BASIC

BAY AREA SCIENCE AND INNOVATION CONSORTIUM

21st Century Workforce Preparedness In the Life Sciences

Summary of Findings

By the

Bay Area Science and Innovation Consortium (BASIC)

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21st Century Workforce Preparedness in the Life Sciences

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BASIC is the Bay Area Science and Innovation Consortium, a program of the Bay Area Council Economic Institute. It is an action-oriented collaboration of the region's major research universities, national laboratories, independent research institutions, and research-and-development–driven businesses and organizations.

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Executive Summary

21st Century Workforce Preparedness in the Life Sciences
BASIC Findings

A range of trends portends challenges in workforce quality in the life sciences over the next decade and beyond, potentially leading to reduced global competitiveness. BASIC investigated these challenges under Project 1.2 of the much broader US Department of Labor WIRED initiative for the California Innovation Corridor. BASIC undertook background study, interviewed 27 employers and doctoral scientists, solicited input from other stakeholders, organized a roundtable, and evaluated findings.

The project uncovered that the industry's structure, company lifecycle, and technology evolution are greatly changing the desired skill and training profiles of managers and technical-level employees in the life sciences over the next 10 years. At the same time, BASIC has identified potential shortfalls in California's ability to deliver enough people who possess these skills.

National findings. A review of national data uncovered findings that were born out or clarified in our interview and roundtable process. Issues included disagreement about the extent and nature of shortages of trained scientists, challenging trends in traditional university training, more career support needed for graduates, need for a professional advanced degree, and hiring cycle challenges unique to life sciences.

Industry perspectives. Interviews of 17 senior executives in the industry addressed a range of concerns:

- <u>Executives see a dramatically evolving industry.</u> The industry is maturing, with several workforce implications. Work is moving beyond healthcare to other sectors such as energy, food, environment, and homeland security. Tighter profit margins and access to capital are creating significant pressures, and the industry is moving toward virtual integration, involving smaller companies. Biotech will increase hiring in non-science positions, but turbulence is expected. Technology convergence and business trends are shifting needs away from traditional lab skills.

- <u>Industry trends affect hiring and training.</u> Executives detailed specific talent shortages at a range of levels from technician to manager, though there is no system for projecting bio industry needs as done in other domains, such as engineering. Solid science background is still essential, but broader and deeper business and information technology skills are required for success, as well as an entirely new level of interdisciplinary scientific knowledge and skills. Research universities have done a good job with producing top-level scientists and innovation, though challenges remain, particularly at lower academic levels. In addition, advanced scientists pursuing academia over industry careers affects private sector attrition, turnover and quality. At the same time, employee turnover and company size make in-house training difficult or impossible. Due to a variety of challenges in filling anticipated talent shortages, California companies plan to import talent or relocate / expand elsewhere. In this context, executives noted issues with relocation and offshoring, and called for a change in US green card policy to help foreign-born scientists remain in the US following university training. Finally, executives called upon state government to do more to combat competition to steal biotech companies from California.

- <u>Executives advocate changes at all levels of the educational system.</u> A top concern was demand to fix a K-12 educational system that has too many drop-outs and too little ability to drive excitement around science. This was seen partly due to popular ignorance of the importance and excitement of science, technology, engineering and math (STEM). There was also demand for postsecondary education to adapt more rapidly to changing workforce needs, to provide more information technology and computational training, and to accelerate advanced scientific and business training. Workforce development needs to inform and be informed by macro trends. Issues in supply of bench scientists and professional training were also explored.

Industry trends map to manager and technician profiles. A series of requirements and acute needs were detailed at both the manager and technician levels. See the full report for details.

Recent PhD Perspectives. Ten interviews were conducted specifically to improve understanding of potential issues in supply and attrition among doctoral level scientists. The results were sufficiently consistent with executive and national data to be directionally valuable. The strongest factor influencing a career in this industry was a good experience in high school or undergraduate study. Although postgraduate students were reasonably satisfied with their academic experience, there was great frustration with the average eight years to complete a PhD; 80% articulated desire to abandon the field, and 30% specifically plan to abandon it. Nine out of ten lacked a clear career plan. Integration of business and information technology was limited. Only half felt that their training gave them the best chance to meet their immediate goals, and university career guidance was weak. There is a glut of PhDs pursuing academic careers, and a general problem is that postgraduate students expect to go into academia instead of industry. Several suggestions were provided to improve quality of the university experience with regard to workforce preparation.

National Lab Perspectives. Federal research laboratories are also employers in this industry. BASIC invited Northern California labs to the May 15 roundtable and invited input by email. The input received shared commonalities with the executive perspectives: the region's universities provide lots of programs; however, there is need for greater interdisciplinary focus and that bio scientists seem less able to cut across disciplines than scientists from other disciplines. Improving team skills is a second top priority.

University Perspectives. The roundtable included participation from four University of California campuses (Berkeley, Davis, San Francisco, and Santa Cruz) and one major private university (Stanford). Their input underscored the academic and research richness available to drive innovation and competitiveness in the life sciences workforce. There was discussion around several issues:

- Pressure from global competition and training models
- Lack of systematic planning for meeting employer needs
- Potential for greater collaboration on talent development
- The proper role of universities in providing specialized training
- The importance of undergraduate talent and workforce development

Cross-cutting Roundtable Discussion. The May 15 roundtable afforded the opportunity for discussion among the gathered stakeholders about the various issues and opportunities raised by this investigation. Several points of consensus and debate emerged, centering on specific opportunities and challenges for delivering stronger, more focused and better planned development of workers and leaders in the life sciences.

Roundtable Recommended Action Items. The roundtable produced a list of potential cross-cutting action items in four broad areas that may be relevant to any US geography seeking workforce improvements in the life sciences. These recommendations include actions to (1) better understand pain points; (2) address acute areas of need; (3) address longer-term needs; and (4) address fundamental interest in and support for science and science teaching.

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21st Century Workforce Preparedness in the Life Sciences
BASIC Findings

Introduction

California enjoys global leadership in most aspects of the life sciences for a variety of reasons. A key ingredient of this leadership is the excellence of the workforce and the ways in which specific assets—from quality of life factors to institutional assets such as research universities and national labs—continue to foster, attract and retain skilled people.

However, a range of trends could portend challenges in workforce quality in the life sciences over the next decade and beyond. In the worst case, if these challenges go unaddressed, Northern California—and the state as a whole—could see a reduction in the global competitiveness of the industry.

BASIC was contracted to examine these issues as part of a much broader US Department of Labor WIRED initiative within the California Innovation Corridor, which is managed by the California Space Authority. BASIC's contract under WIRED Project 1.2 was to investigate workforce profiles necessary for global competitiveness for the 21st Century. Under this scope of work, BASIC chose to focus on the life sciences industry, and we designed a project to investigate the concerns and potential recommendations of employers, graduate students, and universities.

We gained the perspectives of executives and doctoral students through 27 personal interviews. The results of these interviews were analyzed, summarized, and used to organize a broader discussion of the employer and higher education community in the life sciences through an executive roundtable format.

Biology, Biotechnology, Biosciences, or Life Sciences?

A range of names is given to the industry and to scientific activities related to work with living organisms specifically for the improvement of human health and other applications, such as agriculture or energy.

Biology is the name for the overarching academic discipline. With the growth of commercial developments in the field, particularly resulting from genetic research, ***biotechnology*** or ***biotech*** came to be used more widely as a name for this emerging industry. The term ***biosciences*** is also used, often implying a broader scope than biotech.

More recently, the growth of commercial activities beyond healthcare and agriculture into energy, the environment, and homeland security—together with greater use of chemistry, physics, information technology, and other fields—has brought an even broader term into vogue: ***life sciences***.

For this report, we generally use the term *life sciences*, though in some places for variety or to reflect specific words used by respondents, we will use other terms.

BASIC held this executive roundtable on May 15, 2008, at the California Institute for Quantitative Biosciences in San Francisco (also known as QB3, or the Center for Quantitative Biology, Biochemistry and Bioengineering). The roundtable participants included representatives from industry (most of whom had been interviewed prior to the roundtable), universities, a federal laboratory, a workforce development consultant, and observers from the California Space Authority WIRED project and other WIRED partners.

To establish balance, identify broader trends, and inform our investigation, we reviewed and summarized national commentary on the subject.

The project uncovered that specific trends in the structure of the industry, the lifecycle of companies, and the evolution of technology are greatly changing the desired skill and training profiles of managers and technical-level employees in the life sciences over the next 10 years. At the same time, BASIC has identified potential shortfalls in California's ability to deliver enough people who possess these skills.

Findings from National Data

While undertaking executive interviews and developing the interview process for doctoral students, we reviewed national-level information on the subject to establish baseline issues and concerns. The following findings are drawn from a search of relevant news media coverage, opinion pieces, and Congressional testimony published in 2006 and 2007.

