



# Emergence and Resilience in the Life Sciences: The Effects of Public Science on Regional Agglomeration and Industry Dynamics

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\*This is joint work in progress with Jason Owen-Smith (University of Michigan) and has benefited from comments by John Padgett, and generous support from the Co-Evolution of States and Markets program at the Santa Fe Institute.

- Empirical context: the contemporary life sciences, a field that includes dedicated biotech firms, large multinational corporations, research universities, government labs and institutes, leading research hospitals, and venture capital firms.
- Data set: 1988 – 2004, covering all of the above organizations, and their formal inter-organizational collaborations. Developed by Laurel Smith-Doerr (Boston University), Ken Koput (Arizona), Jason Owen-Smith (Michigan), Kelley Porter (Queens University), Kjersten Whittington (Reed College), Jeannette Colyvas (Northwestern) and myself. Today's discussion builds on prior work with all these colleagues.

- Substantive puzzles:

- 1) Even though the sources of knowledge and expertise are widely distributed, both across the U.S. and globally, the biotech industry shows remarkable spatial agglomeration, and is concentrated in just three clusters in the United States. *Why did it emerge in these three communities?*

- 2) The initial dominant organizing logic was for small biotech firms to sell their lead research projects to multinational companies, who developed and sold them globally and garnered the lion's share of the rewards. We term this a Commercialization logic. Over time, the logic shifted to a Discovery logic, whereby DBFs obtained federal research support, university know-how and IP, and venture capital backing, and developed new medical products collaboratively. Eventually, most multinationals switched to this more relational, less transactional mode. *What accounts for this transformation, in which ostensibly weaker participants, or their practices, proved more resilient?*

## SPATIAL AGGLOMERATION

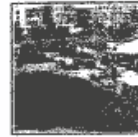
University commercialization activities can lead to economic growth.

**“Across America, high technology is creating localized boomlets like the one in Kendall Square, which is home to companies not only in the biotech sector but also in software and related fields.”**

But high-tech ‘booms’ center in but a few regions.

October 8, 1999

### Across the Country, Universities Generate a High-Tech Economic Boom



By CAREY GOLDBERG

**C**AMBRIDGE, Mass. -- Behold Kendall Square: 50-odd Cambridge acres long a fallow welter of former factories, now the flourishing center of what experts call the most concentrated single cluster of biotechnology in the world.

Behold it from, say, the muddy lot where Biogen Inc. broke ground this week on a new six-story laboratory. Within view lie the butterscotch-beige Genzyme building, the construction site of the coming Amgen building and a new complex housing smaller companies with typically futuristic names like Mitotix and Dyax and Variagenics, all new in the last few years, most connected in some way to two neighbors: the Massachusetts Institute of Technology and Harvard.

"Biotech as far as the eye can see," Janice Bourque, executive director of the industry's Massachusetts Biotechnology Council, proclaimed with a bit of broad-brush artistic license.

The much-trumpeted "knowledge" (or information, or innovation) economy has its own geography, and it consists of much more than Silicon Valley.

**Across America, high technology is creating localized boomlets like the one in Kendall Square, which is home to companies not only in the biotech sector but also in software and related fields.**

And if there is one never-absent factor at work on these silicon

## U.S. Dedicated Biotechnology Firms - 1988



## U.S. Dedicated Biotechnology Firms - 1998





## Geographic Agglomeration

The Boston, San Francisco Bay Area, and San Diego regions represent important hubs of the global biotechnology industry.

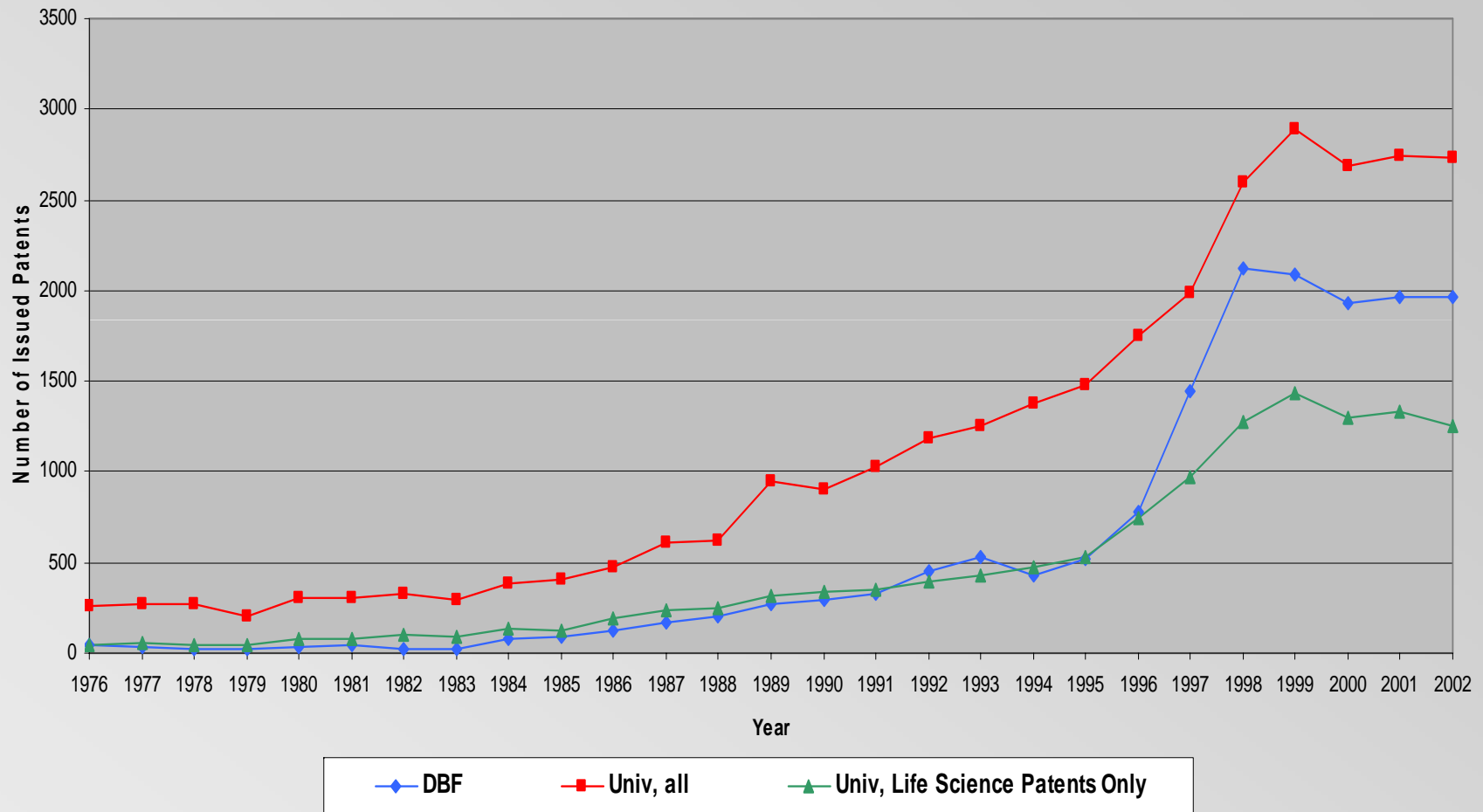
Firms in these major clusters have:

