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Penn Institute for Urban Research

PENN IUR **SPECIAL REPORT**

University-led Innovation Initiatives: Lessons from PRAI 2015

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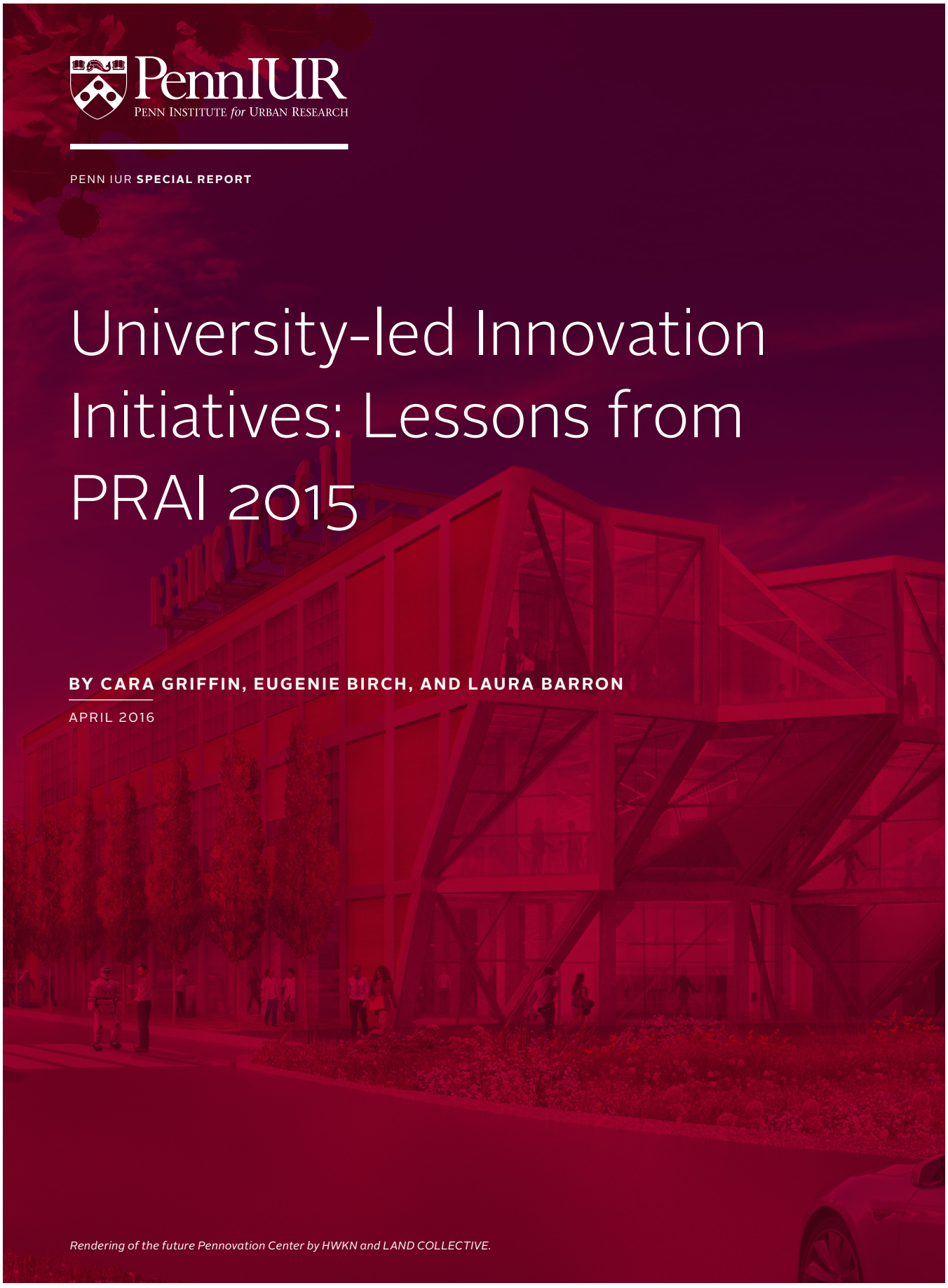

Rendering of the future Pennovation Center by HWKN and LAND COLLECTIVE.

This paper is available on the Penn IUR website at ***penniur.upenn.edu***

The Penn IUR Roundtable on Anchor Institutions (PRAI) is a leadership "think tank" that convenes executive-session meetings of high-level anchor institution leaders to explore innovative strategies in urban development. Through PRAI, Penn IUR is building a national network of anchors with strong public missions and is expanding scholarship on the role of urban anchors. Since 2004, Penn IUR has facilitated seven roundtables; most recently, Penn IUR convened leaders of six university technology transfer offices—the offices responsible for translation of university innovations to the marketplace—to discuss university-led innovation initiatives. Participants at PRAI 2015 discussed the changing fiscal and cultural environment in which commercialization of intellectual property (IP) is taking place, the factors necessary for universities to adapt and thrive in this changing climate, and the interrelationships between innovation initiatives and universities' host communities.

Penn IUR's interest in these issues stems from a commitment to strengthening urban anchor institutions and understanding how changes to and within such institutions affect the cities in which they are located. Universities, exemplars of such urban anchor institutions, have grown increasingly important to their host communities. Anchored by their real estate holdings, missions, and histories, they are large, stable employers; many have adopted local hiring and purchasing, community service, crime prevention, greening, sanitation, and education initiatives, making them even more important to the neighborhoods in which they are situated. They make strong contributions to the economic bases of their host communities with their "product"—knowledge—taking many forms: education, research, and commercial applications. More recently, they have begun serving as sources of invention and reinvention as they meet their spatial needs for laboratories on and off campus.

University-led innovation initiatives may potentially bring jobs, coveted knowledge workers, and opportunities for economic cluster development to the communities in which they are located. This paper puts the inception of university-led innovation initiatives in context, beginning with a discussion of the innovation process and a review of the evolution of university-based research and technology transfer offices in the United States. It then examines the role of research universities in research and development (R&D) in the United States. Next, the paper presents six case studies of universities grappling with the changing R&D environment, and concludes with lessons learned from these experiences.

Innovation and R&D

Innovation refers to generation of new knowledge, products, and processes. R&D, which drives innovation, encompasses both basic research (focused on fundamental principles and theories) and applied research (directed toward gaining knowledge to solve a specific problem) and development (the application of knowledge in order to produce useful materials or methods to meet specific needs). Basic research tends not to have a commercial end, while applied research and development may result in marketable knowledge or products.

Traditionally, universities have excelled at basic research, while the private sector has focused on the other end of the spectrum. This distinction has begun to blur, however, with partnerships between universities and the private sector growing more common and universities ramping up to operate in the applied research and development areas. This has taken the form of universities' more active pursuit of partnerships with industry actors, as well as of promotion by universities of entrepreneurism among students and faculty.

Evolution of University-Based Research and Tech Transfer in the United States

Historically, U.S. research universities have played a major role in stimulating innovation through research, especially basic research—an arrangement that did not happen by chance. The 1862 Morrill Act (and subsequent amendments) offered federal land to states (30,000 acres per member of a state's congressional delegation) that created institutions dedicated to instruction in research in agriculture and engineering, thus creating a partnership between the federal government and the states in building universities to support a modern agricultural sciences and industrial economy for the twentieth century.

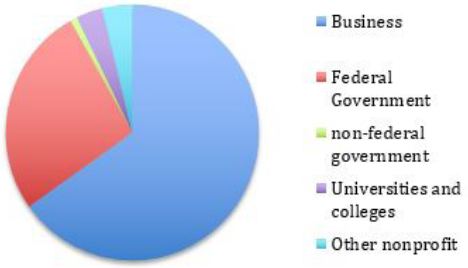

Figure 1. Funding of U.S. R & D.

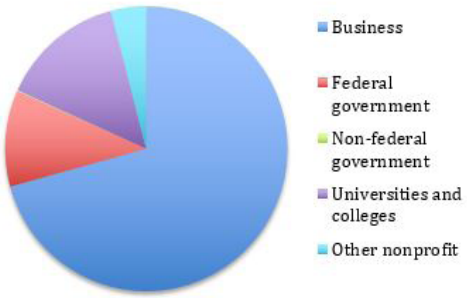

Figure 2. Performance of U.S. R & D.

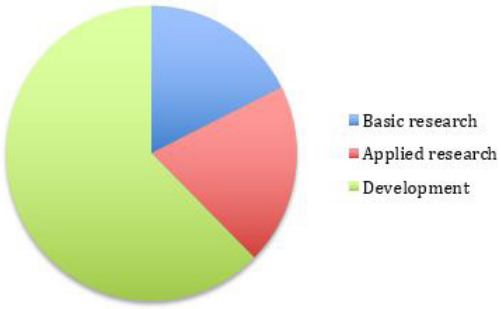

Figure 3. Character of U.S. R & D.

Following World War Two, the federal government revisited its research policies. The importance of government-sponsored university research had intensified during the War, leading to breakthrough discoveries critical to the Allied victory, including radar, the proximity fuse, penicillin, DDT, the computer, jet propulsion, and the atomic bomb (Madanipour 2011). Drawing on this experience, the government opted for decentralizing publicly funded research in defense and health activities to universities. It created key funding authorities: the National Institute of Health (NIH, 1947) and the National Science Foundation (NSF, 1950) while increasing R&D budgets to other federal agencies, including the Department of Defense. Between 1953 and 2012, federal allocations for R&D increased 588% (in constant 2005 dollars: from $17 billion to $117 billion) (Boroush 2013).