There is disagreement about the extent and nature of shortages of trained scientists. Government continues to contend there is a current and projected shortage of trained scientists, but independent research shows that this may not be true across the board.[1] Evidence suggests that there is actually an oversupply of PhDs trying to get into academia. We did not study trends with BS-level graduates, so the situation nationally within industry is less clear-cut, where there may be (1) an oversupply of PhDs versus lower level scientists, (2) a cycle of oversupply now with potentially insufficient graduates in the future, and/or (3) too many PhD graduates who choose not to pursue careers in industry or non-university research. In addition, some point out that more-qualified foreign students dominate the applications for graduate slots, and a great percentage these students may be forced to leave the US after their studies. Attrition is also a problem: many doctoral graduates and mid-career engineers have left science.[2]

There are challenging trends in traditional university training for advanced scientists. The comparatively greater length of time and cost of university training in the US for doctoral level study may unfavorably influence the number and quality of students.[3] The growing length of time to complete

[1] In the US, there were a record 28,000 PhDs in science and engineering in 2005, and the number of doctorate scientists in biomedical departments increased from 4000 in the 1980s to more than 7000 in 2004. In addition, the number of temporary positions for younger scientists doubled between the mid-1980s and 2004. Properly comprehensive and trend data would be needed to make any policy statements about these numbers.

[2] We have not compiled quantitative data on this point, but the contention has been advanced by Paul J. Kostek, Institute of Electrical and Electronics Engineers and supported by our limited interviews with doctoral students.

[3] Obtaining a PhD in science is taking longer than in the past and longer than in other countries. In England, chemistry students obtain doctorates in 3.5 years, while 7 is required in the US. In the biosciences, the average period of post baccalaureate study has increased from 7-8 years to 9-12 years. The time to earn a PhD has increased to 7-8 years from 6 years, and the time for postdoctoral apprenticeship has grown to 2-5 years from 1-2 years.

doctoral degrees may be driven by disincentives within universities to graduate people swiftly, [4] as well as lack of grants.[5] These problems may not extend to undergraduate degrees, but currently there is a dearth of programs between the Bachelor of Science and the PhD, forcing those individuals wishing to pursue advanced science into PhD tracks.

Graduates need more career support. Graduate students and post-docs need to increase their career-oriented experience, and universities need to provide career support.[6] Some observers assert that the training program in many universities is too narrow. PhD candidates need exposure and experience in a broader set of activities to prepare for industry or government-industry careers, including entrepreneurship, business/finance, and marketing. Students need more accurate information about career options and employers, they need mentoring and professional development, and they need career placement assistance for initial and subsequent jobs.[7]

It may be useful to promote a professional "Masters of Science" degree. A professional degree track, with a broader set of activities, shorter duration of study, and opportunities for practical internship experience, may be a preferred alternative to an academic track, but there are three major reasons this is a contested idea. First, universities have a cultural and business aversion to professional degrees. Second, doctoral programs have a higher status and revenue per student. Third, there are challenges with making a professional degree responsive and appropriately scoped to meet industry needs.

The educational and workforce development community needs to respond to hiring cycle challenges in the life sciences. As an immature industry with a very long lab-to-market cycle, careers in the biosciences are particularly impacted by cyclical effects in hiring. Students need to be graduated and placed more swiftly to reduce the problem of doctoral supply being out of phase with hiring demand. Further consideration needs to be given to career placement of individuals who are entering the job market during a hiring downswing.

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[4] Reductions in research funding have driven a need for tuition increases and for student labor. This may in turn create a conflict of interest for PI / doctoral advisors in moving a student to completion swiftly.

[5] Despite doubling of the National Institutes of Health (NIH) budget since 1998, the percentage of grants to scientists aged 40 and younger has decreased from 25% in 1995 to 15% in 2005. The lack of grants for younger scientists presumably has a negative effect on development and retention of new scientists, and there is increasing demand by institutions for tenure candidates to show a track record of attaining grants.

[6] To understand actual trends, it would be useful to obtain outcomes data for career placements and advancement from universities, major employers, research institutions, professional societies and other resources.

[7] Further, small and highly specialized academic departments / programs (e.g., bioinformatics) face unique challenges for career development due to their lack of scale.

Executive Perspectives

Combined Results of Personal Interviews and Roundtable

To understand industry trends and workforce issues, BASIC contracted with the BayBio Institute to interview senior individuals in the life sciences industry. Seventeen interviews were completed, which were summarized. The summary of findings was distributed to participants in the May 15 executive roundtable, and discussed. The combined data resulted in the following findings.

Executives See a Dramatically Evolving Industry

The life sciences industry is maturing similar to the region's semiconductor industry. Like the semiconductor industry of 25-30 years ago, the young life sciences industry is maturing, with a variety of implications. R&D and business development are likely to remain in the Bay Area, while manufacturing and production will likely move out (although certain factors could retain domestic production to some degree).[8] Further trends are detailed below.

Industry growth drivers extend far beyond therapeutics, but medical applications still drive the core debate and hiring. The industry is still concentrated primarily on medical therapies, and most of the respondents spoke entirely about healthcare applications. US healthcare demand (particularly with the aging population), and a more holistic approach to medicine, will drive the future of life sciences. However, increasingly the industry will go beyond biotherapeutics. The top US and global economic concerns can be addressed with life sciences solutions, from dealing with energy (biofuels) and food to industrial biotech, waste management, water quality, homeland security, and even clothing. Growth potential is strong, but skills shortages will have the potential for impact across the economy.

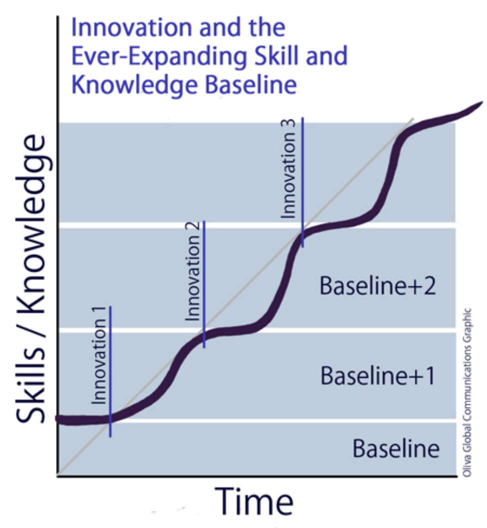
The biotherapeutics industry is being driven toward smaller profit margins. In the biotherapeutics field, a combination of the aging population, healthcare reform, personalization of healthcare and innovations in technology/diagnostics are driving industry toward increasing specialization and niche drugs (with fewer blockbuster drugs and greater caution about development choices). The growth of generics, the trial and approval process, development costs, declining approval rates, problems with blockbusters such as Vioxx, government pressure to reduce costs, and even the rise of India and China, have had dramatic effects. They have, for instance, affected the ROI model, reduced the importance of blockbusters, and generated uncertainty for growth plans. As margins resultantly become smaller and profits tighten, the industry will need to deploy modern business and operational practices and the workforce to utilize them.

[8] A significant issue in moving production of the large molecules involved in biotech manufacturing (as opposed to the smaller chemical compounds in traditional pharmaceuticals) is that various environmental conditions such as air pressure and humidity can make it difficult to replicate manufacturing in an alternative location, even if that location is lower cost.

Industry lifecycle trends are driving growth of smaller and more virtually integrated companies. In general, biotherapeutic efforts are moving from research-dominated work to a “product era” emphasizing commercialization and launch. As the industry matures and strives to balance research and commercialization activities, it is moving away from vertical integration and toward the "virtually integrated" pharmaceutical company model (VIPCO), with major functions contracted to partners such as contract research organizations (CRO) and non-research/development-only (NRDO) companies. This will continue to drive growth in the number of small companies.[9]

Biotech will increase hiring in non-science positions, but turbulence is expected. As biotech's focus shifts to product commercialization, it will evolve into a more general employer in the next decade, meaning hiring growth in non-scientist job categories (e.g., marketing, accounting, finance, regulatory affairs) and possibly a relative reduction in research. All the factors of uncertainty noted above presage uncertainty and turbulence in employment.

Technology convergence and business trends are shifting workforce needs. To look at workforce needs, it is possible to make projections based on the confluence of industry, academia and government. The need for particular skills will be driven by the convergence of biology, chemistry, physics, engineering, and information technologies.[10] Manual technical processes in the lab, such as gene sequencing and using pipettes, will be increasingly automated. New diagnostic technologies will require strong technical and computational skills to manage the equipment and the resulting mountains of data. The accumulation of genetic information and a rapidly growing ability to utilize this information will drive demand for geneticists, medical genetic counselors and genetic laboratories. One executive emphasized a *biology-plus* dynamic, in which each subsequent innovation adds a new skill and knowledge set to the required baseline for workers in the industry (*see accompanying graphic*). The size of the employment *base* will not grow dramatically, but *hiring* will grow due to demographic trends,[11] and as innovations take place, new hires will need the broader "biology-plus" set of skills and knowledge.



[9] As noted by the BayBio Institute, the transformation is shown in the numbers. Thirty years ago, there were 60 big pharma companies across the country, and maybe 100 small ones. Now, there are around 15 big companies and 1500 small companies.

[10] This will be accelerated in part by government support for "Bench-to-Bedside" research designed to speed translation of promising laboratory discoveries into new medical treatments (also referred to as Transitional Science or Transitional Medicine).

[11] This is a 30-year-old industry, with many original people who will be retiring. In addition, demographics and turnover (now hitting 18%-20% in some companies) will drive hiring demand and inflation of wages, benefits, and job titles.

