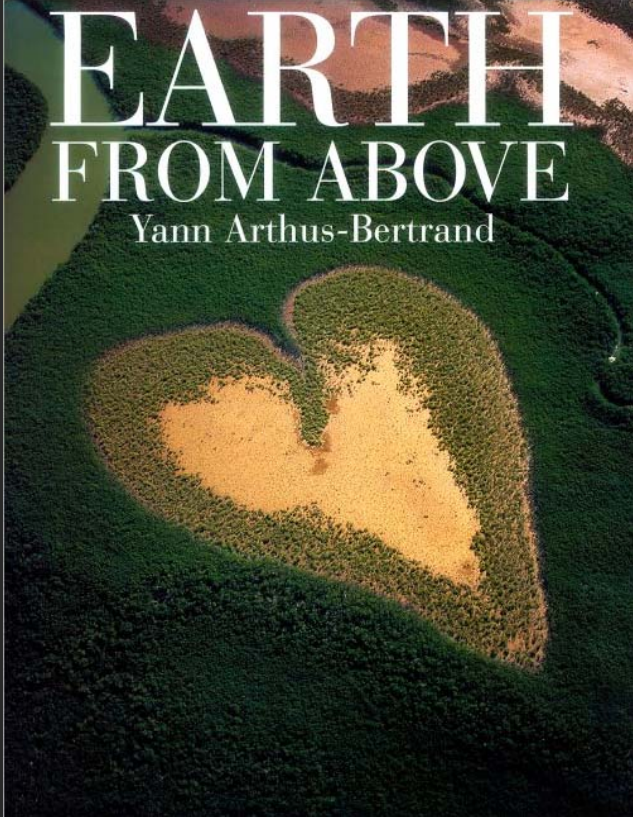


Science from Above

Dr. Katy Börner

Cyberinfrastructure for Network Science Center, Director
Information Visualization Laboratory, Director
School of Library and Information Science
Indiana University, Bloomington, IN
katy@indiana.edu

*The 2009 North American Conference on Computing and Philosophy
NA-CAP@IU 2009: Networks and Their Philosophical Implications
Indiana University, Bloomington
June 15th, 2009*

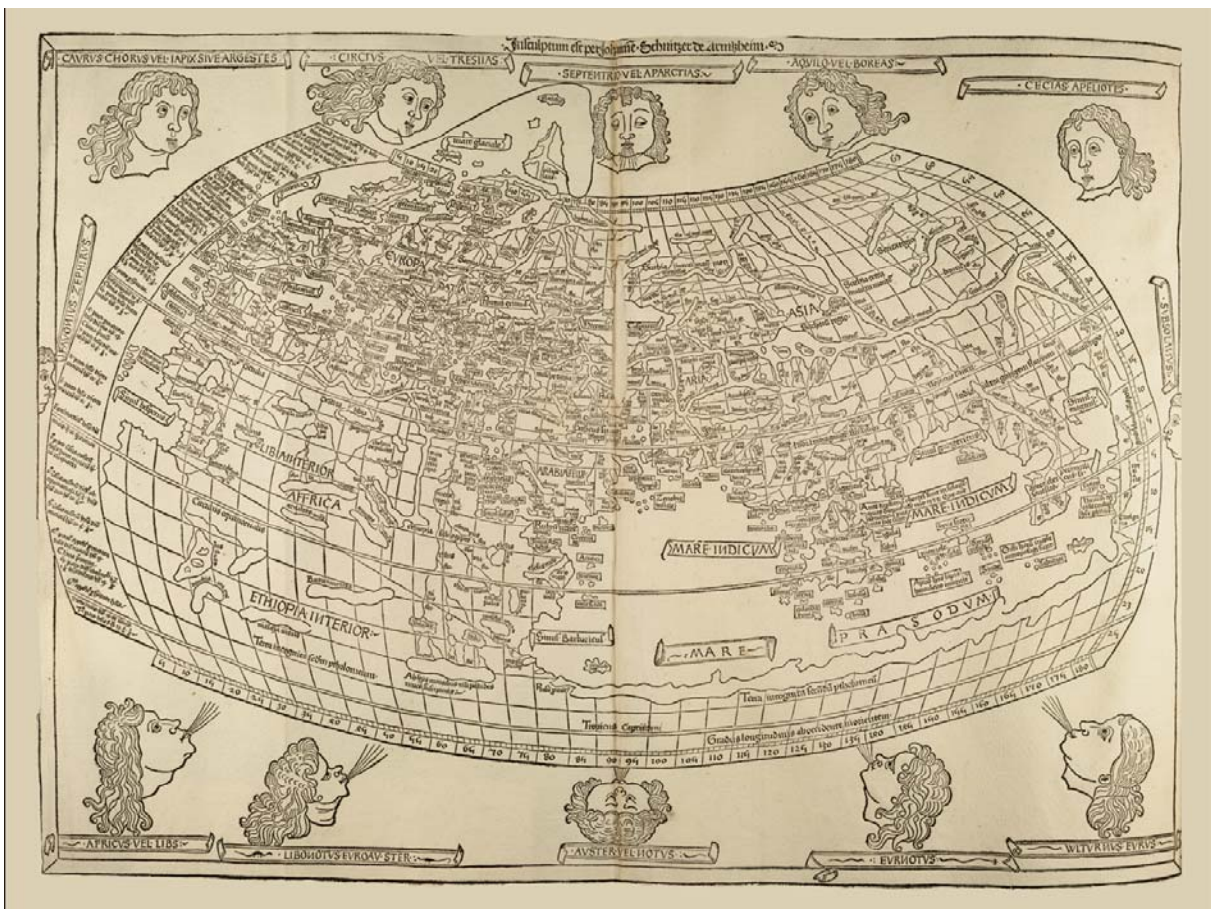


**EARTH
FROM ABOVE**
Yann Arthus-Bertrand

Cartographic maps of physical places have guided mankind's explorations for centuries.

They enabled the discovery of new worlds while also marking territories inhabited by the unknown.

Without maps, we would be lost.





Domain maps of abstract semantic spaces aim to serve today's explorers navigating the world of science.

These maps are generated through a scientific analysis of large-scale scholarly datasets in an effort to connect and make sense of the bits and pieces of knowledge they contain.

They can be used to identify objectively major research areas, experts, institutions, collections, grants, papers, journals, and ideas in a domain of interest. Science maps can provide overviews of "all-of-science" or of a specific area.

They can show homogeneity vs. heterogeneity, cause and effect, and relative speed. They allow us to track the emergence, evolution, and disappearance of topics and help to identify the most promising areas of research.



places & spaces

Cartography of the Physical and the Abstract

An exhibition created for the conference "Mapping Humanity's Knowledge and Expertise in the Digital Domain" at the 2005 Meeting of the American Association of Geographers that is updated regularly with new maps and explanations.



Home Browse Maps Compare & Contrast Maps Connect
Home







Exhibit Purpose and Goals

The Places & Spaces exhibit has been created to demonstrate the power of maps.

An initial theme of this exhibit is to compare and contrast first maps of our entire planet with the first maps of all of science as we know it.