Prior to 1980, the government retained ownership of any Intellectual Property (IP) generated from research conducted with federal funds. The passage of the Patent and Trademark Law Amendments Act in 1980 changed this. This Act, more commonly known as the Bayh-Dole Act, gave universities ownership of the IP generated by university researchers with federal funds. With the passage of the Bayh-Dole Act, universities could pursue commercialization of any inventions discovered as a result of federally funded research.

Starting in the 1980s, universities began to develop licensing technology transfer offices adept at marketing the rights to use university-owned patents or knowledge for private business ventures. These offices were tasked with protecting the IP created by university researchers through patents or copyrights, and licensing these technologies to private sector companies.

Today's tech transfer offices retain these responsibilities, with many significantly broadening their roles to include more active marketing of university IP to the private sector, more active management of IP once it is licensed, negotiation of novel research partnerships with industry players, and a variety of technical, financial, and institutional support for faculty and students who want to launch new businesses based on their discoveries. These offices have evolved from largely reactive, transactional centers to far more proactive entities. The six universities profiled below exemplify the latter.

Research Universities' Role in U.S. R&D

In 2013, the United States spent $456.1 billion on research and development. This was an increase of $20.7 billion over the previous year's figure ($435.3 billion, revised down from earlier estimates), which in turn had been an increase over the 2011 figure ($427.8 billion) (Boroush 2015).

R&D in the United States can be characterized in terms of who funds it (figure 1), who performs it (figure 2), and its character (i.e. basic or applied research, or development, figure 3). The business sector is the largest player in terms of both funding and performance, with government second in terms of funding, and universities and colleges second in terms of performance. About 63% of total U.S. R&D goes toward development, with about 20% toward applied research and 18% toward basic research (Boroush 2015). As described further below, the character of research funded and performed varies considerably by sector.

Overall, the business sector funds most R&D (65%, or $297.3 billion in 2013), focusing its spending on development ($229.8 billion) over applied ($46.3 billion) or basic ($21.2 billion) research. Business also performs most R&D (71%, or $322.5 billion in 2013), again focusing mainly on development ($255.0 billion) over applied ($51.0 billion) or basic ($19.5 billion) research. The vast majority (98%) of R&D funding by this sector is performed by this sector (Boroush 2015).

The federal government is the second-largest funder (26.7%, or $121.8 billion in 2013), but only the third largest performer (performing 10.9%, or $49.9 billion in 2013) of U.S. R&D. Its funding goes mainly to R&D performed by the federal government ($49.4 billion), by universities and colleges ($36.9 billion), and by the business sector ($29.4 billion) (Boroush 2015). In terms of type of research funded, federal government-funded R&D breaks out as follows: development, $50.6 billion; applied research, $33.4 billion; and basic research, $37.8 billion.

While universities and colleges do not fund an exceptionally large percentage of U.S. R&D (3.3% in 2013), they are the second-largest performer of R&D, performing 14.2% ($64.7 billion) in 2013; this share hovered between 11% and 15% in the period 1993-2013 (Boroush 2015). According to a recent NSF report, colleges and universities spent $67.3 billion on R&D in FY2014. Most of this funding (56.5%) came from the federal government (non-American Recovery and Reinvestment Act of 2009 (ARRA) sources); while this may be a majority of 2014 funding, it is down from its peak of 62.5% of funding in 2011 and is a record low since the 1972 beginning of the annually collected data series (Britt 2015).

While federal funding as a source of university R&D declined, other sources of funding increased between 2013 and 2014. Universities' own funds used for R&D increased by 5.3% over the previous year (to $15.8 billion) in 2014, while state and local government-funded R&D rose 5.9% (to 3.9 billion). Expenditures funded by business rose 6.2% (to 3.7 billion) (Britt 2015).

In 2013, universities spent $41.3 billion on basic research, 58% (24.1 billion) of which was from the federal government. Universities perform just over half (51.3%) of the national's basic research, a fifth of the nation's applied research (20.5%), and just 1.7% of its development (Boroush 2015, table 3). Universities spent nearly two-thirds (64.5%) of their R&D in 2014 on three fields: medical sciences, biological sciences, and engineering (Britt 2015).

Case Studies

This section explores the specific experiences of six institutions involved in university-led innovation initiatives, with a special focus on the evolution and role of their technology transfer offices. The case studies focus too on university relationships with, and impacts on, the cities and communities in which the institutions are located.

The case studies presented here reflect a variety of institutions: both public and private; with varying mixes of graduate and undergraduate enrollment; and with a wide range of research expenditures (see table 1).

Table 1. Case study institutions at a glance, 2013-2014 (most recent year for which data is available, source: U.S. Department of Education 2016.

Institution	Public or Private	Total Research Expenses*	Total Enrollment (Undergraduate Enrollment)**
University of Pennsylvania	Private	$722,970,000	27,900 (12,583)
Yale University	Private	$481,707,477	13,335 (6,615)
Emory University	Private	$404,544,000	15,852 (8,586)
University of Chicago	Private	$334,520,483	17,357 (6,179)
University of California-San Francisco	Public	$924,549,741	3,130 (0)
Arizona State University* **	Public	$269,688,000	88,862 (71,366)

** The sum of all operating expenses associated with activities specifically organized to produce research outcomes and commissioned by an agency either external to the institution or separately budgeted by an organizational unit within the institution. The category includes institutes and research centers and individual and project research. This function does not include nonresearch sponsored programs (e.g., training programs), FY2014 (IPEDS data center)*

*** 12-month unduplicated headcount total (undergraduate total in parentheses), 2013-14, indicating how many the institution served over a 12-month period (IPEDS data center)*

****ASU has five campuses. The enrollment numbers include students at all five campuses: Tempe, Skysong, Downtown Phoenix, West, and Polytechnic. The total research expense figure reflects expenses at Tempe, ASU's most research-intensive campus (no research expenses were reported to IPEDS from the other four campuses).*

The case studies illustrate how institutions with very different characteristics, contexts, and histories are working to stimulate innovation. The specific programs and approaches each institution takes differs—and yet by comparing their approaches, some principles can be derived from these experiences. Lessons drawn from these case studies are discussed in the paper's concluding section.

A. University of Pennsylvania, Philadelphia, PA

The University of Pennsylvania is Philadelphia's largest private employer (PA Department of Labor & Industry 2015), with more than 30,000 employees and a $6 billion operating budget (Birch 2015). Penn has long seen itself as a leading anchor institution in Philadelphia, and is known for its pioneering role in the transformation of West Philadelphia. Along with its tremendous size and impact has come some distrust of its outsize influence and of the gentrification that has accompanied the University's investment in its neighborhood.

Penn's 2013-2014 enrollment was 27,900 (12,583 undergraduate) students. Its Carnegie classification is "Doctoral Universities: Highest Research Activity" and its 2013-14 research expenses were $722.9 million. The university's research strengths include biosciences and medicine, particularly diagnostics and therapeutics (especially oncology and cardiovascular medicine), as well as robotics, materials and computer science, and nanotechnology. It has the capacity to be strong in medical devices (especially if medicine and engineering work even more effectively together); and is strong in instrumentation (i.e. around novel ways to do things like DNA sequencing). In arts and sciences, University research into carbon-free renewable energy, and more efficient capture, storage, and conversion of energy is cutting-edge. In the social sciences, there are already a number of small start-up companies delving into the accessibility of social media.

Evolution of Tech Transfer at Penn

The University of Pennsylvania was founded on the innovative, pragmatic, and civic-minded ideals of Benjamin Franklin. President Amy Gutmann, who took office in 2004, has advanced these ideals by emphasizing the role of research and innovation in her vision for the University, as outlined in 2004 in the Penn Compact (a vision statement for the University) and again in 2013 in the Penn Compact 2020. The Penn Compact emphasizes increasing student access to Penn, integrating knowledge across the University, and leveraging Penn resources

both locally and globally. The Penn Compact 2020 recommits the University to this vision with a focus on innovation in the pursuit of integration of knowledge. The Penn Compact 2020 led to the launch of various university-wide programs and initiatives announced in 2014, among them the evolution of Penn's original tech transfer office, the Center for Technology Transfer (CTT), into the Penn Center for Innovation (PCI).

This evolution had been underway for years, with several key improvements to CTT—originally a patenting and licensing, transaction-based center—having been made under Provost Ron Daniels during his 2005-2009 tenure. One significant step in this process occurred in 2010 when then-Vice Provost Steve Fluharty led a process that resulted in numerous amendments to the University's patent policy.

The relatively gradual improvement of CTT took a leap, though, with President Gutmann's appointment of the Executive Planning Group (EPG) on Technology Transfer and Commercialization, which was tasked with crafting recommendations to move the University's research commercialization efforts to the next level. Co-Chaired by Steve Fluharty (who brought an academic vision to the effort), and Craig Carnoroli, Penn's Executive Vice President (who brought a business perspective), the EPG recommended how to: 1) change University culture to be more supportive of research commercialization; 2) consolidate the University's diversity of innovation and tech transfer programs and initiatives into a coordinated and comprehensive approach; and 3) build a tech park and incubator space that would foster University-generated companies as well as serve as a place to catalyze interactions between faculty, students, entrepreneurs, investors, and industry.

