Knowledge workers in Biotechnology:
Occupational structure, careers & skill demands

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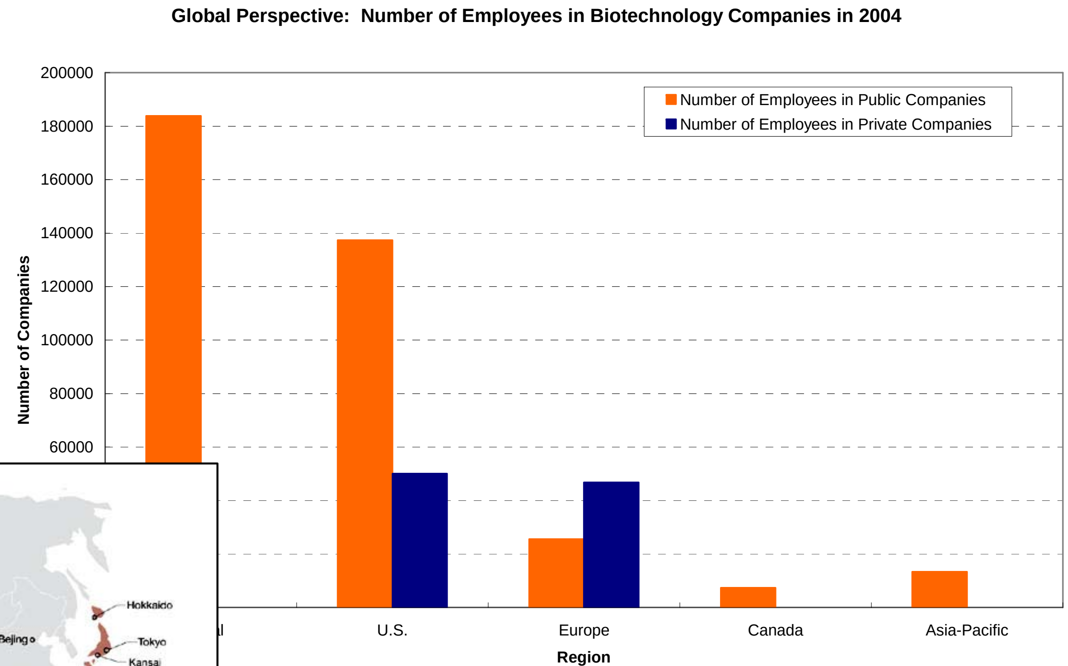
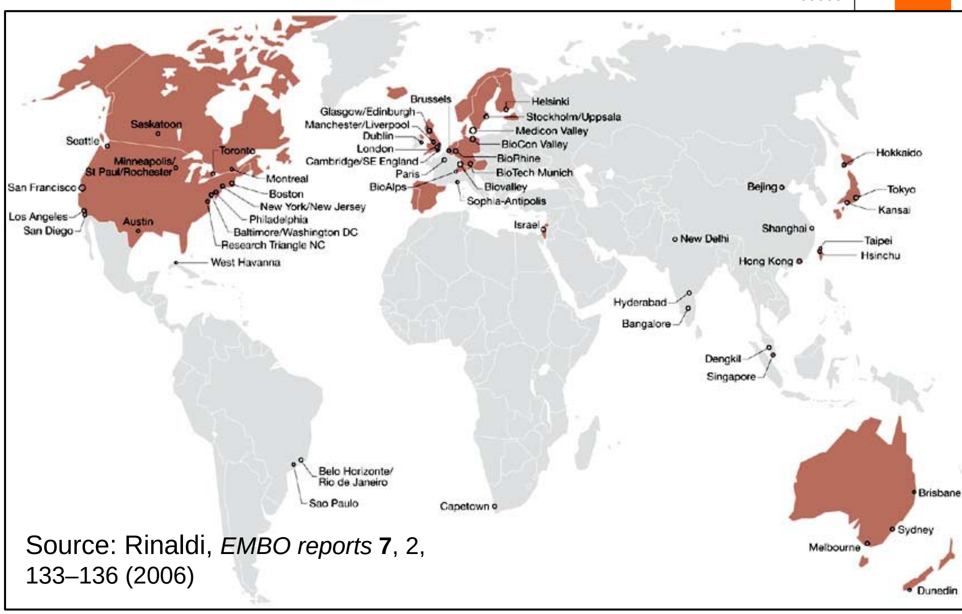
More than 4,000 dedicated biotech firms exist worldwide in highly concentrated clusters with ~1500 firms & 200,000 jobs in the US





Source: Rinaldi, *EMBO reports* **7**, 2, 133–136 (2006)

"Biotech is highly concentrated within those areas that combine a strong research capacity with the ability to convert research into substantial commercial activity" (Cortright & Mayer 2002)

Top US centers include San Francisco, Boston, San Diego, Raleigh-Durham, Seattle, & Washington/Baltimore (Brookings 2002)

Employment in DBFs is only 0.2% private sector employment but provides significant benefits to the US economy

- Employment share reaches 1-2% in regions with vibrant biotech clusters (Mass Biotech Council, 2005)
- Total U.S. employment in the biosciences sector reached 1.2 million in 2004 (1.1%)**
- Generated an additional 5.8 million jobs (multiplier effect)
- Average wage of bioscience workers in the United States was $65,775 in 2004, > $26,000 greater than the average private sector wage
- Above average employment growth - 12.3% (U.S. Department of Commerce)
- >30% employment is scientific knowledge work vs. 2.2% in the private sector overall

