

CHAPTER NINE



Research

Call it an idea whose time has come: Milo Sensors, a tech startup founded by recent UC Santa Barbara alumni Evan Strenk (B.A.) and Bob Lansdorp (Ph.D.), has evolved from a student-driven, smart business proposal into a burgeoning leader in the next wave of wearable technology.

The brainchild of enterprising science and engineering students, the startup took First Place in the 2018 University of California Startup Showcase sponsored by Silicon Valley-based venture capital firm Vertical Venture Partners.

“We are immensely proud of Milo Sensors’ first place win at the UC Startup Showcase — topping a highly competitive selection of companies from across all ten UC campuses,” said Tal Margalith, executive director of technology at UC Santa Barbara’s California NanoSystems Institute (CNSI), whose unique, wet-lab technology incubator is currently hosting the tech startup. “Their award not only speaks to their strength as a team, but it also showcases how the innovation and entrepreneurship infrastructure at UC Santa Barbara helps nurture, incubate, and launch successful ventures.”

Three graduate students who worked on the Milos Project are pictured, left to right: Adam Chinn, William Ramsay, Rashad Hamid.

RESEARCH

The broad scope of UC research

The California Master Plan for Higher Education designates the University of California as the primary state-supported academic agency for research. UC research contributes to the state and to the nation through discoveries that improve health, technology, welfare, and the quality of life. Research represents the creation of new knowledge, which can be communicated, curated, and cultivated to benefit society.

UC has more than 800 research centers, institutes, laboratories, and programs that span ten campuses, five medical centers, three national energy laboratories, and numerous other research facilities.

Breadth of vision has been a virtue of UC's research since the University's founding more than a century and a half ago. All forms of intellectual inquiry are represented in the research enterprise: the architecture of atoms and the structure of the universe; the study of human cognition and the development of machine learning; the study of human pathogens and the creation of disease-resistant crops. The diversity of this vision contributes to society in ways often hard to predict at the outset.

As one example of this vision, UC's Research Grants Program Office (RGPO) oversees a broad grant-making portfolio of approximately \$110 million awarded annually from a variety of sources, with over 500 active research awards that provide first-mover advantage to UC and California investigators. RGPO grants catalyze advances in new areas yet to be supported on a large scale by federal and other sources, and enhance research capacity and excellence across California, thus making it easier to attract and retain outstanding faculty, to further the careers undergraduate, graduate, and postdoctoral researchers, and to promote research collaborations.

Evaluating the research enterprise

This chapter presents a largely quantitative description of UC's research activities. The sources of research funding influence the nature of the research. Federal support initiated UC's research mission and currently provides nearly half of all research funding (9.1.1). Most research funds pay the salaries and benefits of UC's research community, of which faculty are only a small proportion (9.1.2). While UC's research spans many disciplines, medical research is the largest expenditure component, and its share has grown over the last two decades (9.2.1).

UC performs nearly one-tenth of the nation's academic research (9.2.2). Compared to other research universities, UC has a higher rate of research expenditures per ladder-rank faculty (9.2.3), especially at UC campuses with medical schools (9.2.4). Three National Energy Laboratories are affiliated with the University of California, conducting research that is vital to the nation's security and energy future.

This chapter considers the impact of this research on society. One of the goals of research is the dissemination of its findings; the global distribution of downloads from UC's eScholarship repository (9.3.1) indicates how eagerly this knowledge is sought. The frequency with which UC research is cited is another indicator of its quality and importance (9.3.2). UC research advances the economy and technology through licenses and startups resulting from UC's patents (9.3.4, 9.3.5).

These measures, however, do not capture the wide range of curiosity-driven research at UC. Quantitative measures emphasize fields that receive sizable funding and produce large numbers of publications, such as medicine, physical and material sciences, and engineering. These measures underrepresent research achievements in the arts, humanities, social sciences, and theoretical sciences, where work leaves less of a financial footprint, and where results are disseminated in books or performances rather than journal articles.

Quantitative measures cannot capture how UC research contributes indirectly and over time to the state and to the nation through discoveries that improve health, technology, and the quality of life; how involvement in research and hearing about discoveries from the world’s foremost researchers enhances the learning experiences of UC’s graduate and undergraduate students; or how thoughtful work in the arts and humanities furthers our understanding of ourselves as one species among many on this planet.

The size and scope of UC’s research programs

While research expenditures track only some of this activity, they can indicate how research changes in scope and focus over time, and can provide some relative sense of how research institutions compare to one another. During 2017–18, direct expenditures for research at UC totaled nearly \$4.8 billion, with federal funds providing about half. Private sources account for about 21 percent — 14 percent from nonprofit organizations and seven percent from corporate sponsors. About one-quarter represented the University’s own funds derived from gifts, endowments, general funds, and other sources. Over half of research expenditures in 2017–18 went to salaries and benefits. Of this, about one-quarter went to faculty; the majority supported staff researchers, and about one-quarter went to students and postdoctoral scholars.

