

# Mapping the Evolving Interface of Mainstream Chemistry and the Fields of Biochemistry, Biology, and Bioengineering

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(Collaborative work with Kevin W. Boyack & Richard Klavans)

*2:35-3:10 pm, May 22, 2007 @ NetSci*

CHE-0524661



## Outline

- Mapping Science
- Cyberinfrastructure Development
- Case Study: Mapping Chemistry

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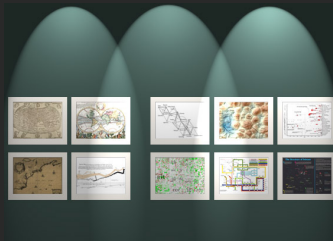
- Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains.** In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology, Volume 37*, Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, chapter 5, pp. 179-255.
- Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains.** *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl\_1).
- Börner, Katy, Sanyal, Soma and Vespignani, Alessandro (in press). **Network Science.** In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology, Information Today, Inc./ American Society for Information Science and Technology, Medford, NJ, volume 41, chapter 12, pp. 537-607.*



• Online at <http://scimaps.org>

# The Power of Maps

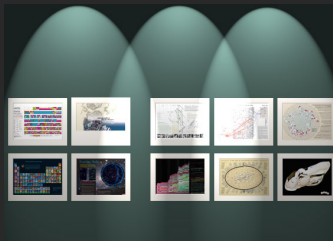
Four Early Maps of Our World  
VERSUS  
Six Early Maps of Science



*(1st Iteration of Places & Spaces Exhibit - 2005)*

# The Power of Reference Systems

Four Existing Reference Systems  
VERSUS  
Six Potential Reference Systems of Science



*(2nd Iteration of Places & Spaces Exhibit - 2006)*

## Illuminated Diagram Display



TOPIC MAP: HOW SCIENTIFIC PARADIGMS RELATE

GEOGRAPHIC MAP: WHERE SCIENCE GETS DONE

You may run your finger over each of these maps to control the lighting on the other: touching a place on the world map will light up topics studied in that place; touching a paradigm on the topic map will light up the places that study that topic.

### Nanotechnology

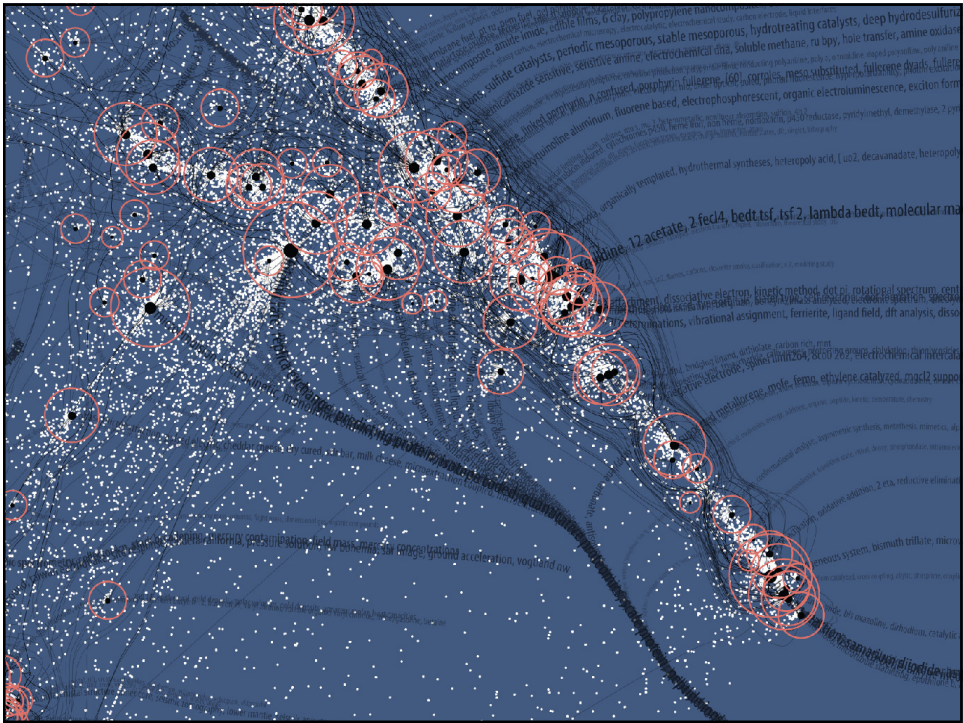
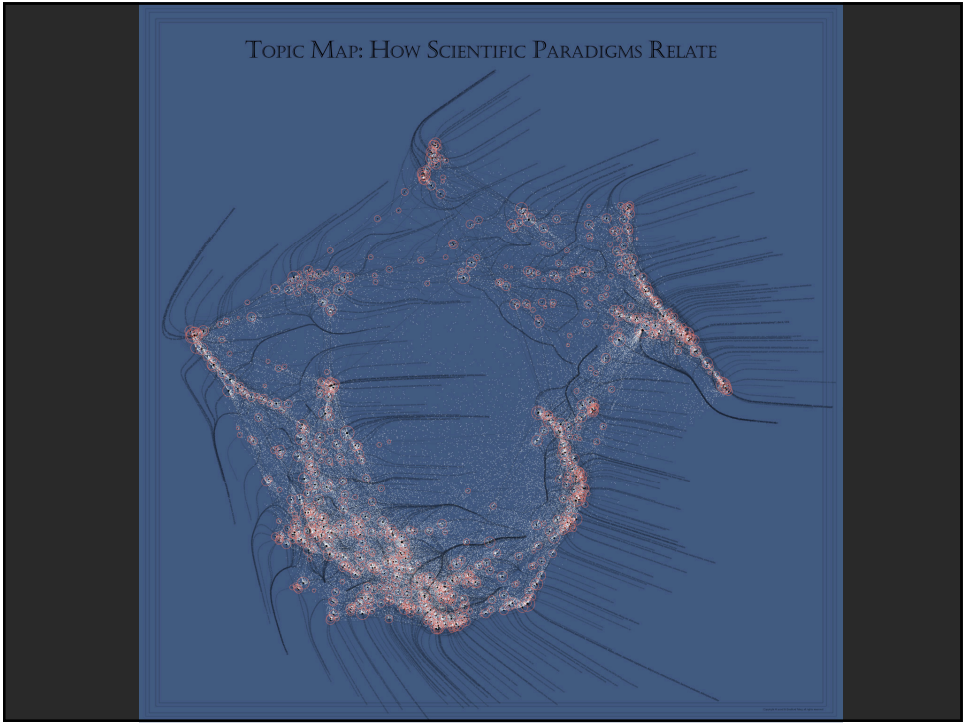
This overlay shows the distribution of nanotechnology within the paradigms of science. The majority of current work in nanotechnology takes place in physics, chemistry, and materials science, at the upper right portion of the map. However, an increasing amount of nanotechnology is being applied in the biological and medical sciences, at the lower right.