U.S. Average Annual Wages per Employee, 2004

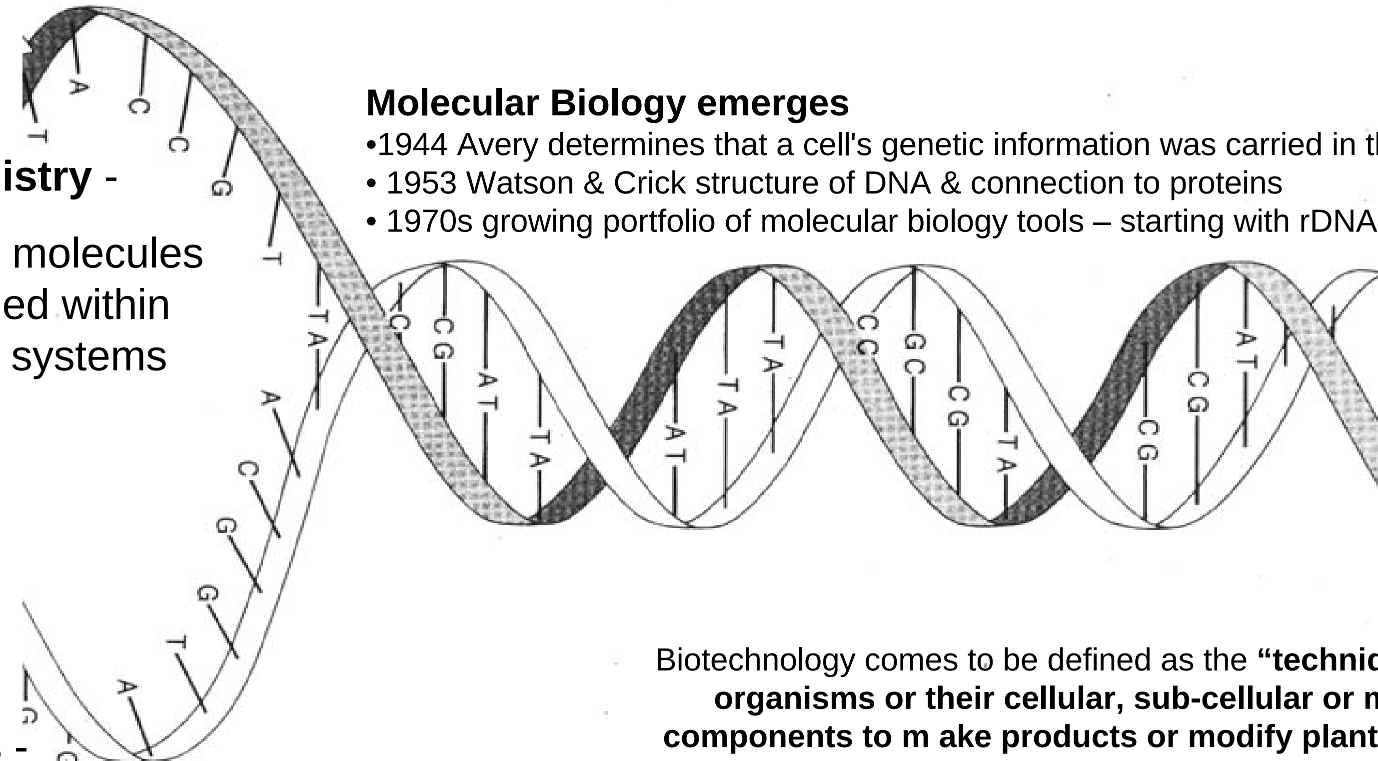
Drugs & Pharmaceuticals	**$ 79,303**
Finance & Insurance	$ 69,889
Total Biosciences	**$ 65,775**
Research, Testing, & Medical Laboratories	**$ 65,414**
Agricultural Feedstock & Chemicals	**$ 63,383**
Professional, Scientific, & Technical Services	$ 62,411
Information	$ 60,530
Medical Devices & Equipment	$ 56,449
Manufacturing	$ 47,705
Construction	$ 40,297
U.S. Total Private Sector Avg	**$ 39,003**

Source: Battelle calculations based on Bureau of Labor Statistics, QCEW program data from the Minnesota Implan Group. Data include Puerto Rico.

Source: Growing the Nations Bioscience Sector, BIO 2006

** Bioscience sector defined via NIACS codes as agricultural feedstock & chemicals, drugs & pharma, med devices, research, testing & medical labs)

Scientific foundations of the sector lie in the creation of a new discipline of molecular biology in the period from 1950 - 1970



Biochemistry -

- how are molecules transformed within biological systems

Molecular Biology emerges

- 1944 Avery determines that a cell's genetic information was carried in the DNA
- 1953 Watson & Crick structure of DNA & connection to proteins
- 1970s growing portfolio of molecular biology tools – starting with rDNA

Genetics -

- studying genes and their mode of action

Biotechnology comes to be defined as the **"techniques that use organisms or their cellular, sub-cellular or molecular components to m ake products or modify plants, animals & micro-organisms to carry desired traits"**

"Set of enabling technologies used by a broad array of companies in their research, development & manufacturing activities" (U.S. Office of Technology Policy 1997)

Many potential applications of bio- technologies => industry not defined by its products, but by the technologies used to make them

⇒ Not easily mapped to NAICS codes

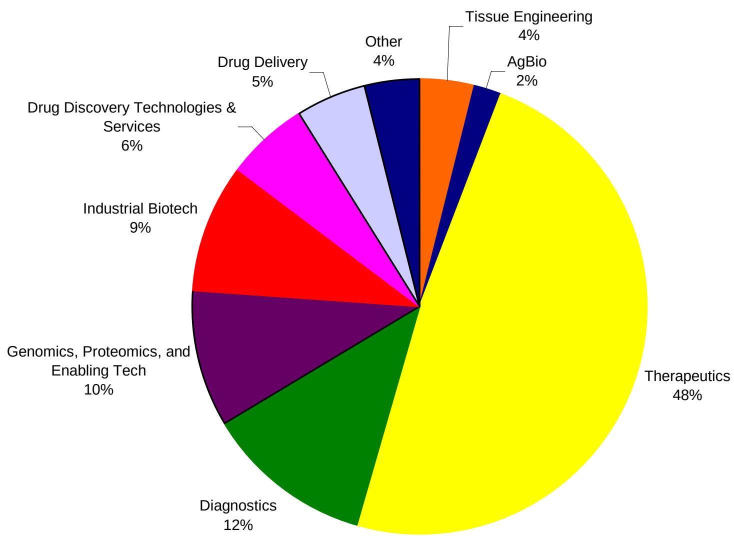
⇒ No systematic government coverage of the industry

⇒ Many definitions of the biotech sector

Narrow definition considers **Dedicated Biotech Firms** (DBFs) to be companies founded “primarily to commercialize biotechnology” across many segments

Many large diversified firms also use bio-technologies e.g. pharma – with implications for skill demands & the labor market