Budgets for externally funded research include both a direct cost component — the actual amount spent on salaries, benefits, equipment, and materials directly linked to the project — plus a percentage to cover the facilities and administration required to support the research project, including debt service, maintenance, and libraries. These facilities and administration costs are called “indirect costs.”

In 2017–18, UC’s indirect cost recovery was just over \$1.1 billion, with the great majority from research activities. (Other forms of sponsored projects, such as service and training grants, also include indirect cost components.) The true indirect costs of research, however, are typically higher than the rate that research sponsors are willing to pay. Rates negotiated with federal agencies are 18 to 20 percentage points below the true indirect costs. Non-federal research sponsors, including corporations, nonprofits, and the state of California, have policies that limit indirect cost rates to well below federal rates. The true costs of UC research exceed recovered amounts by hundreds of millions of dollars annually.

The research community

Research funds principally pay for people’s time. Of the roughly 159,000 full-time equivalent (FTE) employees at the University, nearly 28,000, or about 18 percent, were paid with research funds.

UC’s Research Workforce, 2017–18, FTE

Students	Postdoctoral Researchers	Other Staff	Other Academics	Faculty	Total
4,443.4	4,682.4	11,308.4	4,847.6	2,694.0	27,975.9
16%	17%	40%	17%	10%	100%

While faculty serve as Principal Investigators for research projects, submitting proposals and managing the research, they make up only ten percent of the research community, as measured in terms of compensated time. However, this figure, principally representing projects with research grants, underrepresents the time faculty spend on research. Virtually every faculty member at UC engages in research, often involving no expenditures other than the faculty member’s time. As in all research universities, career advancement at UC (including tenure),

requires a significant body of scholarly or creative work. The research community includes over 4,600 FTE postdoctoral researchers, representing about 6,500 individuals (many postdocs either teach or are less than full-time). As shown in Indicator 5.1.4 of this report, postdoctoral scholars are most prominent in medical research and life science fields.

Research results — enhancing instruction

UC's research enhances the student experience. Faculty incorporate their research into their courses, providing students with access to insights and discoveries, sometimes before they are published. Postdoctoral scholars, representing one-sixth of the research workforce, contribute to instruction by working with graduate students. Students make up another one-sixth of the research workforce. In 2017–18, about 10,500 students were employed as paid research assistants. Though most are graduate students, UC undergraduate students also participate in research; the 2018 UC Undergraduate Experience Survey found over 40 percent of UC students had been involved in faculty-directed activity other than coursework, such as research or creative projects.

Research results — spurring the economy

Many businesses in California are based on technology developed at UC or rely on the skills of UC graduates. Over the past two decades, UC has secured more licensable patents than any other U.S. research university. Since 1976, over 1,000 startup companies have been founded around UC inventions, with about 85 percent based in California. UC researchers submit nearly five new inventions per day in such diverse areas as agriculture, technology, biotech, and clean energy. The discoveries made through research become public knowledge through publications and the patent process. These innovations enhance industries, stimulate economies, and improve health and well-being.

Research results — communicating and curating knowledge

Publications are perhaps the most visible results of research. Between 2012 and 2018, UC campuses produced about one-twelfth of the nation's research publications. This chapter compares the volume and impact of UC research publications to nationwide averages and to the output of peer AAU institutions.

The books, periodicals, and journals in which research findings are published are costly and beyond the reach of many researchers, students, and journalists. To ensure that research findings become public, UC has adopted Open Access (OA) policies that are the most comprehensive of any academic institution in the United States. All UC employees must now deposit their research papers, upon publication, in the eScholarship repository operated by UC's California Digital Library (CDL) and grant a non-exclusive license to UC to make those materials openly available. CDL is negotiating agreements that reduce or eliminate the costs of publishing OA with publishers, developing models to transition subscription journals to open access, and supporting tools and services to disseminate research.

UC also disseminates its research directly. In 2018, UC celebrated the 125th anniversary of the founding of the UC Press. In 1893, the University's governing board funded a non-profit publishing program, establishing the UC Press. Today, the UC Press is among the six largest university publishers in the United States, and publishes approximately 200 books and 40 multi-issue journals annually. Of the nation's top university presses, UC press is the only one associated with a public university.

Research results — improving health

Clinical research projects are another example of cultivating new knowledge to benefit society. During 2017–18, UC received more than 1,500 new grants for clinical trial research projects in addition to the 3,300 already

underway. These projects represent a crucial stage in the journey from a scientific discovery to an effective treatment. Of the research dollars that came to UC from businesses during 2017–18, 52 percent was directed toward clinical trials.