Access to capital is an issue. Access to capital is an issue, particularly with growth of middle-stage companies with broad product pipelines. Wall Street is short-sighted, and this is a long-term industry.

Industry Trends Affect Hiring and Training

There is no system for projecting bio industry needs as other industries do. During the roundtable there was discussion by both executives and universities about the lack of any system for projecting hiring needs and incorporating that information into academic programming and placement. Such a system is addressed in other domains, such as in medicine. The group acknowledged the challenges in so doing; for instance, the bio industry finds it difficult to anticipate needs greater than three years in advance, and data on hiring needs can be skewed due to greater response from larger companies.[12] Even when data is collected, actions taken on the data are relatively ad hoc and not based on a strategic plan.[13] However some felt that even with the challenges posed by industry turbulence and the concentration of small companies, it should be possible to look at more overarching trends that would be indicative of future hiring needs: healthcare trends, government funding, regulatory trends, etc. It was commented there would be potential multiple benefits of an organization helping to assess needs, including even helping individual companies undertake a self-assessment process.

Science is still essential. General science acumen is essential across the board, particularly for CEOs and business leaders to understand the science at a fairly deep level and what drives it. Everyone—not just scientists—needs a thorough grounding in math and science, the principles of documentation, the principles of research, and an understanding of scientific inquiry and the scientific process. Managers don't necessarily need to be post-doc PhDs, but they do need to know what is driving the science, what is driving the scientists, where the science behind the business is leading it, and what constitutes good science and a good science investment.

Business skills are required. The business of science and managing science toward commercial products is a unique and essential skill set. The *bench-to-market* concept requires people with hybrid skills, so-called "systems-ready" people. As companies in this industry become more and more virtually integrated, the person or team developing a compound is more likely to be responsible for a wide variety of business aspects of the lifecycle of that compound—how it will be researched, product trials and movement through the approval process, manufacturing, licensing, partnering, and marketing. On the operational side, companies must deal with the maturation of the industry and cost drivers requiring operational excellence and efficiencies. Externally, the industry will need to deal with increasingly savvy

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[12] Examples were mentioned during the roundtable regarding state research and responses on needs from 1995 onward, including work by the California Employment Training Panel, as well as NOVA and the City of San Jose.

[13] Matt Gardner provided the example of a manufacturing technician program that only produces 20 graduates per cohort and could produce ten times that much to meet industry needs. Gardner cited data from 2006-2007 that suggests industry need could expand faster than the ability to generate talent. Even this assertion was contested, though, by another participant familiar with that specific training program who found that demand for placements was declining.

consumers, train service providers and nurses, improve communication with older people, and develop more clinical scientists, technicians, and genetic counselors. Further, there needs to be greater interaction between PhDs and MDs to deliver on the opportunities of bench-to-bedside research.

Employee turnover and company size make in-house training difficult or impossible. Industry structure and trends increase employee mobility,[14] reduce company size, and squeeze ROI, so employee development programs don't make sense, particularly for smaller companies. In addition, the workforce is now incredibly diverse. Small companies don't have the resources to build talent, so they must hire it in. However, they have difficulty finding talent, both due to marketplace cycles and the fact that innovative companies are not looking for what's hot today but what will be hot tomorrow (while schools and students typically focus on what's hot today or even a few years ago). Competition with large companies for talent is also a key issue; it's very challenging for small companies to compete with the big companies for both technical and professional talent, and it is difficult to match benefits. In the context of thin margins and rapid change, employers need employees to be instantaneously productive. Further, there are naturally differences between large and small companies. The former tend to focus on resume-driven credentials, work history, and specific skills; the latter emphasize creativity, generating new ideas, and risk acceptance.

Research universities have done a good job, though challenges remain, particularly at lower academic levels. The roundtable stimulated some further points and counterpoints on the role of research universities. Executives acknowledged that the higher educational system has built top quality educational infrastructure, but they still saw challenges to meet the needs of industry. On one hand, industry sees strong performance from top universities. Executives report consistently high idea approvals for university research, and good production of top performers at the highest levels. However, executives were concerned about the lower production of graduates in the industry at lower academic levels. Roundtable participants felt industry demand was likely to require involvement of community colleges in addition to action at higher academic levels.

An imbalance between advanced scientists pursuing academia and industry careers affects attrition, turnover and quality. The production of science grads has increased around the world, but opinions on the net rise in availability of trained people depend on whom you ask. For a variety of reasons, most students pursuing advanced degrees seem to assume they will work in academia; however, there are only positions available for about 30% of the grads to do so. Ultimately, then, 40% go into some form of related industry position or abandon the field—perhaps going into a biotech firm, law, consulting, industry analysis firm, venture capital or into another position in the private sector. About 25%-

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[14] The average turnover is estimated at 5-6 years, during which time the company is likely to change twice due to acquisitions, management changes, or developments in the product pipeline.

30% stay in some non-university position dedicated to raw research—such as at the National Institutes of Health (NIH) or other non-corporate lab. There is also a growing desire among students for faster hiring and career advancement, which tends to cause abandonment of advanced programs and depress supply of talent at the higher levels. Low output of qualified people for industry results in higher turnover, cannibalization into stretch positions, stealing employees from other companies, and less experienced people in more senior positions.

Education and training need to focus on interdisciplinary knowledge and skills. All levels need interdisciplinary skills encompassing science, business (including collaborative teamwork and communication), IT, engineering, and computational skills. All workers need the ability to improvise and deal with an evolving environment. These skills are not as strong as they should be. For those pursuing advanced training, some respondents would advocate a program of 35-38 units of bench science, business, and management along the lines of the Keck model. A research management track would require the addition of project management and leadership/people skills. Becoming a content area expert would require the development of a deep understanding of some particular area of science. The business side would require a broader sweep of business classes. For all advanced training, some felt it would be good to include some component of rigorous research of a doctoral program to build skills related to independent research. Other specific skills named: understanding of partnering, applied computational skills, group theory, supervisory learning, how to manage difficult situations, good record-keeping and documentation skills, skills to address hurdles beyond science, ability to work in a matrixed rather than directive environment, and a grounding in ethics.

There are specific talent shortages at a range of levels. Executives voiced concerns about current or anticipated talent shortages over the foreseeable future in many general and specific areas. Most generally, some executives described across-the-board shortcomings among professional, middle-management and leadership levels. These shortcomings center on lack of solid background in a combination of science, clinical development, and business, including business development, finance, regulatory affairs, and quality management. More specifically, there are shortages in key areas: the next generation of CEOs; doctoral-level scientists and lawyers who possess intellectual property management expertise; and both managerial and technical-level specialists in pre-clinical, clinical and regulatory affairs. There are also niche shortages, such as lack of qualified chemists. Growth of the diagnostic industry and personal informatics will drive demand for genetic labs, lab personnel and statisticians. Certified clinical laboratories are finding it difficult to find fully qualified clinical laboratory directors (CLD), scientists (CLS) and technicians (CLT). There is *not* a lack of people seeking posts in academia, and it was reported that there is *not* currently a shortage of technicians in manufacturing or at contract research organizations (CRO), and no shortages in certain professional positions such as marketing. Finally, it was noted that there is a need for more excellent, committed, motivational math/science teachers.

There are a variety of challenges in filling these talent shortages, and California companies will need to import talent or relocate / expand elsewhere. Niche talent shortages affect industry potential. In the face of these challenges, some commented on the ability to obtain talent globally by importing talent. It was asserted that California companies will be required to import talent (other than UC-produced PhDs) for entry-level positions requiring a typical BS degree for the next decade. However, many also commented on the difficulty not only in finding homegrown talent, but also tapping talent from outside the country, even when the foreign talent is fully trained here. Searching the world for talent is very expensive for small and mid-sized companies. Some commented that it should be easier to retain people from outside the country who have been trained here. Due to cost of living and cultural differences, some executives feel the Bay Area is like a walled city: it's difficult and expensive to find and relocate a new hire, which drives increases in local turnover (with resulting wage inflation and people moving upward too quickly) and may tend to drive company expansion outside of the region. As far as cultural differences, some noted that compared to suit-and-tie workplaces, smaller bio companies have a workplace that is not right for everyone, including an entrepreneurial spirit, pride in the workplace, more casual work environment, very broad role definition, a wider scope of interests, greater importance of individual contributors, and more interest in innovation.

The US should not be sending foreign born scientists home. During the roundtable, there was further discussion about paradoxical US visa policies that send home foreign-born scientists who attain scientific degrees here. The practice needlessly drives up the cost of hiring here and sends home innovators who will ultimately compete against US products. Several roundtable participants felt that industry should push for a compromise on green card caps, leading to a fast track program for green cards in designated disciplines.

Executives recognize the disadvantages of expanding outside California or offshoring. In the worst case, companies will hire and expand outside the state and nation by relocation, outsourcing or offshoring if workforce needs cannot be addressed sufficiently here. Executives noted that location does matter: there is value in proximity, in the ability for immediate contact/communication, in a stable IT environment, and in the desired ability to tightly control relationships, assets and infrastructure. At the same time, a broader question of economic policy underscores that relocation is a greater concern than outsourcing. Outsourcing can stay local. Offshoring can at least keep core employment here. Relocation is a complete loss to the state. However, as one executive pointed out, offshoring in the realm of R&D and production is ultimately a loss of talent and production base, as it involves paying another country to build up resources to compete with you later on.