<p><b>All Topics</b></p> <p><i>Sweep through all 776 scientific paradigms</i></p>	<p><b>Nanotechnology</b></p> <p><i>Science on the tiny scale of molecules</i></p>	<p><b>Francis H. C. CRICK</b></p> <p><i>Co-discovered DNA's double helix</i></p>	<p><b>Albert EINSTEIN</b></p> <p><i>Revitalized physics with Relativity theories</i></p>	<p><b>Michael E. FISHER</b></p> <p><i>Models critical phase transitions of matter</i></p>	<p><b>Susan T. FISKE</b></p> <p><i>Connects perception and stereotypes</i></p>
<p><b>Sustainability</b></p> <p><i>The science behind our long-term hopes</i></p>	<p><b>Biology &amp; Chemistry</b></p> <p><i>The interface between these two vital fields</i></p>	<p><b>Joshua LEDERBERG</b></p> <p><i>Pioneer in bacterial genetic mechanisms</i></p>	<p><b>Derek J. de Solla PRICE</b></p> <p><i>Known as the "Father of Scientometrics"</i></p>	<p><b>Richard N. ZARE</b></p> <p><i>Uses laser chemistry in molecular dynamics</i></p>	<p><b>About this display</b></p> <p><i>People &amp; organizations that helped create it</i></p>

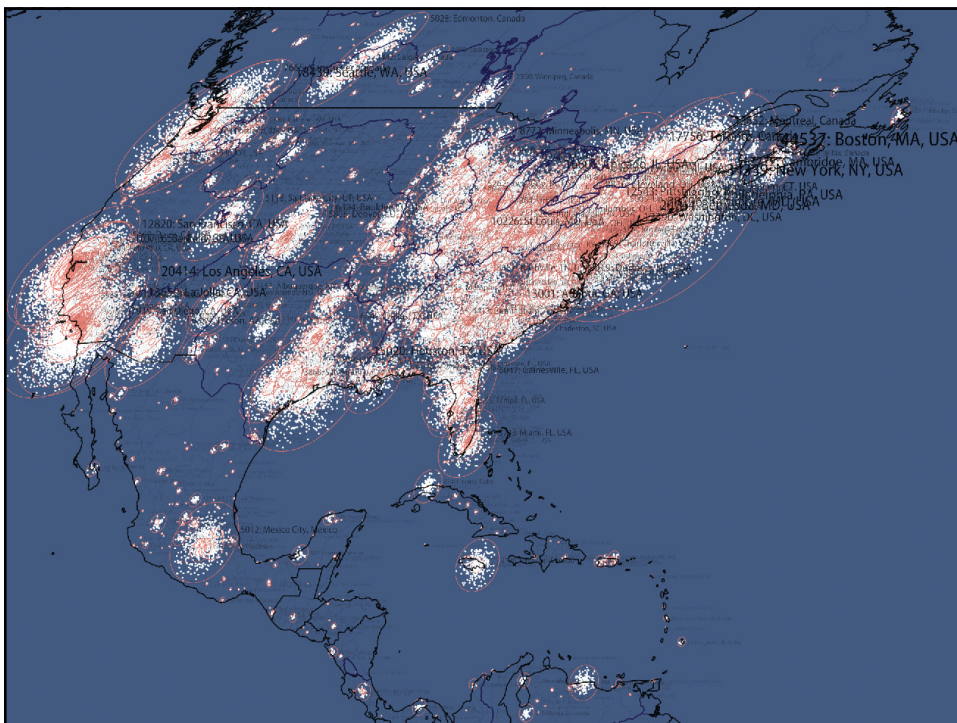
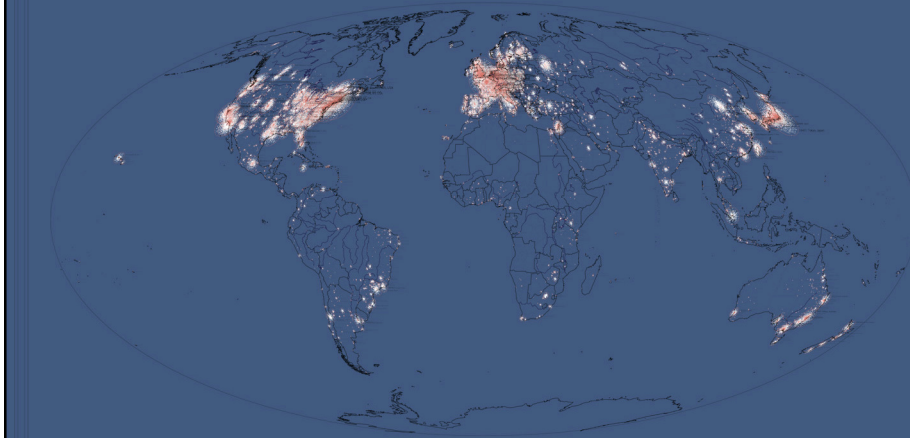
*We sweep slowly through adjoining related topics, lighting up the places in the world that study each topic. You may select a subset of the topics that deal with these three interesting subjects by touching it.*

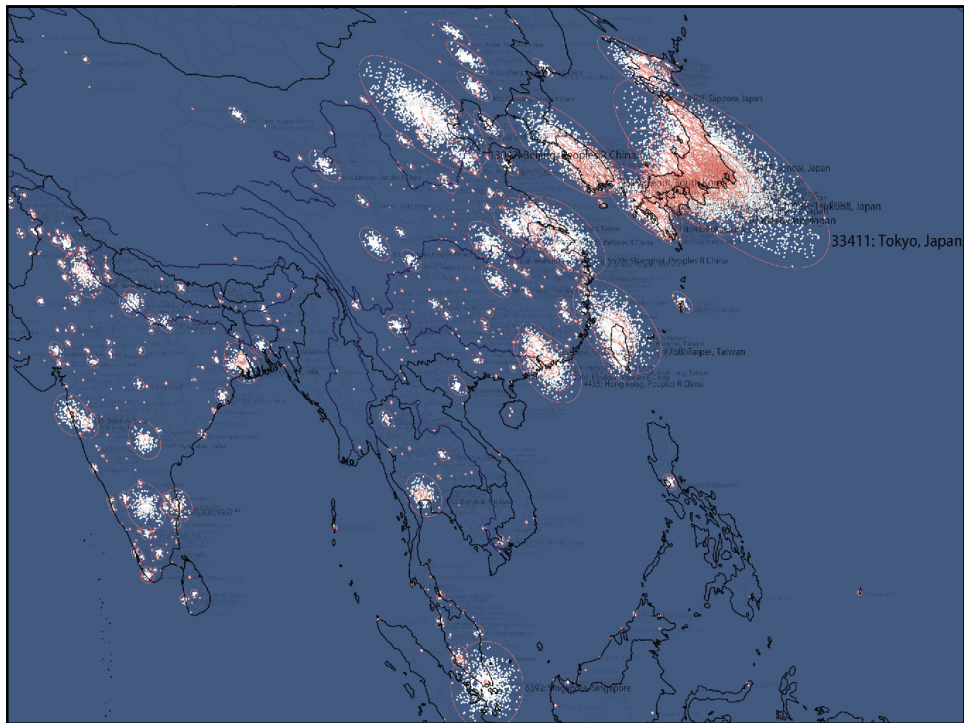
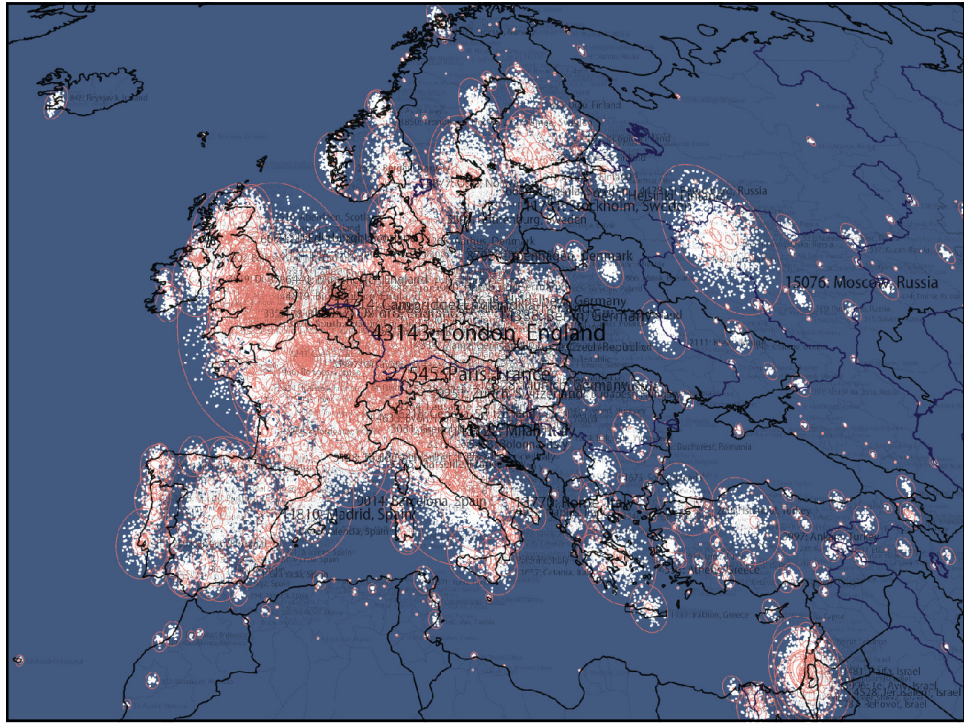
*A single person's spreading influence is shown as a series of four snapshots. First, we light only topics and places relating to that person's papers—papers that are still highly cited today. The second lights everything that cites that original work. Note that this first-generation impact extends to far more topics than did the original work. The third snapshot lights science that cites the second; and the fourth lights science that cites the third.*