Research results — assessing climate change and charting the energy future

UC is a national and global leader in research on climate science, including monitoring atmospheric changes and global temperature rise, as well as assessing the impacts of climate change on marine and land-based ecosystems and the built environment. UC scholars and students carry out some of these studies at UC's 39 Natural Reserve System (NRS) sites around California. Most of UC's climate science work is funded by federal agencies. Each year, the University, together with the UC-affiliated Lawrence Berkeley and Lawrence Livermore National Laboratories, receives an average of \$218 million in federal funding to pursue climate research.

UC National Laboratories — science in the national interest

The three University of California-affiliated National Laboratories — Lawrence Berkeley (LBNL), Lawrence Livermore (LLNL), and Los Alamos (LANL) — are among the nation's premiere multi-disciplinary research and development (R&D) laboratories for energy and national security. The University has played a public service role as a manager of these three Department of Energy (DOE) National Laboratories, with annual budgets of over \$5 billion and a combined workforce of more than 22,000. The Laboratories also support UC's educational mission. At LBNL, 23 percent of employees are student assistants, graduate research assistants, or postdoctoral scholars. At LLNL, four percent of the workforce are postdocs, and at LANL, 13 percent are postdocs or student assistants.

Looking forward — uncertainties in federal research funding

With federal funding supporting about half of UC's research, the vitality of UC's research enterprise is dependent on agencies whose funding is reviewed annually. The fiscal year 2018 budget, passed in March 2018, increased support for academic research. In contrast, the President's Budget Proposal would have drastically reduced all agency appropriations for research, including a cut of over 21 percent at the National Institutes of Health, UC's largest single source of research funding. The 2019 federal government shutdown signaled further conflict over federal appropriations. Long-term prospects for federal research sponsorship, particularly for climate and environmental science, but including fundamental medical research, are uncertain.

Whatever changes in priorities are embodied in the federal budget, one certainty is that federal funding is becoming increasingly competitive. At the National Institutes of Health, only one proposal is funded for every five received, compared to about 32 percent fifteen years ago, even though total appropriations for research have increased. UC is competitive in garnering these awards, but this comes at a cost. The administrative effort of drafting, reviewing, submitting, and tracking proposals is one of the less-visible costs of conducting research — costs that are not fully recovered from federal sponsors.

For more information

UC's Budget for Current Operations 2018-19:

ucop.edu/operating-budget/_files/rbudget/2018-19budgetforcurrentoperations.pdf

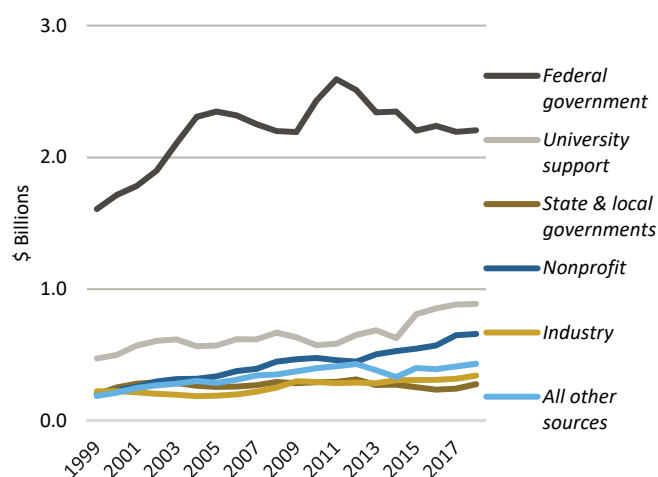
UCOP office of Research and Graduate Studies: ucop.edu/research-graduate-studies

A map of the economic impact of UC research activity in California: ucop.edu/institutional-research-academic-planning/_files/UC-research-impacts-in-california.pdf

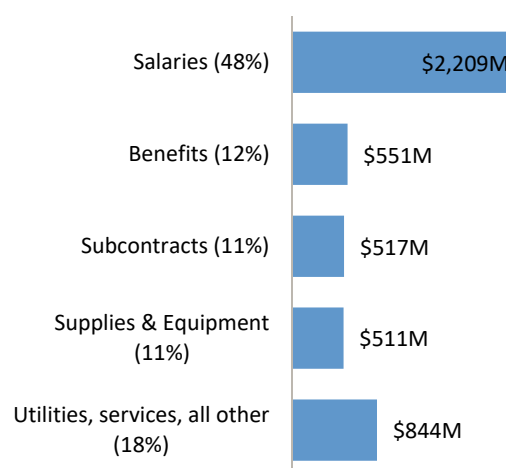
9.1 RESEARCH EXPENDITURES

Federal funds support most of the research conducted at UC. Salaries and benefits represent more than half of all research expenditures.

