

Mapping Science ~ History and Future

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



Several slides were taken from a talk by Kevin W. Boyack
for the UCGIS Summer Meeting, June, 2009.

Visualization for Collective, Connective & Distributed Intelligence
Dynamic Knowledge Networks ~ Synthetic Minds
Stanford University, CA: August 12, 2009



Early Maps of the World

VERSUS

Early Maps of Science



3D

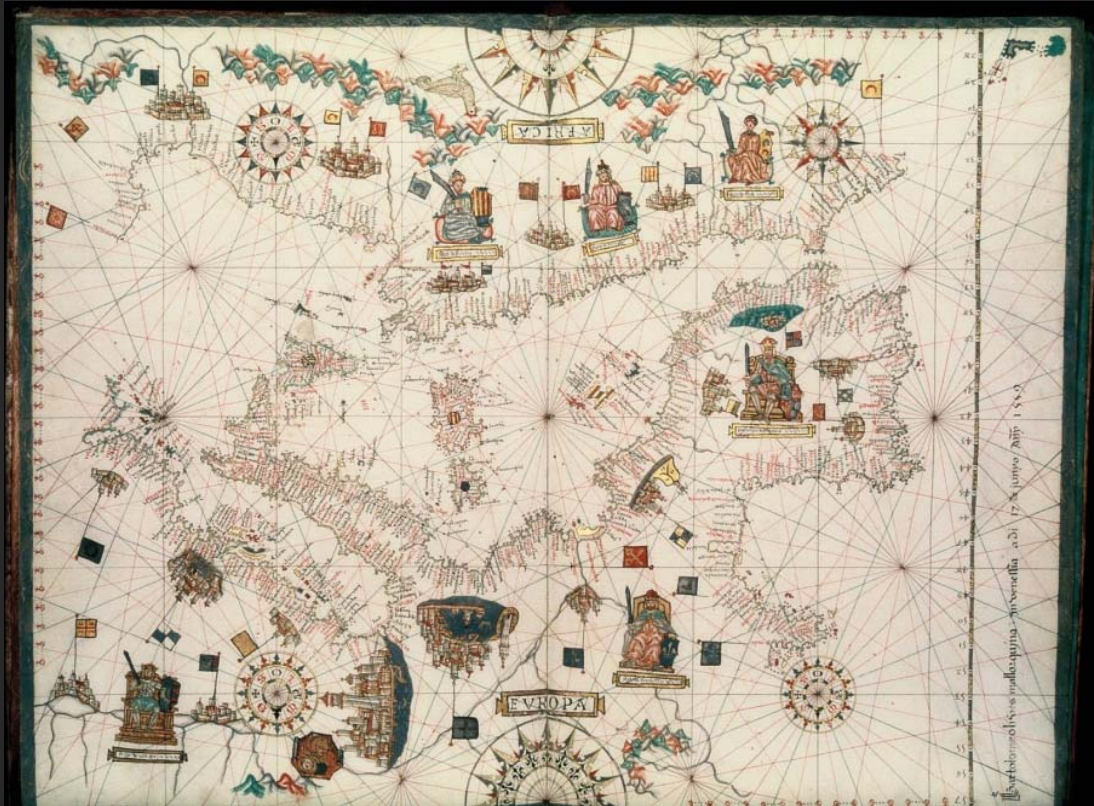
Physically-based
Accuracy is measurable
Trade-offs have more to do with granularity
2-D projections are very accurate at local levels
Centuries of experience
Geo-maps can be a template for other data

n-D

Abstract space
Accuracy is difficult
Trade-offs indirectly affect accuracy
2-D projections neglect a great deal of data
Decades of experience
Science maps can be a template for other data

Kevin W. Boyack, UCGIS Summer Meeting, June, 2009

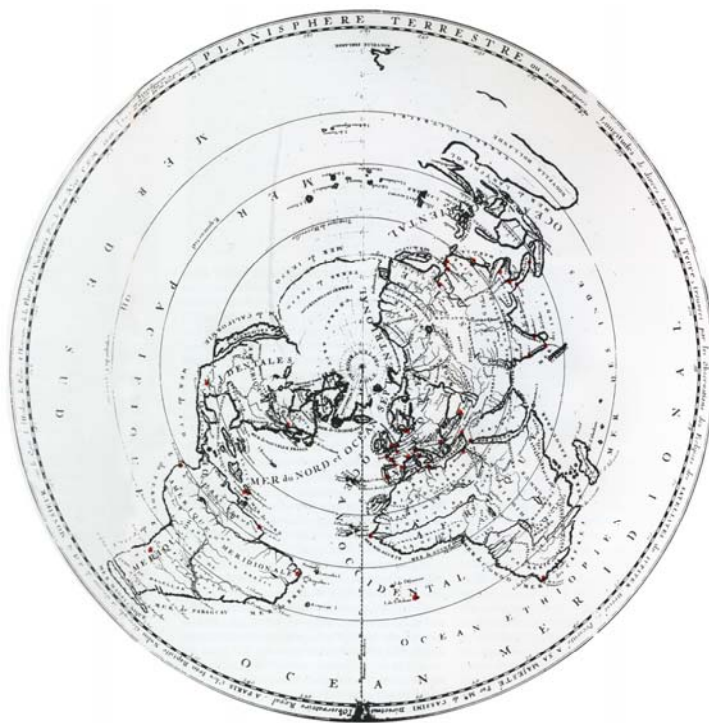
Towards a World Map



Portolan chart of the central and western Mediterranean and part of the Atlantic - Bartolomeo Olives - 1559



Islandia - Abraham Ortelius (1527-1598) - 1606

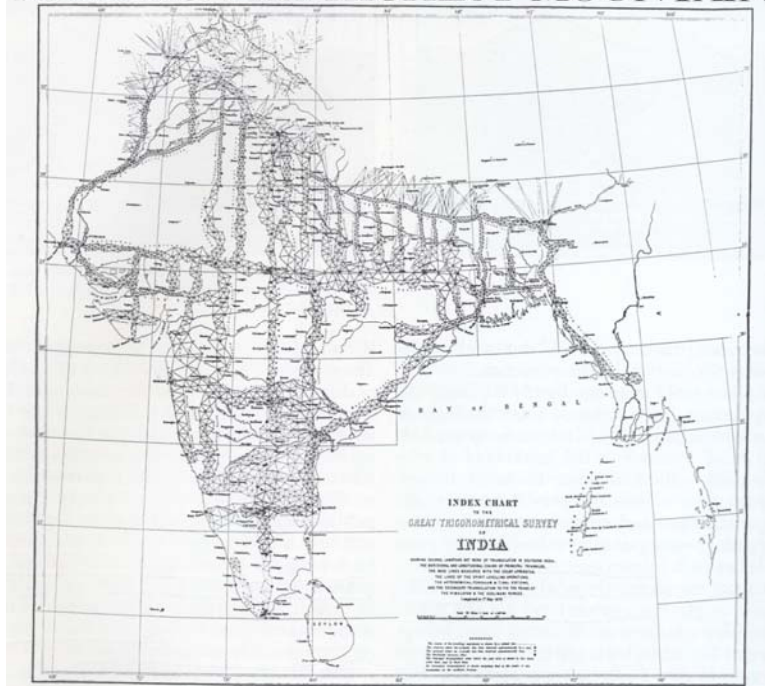


Februarius. 1668.
Configurations Medicorum.
Hora 7. P.M.

