Science from Above

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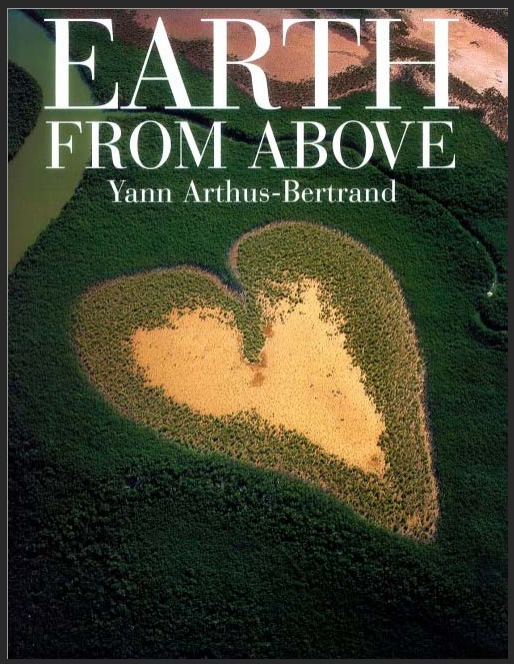
Cyberinfrastructure for Network Science Center, Director

School of Library and Information Science
Indiana University, Bloomington, IN

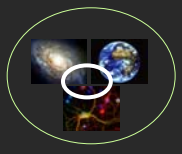
AMSE, January 3rd, 2008



The Problem:
Being Lost in Space

15th Century: One person can make major contributions to **many areas of science**

Mankind's Knowledge



use

contribute

Human Brain

Amount of knowledge on brain can mange

Leonardo Da Vinci (1452-1519)

20th Century: One person can make major contributions to **a few areas of science**

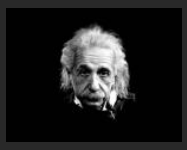
Mankind's Knowledge

use

contribute

Human Brain

Amount of knowledge
on brain can mange



Albert Einstein
(1879-1955)

21th Century: One person can make major contributions to **a specific area of science**