9.1.1 Direct research expenditures by source
Universitywide
1997–98 to 2017–18



9.1.2 Total research expenditures by category
Universitywide
2017–18



Source: UC Corporate Financial System. Direct amounts have been adjusted for inflation and do not include accrual funds for postemployment retirement benefits or indirect cost recovery funds.

UC's direct research expenditures during 2017–18 were about \$4.8 billion. Of this, 46 percent came directly from federal agencies. This is the same percentage as last year, lower than any other time in the previous 16 years. A further seven percent represents federal flow-through funds that came to UC from the state, corporations, nonprofit organizations, or other universities. About three-quarters of UC's federal research support was provided by the National Institutes of Health and the National Science Foundation. Fluctuations in federal appropriations impact UC's research. Cutbacks at federal agencies starting in 2006 ended a long period of growth. This was temporarily reversed during 2009–10 by the American Recovery and Reinvestment Act, which provided over \$1 billion in research funds to UC.

University support accounted for almost 20 percent of 2017–18 research expenditures. These funds

include UC and state general funds, endowment income, and gifts. When over \$1 billion in recovered indirect costs are included, UC's 2017–18 research expenditures amounted to nearly \$6 billion, representing almost one-fifth of UC's total expenditures.

The majority of research expenditures pay for the salaries and benefits of UC's research workforce. Over one-fifth of research salaries went to faculty, while nearly one-quarter went to non-faculty academic researchers.

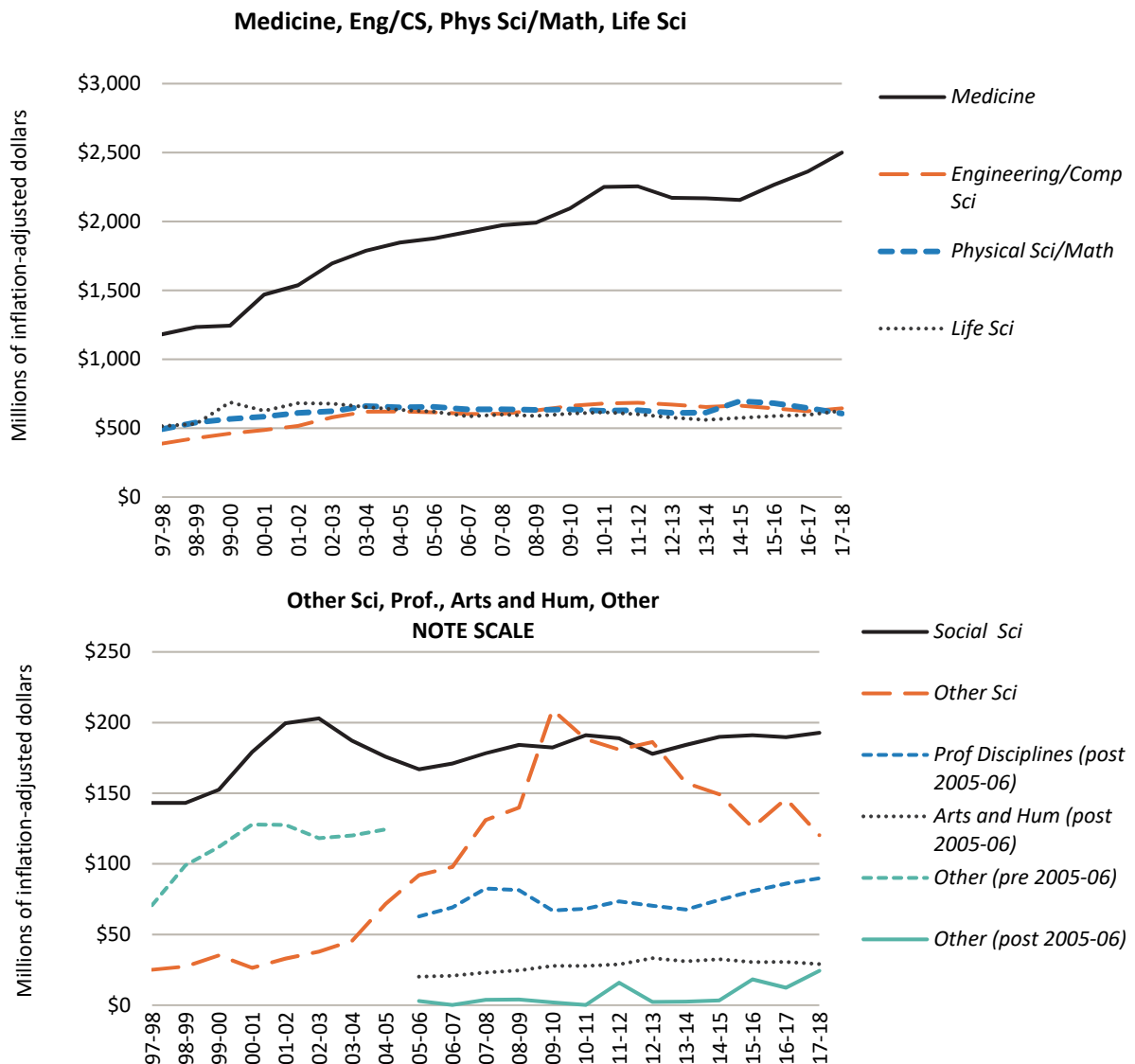
Research salary distribution (\$ millions)