Die	Configurations Medicorum
1	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
2	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
3	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
4	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
5	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
6	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
7	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
8	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
9	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
10	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
11	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
12	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
13	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
14	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
15	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
16	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
17	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
18	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
19	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
20	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
21	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
22	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
23	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
24	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
25	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
26	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
27	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
28	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓
29	☉ ☽ ☿ ♀ ♁ ♃ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓ ♄ ♅ ♆ ♇ ♈ ♉ ♊ ♋ ♌ ♍ ♎ ♏ ♐ ♑ ♒ ♓

In 1696, the first accurate map (shown below left) of the Earth was drawn by César-François Cassini de Thury based on 40 points (given in red) of accurate latitude and longitude. The north-south position (latitude) of any point on Earth could be determined via star paths. To measure the east-west position (longitude), exact time measurement was essential: one minute of uncertainty implied a 10-mile margin of error in location. Inspired by Galileo's work, the mapmakers used the planet Jupiter as a "clock in the sky." They carefully recorded the motions of Jupiter's moons (see Cassini's 1668 table of the eclipses of Jupiter's moons below).

MAPPING THE HIGHEST MOUNTAIN



In 1744, Cassini's team started to map France in a rigorous fashion using triangulation. In the late 1700s, the world's first national land survey of France was completed. In 1870, Captain George Everest embarked to map India by triangulation. For generations, a vast network of repeating sightline triangles was meticulously measured and recorded (see map below). What resembles a pattern of eyelashes on the northern border represents the sightlines to stations built above treetops. While analyzing the triangles in the calculating offices of Calcutta, the mapmakers discovered the highest peak in the world: Mount Everest



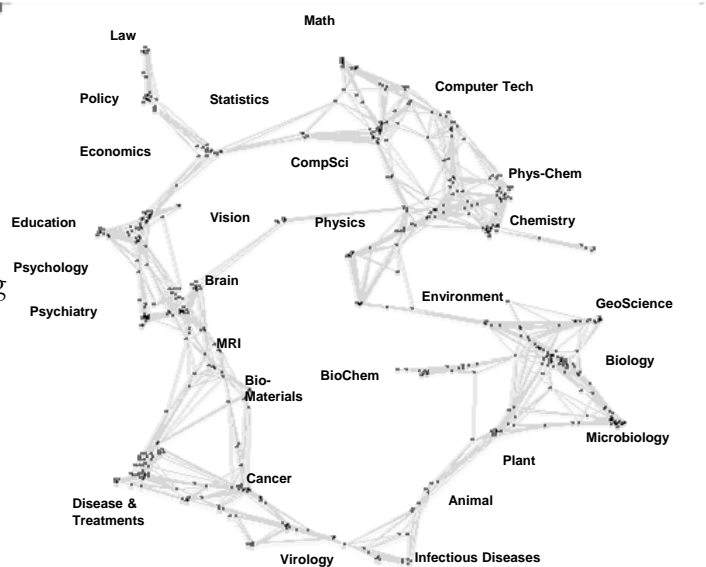
A New Map of the Whole World with Trade Winds According to the Latest and Most Exact Observations - Herman Moll - 1736

Towards a Map of all Sciences

2002 'Base Map' of Science

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007). *Mapping the Structure and Evolution of Chemistry Research*. 11th International Conference on Scientometrics and Informetrics. pp. 112-123.

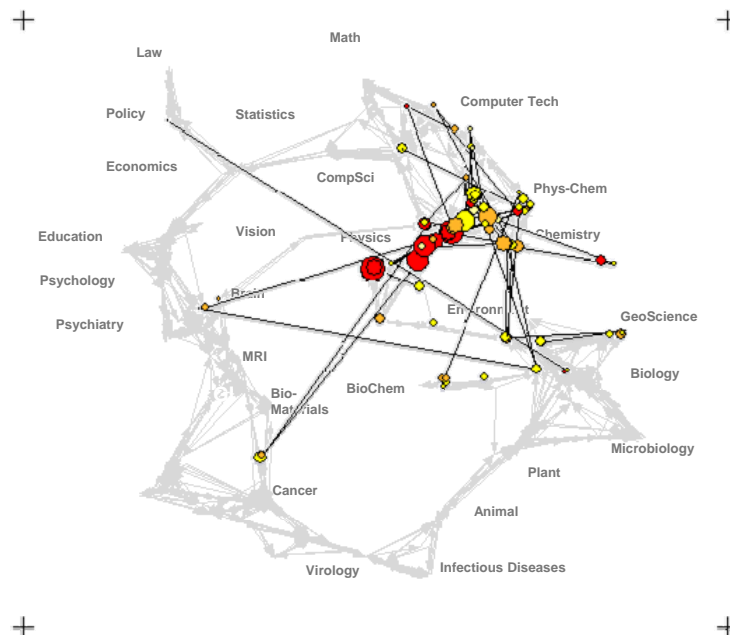
- Uses combined SCI/SSCI from 2002
 - 1.07M papers, 24.5M references, 7,300 journals
 - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
 - (x,y) positions for each journal cluster
 - by association, (x,y) positions for each journal



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

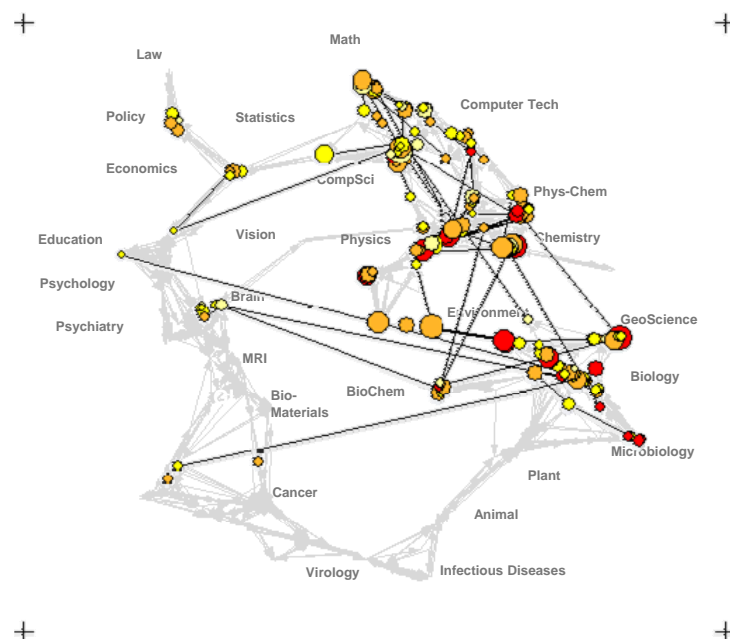
Funding patterns of the US Department of Energy (DOE)



Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

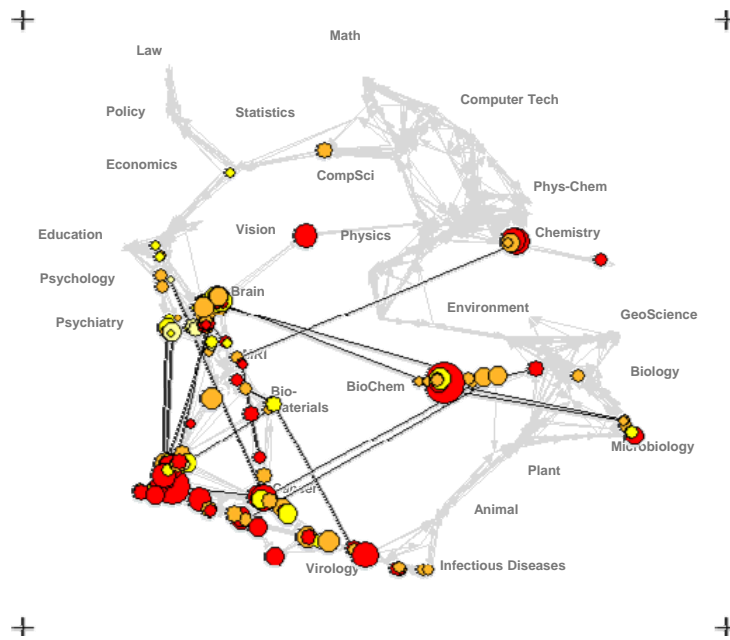
Funding Patterns of the National Science Foundation (NSF)