# TOPIC MAP: HOW SCIENTIFIC PARADIGMS RELATE



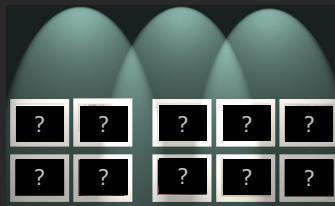
## GEOGRAPHIC MAP: WHERE SCIENCE GETS DONE





# The Power of Forecasts

## Four Existing Forecasts VERSUS Six Potential Science 'Weather' Forecasts



(3<sup>rd</sup> Iteration of Places & Spaces Exhibit - 2007)

**Chart toppers**  
An exhibition epicure's diverse ways of putting data on the map.

**SEED**  
The Current Issue  
SCIENTIFIC METHOD: F  
AMONG SCIENTIFIC PA

**BRILLIANT DISPLAY**  
From a jewel-like bird, rarer than any diamond, to the delicately poetic swirls generated inside aircraft engines, the pursuit of knowledge turns up its fair share of beauty. This issue, Nature wraps up the year with an arresting series of images from 2006. We've divided them into the art of the natural world, planet-scapes both domestic and extraterrestrial, and the splendour of modern technology. Just because something enhances our knowledge doesn't mean it can't also be bewitching.

**2006 GALLERY**

**How Scientific Paradigms Relate**  
Journal written by Allen54 (180866) and posted by klawson on Tuesday March 20 in the connections dept.

...is a giant chart mapping relationships among scientific paradigms, as published in the journal Nature. This map was constructed by sorting roughly 0,000 published papers into 776 different scientific paradigms (shown as pale circular nodes) based on how often the papers were cited together by authors of their papers. Information Esthetics, an organization founded by map co-creator Bradford Pal... of the chart... makes th... inferences.

**A MAP OF SCIENCE**  
Sunda National Laboratories - Netpage

**Mapping SCIENCE**  
Map shows how scientific papers and books relate



## Outline

- Mapping Science
- Cyberinfrastructure Development
- Case Study: Mapping Chemistry

**SDB SCHOLARLY DATABASE**

# SCHOLARLY DATABASE

SEARCH INTERFACE: <https://iv.slis.indiana.edu/db/>  
DOCUMENTATION: <http://iv.slis.indiana.edu/db/>

**DB PROJECT LEAD**  
Gavin LaRowe  
[glarowe@indiana.edu](mailto:glarowe@indiana.edu)

**DB DEVELOPER**  
Sumee! Ambre  
[sambre@indiana.edu](mailto:sambre@indiana.edu)

**PROJECT MANAGER**  
Katy Börner

**STATUS**  
as of 06.08.28

Information Visualization Laboratory  
Cyberinfrastructure for Network Science Center  
School of Library and Information Science  
Indiana University  
Bloomington, IN 47405, USA

**DOCUMENT TABLE**

**PAPERS**

- SDB MEDLINE
- SDB PHYSREV
- SDB PNAS
- SDB JCR

**PATENTS**

- SDB USPATENTS

**KNOWLEDGE WEBS**

- SDB WIKI

**GRANT AWARDS**

- SDB NSF
- SDB NIH

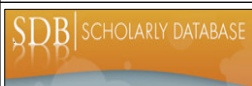
**FUNDING OPPORTUNITIES**

- SDB CCS

DESIGN BY ELISHA HARDY

Börner: "Mapping the Evolving Interface of Mainstream Chemistry and the Fields of Biochemistry, Biology, and Bioengineering."

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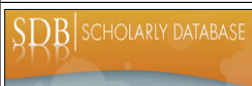
## Scholarly Database: Web Interface

Search across publications, patents, grants.

Download records and/or (evolving) co-author, paper-citation networks.

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## Scholarly Database: # Records & Years Covered