The second set of recommendations resulted in the transformation of CTT into PCI, pulling together the numerous separate commercially focused resources across the University into one organization with a much more proactive and efficient approach. PCI has taken the form of a hub-and-spoke model with representatives physically based in the biggest research schools (such as medicine and engineering) in order to build more personal client relationships with researchers. Additionally PCI now serves as a one-shop-stop for facilitating relationships with all private sector partners that want to leverage Penn's early stage technologies and related business opportunities. The final set of recommendations resulted in the development of Pennovation Works, the 23-acre innovation district now under development adjacent to the University campus, which will serve as the base for PCI's activities related to start-up company formation. The first set of recommendations—regarding changing University culture—included better engaging alumni, developing outreach and educational programs, hosting days devoted to industry interaction with faculty, and convincing Deans to communicate with faculty that research commercialization is important; these efforts are ongoing.

About Penn Center for Innovation—Partnerships and Programs

PCI's stated mission is "to be the leader in facilitating the translation and commercialization of research discoveries made at Penn into products, goods and services that improve quality of life and generate socioeconomic impact." It does this by engaging internal and external stakeholders, initiating and catalyzing private-sector partnerships, and fostering an entrepreneurial culture at Penn and in the Philadelphia region.

PCI partners with clients both in and outside of the University. Internally, partners include, most importantly, the faculty who are doing the research, as well as the many other innovation efforts at Penn (described below). As noted above, PCI's hub-and-spoke model allows the creation of personal client relationships with faculty researchers and with departments. Other University partners include Facilities and Real Estate Services (FRES), which is leading the development of Pennovation Works, and the many programs across campus focused on supporting innovation. These are mainly targeted toward students and include numerous competitions, classes, and hands-on learning opportunities.

External partners include industry partners, investors, entrepreneurs, and government entities. As Penn's technology transfer office, one of PCI's primary roles is to facilitate corporate partnerships, including licensing of new technology, creating sponsored research partnerships, and marketing Penn technologies.

One of the largest and most widely known partnerships is between Novartis and Penn, focusing on the groundbreaking work of Carl June and his colleagues. June, the Richard W. Vague Professor in Immunotherapy, leads Penn's immunotherapy research. In 2012, the University announced a research and licensing agreement with Novartis for the study and commercialization of immunotherapies that would target a variety of cancers. This alliance stands out not only for its shear size, but also because it diverges from the traditional licensing of a technology to be a true research alliance.

In addition to such private sector partnerships, PCI also supports the creation of new businesses in direct partnership with Penn faculty, mainly through PCI Ventures. PCI Ventures supports the launch and development of businesses through various programs and services: Upstart, UPAdvisors, and AppItUP, among others. Upstart, a virtual incubator for faculty and staff, offers guidance and support throughout the establishment of a business: from selecting a name and structuring the company, to finding a CEO, funding, and advisors, to setting up operations. UPAdvisors, for anyone associated with Penn (not just faculty and staff), is an advisory service for entrepreneurs who may want general guidance or some specific advice but who intend to establish and operate their businesses with minimal ongoing support. AppItUP is targeted to the broader Penn community; in this mobile application design competition, the top five competitors are partnered with technical and financial resources that allow them to start companies and develop prototypes.

The National Science Foundation (NSF) Penn I-Corps program facilitates commercialization of university research. Established in 2015 with a three-year NSF grant awarded to Penn and PCI, the program helps PCI to speed the translation of university research into commercial technologies. This business-accelerator program includes, in its first year, thirty teams selected through an application process; each team includes three leaders, an entrepreneurial lead (often a student); a business lead (a private-sector partner); and an academic lead (a faculty member). Over Summer 2015, they created business plans that took an idea and translated it into a pragmatic, commercial technology. At the end of the program, teams may choose to seek further funding (perhaps from NSF) to further develop their tested idea. PCI administers this program in partnership with the Mack Institute at Wharton, the Center for Healthcare Innovation at the Perelman School of Medicine, Ben Franklin Technology Partners of Southeastern Pennsylvania, and the City of Philadelphia.

PCI Fellows is a training program for graduate and post-doctoral students. This one-year Fellowship seeks to give students hands-on training in commercialization of research. Fellows take a one-semester seminar on biotechnology commercialization and work as paid interns at PCI, assessing the commercialization potential of faculty-disclosed inventions.

Pennovation Works

While PCI considers itself the "one-stop-shop" for commercialization of innovative research, it is not the only effort at Penn to spur innovation. Of course, as a major research university, one of the main purposes of the school is to further knowledge. But even beyond the University's fundamental role, many programs, centers, and initiatives across campus are focused on innovation; most of these, as noted above, are targeted to students.

Perhaps the most visible partnership is the one between PCI, FRES, Office of the Vice Provost for Research (VPR), and the Office of the Executive Vice President to create Pennovation Works, Penn's newly established innovation district, with its iconic three-story building. This 23-acre district adjacent to the Penn campus is being developed to foster innovation, further commercialization of University research, to nurture startup organizations, and provide a space that facilitates multidisciplinary collaborations.

Formerly industrial land, Penn acquired the underdeveloped Schuylkill Riverfront property in 2010. Then called Penn's South Bank, the University began redeveloping the lot in 2011, moving its Transportation and Parking Services to the site. Now, some researchers, technology commercialization tenants, and warehouses are on

site, with much more planned. The Master Plan calls for a phased approach, with early stages focused on light industrial and flex-use spaces. Built and operated by the University's Facilities and Real Estate Services (FRES) with University funding, Pennovation Works is ultimately expected to be financially self-sustaining.

The site will be anchored by Pennovation Center, a 58,000 square foot industrial building currently being redeveloped. Anticipated to open in 2016, the Center will house an incubator for technology transfer startups, a mix of creative spaces, shared "damp" labs, office space, and co-working areas. The Center's design, by HWKN (Hollwich Kushner) architects, is dramatic, intended to reflect the innovative work taking place in the district: the northern façade is a wall of angular glass panes emerging from the rehabilitated structure.

Design and operation of Pennovation Works is focused on fostering an entrepreneurial and creative culture. To this end, FRES has emphasized the inclusion of arts and culture in the districts development: tenants include both the historic preservation and fine arts departments; programming includes; the building and logo design are intentionally more dramatic than the University's traditional look; and the vision for the site is of a functional, flexible, and slightly "rough around the edges" creative space. In fostering a creative culture, FRES faces tension between the presence of established corporations, which have money and opportunities, and small start-ups, which provide innovation. Bringing together people who might otherwise not have opportunity to interact—academics, private-sector players, entrepreneurs, and a variety of people in diverse fields—is another strategy for creating an innovation ecosystem.

PCI works closely with the Pennovation Works, facilitating corporate partnerships and attracting private sector tenants. The PCI Ventures staff provide services and support to start-ups who are or may become tenants of Pennovation Works. Finally, PCI actively provides education and sponsors events to foster innovation.

University's Role in City and Region and State

The Philadelphia MSA is the country's sixth most populous MSA, with a population of 5.9 million in 2010 (US Census Bureau). In 2013, according to the Bureau of Labor Statistics, its GDP was $383.4 billion. Major industry sectors include finance and insurance, health education and research, and tourism.

As with many metropolitan areas with major research universities, the Philadelphia region struggles to retain the start-ups engendered at the University of Pennsylvania. The region simply lacks the investors and the cachet necessary to retain entrepreneurs to the same degree as San Francisco, Boston, or New York.

Philadelphia does have many advantages to offer potential entrepreneurs, however, including a diversified economy, affordability, size, and location. PCI partners with city organizations to help market these strengths and to create the networks necessary to create jobs and retain startups. For example, the Philadelphia Industrial Development Corporation (PIDC)is a public-private economic development organization founded by the City of Philadelphia and the Greater Philadelphia Chamber of Commerce in 1958 to attract and retain businesses. It offers financing and leases real estate to commercial tenants; while PIDC owns property throughout the city, its main locus of properties is at the Navy Yard, a former naval center in South Philadelphia.

Additionally, the Philadelphia region is one of the largest health care and medical research centers in the United States. Penn's research strengths in medicine and biotechnology contribute to the region's strengths in health care, and Penn entrepreneurs in these fields may benefit from being in this economy.

The Lower Schuylkill Master Plan—developed through a collaboration with PIDC, the Philadelphia City Planning Commission, and the City of Philadelphia Department of Commerce—lays out a vision and redevelopment plan for the historically industrial east and west sides of the Schuylkill River. Intended to attract jobs and generate economic activity in an environmentally sustainable way, the Plan includes a vision for an innovation district along the River's east side. The Pennovation Works property is the first outpost of this future district, and as

such is an important partner in making the vision of an economically productive and environmentally sound Schuylkill corridor a reality.

Penn's Innovation Strengths

In its efforts to foster innovation, the University of Pennsylvania has a number of strengths. Not only does it have a long history of innovation, but strong leadership from the President means that this culture has support and guidance as well as the institutional will to invest in physical real estate projects, like Pennovation Works, that support innovation into the twenty-first century.

B. Yale University, New Haven, Connecticut

Yale is the nation's third oldest institution of higher education. Yale's 2013-2014 enrollment was 13,335 (6,615 undergraduate) students. Its Carnegie classification is "Doctoral Universities: Highest Research Activity" and its 2013-2014 research expenses were $481.7 million.