Distribution of US Companies by Segment in 2005
Public and Private Companies



Source: Ernst & Young 2006

Knowledge work in the biotechnology sector

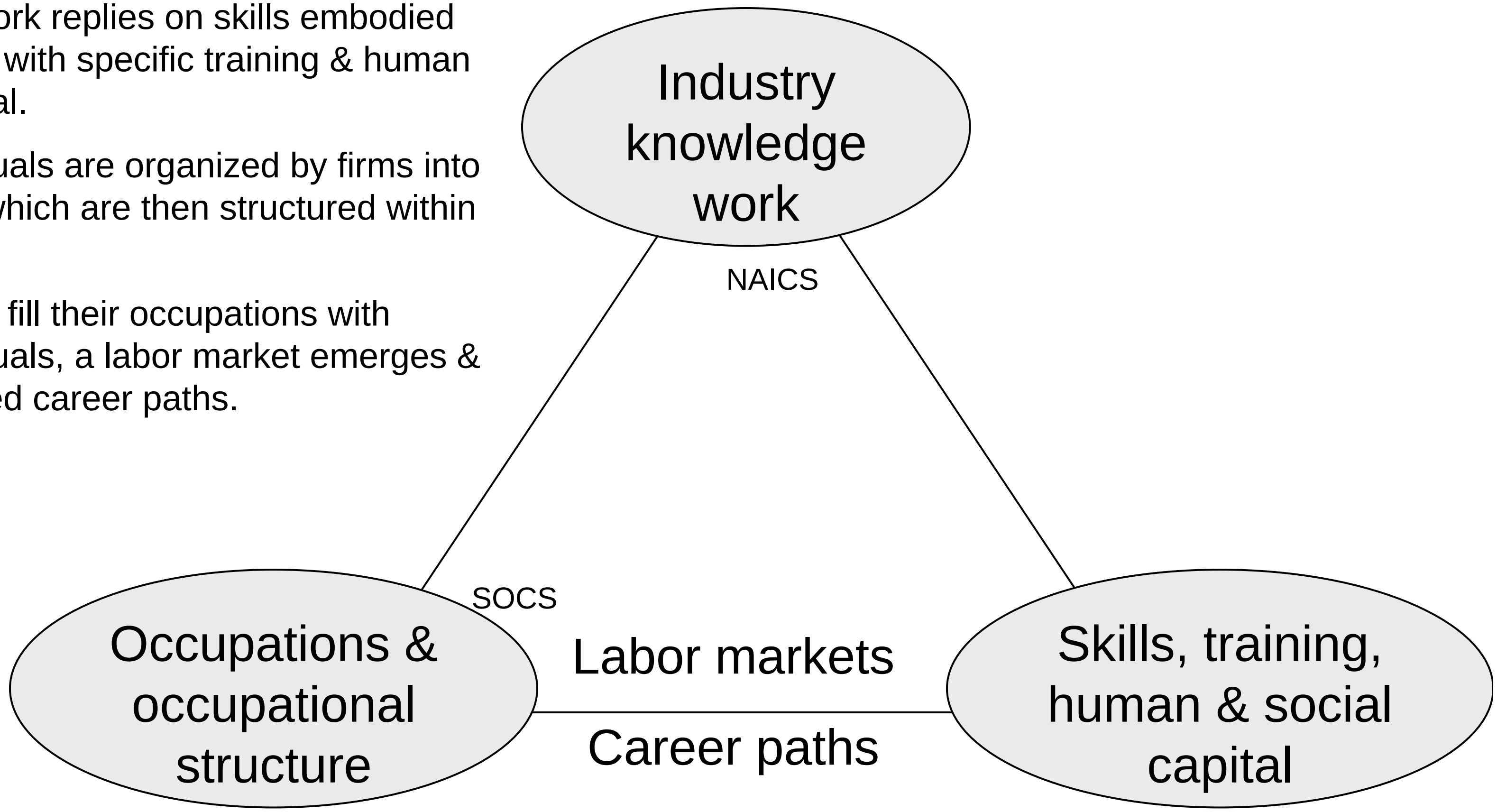
How should we analyze the knowledge work undertaken by the 200,000 employees in US dedicated biotechnology firms?

Firms engage in knowledge work (driving performance)

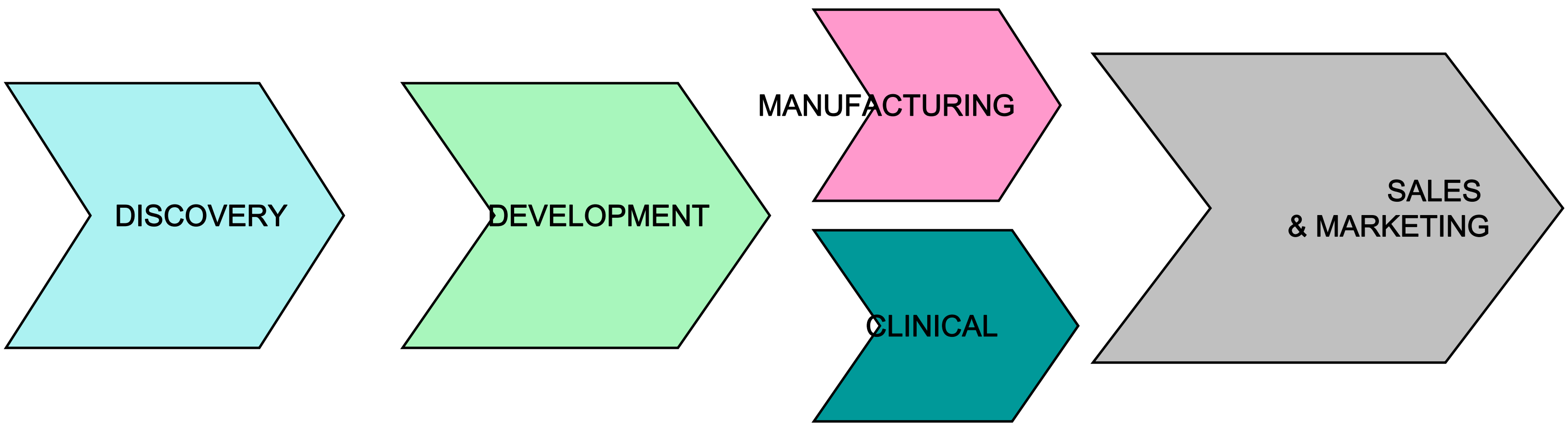
Knowledge work replies on skills embodied by individuals with specific training & human & social capital.

These individuals are organized by firms into occupations which are then structured within the firms.

As firms try to fill their occupations with skilled individuals, a labor market emerges & a set of defined career paths.

