WASHINGTON RESEARCH COUNCIL Economic Profile

November 2009

WASHINGTON LIFE SCIENCES ECONOMIC IMPACT STUDY

The life sciences have been a rapidly growing part of the world economy as major scientific advances in the past few decades have opened the promise of substantial improvements in health, agriculture, energy and the overall quality of life. These advances have provided cures for diseases and mitigations of a wide range of disabilities common in the industrialized world. They also hold the promise of alleviating widespread suffering and death in developing countries where infectious diseases and poor health infrastructure are common. Agricultural advances have improved crop yields and created promising new sources of renewable energy.

Significant parts of this exciting activity are happening in Washington. Important scientific discoveries are being made by both start-up and established bio-pharmaceutical companies that are turning their innovations into useful products and services. The state's research universities and not-for-profit institutions contribute immensely to the scientific exploration and innovation taking place in the field. And in a short period of time, the state has become a major center for global health, leading efforts to eradicate disease and improve the lives of billions of people.

All of this activity, which has been growing quietly for decades, adds up to an important part of the state's economy. But because it involves a diffuse group of organizations without clearly delineated markets, it is difficult to recognize. Although the life sciences may not meet the exact definition of a "cluster," this group of enterprises and institutions certainly contains many of the characteristics of a self-sustaining activity around which economic development strategies can be built. Hence, we will refer in this report to the "life sciences industry."

This industry is important not only because of its size, but also because of its potential for growth. As societies become wealthier they tend to consume healthcare services at higher rates, and science and technology keep providing new products and services that have value to consumers. The new emphasis on global health increases the need for products and services aimed at developing countries, and the push for reducing carbon emissions is leading to a gold rush for renewable biofuels.

Measuring the life sciences industry is a challenge. The data normally used to undertake economic impact analysis simply does not exist for it. Activities in the life sciences cut across various industry and employment classifications, making it difficult to quantify the industry. Therefore, this report will use a combination of quantitative methods to indicate the economic impact of the life sciences, and qualitative descriptions to show the ways in which these industries shape the economy now and how they will grow in the future.

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THE LIFE SCIENCES INDUSTRY AND WASHINGTON'S ECONOMY

The life sciences industry forms an important and growing segment of Washington's economic base – that is, enterprises that bring in money from out of state and export value to the rest of the nation and the world. The earnings of the economic base are what allow us to import consumer products, such as cars or appliances or clothing, that are made elsewhere. Dollars earned by those working in industries that make up the economic base circulate within the state to create jobs in retail, construction and other local services.

The analysis in this report conservatively estimates that the various segments of the life sciences industry directly employ over 22,000 people in the state. Those jobs may support as many as 55,000 additional jobs throughout the state's economy. This puts life sciences on par with the state's computer and electronics products manufacturing industries

But unlike electronic products, or other familiar industries such as aerospace, food products, software or tourism, life sciences is not an easy industry to grasp in the mind's eye. When we think of a sector of the economic base, we typically think of industries that are dominated by the private sector, such as aerospace or software, or are totally public sector, such as the military. The life sciences, by contrast, comprises private sector firms, not-for-profit research organizations, and public universities and laboratories. The work of the life sciences can move fluidly among these organizations, beginning, say, with a privately funded discovery in a university laboratory, which moves to a non-profit laboratory for further refinement, and then to a private firm for commercialization.

Making things even more complicated is that key personnel also move fluidly among the institutions. Researchers may be on the faculty at a university, hold a fellowship at a research institute, and also have a stake in a for-profit firm. Individuals can shift among these sectors as new opportunities arise.

Perhaps the best way to view the life sciences is to think of it mostly as the creation of knowledge and intellectual property. While the state does have employment in the production of products and services pro-

Life Sciences Profile

Name:	Amgen
Location:	R&D facility in Seattle. Manufacturing facility in Bothell.
Year founded:	1980.
Structure:	Public corporation
Employees:	~900 in Washington; 16,000 worldwide .
Annual sales:	2008: $15 billion

Business. Amgen is the largest biotechnology company in the world and the largest commercial biotechnology company in Washington state.

Patients suffering from the greatest unmet medical needs are Amgen's first priority. Amgen therapeutics have changed the practice of medicine, helping millions of people around the world in the fight against cancer, kidney disease, rheumatoid arthritis, and other serious illnesses. Approximately 90 percent of the new molecules that Amgen is bringing into the clinic target pathways that have never been previously addressed in humans.

The company has facilities around the world, and its Seattle campus is the largest R&D site outside of its headquarters. Amgen's hundreds of Seattle-based scientist are dedicated to developing novel approaches to treating cancer and inflammatory disease.

Growth potential. A pioneer in biotechnology, Amgen will celebrate 30 years of helping patients in 2010. Amgen currently has eight marketed products, and 50+ molecules in development from late discovery research through phase 3. The company is pursuing programs in bone, cardiovascular disease, inflammation, metabolic disorders, nephrology, neurosciences, oncology and hematology; with nearly 300 active studies and more than 45,000 patients enrolled in Amgen clinical trials in more than 50 countries.

vided directly to the healthcare, agriculture or energy industries, the bulk of the output of the life science industry in the state is scientific discovery and the translation of discovery into the design and engineering of useful products. This means that the most important policy direction for enhancing the industry in the state is one that promotes innovation, protects intellectual property, and enhances the ability of the industry to attract and retain its most important "capital" assets, its people and the tools they need to do their work.

Life Sciences Profile

Name:	Spiration, Inc.
Location:	Redmond
Year founded:	1999
Structure:	Private corporation
Employees:	45
Annual revenue:	N/A

Business. Spiration has developed a device, the IBV Valve System, that is implanted in lungs to prevent air from getting to damaged areas of the lung. The product is intended mostly for use with patients with emphysema, redirecting airflow to healthier areas of the lungs where it can be processed. It can also be used seal lungs following surgery.

The IBV valve system has been approved for use in Europe for all applications. It received a Humanitarian Device Exemption from the FDA, allowing the device to be used on a limited basis for patients having had lung surgery. The device is still under clinical trials in the U.S. and Canada for general use.

Growth potential. Emphysema is the most common form of lung disease in the U.S., and one of the most common causes of death overall. There are no cures for the disease, and the treatments currently available can only slow progression of the disease and relieve symptoms. Around 2 million Americans suffer from the disease, although it is not clear how many of those would be at a stage where Spiration's products would be applicable. But according to company literature, The IBV Valve is the only device of its type in use today. So, once approved, the device could have wide applicability.

On this last point, one thing is critical: size. Agglomeration economics suggests that the larger the pool of people doing similar work, the more productive those people will be. Concentrations of people lead to the sharing of ideas and perspectives, and maximizes the likelihood that individuals will find the best place to use their talents. Furthermore, a large industry presence decreases risk for individuals by increasing the possibilities for employment should they need to leave their current job. Areas with larger industry concentrations tend to be more attractive place to pursue a career. We can think of the life sciences industry as increasing in quality and vitality exponentially with size. Thus, the discussion below about Washington's success along various metrics with respect to other states is not about bragging rights but about the viability of the industry.