Faculty	491	22%
Academic researchers	541	24%
Other staff	656	30%
Postdoctoral researchers	283	13%
Students	238	11%
Total	2,209	100%

9.1 RESEARCH EXPENDITURES

Inflation-adjusted expenditures for research since 1997–98.

9.1.3 Direct research expenditures by discipline Universitywide 1997–98 to 2017–18



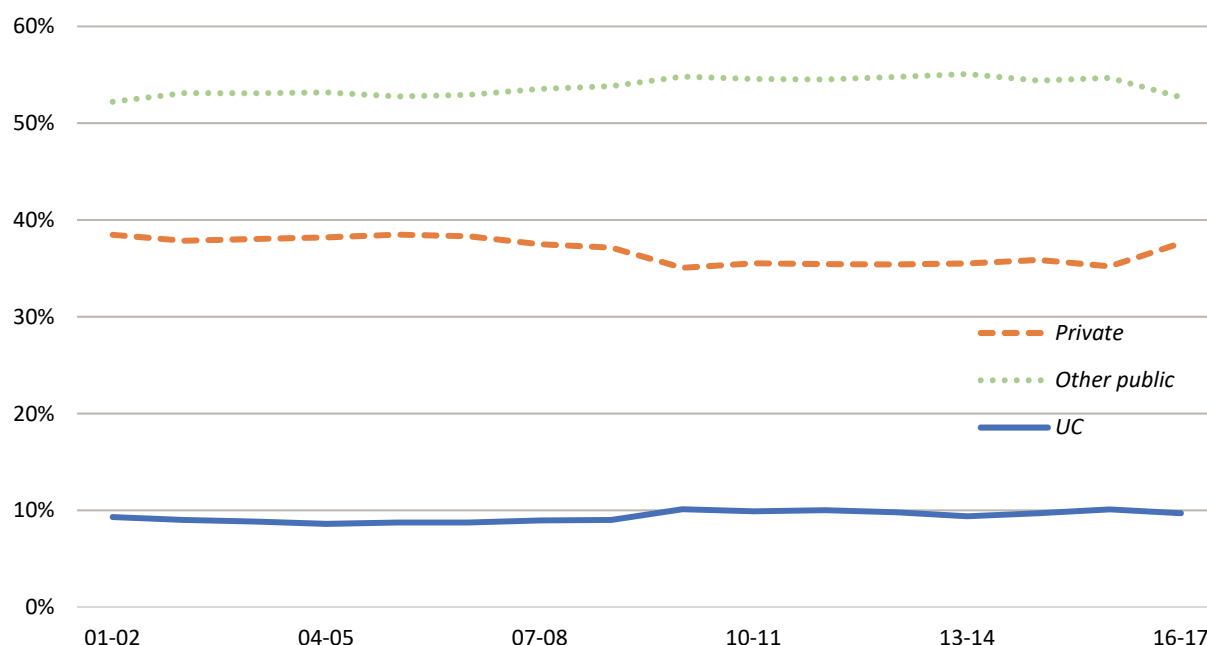
Prior to 2005–06, “Other” included professional and arts and humanities. Source: UC Corporate Financial System

Research expenditures in all STEM (science, technology, engineering, and mathematics) and medical fields represented over 90 percent of total research expenditures each year during the past decade. This reflects the availability of funding and parallels the nationwide pattern.

Measures based on expenditures substantially underrepresent research activity in the arts and humanities, social sciences, and professional disciplines, which make important contributions to scholarship and the quality of life, yet have relatively little access to external funding.

The University of California performs nearly one-tenth of all the academic research and development conducted in the United States.

9.1.4 UC share of US research expenditures Universitywide 2001–02 to 2016–17



Source: IPEDS

Universities have been responsible for much of the innovative research activity that has led to the nation's global leadership in science, technology, and the arts and humanities. The scale of the US academic research enterprise has expanded greatly in recent years, increasing from about \$38 billion at the turn of the millennium to over \$58 billion in 2016–17, in current dollars. More than half of the nation's funding for research comes from the federal government.