Come see with your own eyes the extent to which maps can be employed to help make sense of the flood of information we are confronted with and how domain maps can be used to locate complex and beautiful information.

This online part of the exhibit provides links to a selected series of maps and their makers along with detailed explanations of why these maps work. The physical counterpart supports the close inspection of high quality reproductions for display at conferences and education centers. It is meant to inspire cross-disciplinary discussion on how to best track and communicate human activity and scientific progress on a global scale.



Places & Spaces: Mapping Science

a science exhibit that introduces people to maps of sciences, their makers and users.

Exhibit Curators:
 Dr. Katy Börner & Elisha Hardy
<http://scimaps.org>





Mapping Science Exhibit – 10 Iterations in 10 years

<http://scimaps.org/>



The Power of Maps (2005)



Science Maps for Economic Decision Makers (2008)



The Power of Reference Systems (2006)



Science Maps for Science Policy Makers (2009)

Science Maps for Scholars (2010)

Science Maps as Visual Interfaces to Digital Libraries (2011)

Science Maps for Kids (2012)

Science Forecasts (2013)

The Power of Forecasts (2007)



How to Lie with Science Maps (2014)



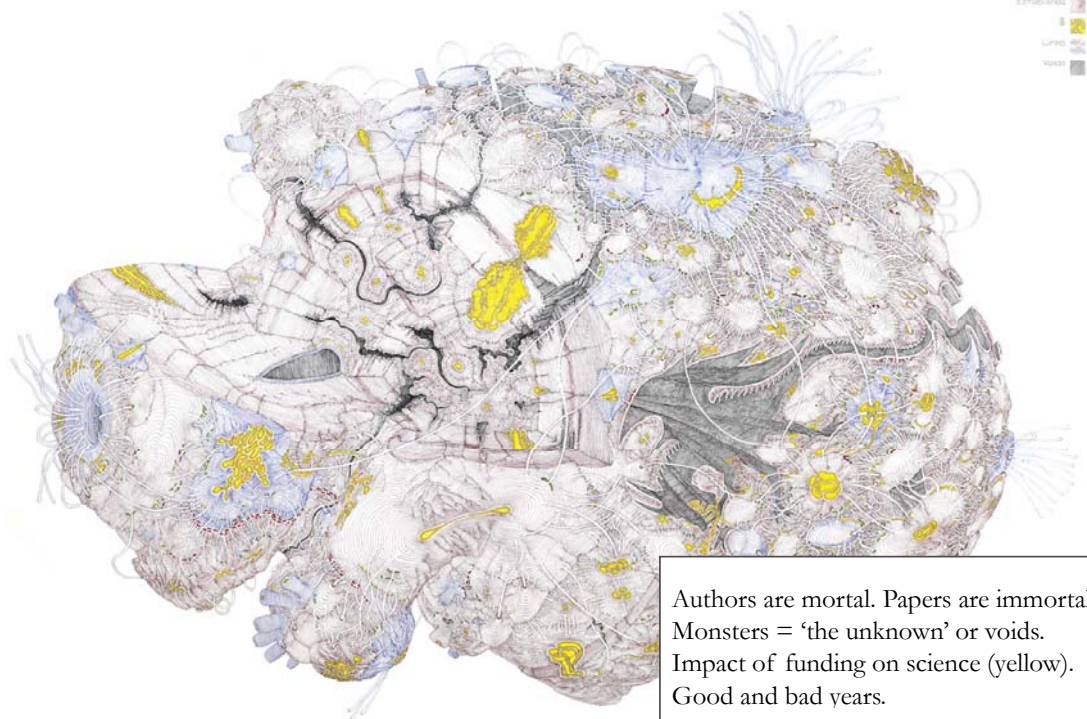
- Exhibit has been shown in 52 venues on four continents. Also at
- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA.
 - Chinese Academy of Sciences, China, May 17-Nov. 15, 2008.
 - University of Alberta, Edmonton, Canada, Nov 10-Jan 31, 2009
 - Center of Advanced European Studies and Research, Bonn, Germany, Dec. 11-19, 2008.





Debut of 5th Iteration of Mapping Science Exhibit at MEDIA X was on May 18, 2009 at Wallenberg Hall, Stanford University, <http://mediax.stanford.edu>, <http://scaleindependentthought.typepad.com/photos/scimaps>

HYPOTHETICAL MODEL of the EVOLUTION and STRUCTURE of SCIENCE



Emerging
Established
Impact of funding on science (yellow)
Void

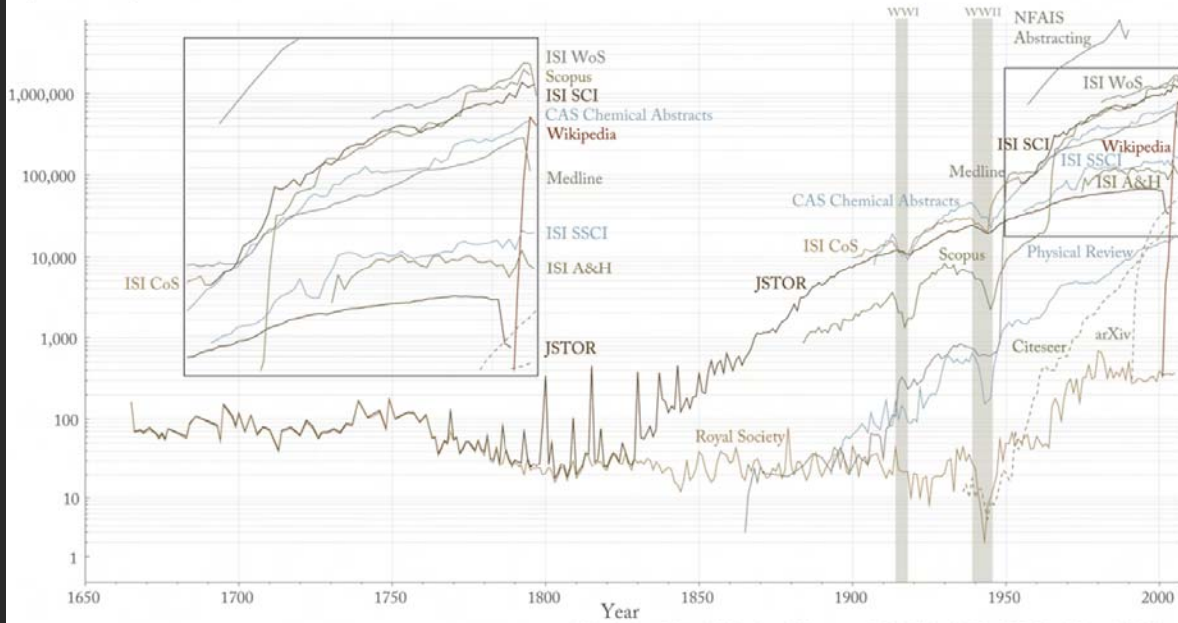
Authors are mortal. Papers are immortal.
Monsters = 'the unknown' or voids.
Impact of funding on science (yellow).
Good and bad years.