Describing the Life Sciences Industry

The components of the life sciences industry can be categorized in many ways. We will describe the industry in four categories, based roughly on the output or end user of the technologies being developed and sold. While there is some overlap among them, these groupings tend to be the ones within which organizations collaborate and within which individuals move throughout their careers.

Biopharmaceuticals. This category of organization works to develop and sell drugs aimed at curing or mitigating a wide range of disorders, particularly those of concern in industrialized societies. Much of the research that forms the basis for these products begins in privately funded research facilities owned and operated by the bio-pharmaceutical industry, in university laboratories, or in organizations such as the Fred Hutchinson Cancer Research Center in Seattle. Individual for-profit firms, often labeled "biotechnology" companies, can begin with discoveries from universities or laboratories, or with their own proprietary discoveries. But whatever the origins and path of the technology, the final goal is a pharmaceutical product that gains FDA approval and has a promising market share.

The challenge in the biopharmaceutical business is that capital requirements are extremely high, along with the risk of failure. Investors must put up huge amounts of cash to fund research and clinical trials, always aware that the promised breakthrough may never arrive or that the product may be rejected by regulators. When a firm does achieve success, the outcome is frequently to sell the successful product, or the entire firm, to a large pharmaceutical manufacturer that undertakes production, marketing and distribution.

Thus, although the state has seen its share of breakthroughs in biopharmaceuticals, it has not seen many large firms grow out of those. A pattern has emerged 30 years after the first biotech companies formed: the state's formidable talents and resources for research and development of pharmaceuticals support a robust and valuable research industry, but the state's lack of competitiveness as a manufacturing site inhibits the growth of large production and distribution facilities. From an economic development perspective this is a good-news, bad-news story. The good news is that the state continues to attract highly skilled researchers who are paid well and boost the state's average wages. The bad news is that manufacturing jobs do not follow.

Medical devices. This sector produces hardware and its accompanying software, as well as implanted devices, for use in medical diagnostics and treatment. This industry pre-dates the emergence of biopharmaceuticals in the state, with several firms growing out of technologies developed at the University of Washington in the 1970s. In particular, medical ultrasound was developed at the UW, and several firms have spun that technology out into large imaging companies.

Life Sciences Profile

Name:	IsoRay Medical
Location:	Richland
Year founded:	1998
Structure:	Public Corporation
Employees:	37
Annual revenue:	'07 –'08: $7.1 million; '08 –'09: $5.4 million

Business. IsoRay Medical was founded to produce therapeutic medical isotopes and associated devices for treatment of solid tumor cancers. Its current sales are based on brachytherapy seeds for the treatment of prostate cancer. The company's major breakthrough was in developing a method of using cesium-131 isotopes which, according to company literature "are expected to decrease radiation exposure to the patient and reduce the severity and duration of side effects, while treating cancer cells as effectively, if not more so, than Iodine-125 or Palladium-103."

The firm expects to expand beyond treatment of prostate cancer and develop treatments for breast, liver, lung and pancreatic cancers. The product has been cleared for these treatments.

IsoRay obtains its radioactive materials from laboratories in the United States, and, increasingly, from laboratories in Russia. Its 15,000 square foot manufacturing facility is located in the Applied Process Engineering Laboratory, an incubator facility in Richland operated by Energy Northwest.

Growth potential. IsoRay believes that its cesium based product has the potential to become the leading seed therapy choice among clinicians. The cancers treated by IsoRay products will occur in hundreds of thousands of patients in the U.S. alone, and the firm still has relatively low market penetration for these treatments. If it can expand beyond the relatively small number of treatment facilities currently using its products, IsoRay has the potential to significantly expand production and sales.

The medical device companies face many of the same capital and regulatory hurdles that the biopharmaceutical firms do, but approvals can be shorter, especially for diagnostic equipment. FDA approval for therapeutic and implanted devices, however, can be quite complex and expensive. Manufacturing of medical devices is very complex and costly, as these devices must meet exacting standards.

There is continuing national and global consolidation in the medical device field, and medical device firms are frequently acquired once they become successful. If the target of the acquisition is simply intellectual property, an acquired firm may lose its presence in the state. But many firms have been acquired by large multi-nationals and kept their state presence. Manufacturing operations, however, can be vulnerable to out-sourcing or inter-firm consolidation.

Global health. This collection of organizations cuts across both the bio-pharmaceutical and medical device categories, but also includes groups that address the management and delivery of health services. Global health efforts operate at several levels. First are efforts to develop new products to prevent and treat diseases that are common in developing countries but that have been given little attention by Western pharmaceutical companies. Second is to promote the distribution of existing medications and vaccines in areas that need them, with the goal that no one should die of a disease that we already know how to cure. Third concerns the development of healthcare infrastructure in developing countries.

As one might imagine, much of the activity in global health is carried out by universities and non-profit research institutions. Washington has seen a significant expansion in such organizations, and is thought by many to be second only to Geneva in its concentration of global health assets. But with the need to produce large quantities of healthcare products destined for developing countries, there are also private firms now targeting those markets. The scale of global health efforts, however, tends to favor large, established firms rather than small start-ups. With the leadership of the Gates Foundation, the World Health Organization and other agencies, the perception that there is no money to be made in global health is changing rapidly.

In a 2007 study, "Economic Impact Assessment of Global Health on Washington State's Economy," an interdisciplinary team at the University of Washington found that global health activities aimed at developing countries produced over $700 million in direct economic activity in the state in 2005. This activity produced 3,650 direct jobs and 10,470 additional jobs throughout the economy. The study found that global health activities at the University of Washington and Washington State University are worth about $130 million per year.

Life Sciences Profile

Name:	Seattle Genetics
Location:	Bothell
Year founded:	1998
Structure:	Public corporation
Employees:	260
Annual revenue:	2007: $22 million; 2008: $35 million

Business. Seattle Genetics describes itself as "a clinical stage biotechnology company advancing a broad product pipeline of antibody-based therapies." Its technology is aimed at treating cancers and autoimmune diseases, and currently has a number of products in the pipeline.

Seattle Genetics' lead product, SGN-35, is currently in pivotal trials with patients experiencing recurring Hodgkins Lymphoma. Three other products for treatment of cancer and autoimmune disorders are also in clinical trials. Even though it has no products on the market currently, the firm does receive revenue from large pharmaceutical firms that partner with Seattle Genetics in the use of its proprietary antibody-drug conjugate (ADC) technology.

The firm has a long term strategy of leveraging its ADC technology and continuing to move new discoveries into the approval pipeline. This is a capital intensive business: in 2008, Seattle Genetics spent $111 million on research and development, and another $16 million on operations, while bringing in $41 million.

Growth potential. The cancers that are the target of Seattle Genetics' initial products affect tens of thousands of people in the United States alone each year. Although initial remission rates have been climbing, substantial numbers of patients have recurrences that would be treated by these products.