The state of California needs to do more about competition to steal bio. While most respondents mentioned or implied issues with competition, a quarter of the respondents explicitly stated some serious competitiveness issues, noting the rest of the world is trying to take California's place as a leader in bioscience. One person said, "California has been successful despite itself" and that the state needs to do more to stay competitive against other states. They pointed out that other states present highly coordinated approaches (North Carolina is a strong example). This person concluded, "California has a few good programs to assist and retain business, but no coordination, and if you don't know the programs are there, you'll miss them entirely." Another person asserted, therefore, that there needs to be an increase in collaboration across government; additionally, there needs to be increased access to training necessary to remain globally competitive. More specifically, a third person pointed out, the workforce development system consists of two silos: education and workforce people on one side and business and economic development on the other. These two sides need to work together more effectively. As this person stated, "If you think nothing's at risk, you're wrong: simply walk the floor at the [annual Biotechnology Industry Organization] BIO conference and listen to everyone saying it's necessary to leave California."

Executives Advocate Changes at All Levels of Educational System

Executives touched on issues at all levels of the educational system, from elementary schools to advanced study and professional training.

Fix the K-12 educational system. A majority of executives voiced grave concerns about K-12 education. They said public education is failing and that the situation may have already moved to a crisis stage given the long lead time needed for changes. The more specific issues split into a range of areas. All agreed that there is a need to redefine the basics, focusing on imparting flexibility of thought and teaching how to read, write and listen rather than answering rote questions on standardized tests. There were also pointed observations on the need to establish a policy priority to eliminate drop-outs, reduce social disruption, develop academic stars, and improve the sophistication of all students with regards to math and science. Within the mix is the need to sell science and do a better job of directly linking science education to real careers. Further, some executives noted that the ability to think and act flexibly and creatively comes down to more than science: marching band, sports, the arts, all of these things are important for building smart, flexible people, who will form a strong business community that will be effective in the world. Within this set of imperatives, some executives were very concerned that schools are not measuring the right things for educational attainment.

Produce a more STEM-literate populace.[15] Most executives also expressed the need for schools at all levels—as well as policymakers—to build a better educated populace that better appreciates science and understands why it's cool that innovation is here, supports appropriate policies, and has the ability to produce and support kids who can directly impact the future growth of the industry. There was also a desire to build a pro-science culture with positive role models—a culture that understands and values the

[15] STEM: Science, technology, engineering and math.

scientific method and understands the role of failure as part of success. Everyone—even marketing majors, not just scientists—needs a thorough grounding in math and science, the principles of documentation, the principles of research, an understanding of scientific inquiry and the scientific process, and the importance of well-documented failures.

The postsecondary education system needs a better, more effective way to adapt to rapidly changing needs. Although several respondents commented that educators and administrators seem generally ready to listen to and work with industry, they felt the educational system (overall and at the postsecondary level) does not understand the industry, still does not do enough to promote interest in and understanding of careers in science, and is unable to adapt quickly enough to needed changes. Some felt there are not any systems at all for education to be responsive to industry needs. They point out that the timeframe to adopt a new training commitment, approve the curriculum, and fund the classrooms and faculty to make it happen is measured in years, while bioscience cannot generally project its needs beyond three years. Executives would like the educational system to be able to learn and adapt curricula to what's hot tomorrow and the *biology-plus* dynamic, though dealing with the shortage of great math/science educators needs to take priority over agility. Some thought more could be done to bring industry to the classroom. Others mentioned that an academic bias sometimes complicates industry partnerships, and sometimes the educational system does not listen well enough. Some felt that community colleges and high schools seem better able than universities to adapt quickly. One person commented that postsecondary institutions need to prioritize training that supports strength in R&D and new company development rather than manufacturing technology jobs. In any case, because of this dynamic environment and the limited responsiveness of the educational system, it is essential that industry, the workforce development community, and educational institutions at least do an excellent job teaching people broad skills, driving self-education skills (investigating ideas, expanding understanding and knowledge), and motivating workers to take advantage of whatever ongoing training is available.

The educational system needs better science infrastructure. Some executives stated that part of the problem is that the system needs broader life sciences training infrastructure so that the classrooms and faculty exist in greater numbers. This would be necessary to respond to short-term needs such as the current crisis in regulatory and clinical affairs, to deal with what's hot tomorrow and the *biology-plus* dynamic, and to sell it effectively to incoming students.

There needs to be more IT and computational training at all levels, particularly postsecondary. Educational institutions need to look at augmenting classic skills with a focus on technology systems as companies move to higher levels of automation for research, production and systems such as databases.

There needs to be a way to accelerate advanced scientific and business training. Either through a Masters of Science or through some system of applied experience and training, there needs to be a way to impart a stronger grasp of both business and science upon management-level and some professional/technical level employees. To drive innovation, industry needs people who have deeper training and experience than a BS/MS degree, but PhD programs are not necessarily effective and need to evolve. The business training would not consist of strictly MBA-style business courses, but true management courses on leading and teaming. Project-based learning, mentoring, internships, group theory, supervisory learning, how to manage difficult situations, and manufacturing efficiency are all on the wish list of executives for advanced training.

Workforce development needs to inform and be informed by macro trends. The confluence of industry, academia, and government shades the overall market for talent. Education and training stakeholders need to look at trends in NIH and other government funding—as well as changes in the healthcare system, aging population, capital market interests, and other drivers—to assess the future direction of industry and thus to understand workforce needs. Careers in the life sciences will follow, in part, where the government lead goes.

There is lack of consensus about shortages of bench scientists. The majority of executives felt there is indeed a lack of interest in becoming a bench scientist, though there were various reasons cited at differing stages of education and career. A few thought this may be due in part to the lack of opportunities to participate in bench science early on, resulting from reduced lab operation at schools and/or lack of good math/science teachers to inspire such a career. Some noted science's image problem of nerds and geeks, not explorers. Another factor is the demand for faster careers than is afforded by the bench research route. This concern about career advancement led into a discussion of the dynamic within companies, where people abandon research because there is a perception (and often reality) that you cannot advance into management while continuing in a bench research position. One person felt there wasn't necessarily a declining interest in bench research but rather competition with large companies for available researchers. Another person pointed out that the issue was more retention of researchers in smaller companies when the research interests of the individual and the company diverged. In any case, some respondents noted that the career advancement issues can be solved by dual career tracks and broad-banding job descriptions, and one person was more concerned with obtaining people with teaming and leadership skills than with hard science.

Professional training is needed, but not necessarily available. For professional and management positions, easily accessible training in areas of acute need is a direct way to address the challenge, however there was not a complete consensus about its availability and nature. Some felt that not enough of such training was available and that more was needed for companies in the region to remain globally competitive. One felt that training was in fact fairly easily available. Still another executive pointed out that professional training was accessible, but only if a person was willing to pay for it—and that the limited publicly available training combined with the limited resources of smaller companies result in minimal continuing education. Some areas were cited as needing more accessible training: training to facilitate retention and cross-industry knowledge; skill transfer from other industries (such as retraining airline mechanics to be bio industry techs); integrated management training, including communications, working in groups, and finance; and training to self-educate. A few executives voiced the need for better abilities at small and large companies to grow talent in addition to hiring, which would include increasing the perceived value of ongoing training and help provide more opportunities for continuing training. It was also pointed out that the human resources community could do more to develop a greater focus on training. Further, HR can be better integrated into business models to establish a more effective linkage between training and business demand for skilled employees, as well as to work on promotions based on management potential and not just science. However, with the proliferation of smaller companies and tighter profit margins, the economics often don't work for employers to undertake significant employee training. One executive at a larger company noted they have implemented internal training for management and interpersonal skills. The executive also cited the universities in the Bay Area as a good local source for talent and that the company is working with colleges and other groups, including underprivileged groups, to help build a better workforce generally.

Industry Trends Map to Manager and Technician Profiles

All executives were asked to describe the skill/educational profile of the ideal manager and technician today and in ten years.

Manager profile. As noted at length above, managers will need a strong science and business background; people skills; ability to motivate and articulate a vision; knowledge of what is driving the science, scientists, and where the business is going; ability to see what is good science and a good science investment; and skill with managing internal competition for product development resources. Most of the things needed in ten years are also needed today, but there were a large number of things cited as growing in importance. The first is the ability to understand the complete timeline of a product, from discovery in the university to development and production, to asserting the product's utility to the FDA and reimbursement agencies, to delivering the product to doctors and patients. Managers must be increasingly comfortable in a regulatory and quality assurance environment—one that is more virtual and remote, that is matrixed rather than directive, operating at a smaller scale, with more external partners and contributors. They must be able to understand the management and utilization of information technology, and be comfortable and skilled with bio-IT convergence and convergence between sciences, including the explosion of data management and computational skill needs due to genetics and diagnostics. They will need to understand how their company and industry is affected by the global, regional and national economy and drivers, as well as by macro things such as healthcare economics and reimbursements, or energy economics with biofuels. All professional and technical employees will need to be motivated to self-educate.