- have developed the bulk of new medicines
- produced well over half the patents issued to biotechnology firms
- make up more than 50% of the formal contractual relationships linking biotechnology firms to other organizations

- The standard arguments from economic geography for regional agglomeration stress:
  - Information spillovers – “the secrets of industry are in the air”
  - Increasing returns – concentrated supply of skilled labor, support services
- Such claims may account for successes, but don’t explain why some areas abundant in resources never take off. We add:
  - Relational Density – Networks channel information and resources, contributing to the generation of novel ideas. Density enables both “local buzz and global pipelines”
  - Institutional Diversity – for-profit, nonprofit, and public organizations foster a robust community ecology because they operate according to different rules

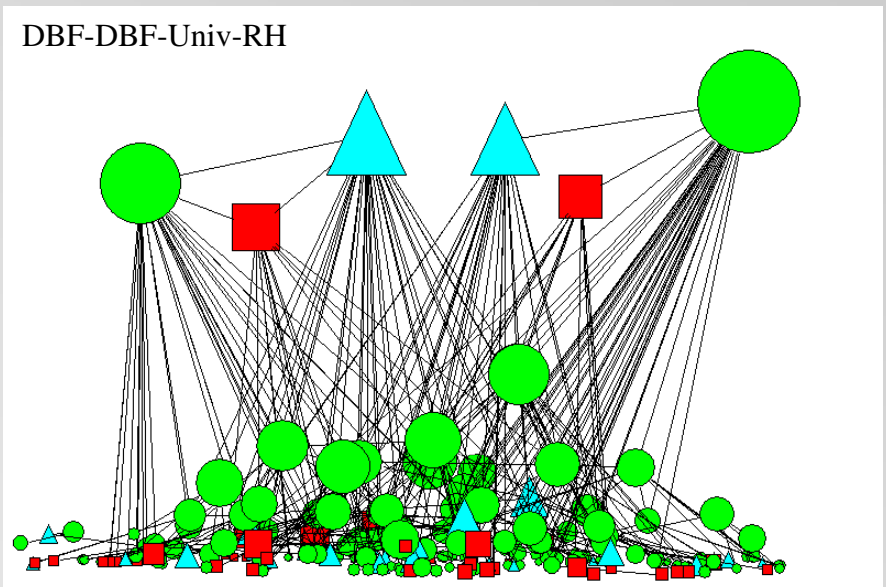
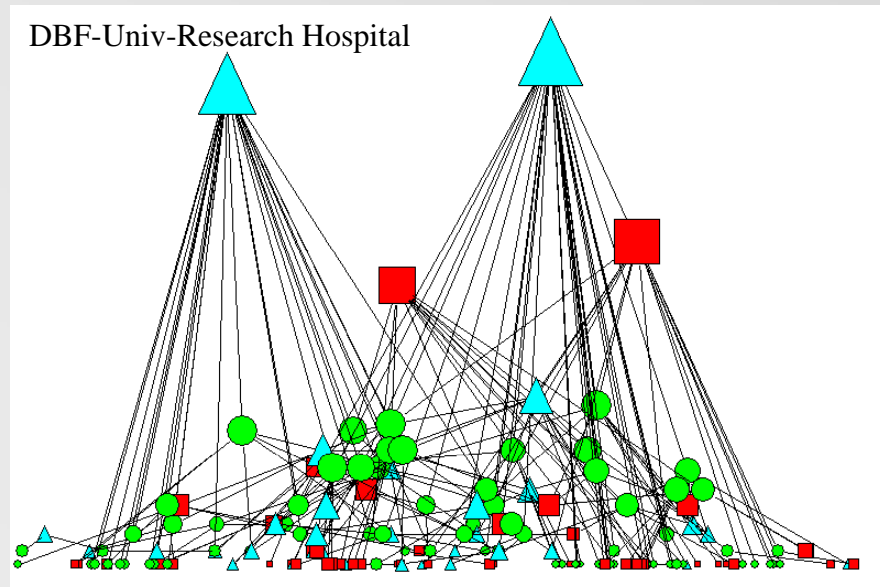
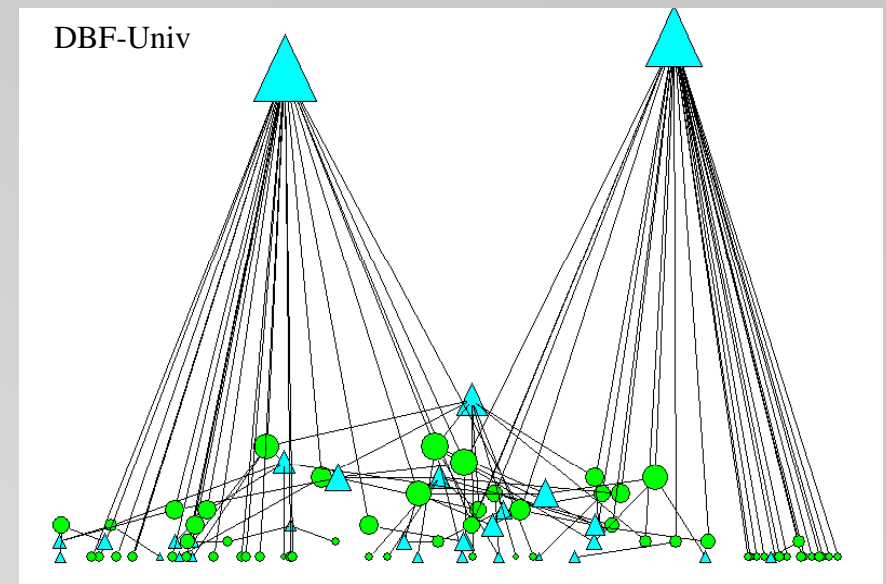
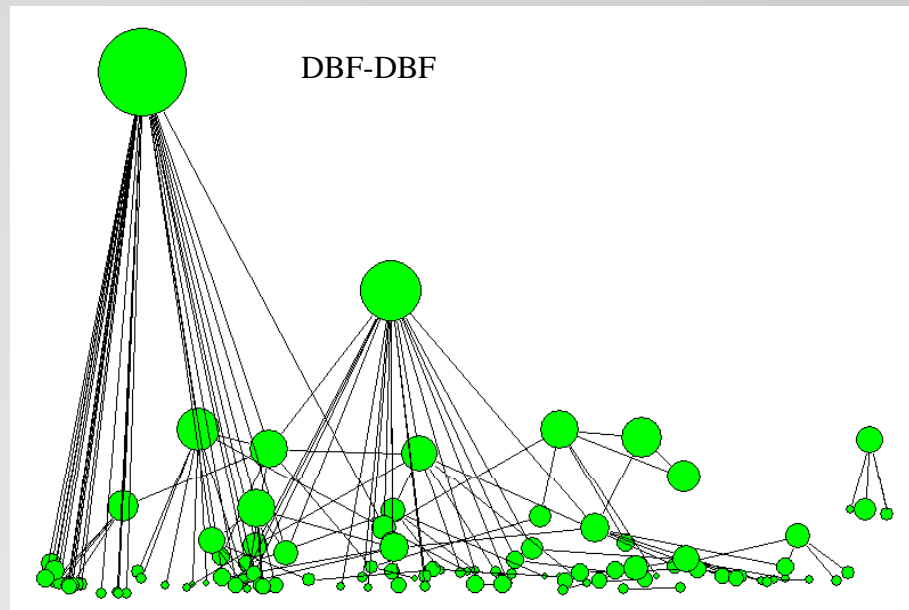
- **Relational density:**
  - Proximity, long-term relationships
  - Local norms for collaboration and knowledge-sharing
  - Forbearance and relational contracting
  - Competition *and* cooperation through repeated exchanges, fluid labor markets (“regionally bounded, relationally defined”)
  - Intense incubator for scientific ideas and business models, jockeying for success on meritocratic grounds
  