One of Many Possible Interpretations

Daniel Zeller 2007

Hypothetical Model of the Evolution of Science - Daniel Zeller - 2007

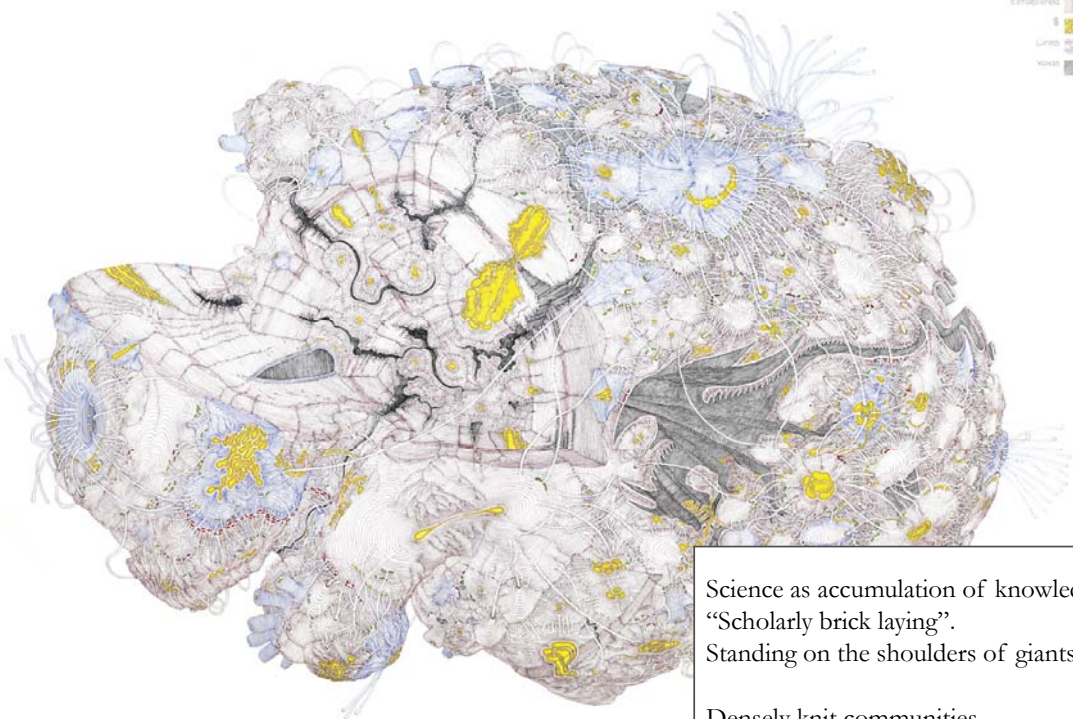
Papers & Wikipedia Entries



Atlas of Science: Guiding the Navigation and Management of Scholarly Knowledge, Part I: The Rise of Science and Technology. Chart showing the number of papers/Wikipedia entries for different databases and publication years. Contact Katy Borner <katy@indiana.edu> or Elisha Hardy <ehardy@indiana.edu> for details.

Atlas of Science - Katy Borner - 2010

HYPOTHETICAL MODEL of the EVOLUTION and STRUCTURE of SCIENCE



Science as accumulation of knowledge.
 "Scholarly brick laying".
 Standing on the shoulders of giants.
 Densely knit communities.
 The importance of weak links.

One of Many Possible Interpretations

Hypothetical Model of the Evolution of Science - Daniel Zeller - 2007

This map of science was constructed by sorting more than 7.2 million journals into disciplines, (disciplines represented as nodes, are sets of journals that share a common location). A three-dimensional map was used to determine the position of each discipline on the surface of a sphere based on the linkage between disciplines. The most direct links like carbon bonds connecting to other nodes are shown in each color. Each of disciplines without links need to end up in different sides of the map.

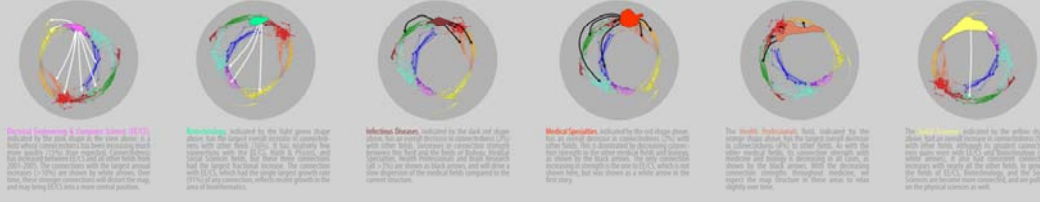
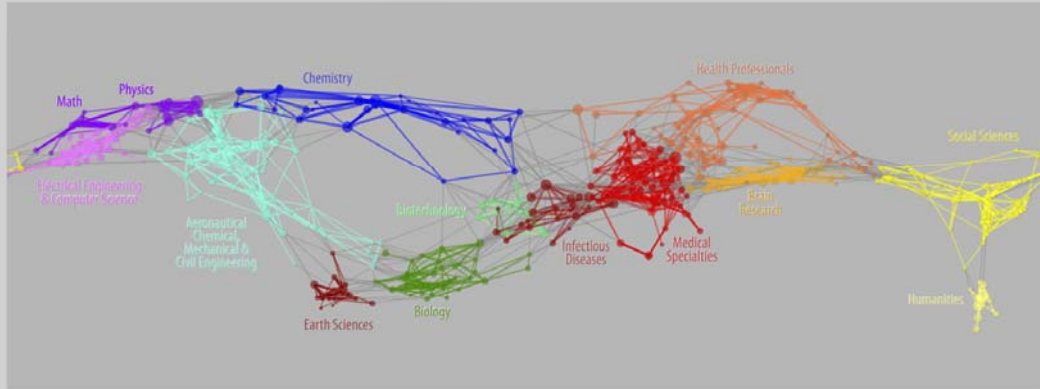
MAPS OF SCIENCE

Forecasting Large Trends in Science

A visualization of 7.2 million scholarly documents appearing in over 16,000 journals, proceedings or symposia between Jan, 2001 and Dec, 2005

Calculations were performed using the large network graphs of disciplines (fields) to determine a set of three axes used to sort large in the change in the structure of science over time. Correlation coefficients between fields were calculated for each individual year (2001-2005). A single regression pattern was conducted to see if there were significant changes in these correlation coefficients from year to year.

The spherical map, which is not shown here, was converted to a linear projection (the same one used to show the continents of the earth on a two-dimensional map) to give the large map shown below. This projection shows perspective of the entire map in color or each field that the disciplines tend to cross along the middle of the map. If this were a map of the earth it would be like a single colored equatorial band along the equator. There are no straight lines in this map. The map is a projection of a sphere. The map is a projection of a sphere. The map is a projection of a sphere.



Physical Sciences & Computer Science (2001) - The physical sciences and computer science were the most prominent fields in 2001. The map shows a sparse network of connections between these fields and other disciplines.

Interdisciplinary - Indicated by the light green color above the main map, interdisciplinary connections were prominent in 2002. The map shows a more dense network of connections between fields.