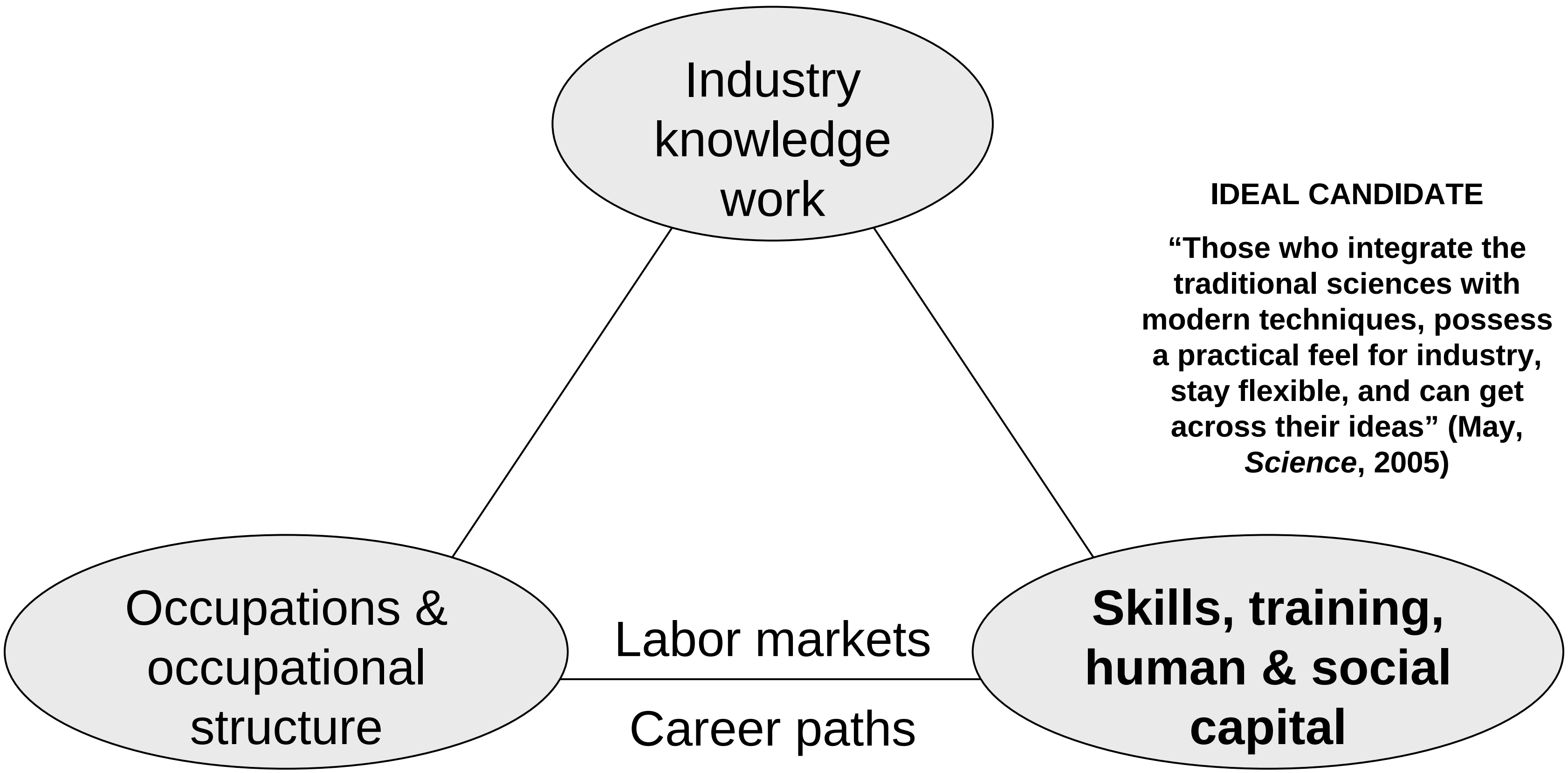


DBFs in healthcare typically move down the "value chain" of drug development & incorporate a broader range of activities as they are successful & grow



- Firms use collaborations for many of these activities (Powell et al 1996, Casper & Murray 2004, Liebeskind et al. 1996, Henderson & Cockburn 1994)
- Discovery alliances are structured with academia (often via a license + sponsored research) – most of the top 10 best selling biotech drugs were licensed from academia (Edwards, Murray & Yu 2003)
- Development & clinical alliances with pharma firms (typically a license with joint development & pharma marketing but terms vary with experience) (Stuart, Hoang & Hybels 1998)

BIOTECHNOLOGY SKILLS, TRAINING, HUMAN & SOCIAL CAPITAL



IDEAL CANDIDATE

"Those who integrate the traditional sciences with modern techniques, possess a practical feel for industry, stay flexible, and can get across their ideas" (May, *Science*, 2005)

Most biotech knowledge work requires BS, MS or PhD training in one of a range of bioscience disciplines

Table A-1. Occupational Employment in Dedicated Bi
Companies, 1989

Occupation	Total Employed	Total Employec Ph.D.s
BIOTECHNOLOGY SPECIALTIES		
Molecular Genetics	724	340
Classical Genetics	42	20
Industrial Microbiology	311	72
General Microbiology	665	248
Human/Animal Cell Biology	471	198
Plant Cell Biology	86	45
Human/Animal Molecular Biology	508	309
Plant Molecular Biology	90	55
Human/Animal Biology	246	87
Plant Biology	42	25
Pharmacology	209	93
Toxicology	73	17
Enzymology	81	59
Immunology	532	216
other biology	154	39
Analytical Biochemistry	377	156
General Biochemistry	1042	498
Other Chemistry	1397	644
Other Biotechnology Specialties	369	163
TOTAL	7420	3282

Breakdown of scientific employment from a survey of ~500 DBFs in 1989 with over 53,000 employees (NAS/NSF).

Firms employed an additional:

• 1500 scientists in other specialties including computer science & medicine
• 3000 engineers – mainly biochemical & bioprocess engineering

•Firms hire most technicians at the BS/MS level

Biotechnology Skills **Managerial Expertise**

Skills beyond "science" - important to appreciate not only the scientific merit of ideas but also their commercial application

"Anyone looking for work here must really understand that they would be joining a drug hunting culture, a company extremely interested in taking topics from the cover of Science to the clinic."

Work in Pasteur's Quadrant

- Need to recognize commercially relevant science
- Not always correlated to high quality science (Kogut & Gittelman 2003)
- Firms whose publishing scientists also patent are more effective (Cockburn & Henderson)

		Consideration of Use?	
		NO	**YES**
Quest for Fundamental Understanding?	**NO**		**Edison (patenting)**
	YES	**Bohr (publication)**	**Pasteur**

Source: Stokes, *Pasteur's Quadrant* 1997

Biotechnology work requires skills beyond pure knowledge – ability to communicate ideas & collaborate on research teams

Research more team based than in academia (evidence from publications & patents)

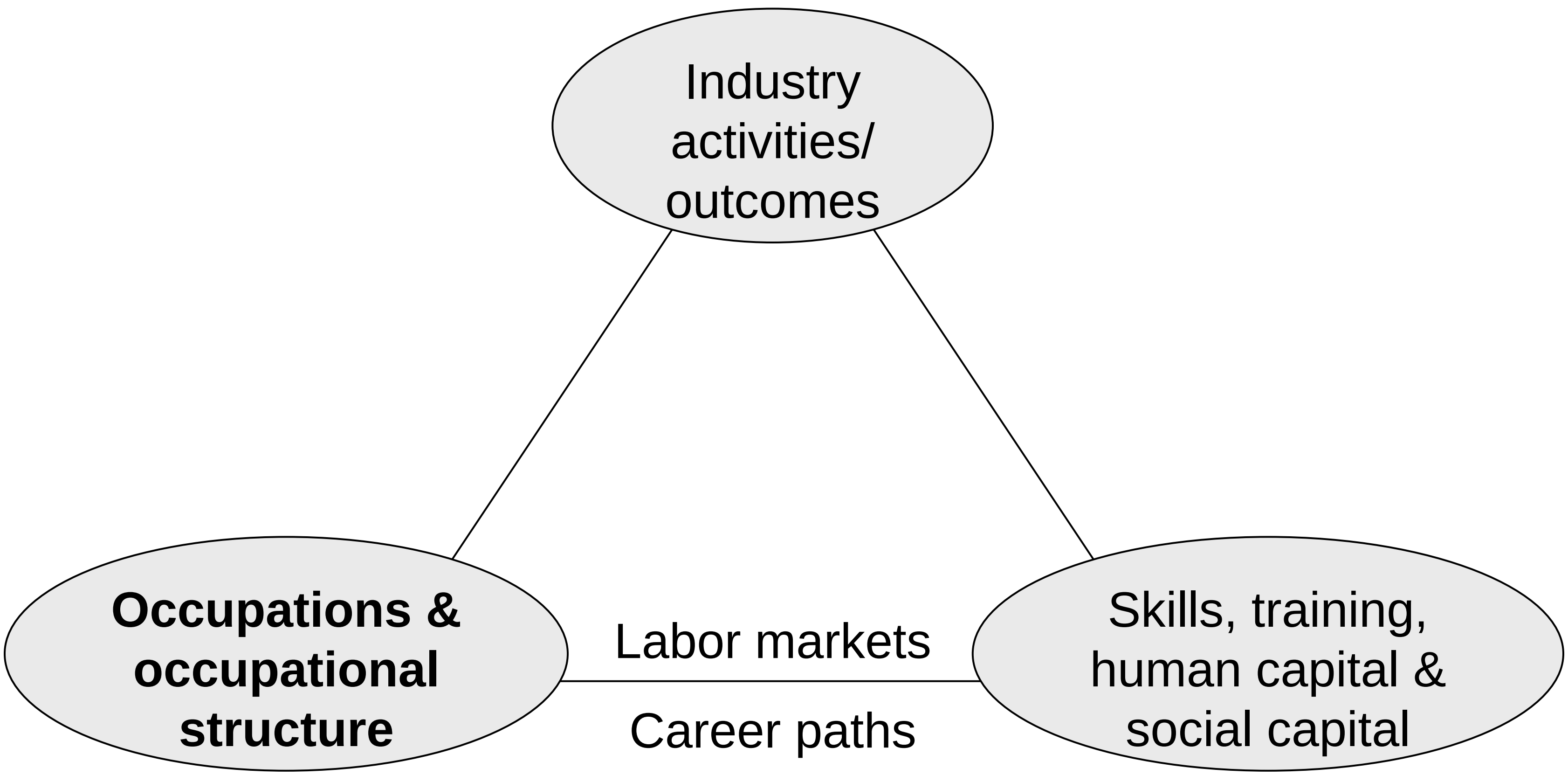
- “Almost all our research is done collaboratively as part of a team…So we prefer applicants who have a record of successful team projects, preferably with previous industry experience.” (Johnson, Rosetta Pharmaceuticals)