- **But what causes this density to catalyze a community?**
  - a) Cross-realm interaction (playing the science card in business world)
  - b) Diversity of organizational forms and practices; multiple organizational forms entail divergent selection environments, varied strategies, and different rules for information exchange
  - c) Anchor tenant - - commercial activity builds on the scaffolding of ties to other types of organizations.

## A) Cross-Realm Interaction: Research University and Biotech Company Patenting, 1976-2002



- Extensive cross-citation on patents (Owen-Smith and Powell, 2006)

## B) In Boston, organizational diversity drives innovation networks.



Source: Powell et al, *Minerva*, 2007

## C) The Public Science Anchor of the Boston Biotech Community

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All contractual ties involving DBFs or partner organizations located in Boston and all organizations, regardless of location, that are partners to those ties from 1988-1999.

### Within Boston

- 58 Dedicated Biotechnology Firms
- 19 Public Research Organizations
- 37 Venture Capital Firms
- 201 observed ties among 114 Boston area organizations.

**Note the diverse array of organizational forms (public, nonprofit, private, large and small). Recall Lindblom (1977): Markets are like a hand with only fingers, while states are all thumbs.**

### Boston Plus

- 212 Dedicated Biotechnology Firms
- 96 Public Research Organizations
- 240 Venture Capital Firms
- 24 Governmental Agencies
- 168 Pharmaceutical/Healthcare Companies
- 1559 observed ties among 740 organizations with at least one connection to a Boston area organization

# Methods: Visualizing Social Networks With Pajek

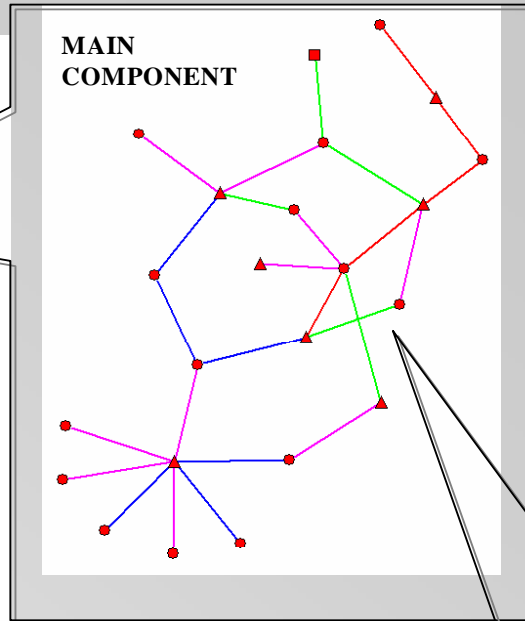
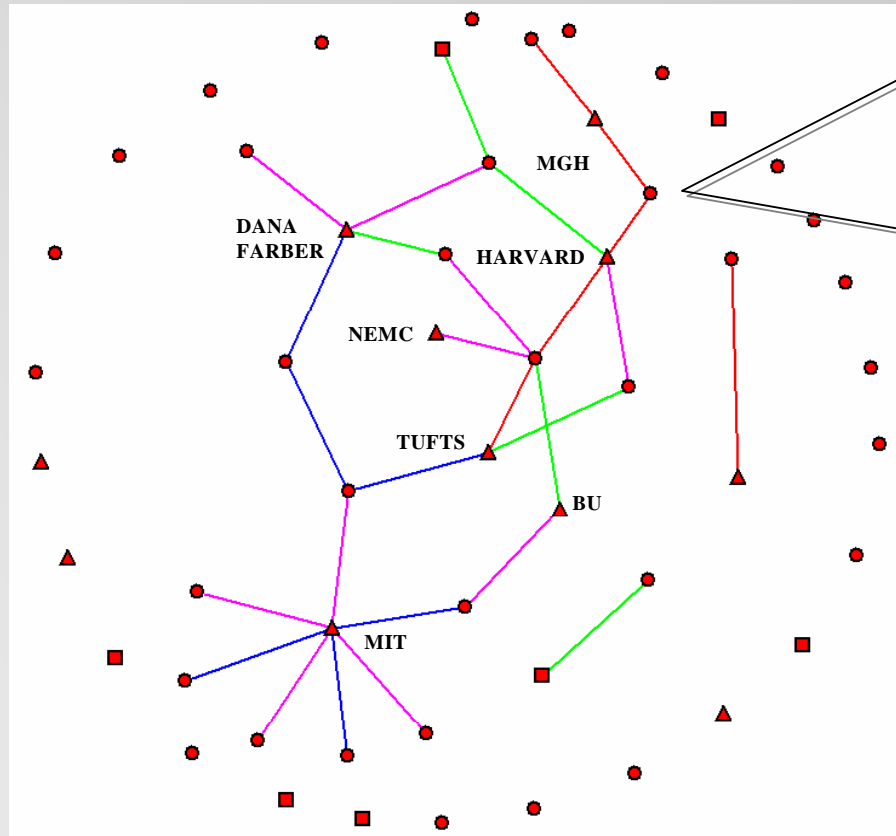
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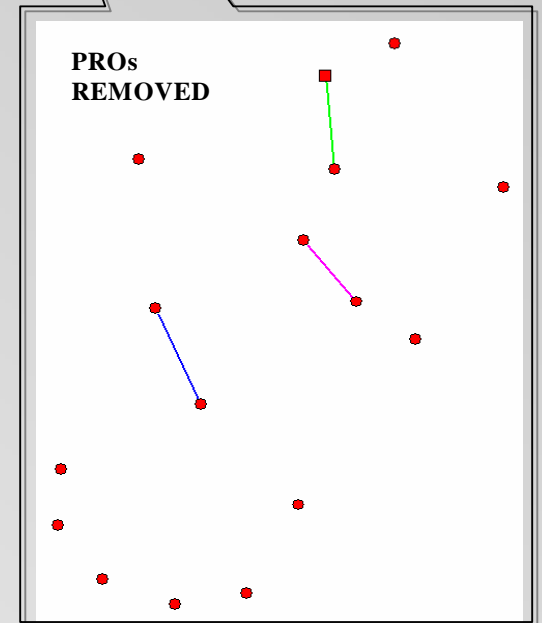
*Pajek* (Slovenian for ‘Spider’) is a freeware package for the analysis and visualization of large networks created by Vladimir Batagelj and Andrej Mrvar and available online at <http://vlado.fmf.uni-lj.si/pub/networks/pajek/>