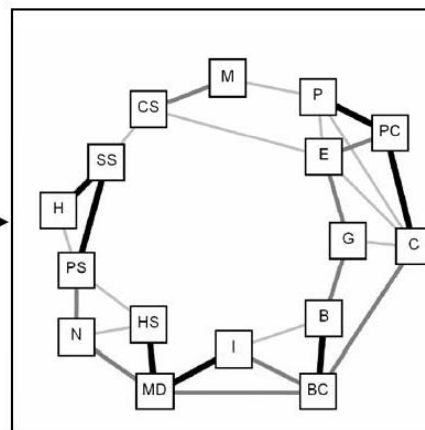
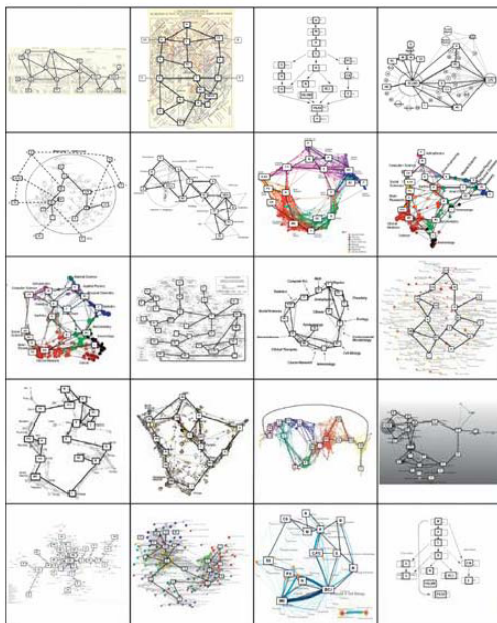
Science map applications: Identifying core competency

Kevin W. Boyack, Katy Börner, & Richard Klavans (2007).

Funding Patterns of the National Institutes of Health (NIH)



Towards a Consensus Map of Science



Klavans, R., & Boyack, K. W. (2009). "Toward a consensus map of science." *Journal of the American Society for Information Science and Technology* 60(3), 455-476.

Kevin W. Boyack, UCGIS Summer Meeting, June, 2009

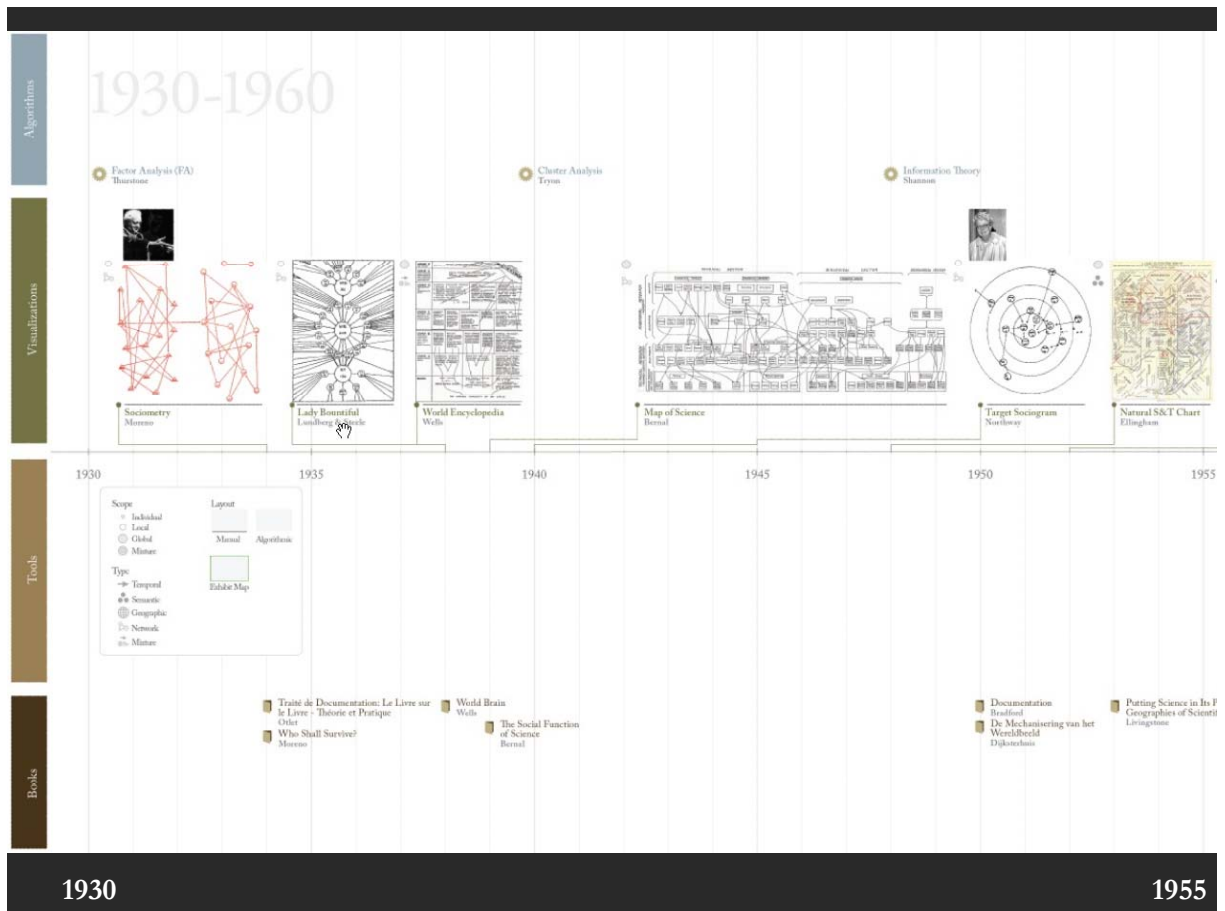
Milestones of Mapping Science



1934

2007

Börner, Katy. (2010). *Atlas of Science: Visualizing What We Know*. MIT Press.



1930

Sociometry
Moreno

1935

Lady Bountiful
Lundberg & Sten

Scope

- Individual
- Local
- Global
- Mixture

Layout

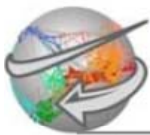
Manual Algorithmic

Type

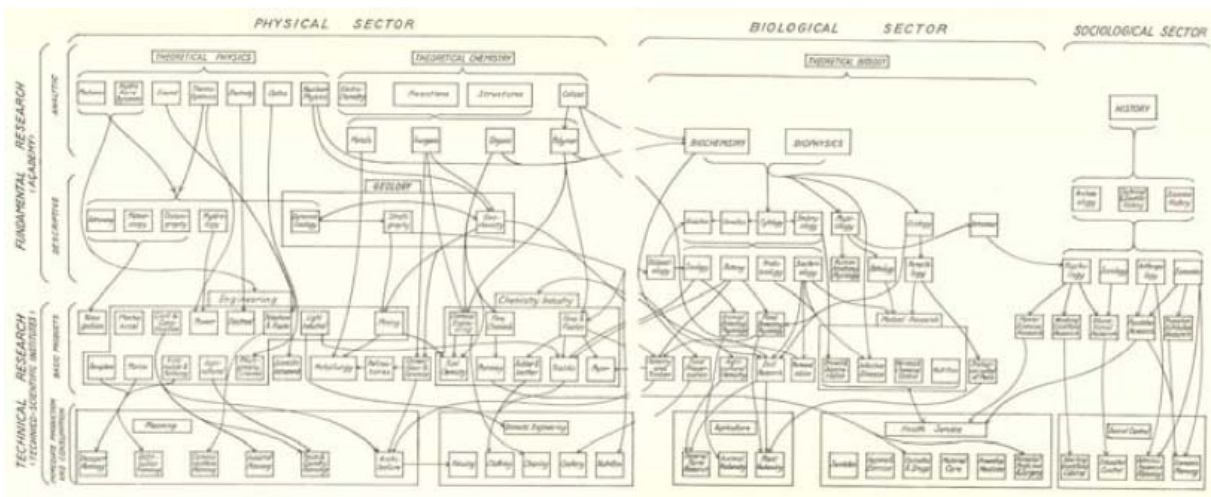
- Temporal
- Semantic
- Geographic
- Network
- Mixture

Exhibit Map

Zoom into one map and legend



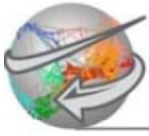
Bernal, 1939



John D. Bernal was a world renowned physicist, a historian of science, and a sociologist of science. He is considered to have produced one of the first 'maps' of science.