Key to the firm's strategy is to maintain an active research program that continually looks for new products and technologies that can feed into the pipeline for eventual clinical trials. Its most recent SEC filings indicate that the firm has six products in various stages of testing, in addition to SGN-35. Seattle Genetics also has six active collaborative agreements with other biopharmaceutical firms for use of its ADC technology.

Agriculture, energy and environment. The life sciences do not stop with medicine. The state has active research and industries in plant and animal sciences to improve agriculture, and, increasingly to develop sustainable biofuels. The state's two research universities are heavily involved in these areas, as is the Pacific Northwest National Laboratory in Richland.

Life Sciences Profile	
Name:	Signature Genomics
Location:	Spokane
Year founded:	2003
Structure:	Private LLC
Employees:	107
Annual revenue:	N/A

Business. Signature Genomics Laboratories provides diagnostic testing for a wide range of disorders in its "state-of-the-art array-based comparative genomic hybridization (array CGH) diagnostic laboratory." The firm's testing services are based on proprietary technology embedded in its SignatureChipWG, SignatureChipOS, and Signature PrenatalChip.

Signature Genomics was formed in partnership with Pathology Associates Medical Laboratories and Sacred Heart Medical Center in Spokane. The laboratory began offering testing services directly to clinicians in2004, one year after opening the firm. The laboratory in Spokane accepts direct shipments of samples. Over 30,000 cases have been processed.

Growth potential. In just a few years Signature Genomics grew from three employees to over 100, offering its services nationally. Diagnostic testing is a competitive business, but Signature Genomics growth attests to the strength of its proprietary technology, and future growth will depend on keeping that technology current.

The nation's first attempts to radically increase the use of biofuels – ethanol and bio-diesel – did not turn out well, due to the unsustainability of the stream of feedstocks. Researchers and entrepreneurs are in a race to find ways to create feedstocks that do not compete with food sources, do not use excessive resources, and do not, themselves, result in high output of carbon during production.

This is an intensely competitive business right now, with scientists and engineers around the world looking for ways to extract fuel from various plants and algae, and it is likely that only a few technologies will emerge as winners. So, unlike biomedical industries, where there are thousands of disorders in need of attention, there are just a handful of fuels that need renewable substitutes. The risk for these businesses is very high, but given the amount of fuel that needs to be created, the corresponding rewards are very tempting.

What about healthcare? The delivery of healthcare services—hospitals, clinics, doctors, laboratories—is not included in the definition of life sciences for purposes of this report (we do count research performed at some medical institutions in the state, as specifically delineated by those institutions). The reason for omitting healthcare itself is that the vast majority of healthcare services performed in the state are consumed by residents of the state, and therefore do no constitute part of the state's economic base. It is true that patients do come to Washington from other states and nations to receive specialized care, but those exported services are not measured in any systematic way.

Very little of the output of Washington's life sciences industries is offered at the retail level. The industries, firms and organizations described in this report are in the business of scientific discovery and the translation of that discovery into useful products and services that can be "wholesaled" to healthcare and other "retailers" around the world. Often, the underlying goal of start up firms in the life sciences is to develop valuable intellectual property that can be sold, rather than to develop a viable long term business.

DIVERSE SOURCES OF REVENUE

Describing the life sciences industry is further complicated by the unusual ways in which money flows into the state to the industry: it is often quite different from other parts of the economic base. We can easily imagine money flowing into Washington to purchase aircraft or geoducks, or to pay fees for architectural services or for a hotel stay. We can also imagine money flowing in for payroll at military bases. Large parts of the life sciences industry, however, do not bring dollars into the state in traditional ways – but the dollars are just as green. Sources of revenue for the life sciences industry include:

Internal company funds. Many life sciences firms in Washington are branches of national or global firms, either under their own name or their parent company name. The research and development operations of these firms in Washington are funded by internal operating funds of the parent firm. For example, Amgen's R&D facility in Seattle is one of just four in the nation, with its payroll and operating costs paid for by revenues generated though Amgen's global sales of pharmaceutical products. Amgen reports that in 2008 it spent over $3 billion companywide on R&D, or about one third of its operating expense.

Venture Capital. Research and development activities that take place within private firms with an eye toward commercial products are funded mostly with venture capital. While the state does have a robust venture capital community that attracts investors from within the state, most venture funding still comes from out of state, and most of the investors in those funds are not from Washington. In many respects, the investors in these venture funds are paying firms in the life sciences industry of the state to produce intellectual property that will eventually be sold at a large profit.

Figure 1
Venture capital in Washington

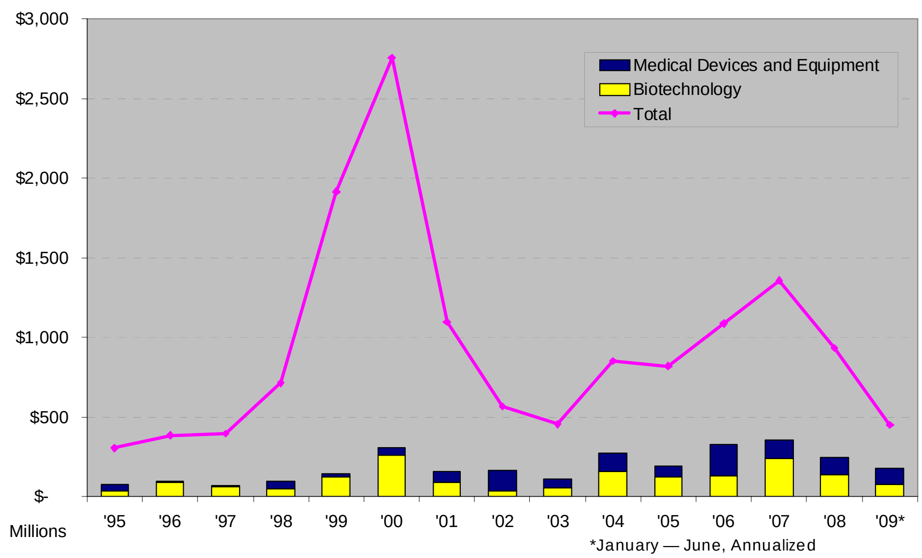


Figure 1 shows venture capital placements in Washington since 1995. The bars show funds going to life sciences, firms, both biotechnology and medical equipment. The line shows the trend in total venture capital investments in the state, reflecting the very high rate of investment during the dot-com boom of 2000. Investments in the life sciences have been more steady, if not as spectacular. Investments in the life sciences now account for about 40 percent of venture capital invested in the state. Figure 2 shows the venture capital deals in the life sciences in Washington that were placed in the second quarter of 2009. In that quarter, three times as much funding went into biotechnology firms as went into medical devices.