Its research focuses heavily on the life sciences, with the majority of innovative research on campus in the biotechnology sector. However, many students from social sciences and business are also involved in innovation at the University: the Internet technology space is a strong emerging market for the university and students have increased their focus on social entrepreneurship in recent years, which has resulted in the creation of local and national organizations that address issues such as poverty, racial issues, and youth education in New Haven.

Evolution of Tech Transfer at Yale

Yale's tech transfer office was created in 1982 to license and commercialize innovations on campus. With its recreation as the Office of Cooperative Research (OCR) in 1996, the office began pursuing these activities more proactively, and in the process has helped foster an entrepreneurial ecosystem on campus and in New Haven and has served as an engine of regional economic development.

Over the past several decades, Yale's tech transfer office has transitioned through what it identifies as three phases of innovation: incremental, synergistic, and catalytic. In its early stages, the office incrementally increased innovation by encouraging the licensing and commercialization of inventions by professors. As University players became better acquainted with the commercialization process and Yale successfully patented and marketed several well-known technologies—ranging from Bristol-Myers Squibb's anti-AIDS drug Zerit to Amgen's multiple myeloma drug Kyprolis to the popular French language course "French in Action" to Coupled Amplification and Sequencing (CAS) and personalized home genetic testing—University support for innovation increased.

With the estsablishment of OCR, Yale developed complimentary programs, described below, to facilitate innovation at all levels. These programs have worked together synergistically to further a culture of innovation on campus. Over the past five years, the culture of innovation has grown. With the expansion of programs and resources supporting entrepreneurship at every stage, Yale is now in a catalytic phase of innovation and development.

About the Office of Cooperative Research—Partnerships and Programs

OCR advances cutting-edge technologies among faculty and students of all levels, focusing on innovations in the life sciences, software technologies, and product development. It seeks to foster economic development through its initiatives and it nurtures a culture of innovation and collaboration across campus.

Partnerships are key to OCR's work. In addition to its traditional role as a tech transfer office managing IP (creating partnerships between innovators and industry), OCR works closely with other University initiatives to

support the creation of startups and to impact the city and community (see "City and Regional Role," below). Since the opening of OCR, Yale has developed many research centers on campus that both contribute to the innovation ecosystem that feeds OCR's activities, and work in partnership with OCR to generate marketable technologies. Yale now maintains seventy-one collaborative centers across campus in science, medicine, engineering, policy, and more. These include the Yale Entrepreneurial Institute (YEI) operated by OCR and the Center for Engineering, Innovation Design (CEID) in the School of Engineering and Applied Science, with which OCR regularly partners.

YEI acts as a physical hub for Yale students and faculty working to turn promising inventions and ideas into businesses. The OCR and YEI jointly developed the Technology Commercialization Program to assist faculty in bringing their patented technologies to the marketplace by matching faculty with graduate and professional students to form startups around their inventions. This program, which emphasizes multidisciplinary collaborations, has spawned some of Yale's most successful non-biotech startups—including Hadapt, which offers a cloud-optimized analytical platform for performing complex analytics on structured and unstructured data, and Oasys Water, a desalination tool that uses integrated forward osmosis systems for high-recovery desalination—which have collectively raised over $52 million in venture financing.

YEI operates a summer fellowship program with support from the OCR for undergraduate, graduate, and professional school students with promising innovations to build and launch their ventures with $15,000 in funding and resources that include: expert mentors, corporate partners, Lean Startup education, pitch guidance and introductions to venture capitalists. The YEI Innovation Fund, created with $750,000 from Connecticut Innovations, Yale, and First Niagara Bank, is another source of support for innovators at Yale—offering $100,000 in pre-seed funding to select startups that have participated in a YEI program. This fund, along with other YEI programs and activities on which OCR collaborates, contributes to OCR's larger efforts to nurture an ecosystem of innovation throughout campus.

The Center for Engineering Innovation & Design (CEID), created in 2013 with programmatic and administrative support from OCR, also acts as a convener space for collaboration, learning, and creating. With a lecture area and meeting rooms for the exploration of new ideas, machine shops, a wet lab, and a studio for the creation of physical prototypes, CEID provides both students and faculty with a shared space to innovate. Individual departments, particularly in engineering, medicine, and the sciences, provide lab space specifically for faculty and their graduate students as well. Nonetheless, with a growing interest in innovation in the student community and the shift towards innovation among faculty researchers, OCR and YEI struggle to keep up with the demand for lab spaces.

University's Role in the City and Region

The New Haven MSA is the country's 60th most populous metropolitan statistical area (MSA), with a population of 861,113 million in 2011 (US Census Bureau). In 2013, according to the Bureau of Labor Statistics, its GDP was $40.1 billion. Major industry sectors included services (especially health, business, and financial services) as well as education. In part due to Yale's presence, New Haven has increasingly been recognized as an emerging hub for biotechnology.

Over the past two decades, Yale University has shifted its approach toward New Haven from inward-focused to cognizant of its impact on, and interdependent relationship with, its community. With this shift, Yale has contributed directly to the development of downtown New Haven through real estate development projects and has encouraged student and faculty partnerships with industry throughout the region.

OCR works closely with Yale's Office of New Haven and State Affairs (ONHSA), which "spearheads Yale's partnerships to strengthen New Haven through fostering economic development, revitalizing neighborhoods, supporting public school and youth programs, and creating a vital downtown." Throughout the incremental

and synergistic phases of innovation at Yale, OCR worked closely with Bruce Alexander, Yale's Vice President for New Haven and State Affairs and Campus Development. Alexander, a leader in private development who formerly worked for the Rouse Company on high-profile mixed-use redevelopments throughout the United States, began his relationship with Yale as a volunteer advisor focused on positive community development opportunities. Now, as VP of New Haven and State Affairs and Campus Development, Alexander leads the University's initiatives for the revitalization of New Haven, which have strengthened relations with the community and extensively redeveloped commercial properties adjacent to the Yale campus.

Over the past twenty years, Alexander has sought to benefit the larger New Haven community by developing five areas of interest:

- real estate development, through the creation of commercial retail owned by Yale throughout the downtown;
- economic development, primarily through development of housing in the downtown area;
- human development, involving mentoring programs and high school scholarship support;
- neighborhood partnerships, focusing on opening lines of communication between Yale and adjacent communities; and
- marketing and promoting New Haven to attract new businesses and residents to the city.

This multi-faceted community development approach has grown New Haven and its downtown into an attractive location for corporations and investors who have diversified the Yale community and facilitated the retention of Yale startups.

Many of these redevelopment projects have reinforced OCR's efforts to launch and retain new ventures, especially those in biotechnology. Several projects of note include: wet lab and biotechnology space at 300 George Street; Science Park in the northwest quadrant of campus; headquarters for Higher One—a 600-employee company started as a Yale student venture; and, most recently, Downtown Crossing, a 600,000-square-foot development expected to open soon, which will serve as the headquarters for 1,700 Alexion Pharmaceuticals employees (Alexion Pharmaceuticals was first founded in 1992 with Yale science input). Due to New Haven's geographic proximity to both Boston and New York City, businesses that get their start at Yale are well located for attracting venture capital funding.

Because the city is heavily influenced by Yale's activities, the University's support of entrepreneurship and innovation has significantly and positively impacted the community; OCR recognizes its role in community development and seeks to use entrepreneurship as an avenue for social impact. Over the past fifteen years, Yale startups have raised $1 billion. While OCR is currently refining its goal for the next ten years, it is considering a goal of raising an additional $1 billion and impacting 100 million lives (in terms of patients who are treated with drugs developed by Yale research, and touched by products, processes, and services created at the University).

Despite the enormous impact Yale has had on the New Haven area, the region still has some deficits that inhibit innovation. Namely, the region lacks early stage investment capital in life sciences. To help address this, OCR is creating a $20 million accelerator fund (created through alumni donations), which will provide some much-needed support, but not enough to be truly self-sustaining. The region also lacks successful, serial entrepreneurs who can act as leaders and mentors. To help fill this gap, the OCR has created a Venture Mentor Network of over 150 skilled professionals as well as a six-person Entrepreneurs-in-Residence program to work with student and faculty innovators interested in launching new ventures.

Innovation Strengths

With a culture of social entrepreneurship and a large presence in the city and region, Yale's OCR has had a unique opportunity to shape larger economic development trends in New Haven. By targeting initiatives to benefit both the Yale and the New Haven communities, innovation has brought significant development to the area.

C. Emory University, Atlanta, Georgia

Emory University is a medium-sized, private research university. Emory's 2013-2014 enrollment was 15,852 (8,586 undergraduate) students. Its Carnegie classification is "Doctoral Universities: Highest Research Activity" and its 2013-2014 research expenses were $404.5 million.

Emory's research is 90 percent in the life sciences. Its affiliation with a large hospital greatly drives the University's research agenda, resulting in a focus on medical-related IP generation. Emory's relatively small student body means that, while undergraduate education is important and respected, the University's research activities are especially visible and strongly influence the institution's culture.

Evolution of Tech Transfer at Emory

Over the past three decades, the Emory Office of Technology Transfer (OTT) has evolved from a largely transactional office into a much more sophisticated entity with a broader purview and greater expertise. Its evolution can be explained in large part by its experience with innovations in HIV treatment.