Mankind's Knowledge

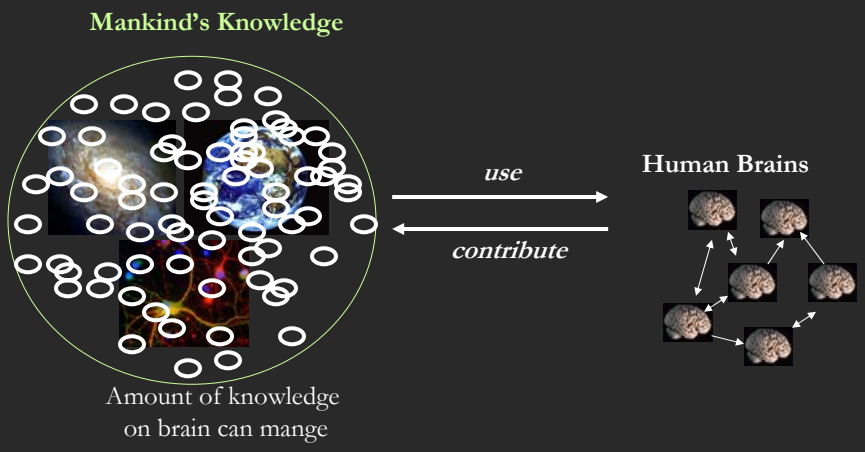
use

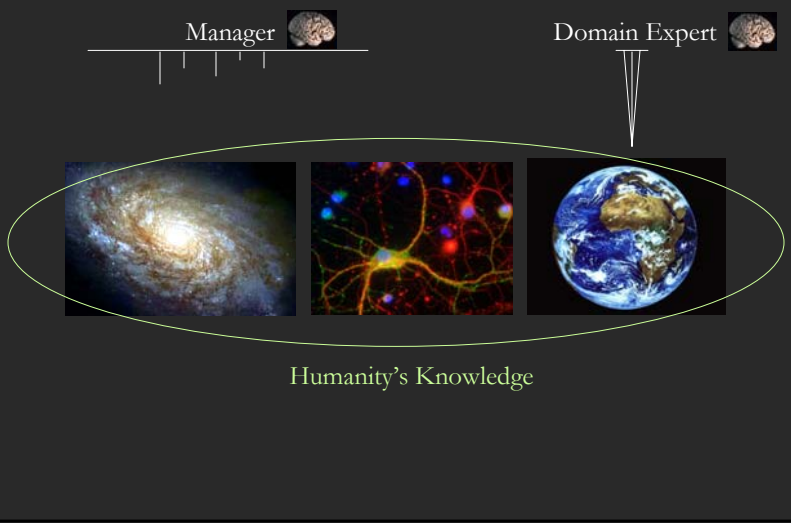
contribute

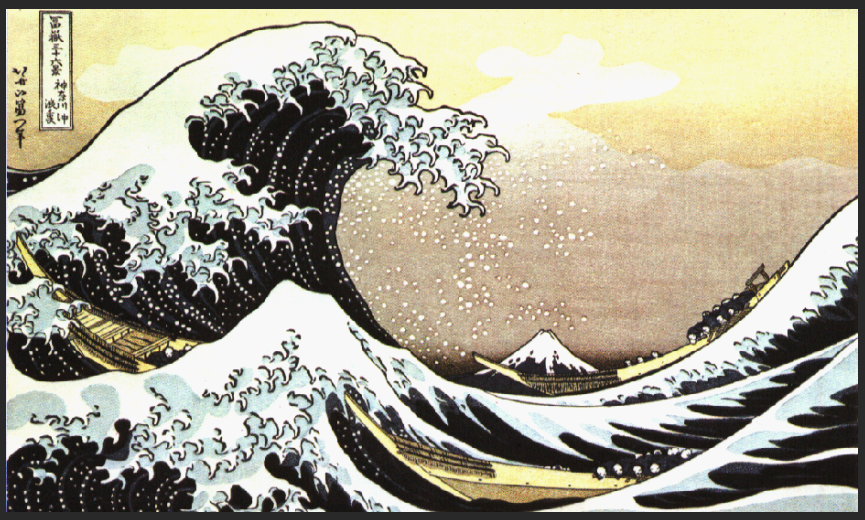
Human Brain

Amount of knowledge
on brain can mange

21th Century: One person can make major contributions to **a specific area of science**

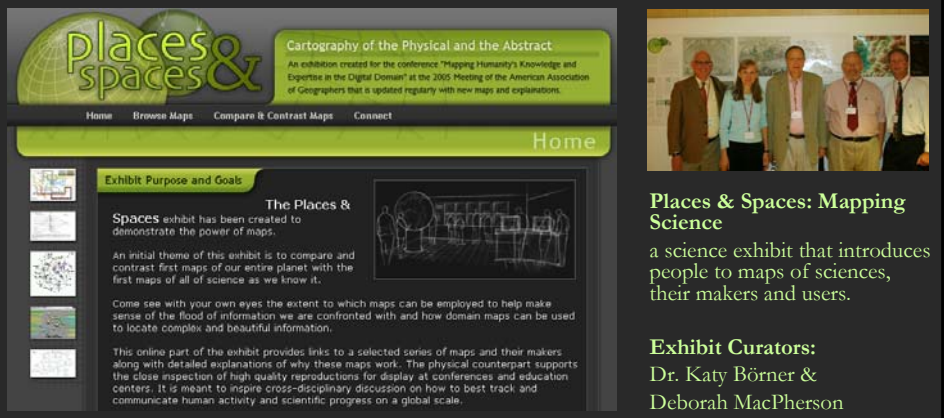






The Great Wave Off Kanagawa (Katsushika Hokusai, 1760-1849)