The following managerial level positions were noted as specific workforce development needs, all of which must include the specific skill and experience profile described above:[16]

- Next-generation chief executive officers
- Additional training for incumbents to acquire more solid backgrounds in science, clinical development, and business, including business development, finance, regulatory affairs, and quality management
- Doctoral-level scientists and lawyers who possess intellectual property management expertise
- Managerial specialists in pre-clinical, clinical and regulatory affairs
- Clinical laboratory directors (CLD) and scientists (CLS)

Technician profile. The technician level naturally must possess a strong science background within their field, and be trained in the relevant processes and procedures; further, they must be very familiar with the entire supply chain and their own role in it, be in tune with delivering a product successfully to a patient or customer, and be able to utilize and manage technology, multiple data sources, and analysis. The bio-IT convergence, convergence between sciences, and growth of virtual R&D networks will have a profound impact over the next ten years. As with managers, technicians must be increasingly comfortable with more virtual and remote operations, with more external partners and contributors. Very importantly, the drive to automation will increasingly require technical level employees to be less focused on lab technique and more on what they can get a machine to do, along with data management and computational skills due to diagnostics. In ten years, IT skill will be a base requirement. The increased reliance on equipment requires much stronger troubleshooting, teamwork, and problem resolution. At least one executive commented that their company is building a multi-craft approach to talent to get better and faster troubleshooting, and it was observed that automation will eventually evolve some positions into a "super pro tech" who is able to take a research project from start to finish. As with managers, technical level workers will also need to possess the ability to self-educate and work in a matrixed rather than directive environment. All employees must be thinking about improvement. One executive summed it up as needing "people with a science foundation, who know the equipment plus the molecule, who have IT skills and interpersonal skills, and who think about six sigma and operational excellence."

The following technical level positions were noted as specific workforce development needs, all of which must include the specific skill and experience profile described above:[17]

- Technical-level specialists in pre-clinical, clinical and regulatory affairs

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[16] Note that this only represents the top concerns of respondents and does not represent a comprehensive or systematic list across the various disciplines within the industry

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- Advanced technicians for pre-clinical and clinical work who can take a research project from start to finish, including managing and troubleshooting automation and project teams
- Chemists with biology training / biochemists
- Genetic lab technicians and statisticians, including qualified clinical laboratory scientists (CLS) and technicians (CLT)
- Excellent, committed, motivational math/science teachers

Recent PhD Perspectives

Combined Results of Personal Interviews

Because of the significant questions raised nationally and locally concerning potential issues in supply and attrition among doctoral level scientists, the project sought to gain the perspectives of recent PhD candidates. Ten interviews were conducted, and the range of institutions and programs is too limited to be fully representative. However, even these limited responses should be directionally valuable where there is consistent response or amplification of executive or national data.

Profile of the Respondent Pool

Primary fields of the respondents: biophysics and bioinformatics, one respondent in pharmaceutical science and pharmacogenomics. PhD years: 2007 and 2008. Age range: 27-35. Institutions: UC San Francisco (7), UC Berkeley (1), Stanford (1), Washington University (1 – this person works in the Bay Area).

Early Career Influences

We wanted to explore what originally generated interest in bioscience and at what point. Respondents cited a range of positive factors leading to their interest in the field:[18] High school or undergraduate interest, good experience or good teacher (mentioned by 50%); Want to make an impact (20% mentioned); Interest in research and scientific freedom (30%); Interest in computer science (20%); Didn't like first career pursued (20%). Half of the respondents had no real interest in a science career in elementary school. Ultimately, all but one chose some form of math or science for their undergraduate program, and six of ten chose a pre-med or biology-related program in their undergraduate studies. Mentors were not a big early influence, with only three people stating a mentor was very significant; five people responded that mentors were nothing more than subtle or general.

[18] PLEASE NOTE: Responses total more than 100% due to multiple reasons stated.

Academic Experience

The interview then turned to how well the academic experience in their doctoral program had turned out and any difficulties or excellence experienced.

Satisfaction and balance. Overall, the respondents were satisfied with their academic experience, but the majority were not strongly so (70% scored their satisfaction at 5 to 7 on a 10-point scale, while the remainder gave scores of 8 or 9, and no one scored the experience at the top end of the scale as a 10). Nearly all felt their program provided a good balance of research interests. No one reported unqualified satisfaction with the *university experience* exceeding expectations, though 60% reported that their expectations were exceeded in some more generalized way (such as the diversity and cultural offerings of the university locale, the subsequent professional opportunities in industry, or the quality of their program compared to a poor program previously experienced).

Time to completion. There was significant frustration with the length of time to complete the program. Just 30% completed the program in 5 to 6 years, 20% completed it in 6 to 8 years, and 50% took 8 years or more to complete (the longest was 14), for an average of 8 years. Half expressed economic concerns related to the length of time, citing big opportunity costs with the program taking so long, frugal living compared to peers, and the psychological challenge.

Quitting. Eight out of 10 articulated points at which they thought about or actually decided to abandon a career in the field. These included realizing a mismatch between their expectations and the program, concern about the amount of time to finish, project funding difficulties, publishing challenges and time requirements, loss of faculty mentor due to move to another institution, lack of desired lab opportunities, lack of openings in academia, sluggish career advancement / money compared to peers, and lack of novelty / minutia in the research.

Career plans. Only one of the respondents felt they had much of a clear career plan. The biggest issue cited (60%) was that all the faculty, university staff and peers assumed that the proper career for a PhD was in academia. Some (20%) didn't feel the lack of career details was a big deal because they had a general sense of what they wanted to do. Perhaps unsurprisingly, 90% reported feeling a lack of support either entirely or in part for exploring career options, or for pursuing coursework that was relevant to their general career plans.

IT and business experience in program. Six in 10 reported they gained no experience with integrating information technology into their program. Business experience was somewhat better, with 80% reporting some form of experience, but other than two people availing themselves of coursework opportunities and a Center for BioEntrepreneurship, the business experience was mostly limited to taking a single business-related class or mentoring others. Six in 10 of the respondents stated there were some business-related offerings but they were uninterested (due to the presumption that their career would be in academia and lack of understanding of the importance of business experience).

Post-graduate Experience

The interviews also explored the respondents' experience or anticipated experience following receipt of their degree.

Post-graduate plans. Coming out of their program, 30% plan to abandon their specific doctoral field and try to pursue a non-research career (e.g., project management, finance, policy). The remainder are either working in a related temporary or post-doc position or have such work lined up. Half completed, attained or are working on attaining a post-doc placement, although one person who is abandoning the field may try to obtain a science education post-doc placement. One person was accepted for a post-doc position but declined the opportunity based on low compensation and lack of interest. One person reported completing a short post-doc solely because they feared being unemployed while pursuing a full-time job search for a position outside of academia.

Future employment goals. Six in 10 respondents reported varying degrees of uncertainty on a focused goal for their future employment. As far as stated goals for the desired type of workplace, 40% responded that collaboration and mentoring were a top consideration; the same number of people stated that quality and independence of research and publishing were a key goal. Other responses, in order, included desire for business/entrepreneurial (not academic) deliverables, money/title, intellectually interesting colleagues, diversity of experience, flexible hours, and a great place to live. Goals for these respondents over the long term overwhelmingly focused on quality-of-life criteria: being happy, doing a good job, constantly learning, and enjoyable work. Other key goals, in order, included improving the world / serious accomplishment; money; title; independence; publication record.

Preparation for goals. When asked if their training had given them the best chance to achieve their immediate goals, only half responded yes. The negative comments included a feeling that the training for the work world was poor and that the university training was irrelevant because the person chose to go into a different field or already possessed the skills/resume to attain their desired job based on prior experience. Others reported that the PhD provided key credibility, contacts, critical thinking skills and/or confidence—but did not cite the strength of the actual program as a key benefit.

University career guidance. Institutional help with finding career paths was neither strong nor systematic. Only 40% felt that their program was at all helpful with exploring career paths. Three in 10 respondents bluntly stated that the university mostly prepared them for academia, not careers, and one person reported being actively discouraged by their academic advisors from pursuing their career goal in industry. The remaining respondents reported mixed support: that advisors were happy to help people find careers, that students and alumni organized things, or that the university (but not their program) helped to some extent. Two people reported significant progress by the university toward the end of the program with helping students pursue non-academic career paths.

Student Observations

Suggestions. There was a broad range of suggestions for universities to improve career preparation:

- Offer a required class on career options early in the program, including a realistic discussion of the state of career prospects in academia
- Don't make it seem like a failure to leave academia
- Arrange internships—potentially even mandatory rotations out of academia—and make them more integrated, as they are in business school, so they don't add a large time commitment to completion of the program
- Improve management skills of advisors and/or provide a way for students to remedy advisor conflicts or delays; make real improvements with speeding time to completion of a PhD; require the periodic check-in with an advisor and/or non-advisor faculty member to include a career discussion and be more than about the research project
- Bring in outside speakers to talk about careers
- Provide better encouragement and rationale to take a broader set of courses of career benefit
- Develop funding and/or opportunities for travel to learn more about the field and career options
- Develop industry-academia collaborations to give exposure to business opportunities

Observed attrition. All respondents report seeing attrition out of the PhD program. The top reason cited was the lack of opportunities in academia (80% mentioned this issue, which included lack of openings, funding drying up, leveraging the PhD for something else, and seeing better opportunities elsewhere). The second most frequently mentioned reason was that people leaving were ultimately not willing to sacrifice the time and money for a PhD (50% voiced this concern). Other reasons mentioned included lack of good fit with the advisor, lab or project; burnout with the topic or science generally; the arbitrary power of the advisor with respect to completion of the degree; and felling "not cut out" for grad school.