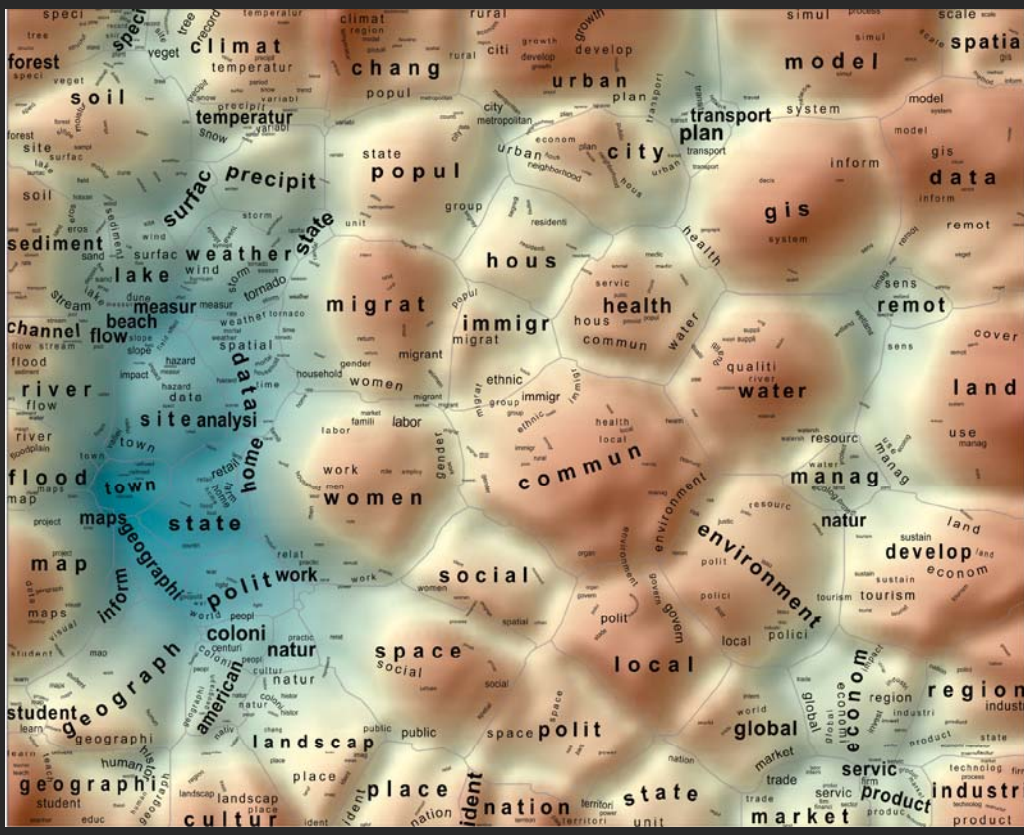
Infectious Diseases - Indicated by the dark red color above the main map, infectious diseases were a prominent field in 2003. The map shows a more dense network of connections between fields.

Medical Specialties - Indicated by the red color above the main map, medical specialties were a prominent field in 2004. The map shows a more dense network of connections between fields.

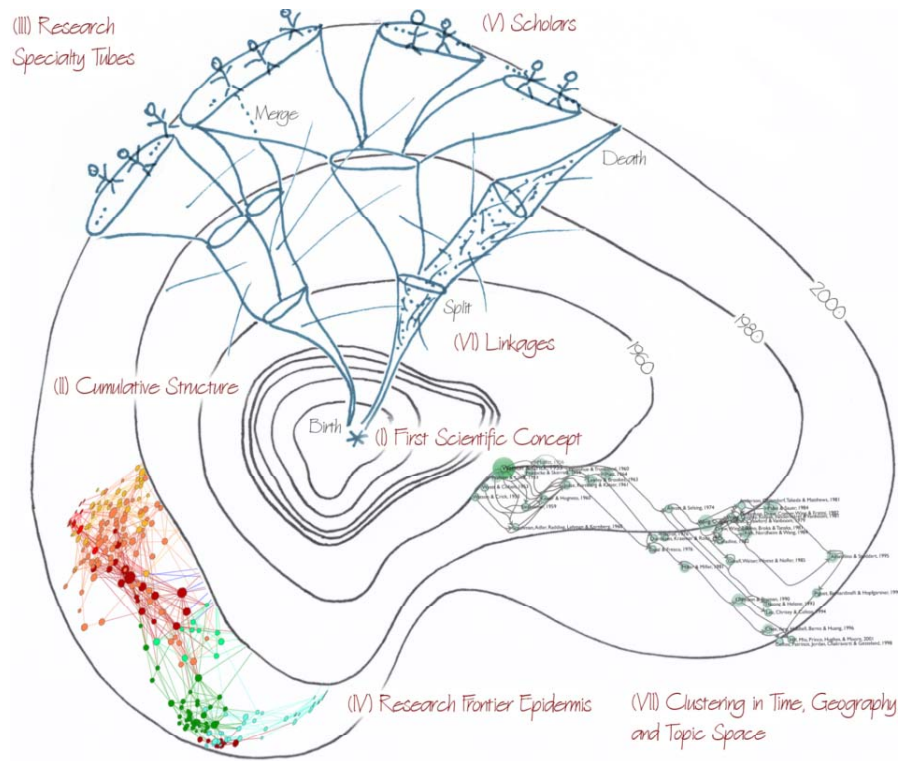
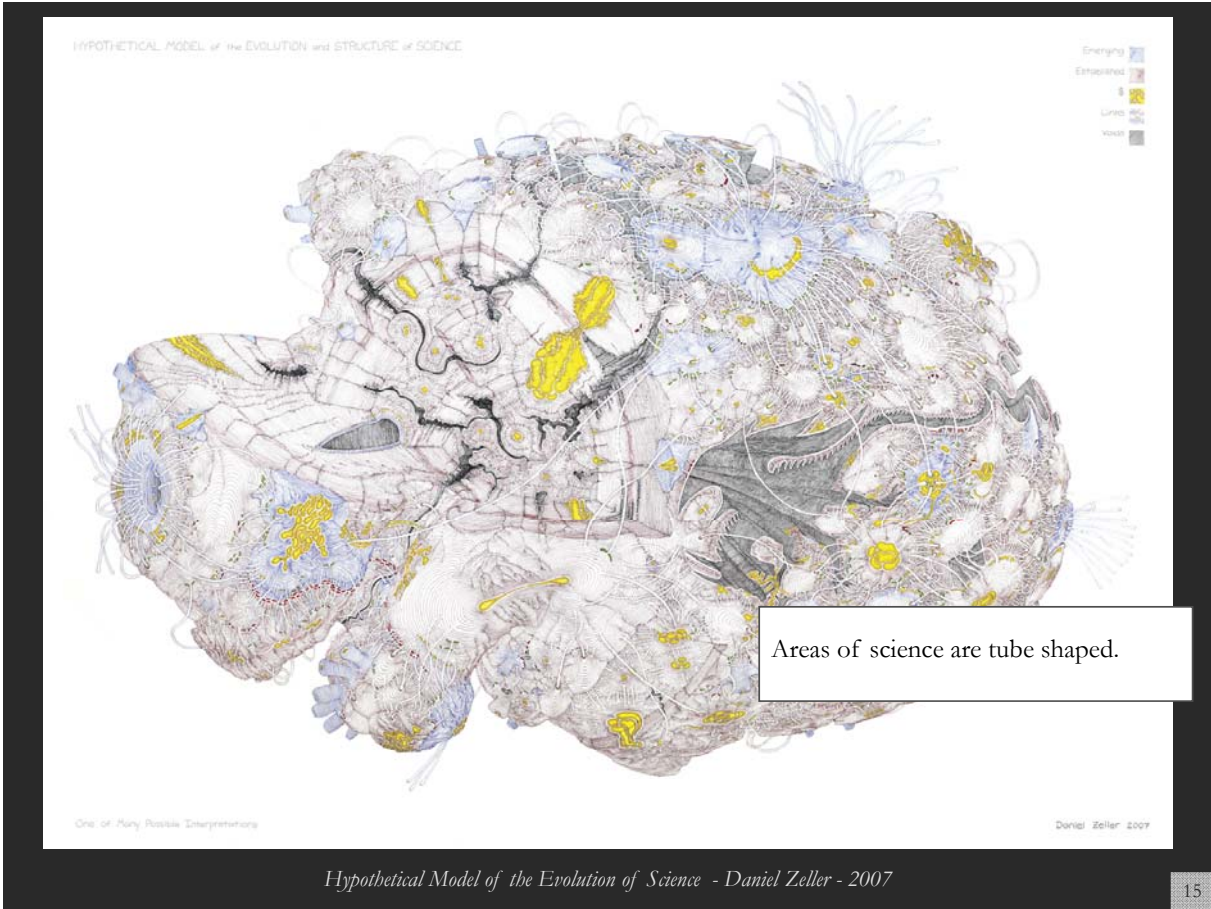
Health Professionals - Indicated by the orange color above the main map, health professionals were a prominent field in 2005. The map shows a more dense network of connections between fields.