Bernal, J.D. (1939). *The Social Function of Science*. London: Routledge & Kegan Ltd.



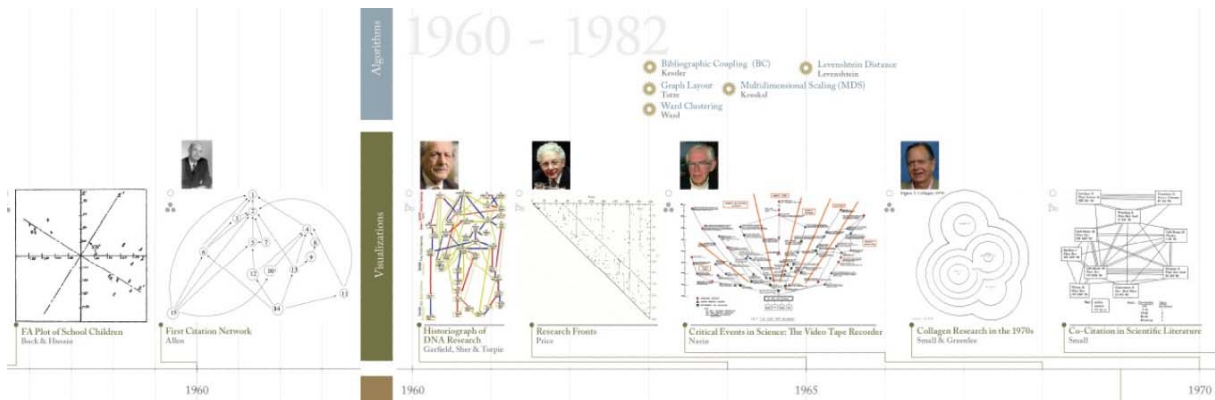


Ellingham, 1948

Ellingham's "Relations Between the Branches of Natural Science and Technology" with an overlay of "Abstracts or Groups of Abstracts Covering A Very Wide Field" (1948)

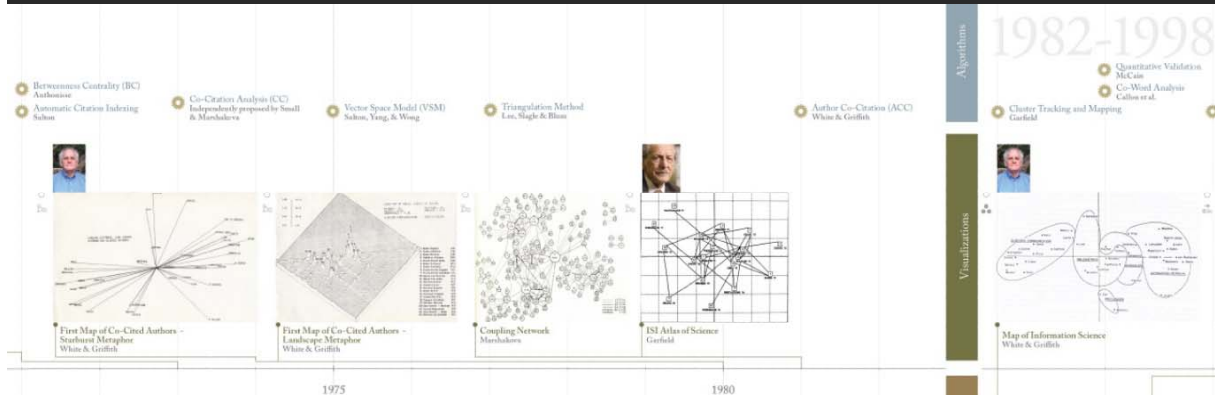


H. J. T. Ellingham (1948). "Divisions of Natural Science and Technology," Royal Society Scientific Information Conference, 21 June to 2 July 1948, London: Burlington House,



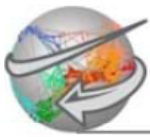
1952

1973



1980

1982



Garfield, 1964

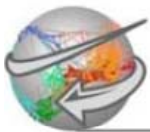
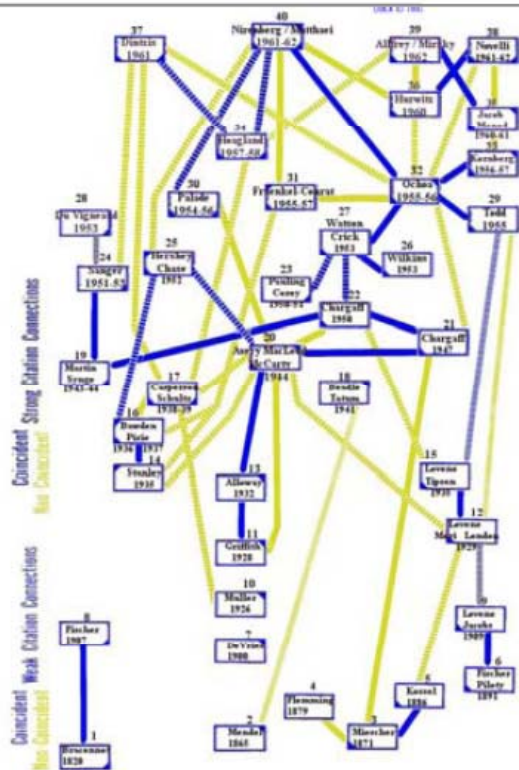
Historiograph of DNA Development



Eugene Garfield,
recent photo.
Creator of the ISI
Web of Science
citation database.

<http://www.garfield.library.upenn.edu/>

Garfield, Sher, & Torpie (1964). "The Use of Citation Data in Writing the History of Science." Air Force Office of Scientific Research under contract F49(638)-1256.



Small, 1973

Using co-citation to create domain maps

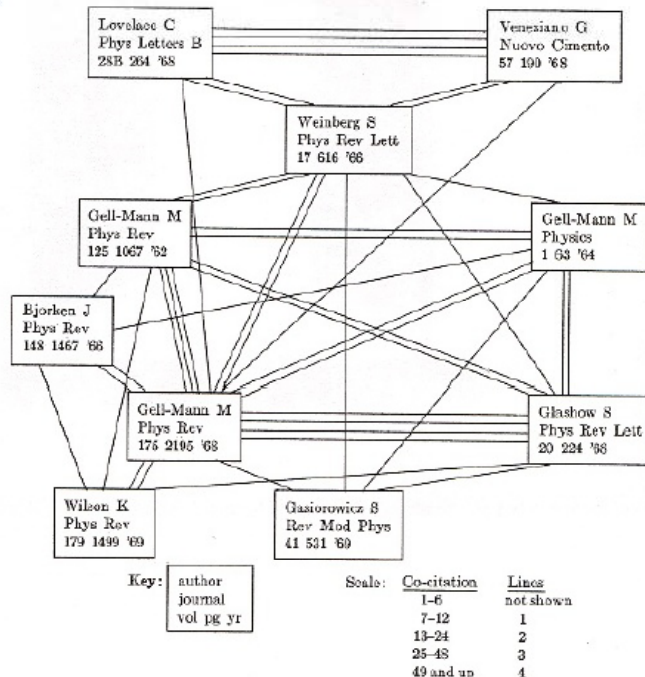


Henry Small.
Head of research
at ISI, now
Thomson Reuters
Scientific.