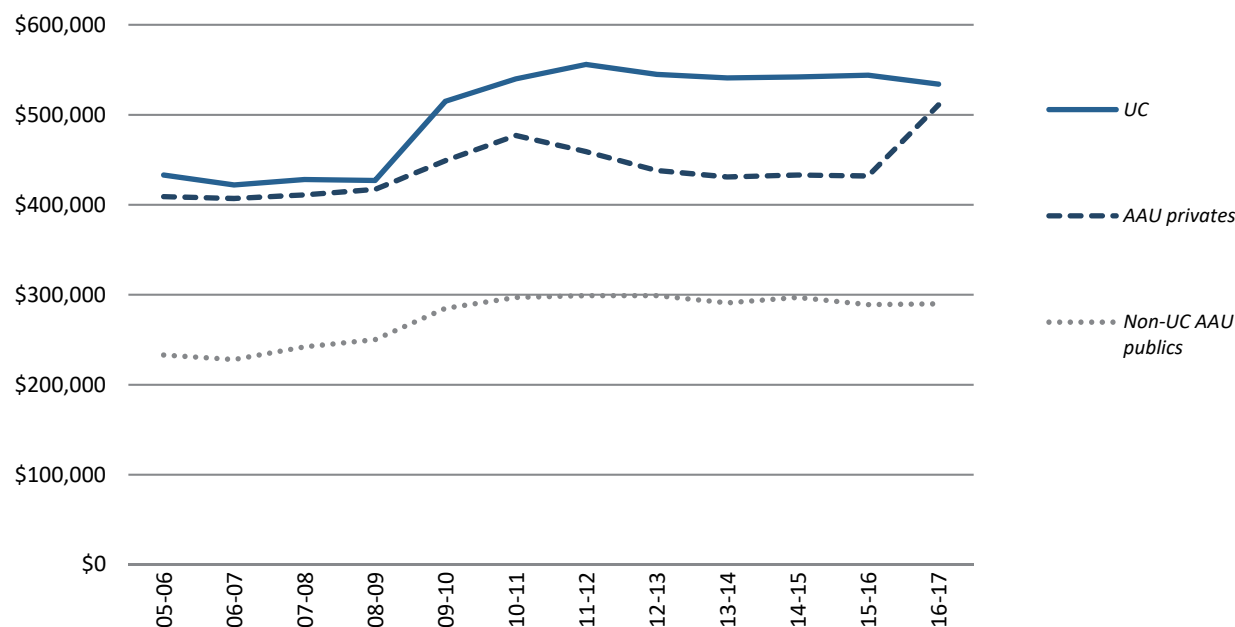
The University of California is the world's largest academic research system, and over the last decade has consistently performed between nine and ten percent of the academic research and development activity in the United States.

This reflects both UC's continuing competitiveness in securing federal awards and UC's ongoing successful relationships with the private sector. UC is the largest single recipient of funding from the two federal agencies principally responsible for academic research: the National Institutes of Health and the National Science Foundation. UC generally receives five to six percent of NIH's annual appropriations for research and seven to eight percent of NSF's annual research appropriations.

9.1 RESEARCH EXPENDITURES

Average research expenditures per ladder-rank faculty are higher at UC than its comparison peers.

9.1.5 Average inflation-adjusted research expenditures per ladder-rank faculty
UC and AAU comparison universities
2005–06 to 2016–17



Source: IPEDS

UC faculty are extremely successful at attracting research support from both government and private sponsors. On average, UC annually spends \$534,000 in externally sourced research funding per tenured and tenure-track faculty member, which surpasses the average of \$511,000 per faculty member for Association of American Universities (AAU) private institutions, and \$290,000 for AAU public institutions.

The largest single source of research sponsorship is the National Institutes of Health, and campuses with medical schools and hospitals are in the best position to compete for these funds. UC's second-largest source of research support is the National Science Foundation.