Federal research grants. The state's two research universities, the Pacific Northwest National Laboratory, the Fred Hutchinson Cancer Research Center and other non-profit research centers attract billions of dol-

Figure 2
2nd Quarter 2009 VC Deals in Washington

Biotechnology firms	Location	Product	Stage	Amount
Calistoga Pharmaceuticals	Seattle	Treatment of Cancer and inflammatory diseases	Early stage	$15 million
Immune Design Corporation	Seattle	Vaccine development	Early stage	$1.7 million
NanoString Technologies	Seattle	Bar coding system for single molecules	Expansion	$14 million
XORI Corp.	Seattle	Platform for antibody discovery	Start up	$2.1 million
Medical device firms				
EndoGastric Solutions	Redmond	Device to treat gastro esophageal reflux disease	Later stage	$3.8 million
Generic Medical Devices	Gig Harbor	Production of medical devices	Expansion	$5 million
Pathway Medical Technologies	Kirkland	Devices for treatment of arterial disease	Later stage	$2.3 million

Source: PricewaterhouseCoopers

Figure 2
Largest Washington recipients of funding from the National Instutes of Health

	FY 2007	FY 2008	Total 2007-2008
University of Washington	448,379,740	394,928,665	843,308,405
Fred Hutchinson Cancer Research Center	227,438,213	218,711,483	446,149,696
Children's Hospital And Regional Medical Ctr	15,187,100	22,704,592	37,891,692
Washington State University	18,557,867	16,878,535	35,436,402
Center for Health Studies	16,789,559	18,353,195	35,142,754
Seattle Biomedical Research Institute	17,920,044	9,832,725	27,752,769
Battelle Pacific Northwest Laboratories	11,619,361	16,105,920	27,725,281
Institute for Systems Biology	11,055,471	7,816,623	18,872,094
Benaroya Research Institute At Virginia Mason	8,786,320	7,401,877	16,188,197
Decode Biostructures	3,908,215	3,853,482	7,761,697
Seattle Institute for Biomedical & Clinical Research	3,285,843	3,569,505	6,855,348
Program for Appropriate Technology in Health (PATH)	3,947,675	2,542,638	6,490,313
Puget Sound Blood Center	3,105,525	2,693,252	5,798,777
Axio Research, LLC	4,554,322	416,474	4,970,796
Talaria, Inc.	1,680,004	3,165,222	4,845,226
Pacific Northwest Research Institute	2,191,934	2,215,371	4,407,305
Infectious Disease Research Institute	1,352,157	2,295,697	3,647,854
Swedish Medical Center, First Hill	1,146,511	1,700,489	2,847,000
Behavioral Tech Research, Inc.	514,246	1,974,912	2,489,158
Geneva Foundation	1,171,119	1,170,346	2,341,465
Syntrix Biosystems, Inc.	1,569,056	657,348	2,226,404
Firsthand Technology, Inc.	-	2,090,845	2,090,845
Vpdiagnostics, Inc.	991,848	1,028,641	2,020,489

Source: National Institutes of Health

Figure 3

Ten largest NIH grants in Washington in 2008

Organization Name	Project Title	Award
Fred Hutchinson Cancer Research Center	Leadership Group for a Global HIV Vaccine Clinical Trials Network	$26,907,846
Fred Hutchinson Cancer Research Center	HVTN Laboratory Program	$15,927,918
Fred Hutchinson Cancer Research Center	Leadership for HIV/AIDS Clinical Trials Networks; HIV Vaccine Trials Network	$14,380,617
University of Washington	National Primate Research Center	$12,480,373
University of Washington	The WWAMI RCE for Biodefense and Emerging ID	$11,401,047
Fred Hutchinson Cancer Research Center	Cancer Center Support Grant (Comprehensive)	$9,979,932
University of Washington	Institute for Translational Health Science (UL1)	$9,919,954
Fred Hutchinson Cancer Research Center	Leadership for HIV/AIDS Clinical Trials Networks; Microbicide Trials Network	$7,116,100
Fred Hutchinson Cancer Research Center	Leadership for HIV/AIDS Clinical Trials Networks; HIV Prevention Trials Network	$6,867,620
University of Washington	EMS Network Data Coordinating Center	$5,008,796

Source: National Institutes of Health

lars in research funding for the life sciences. Most of these grants are competitive, so in many respects, these institutions compete for customers like any service business.

The federal government has long made a commitment to basic research that is not directed at solving any particular problem. Thus, much of what is discovered is not tied to any product or immediately usable outcome, but simply advances knowledge in certain areas. We can think of the state's life sciences research capacity as an industry in itself, rather than as simply a stop on the path toward commercialization.

The vast majority of federal research funding for the life sciences comes through the National Institutes of Health (NIH). In 2008, NIH awarded 1621 separate grants in Washington, totaling $761 million, for an average grant of $470,000. Figure 3 shows the recipients of NIH funding in Washington that received at least $2 million during 2007 and 2008. Figure 4 provides brief descriptions of the top ten grants awarded in 2008.

Foundation grants. The research organizations that receive federal grants also receive grants from private foundations. The largest of these,

Figure 3

Major Washington recipients of Gates Foundation grants in 2007

	Grants	Total funds
Program for Appropriate Technology in Health	25	90,150,712
University of Washington	9	35,253,851
Seattle Biomedical Research Institute	5	12,784,754
Infectious Disease Research Institute	2	12,110,881
Fred Hutchinson Cancer Research Center	3	5,550,276

Source: Bill and Melinda Gates Foundation

Life Sciences Profile

Name:	Pacific Northwest National Laboratory (PNNL)
Location:	Richland
Year founded:	Current contract with Battelle signed in 1965
Structure:	Owned by U.S. Department of Energy. Operated by Battelle.
Employees:	4,600 (all scientific areas)
Annual volume:	$880 million

Services. PNNL is one of ten laboratories owned by the U.S. Department of Energy (DOE). Its mission is to conduct basic research for the department, as well as other federal agencies and private entities. The laboratory is operated by the Battelle Memorial Institute, which operates three other national laboratories.

As would be expected by its ownership, PNNL has a heavy concentration in research on energy, and within this concentration, the lab does extensive work in the area of sustainable biofuels. Current projects include efforts to convert biomass into usable substitutes for gasoline and diesel fuel. PNNL also has an extensive practice in environmental remediation and protection.

PNNL's biological sciences division has a staff of 200 and receives substantial funding from both DOE and NIH.

The laboratory's size and scope make it a natural partner for researchers across the Northwest. Recently, a partnership between PNNL and Washington State University resulted in the opening of the new Bioproducts, Sciences, and Engineering Laboratory, a 57,000-square-foot, $24.8 million facility in Richland.

Growth potential. Because of its diverse funding sources it is difficult to estimate the growth potential for PNNL. It did see 20 percent growth in volume between 2005 and 2008, so the institution is clearly meeting the needs of its federal and private sponsors. In the life sciences, the new partnership with WSU should yield significant growth results in the coming years as that facility hits its stride.

the Gates Foundation, is located in the state, but because its assets are largely held outside the state and it operates on a global basis, its grants are not the same as other money that circulates within the state. Figure 3 shows the five largest recipients of Gates Foundation grants for the life sciences in Washington. At over $150 million in grants for these five institutions alone in 2007, the Gates Foundation is clearly a major influence on the region's life sciences industry.