Small, H. (1973). "Co-citation in the scientific literature: A new measure of the relationship between two documents." *JASIS*, 24, 265-269.

Marshakova, I.V. (1973). "A system of document connections based on references." *Scientific and Technical Information Serial of VINITI*, 6, 3-8.

FIGURE 1
Co-citation Network for Frequently Cited Papers in Particle Physics
(Data from the 1971 *SCJ*)



1987

- Spring Graph Layout Eades
- Self-Organizing Map (SOM) Kohonen
- Journal Co-Citation Mapping McCaa
- Tree Map Layout Johnson & Shneiderman
- Frischerman Reingold Graph Layout Frischerman & Reingold
- Pathfinder Network Scaling (PFNet) Schreyer
- Latent Semantic Analysis (LSA) Deerwester et al.
- Kamada-Kawai Graph Layout Kamada & Kawai
- Identifying Scientific Frontiers Garfield & Small

NoteCards Hilson, Moran & Trigg at Xerox PARC

Specialties in Sociology Easte

SOM of Newsgroup Postings Kohonen

Butterfly Citation Browser Mackinley, Cool & Row at Xerox Research

SOMET Map H. Chen et al.

Concept Map Nowak

1997

1998

1999

- Automatic Citation Indexing Giles, Bolacker & Lawrence
- PageRank Brin & Page
- Hubs & Authorities Kleinberg
- Fixing Complementary Literatures Swenson & Sandhu
- Combined Linkage Small
- Longitudinal Coupling Small

Dewey Tree Map Swenson

NDS Map of Information Science White & McCaa

Map of the Market Wainwright

Collaborative StarWalker C. Chen et al.

1996 Map of Science Small

1997

1999



SPIRE, Themescape, 1995

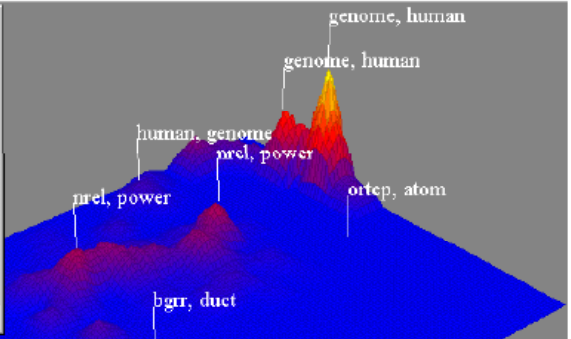
Pacific Northwest Labs introduces a mapping tool based on text

2.5-D representation of intensity of "themes" using topography

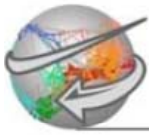
Later spinoff of same technology used in patent analysis products

Word	Contribut...
human	<div style="width: 100%;"></div>
genome	<div style="width: 100%;"></div>
gene	<div style="width: 100%;"></div>
genetic	<div style="width: 100%;"></div>
dna	<div style="width: 100%;"></div>
genes	<div style="width: 100%;"></div>
sequence	<div style="width: 100%;"></div>
sequencing	<div style="width: 100%;"></div>
genetics	<div style="width: 100%;"></div>
chromosome	<div style="width: 100%;"></div>

Java Apple Window



Wise, Thomas, Pennock, et al. (1995). "Visualizing the non-visual: Spatial analysis and interaction with information from text documents." Paper presented at the IEEE Symposium on Information Visualization '95, Atlanta, Georgia, USA., October 30-31, 1995.

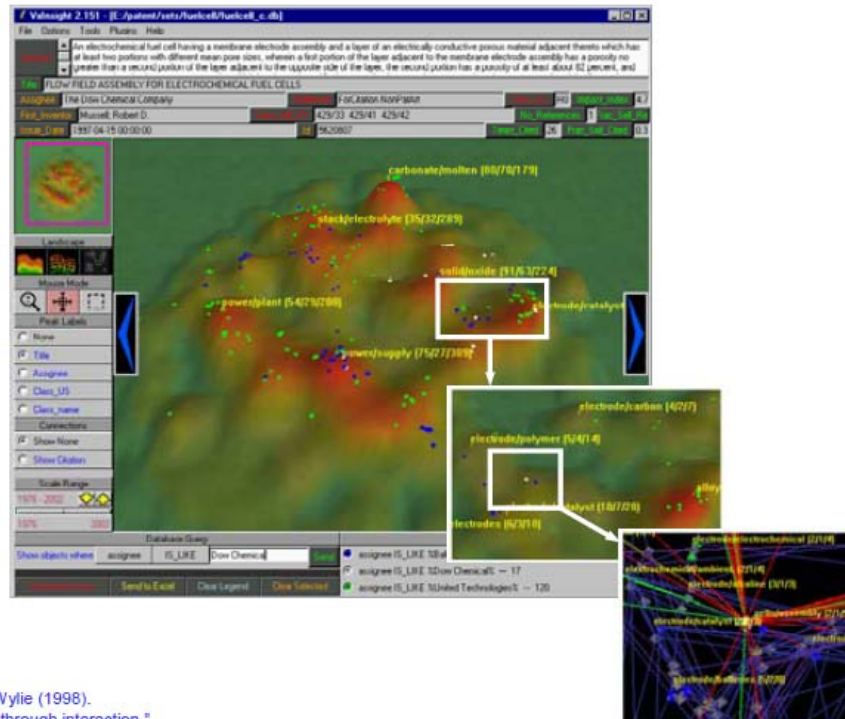


VxInsight, 1998

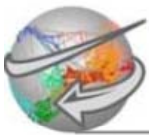
Sandia National Labs introduces an interactive browsing tool for exploring "maps"

Primarily for exploring citation-based maps, but ultimately used in science studies and genomics

Zoom, pan, query, etc. capabilities



Davidson, Hendrickson, Johnson, Meyers & Wylie (1998). "Knowledge mining with VxInsight: Discovery through interaction." *Journal of Intelligent Information Systems*, 11(3), 259-285.



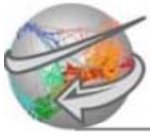
Author Co-citation Map, White, 1998

120 highly-cited authors in Information Science

Layout using multi-dimensional scaling



White & McCain (1998) "Visualizing a discipline: An author co-citation analysis of information science 1972-1995." *JASIS* 49(4), 327-356.