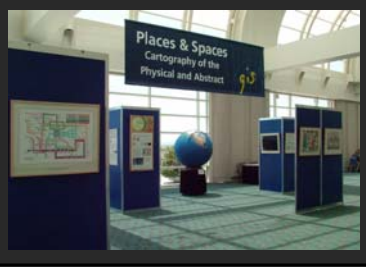
A Solution:
Science Maps

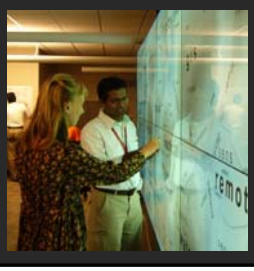


Places & Spaces: Mapping Science

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

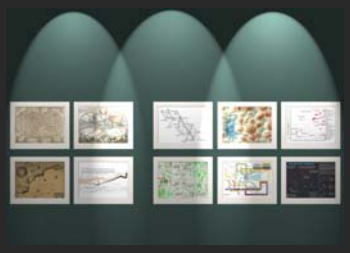
Exhibit Curators:
Dr. Katy Börner &
Deborah MacPherson



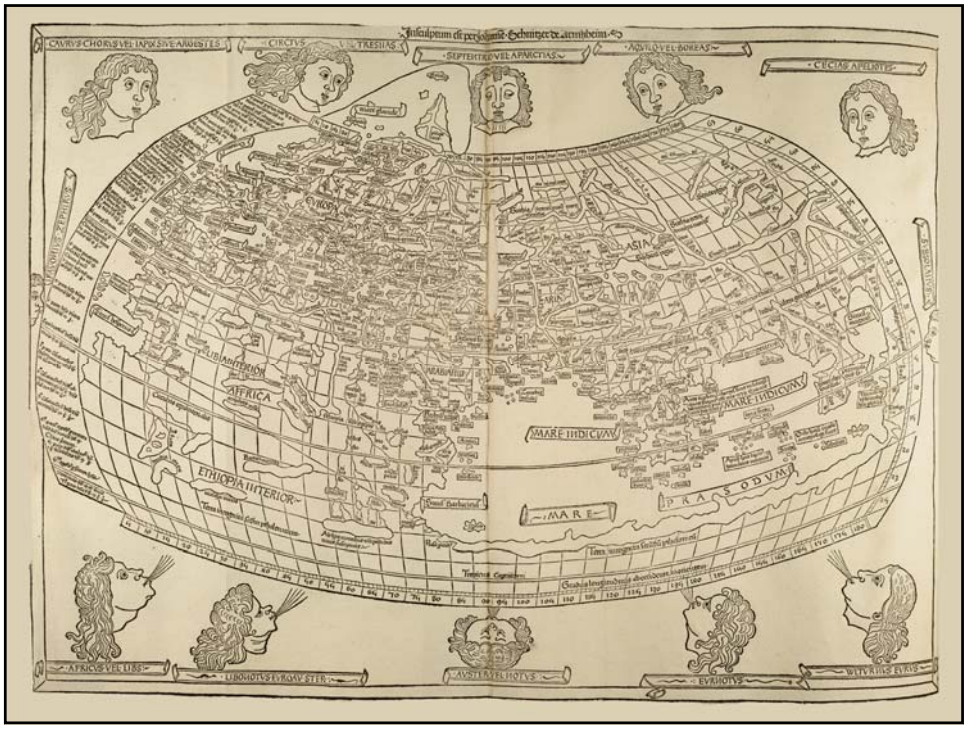


The Power of Maps

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



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


CAURUS CHORUS VEL IAPYX SIVE ARGESTES
CIRCIUS VEL THRESKIAS
SEPTENTRIO VEL APARCTIAS
AQUILO VEL BOREAS