Licensing and partnership revenue. Most life sciences start up firms are built around proprietary technology that is used to produce innovative pharmaceutical or agricultural products. These new technologies are often of great interest to larger firms elsewhere in the country that see the applicability to their own products. Some of the state's life sciences firms engage in licensing agreements or develop partnerships with out-of-state firms through which they collect fees for the use of their proprietary technology.

Product and service sales. The most basic form of revenue generation in the economy is often the least available source for life sciences companies in Washington. The state has never had a significant presence of pharmaceutical manufacturing firms, so the production, marketing and sales operations that generate direct revenue for these products and services do not occur very much in the state. The state does still have a significant number of manufacturers of medical devices, so revenue from sales of those products will flow into the state.

Life Sciences Employment in Washington

An economic impact analysis of an industry generally begins with the employment in that industry, and uses an economic model to determine how many additional jobs are generated by the export activity of the industry. The additional employment generated by the industry comes from two sources. "Indirect" employment is generated through purchases made by the industry in the local economy, such as supplies, utilities, financial and legal services. "Induced" employment is generated by the spending of households who are employed either directly or indirectly in the industry. The combination of the three employment sources

– direct, indirect, induced – yields a "multiplier" which, when applied to the direct employment, yields the total employment created by the industry.

Life Sciences Profile

Name:	Seattle Biomedical Research Institute (SBRI)
Location:	Seattle
Year founded:	1976
Structure:	501-c-3 Not-for-profit corporation
Employees:	250
Annual budget:	$40 million

Services. SBRI is an independent research organization that concentrates on finding ways to eliminate infectious diseases, especially those prevalent in developing countries. While infectious disease is not a primary cause of death in industrialized countries, it is by far the leading cause of death in Africa and parts of Asia, and, in all, is the leading cause of death in the world.

SBRI is currently addressing the "unholy trinity" of malaria, HIV/AIDS, and tuberculosis, as well as lesser-known diseases such as African Sleeping Sickness and Leishmaniasis. The institute conducts basic research at its Seattle facility and its field laboratory in Tanzania, often partnering with researchers around the world. The institute is also involved with the development and testing of vaccines.

SBRI began as a small independent research organization, but soon developed strong ties with the University of Washington School of Public Health and Community Medicine. Today, most of the senior research staff at SBRI also hold professorships at the UW, many in the new Department of Global Health.

Growth potential. SBRI is one of the world's leading research institutions in a field that has seen rapid and accelerating growth. It already has a close partnership with the Gates Foundation, the leader in private funding of global health research, and has successfully partnered with organizations around the world. Furthermore, its headquarters is in the center of what may be the second largest global health cluster in the world. All signs point toward continued growth for SBRI

There are two basic ways to collect employment data. The first is to use administrative records that capture data as part of compliance with employment law. The most commonly used employment data is collected through unemployment insurance programs, and measures all individuals who are covered under the program. "Covered employment statistics" are quite accurate in terms of the count of individuals, but are only as useful as the categories into which the employees are placed. This report uses covered employment data, supplemented by other sources. Covered employment data was also used in recent national studies of the life sciences conducted by Battelle (2008) and Archstone Consulting (2009).

The second way to collect employment data is to survey the universe of employers. This method was used in a 2002 study of Washington's biotechnology and medical device industry (Chase 2002), which used employment numbers from a survey by Lifesciences.com. Similarly, the Community Attributes study of biomedical devices (2008) and the UW study of global health (2007) used survey data.. This method is more transparent than using administrative records, but is accurate only to the extent that the surveyor correctly identifies the universe of employers and that these employers respond to the (voluntary) survey. The Lifesciences.com survey has not been updated since 2005.

For purposes of this report, the covered employment data from the Washington State Department of Employment Security (ESD) has some problems, stemming from the categorization available in the North American Industrial Classification System (NAICS). ESD uses NAICS codes for detail on employment in the medical device and pharmaceutical manufacturing sectors, and for the past two years ESD has used a new NAICS code called "biotechnology." But the rest of the private sector life sciences research employment, including most of the employees of the state's non-profit research institutions, are included in a broad NAICS category called "research and development in the physical, engineering, and life sciences." To address this shortcoming, we employ a methodology used by Battelle. For its 2008 State Biosciences Initiatives report, Battelle estimated that 43 percent of those working in the larger five-digit NAICS category (which includes biotechnology) do their work in the life sciences. (In similar studies, the Milken Institute simply ignores the larger NAICS R&D category and only uses the biotechnology category begun in 2007.)

ESD data does not break out two important life sciences employers. Researchers who are on the faculty or staff of a university are listed under "education" and no attempt is made to break them out by research focus. Finally, researchers who work in a hospital are categorized under healthcare. For these categories not broken out in ESD data we use various estimating methods.

Employment impacts of the life sciences are determined as follows:

Manufacturing. The NAICS system provides detailed data on employment in manufacturing operations of all kinds. Figure 8 shows employment in ten categories of manufacturing related to the life sciences, for a 2008 total of 8,930 jobs. The largest of these, electromedical devices, covers the state's substantial industry in medical imaging devices.

Private sector research and development. This category will consist mostly of not-for-profit research institutions, along with some for-profit firms that are strictly engaged in research (as opposed to doing research associated directly with the manufacture of a product or provision of a service). ESD provides two NAICS codes for R&D. The first, 541711, is the category created two years ago to break out R&D in "biotechnology" specifically. ESD reports that in 2008, 2,679 people worked in that category at an average annual wage of $87,482.

The second NAICS code for R&D, 541712, contains all other scientific work in "engineering, physical and life sciences." So, life sciences research work that is not specifically associated with the molecular manipulations that usually define biotechnology, will be found in this category, along with all other kinds of research that have little or nothing to do with life sciences. To find the life sciences component, we revert back to NAICS 54171, which includes both 541711 and 541712. ESD reports that in Washington in 2008, 18,271 people worked in all of NAICS 54171, so, applying Battelle's ratio, we can estimate that 8,039 worked in the life sciences. Then, subtracting the 2,679 people who worked in biotechnology (541711), we arrive at an estimate that 5,360 people worked in non-biotech life sciences R&D.

Figure 6
2007 R&D expenditures in the life sciences at universities and colleges

	All life sciences	Agricultural sciences	Biological sciences	Medical sciences	Other life sciences
University of Washington	513,821	13,479	85,218	405,409	9,715
Washington State University	129,984	60,532	57,728	6,164	5,560
Western Washington University	1,963	0	1,963	0	0
Eastern Washington University	334	0	334	0	0
University of Puget Sound	251	0	231	0	20
Heritage University	210	0	190	20	0
Central Washington University	185	0	185	0	0
Pacific Lutheran University	121	0	121	0	0
Evergreen State College	65	0	65	0	0
Seattle University	63	0	0	0	63
Seattle Pacific University	56	0	32	12	12
Total	647,053	74,011	146,067	411,605	15,370

Thousands of current dollars

Source: National Science Foundation

Figure 7

Research at medical institutions

	Total 2008 research funding
Children's Hospital And Regional Medical Center	36,977,801
Benaroya Research Institute At Virginia Mason	24,543,000
Puget Sound Blood Center	5,600,654
Swedish Medical Center, First Hill	2,439,000
Tacoma General Hospital	691,655
Seattle-King County Public Health Dept	456,240
Total	70,708,350

Sources: NIH, institutions

University faculty and staff. ESD reports none of the state's R&D employment within the public sector, so all university faculty and staff who are working in R&D in the life sciences will appear in the larger "education" category (we assume that faculty and staff at private universities do as well). To estimate the number of jobs attributable to life sciences R&D, we begin with the total value of R&D activity at the state's institutions of higher education. Figure 6 shows that in 2007 the state's higher education institutions performed $647 million worth of life sciences research. Using the ratio of spending to employment from some large institutions we estimate that every $1 million in research spending produces 7.5 jobs (ECONorthwest 2009). Thus, life sciences R&D spending at the state's higher education institutions results in approximately 4,850 jobs.