Research must engage a broader range of constituents than in academia

- “ Good writing and oral presentation skills also make a significant impact on our evaluation of candidates.” (Johnson, Rosetta Pharmaceuticals)
- “You need people who are able to communicate and learn the languages of other team...” (Critchfield, Myriad)

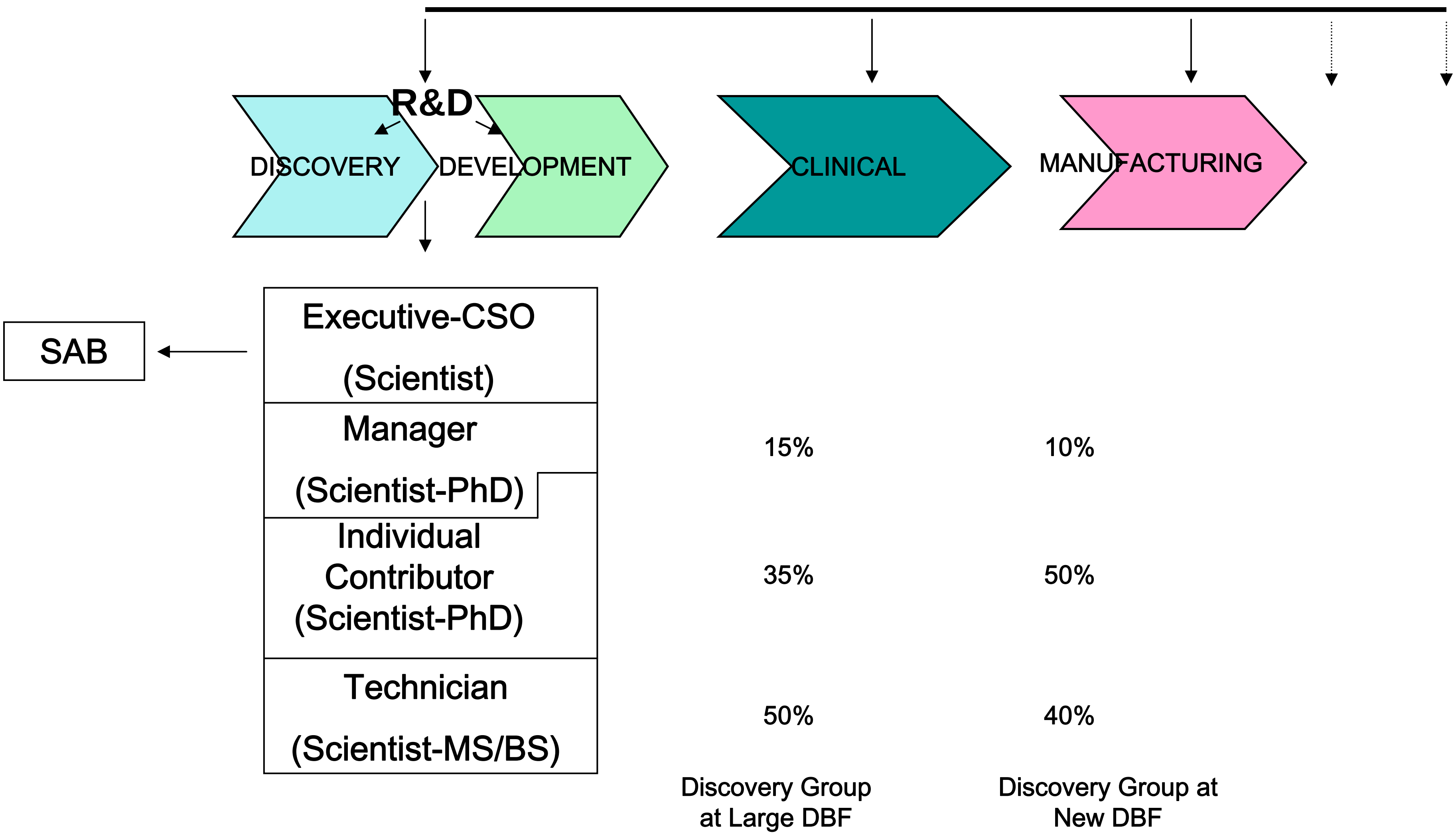
“Genomics: Bridging Research Areas”, Gwynne, 9 May 2003)