Social Sciences - Indicated by the yellow color above the main map, social sciences were a prominent field in 2005. The map shows a more dense network of connections between fields.

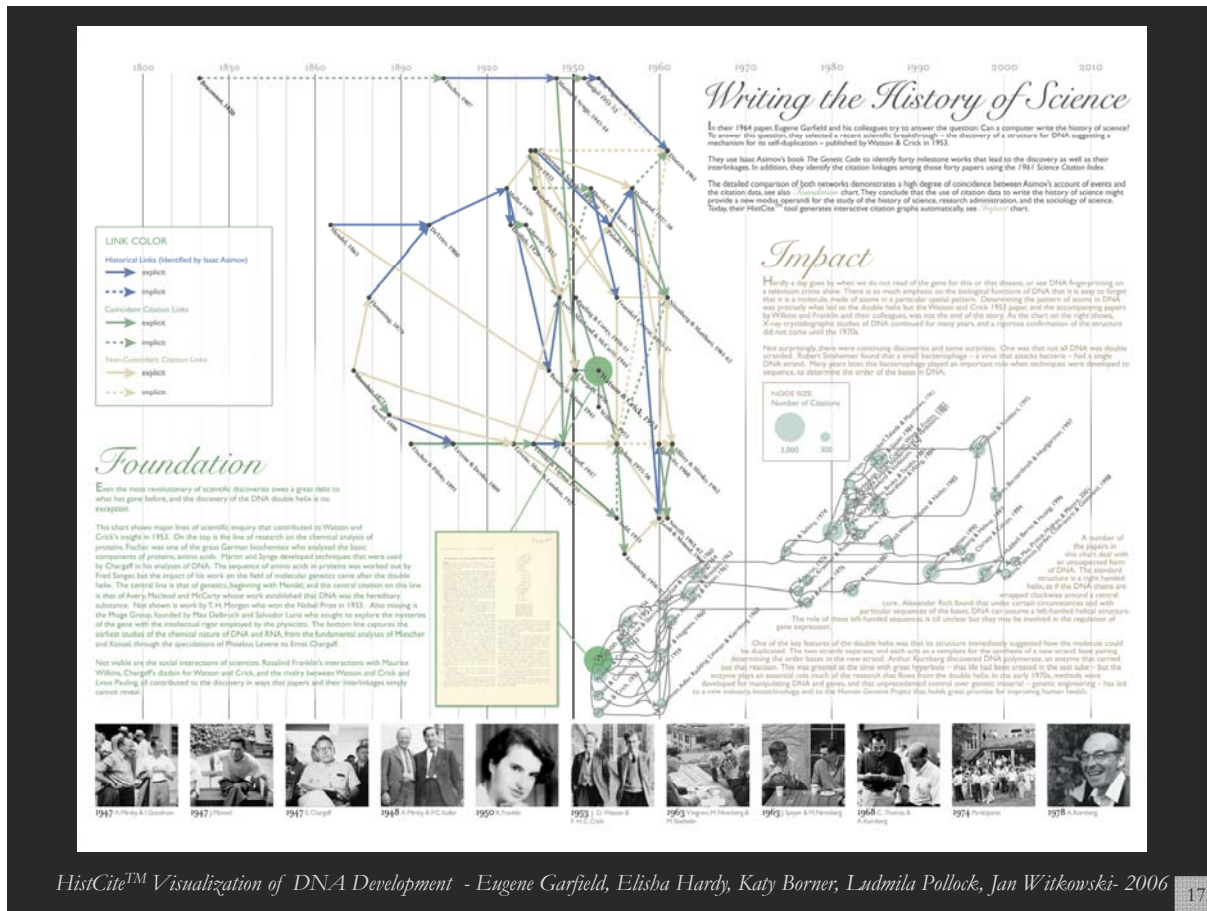
Maps of Science: Forecasting Large Trends in Science - Richard Klavans, Kevin Boyack - 2007