In the early 1990s, Emory researchers Ray Schinazi, Dennis Liotta, and Woo-Baeg Choi announced the discovery of a molecule (FTC) and a chemically similar compound (3TC) that would revolutionize HIV treatment (more than 90 percent of people in the U.S. who have HIV take at least one of the drugs based on these discoveries). These antiretroviral drugs work against the enzyme that copies HIV RNA into new viral DNA. In 2005, these high-revenue, high-profile discoveries brought in $540 million— the largest royalty sale at the time in higher education. This money has engendered within the University a respect for the potential of commercialization to save lives and to generate revenue, and has enabled the University to adequately fund its technology transfer activities.

The OTT's experience with these HIV treatments created a sophisticated institutional familiarity with the process of commercialization. With this sophistication has come a willingness to engage in legal disputes in order to protect university IP and a strong, post-license function in the office. Now, Emory takes a much more thorough approach, keeping an eye on how the companies that license University IP are using those technologies and ensuring that that use conforms to license agreement terms.

Emory's OTT established an in-house patent group five years ago to more closely align patent and licensing strategy. Because of Emory's narrow focus on the life sciences, the OTT's patent group can focus exclusively on life science innovation, rather than needing to have deep expertise in a wide range of IP fields (it does not need legal expertise in engineering patents, for example, since Emory has no engineering school).

Last fiscal year, Emory reorganized its contracting function and moved industry contracting into OTT. This function, along with a newly created, shared position with the development office will allow Emory to more proactively address research collaborations. OTT plans to take a more holistic approach to managing industry relations.

Emory Office of Technology Transfer—Partnerships and Programs

The mission of the Emory OTT is to "support the University's mission through comprehensive management of Emory innovations to maximize the benefit to the University and to humanity." The office protects University IP, negotiates and manages licensing agreements, builds partnerships with industry, and develops commercialization strategies to move ideas from the lab to the marketplace. It is a key player in a University-wide effort to support innovative research and to translate this research into impact.

This effort relies on partnerships that the OTT is a party to and/or has helped facilitate. One exceptional partnership program is Drug Innovation Ventures at Emory (DRIVE), created with funding from the HIV drugs. This private company is wholly owned by Emory University. DRIVE combines Emory's research prowess with capital, as well as business and management experts, in order to move ideas into proof-of-concept clinical trials. Technologies can then be licensed to private companies, partnered with foundations or government entities, or spun-out into companies financed by venture capital firms.

Another notable collaboration is that between Emory and Georgia Institute of Technology (Georgia Tech, or GT). In 2000, these two universities partnered with the Wallace H. Coulter Foundation to create the Wallace H. Coulter Department of Biomedical Engineering at Georgia Tech/Emory, a joint bioengineering department that builds on Emory's exceptional life sciences research and Georgia Tech's strengths in engineering. Housed at GT, this department recently received funding from the Coulter Foundation to create the Emory/GT Coulter Translational Partnership (CTP), a shared endowment to promote the translation of research into products.

The OTT is a partner in Forge, a nonprofit organization founded in 2014 to address challenges in healthcare by bringing together people who can identify problems and unmet needs in the field with entrepreneurs who can solve those problems. Through networking events and the Health Innovation Challenge (an annual hackathon), Forge supports healthcare-related startups by connecting them to clinicians, investors, and mentors.

Other OTT programs supportive of startups include an accelerator program launched in 2004 with the Georgia Research Alliance (GRA), a nonprofit that supports research and commercialization capacity in Georgia's universities. GRA Ventures identifies potentially marketable university research discoveries in their early stages, connects researchers with the necessary funding and business expertise to launch a business around these new technologies, and supports startups as they grow. The OTT's Faculty and Start-up Services program integrates the GRA Ventures program with OTT operations. OTT has also created a Venture Advisory Board—consisting of successful, experienced entrepreneurs, venture capitalists, industry experts, and legal experts—to provide professional advice to young companies.

Kauffman FastTrac TechVenture is an entrepreneur training program offered by the OTT in partnership with the Atlanta Clinical and Translational Science Institute (ACTSI) and University of Georgia's Small Business Development Center. This is a six-day course, offered once a year to faculty. OTT also hosts a semi-annual breakfast meeting to introduce select technological innovations made at Emory to Atlanta's entrepreneurs, investors, and industry representatives.

While the OTT's primary role is to work with faculty researchers, it also offers internships to students, promotes graduate student research, and partners with departments throughout the University to support students who want to start businesses or license research.

University's Role in City and Region

The Atlanta MSA is the country's 9th most populous metropolitan statistical area (MSA), with a population of 5.52 million in 2012 (US Census Bureau). In 2013, according to the Bureau of Economic Analysis, its GDP was $307.2 million. Home to a number of Fortune 500 companies, metro Atlanta is also the headquarters of major

national and international companies (such as Coca-Cola and UPS). Major industry sectors include logistics and transportation, financial services, and high-tech.

The Atlanta MSA's sprawling geography creates challenges to innovation. Making connections among researchers, entrepreneurs, and investors is essential, and the dispersal of these players' geography is a hurdle. One of the MSA's most ambitious goals for the future includes the creation of a hub for life science innovators, young startups, and established corporations to convene in Atlanta. This has already happened in the high technology space for which Atlanta has a robust cluster.

The healthcare and biomedical sector is growing, though it is not as large a cluster as Emory would like. So, unlike bioscience-focused research institutions in San Diego or Boston where the local and regional biotechnology sector is especially strong, Emory must do business globally. The majority of Emory's innovations are in medical diagnostics and therapeutics as well as healthcare information technology, but only a small percentage of its deals are done locally.

Emory University and the Atlanta region would both benefit from a stronger regional biosciences cluster, additional venture capital, and the retention of inventions and inventors. The lack of a strong biocluster has repercussions for retention of startups, which may prefer to locate in regions with stronger biotechnology clusters. Like many metropolitan areas, Atlanta has its share of public and private initiatives working to recruit companies and capital and to support the launch and retention of startups as a means of attracting knowledge workers and lucrative jobs.

Still, as a private institution in a large metropolitan area, Emory finds it does not need to provide all infrastructure necessary for innovation: it can rely in part on the resources available in its metropolitan region. Wet labs, for example, can be found throughout the region—they do not have to be at Emory. This partially explains why Emory no longer has the incubator that it once supported in partnership with GT: after the financial crash, the expenditures necessary to support the incubator no longer made financial sense and the incubator closed in 2010. Additionally, when the incubator had opened in 2000, regional wet lab space was scarce; the incubator filled this hole with state-of-the-art facilities. But, 10 years later, regional wet lab space had become available elsewhere. Moreover, within several years, the facility would likely have needed an overhaul to bring it up to date. Nonetheless, Emory's OTT would like the university to have physical space dedicated to innovation.

Innovation Strengths

University administration views the OTT as a highly successful venture and takes tech transfer seriously, which means that it devotes adequate resources to this effort with the philosophy that "it takes money to make money." Because Emory is a private institution, a focus on revenue-generation is particularly important, especially as federal research funding stagnates.

D. University of Chicago, Chicago, Illinois

The University of Chicago is a premiere research university, with leading graduate programs in economics, business, law, and medicine. It operates twelve research institutes and 113 research centers on campus, as well as a number of off-campus affiliated research institutions (three of the best known are the two Department of Energy Labs, Argonne Lab and Fermi National Accelerator Lab, and the Marine Biological Lab). Its 2013-2014 enrollment was 17,357 (6,179 undergraduate) students. Its Carnegie classification is "Doctoral Universities: Highest Research Activity" and its 2013-2014 research expenses were $334.5 million.

Evolution of Tech Transfer at the University of Chicago

The University of Chicago has historically had a reputation for exceptional academic research but has also been known for its emphasis on pursuit of academic, rather than practical, knowledge. However, the institutional culture has changed during the past decade, partly as a result of the culture wars that consumed academia beginning in the early 1990s, as well as to pressure to make the University more attractive to students and encouragement from the city and the neighborhood to further engage with the community. Policy direction from UChicago presidents have combined to result in this culture change. This includes such changes as revision of the undergraduate curriculum to be more flexible (President Hugo Sonnenschein, 1993-2000); greater investment in infrastructure, including research facilities (President Michael Randel, 2000-2006); and greater engagement with Chicago (President Zimmer, 2006-present).

The institution is now more supportive of the elements that go into creating a system that generates innovation and its practical application, such as interdisciplinary research, social impact, and collaboration between university and industry. The university's tech transfer office (University of Chicago Center for Technology Development & Ventures (UChicagoTech)) is at the center of this evolution; not only does its work rely on the innovative discoveries that comes out of this culture change, but it also is the entity directly tasked with negotiating partnerships between the University and industry.

About UChicagoTech—Partnerships and Programs

UChicagoTech describes its work in terms of partnerships, both internal and external. The office "drives the transformation of UChicago's research into tangible products and services by engaging with partners in the University, in industry, and across the broader innovation community." It does this by networking with industry and investors to identify entities with which to partner; directly supporting innovation by providing mentorship, proof-of-concept funding, and resources for new ventures; and facilitating commercial endeavors by providing professional services including market analysis, IP protection, and negotiation of licenses and other agreements with private sector entities.

Some of the many internal partnerships that are central to UChicagoTech's work include: University faculty, whose research constitutes the substance of the office's work; the University's many research centers that provide the infrastructure for innovative research; and the myriad efforts throughout the University to support innovation, including in particular resources offered by two of UChicagoTech's key partners, the Michael P. Polsky Center for Entrepreneurship and Innovation (a center at the Booth School of Business with resources for entrepreneurs, particularly for student entrepreneurs) and the Chicago Innovation Exchange (CIE) (a recently opened innovation center with which UChicagoTech partners; more on CIE below).