BIOTECHNOLOGY OCCUPATIONS & OCCUPATIONAL STRUCTURE

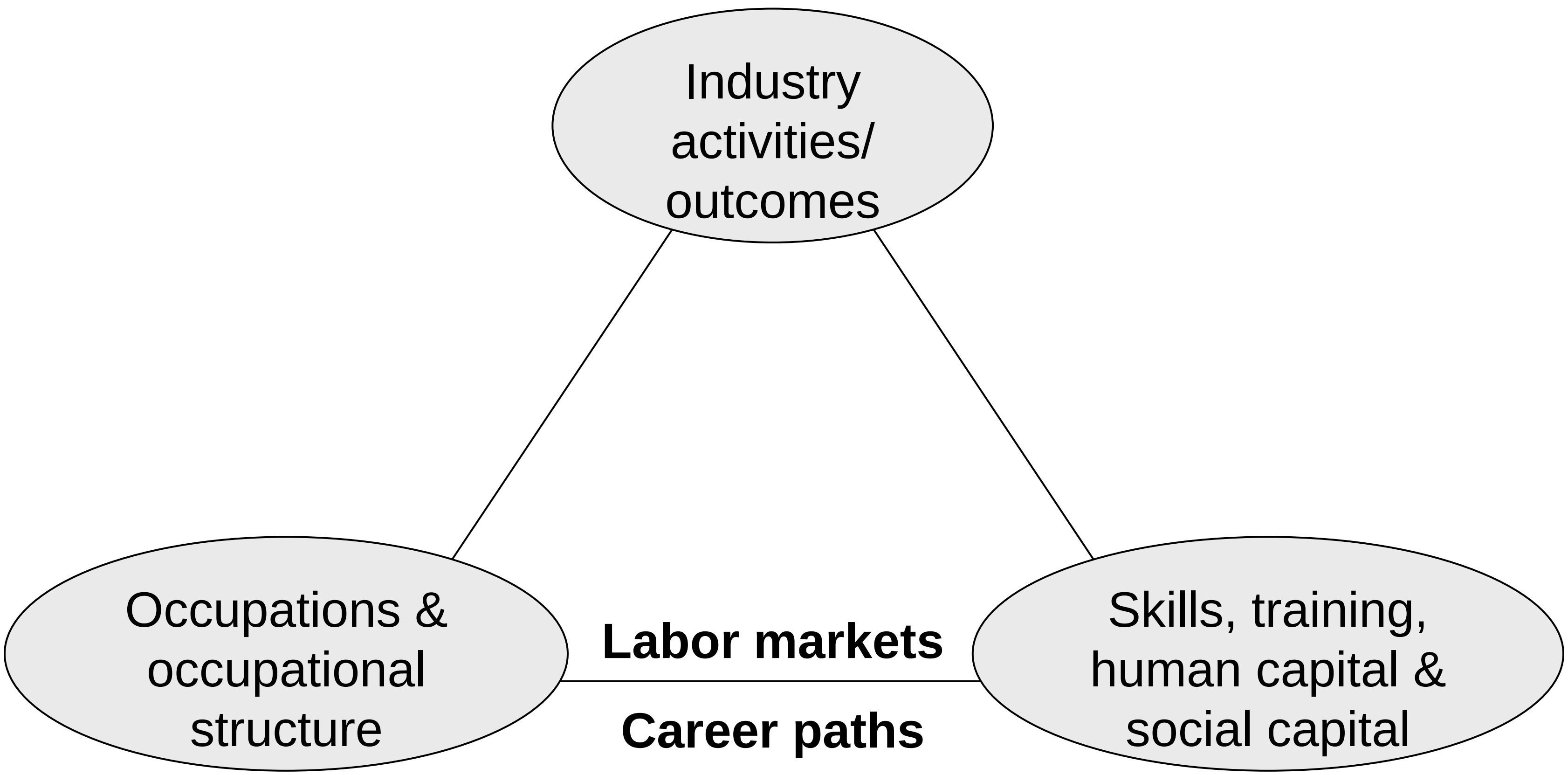


Biotechnology Occupational Structure

Biotechnology work arranged around functions - most scientific knowledge work in the R&D function (caveat – recent shift to project & matrix based organization is changing occupational roles)

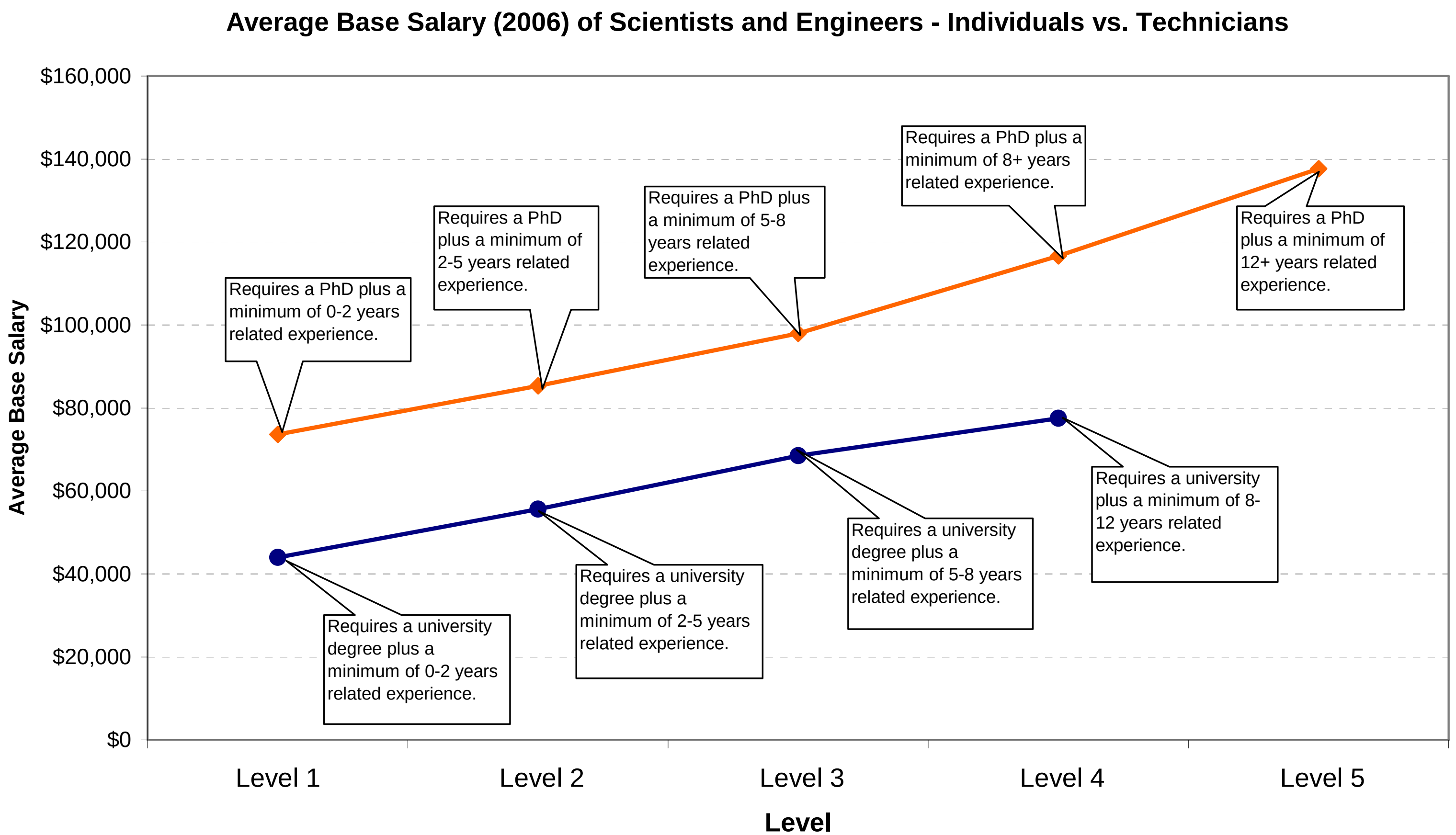


BIOTECHNOLOGY LABOR MARKETS & CAREER PATHS



Labor Market

PhD receives a US$40k premium, little industry-wide variation by discipline (ex. MDs) or by geography. Limited premium for scientific experience (~US$3k per year)