Figure 8

2008 Employment in the life sciences in Washington

Sector of the life sciences industry	NAICS Code	Employment	Average Annual Wage
Medicinal and Botanical Manufacturing	325411	317	$39,162
Pharmaceutical preparation manufacturing	325412	1,166	$92,520
In-Vitro Diagnostic Substance Manufacturing	325413	429	$60,792
Biological Product (except Diagnostic) Manufacturing	325414	578	$59,782
Electromedical and electrotherapeutic apparatus manufacturing	334510	3,619	$92,088
Analytical laboratory instrument manufacturing	334516	508	$97,977
Surgical and medical instrument manufacturing	339112	454	$71,883
Surgical appliance and supplies manufacturing	339113	1,387	$40,089
Dental Equipment and Supplies Manufacturing	339115	117	$34,082
Ophthalmic Goods Manufacturing	339116	355	$34,699
Research and development in biotechnology	541711	2,679	$87,482
Estimate of research and development in life sciences	541712	5,360	N/A
Estimate of university faculty and staff working in life sciences	N/A	4,850	N/A
Estimate of hospital staff in research activities	N/A	530	N/A
Estimated total direct life sciences employment		22,349	

Sources: Washington State Department of Employment Security, National Science Foundation

Hospitals and institutions. Six medical institutions in the state received grants from the NIH in 2008. Further research finds that these hospitals had additional sources of research funding, with the total shown in Figure 7. Using the same ratio of spending to jobs that we used for university research, we can conclude that hospital research generated about 530 direct jobs in the state.

Figure 9
Major industries in Washington

	2008 Employment
Transportation equipment manufacturing	94,973
Agriculture	63,445
Food and beverage manufacturing	38,240
Computer and electronic product manufacturing	22,366
Life sciences	***22,349***
Fabricated Metal Product Manufacturing	19,867
Wood products manufacturing	16,708
Mineral and primary metal manufacturing	15,951
Chemical and plastics manufacturing	15,626
Machinery Manufacturing	15,198
Paper products manufacturing	10,418

Source: Washington State Department of Employment Security

Figure 8 summarizes employment in the life sciences in Washington, based on data from ESD and estimates from other sources. A base of over 22,000 jobs makes the life sciences industry an important part of the state's economy. Figure 9 shows 2008 employment for the life sciences in Washington along with employment in other major industries that contribute importantly to the economic base of the state. Life sciences has surpassed basic industries such as wood products and paper products, replacing employment as those industries have matured.

ESTIMATING THE ECONOMIC IMPACT OF THE LIFE SCIENCES IN WASHINGTON

With reasonable estimates of life sciences employment in the state we can estimate the additional jobs that are produced in the economy as a result of spending by life sciences institutions and firms, and the spending of households. We use a model constructed for the Research Council by Regional Economic Models Inc. (the WRC-REMI model) to derive the multipliers for the various sectors. The REMI model provides multipliers for each of the NAICS codes except the new biotechnology code. We have only one multiplier to use for all of the R&D in the sciences.

Figure 10-a shows the results of applying the multipliers to the employment estimates. We can estimate that the direct employment in the life sciences results in nearly 55,000 additional jobs throughout the state, for a total economic impact of 77,000 jobs. It is worth noting that the 2002 study of the state's biotechnology and medical device industries arrived at a combined multiplier of 3.23, which is very close to the average multiplier of 3.44 derived by dividing the total employment impact by the total direct jobs identified in this study. Figure 10-b shows the impact of these jobs on the state's GDP and personal income.

THE LIFE SCIENCES INDUSTRY AROUND THE STATE

The life sciences industry tends to respond to clustering effects, with the largest concentrations of firms and institutions near the University of Washington. Activity is, however, spread around many other areas of the state. Figure 11, based on employment data from the Puget Sound

Figure 10-a
2008 Economic impact of the life sciences in Washington: Employment

Sector of the life sciences industry	Direct Employment	Multiplier*	Indirect/induced employment	Total employment impact
Pharmaceutical and medicine manufacturing	2,490	5.41	10,981	13,471
Electromedical and electrotherapeutic apparatus manufacturing	3,619	4.06	11,073	14,692
Analytical laboratory instrument manufacturing	508	5.00	2,032	2,540
Surgical and medical instrument manufacturing	454	3.14	971	1,425
Surgical appliance and supplies manufacturing	1,387	2.63	2,261	3,649
Dental Equipment and Supplies Manufacturing	117	2.62	190	307
Ophthalmic Goods Manufacturing	355	2.13	401	756
Research and development in life sciences (including biotechnology)	8,039	3.08	16,721	24,760
Estimate of university faculty and staff working in life sciences	4,850	3.08	10,088	14,938
Estimate of hospital staff in research activities	530	3.08	1,102	1,632
Total	22,349	3.44	54,570	76,919

*Multipliers derived from WRC/REMI model; totals less than sums of industry effects due to adjustment for intraindustry impacts

Sources: Washington State Department of Employment Security, National Science Foundation

Figure 10-b
2008 Economic impact of the life sciences in Washington: GDP and personal income

Sector of the life sciences industry	Direct Employment	GDP (2000$, millions)	Personal Income (Current$, millions)
Pharmaceutical and medicine manufacturing	2,490	$1,105	$991
Electromedical and electrotherapeutic apparatus manufacturing	3,619	$1,283	$892
Analytical laboratory instrument manufacturing	508	$199	$135
Surgical and medical instrument manufacturing	454	$118	$83
Surgical appliance and supplies manufacturing	1,387	$301	$179
Dental Equipment and Supplies Manufacturing	117	$24	$14
Ophthalmic Goods Manufacturing	355	$55	$337
Research and development in life sciences (including biotechnology)	8,039	$1,629	$1,683
Estimate of university faculty and staff working in life sciences	4,850	$983	$1,015
Estimate of hospital staff in research activities	530	$107	$111
Total	22,349	$5,712	$5,353

Impacts derived from WRC/REMI model; totals less than sums of industry effects due to adjustment for intraindustry impacts

Regional Council and ESD, shows the distribution of employment in the readily identifiable segments of the life sciences industry in the Puget Sound region and elsewhere in the state. (Data suppression—not providing data that could lead to disclosure of proprietary information about firms – makes it difficult to calculate employment distribution at a finer grain than this.)