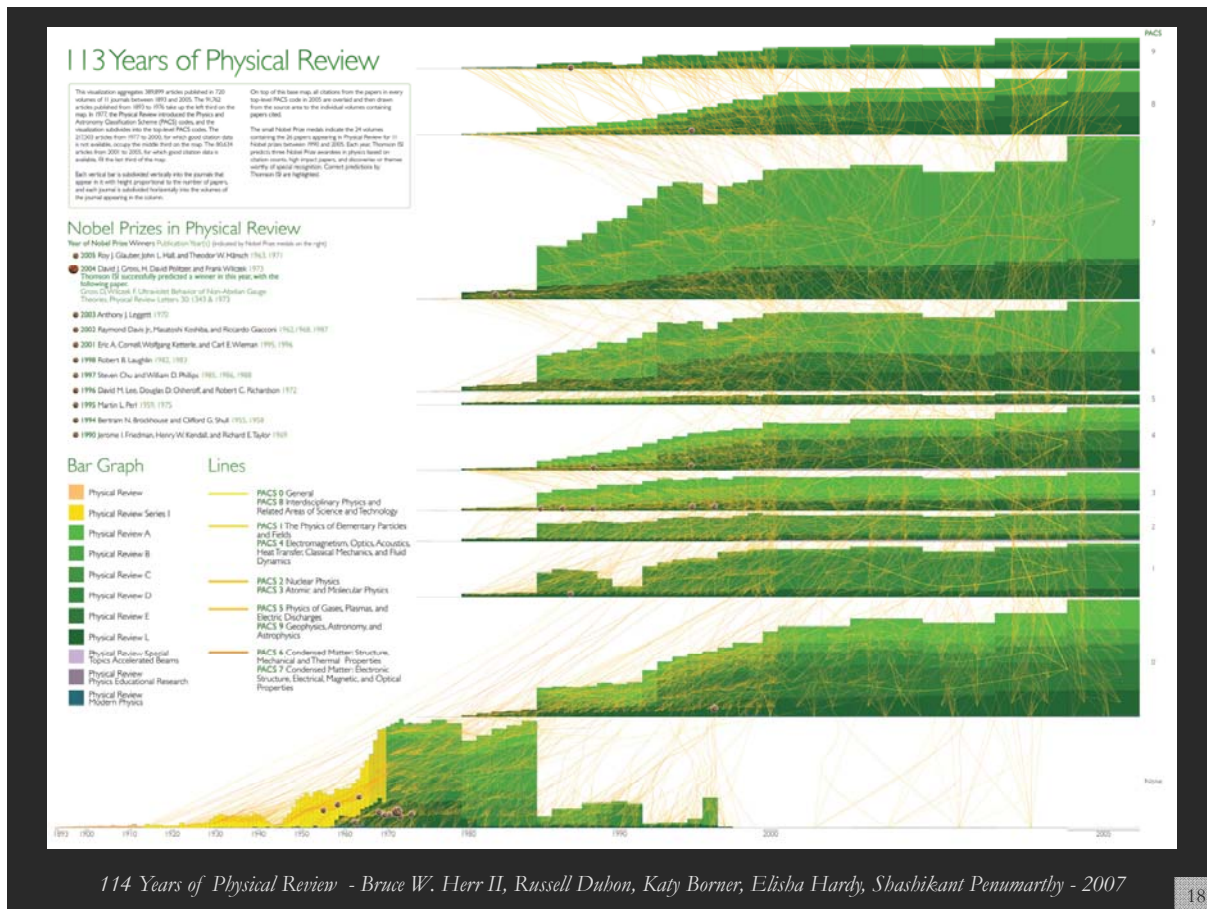
In Terms of Geography - Andre Skupin - 2005

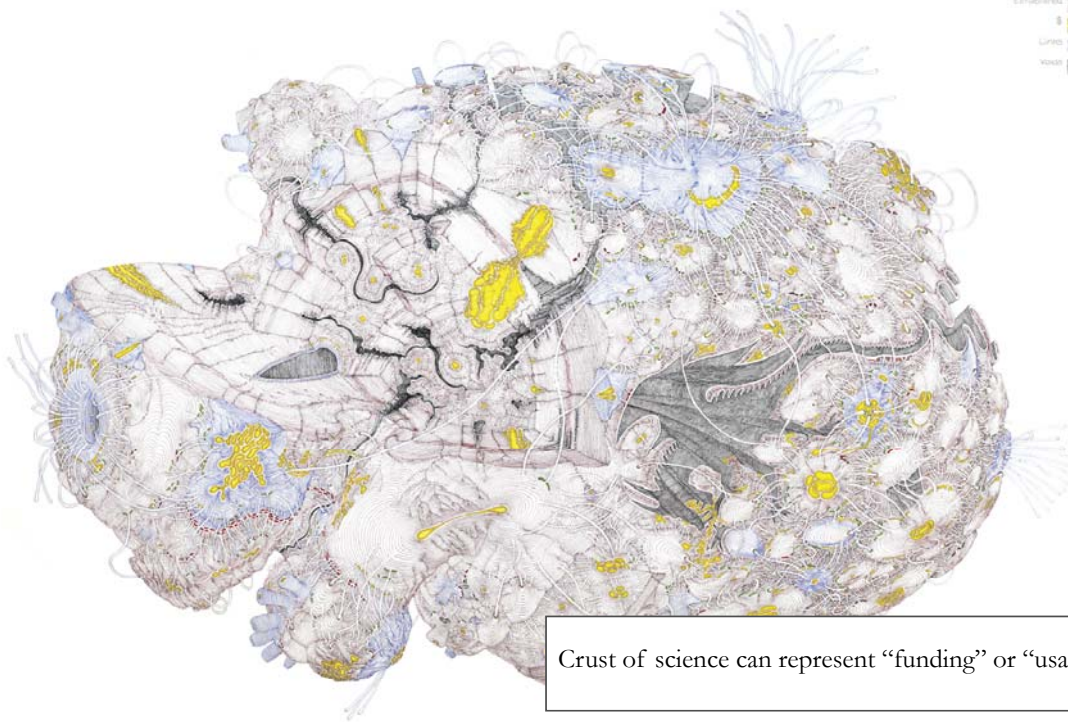


Atlas of Science - Katy Borner - 2010



HistCite™ Visualization of DNA Development - Eugene Garfield, Elisha Hardy, Katy Borner, Ludmila Pollock, Jan Witkowski - 2006





Crust of science can represent “funding” or “usage”.

One of Many Possible Emergencies

Daniel Zeller 2007

Hypothetical Model of the Evolution of Science - Daniel Zeller - 2007

CLICKSTREAM MAP OF SCIENCE

LEGEND

- Physics
- Chemistry
- Biology
- Earth & Planetary Sciences
- Social Sciences
- Humanities

● Connection

DATA 03/01/06 - 02/01/07

356,000,000	user requests
6,700,000	connections from raw data
97,532	articles in raw data
50,000	top connections for map (> 170)
2,307	journals for map

mesur

More information on this map can be found in Bollen, J., Van de Sompel, H., Hagberg, A., Goltzschew, L., Chute, R., Rodriguez, M., and Balakireva, L. (2008) Clickstream Data Yields High-Resolution Maps of Science. PLoS ONE 3(3): e2803. doi:10.1371/journal.pone.0004863 (Peer-reviewed online)

When we cut the A&T taxonomy at the top level, only two distributions remain: natural sciences (blue nodes) vs. the social sciences and humanities (yellow nodes). Some journals along the spokes of the wheel have classifications (colors) that do not correspond to their location in the map. The rectangles either that journal in question is highly interdisciplinary, and/or has been assigned a classification that does not correspond to how scientists actually use the particular journal.

This is the first map created from large-scale, world-wide, scholarly usage data. It visualizes the collective flow of scientists' movements from one journal to another in their online navigation behavior.

The MESUR project (www.mesur.org) collected a database of nearly 1 billion user requests recorded by the web portals of some of the world's most significant publishers, aggregators and large university consortia, among them Thomson Scientific (Wiley, Science, Elsevier, Scopus), JSTOR, Inspec, University of Texas (4 campuses), iHealth institutions, and California State University (23 campuses). All usage logs acquired by the MESUR project contain session identifiers that identify the individual clickstreams of individual scientists navigating from one article to the next.

Pairs of journals are connected when they have a high probability of being followed by each other in same clickstreams. The circles represent individual journals. A line between two circles indicates that they are strongly connected in either direction. The colors indicate the scientific domain a journal belongs to according to their Dewey (journal) and JSTOR classification codes that were mapped into the Getty Research Center's Arts and Architecture Thesaurus (AAT) to allow disambiguation at various levels of detail. The size of circles corresponds to the strength (degree centrality) of a journal's connections in the map. The map is arranged by the Fruchterman-Reingold algorithm that treats connections like springs; connected journals are drawn together, but they are not allowed to get too close.