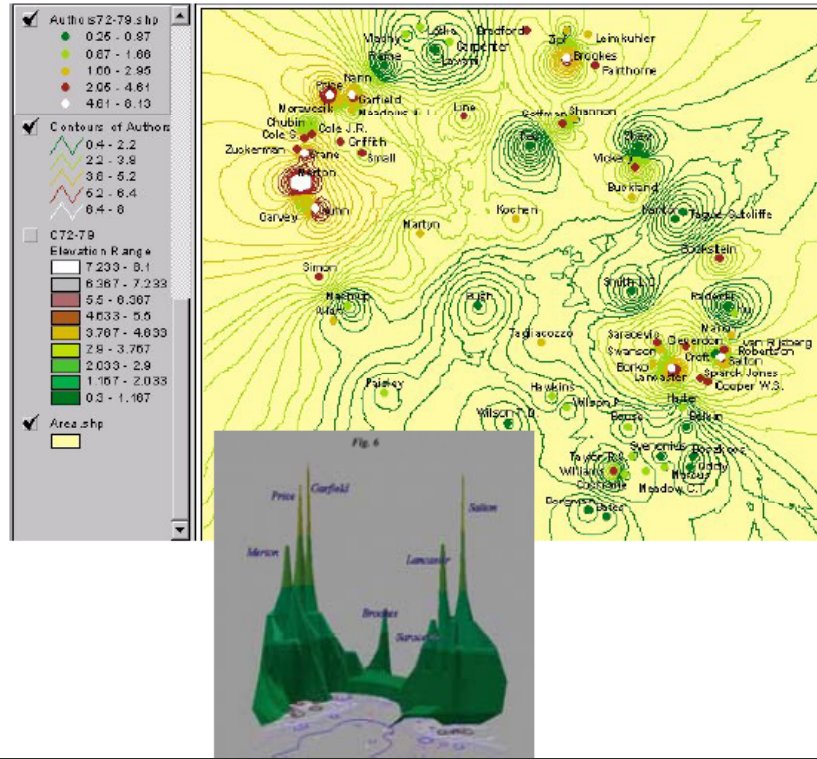
Old, 2001

Utilizing spatial information systems for non-spatial data analysis

Authors in Information Science

Topography added

3D representation also



<http://php.indiana.edu/~jold/SLIS/L710/L710.htm>

2000

Bill Chien, Lijun Gong, and Chiao Ouyang
Shanghai, China; CUHK, HK

Aurika
Bremen

Lighthouse Clustering Visualization
London, UK

Visual Net™
Bologna, Italy

2000

Algorithms

Karim Visual Interface to Search
Bremen

Visualizations

1999
2000

2001

Multi-Layer Science Map
Chen & Paul

Co-Author Environment
Newman

GIS Map of White & McCain
OU

Ideas
Martin Wattenberg

Best Direction
Kleinberg

Topic Model
Gaffik & Stevens

Combine Link and Content Information
Rakshon & Domingos

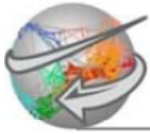
Community Structure Detection
Givens & Newman

Visuals Search
Andrew et al.

S&T Forecasting
Zhu & Porter

Illuminated Diagram Display
Paley

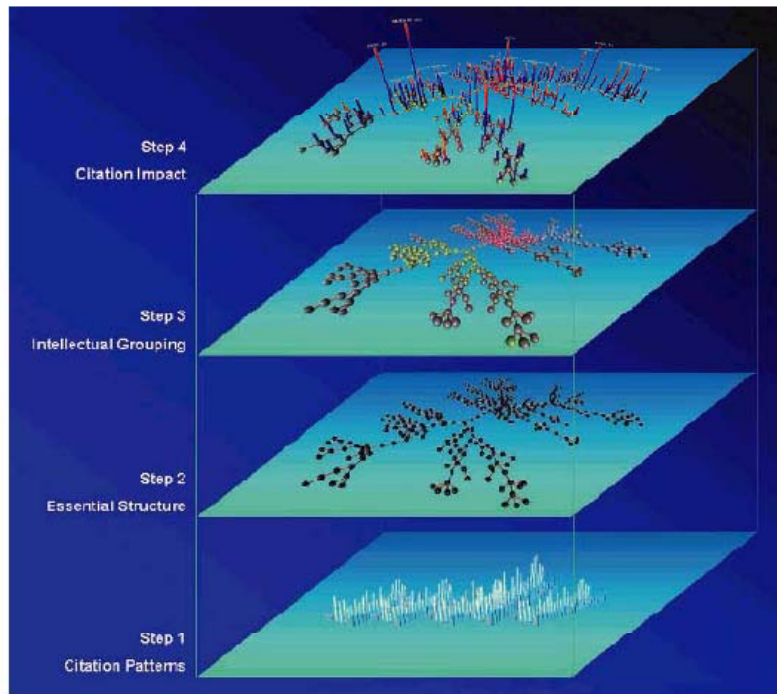
2001
2001



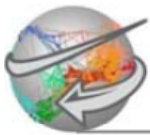
Chen, 2001

Software: CiteSpace I

Four-step procedure for visualizing intellectual structures using co-cited documents



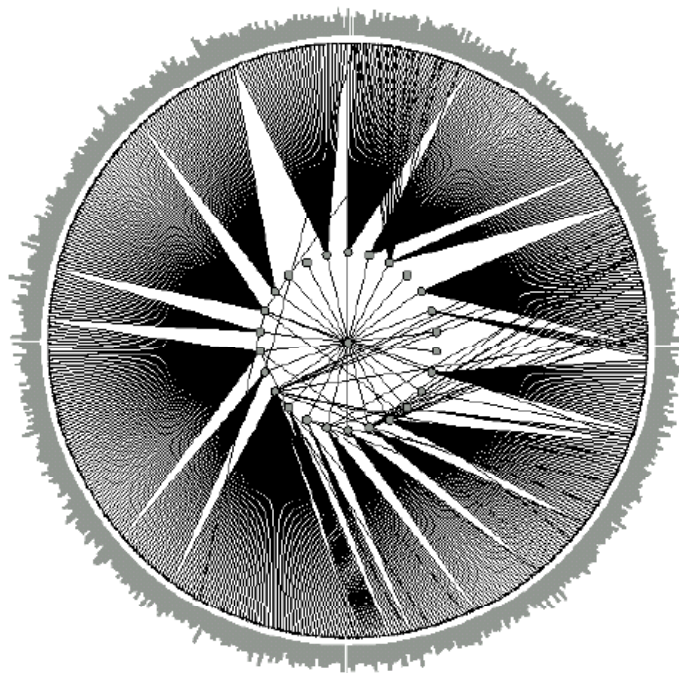
Chen & Paul (2001). "Visualizing a knowledge domain's intellectual structure." *Computer*, 34(3), 65-71.



Newman, 2001

Physicist bringing new tools to the problem

2-generation co-authorship graph of Mark himself (center node)



Newman, M.E.J. (2001). "Scientific collaboration networks. II. Shortest paths, weighted networks, and centrality." *Physical Review E*, 64, paper # 016132.

Algorithms

2002 2003

Visualizations

Cartographic Map of Conference Abstracts Skupin

AuthorLink & ConceptLink Lin, Whinn, & Berezilowski

Scholarly Genealogies Lorenz

Geography of Science Berry

Linking Papers and Funding Royak & Börner

Tools

2002 2003 2004

SOCNET Heinman & Dojca

JUNG O'Mahain et al.

Information Visualization Cyberinfrastructure Baumgartner et al.

Sonia Social Network Image Animator Bandy-deMall & McFarland

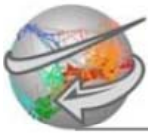
RefViz Overviews of Literature Search Results Thomson ISI ResearchSoft

Tulp Software Amber

Books

2002 2003

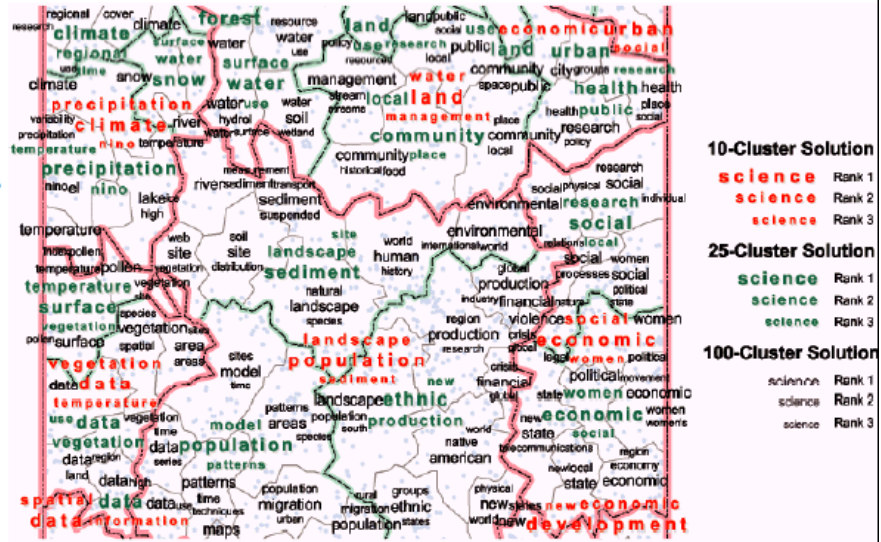
Theories of Communication Networks
 Mørup & Costantini
 Six Degrees
 Watts



Skupin, 2002

Applied self-organizing map to conference abstracts

Applied cartographic principles and techniques to the resulting SOM



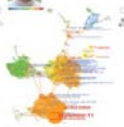
Skupin, A. (2002). "A cartographic approach to visualizing conference abstracts." *IEEE Computer Graphics and Applications*, 22, 50-58.