The Polsky Center was established in 1998 to support entrepreneurial efforts. It received a big boost (and a name change) in 2002 with a donation from Michael P. Polsky ('87); Polsky doubled his donation in 2012, allowing the Center to expand to serve the entire University (not just business school students). The Polsky Center's programs are primarily, though not exclusively, targeted to students and alumni. Polsky programs that complement UChicagoTech's work include an Innovation Workshop Speaker Series; New Venture Challenge, a nationally recognized accelerator program; and D4Lab, a program that combines entrepreneurship with human-centered design. UChicagoTech and Polsky together facilitate collaboration between faculty researchers and student entrepreneurs.

One highly visible collaboration is the University's new Chicago Innovation Exchange (CIE)—a redevelopment project that offers multi-function incubator space as well as programs and services to support innovation by students, faculty, and community members. UChicagoTech and the Polsky Center have been key University players in planning CIE. UChicagoTech Director Alan Thomas is on CIE's Board.

CIE manages, in partnership with UChicagoTech and the Polsky Center, the Innovation Fund, an investment fund that awards grants and invests in promising technologies and start-ups created by current faculty, students, and staff. This $20 million venture philanthropic fund, started with donations from alumni and others, focuses on critical proof-of-concept work that can catalyze for-profit investment funds and translational grant awards. UChicagoTech piloted this fund in 2010, then folded into the CIE and expanded in dollars, scope, and prominence when the CIE was launched in the fall of 2014.

Another program founded by UChicagoTech include Chicago Innovation Mentors, which pairs early-stage science commercialization projects with expert mentors from the community who volunteer their time. This program is modeled on and adapted from MIT's Venture Mentor Service and includes other institutional co-founders throughout the metro region including Northwestern University, the University of Illinois, Argonne National Lab, and the Illinois Chapter of BIO (IBIO).

UChicagoTech brings seasoned technology entrepreneurs and executives to the University on an extended basis to facilitate faculty venture creation through its executives-in-residence (EIR) program. UChicagoTech also has a Fellows program that provides PhD's and postdocs from medicine and life and physical sciences with opportunities to participate in technology commercialization.

Chicago Innovation Exchange

A recent and highly visible initiative on which UChicagoTech has partnered is the creation of the Chicago Innovation Exchange (CIE), a new innovation hub in Hyde Park that will provide resources for University faculty and students and local entrepreneurs to turn their innovations and ideas into startups, in order to generate economic activity and translate research into social impact.

The CIE's main space is a 17,000-square-foot facility located on the second floor of a theater building on East 53rd St., a retail corridor in Chicago's South Side that the University of Chicago is working to revitalize. An additional 7,000 square foot space is opening this fall and a CIE conference center space opened two blocks away in early 2014.

The CIE houses a startup incubator, coworking space, and various flexible gathering spaces, as well as a fabrication lab (with 3D printers and other equipment), and dedicated office space for the CIE management team, staff from University labs (e.g., from Argonne National Laboratory's Joint Center for Energy Storage Research and from the Institute for Molecular Engineering).

The CIE is available to University of Chicago students, faculty, and staff as well as community members. People who want to access the space to work, get advice, network, and participate in workshops can apply for membership (for a monthly fee, though free for students). Entrepreneurs with a developed business idea can apply to take part in the CIE business incubator (CIE charges a monthly fee, but does not take equity), which includes dedicated office space and tailored mentorship.

For expertise and resources, CIE draws on partners within the University of Chicago, such as: UChicagoTech, The Polsky Center, research labs, and many others. CIE also works with external partners: the entrepreneurial community on the South Side of Chicago and through the metro region; the University of Illinois at Urbana-Champaign; corporate partners (such as JPMorgan Chase, Samsung, and Cisco Systems); and public entities (such as the State of Illinois, which contributed $1 million to CIE, and the Chicago Department of Public Health, which is partnering on a program aimed at finding innovative approaches to public health challenges).

University's Role in City and Region

The Chicago MSA is the country's 3rd most populous MSA, with a population of 9.73 million in 2010 (US Census Bureau). In 2013, according to the Bureau of Economic Analysis, its GDP was $590 billion. It is a major

global financial sector; in addition to financial services, major industry sectors include education, logistics, and healthcare.

In comparison to cities on the coasts, the Chicago metro area has less venture capital and a less dense startup culture, which is a challenge in terms of retaining new businesses. On the other hand, its quality of life is attractive and the costs of living and of doing business are relatively low.

The University of Chicago is conscious of its role as a major anchor institution within Chicago, and works to positively impact its city and immediate surroundings. It is, for example, a member of Chicago Anchors for a Strong Economy (CASE), a network of regional institutions interested in redirecting their spending to local businesses. The South Side of Chicago, where the University of Chicago is located, is a historically industrial neighborhood (meatpacking and manufacturing) that suffered from the decline of its main industries in the decades since the mid-twentieth century. The University has shifted from an inward-focused development pattern and approach to its declining surroundings to an engagement with its community—a change that has largely been welcomed (though not without hiccups). It is within this context that the University's investment in CIE has come about. With its reuse of a historic building on a retail avenue with many vacancies, and its community programs, its local community has generally embraced CIE.

Innovation Strengths

The University of Chicago is a premiere research university, with leading graduate programs in economics, business, law, and medicine. While the University of Chicago has undergone a significant change in culture since the 1990s, increasing University-wide recognition of the value of commercialization is a continual effort. Another challenge relates to Chicago's geography: the region's sprawling geography causes difficulties in creating synergies among regional institutions.

E. University of California-San Francisco, San Francisco, California

The University of California-San Francisco is a global leader in health care research, delivery, and education. A research university dedicated solely to graduate education in health and biomedical sciences, UCSF has three major campuses in San Francisco (Parnassus, Mount Zion, and Mission Bay), nineteen UCSF-owned or -licensed sites, and two affiliated hospitals (San Francisco General Hospital and San Francisco Veterans Affairs Medical Center). Its 2013-2014 enrollment was 3,130 (no undergraduate students). Its 2013-2014 research expenses were $924.5 million and its Carnegie Classification is "Special Focus Four-Year: Medical Schools & Centers."

Evolution of Tech Transfer at UCSF

UCSF has hundreds of research centers, institutes, and laboratories focused exclusively on health and biomedical science. Widely known for its advances in medical research and patient care, the University is strongly supportive of the elements that generate these discoveries—elements such as collaboration, entrepreneurship, and pursuit of social impact. This institutional support buttresses the culture of innovation found among students and faculty, who are driven by a desire to improve health and see commercialization of their ideas as a way to do that. UCSF has invested heavily in the infrastructure and networks necessary to support innovations and translation of innovations into the market and practical use.

In recent years, this investment includes the development of the Mission Bay campus, UCSF's second largest campus after its primary Parnassus Heights campus. Its development has dramatically increased the University's research capacity.

Further, the culture of innovation found in the San Francisco Bay Area informs and is informed by UCSF's internal culture. The San Francisco Bay Area is widely known as a locus of high-tech industry, with the industry's epicenter in Silicon Valley in the southern part of the Bay. The presence of major high-tech

corporations, thousands of startups, and of venture capital creates an environment conducive to innovation and commercialization.

It is within this internal and external environment that the UCSF's tech transfer office—the Office of Innovation, Technology and Alliances (ITA)—works. Officially established in 2011, ITA came out of the consolidation of the Office of Technology Management (OTM)—which managed UCSF's IP— and the Industry Contracts Division (ICD) with University efforts to support entrepreneurs as well as efforts to form strategic partnerships with the private sector. OTM and ICD had been established in the mid-1990s; before OTM, tech transfer activities at UCSF had been handled by the University of California Office of the President. In 1993, the Ad Hoc Technology Transfer Advisory Committee was established to examine the state University's approach to tech transfer. The committee concluded that technology transfer activities must be an integral part of the intellectual culture and research environment and that the enhancement of research and education, rather than maximization of patent income, must be the highest priority of the University's technology transfer activities.

About UCSF Office of Innovation, Technology and Alliances (ITA)—Partnerships and Programs

ITA is within the UCSF's Office of Research, whose mission is "to promote research and improve health by providing high quality service to investigators; fostering new research initiatives; and promoting translational discoveries into public benefit." ITA's mission is "bringing research and industry together to advance health science through innovation and entrepreneurship."

ITA has partnerships throughout the university—partnerships that defy easy description because offices and departments work with each other without excessive top-down planning; rather, collaborations are allowed to form as opportunities arise.

For example, it works with the Center for Digital Health Innovation (CDHI) to create agreements with its commercial and nonprofit partners. CDHI, created in 2013, advances research related to individualized precision medicine, which takes into account a patient's genomics as well as the behavioral and environmental data found in electronic health records and social media. CDHI strategically collaborates with commercial and nonprofit entities to accelerate the development, validation, and evaluation of new technologies related to digital health.

One of its most recent and high profile collaborations is with Samsung Electronics Co., Ltd., a partnership that ITA facilitated. This industry partnership has led to the creation of the UCSF-Samsung Digital Health Innovation Lab, a laboratory that accelerates validation and commercialization of sensors, algorithms, and other innovative digital health technologies for preventive health solutions. The new lab space, located in UCSF's Mission Bay campus, opened in 2014.