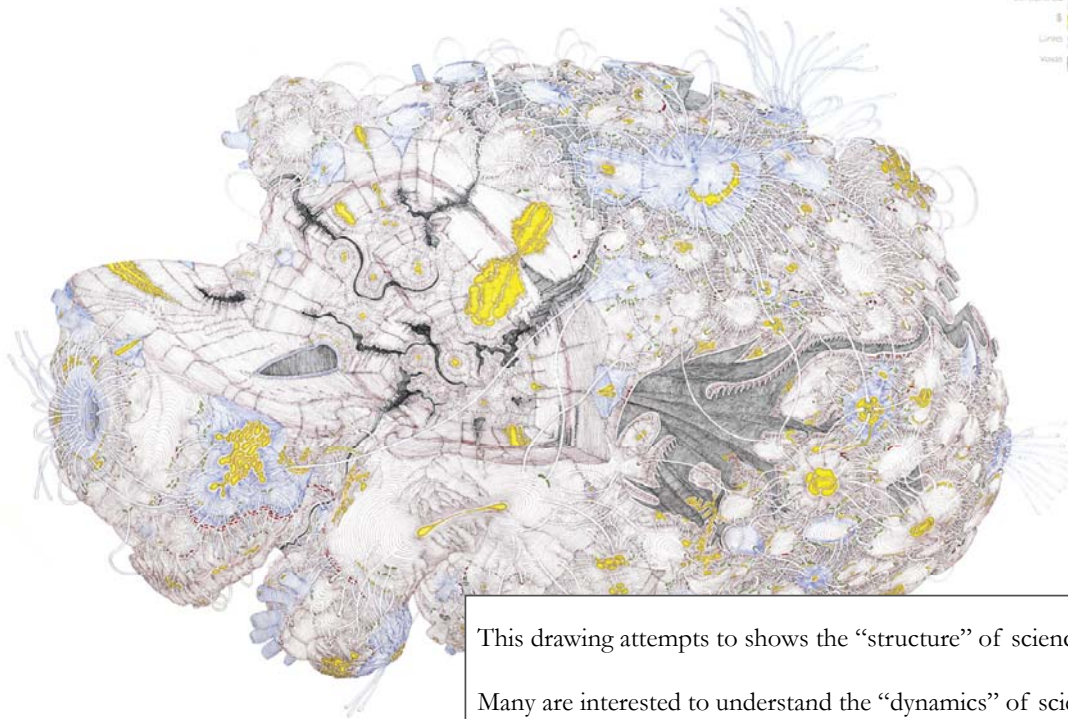
The map is derived from usage data and therefore also reflects the actions of those who read the literature but never publish themselves, e.g. practitioners and laypersons. As a result, practitioners-driven domains such as nursing, social work and tourism studies are prominently featured. The natural sciences on the most expensive and humanities groups are less distinct clusters that are connected via various specific interdisciplinary "spokes". Most domains are highly interdisciplinary, but this is more so the case for the social sciences and humanities. Geography, mathematics and computer science are not represented as one specific cluster, but spread-out through the map.

Like citation maps, this map is based upon a particular sample of the scientific community, albeit one that includes non-publishing scientists and practitioners and a much greater sample of publications. From MESUR's database of 1 billion user events, we created a matrix of 6 million connections between approximately 100,000 articles. From that matrix we selected only 50,000 connections with the highest number of observations, ranging from approximately 40,000 to 170 observations. The subset of connections pertained to the 2,307 most used journals. This procedure may produce specific biases which require investigation. This map should therefore not be construed as a final map of scientific activity, but as a hypothesis for the visibility of tracking scientific activity from usage data. We hope this methodology will provide unique insights into the real-time structure of scientific activity as it can be observed from scholarly clickstream data.

Design layout by: Jeremy D. Chacon

A Clickstream Map of Science – Bollen, Johan, Herbert Van de Sompel, Aric Hagberg, Luis M.A. Bettencourt, Ryan Chute, Marko A. Rodriguez, Lyudmila Balakireva - 2008

Emerging
Established
Limes
Voids



This drawing attempts to show the “structure” of science.
Many are interested to understand the “dynamics” of science.

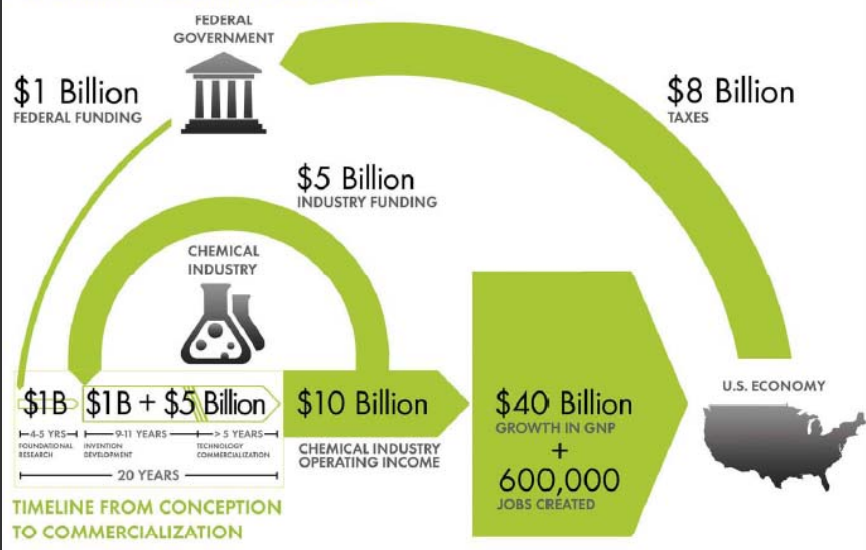
One of Many Possible Interpretations

Hypothetical Model of the Evolution of Science - Daniel Zeller - 2007

Chemical Research & Development Powers the U.S. Innovation Engine

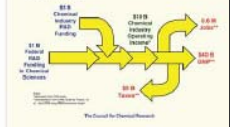
Macroeconomic Implications of Public and Private R&D Investments in Chemical Sciences

INVESTMENT IN CHEMICAL SCIENCE R&D



The Council for Chemical Research (CCR)

has provided the U.S. Congress and government policy makers with important results regarding the impact of Federal Research & Development (R&D) investments on U.S. innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to policy makers, CCR developed the graphic below as a communication tool that distills the complex data produced by these studies in direct, concise and clear terms.

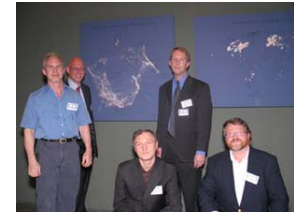


The design shows that an input of \$1B in federal investment, leveraged by \$5B in industry investment, brings new technologies to market and results in \$10B of operating income for the chemical industry, \$40B growth in the Gross National Product (GNP) and further impacts the US economy by generating approximately 600,000 jobs, along with a return of \$8B in taxes. Additional details, also reported in the CCR studies, are depicted in the map to the left. This map clearly shows the two R&D investment cycles; the shorter industry investment at the innovation stage to commercialization cycle; and the longer federal investment cycle which begins in basic research and culminates in national economic and job growth along with the increase tax base that in turn is available for investment in basic research.