2004

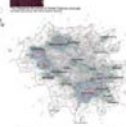
Weighted PageRank Algorithms
Wang & Gluckman



Evolution and Distribution of Patent Classifications
Katz



Mapping Scientific Frontiers
C-Class



Common Subgraphs of Social Science
Journals



Mapping Topic Barriers
Shank & Bollen

2004

Algorithms

Visualizations

Tools

Books



GIS Map of Geography
Shapiro



Subway Domain Map
Sutton

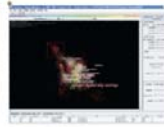


Evolving Co-Author Networks
Fu, Sheng & Veszteg

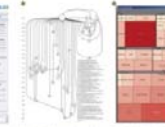
2004



Dyno Dynamic Network Software Package
ATIS



CiteSpace Trend Analysis
K. Chen



Hincite Heterogeneous
Visualization



The Future Trends
Fisher

Mapping Knowledge Domains
Muller & Rasmussen (Eds.)
Handbook of Quantitative Science and Technology Research: The Use of Publication and Patent Statistics in Studies of R&D Systems
The Development of Social Network Analysis: A Study in the Sociology of Science
Innovation and Incentives
Rosenbloom

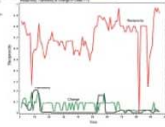
2004

2005

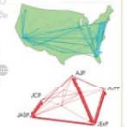
New-Evaluation Spring Embedders
Rubinov & Wampler
Time Map Layout
Phan et al.
Acknowledgment Indexing
Cormier et al.



Critical Paths and Trajectories of Individuals
Bender & Mall



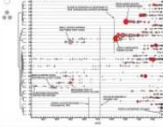
Longitudinal Social Network Metrics
Mondy, McFarland & Bender DeMall



Journal Flow Map of Data by
Author



Treemap View of 2004 Usenet Returns
Smith & Fisher

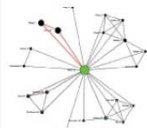


CrossMap of Arthropod Research
Morris



Backbone of Science
Borch, Klann & Bloor

2005



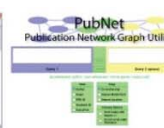
Person Visualization API
Hern, Card & Landay



GUESS Graph Exploration System
Auer



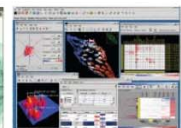
Author-Name Disambiguation
Author et al.
Toviss et al.



PubNet
Douglas et al.



CINI Researchers Link Viewer
Johnson et al.



OmniVis
Bainbridge

Models and Methods in Social Network Analysis
Carrington & Wasserman (Eds.)
The Hand of Science: Academic Writing and its Rewards
Centre
Measurement and Statistics on Science and Technology: 1920
to the Present (Knowledge Studies in the History of Science,
Technology, and Medicine),
Goffin

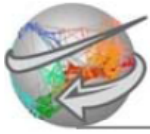
2005

Algorithms

Visualizations

Tools

Books



All of Science: Boyack et al., 2003

Map of over 7,000 journals

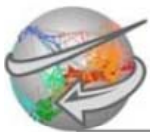
Over 200 clusters of journals based on inter-citation statistics

Graph layout techniques to position clusters

Inaccurate locations: it appears there is a center to science, but it is an artifact of the graph layout



Boyack, K. W., Klavans, R., & Börner, K. (2005). "Mapping the backbone of science." *Scientometrics* 64(3), 351-374.



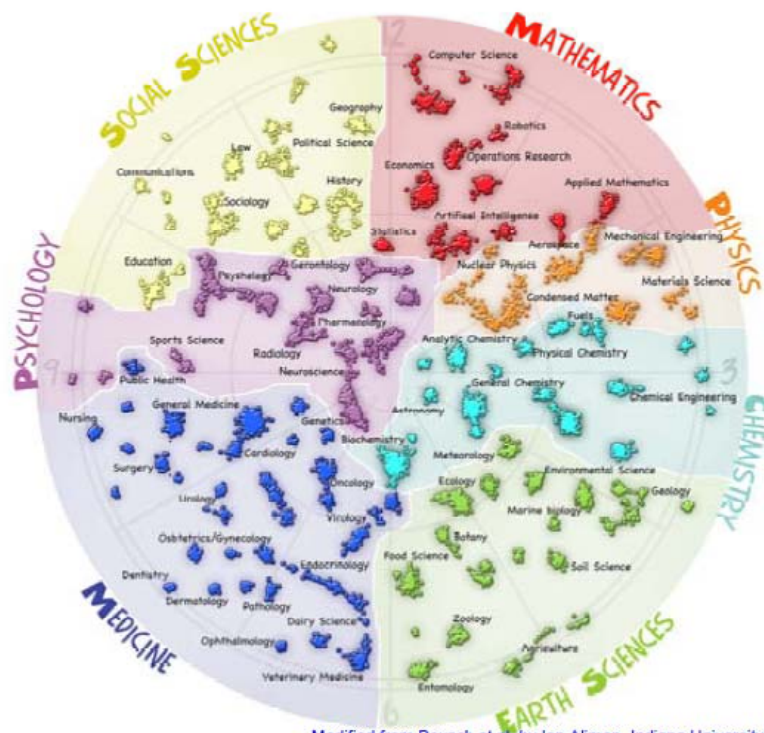
All of Science: Boyack et al., 2003

Map of over 7,000 journals

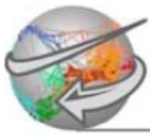
Over 200 clusters of journals based on inter-citation statistics

Graph layout techniques to position clusters

Inaccurate locations: it appears there is a center to science, but it is an artifact of the graph layout



Modified from Boyack et al. by Ian Aliman, Indiana University.



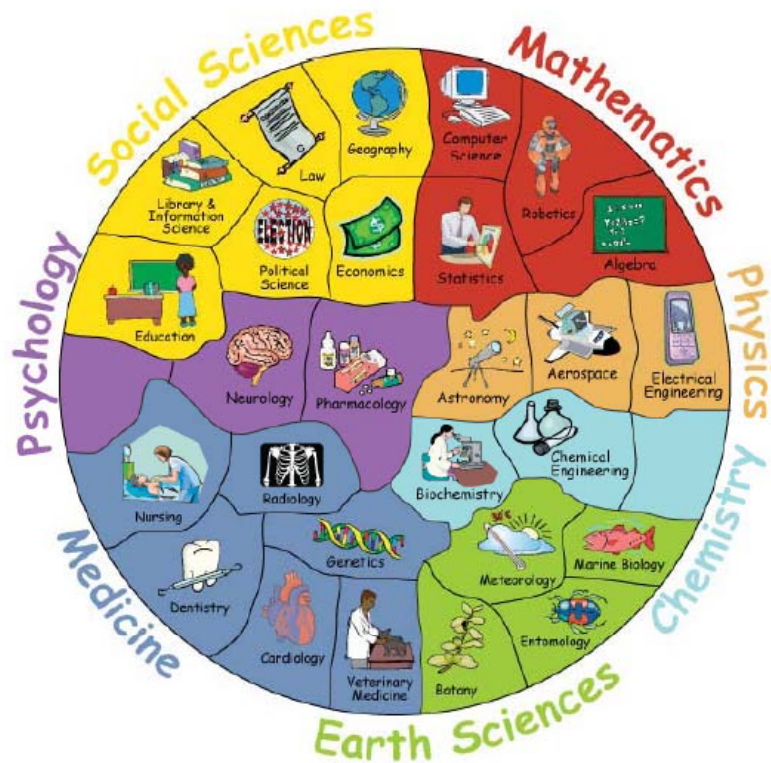
All of Science: Boyack et al., 2003

Map of over 7,000 journals

Over 200 clusters of journals based on inter-citation statistics

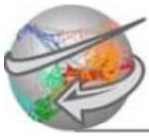
Graph layout techniques to position clusters

Inaccurate locations: it appears there is a center to science, but it is an artifact of the graph layout



2006

Cambrian explosion ~ seemingly rapid appearance of most major groups of complex animals around 530 million years ago.