ITA works with UCSF's QB3 sites as well. QB3, created by University of California in 2000, are "quantitative biosciences labs" - incubators in which researchers take on challenges in molecular biology. There are multiple QB3 research sites across three University of California campuses, two of which are at UCSF: Garage@UCSF and QB3@953; Researchers at these labs patent discoveries and launch startups, activities that ITA facilitates.

ITA also works with the Clinical & Translational Science Institute (CTSI), which facilitates the rapid translation of research to improvements in patient and community health. This cross-school, campus-wide institute provides infrastructure, services, and training to support clinical and translational research.

Additionally, ITA manages the Entrepreneurship Center at UCSF, which provides training and connections to support scientists and clinicians who want to commercialize their inventions through a startup. One of the programs offered through the Entrepreneurship Center is a seven-week National Science Foundation (NSF) I-Corps program that teaches scientists and clinicians how to assess whether an innovation can be developed into a business, showing them how to validate ideas and technology in order to move those ideas to the market.

The course, led by Biomedical Research Acceleration, Integration & Development (UC BRAID), is a joint effort of the five University of California biomedical campuses to accelerate biomedical, clinical, and translational research.

The Entrepreneurship Center offers other entrepreneurship courses and workshops as well; these experiential courses are open to students, faculty, and staff at UCSF, Berkeley, and Stanford, as well as to the business community. The Entrepreneurship Center also hosts networking and educational events, a speaker series, and an "Entrepreneurs Club" (a series in which guest entrepreneurs share their startup stories).

University's Role in City and Region

The San Francisco Bay Area is comprised of nine counties and includes the cities of San Francisco, Oakland, and San Jose. The San Jose-San-Francisco-Oakland combined statistical area (CSA) is the country's 5th most populous CSA, with a population of 8.15 million in 2010; the San Francisco metropolitan statistical area (MSA) is the country's 11th largest MSA, with a population of 4.33 million in 2010 (US Census Bureau). In 2013, according to the Bureau of Economic Analysis, its GDP was almost $412 million.

San Francisco's proximity to Silicon Valley (in the southern part of the San Francisco Bay area), coupled with its density of high tech and venture capital firms, makes it part of one of the top research and development regions in the world. It is also one of the most expensive regions in which to live. The expense of real estate, in particular, has resulted in challenges in the development of physical spaces to support innovation. Siting its QB3 locations was challenging, and the creation of its Mission Bay campus came about in part due to the difficulties the University faced when it wanted to expand its Parnassus campus. Mission Bay opened in 2003 with construction ongoing. It includes the UCSF Medical Center at Mission Bay, education facilities, and research facilities.

The development of the Mission Bay campus came out of three intersecting forces: in addition to UCSF's desire to expand and the challenges it faced in expanding at Parnassus, the City was seeking to develop the biotech industry in the Bay area at the same time that the Mission Bay neighborhood was being redeveloped and in need of an anchor tenant. According to the UCSF website, the Mission Bay campus is now home to more than fifty bioscience startups, nine established pharmaceutical and biotech companies, and ten venture capital firms.

Because UCSF is a public school, it has a mandate for economic development and job creation that private universities do not. UCSF is San Francisco's fourth largest employer, with 20,295 employees in the San Francisco Bay area (22,299 employees total). UCSF also creates jobs indirectly, though the startup companies that spin off from discoveries made in its facilities. Importantly, its QB3 incubators are open to both scientists and clinicians affiliated with the University and those who are unaffiliated. In 2014, companies in the QB3 network (data includes all San Francisco QB3 sites, not only those at UCSF); this includes 411 companies employing 1728 people.

Innovation Strengths

UCSF's internal and external environments are highly supportive of innovation, and of the translation of innovative ideas to impact through commercialization. The University is widely known for its research, and is particularly strong in basic research, translational research, and precision medicine. Specific fields in which its researchers excel include cancer; children's health; diabetes; heart and vascular; immunology and infectious diseases; neurology and neurosurgery; stem cells; transplant services; translational medicine; and women's health.

F. Arizona State University, Tempe, Arizona

Arizona State University (ASU) is one of the largest public universities in the region. ASU's 2013-2014 enrollment was 88,862 (71,366 undergraduate) students across five campuses (Tempe, Skysong, Downtown Phoenix, West, and Polytechnic). Its Carnegie classification varies among its five campuses, with its largest campus (Tempe) having a classification of "Doctoral Universities: Highest Research Activity," and its four smaller campuses designated "Doctoral Universities: Moderate Research Activity" (Skysong and Downtown Phoenix) or "Master's Colleges & Universities: Medium Programs" (West and Polytechnic). Its Tempe campus 2013-2014 research expenses were $269.7 million. Over the past decade and a half, ASU transformed into a first-class research university, a transformation that came about in large part due to the distinct change in culture promulgated by President Michael Crow's emphasis on innovation. In terms of strength of research areas, ASU's life science and bioscience areas are strong—in particular diagnostics and small molecule design (for disease treatment). The Fulton Schools of Engineering is also exceptional. Physical engineering, software development, alternative energy and clean technology research are all areas in which the University excels.

Evolution of Tech Transfer at ASU

Michael Crow became ASU President in 2002. Previously, he had been Executive Vice Provost at Columbia University, where he led efforts to foster innovation and to raise revenue from commercialization of University discoveries. At Columbia, he helped found the Columbia Earth Institute (a multidisciplinary institute comprising dozens of research centers that addresses complex global issues to further sustainable development and social and economic opportunities for the world's poor) and helped Columbia raise over $100 million a year in royalty income (making it one of leading universities in terms of royalty generation).

Once at ASU, Crow sought to make the university a top research institution, implementing some of the same strategies he had used at Columbia to spur innovation and commercialization: breaking down academic silos, encouraging collaboration, attracting exceptional research faculty, and investing in research facilities and infrastructure. Under Crow's watch, ASU established in 2003 the cross-disciplinary BioDesign Institute, 350,000 square feet of LEED-certified bioscience facilities with the stated mission to "conduct use-inspired research, fuse intellectual disciplines and value entrepreneurship." Additionally, ASU combined several departments and schools, fused the University's many campuses into one institution, grew the student body, expanded the downtown Phoenix campus, and built SkySong (the ASU Scottsdale Innovation Center, described further below).

These actions embody Crow's vision of "The New American University," a vision of inclusiveness, exceptional research, and social impact. As articulated by Crow, this model has eight principles: embrace ASU's culture, socioeconomic and physical setting ("leverage our place"); commit to the success of each unique student ("enable student success"); catalyze social change by being connected to social needs ("transform society"); create knowledge by transcending academic disciplines ("fuse intellectual disciplines"); use knowledge and encourage innovation ("value entrepreneurship"); connect with communities through mutually beneficial partnerships ("be socially embedded"); conduct research that has purpose and impact ("conduct use-inspired research"); engage with people and issues locally, nationally, and internationally ("engage globally").

The impact of The New American University philosophy has been felt throughout the university. With its emphasis on research and on social impact, it has had a particularly strong impact on tech transfer and commercialization activities. Under the influence of this philosophy, ASU's tech transfer office—ASU Technology Enterprises (AzTE)—has evolved from a traditional, relatively passive, transactional licensing office into a proactive, exceptionally flexible organization.

About ASU Technology Enterprises (AzTE)—Partnerships and Programs

As ASU's tech transfer office, AzTE manages IP and industry agreements for ASU. Its mission is to "accelerat[e] use-inspired innovation from ASU labs to the marketplace for the benefit of society; facilitat[e] collaborations with industry for the development of next-generation technologies; promot[e] economic growth in Arizona through licensing and start-up company formation." AzTE is housed at SkySong in Scottsdale, an innovation center designed to attract and grow business with support from ASU resources.

AzTE is unique in that it is a separate entity (an Arizona LLC with the ASU Foundation (ASUF) as its only member) that acts on ASU's behalf. Governed by a Board of Directors (with members from ASU, the ASU Foundation, and members at large), AzTE is a nonprofit. This structure, established in 2003, increases flexibility and efficiency in negotiating and supporting startups.

In fulfilling its tech transfer duties (IP identification, development, and protection; commercial due diligence; marketing activities; licensing and other commercialization activities; spin-out ventures; corporate research collaborations), AzTE partners with entities throughout the university and beyond. The office's primary internal relationship is with faculty whose research constitutes the innovation that tech transfer office is tasked with translating into practical use; this includes facilitating the patent filing process, helping to secure funding through licensing revenues and other industry agreements, and supporting venture creation. Some schools (such as the Fulton Schools of Engineering) credit tech transfer activities in the tenure promotion process, one outcome of the culture change instigated by Crow. While many faculty members appreciate this culture change, some faculty members have found the emphasis on practical application of research unwelcome.

While AzTE's core activities focus on faculty research, it also offers support to student innovators: its IP and commercialization services are available to students, if they choose to take advantage of them. For students who want to learn more about the commercialization process, AzTE also offers life/physical sciences internships for graduate students (for those who want to assess technologies or research and write on marketing and finances), operational internships (for those interested in learning about the administrative side of tech transfer), and legal externships (for those who want to learn about the legal issues related to commercialization).

AzTE is part of a larger ASU effort to foster innovation at all levels; to this end it works as part of a university-wide team to generate innovative ideas and technologies, to encourage entrepreneurial thinking, and to make partnerships with industry and/or to launch new businesses in order to move university-generated innovations into the market.