Perceived glut of PhDs. Virtually all respondents felt there were enough or too many PhDs, with 80% flatly stating that there are more PhDs than academic positions available, that the field is saturated, and that they don't see a shortage. Others commented that they were finding it hard to get a bench job because there were more PhDs than openings, and that funding was going down relative to people.[19]

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[19] It should be remembered that these responses are directly related to the desire of most respondents to enter academia, where openings exist for only 30% of PhD recipients. It seems, by contrast, that there are sufficient opportunities for PhD recipients in industry, but most graduates are not seeking out these opportunities for the reasons already detailed.

Overall advice. The interview concluded with the opportunity for the respondents to provide any final advice. Here is what they said:

- Streamline programs. They would like to see programs better define requirements and benchmarks rather than such an exclusively project focus, stop stressing the post-doc, reduce the amount of time needed for completion (6-8 years is too long), and potentially integrate rotation projects better so that they do not increase time to complete the program
- Consider implementing a two-tier PhD system for people heading to industry versus academia and/or a Masters of Science type program
- Provide a broader range of career knowledge earlier on, and arrange more involvement of industry or information about careers in industry through talks or seminars
- Consider limiting the number of people in programs to reduce competition for jobs
- Provide more rotation projects or internships so you "don't have to do a post-doc to determine if you like a career in bioscience"
- Industry needs to be more flexible in matching experience to needs; job descriptions are too insistent on exactly the experience they are looking for
- Have a better system for addressing grievances caused by advisor-student power imbalances
- Universities should not be so doctrinaire that their role is only to teach people to think and not provide formal instruction in a skill if needed in industry; advisors need to be supportive of students doing industry internships and not penalize them

National Lab Perspectives

Federal research laboratories are also, in varying degrees, employers in this industry. BASIC invited Northern California labs to the May 15 executive roundtable and invited input by email.

The input primarily came from Lawrence Livermore National Laboratory. This lab's involvement in the industry is related to bio-security and bio-defense.

The input from LLNL shared commonalities with the executive perspectives. In fact, since the lab employs scientists from various disciplines, it was possible for LLNL's representative to compare and contrast biology scientists with scientists from other disciplines. The lab sees lots of programs—and strong post-doctoral programs—encompassing biosciences at the region's universities. As with the corporate employers, however, our roundtable participant from LLNL emphasized a greater need for interdisciplinary focus. It was perceived that bio scientists seem less able to cut across disciplines into chemistry and computational science than peers from other disciplines. It was discussed that this difference might stem from pressures that are unique to bio, such as the types of projects that bio scientists work on and the narrow focus of PhD funding.

As a result, our roundtable participant stressed the need to do something that gives scientists a better basis and grounding for working directly with people from other disciplines. Team skills are a second top priority. It was noted that the culture of biologists, particularly at the PhD level, is to work in small teams, while labs do projects involving large teams in which bio scientists can feel less comfortable operating.

University Perspectives

It was important to gain the perspectives of key research universities as the primary suppliers of advanced scientists and innovation. The May 15 roundtable included participation from four University of California campuses (Berkeley, Davis, San Francisco, and Santa Cruz) and one major private university (Stanford).

University input had the twofold purpose of clarifying current programs and practices for supplying talent in the life sciences, as well as responding to the various opportunities and challenges presented by the executives, national labs, and doctoral students.

Current Programs in the Life Sciences

The university input underscored that there has been a great deal of attention to developing curricula and supporting programs to expand the region's talent base in the life sciences. The information below only represents the information received by BASIC and is not meant to be a comprehensive survey of offerings by these postsecondary institutions.

California Institute for the Quantitative Biosciences (QB3). The California Institute for Quantitative Biosciences (also known as QB3 or the Center for Quantitative Biology, Biochemistry and Bioengineering) is a cooperative effort among three campuses of the University of California and private industry. It is intended to harness the quantitative sciences—math, physics, chemistry and engineering—to integrate the understanding of biological systems at all levels of complexity for the benefit of human health. The Institute builds on strengths in the engineering and physical sciences at UC Berkeley, engineering and mathematical sciences at UC Santa Cruz, and the medical sciences at UC San Francisco, as well as strong biology programs at the three campuses. In addition to the creation of fundamental new knowledge and potent new technologies, a major goal of the Institute is to train a new generation of students able to fully integrate the quantitative sciences with biomedical research. The Institute involves more than 180 scientists housed in a new building at Mission Bay in San Francisco, in a new building at UC Berkeley, and in two new facilities at UC Santa Cruz.

Stanford University. Stanford offers a complete set of academic programs at the undergraduate and graduate level, as well as extensive research programs. Browsing the university's website shows that life science programs exist in the School of Humanities & Sciences (Department of Biology), School of Earth Sciences (Department of Geological and Environmental Sciences, which includes the study of biogeosciences and geomicrobiology), and the School of Engineering (which includes bioengineering at the Clark Center).

- Department of Biology. This department includes over 110 graduate students and 90 postdoctoral fellows from all over the world. Major research interests of the Department can be roughly divided into the following four areas: (1) Molecular Biology, Cell Biology, Developmental Biology, & Genetics; (2) Plant Biology; (3) Population and Evolutionary Biology and Ecology; and (4) Marine Biology. About half the graduate students are working in the first area, with the remainder spread between the other three areas.
- Graduate Studies in the Biosciences at Stanford (GSBS). Postgraduate study in the field is such a priority at the university that it distributes a 36-page glossy brochure on its offerings and maintains a comprehensive website at http://biosciences.stanford.edu. GSBS offers some 300 faculty across 12 bioscience disciplines, supported by 600 labs ranging from basic biology to clinical disciplines. A unique "Home Program" provides the basis for personalized support while affording access to research and training opportunities across the GSBS program. The 12 GSBS programs include Biochemistry, Biological Sciences/Biology, Biophysics, Cancer Biology, Chemical and Systems Biology, Developmental Biology, Genetics, Immunology, Microbiology and Immunology, Molecular and Cellular Physiology, Neurosciences, and Structural Biology.
- Bioengineering. This program is the first time Stanford has operated a degree-granting program that crosses two schools. Housed in the Clark Center, it produces PhDs with interdisciplinary experience. It also offers a co-terminal masters degree in biology and engineering. Due to its success at the graduate level, Stanford is now looking at a complete undergraduate program in bioengineering.
- Bio-X. Due to increasing number of graduates going into industry, the university expanded biotechnology at the Clark Center through creation of the Bio-X program. This program supports, organizes, and facilitates interdisciplinary research connected to biology and medicine spanning engineering, computer science, physics, chemistry, and other fields. The program is specifically designed to foster interdisciplinary collaborations.
- Interdisciplinary enhancements. Stanford has been working concertedly on interdisciplinary collaboration. In 2003, the university looked systematically at silos in PhD programs and formed a committee to examine areas for improvement. The committee ultimately recommended installing a dean / vice provost of graduate education whose function would encourage interdisciplinary programs. This has led, in part, to one-week and two-week programs on applied and interdisciplinary subjects such as intellectual property and the life sciences, how to lead a group, and other management-relevant experiences.

University of California, Berkeley. UC Berkeley offers a complete set of academic programs at the undergraduate and graduate level, as well as extensive research programs and its relationship with QB3. The university's website includes programs in the College of Letters & Science Division of Biological Sciences (Department of Integrative Biology and Department of Molecular and Cell Biology), the College of Engineering (Department of Bioengineering), the College of Natural Resources (Plant & Microbial Biology), and various specialized groups mentioned below.

- Designated emphasis. The university has a designated emphasis program that allows specialization in key areas such as bioinformatics.
- Undergraduate internships. At the undergraduate level, in conjunction with QB3, UC Berkeley offers a 10-week internship program with local biotech companies.
- CalTeach. At the primary and secondary levels, CalTeach is a new effort underway at UC Berkeley to prepare STEM students interested in being K-12 math/science teachers. It combines an undergraduate math/science degree with all the requirements for obtaining a teaching credential, allowing qualified math and science teachers to enter the classroom immediately upon graduation.
- Interdisciplinary graduate programs. Various programs offer broader PhD training:
    - The Management of Technology (MOT) program between Haas School of Business and College of Engineering focuses on bringing technology to the marketplace and includes courses on a broad range of related management, design, and regulatory subjects. It has over 1000 enrollees, though only a portion of these are related to the life sciences.
    - The Biophysics Graduate Group, part of the university's Graduate Division, trains graduate students for careers at the interface of the biological and physical sciences and draws from a large number of departments.
    - The Interdepartmental Group in Biostatistics addresses issues in the health, medical and biological sciences related to collecting and exploring relevant data. It draws from classes and resources in the School of Public Health and the Department of Statistics, as well as the Department of Biostatistics & Epidemiology at UC San Francisco. The program offers training in the theory of statistics and biostatistics, computer implementation of analytic methods, and opportunities to use this knowledge in areas of biological/medical research.
    - The Interdisciplinary Graduate Group in Comparative Biochemistry offers unique opportunities for students to obtain the PhD and MA degrees in a broad range of disciplines that use biochemical and molecular approaches to problems in the biological sciences. Opportunities for research exist with faculty from diverse departments and research units on the Berkeley campus including Molecular and Cell Biology, Nutritional Sciences, Plant and Microbial Biology, Chemistry, Public Health, Environmental Science and Policy Management, and the Lawrence Berkeley National Laboratory.