All of Science: Klavans, 2007

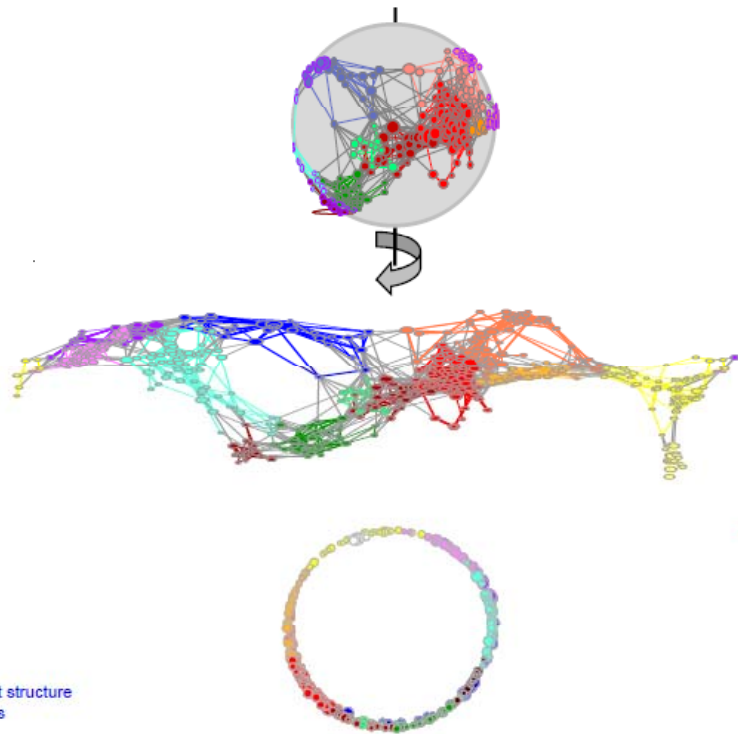
Map of over 16,000 journals and proceedings from ISI and Scopus databases (2001-2005 fileyears)

Two levels of clustering

Spherical layout of 554 clusters

Mercator projection of spherical layout

View from "south pole" is nearly circular

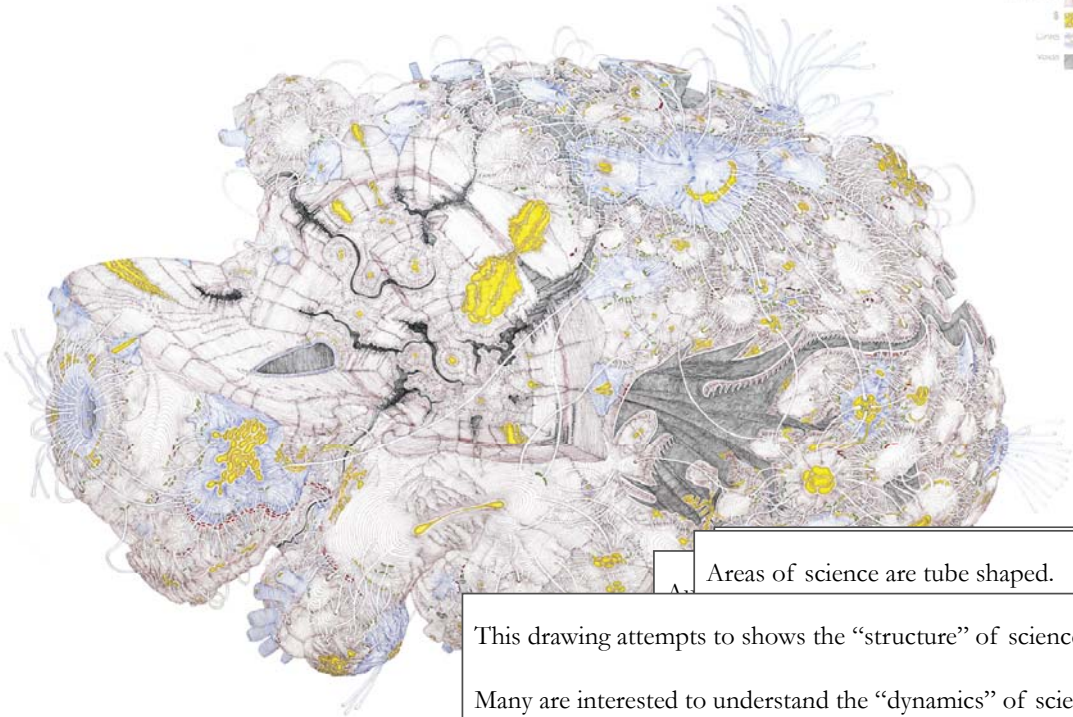


Klavans, R. & Boyack, K. W. (2007). "Is there a convergent structure of science? A comparison of maps from the ISI and Scopus databases." *ISSI 2007*.

New work is built on existing work. Each of the examples below cites a series of works that developed in a progressive fashion, as one born from the other:

- Garfield's original historiography of DNA research (1962); his long-term development of HistCite (first published in 2004); and his exhibit map (2006), which incorporates a re-rendering of the 1962 historiography and the application of HistCite.
- White et al.'s pioneering *Maps of Co-Cited Authors* (1982), *Map of Information Science* (1998), and the interactive AuthorLink (2002).
- Tobler's early works on the visualization of flow, his Flow Mapper tool (1987), and the tool's application in geospatial and network journal data (2005).
- Shneiderman's introduction of treemap layouts (1992, their utilization in the *Devey Map* (1992), H. Chen's *ET Map* (1995), and later Wattenberg's *Map of the Market* (1989) and Smith et al.'s *Usenet visualizations* (2005).
- White and McCain's *Map of Information Science* (1998) and Old's GIS rendering of same (2001).
- C. Chen's *Collaborative Information Spaces* (1999), *Multi-Layer Science Maps* (2001), *Mapping Scientific Frontiers* (2004), and *Mapping the Universe* (2007); and his continuous development of CiteSpace for trend analysis (2004).
- Batty et al.'s work on the geography of science (2003 and 2006).
- Moody et al.'s studies of contour sociograms (2004) and longitudinal social network movies (2005).
- Boyack and Klavans's work toward a base map of science followed by the creation of a series of maps (2005–2007).

Over time, former tools are subsumed by new tools, software APIs, and libraries. Examples include the *Information Visualization Cyberinfrastructure* (2003), Fekete's *The InfoVis Toolkit* (2004), and the *Network Workbench* (2006). Mashups also emerge, such as Herr et al.'s *Interactive Google Map of 2006 Society for Neuroscience Abstracts*.



Areas of science are tube shaped.

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

Science of Science Cyberinfrastructure — P O R T A L —

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 “[TIS: Towards a Macroscopic 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, 30 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>

This is the only mockup in this slide show.

Everything else is available today.



The logo for the Cyberinfrastructure for Network Science Center is a blue circular graphic with a central black dot and radiating lines. To the right of the logo, the text reads "cyberinfrastructure for NETWORK SCIENCE CENTER" and "School of Library and Information Science | Indiana University Bloomington". Below the logo and text is a navigation menu with several categories: "People", "Research", "Events", "Jobs", "Contact", "News", "Cyberinfrastructures", "Teaching", "Outreach", "Visiting Artists", and "Funding". Each category is accompanied by a small representative image.

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