterns of each field. This procedure has and will continue to help maintain the purpose of our selection process and the integrity of our data: to identify researchers with broad community influence and not those whose citation profile is narrow and substantially self-generated.[14]

Three other filters are also employed, two before the analysis begins and one at its conclusion. Highly cited papers that have been retracted are excluded from the analysis. Also, massively multiauthored highly cited papers are not included in our analysis: to award credit to a single author among many tens or hundreds listed on a paper strains reason, so any highly cited paper with more than 30 authors or explicit group authorship, in any of the 21 fields, was eliminated before beginning our analysis. At the end of our analysis, we search for cases of research misconduct among those researchers tentatively selected. Those found to have committed scientific misconduct in formal proceedings conducted by a researcher's institution, a government agency, a funder or a publisher are removed from the list of Highly Cited Researchers.

[14] Jonathan Adams, David Pendlebury, and Martin Szomszor, "How much is too much? The difference between research influence and self-citation excess," *Scientometrics*, 123 (2): 1119–1147, May 2020. DOI: 10.1007/s11192-020-03417-5

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The foregoing is but a tasting of the riches of the Highly Cited Researchers data

The full list can be found at:
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