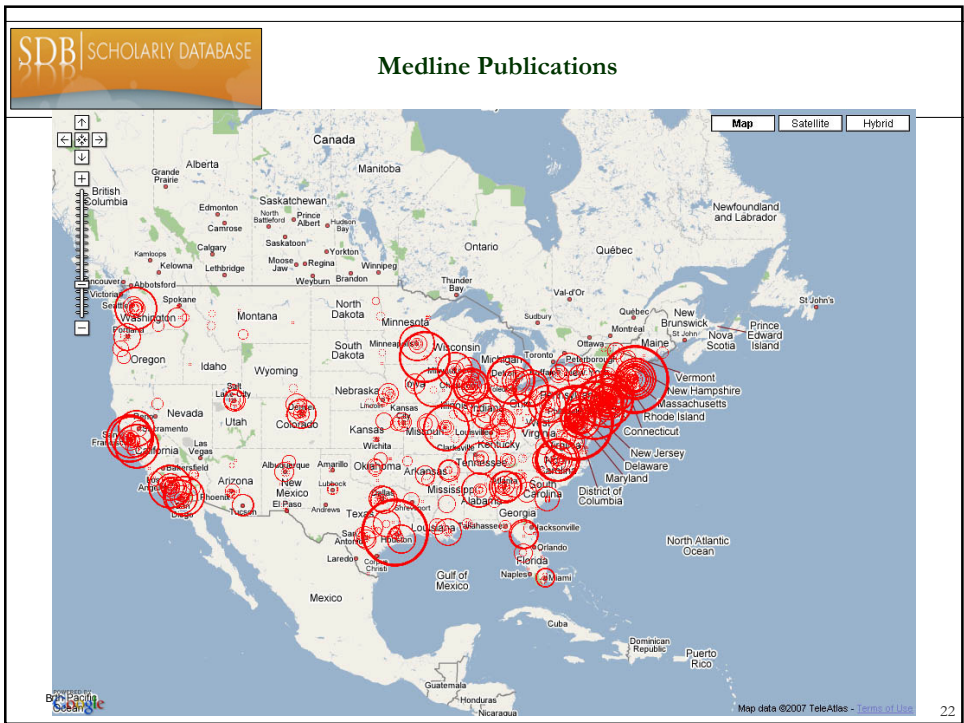
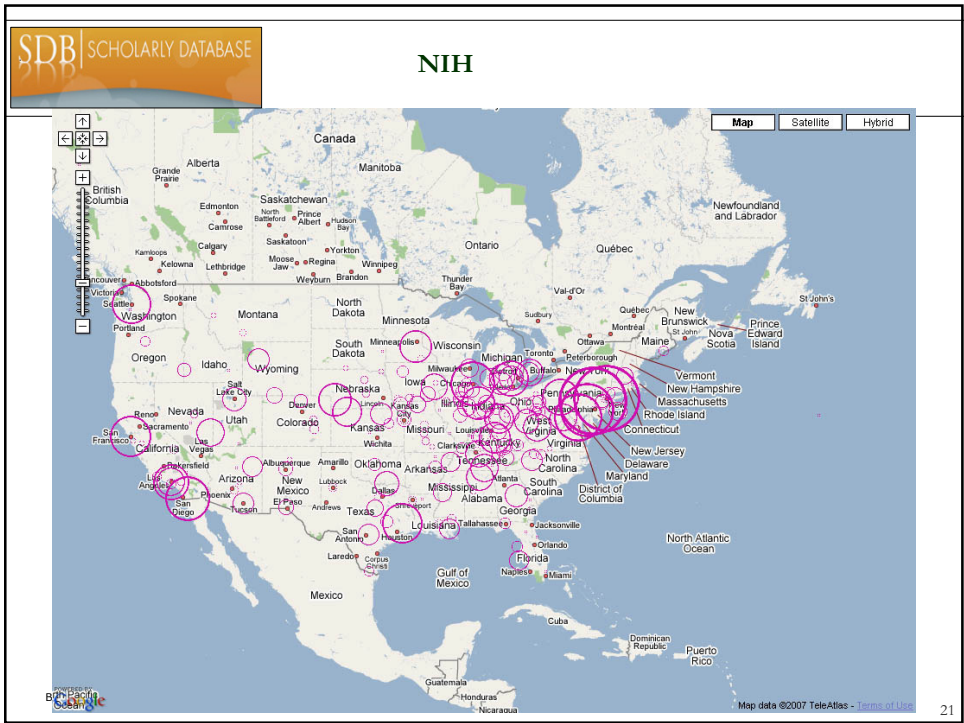
Datasets available via the Scholarly Database (\* future feature)

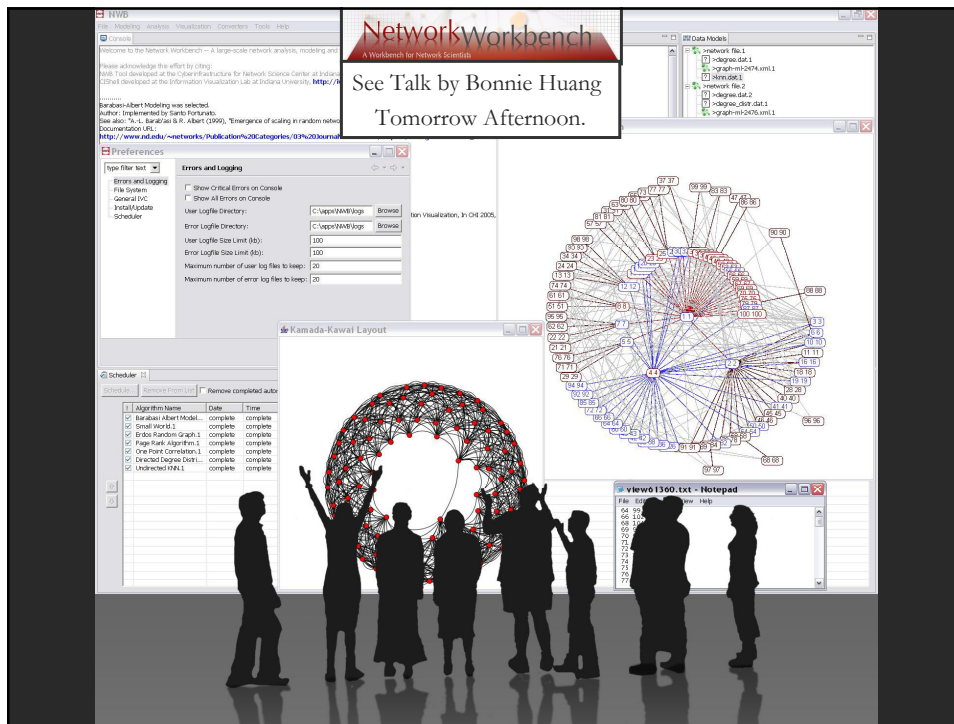
Dataset	# Records	Years Covered	Updated	Restricted Access
Medline	13,149,741	1965-2005	Yes	
PhysRev	398,005	1893-2006		Yes
PNAS	16,167	1997-2002		Yes
JCR	59,078	1974, 1979, 1984, 1989 1994-2004		Yes
USPTO	3,179,930	1976-2004	Yes*	
NSF	174,835	1985-2003	Yes*	
NIH	1,043,804	1972-2002	Yes*	
<b>Total</b>	<b>18,021,560</b>	<b>1893-2006</b>	<b>4</b>	<b>3</b>

Aim for comprehensive geospatial and topic coverage.

Börner: "Mapping the Evolving Interface of Mainstream Chemistry and the Fields of Biochemistry, Biology, and Bioengineering."

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Boyaek, Kevin W., Börner, Katy and Klavans, Richard. Mapping the Structure and Evolution of Chemistry Research, Accepted for 11th International Conference on Scientometrics and Informetrics, Madrid, Spain, June 25-27, 2007.

Boyaek, Kevin W., Klavans, Richard and Börner, Katy. (2005). Mapping the Backbone of Science. *Scientometrics*. 64(3), 351-374.



## Why map science and/or chemistry?

- How does our collective scholarly knowledge grow over time?
- What major areas of science exist and how are they interlinked?
- Which areas are major knowledge producers; which ones are consumers?

Computational scientometrics – the application of bibliometric/scientometric methods to large-scale scholarly datasets – and the communication of results via maps of science might help us answer these questions.

- Chemistry is a field that is undergoing significant change. Interdisciplinary research has increased over time and the lines between chemistry and the life sciences have seemingly blurred.
- This study maps the structures of *Chemistry*, *Biochemistry*, *Biology*, and *Bioengineering*, and their interactions over 30 years using journal citation patterns.

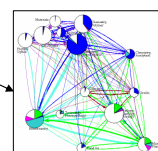
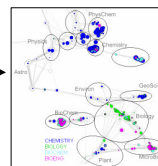
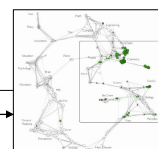
Börner: "Mapping the Evolving Interface of Mainstream Chemistry and the Fields of Biochemistry, Biology, and Bioengineering."

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## How to map science and/or chemistry?