University of California, Davis. UC Davis offers a full degree-granting Biotechnology Program, which was created in 1986 and traces its roots to the College of Agricultural & Environmental Sciences. To encourage interdisciplinary approaches and stimulate interest in the field, the university operates or participates in a number of programs to advance biotech learning, along with opportunities afforded by its relationship to QB3.

- BioTech SYSTEM. UC Davis houses and helps spearhead the BioTech consortium of Solano, Yolo and Sacramento counties for Training, Education & Mentoring. The consortium, born of a grassroots effort to foster collaborative relationships between key members of the biotech community in the Greater Sacramento Valley, seeks to enhance biotech education and promote the development of a biotech-savvy workforce. Members of the consortium include representatives from public colleges and universities, community organizations, local governments, area high schools and biotech industry. The consortium identifies needs and priorities, supports placement of students, develops and shares curricula and equipment, and manages the Teen Biotech Challenge (TBC). TBC is a web-based high school competition that is a capstone experience for students from participating schools and spans six sub-disciplines: Ag & Industrial; Bioenergy & Biofuels; Biomedical Applications & Bioengineering; Forensics; Genomics, Proteomics & Bioinformatics; and Stem Cells & Tissue Engineering.
- Designated Emphasis in Biotechnology (DEB). DEB is an inter-graduate group program operated by the UCD Biotechnology Program that allows PhD students in a variety of allied disciplines (such as plant genetics) to receive training and formal transcript credit with a Designated Emphasis in Biotechnology. DEB promotes integration of multiple disciplinary approaches to the conduct of research and promotes learning in biotechnology, specifically striving to provide tools for students to be leaders, visionaries, entrepreneurs, researchers, and teachers in the broad area of biomolecular technology. The program requires some additional courses, a seminar designed around presentations from industry speakers, and a three-month internship (with placement assistance from the university). University officials state the program succeeds in ultimately placing students in industry.
- Business Development Certificate Program. This one-year program operated by the Center for Entrepreneurship at the UCD Graduate School of Management provides an introduction and hands-on experience in developing new business ventures designed to commercialize research. The Center for Entrepreneurship selects ten students for this program. Alongside their regular lab work, participants take courses in technology management, innovation and entrepreneurship as well as practicum courses working alongside MBA students. The university sees this as a hugely successful way to build PhD students toward becoming an entrepreneur or entering industry.

University of California, San Francisco. UC San Francisco is a graduate health sciences university, thus much of its curriculum and research falls within the broad category of the life sciences. The institution places a high priority on the translation of science into utilization through its schools of dentistry, medicine, nursing, pharmacy and its Graduate Division. The university intends to remain a leading source of innovation in the life sciences. Though much of the university's offerings advance the life sciences, there are specific programs that directly relate to the issues of competitiveness and interdisciplinary needs at the focus of the WIRED project. Among the most important of these is QB3, which is detailed above. In addition, two other programs particularly stand out:

- Center for BioEntrepreneurship (CBE). The center offers programs and resources to develop the next generation of entrepreneurs and leaders in the life science industry. The center creates programs that teach business skills, provide information on career opportunities, and involve industry. Topics include presentations from industry on such essential management topics as core financial skills.

- Science & Health Education Partnership (SEP). SEP is a collaboration between UCSF and the San Francisco Unified School District to support quality science education for K-12 students. There are several specific programs operated by SEP, but one of the core elements is arranging for undergraduate or post-doc students to teach science classes at the K-12 level.

University of California, Santa Cruz. Santa Cruz is more of an undergraduate institution, though it covers a wide range of life science disciplines through its academic and research programs in the Division of Physical and Biological Sciences. Academic programs include Biological Sciences; Chemistry and Biochemistry; Earth and Planetary Sciences; Ecology and Evolutionary Biology (EEB); Environmental Toxicology; Molecular, Cell & Developmental Biology (MCD); and Ocean Sciences. Research programs include Biomedical Research; Center for the Molecular Biology of RNA (RNA Center); Institute of Marine Sciences & Long Marine Lab; MEGAMER (Microbial Environmental Genomics, Applications, Modeling, Experimentation and Remote Sensing); Microbiology; and the STEPS Institute for Innovation In Environmental Research.

The university sees a move toward greater demand by industry for scientists with undergraduate degrees as opposed to graduate degrees (with the number of placement opportunities perhaps split roughly as 70% undergraduate and 30% graduate). But UCSC's roundtable participant did not currently see any organization that helps connect its graduates with specific employer needs and placements, especially compared with the more extensive placement approaches in Germany and to a lesser extent the pharmaceutical industry practices used on the US East Coast. The prevalence in other countries of a culture of technology transfer was also mentioned as a competitive challenge for the US.

In response to growing demand for jobs in quality systems, UCSC has started a program in biotechnology and drug development. It is hard to make this program sound glamorous, but UCSC is working to sell the program based on the earning potential for graduates. The university finds a similar "tough sell" on positions reliant on advanced statistics, regulatory affairs, and other essential but unglamorous-sounding functions.

University Comments and Counterpoint

The presentations by the universities underscored the academic and research richness available to drive innovation and competitiveness in the life sciences workforce. There were several additional comments made and discussion around the presentations.

Global pressures and models. During the university portion of the roundtable discussion, the degree of global competition related to both talent and innovation was mentioned. Participants found it essential for the US to get organized and better compete with models in other countries. The German model for technology education, career placement and commercialization was specifically mentioned.

Lack of systematic planning as it exists in other domains. One of the university participants stated what has been an undercurrent of the discussion in the development of this report. A major challenge is defining the workforce problem and need so as to develop a master plan and model to update academic programs, research, and placements. Such an approach exists in other domains and professions, such as engineering, medicine, dentistry, allied health sciences, and physical therapy. However, in biotechnology, the connection is not there: there is no systematic, coordinated way of linking industry needs with university planning.

Potential for greater collaboration on talent development. One of the university participants underscored the strong potential for a meaningful university-industry-government collaboration on developing talent in the life sciences. This participant pointed out that the large research universities need not necessarily take the lead on a given program, but that effective collaboration could generate creativity to develop practical programs and identify the best institutional frameworks to implement them.

Debate about the role of universities in specialized training. Given the tenor of executive comments pointing toward specialized applied training, there was discussion of the proper role of universities in providing such training. There was some feeling that universities should be able to train excellent, well-rounded talent in fundamentals, and that such education should be able to meet employer needs without going so far as training for very specific, narrowly defined jobs. There was also concern about the challenge of meeting smaller company needs for specifically trained people. Part of these concerns stemmed from the intellectual argument in favor of broader education, and part dealt with industry's acknowledged uncertainty and short timeframes about projecting hiring needs. However, it was pointed out that North Carolina's approach to contract manufacturing showed how postsecondary education and industry could move in a useful direction.[20] The models of engineering schools, medical schools, and law schools were also raised as examples.

Importance of undergraduate talent. Some attendees commented on the importance of undergraduate talent for meeting industry needs. In addition to the North Carolina programs mentioned above, it was stated that a good example was a Semiconductor Industry Association program in Arizona, which developed curricula in conjunction with industry and implemented the recommendations at the community college level.[21] Another university participant felt that at the undergraduate level there was the need for

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[20] Two such examples are the North Carolina Community College System BioNetwork and the Biomanufacturing Education and Training Center at North Carolina State University.

[21] The author was unable to confirm the specific program mentioned in the executive roundtable. However, it may be one of various programs established under a National Science Foundation grant program for community colleges called Advanced Technological Education (ATE) grants. Among these is the Maricopa Advanced Technology Education Center (MATEC) in

more dual-degree programs to enable a BS graduate to get a relevant job immediately out of a four-year program and subsequently consider postgraduate study after some working experience. This approach requires more coordination between industry and schools and needs to extend from program development to internships. In addition, it was asserted that job placement was not being sufficiently addressed. The comparison was made with the financial industry in which students move immediately into a job from graduation. On this basis, the job potential for a program could be a key criterion regarding its design.[22]

Cross-cutting Roundtable Discussion

The May 15 roundtable afforded the opportunity for discussion among the gathered stakeholders about the various issues and opportunities raised by this research. Any points not already well-addressed above are summarized here.