Council for Chemical Research - Chemical R&D Powers the U.S. Innovation Engine.
Washington, DC. Courtesy of the Council for Chemical Research - 2009

Illuminated Diagram Display

W. Bradford Paley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007)
Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007.



Large-scale, high resolution prints illuminated via projector or screen.

Questions:

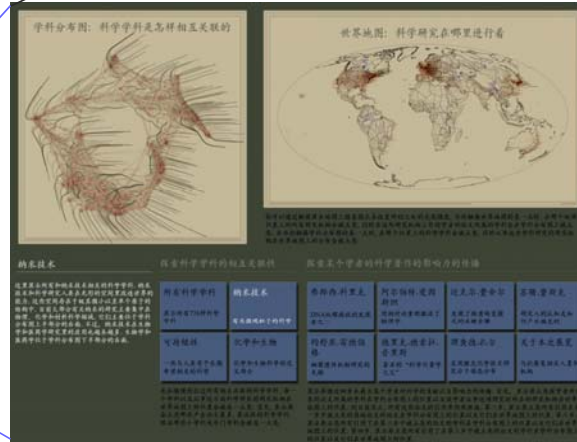
- Who is doing research on what topic and where?
- What is the ‘footprint’ of interdisciplinary research fields?
- What impact have scientists?



Interactive touch panel.

Contributions:

- Interactive, high resolution interface to access and make sense of data about scholarly activity.



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Science Maps in “Expedition Zukunft” science train visiting 62 cities in 7 months

12 coaches, 300 m long

Opening was on April 23rd, 2009 by German Chancellor Merkel

<http://www.expedition-zukunft.de>

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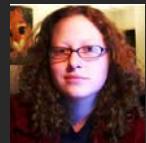
This is the only mockup in this slide show.

Everything else is available today.

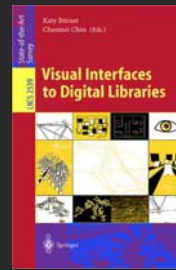


Contact the map makers via the exhibit curators:

Katy Börner (katy@indiana.edu) and Elisba Hardy (elhardy@indiana.edu)



Computational Scientometrics: Studying Science by Scientific Means



- Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains**. In Blaise Cronin (Ed.), *Annual Review of Information Science & Technology*, Medford, NJ: Information Today, Inc./ American Society for Information Science and Technology, Volume 37, Chapter 5, pp. 179-255. <http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf>
- 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). http://www.pnas.org/content/vol101/suppl_1/
- Börner, Katy, Sanyal, Soma and Vespignani, Alessandro (2007). **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. <http://ivl.slis.indiana.edu/km/pub/2007-borner-arist.pdf>
- Börner, Katy & Scharnhorst, Andrea. (2009). **Visual Conceptualizations and Models of Science**. *Journal of Informetrics*. Vol. 3(3), Elsevier. <http://ivl.slis.indiana.edu/km/pub/2009-borner-scharnhorst-joi-sos-intro.pdf>
- **Places & Spaces: Mapping Science** exhibit, see also <http://scimaps.org>.

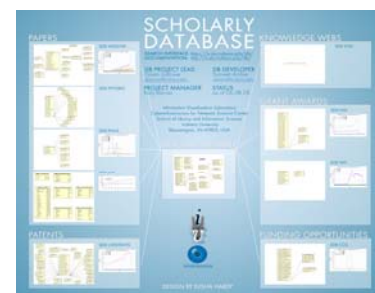
27

Cyberinfrastructures for a Science of Science



Scholarly Database of 23 million scholarly records

<http://sdb.slis.indiana.edu>



Information Visualization Cyberinfrastructure

<http://iv.slis.indiana.edu>



Network Workbench Tool and Community Wiki

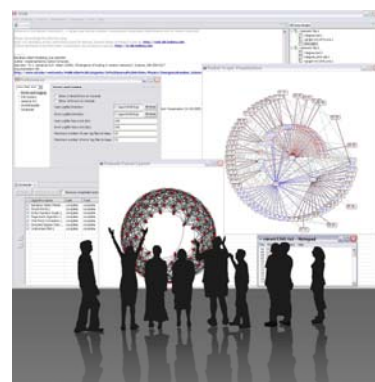
***NEW* Scientometrics plugins**

<http://nwb.slis.indiana.edu>



Epidemics Cyberinfrastructure

<http://epic.slis.indiana.edu/>



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Provided by the [Cyberinfrastructure for Network Science Center](#) at Indiana University.

Introduction
E. O. Wilson writes in *Consilience: The Unity of Knowledge* (1998): "Features that distinguish science from pseudoscience are repeatability, economy, mensuration, heuristics, and consilience." Please see Börner's [recent presentation](#) at the *A Deeper Look at the Visualization of Scientific Discovery* NSF Workshop for a general introduction of the needs and the resources provided here.

Needs Analysis
As part of the "TLS: Towards a *Macroscope for Science Policy Decision Making*" NSF SBE-0738111 award, interviews with science policy makers are conducted to identify what science of science research results and tools might be most desirable and effective. So far, 20 formal, one-hour interviews have been conducted with science policy makers at university campus level, program officer level, and division director level for governmental, state, and private foundations. Data compilation will start in October 2008 and resulting report can be ordered by sending a request to Mark Price (maaprice@indiana.edu).

Conceptualization of Science
A 'science of science' requires a theoretically grounded and practically useful conceptualization of the structure and evolution of science. A special journal issue entitled "[Science of Science: Conceptualizations and Models of Science](#)" edited by [Katy Börner](#), Indiana University & [Andrea Scharnhorst](#), Royal Netherlands Academy of Arts and Sciences invites contributions on this topic. It will be published in the *Journal of Informetrics* 3(1) in January 2009.

Scholarly Database
The [Scholarly Database \(SDB\)](#) at Indiana University aims to serve researchers and practitioners interested in the analysis, modeling, and visualization of large-scale scholarly datasets. The database currently provides access to over 20 million papers, patents and grants. Resulting datasets can be downloaded in bulk. Register for free access at <https://sdb.slis.indiana.edu/>.

Cyberinfrastructures
The Scientometrics filling of the [Network Workbench \(NWB\) Tool](#) provides a unique distributed, shared resources environment for large-scale network analysis, modeling, and visualization. Thomson Scientific/ISI, Scopus and Google Scholar data, EndNote and Bibtext files, or NSF awards can be read and diverse networks can be extracted and studied. Download [User Manual with focus on Scientometrics](#).

<http://sci.slis.indiana.edu>

cyberinfrastructure for NETWORK SCIENCE CENTER
School of Library and Information Science | Indiana University Bloomington

The banner includes a collage of images with labels: People, Research, Events, Jobs, Contact, News, Teaching, Cyberinfrastructures, Outreach, Visiting Artists, and Funding.

Papers, maps, cyberinfrastructures, talks, press are linked from <http://cns.slis.indiana.edu>

The End.