1. **Base Map.** Information from the combined Science (SCIE) and Social Science (SSCI) Citations Indexes from 2002 was used to generate a disciplinary map of 7,227 journals and 671 journal clusters.
2. **Chemistry Disciplines.** Clusters relevant to study the structure and evolution of chemistry were identified using JCR categories and were further clustered into 14 disciplines.
3. **Knowledge Diffusion among Disciplines.** The changing scientific composition of these 14 disciplines and their knowledge exchange via citation linkages was computed. The result is visually communicated using the 2002 map of science introduced in 1.)
4. **Discussion.** Major changes on the dominance, influence, and role of *Chemistry*, *Biology*, *Biochemistry*, and *Bioengineering* over these 30 years are discussed. We conclude with a discussion and suggestions for future work.



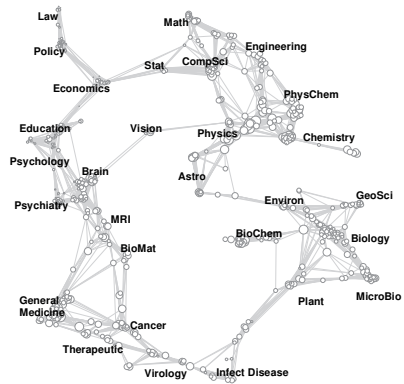
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## 2002 Paper-Level Base Map

- **Combined SCIE/SSCI from 2002**
  - 1.07M papers, 24.5M references, 7,300 journals
  - Bibliographic coupling of papers, aggregated to journals, counts are normalized using cosine index.
- **First step**
  - remove 25 multidisciplinary journals (MD)
  - run graph layout and clustering on remaining journals
  - resulting in 646 clusters
- **Second step**
  - add MD journals back as single-journal clusters, total is now 671 clusters
  - re-aggregate coupling counts at the cluster level
  - layout positions of 671 clusters using VxOrd
  - by association, this gives x,y positions for each journal



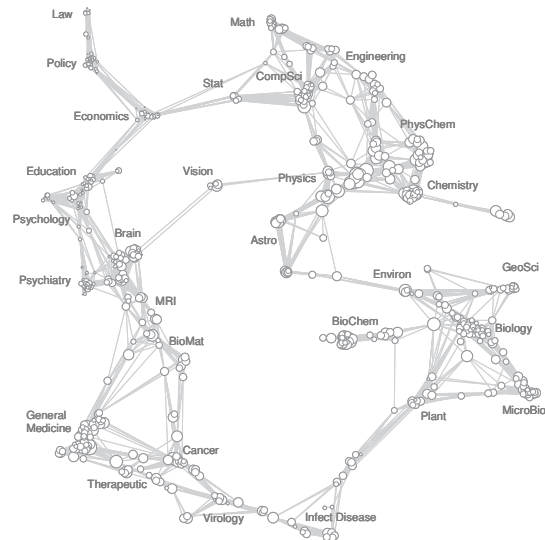
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## 2002 Base Map

Node – cluster of journals  
Edge – similarity of journal clusters based on bibliographic coupling.



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## Identify Chemistry Areas

- JCR data for 1974, 1979, 1984, 1989 | 1993-2004
- JCR categories for journals

Field	JCR Categories
Chemistry	DW – Chemistry, Applied DX – Chemistry, Medicinal DY – Chemistry, Multidisciplinary EA – Chemistry, Analytical EC – Chemistry, Inorganic & Nuclear EE – Chemistry, Organic EI – Chemistry, Physical HQ – Electrochemistry II – Engineering, Chemical GC – Geochemistry & Geophysics UH – Physics, Atomic, Molecular & Chemical
Biology	CU – Biology CX – Biology, Miscellaneous DR – Cell Biology HY – Developmental Biology HT – Evolutionary Biology PI – Marine & Freshwater Biology QU – Microbiology WF – Reproductive Biology
Biochemistry	CO – Biochemical Research Methods CQ – Biochemistry & Molecular Biology individual journals: Science, Nature, PNAS
Bioengineering	DA – Biophysics IG – Engineering, Biomedical DB – Biotechnology & Applied Microbiology QE – Materials Science, Biomaterials

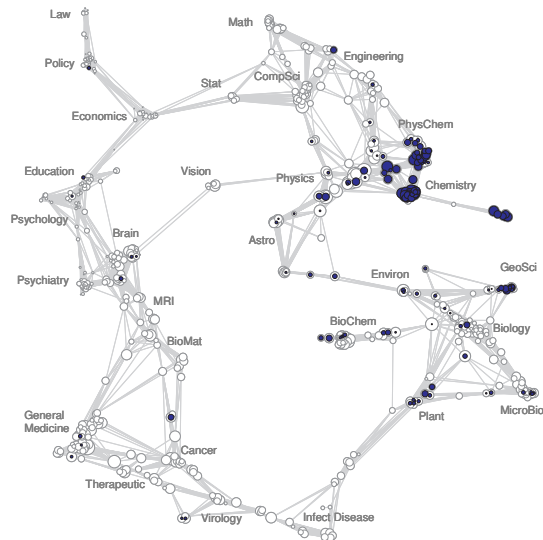
- Split paper counts among fields. If there are 64 papers in *Bioelectrochemistry*, each of the four fields will get 16 papers.

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## Chemistry on the 2002 Base Map

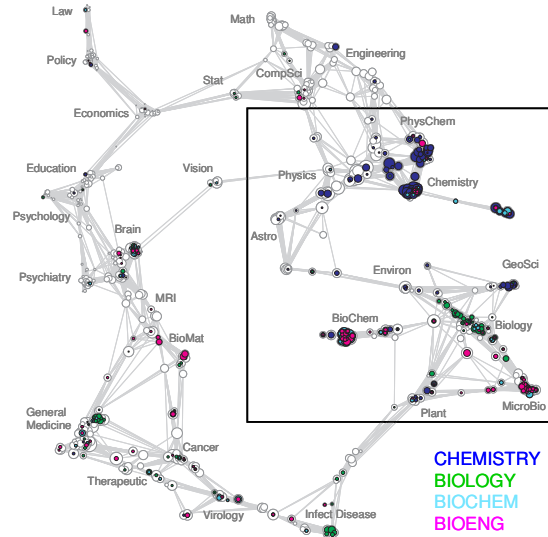


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### Four fields on the 2002 base map