- Ø In Pajek, ‘spring-embedded’ network drawing algorithms enable meaningful representation of social networks in Euclidean space.
  - ‘Particles’ repel one another, ‘springs’ draw attached particles together
  - Drawing algorithms seek a ‘solution’ where the energy of the entire system is minimized
  - In these representations, the positions of nodes are generated by the pattern of ties connecting the entire system
- Ø We draw on two such algorithms
  - Fruchterman-Reingold (FR) (1991) optimizes network configurations without reference to graph-theoretic conceptions of distance
  - Kamada-Kawai (KK) (1989) positions connected nodes adjacent to one another and makes euclidean distances proportional to geodesic path length in the network

**Figure 1. Boston Network, 1988**



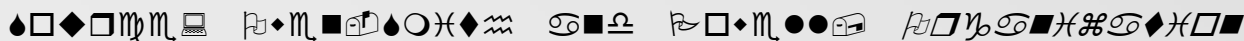
**42.9% Of  
Boston  
DBFs  
Reachable**



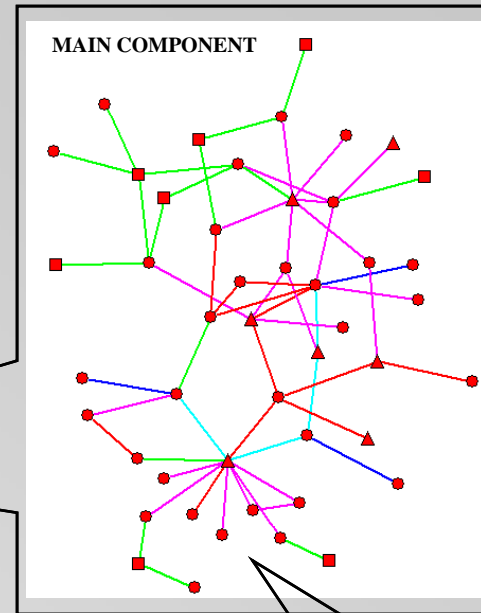
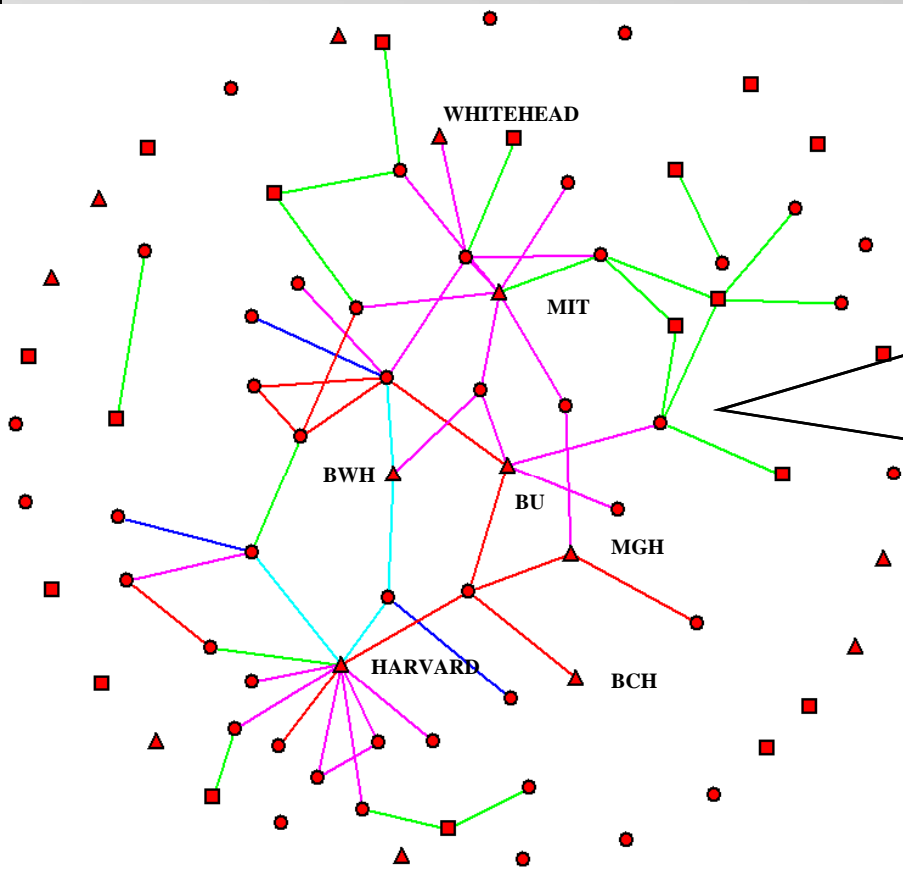
**0.0% of  
Boston  
DBFs  
Reachable**

**Node Key:**

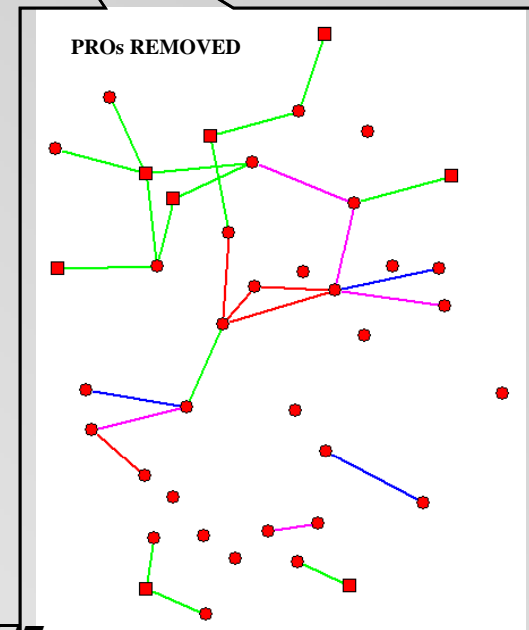
- Circles = DBFs
- Triangles = PROs
- Squares = VCs
- Diamonds = Pharma