CAECIAS APELIOTES
AFRICA
ASIA
MARE INDICUM
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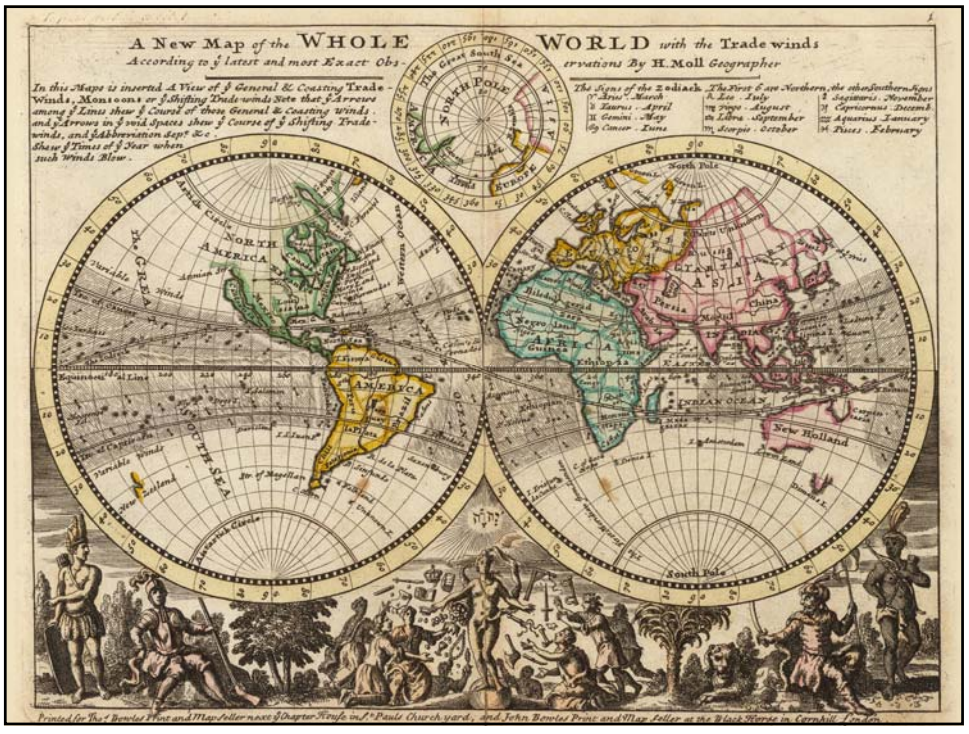
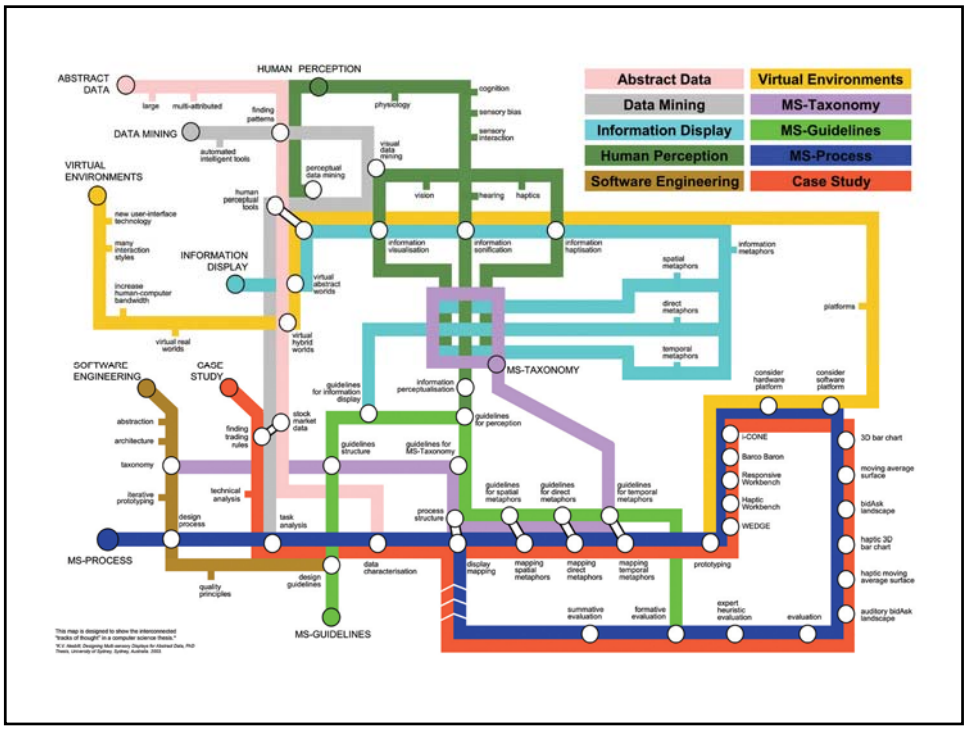
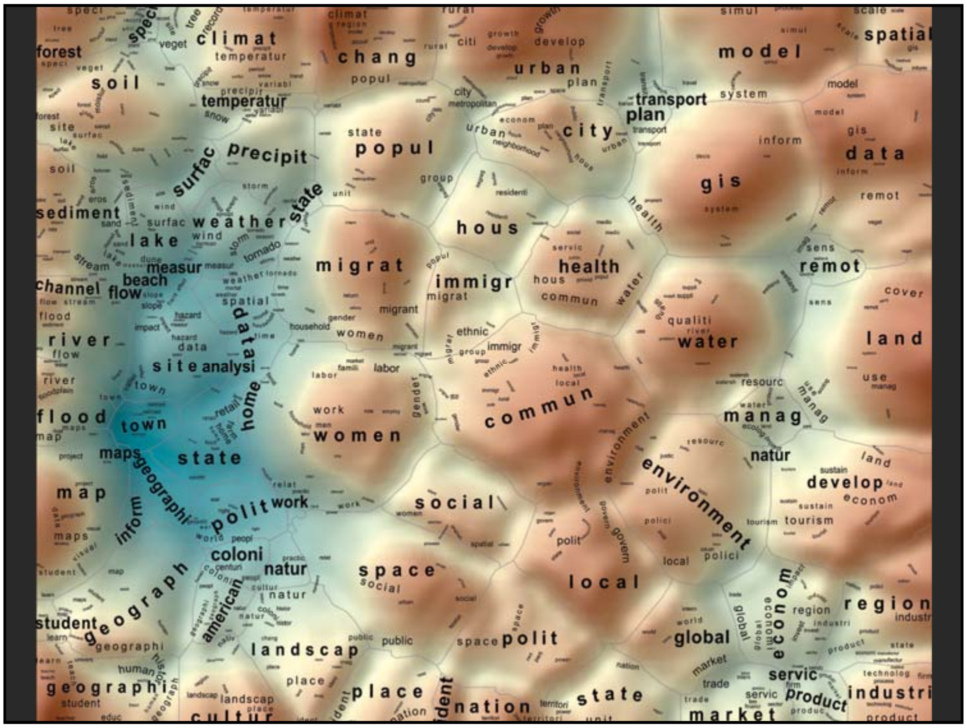
LIBONOTUS SEU ROMUS STER
AUSTER VEL NOTUS
EURUS
VULTURNUS SEU CAECIAS