- There was a strong degree of support for a process enabling real-time university-industry discussion on immediate, evolving needs, as well as doing a better job of conveying job opportunities and job descriptions.
- Developing a system within universities to supplement the role of academic advisor with a person to select, represent and mentor doctoral students is a valuable concept.
- There was also discussion of the opportunity to design specific training interventions to provide specific skills swiftly, possibly with a purpose-specific academy.
- There was further discussion about the concept of internships and their ideal length. Some felt that rather than short placements of a few weeks or months it was important to implement effective, extensive internship programs on real industry projects for a longer term such as one year and/or to organize it as a parallel track during the course of study.
- Significant debate took place on the projection of job needs. Even with the small company and turbulence challenges, it should be possible to look at more overarching trends that would be indicative: healthcare trends, government funding, regulatory trends, etc. It was commented that there would be potential multiple benefits of an organization helping to assess needs, including even helping individual companies undertake a self-assessment process. Not all agreed, though, and some felt it was more important simply to build broadly skilled, flexible people augmented by real-world experiences.
- Many felt it would be important to incorporate high school, community college and state university officials in discussions of these issues and in addressing workforce projections and strategies.

Tempe, Arizona, which developed the first industry-wide skill standards for semiconductor manufacturing in conjunction with the Semiconductor Industry Association.

[22] The example given was that an undergraduate human biology program could be too spread out without being paired with a more specific skill; i.e., if a BA graduate in Human Biology doesn't make it into medical school, it is potentially hard to find a job. However, a more defined undergraduate offering in human biology could be designed with more relevance for employers, or human biology could be paired with another course of study in a dual-degree program to deliver a credential more attractive to employers.

However, it was noted that these other stakeholder communities are relatively more diffuse than the top universities, making it challenging to gain agreement or to implement partnerships.

- All participants agreed on the enormous unmet need for outreach to the public, media, political leaders and students to bridge the lack of understanding, trust, consensus, and effective action.
- A SWOT analysis would be useful to assess priorities, looking at weaknesses in K-12 public education, cost of doing business, international threats, key opportunities, and then specific policy choices to tap the opportunities.
- The discussion was inconclusive on a key question: whether the industry has a labor supply problem (too few people entering) or a capacity issue (inability to graduate enough people).
- There was interest in looking at short-term opportunities to retrain displaced workers.
- Some felt there was a need to better support involvement of scientific research faculty and post-docs in entrepreneurial activity and commercialization of research.

Roundtable Recommended Action Items

The preceding sections covered many specific findings and recommendations that suggested action by individual stakeholder communities, such as employers or universities, as well as specific information on job profiles at the manager and technical levels. In addition, the roundtable produced a list of cross-cutting potential action items in four broad areas that may be relevant to any US geography seeking workforce improvements in the life sciences.

1. Actions to better understand pain points

- Undertake a focused investigation to understand whether the area has a fundamental worker supply problem (lack of people entering relevant courses of study) or a capacity issue (inability to graduate enough people with the right skills)

2. Actions to address acute areas of need

- Develop an ongoing, institutionalized process employers and educational institutions to narrow and define areas of acute and longer term needs; it was noted that it would be possible to choose just a few of the best areas for successful action—it doesn't need to be all areas of acute need
- Establish a specialized technical training academy to supplement university and community college resources with the following:
    - Provide focused, rapidly developed and flexible coursework in very specific areas that address acute needs of industry and potentially incorporate displaced worker retraining
    - Arrange internship placements to address identified needs
    - Leverage trainers and employers to speak at universities to educate students on career opportunities and to serve as adjunct lecturers
    - Look at Trade Adjustment Assistance and DOL funding for financial support

    - Produce a web-based information resource for students, counselors, teachers, and professors on job opportunities, qualifications, pathways[23]

- Work with community colleges & universities to cover other areas of acute need
- Coordinate with local policy organizations on lobbying for a green card fast track program

3. Actions to address longer-term needs

- Bring together the complete set of educational institutions stakeholders spanning representatives from secondary schools, technical training institutions, community colleges, undergraduate institutions, postgraduate universities, and research institutions to be involved in whatever organization is addressing industry-education-government coordination
- Share these findings more widely to gain support for changes within the academic domain (such as eliminating bias toward industry careers, increasing multi-disciplinary elements within university programs, adding a short-track / MS program, adding dual-degree programs, improving career placement services or realigning university mentorship activities with employer needs)
- On an ongoing basis, analyze government spending, macro trends and other indicators to assess medium-term needs and develop a strategic plan to meet industry workforce and other needs

4. Actions to increase interest in and support for science and science teaching

- Engage in a coordinated PR campaign such as the Year of Science
- Rally support for a Junior Achievement-style program for science
- Promote enrollment in STEM teacher training programs such as CalTeach

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BASIC will use the findings of this report to advance the objective in its Action Plan to "Strengthen the Bay Area's Science and Technology Base."

[23] Various web-based job resources exist in this field, but they do not necessarily help an individual systematically choose a career, understand job qualifications, assess income potential, and plan academic study, internships, and continuing training.

Appendix A

LIFE SCIENCES EXECUTIVE INTERVIEW PARTICIPANTS

In Personal Interviews on Science and Technology Required Workforce Skills

Michael A. Alvarez, Director, School of Medicine Career Center, Stanford University

Dave Bieber, Ph.D., Founding Executive Director, National Professional Science4 Masters Association

Helyn Dahle, Associate Director, Patient Advocacy and Community Relations, Cell Genesys, Inc.

Frederick Dorey, Special Counsel, Cooley Godward Kronish LLP

Matthew M. Gardner, President & CEO, BayBio

Kristina Hathaway, Director of Human Resources, Entelos, Inc.

Joerg Heidrich, SVP and Head, Global Product Supply Biotech, Bayer Healthcare

Robert Lee Kilpatrick, CEO and Co-Founder, Technology Vision Group, LLC

David W. Martin, Jr., M.D., CEO, AvidBiotics Corporation

Nola Masterson, Managing Director, Science Futures

Jennie P. Mather, Ph.D., President, Chief Scientific Officer and Founder, Raven Biotechnologies, Inc.

Jeff Peterson, CEO, Target Discovery, Inc.

Howard Simon, Esq., SVP, HR and Corporate Services, Associate General Counsel, InterMune, Inc.

Frank Spada, SPHR, Senior Director, Human Resources, Anesiva, Inc.

Rick Srigley, President & CEO, Aragen Bioscience

Hank Stern, Associate Director, Manufacturing & Collaboration, Genentech, Inc.

Jennifer A. Troia, Vice President, Human Resources and Corporate Operations, Sunesis

BASIC extends its sincere appreciation to the bio executives listed above for their interest in this project and for their generosity in donating time and knowledge to ensure the project's success.

We also appreciate the valued assistance of the two interviewers:

Rob Gamble, Executive Director, BayBio Institute – Conducted bio executive interviews

Courtney Harper, 2007 graduate Ph.D., UCSF – Conducted graduate student interviews

Appendix B

PARTICIPANTS, BASIC ROUNDTABLE ON SCIENCE & TECHNOLOGY WORKFORCE May 15, 2008

California Institute for Quantitative Biosciences (QB3), Mission Bay Campus, San Francisco

BASIC Chairman: Regis B. Kelly, Director, QB3, University of California

Bio Executives

Matt Gardner, President, BayBio
Fred Dorey, Special Counsel, Cooley Godward Kronish
Kristina Hathaway, Director of Human Resources, Entelos, Inc.
David Martin, CEO, Avid Biotics, Corp.
Nola Masterson, Managing Director, Science Futures
Jeff Peterson, CEO, Target Discovery
Frank Spada, Senior Director, Human Resources, Anesiva, Inc.
Hank Stern, Associate Director, Manufacturing & Collaboration, Genentech, Inc.
Jennifer A. Troia, Vice President, Human Resources and Corporate Operations, Sunesis

Universities

Alan Bennett, Associate Vice Chancellor, UC Davis
Phillip Berman, Department Chairman, Biomolecular Engineering, UC Santa Cruz
Arthur Bienenstock, Special Assistant to the President for Federal Research Policy, Stanford
Beth Burnside, Vice Chancellor for Research, UC Berkeley
Eugene Washington, Executive Vice Chancellor, UC San Francisco

National Labs

Nina Rosenberg, Division Leader, Bioscience and Biotechnology Division, LLNL

Other Industry Participants

Mark Butler, Partner, Rockridge Partners, Inc, (workforce consultant)
Christopher DiGiorgio, Managing Director, California, Accenture LLP and
Board Director, Bay Area Council Economic Institute
Kenneth Toren, Executive Director, Parkinson's Institute

Other Stakeholders, Staff and Consultants

Sean Randolph, President, Bay Area Council Economic Institute
Sally DiDomenico, Vice President, BACEI, and Program Manager, BASIC
Gerrie Porciuncula, Executive Assistant, BACEI
Donna Riordan, Director of Programs, California Council on Science and Technology; WIRED Partner
Christine Purcell, California Space Authority, leader of WIRED workforce project
Ray Wells, California Space Authority, leader of WIRED economic development project
Rob Gamble, Executive Director, BayBio Institute
Chandra Alexandre, Director of Development, Bay Area Council
Linda Galliher, Vice President, Education and Healthcare, Bay Area Council
Chuck Castellano, Independent Consultant
Paul V. Oliva, Oliva Global Communications