**Figure 2. Boston Network, 1998**



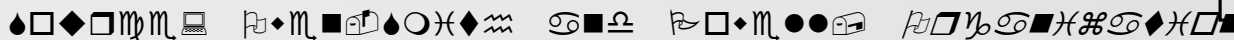
71.1% of Boston DBFs reachable



35.6% of Boston DBFs reachable

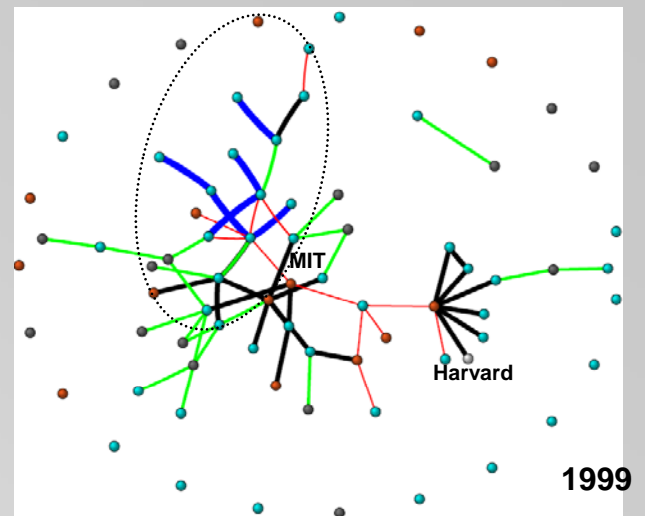
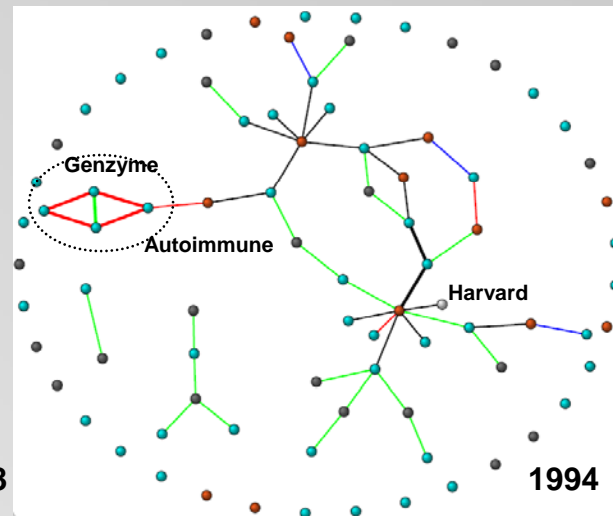
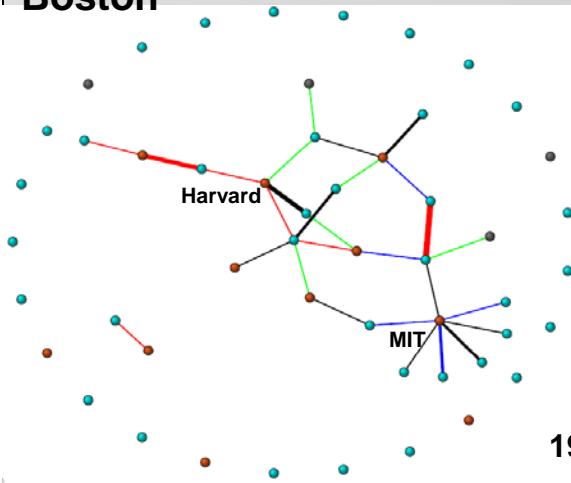
**Node Key:**

- Circles = DBFs
- Triangles = PROs
- Squares = VCs
- Diamonds = Pharma
- Red = Boston
- Gray = Other Area

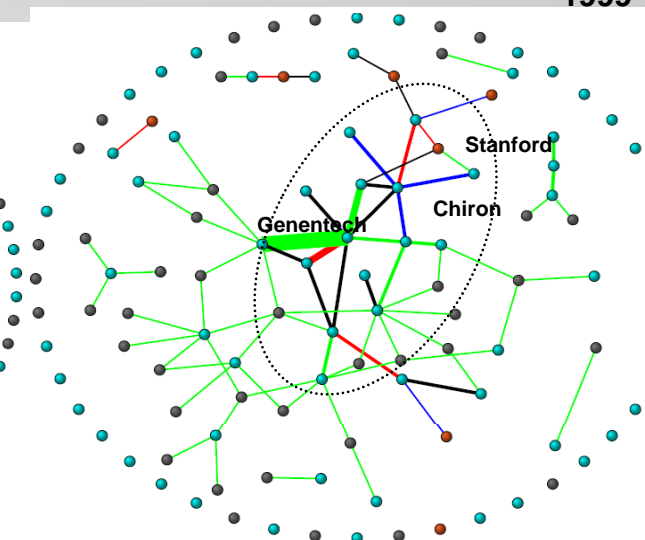
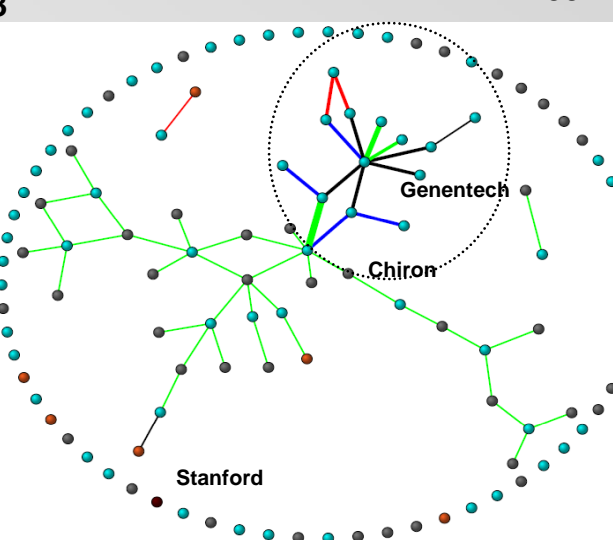
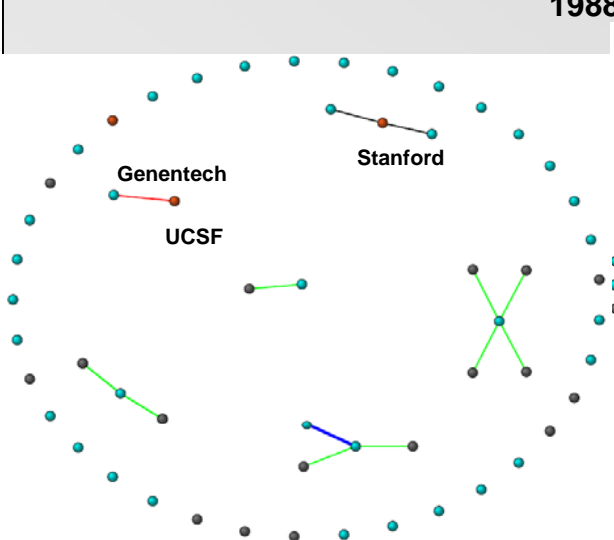