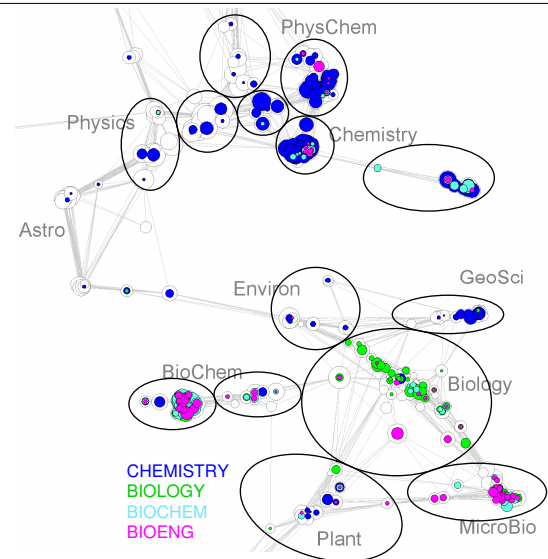


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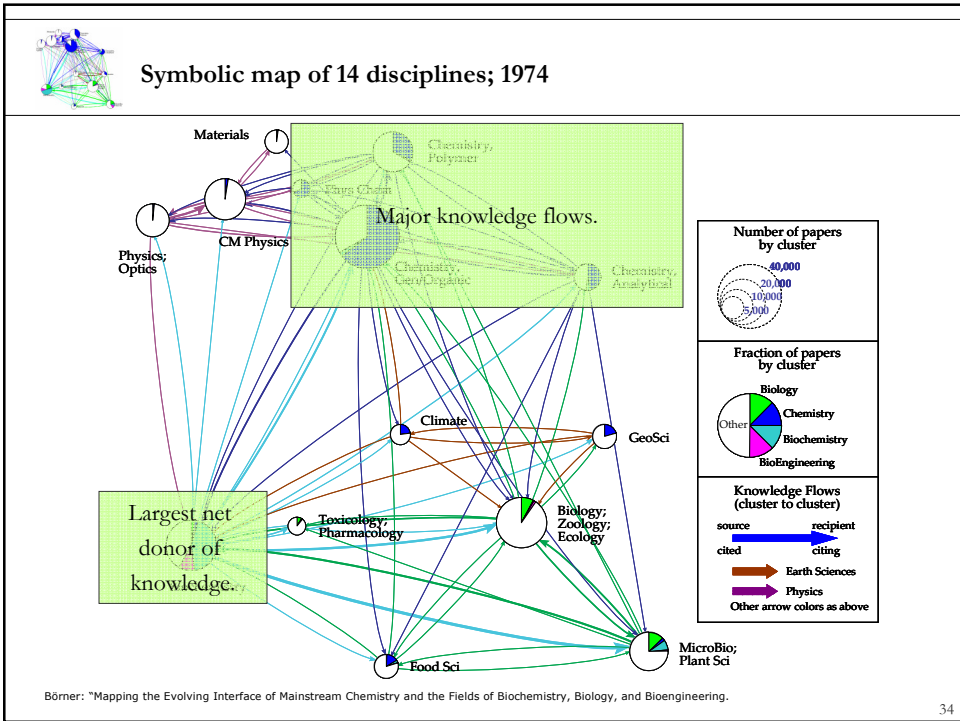
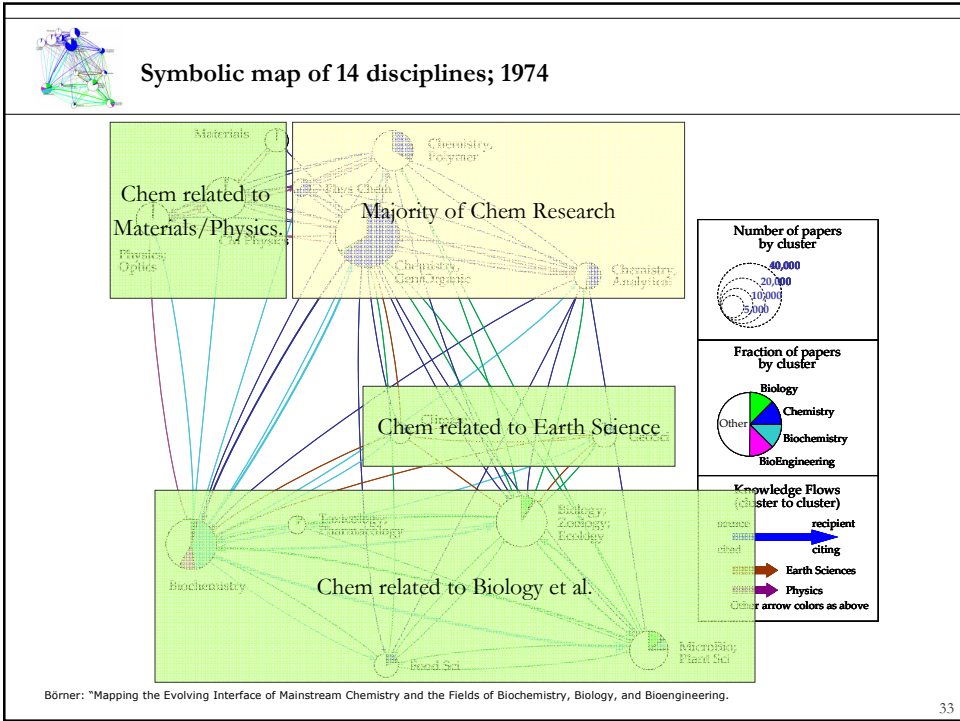
### Definition of 14 disciplines



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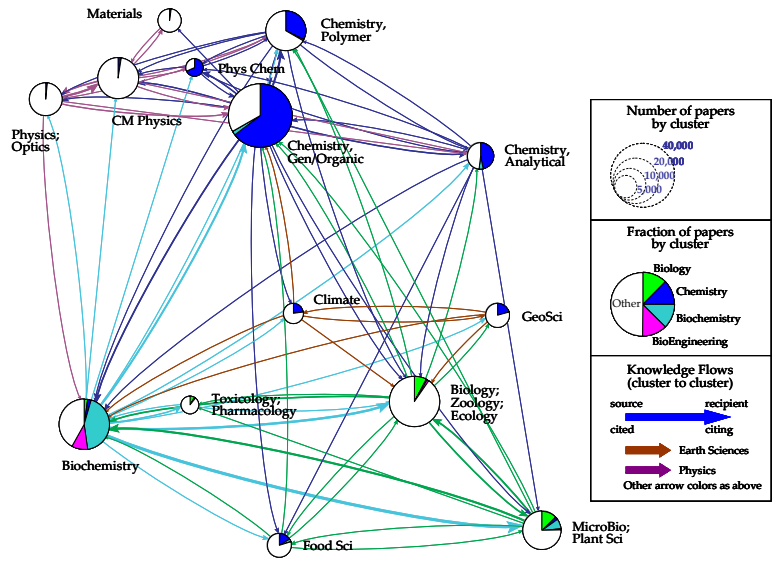
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Symbolic map of 14 disciplines; 1974

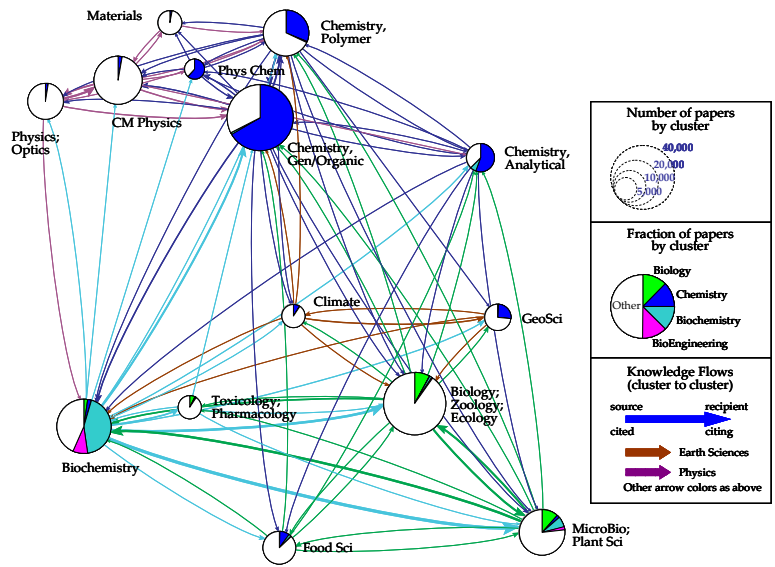


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Symbolic map of 14 disciplines; 1979