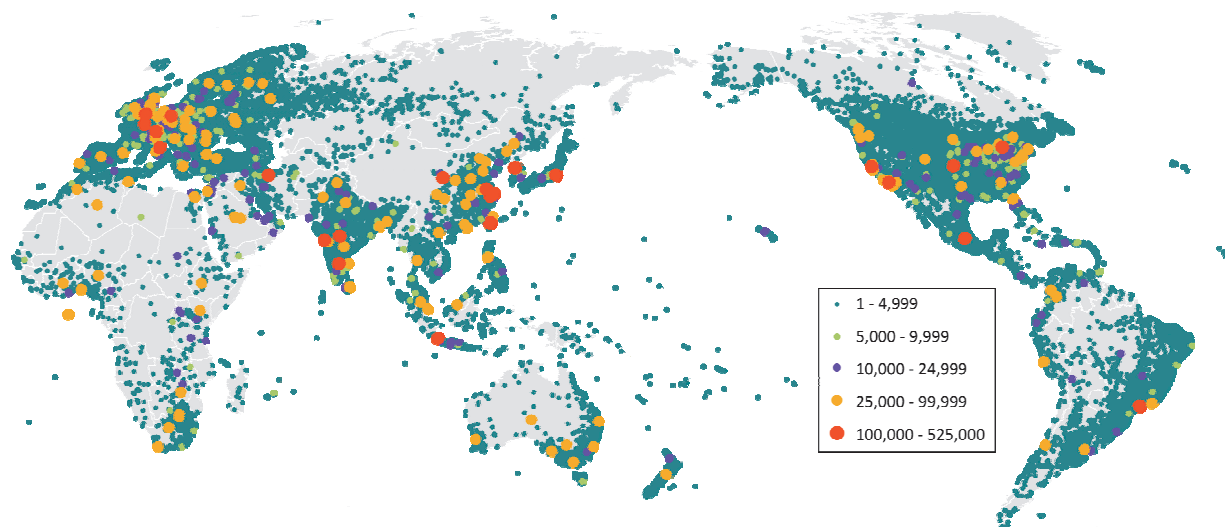
UC Location	Research expenditures per ladder-rank faculty
San Francisco*	\$3,591,000
San Diego	\$709,000
UC AVERAGE	\$534,000
Los Angeles	\$528,000
Berkeley	\$496,000
Davis	\$437,000
Irvine	\$289,000
Santa Barbara	\$256,000
Santa Cruz	\$214,000
Riverside	\$197,000
Merced	\$184,000

*UC San Francisco is an exclusively health sciences campus, where many non-ladder rank (clinical) faculty also conduct significant research.

9.2 RESEARCH IMPACT

UC's Open Access policies continue to add to a growing body of freely available research publications in eScholarship, UC's open-access repository and publishing platform, expanding the global reach of UC's research findings.

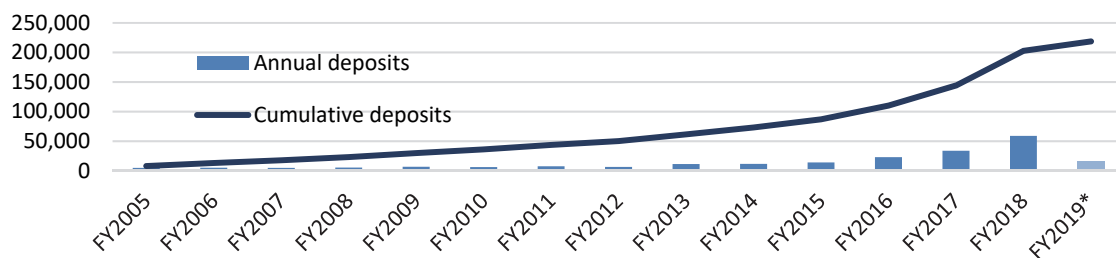
9.2.1 eScholarship downloads of UC scholarly materials Universitywide Through March 2019



This map shows the geographic distribution and concentration of views for scholarly materials deposited in eScholarship, UC's open access (OA) publishing platform and repository managed by the California Digital Library. Since 2002, UC-sponsored research in eScholarship has been viewed and/or downloaded over 54 million times by readers around the world. The repository contains over 220,000 individual items, including many articles, research reports, working papers, and the 80-plus OA journals that are published on the platform.

Deposits to eScholarship have increased substantially since the adoption of the UC Academic Senate's Open Access Policy in 2013, with faculty submitting over 13,000 articles under the policy in 2017–18 alone. The success of this policy has also helped encourage the depositing of almost 30,000 additional scholarly materials (pre-policy publications, electronic theses and dissertations, working papers, etc.) in that same period, making even more UC scholarship publicly accessible to the world.

eScholarship publication deposits



* Fiscal year 2019 includes partial-year data

9.2 RESEARCH IMPACT

The University of California is a major research presence at both the state and national levels, producing nearly ten percent of the nation's research publications.

9.2.2 UC research publication performance, by Field-Weighted Citation Impact (FWCI) and discipline group Universitywide 2012 to 2018



Source: SciVal® database, Elsevier B.V., scival.com (downloaded January 28, 2019)

As a premier research university, UC creates and disseminates new knowledge. From intellectual exploration in the classroom, studio, field, and laboratory to pushing research findings out into the world through academic journals and other venues, the publication of UC's research findings creates an ever-growing foundation for scientific discovery and social impact.