A New Map of the WHOLE WORLD with the Trade winds
According to ye latest and most Exact Observations By H. Moll Geographer
In this Mapp is inserted A View of ye General & Coasting Trade-Winds, Monsoons or ye Shifting Trade-winds Note that ye Arrowes among ye Lines shew ye Coursd of these General & Coasting Winds. and ye Arrows in ye void Spaces shew ye Course of ye Shifting Trade-winds, and ye Abbreviation Sept. &c. Shew ye Times of ye Year when such Winds Blow.
The Signs of the Zodiack
The First & are Northern, the other Southern Signs
NORTH POLE
SOUTH POLE
NORTH AMERICA
AMERICA
EUROPE
ASIA
AFRICA
INDIAN OCEAN
New Holland
SOUTH SEA
Printed for Thos Bowles Print and Map seller next ye Chapter House in St Paules Church yard, and John Bowles Print and Map seller at the Black Horse in Cornhill London.

How would a map of science look?

What metaphors would work best?

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inform
coloni
geograph
space
local
region
student
landscap
polit
global
econom
geographi
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nation
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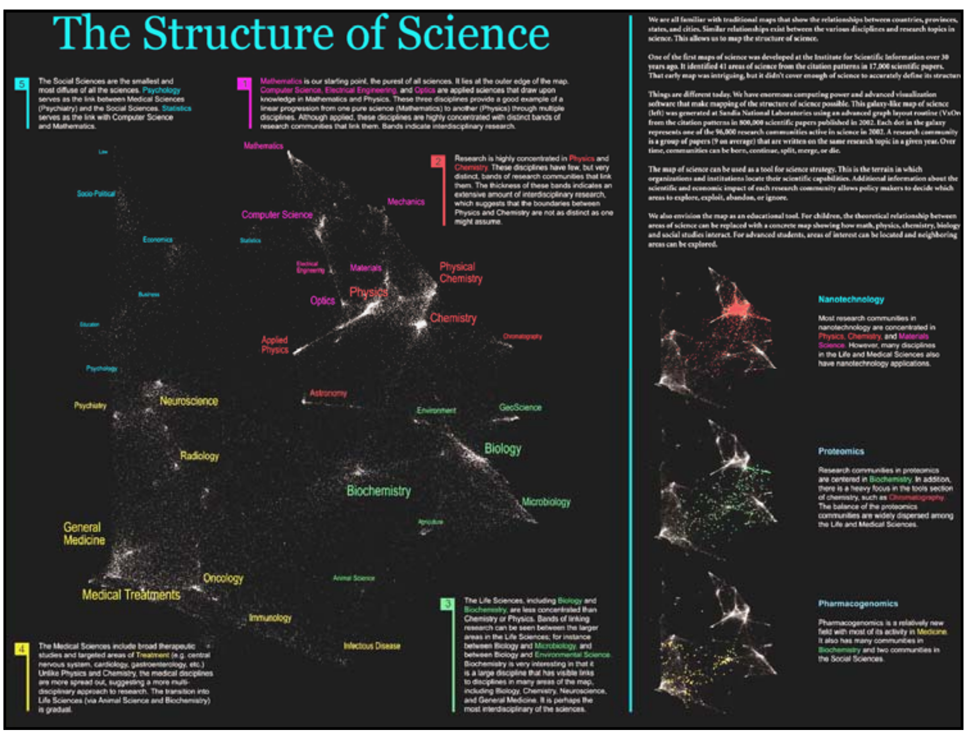
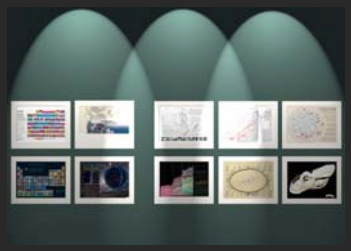
product
industri
market
cultur