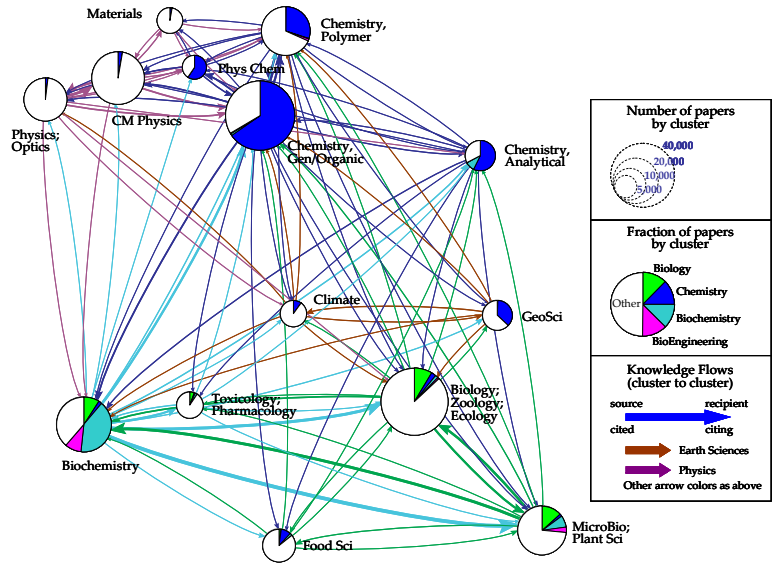


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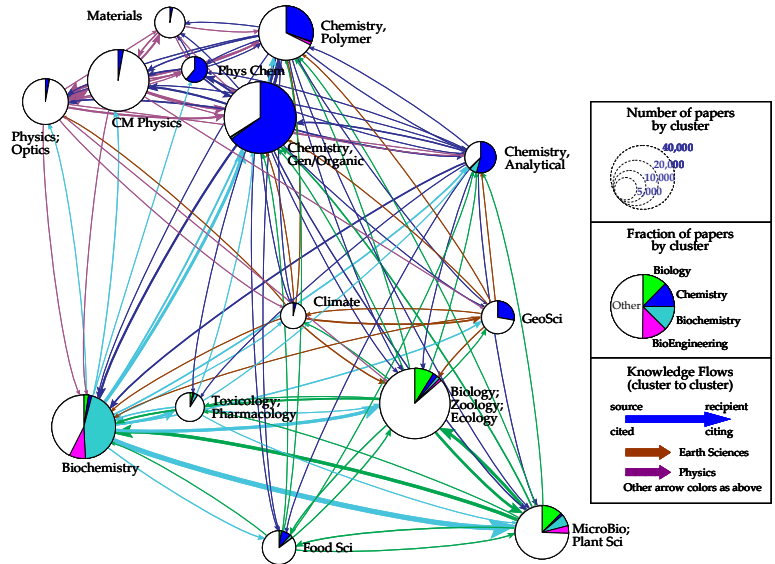
Symbolic map of 14 disciplines; 1984



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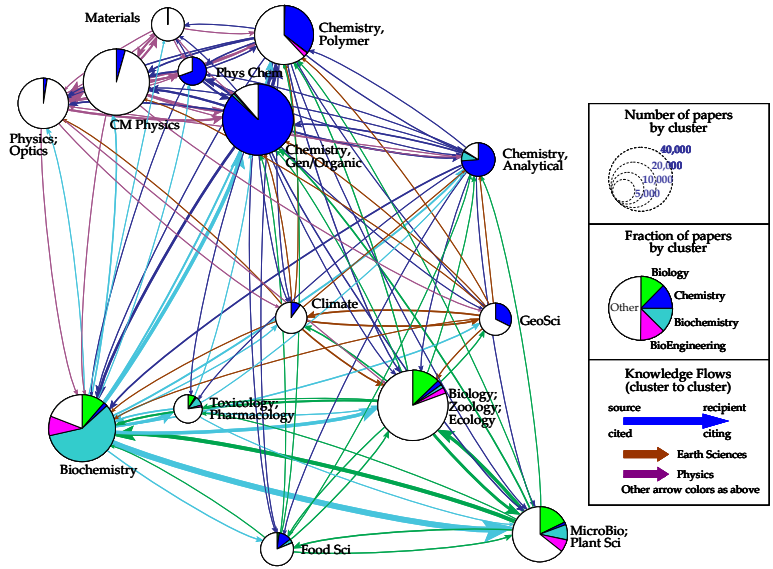
Symbolic map of 14 disciplines; 1989



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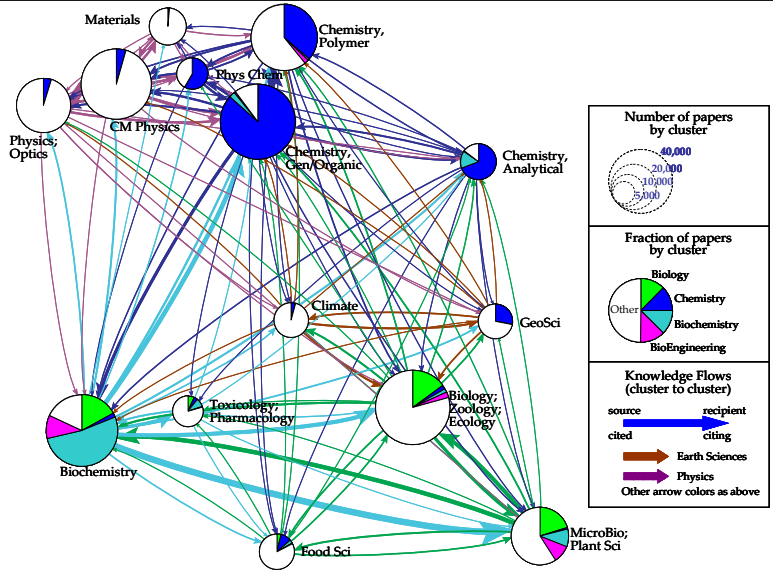
Symbolic map of 14 disciplines; 1994