# Boston and Bay Area Networks, 1988, 1994, 1999

## Boston



## Bay Area



## Comparison to Bay Area and San Diego

- Different organization forms, but similar processes of density and diversity
- Bay Area:
  - 1<sup>st</sup> generation companies emerged from academic laboratories. These companies collaborated intensively with ostensible competitors (invisible college model in world of commerce).
  - Key role of venture capital as linchpin
  - Universities joined in as academic entrepreneurs
- San Diego (Steve Casper's research, 2007):
  - 1<sup>st</sup> generation company - - Hybritech, that was acquired by Eli Lilly; its employees left to found 50+ new companies
  - Central role of Nonprofit Public Research Organizations – Scripps, Salk, Burnham, UCSD
  - Entry of Silicon Valley venture capital, first as branch offices, later as local companies

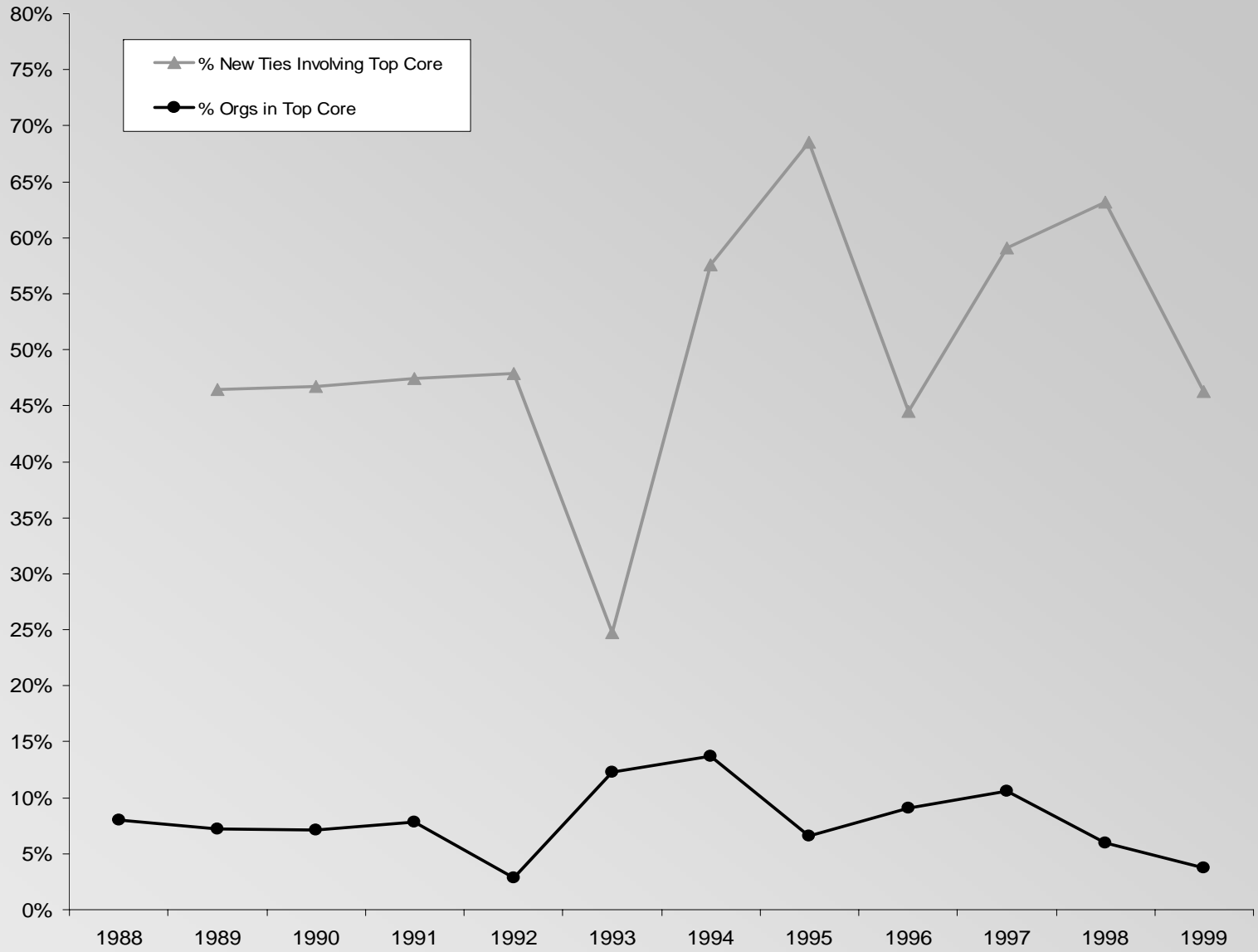
- Universities contribute to industry emergence because they perform commercially relevant research under academic institutional norms (public science).
- Venture capitalists not only help found and finance firms, they transfer knowledge and skills across companies.
- Both enhance openness and flow, expand the size of the community, and catalyze interaction.

- In Kendall Square (Cambridge, MA) and La Jolla, CA, large multinationals moved their R&D labs into these clusters in the early years of the 21<sup>st</sup> century (in one case as a NP subsidiary!).
- These moves reflect the new discovery logic. Let's turn to the second puzzle. How did dominant logic change and a new one emerge? Lots of organizational theory and strategy thinking would suggest this development is unlikely.

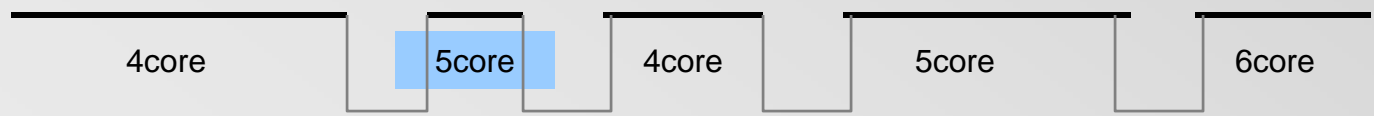
We have argued that biotechnology is characterized by an open elite that is diverse with respect to organizational form, age, and size (Powell et al, 2005). These organizations prospect widely for novelty. But what accounts for the development of a logic of attachment that is responsive to, rather than resistant to, challengers, and adopts a collaborative rather than a control orientation?

To explore this question, we use a type of natural experiment: the formation of a concentrated “core” in 1992 and again in 1998. (Think Moody and White 2003, with k-cores as measures of cohesion.) The core in 1992 did not hold, but the one in 1998 did. What kind of business strategies and “relational glue” typified these different groups?