Note: Scientists include Biology Scientists--(Molecular, Cell, Bio-Assay, Pharmacology and Bio Chemistry (Protein) Scientists) and Chemistry Scientists--(Organic, Medicinal, Combinatorics/Computational, and Analytical Scientists). Engineers include Chemical, Packaging, Manufacturing, Medical Device, Automation, Software, and Bioinformatics Engineers. Technicians include Biology and Chemistry Associates.
Source: Radford Consulting

Implications for Skill Demands

Supply side for scientific training is strong (driven by public research $) & demand side growth in DBFs fast but relatively small with firms experiencing few major skill shortages in "pure science"

Salaries needed to attract top talent linked to outside options

DEMAND \ FIELD	**Biology**	**Chemistry**	**Medicine**
Biotech	✓✓ (traditional science base of biotech firms)	✓ (growing as biotech moves into small molecules)	✓ ✓ ✓ (increasing as firms move down value chain)
Academia	✓✓ ✓ (post-docs & then faculty)	✓ ✓	✓✓ (many clinical options)
Pharma	✓ ✓	✓✓ ✓ (but recent downsizing)	✓✓ ✓
Other industry	✓	✓ ✓ ✓	✓ ✓ ✓ ✓

Some specific areas of skill shortages - driven by a mismatch between academic research agendas (& PhD training) and industry needs & a mismatch in training “style”

Biology

- Need for traditional skills in mammalian biology, patho-physiology in combination with molecular biology techniques

Chemistry

- Continued need for medicinal chemists – organic chemistry in academia has become “too biological”

Medicine

- Limited training in clinical research – not the high status arena of medicine

PhD training does not focus on the required “soft” skills

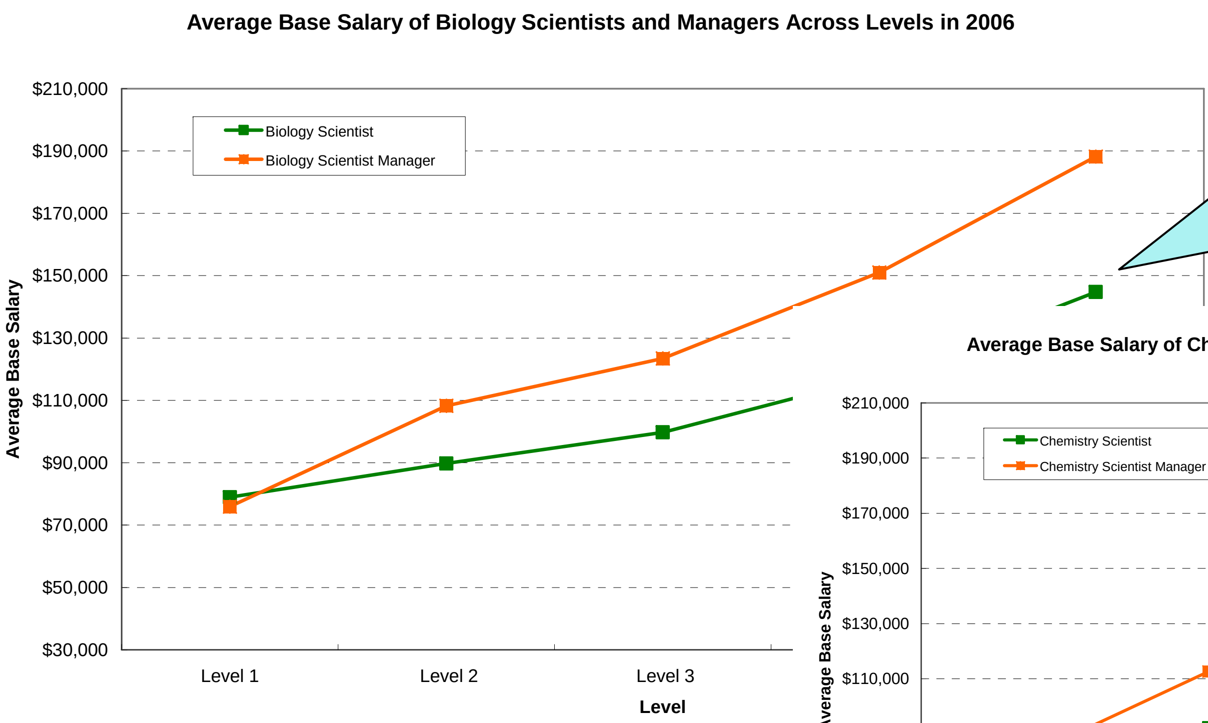
- Too individual in its focus
- Poor team-based skill development
- Limited understanding of science in the broader context
- Individuals trained to be too highly competitive

- Lack of ability to design an experiment to solve a business problem – how risky is this drug, is the process scale-able etc.?

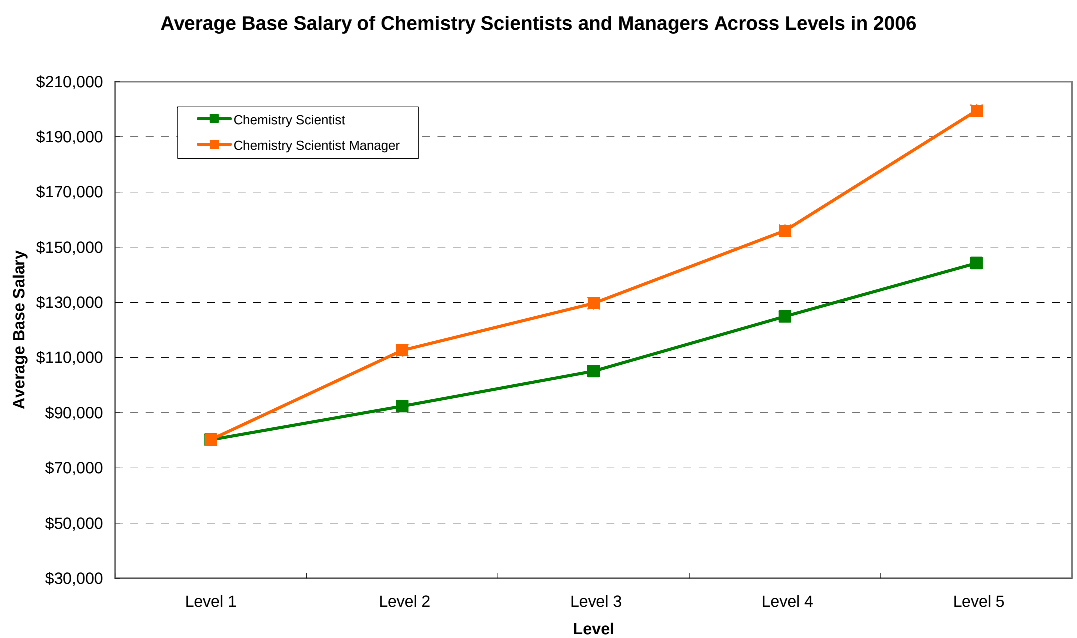
Labor Market

Key occupation in biotech knowledge work that commands a higher salary is managerial ladder & ultimately to Chief Scientific Officer (~ US$300k)