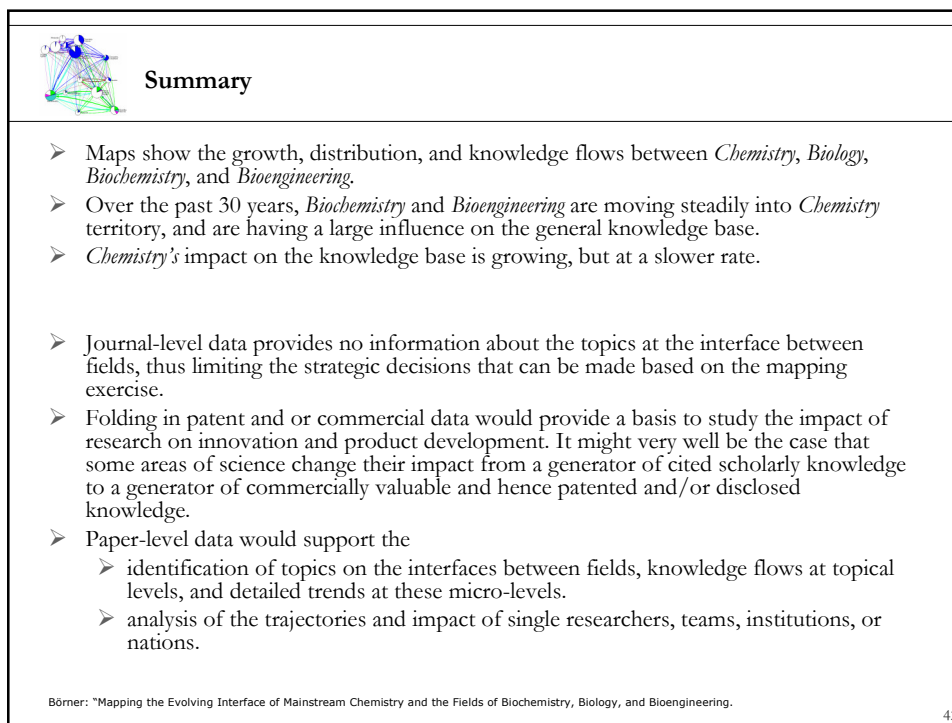
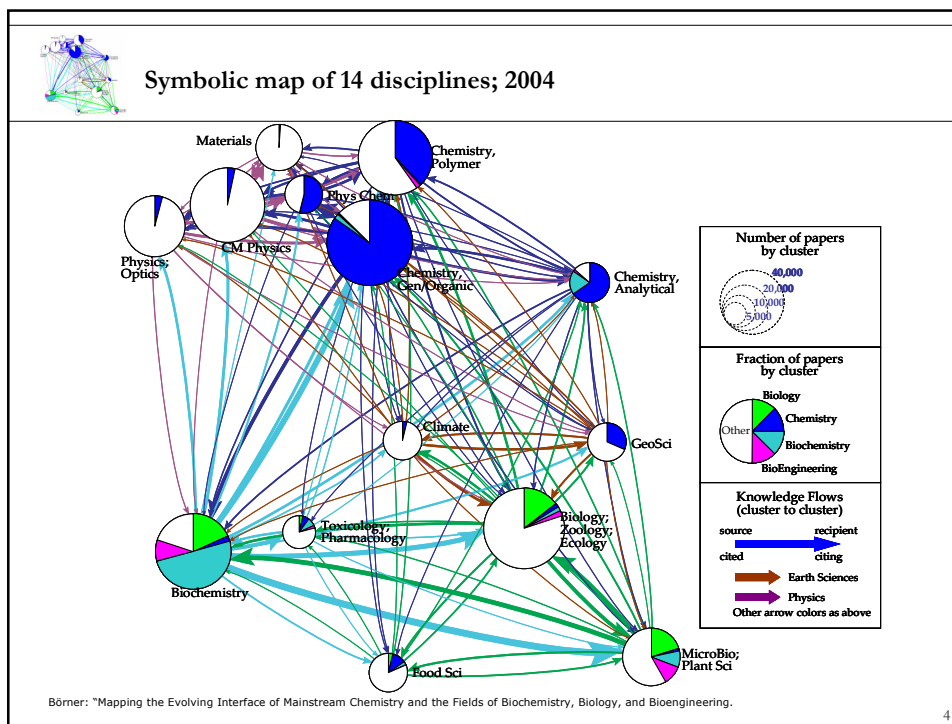
Börner: "Mapping the Evolving Interface of Mainstream Chemistry and the Fields of Biochemistry, Biology, and Bioengineering."



Symbolic map of 14 disciplines; 1999

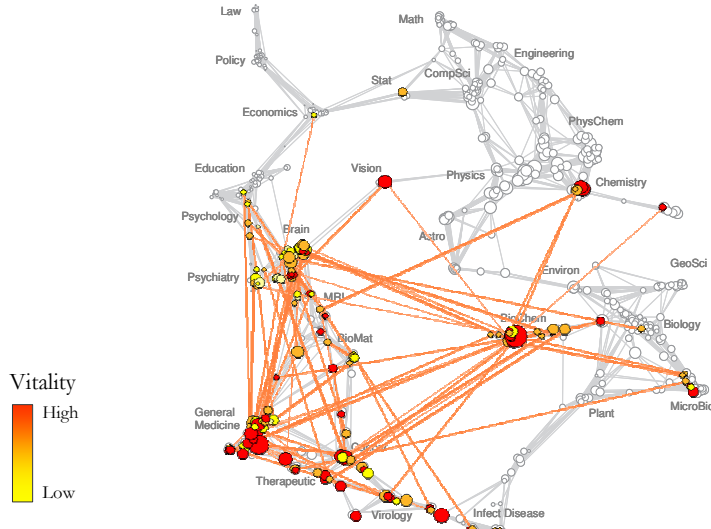


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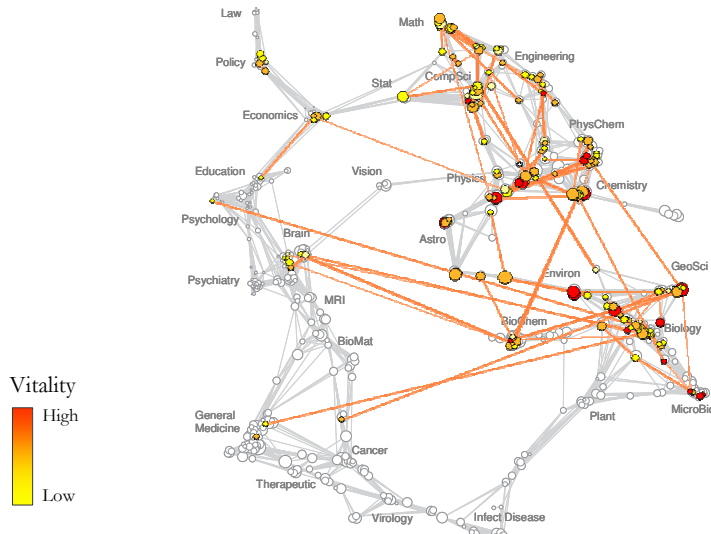
### Funding overlay – NIH funded research (extramural)



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### Funding overlay – NSF funded research



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## Summary

- Maps show the growth, distribution, and knowledge flows between *Chemistry*, *Biology*, *Biochemistry*, and *Bioengineering*.
- Over the past 30 years, *Biochemistry* and *Bioengineering* are moving steadily into *Chemistry* territory, and are having a large influence on the general knowledge base.
- *Chemistry*'s impact on the knowledge base is growing, but at a slower rate.
  
- Journal-level data provides no information about the topics at the interface between fields, thus limiting the strategic decisions that can be made based on the mapping exercise.
- Folding in patent and or commercial data would provide a basis to study the impact of research on innovation and product development. It might very well be the case that some areas of science change their impact from a generator of cited scholarly knowledge to a generator of commercially valuable and hence patented and/or disclosed knowledge.
- Paper-level data would support the
  - identification of topics on the interfaces between fields, knowledge flows at topical levels, and detailed trends at these micro-levels.
  - analysis of the trajectories and impact of single researchers, teams, institutions, or nations.

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## Relevant Events in 2007

- May 22, Award Ceremony for [Visualizing Network Dynamics Competition @ NetSci07](#), New York Hall of Science.
  
- June 25-27, [ISSI](#), Madrid, Spain.
- June 29, [New Network Theory Conference](#), Amsterdam, Netherlands.
- July 3, [Visualization Summit](#), ETH Zürich, Switzerland.
- July 4-6, [Information Visualisation Conference](#), ETH Zürich, Switzerland.
  
- ‘Mapping Science’ Exhibit Displays in 2007:
  - May 1-30, Monroe County Public Library, Bloomington, IN.
  - Sept 7- Dec 30, American Museum of Science and Engineering, Oak Ridge, TN.

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**The End.**