### Figure 3. A Natural Experiment: Key Elite Transitions



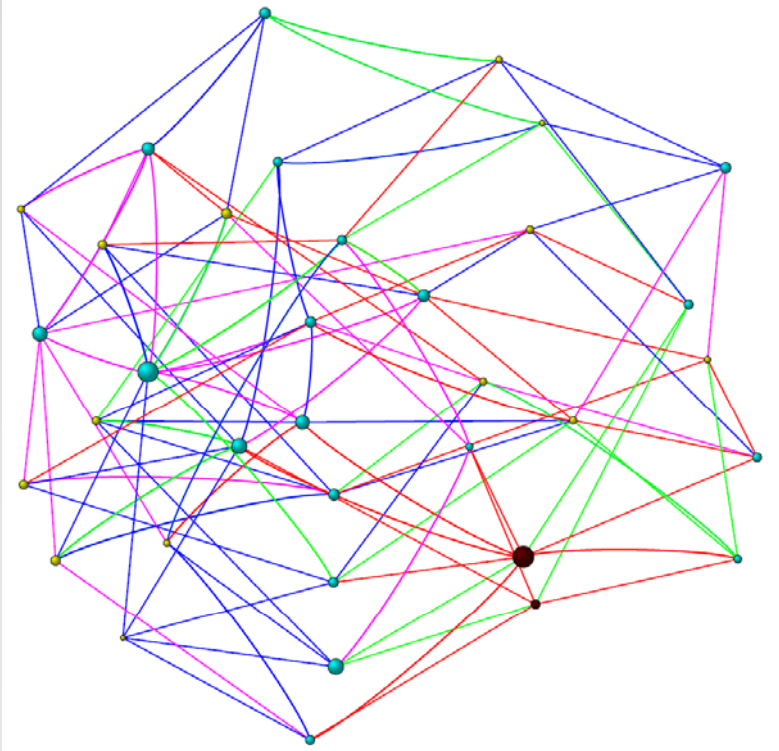
Highest Cohesion Level



Structural Transition

Consolidation    Decay    Consolidation    Consolidation

Figure 4. A Fragile and A Robust Elite 1992 & 1998

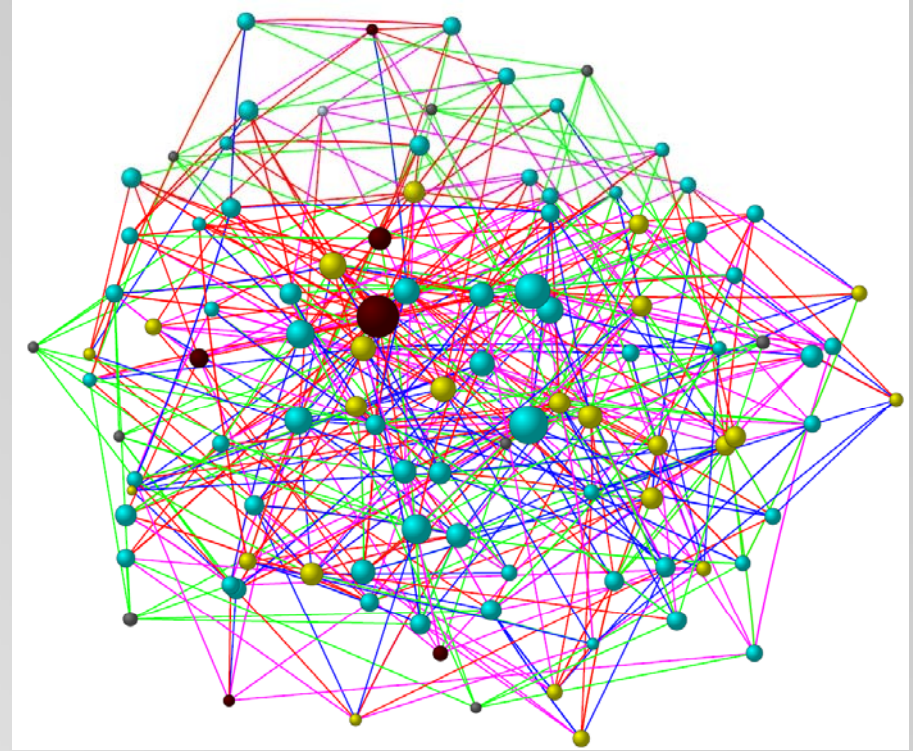


1992, A Fragile Elite

**Activity Key**

- Red = Science
- Green = Finance
- Blue = Commerce
- Magenta = Licensing

Dominated by large multinationals, little organizational diversity, commercialization is the core activity



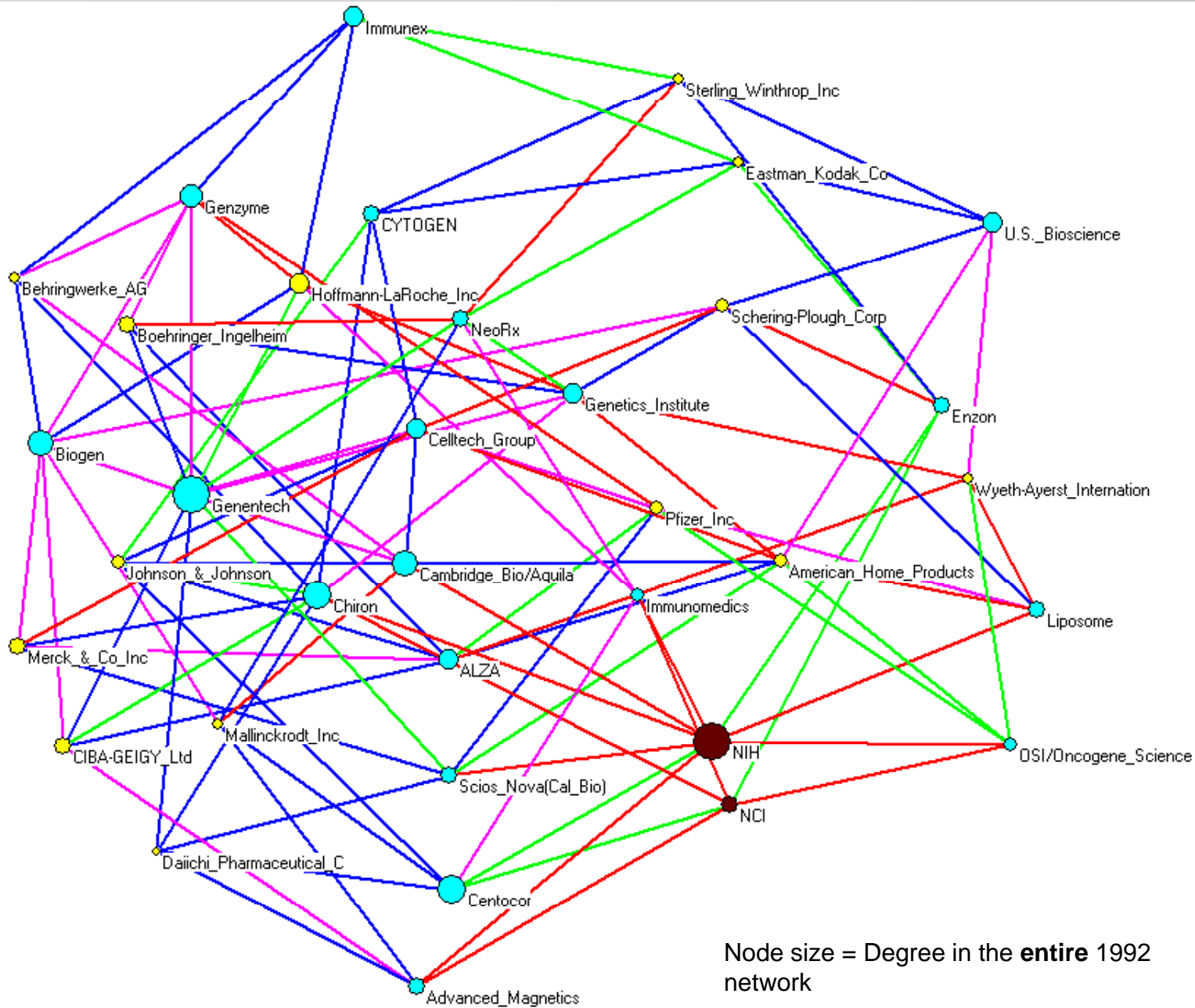
1998, A Robust Elite

**Node Key**

- Cyan = DBF
- Brown = Public
- Green = VC
- Yellow = Pharmaceutical
- Size = Prior Year Degree

Greater mix of org. forms – large and small firms, government institute NIH at center, research universities, and venture capital. Still commercial– but with a different logic.