Figure 11
Life sciences employment in Washington

	Biotech R&D + Biopharma Manufacturing	Medical Device Manufacturing
Total Employment	4,951	5,293
Seattle	46.5%	6.8%
I-90 & I-405 corridors	18.4%	66.8%
Balance of Puget Sound region	11.9%	6.4%
Balance of state	23.2%	20.0%

Source: Puget Sound Regional Council, ESD

Figure 12 shows the distribution of life sciences businesses and institutions in cities around the state. Figure 13 shows the distribution of grants from the NIH around the state. Both figures indicate that, while most firms want to be near the major research institutions and laboratories, researchers can locate themselves well outside these centers.

Economic drivers of the life sciences industry

Washington has among the strongest life sciences industries in the nation, relative to its size. According to a 2008 study by Battelle, on a per capita basis, Washington ranks sixth among the states in research funding from the National Institutes of Health, eighth in biosciences employment, sixth in the awarding of biosciences degrees and seventh in placement of biosciences venture capital. The states that consistently ranked higher than Washington in these per capita measures were Massachusetts, Maryland and Connecticut.

But how can we ensure that the state remains strong in the life sciences? The Battelle study lists a number of key "success factors of biosciences industry growth." Among them are:

Engaged research institutions with active leadership. The report states that "without major research stature, reputation and standing within given fields, no region can succeed with a biosciences-driven strategy for its economic growth." Washington certainly has excellent research institutions, with its two major research universities and non-profit institutes.

Available risk capital covering all stages of the business cycle. Washington consistently ranks among the top states in the placement of venture capital funding. In addition to the Battelle ranking of seventh in the placement of biosciences venture capital, the Milken institute ranks Washington third in overall per capita venture capital placement. A persistent concern in the state, however, has been the reliance on venture funds from out of state: of the 60 venture capital firms that completed at least five financing deals in the second quarter of 2009, only two were from Washington. Another concern has been the challenge of finding "angel" capital for very early stages of firms.

Workforce and talent pool. The pool of talent that feeds the life sciences industry requires specialized training that is not widely available. Washington's universities graduate individuals in these fields, but not

Figure 12
Numbers of firms and non-profit organizations by city, 2009

	Biotech/ pharma	Medical Device	Non-Profit Research
Arlington		3	
Auburn	1	4	
Bainbridge Island	2		
Battle Ground	1		
Bellevue	8	13	1
Bellingham	3	4	
Black Diamond		2	
Boistfort		1	
Bothell	20	15	
Burien		1	
Burlington		1	
Camas		1	
Carnation		1	
Centralia		1	
Chehalis		1	
Eastsound		1	
Edmonds			1
Enumclaw		1	
Everett	2	9	
Federal Way	1		
Ferndale		2	
Gig Harbor		2	
Glacier		1	
Goldenadle		1	
Issaquah		2	
Kenmore	1		
Kennewick	1	2	
Kent	1	8	1
Kirkland	3	3	
Lacey	2	1	
Lakewood	1		
Leland		1	
Liberty Lake		1	
Longview		1	
Lynnwood	1	3	
Marysville		1	

	Biotech/ pharma	Medical Device	Non-Profit Research
Mercer Island		1	
Mount Vernon		1	
Mountlake Terrace		2	
Mukilteo	1	3	
North Bend	1		
Port Gamble		1	
Port Ludlow		1	
Port Orchard		1	
Poulsbo		6	
Pullman	4	1	
Puyallup		2	
Redmond	17	18	
Renton		2	1
Richland	1	3	1
Sammamish	2		
Seattle	87	37	18
Sedro Woolley		1	
Sequim		1	1
Shoreline	1		
Silverdale		2	
Snoqualmie	1	1	
Spokane	5	7	4
Spokane Valley		3	
Stanwood	1		
Sumas		2	
Sumner		1	
Tacoma	1	2	
Tukwila		1	
University Place		1	
Valleyford	1		
Vancouver	2	7	
Vashon	1	1	
Washougal		1	
Wenatchee		1	
Woodinville	1	5	
Yakima		1	
Total	175	205	28

Sources: biotech/pharma and nonprofit research, Lifesciences.com; medical device, Canon Communications

Figure 13
NIH grants in Washington by city

	2007	2008
Seattle	778,580,373	710,548,701
Bellevue	2,048,599	1,764,612
Bothell	2,222,036	1,719,983
Kirkland	822,374	937,751
Redmond	968,104	99,431
Auburn	1,569,056	657,348
Bainbridge Island	3,908,215	3,853,482
Burien	39,150	-
Edmonds	-	100,000
Gig Harbor	756,989	739,555
Kenmore	558,673	628,910
Lakewood	1,171,119	1,170,346
Maple Valley	299,916	268,590
Mountlake Terrace	198,167	803,348
Newcastle	50,932	60,249
Shoreline	100,000	-
Stanwood	100,000	6,000
Tacoma	1,068,994	1,081,975
Vashon	-	520,467
Bellingham	779,906	354,989
Ellensburg	65,459	70,909
Friday Harbor	871,788	-
Granger	-	32,400
Olympia	99,928	939,960
Pullman	18,557,867	16,878,535
Richland	12,237,855	16,777,365
Sequim	500,000	500,000
Spokane	329,871	517,631
Vancouver	1,271,897	368,510
Woodinville	105,213	-
Total	829,282,481	761,401,047

Source: National Institutes of Health

nearly enough to meet the needs of the state's life sciences industry. A glance through the backgrounds of the leading scientists in the state's research institutions and biotech firms indicates that we import the majority of the talent working in the life sciences in the state.

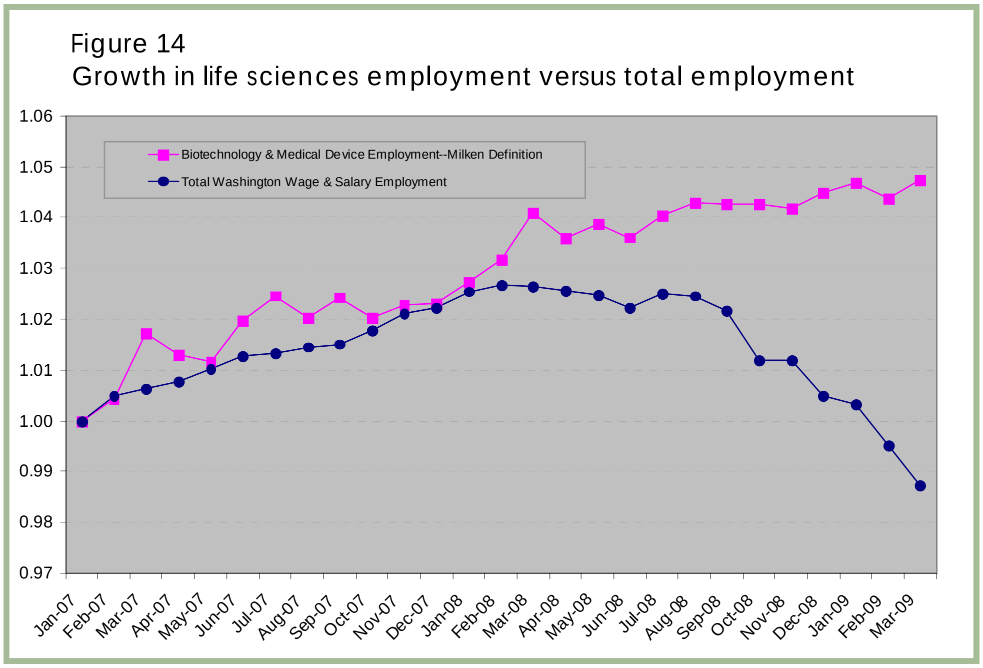
There is perhaps no more important factor for the future of Washington's life sciences industry that our ability to attract and retain top scientific and technical talent from around the world. While Washington is an attractive place to live, we do need to be mindful that we are competing with states such as Massachusetts, California and New Jersey that offer outstanding career prospects for talented scientists and engineers. While impressive, Washington's life sciences industry does not yet offer as many career paths for scientists such that they will move to the state confident that if their current employment ends they will be able to find new employment easily.