Senior individual contributors are those who cannot and do not want to move into management…"these are strange people – we like to think of them as our "drug hunters"…"



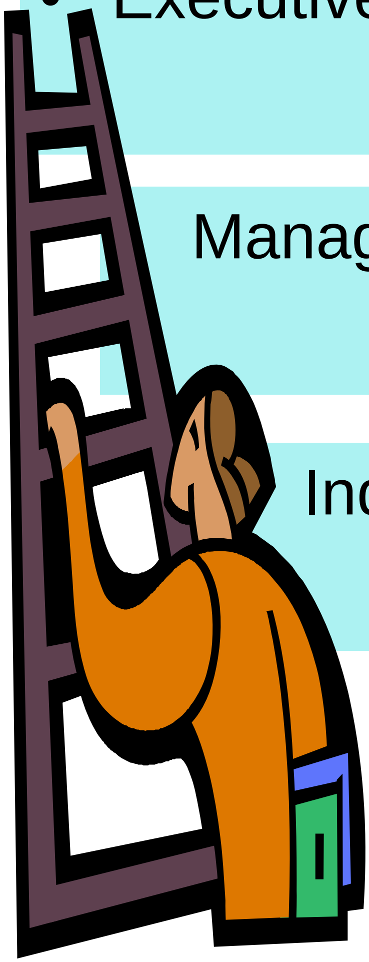
Note: Biology Scientists include Molecular, Cell, Bio-Assay, Pharmacology and Bio Chemistry (Protein) Scientists. E
Managers who direct the activities of a biology research and development group.
Source: Radford Consulting



Note: Chemistry Scientist includes Organic, Medicinal, Combinatorics/Computational, and Analytical Scientists. Chemistry Scientist Manager includes Scientific Managers who direct the activities of a chemistry research and development group.
Source: Radford Consulting

Implication for Skill Demands

Science-based knowledge work in biotech operates at four distinctive levels with different skill demands



- Executive

Need for experienced CSOs – typically part of an executive team – depends on cluster dynamics/ cluster maturity – US>>Europe

Managerial

Need for >> managerial talent among scientists –training programs e.g. KGI, MIT-BEP etc. but limited – firms unclear how this should be done

Individual

Need for v. specific areas of technical expertise – varies depending on industry/ academic conditions. Also strong & ongoing need for better team/collaboration skills.

- Technician

Need for technicians in specialized functions particularly clinical/regulatory & also bioprocessing/manufacturing where BS/MS education is less relevant

Future Trends

Driven by increased focus on productivity in biotech investors demand that spending on knowledge work produces more results

1. Deskilling of knowledge work
    - Profiles of new hires are changing towards being less PhD intensive
    - Increased need in the industry for " more pedestrian skills which may be lower than Bachelor's degrees"
    - "Genentech is reversing the stratification of its workforce, from 70 percent Master's degrees and above to 70 percent Bachelor's degrees and below."

2. Knowledge work as integration
    - As biology grows ever more interdisciplinary the need for more broadly trained scientists expands… "we need people who are trained along broader lines."
    - "many recent graduates have strong computational skills and a good biology background, few seem to have experience putting them together. The rarest are candidates who also have the biological insight to frame testable genomic hypotheses that can impact pharmaceutical research."

3. Partitioning knowledge work for off-shoring
    - Experimenting with what types of knowledge work can be moved off-shore
    - Chemistry moving more rapidly than biology
    - Requires task partitioning for efficiency, coordination & to avoid IP issues

Broad scientific skills in China & India still not approaching US but pockets of expertise & broad skills in techniques – chemistry & biology

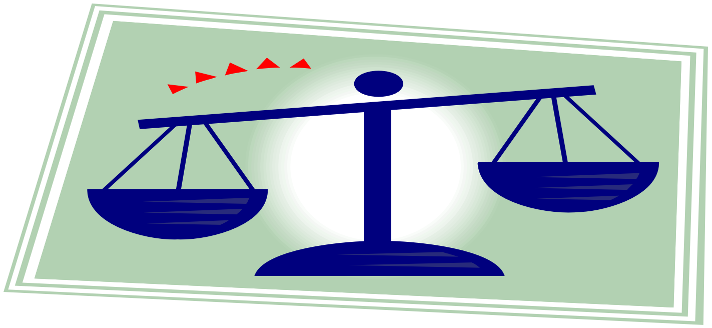
Field	Percentage of papers from China 2000-04	Relative impact compared to world
Materials Science	11.56	-22
Physics	9.15	-36
Mathematics	8.95	-16
Chemistry	8.29	-36
Engineering	6.89	-23
Geosciences	5.76	-34
Computer Science	5.48	-25
<--- China's overall % share, all fields: 4.66 --->		
Ecology/Environmental	3.84	-40
Pharmacology	3.71	-51
Plant & Animal Sciences	2.40	-28
Biology & Biochemistry	2.30	-54
Agricultural Sciences	2.16	-17
Microbiology	2.12	-43
Molecular Biology	1.84	-47
Clinical Medicine	1.70	-24
Neurosciences	1.35	-44
Immunology	1.06	-59

Field	Percentage of papers from India, 2000-04	Relative impact compared to world
Agricultural Sciences	5.30	-65
Materials Science	4.79	-29
Chemistry	4.23	-38
Physics	3.45	-21
Plant & Animal Sciences	3.39	-70
Pharmacology	2.83	-57
Engineering	2.63	-35
Geosciences	2.53	-50
<--- India's overall percent share, all fields: 2.39 --->		
Ecology/Environmental	2.29	-58
Microbiology	1.88	-53
Biology & Biochemistry	1.85	-63
Mathematics	1.83	-44
Computer Science	1.46	-18
Clinical Medicine	1.02	-60
Molecular Biology	1.00	-68
Immunology	0.93	-68
Neurosciences	0.50	-49

Future direction of skill demands depend upon your perspective on the nature of knowledge work in biotech – is it an art or a science?

Knowledge work in biotech as an ART

Competitive advantage thru people



Knowledge work in biotech as a SCIENCE

Competitive advantage thru processes & efficiency

Managerial skill demands

- Creating a collaborative work environment to attract the star scientists
- Productivity gains thru autonomy

Technical skill demands

- Focus on the "rich intersection" & on knowledge integration across disciplines

Managerial skill demands

- Focus on metrics, efficiency, task partitioning
- Managing off-shored relationships

Technical skill demands

- De-skilling, highly specialized training of technicians
- Low-cost off-shored talent for partitioned tasks