Publication databases can be analyzed to develop measures of the output and impact of UC researchers. Elsevier's SciVal® tool can establish quantitative metrics to assess the University's research performance. SciVal's data analytics capabilities are built on Elsevier's Scopus® database, which contains 48 million publication records from over 22,000 journals and 5,000 publishers worldwide. It provides metrics and data

visualizations of the University's research publications, citations, and usage data, enabling the University to identify research strengths, benchmark progress over time, and analyze opportunities for collaboration both across UC and with other institutions throughout the world.

The quality and impact of UC research publications can be characterized by a metric called the Field-Weighted Citation Impact (FWCI), which takes into account the differences in research publication practices across disciplines and normalizes publication impact against a global baseline. The FWCI can be used to benchmark the impact of individual or groups of publications regardless of differences in publication length, discipline, age, and type. In any given disciplinary area, the global average FWCI is arbitrarily taken to be equal to 1.00; publications with FWCI greater than 1.00 have been cited more frequently than would be expected based

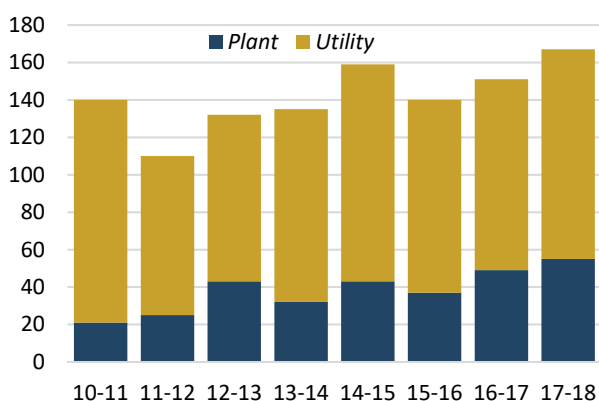
on the world average for similar publications, while publications with FWCI less than 1.00 have been cited less than would be expected based on the world average for similar publications. UC's average FWCI across the nearly 330,000 publications produced by its research workforce between 2012–18 is 2.01, or more than twice the global average.

UC's publication impact is particularly high in the fields of arts and humanities, economics, computer science, engineering, and medicine. Additionally, UC's multidisciplinary publications have a relatively high FWCI of 2.82, which indicates that UC research is at the forefront of discovery in emerging fields involving multiple traditional disciplines.

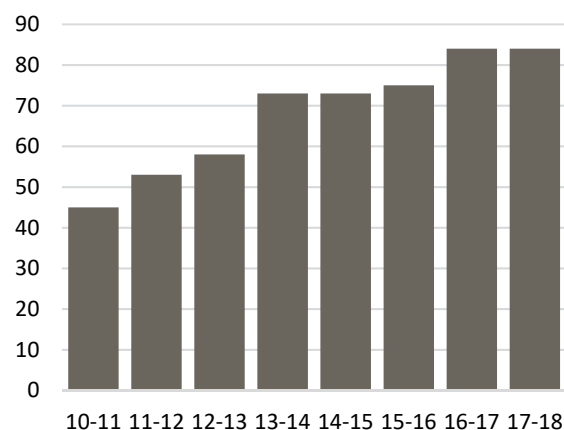
9.2 RESEARCH IMPACT

Licenses issued in California contribute to successful businesses. The number of active plant and utility licenses in California is growing.

9.2.3 New licenses for UC technology issued to California businesses
2010–11 through 2017–18



9.2.4 Startups based on UC technology formed per year in California
2010–11 through 2017–18



Source: UC Office of Innovation & Entrepreneurship

Research is part of UC's mission, and much of this research is basic, foundational research. Some UC research leads directly to new inventions and innovations; bringing them to the marketplace is part of UC's public service mission. Innovations from UC take two paths to the marketplace: they may be licensed to an existing company or they may become the cornerstone of a new startup. Both can ultimately benefit the economy.

University inventions are classified as utility licenses or plant licenses. Utility licenses cover inventions protected by utility patents, such as processes, machines, manufactured items, or compositions of matter. Utility licenses are often issued exclusively to the licensee. Plant licenses cover plant varieties and are often licensed via nonexclusive licenses to nurseries and distribution centers. From the high-tech centers of San Diego and Silicon Valley to the agriculture of the Central Valley, UC technology is licensed throughout California. As of 2018, UC's license portfolio in California included 1,460 utility and plant licenses to 655 separate companies.

UC technology licenses active in California, 2018

	Utility	Plant	Total
Active licenses	867	593	1,460
Number of licensees	515	140	655

UC startups are independently operating companies that were formed to commercialize a UC technology. By the end of fiscal year 2018, 84 startups based on UC technology were formed.