Stable and supportive business, tax and regulatory policies. In the past decade Washington has made some progress in becoming friendly to technology businesses, but barriers do remain. The state's tax breaks for R&D equipment are favorable for start-up businesses building or expanding laboratory space and a sales and use tax deferral for life sciences manufacturing. The state also offers a B&O tax credit for a portion R&D expenses for firms that for the most part are still in the unprofitable start-up phase. However, employment taxes in the state are among the highest in the country, which can be a burden for labor-intensive research. Life sciences businesses may be concerned about the stability of the state's tax regime, given the regular calls to eliminate tax preferences such as the B&O tax credit.

Patience and a long term perspective. The Battelle report notes that such well-known life sciences centers as Route 128 in Massachusetts and North Carolina's Research Triangle took decades to develop. Similarly, Washington's life sciences industry has built slowly over decades. The University of Washington built its research and medical capacity over many years. The Fred Hutchinson Cancer Research Center has been steadily growing since the 1970s. The Seattle Biomedical Research Institute began as a three-person laboratory in Issaquah in the 1970s and now employs hundreds of people in its Seattle and Tanzania laboratories.

In some ways, the necessity of this report, documenting the life sciences industry, is a testament to its almost unnoticed growth. While individual institutions have executed growth strategies, and county-level economic development organizations have promoted the life sciences, the industry has grown largely without any high profile, long term strategic actions on the part of government.

Although not mentioned specifically in the Battelle report, another critical factor in the growth of the life sciences industry is the presence of support services. Of particular interest is the legal and accounting services required for investors and for intellectual property protection. The steady growth of a range of technology-based businesses has been accompanied by strong growth in the state's related services sector.



Recent Performance

Figure 14, which is based on a relatively conservative measurement of life sciences employment in the state (the estimating method used by the Milken Institute, as discussed above, which excludes non-biotech life sciences R&D, universities and hospital R&D), shows that in the past two years, while general employment in the state has fallen, employment in the life sciences has expanded. Since this chart shows just employment in private for-profit businesses, many of which are in the research phase, this trend indicates the optimism with which the financial community views the life sciences. Investors are willing to stick with their bets on the future of the life sciences.

Conclusion

The life sciences industry has grown to be an important part of Washington's economy. In employment it has passed many of the traditional resource based industries on which the state's economy was founded, and is in the same range of importance as some of the new, technology-based industries of the state. It is, however, difficult to recognize the importance of the life sciences industry because it is comprised of a diffuse array of organizations and firms, its "product" consists of everything from scientific papers to surgical instruments, and its "revenue" comes from all manner of public and private sources. Describing the life sciences industry is not as easy as describing the production and sale of lumber.

The growth of the life sciences industry is good news for the state. Demand for the products and services generated by the industry will continue to grow rapidly, in three principal areas: domestic healthcare, global health and sustainable biofuels. The state's life sciences industry has a good position in the first of these, is the national leader in the second, and has promise in the third.

The economic potential of the life sciences has, of course, not gone unnoticed in the rest of the country and the world. The competition for talent and investment capital is intense, and in spite of its excellent assets, Washington is still not among the top regions for the life sciences, but perhaps near the top of the second tier. Massachusetts, with its complex of leading universities, the San Francisco Bay area, with its universities and huge technology industry base, and New Jersey, with its large pharmaceutical industry, all have larger life sciences industries than Washington.

Washington has developed its niches in the areas of research and development and global health, and will not likely be a major area for manufacturing of pharmaceutical products. These are, however, very valuable and lucrative niches which depend primarily on one input: talent. Washington may not have the largest life sciences industry in the nation, but it still competes at the highest level to attract and retain the best scientific and technical minds in the world. The future of Washington's life sciences industry will continue to be tied to the quality of talent in the state.

There are many complex factors that determine success in the life sciences industry, but none more important than ensuring that the state's universities, research institutions and businesses have the highly skilled people they need working in an environment that encourages innovation.

APPENDIX: ABOUT THE WRC-REMI MODEL

The Washington Research Council uses a model of the Washington State economy constructed especially for WRC by Regional Economic Models, Inc. Because it allows supply and demand to respond to changes in prices and wages, and permits substitution among factors of production, the WRC-REMI model is more elaborate than the standard input-output models commonly employed to estimate regional economic impacts (Treyz 1993).

The core of the standard input-output model is a catalog of interindustry purchases for the region in a base year, arrayed in an input/output matrix. The model assumes that as a specific industry's production increases or decreases, its purchases from the region's other industries will change proportionately. Likewise, the industry's employment will change by the same proportion that its output changes.

Based on these assumptions, the model traces the cascading effects as one industry's increase in output stimulates an increase in the output of other industries (and its own). These effects are distilled in multipliers that measure how a change in the demand for the output of one industry will affect the total output of the local economy, or how a change in the employment of one industry will affect the total output of the local economy (Chase, Bork, and Conway 1993).

But the standard input-output model is incomplete. It fails to model the numerous capacity constraints within the economy, the processes that set prices for goods and services and the responses of consumers and producers to changes in these prices. In the input-output model, industry and labor supply are perfectly elastic—so prices and wage rates do not matter.

Prices and wages do matter in the WRC-REMI model. The model divides the state into two subregions: the four central Puget Sound counties (King, Kitsap, Pierce, and Snohomish) and the balance of the state. There are 53 industrial sectors within each subregion. Within each subregion the model tracks interindustry transactions, much as an input output model would.

Unlike an input-output model, however, the WRC-REMI model incorporates a number of significant behavioral responses to changes in prices and costs: The wage rate depends on the supply and demand for labor, migration and labor force participation rates respond to changes in wage rates, and consumer purchases of specific goods and services respond to changes in relative prices and personal income. In addition, producers substitute among production factors in response to changes in relative factor costs, market shares respond to changes in regional production costs, and investment rises in response to increases in output.

This report uses version PI^{+} 1.0.114 of the WRC-REMI model.

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