While many ASU technologies find commercial applications through AzTE-facilitated agreements with industry, others are put into practical use through the creation of new ventures. One of AzTE's key partners in supporting startups is the Entrepreneurship + Innovation Group, an initiative of the Office of Knowledge Enterprise Development (which oversees university research). The Entrepreneurship + Innovation Group connects innovators with University resources to support their business ventures.

Resources at ASU include a number of accelerators, such as: the Furnace Technology Transfer Accelerator, which targets start-ups based on university research, marketing and managing IP from participating universities (not only ASU) and offering education and advising to help entrepreneurs form and launch companies; the ASU Startup Accelerator (targeted to community entrepreneurs); the Edson Student Entrepreneur Initiative (a student competition, with winning teams receiving seed funding, office space, and training and mentoring); and The Startup School (for students, a series of workshops organized around three stages of startup development (refining an idea, launching a business, scaling a venture).

To further its economic development impact on the state, ASU has recently launched the ASU Startup Mill.

This initiative was designed to retain more home-grown startups by pairing promising technologies with accomplished entrepreneurs looking for their next opportunity. ASU, like many universities, deals with a lack of venture capital concentrated in the state. Consequently, some of the startups that are created end up exiting Arizona if an out-of-state venture capital fund requires it. The university is also launching its own angel group to help provide early stage seed capital for its startup ventures. Another ongoing effort that ASU would like advance is the attraction of global entrepreneurs and industry partners for the dissemination of new discoveries on a global basis.

Other ASU resources for entrepreneurs include professional mentoring, funding opportunities, academic classes and programs, and physical space and tools (including office, lab, technical, and networking space). ASU works to instill an entrepreneurial attitude throughout the university – as its website states: "Entrepreneurial thinking is more than a skill; it is a mindset – one that manifests itself across all majors and programs at ASU."

SkySong (ASU Scottsdale Innovation Center)

SkySong, or the ASU Scottsdale Innovation Center, is a 42-acre mixed-use development in Scottsdale, AZ designed to help form and grow new businesses through provision of physical space, support services, and ASU resources. AzTE's offices are housed here; it is a tenant, as are other ASU entities with a presence at SkySong, but it is not only a tenant, it is also a partner. Like AzTE, SkySong works to foster partnerships with the private sector and to generate economic activity in the state. SkySong's goal is "to attract cutting-edge and innovative companies and their base of knowledge workers from around the world, integrating the resources of ASU with the opportunities of the private sector."

SkySong is built on the site of a defunct shopping mall. In the early 2000s, the owner of the site attempted to redevelop the property—proposing first a hockey stadium and later a big box retail development—but these proposals were unpopular with the community. The City of Scottsdale then bought the site and, in 2005, entered into an agreement with ASU to build an innovation center: the agreement called for ASU, with ASUF and real estate firm The Plaza Cos., to develop the site and for Scottsdale to issue $80 million in bonds to fund site infrastructure. SkySong 1 and 2, the complex's first two office buildings, opened in 2008; initial leasing was slow, due to the challenging real estate climate, but by 2011 the buildings were 95 percent occupied. SkySong Apartments (a four-story building with 325 units ranging from studios to three-bedrooms) opened in 2013 and SkySong 3 opened in January 2015. SkySong 4 is expected to open in 2016. A restaurant and retail building is also underway on the site; this 12,000 square foot development is being built and leased by Wetta Ventures, a Phoenix-based real estate firm.

At build-out, SkySong is expected to have eight buildings with 1.2 million square feet of mixed-use development. The project is LEED-certified, with an iconic shade structure and distinctive, modern design.

ASU is SkySong's largest tenant, as well as one of its biggest attractions; SkySong's leadership identifies three of the characteristics tenants find most attractive as: its relationship to ASU, its proximity to the highway, and its proximity to the airport. Several clusters of business activities have emerged at SkySong that leverage ASU strengths and resources; these include information communications technology, education innovation, and sustainability. Tenants range in size from one to two -person startups to larger corporate entities such as TicketMaster and Canon.

University's Role in City and Region and State

The Phoenix MSA is the country's 12th most populous metropolitan statistical area (MSA), with an estimated population of 4.49 million in 2014 (US Census Bureau). In 2013, according to the Bureau of Economic Analysis, its GDP was nearly $210 million. Major industry sectors included manufacturing and tourism. Information technology and financial services are also growing industries.

The region—known as "The Valley of the Sun"—is particularly attractive to businesses and researchers who work with solar technologies (e.g. alternative energy technologies), and its climate and low cost of living make it a desirable place to live, although it is strongly affected by cyclical trends in real estate and is geographically sprawling.

ASUF and the University's CFO are responsible for the University's real estate development initiatives, while more traditional economic and development and community relations are within the purview of the Office of Knowledge Enterprise Development. As the tech transfer office, AzTE is not directly responsible for economic development activities, but is a partner in the larger university effort; it contributes by making agreements with industry partners and by working with internal university players to foster a culture of innovation and recognition of the value of commercialization.

A distinguishing aspect of ASU's economic development strategy is its aspiration to attract businesses from around the world. Both AzTE and SkySong are instrumental in this effort.

As a state institution, ASU's "community" can be considered the State of Arizona, not just the Phoenix metropolitan region (where the majority of its students study) or the immediate neighborhoods surroundings its five campuses. ASU works with the Arizona Commerce Authority—a quasi-governmental economic development agency—to retain businesses in the state. Locally, ASU works with GPEC, the Greater Phoenix Economic Council, to further economic development.

Innovation Strengths

The importance of strong leadership from President Crow in raising the bar (in terms of quality and quantity of research) and in changing the culture (in terms of valuing entrepreneurship and partnerships with the private sector) cannot be understated. Crow's influence has also helped ASU stand out for its support for collaboration and cross-disciplinary research. The University's focus on practical application of research is distinctive as well.

Lessons Learned

These universities share many traits: exceptional research, an institutional commitment to innovation and tech transfer, and an understanding of the powerful role anchors can play in their communities. But each evolved within a particular social, economic, and physical geography and with its own experiences; the case studies of how the six research universities are stimulating innovation illustrates the necessarily contextual nature of the solutions that these universities are producing. Nonetheless, some themes and commonalities are evident.

Innovation Ecosystems

First, all of the universities profiled here subscribe to the idea that the best approach to stimulating innovation is by creating an environment conducive to happy accidents, where people and ideas can mix in novel, unplanned ways. Such an environment is often referred to as an "innovation ecosystem"—those diverse mixes of people and resources that together create environments supportive of innovation and commercialization.

Innovation ecosystems may be created through planned "innovation districts"—geographic areas where leading-edge anchor institutions and companies cluster and connect with start-ups, business incubators, and accelerators—or they may evolve more organically. Cities, which concentrate diverse people and resources, are naturally conducive to fostering innovation. Similarly, research universities, which are fundamentally knowledge-generators, can be considered the original innovation districts.

Dedicated Physical Space

Several of those profiled have built dedicated physical space —whether laboratories, coworking space, or similar—that can serve as an innovation ecosystem. These vary in scale from single buildings or dedicated spaces within buildings to redeveloped districts. Pennovation Works, ICE, SkySong, and the QB3 incubators are all examples of newly developed physical spaces—built at different scales, in different contexts, but all with the aim of creating a space in which elements conducive to innovation can mix.

Size and Density

In addition to these real estate projects, many of the profiled universities are working to make linkages within the larger ecosystem (the city and region) in which they are located. In this regard, larger and denser cities—i.e. those with a greater number and variety of resources in closer proximity to each other—are in a better position than smaller and more sprawling cities. UCSF stands out in this regard: it benefits from the metropolitan region's culture of innovation, its venture capitalists, and its density. Others, with more sprawling geography, need to work harder to make connections, as Chicago and Emory have found.

New Haven is another, very different example of how a university can reach out to its community to find and create synergy: it has essentially generated size and density that did not previously exist. Unlike UCSF, it is not in a metro region full of other institutions and investors. Rather, it is New Haven's one major anchor—and, as a result, has sought to redevelop its environs to create an external environment attractive to the faculty, faculty spouses, students, and businesses that it seeks to attract.

Leadership

Internal environment is critical too—specifically the culture of innovation within an institution, which must be fostered through strong leadership and institutional support. ASU's experience provides a clear example. Support from President Crow in raising the bar (in terms of quality and quantity of research) and in changing the culture (in terms of valuing entrepreneurship and partnerships with the private sector) cannot be understated. Crow's influence has also helped ASU stand out for its support for collaboration, cross-disciplinary research, and emphasis on practical application of knowledge.

Experience

Institutional support for a culture of innovation can also be created through positive experience. In Emory's case, institutional support appeared virtually overnight, when the sale of two HIV drug patents brought the University a windfall that proved the value of tech transfer. In Chicago's case, the support is growing incrementally. Known for its extremely rigorous and highly academic research, the university's culture has not been supportive of applied research and commercialization; but even here, with small steps taken over many years, the culture is beginning to change.

Conclusion

The R&D funding picture is changing, with federal funding for research stagnating and the relationships among funders of research and performers of research changing as well. Pursuit of innovation and commercialization, and of new relationships with the private sector, is one way in which universities are attempting to grapple with these trends. While universities approaches differ based on their singular histories and geographies, the six case studies presented in this paper reveal some common supporting characteristics: an embrace of an ecosystem approach, dedicated physical space, size and density, leadership, and experience.

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