# Ties Among 1992 5-core Members



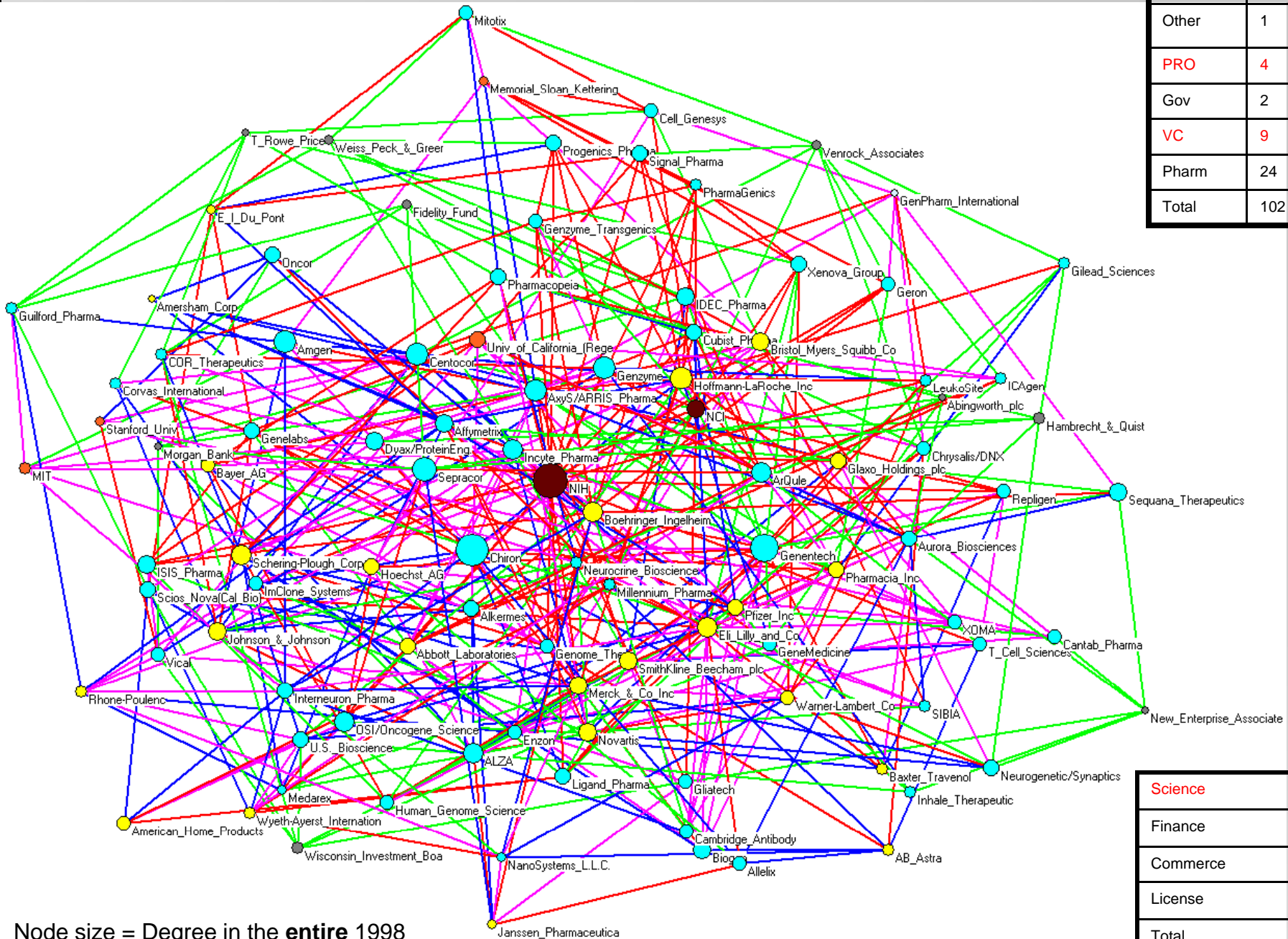
nodes

DBF	19
Other	0
PRO	0
Gov	2
VC	0
Pharm	14
Total	35

ties

Science	36
Finance	34
Commerce	60
License	34
Total	164

# Ties Among 1998 6-core members



DBF	62
Other	1
PRO	4
Gov	2
VC	9
Pharm	24
Total	102

Science	256
Finance	143
Commerce	153
License	166
Total	719

Node size = Degree in the entire 1998 network

- Conclusions:
  - Ability to pursue multiple activities with diverse partners precludes ossification and lock in, while providing access to promising new entrants
  - Scientific networks provide the skeleton for an open elite that prospers rather than preserves
  - The motor of openness is both institutional and ecological - - powered by the diversity of logics and selection environments represented by different organizational forms
- Common mechanism in diverse inquiries - - multiconnectivity; heterarchy (Stark, 1996); robust action (Padgett and Ansell, 1993).
- Limitations:
  - Public research organizations most typically serve as an organizational/institutional commons when their R&D is critical to the continuing development of new technologies.

## Recent Papers

- Owen-Smith & Powell (2004) “Knowledge Networks as Channels and Conduits: The Effect of Formal Structure in the Boston Biotechnology Community.” *Organization Science* 15(1): 5-21.
- Powell et al. (2005) “Network Dynamics and Field Evolution: The Growth of Interorganizational Collaboration in the Life Sciences.” *American Journal of Sociology* 110,4 (Jan.): 1132-1205.
- Owen-Smith and Powell (2006) “Accounting for Emergence and Novelty in Boston and Bay Area Biotechnology.” In P. Braunerhjelm & M. Feldman (eds.) *Cluster Genesis: The Emergence of Technology Clusters and Their Implications for Government Policy*, Oxford University Press.
- Powell, Owen-Smith, and Colyvas (2007) “Innovation and Emulation: Lessons from American Universities in Selling Private Rights to Public Knowledge.” *Minerva* 45: 121-42.
- Owen-Smith and Powell (2008) “Networks and Institutions.” *Handbook of Organizational Institutionalism*, R. Greenwood, ed., Sage.