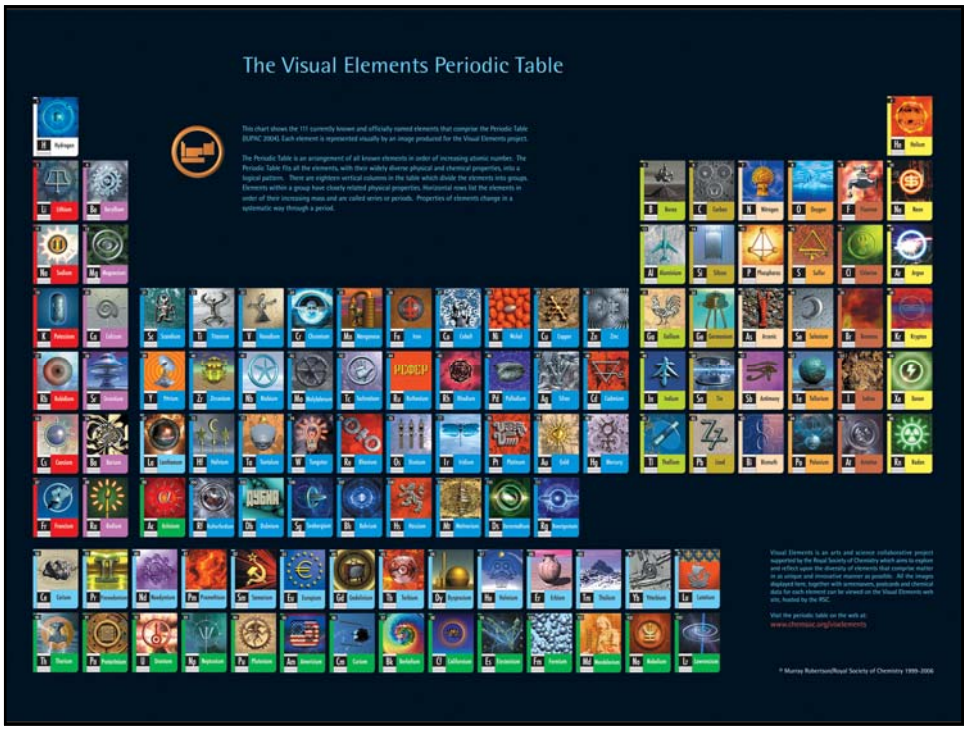

The Structure of Science
5
The Social Sciences are the smallest and most diffuse of all the sciences. Psychology serves as the link between Medical Sciences (Psychiatry) and the Social Sciences. Statistics serves as the link with Computer Science and Mathematics.
1
Mathematics is our starting point, the purest of all sciences. It lies at the outer edge of the map. Computer Science, Electrical Engineering, and Optics are applied sciences that draw upon knowledge in Mathematics and Physics. These three disciplines provide a good example of a linear progression from one pure science (Mathematics) to another (Physics) through multiple disciplines. Although applied, these disciplines are highly concentrated with distinct bands of research communities that link them. Bands indicate interdisciplinary research.
2
Research is highly concentrated in Physics and Chemistry. These disciplines have few, but very distinct, bands of research communities that link them. The thickness of these bands indicates an extensive amount of interdisciplinary research, which suggests that the boundaries between Physics and Chemistry are not as distinct as one might assume.
Mathematics
Socio-Political
Computer Science
Mechanics
Physical Chemistry
Optics
Physics
Chemistry
Applied Physics
Astronomy
Neuroscience
Environment
GeoScience
Biology
Radiology
Biochemistry
Microbiology
General Medicine
Oncology
Animal Science
Medical Treatments
Immunology
Infectious Disease
3
The Life Sciences, including Biology and Biochemistry, are less concentrated than Chemistry or Physics. Bands of linking research can be seen between the larger areas in the Life Sciences; for instance between Biology and Microbiology, and between Biology and Environmental Science. Biochemistry is very interesting in that it is a large discipline that has visible links to disciplines in many areas of the map, including Biology, Chemistry, Neuroscience, and General Medicine. It is perhaps the most interdisciplinary of the sciences.
4
The Medical Sciences include broad therapeutic studies and targeted areas of Treatment (e.g. central nervous system, cardiology, gastroenterology, etc.) Unlike Physics and Chemistry, the medical disciplines are more spread out, suggesting a more multi-disciplinary approach to research. The transition into Life Sciences (via Animal Science and Biochemistry) is gradual.
We are all familiar with traditional maps that show the relationships between countries, provinces, states, and cities. Similar relationships exist between the various disciplines and research topics in science. This allows us to map the structure of science.
One of the first maps of science was developed at the Institute for Scientific Information over 30 years ago. It identified 41 areas of science from the citation patterns in 17,000 scientific papers. That early map was intriguing, but it didn't cover enough of science to accurately define its structure.
Things are different today. We have enormous computing power and advanced visualization software that make mapping of the structure of science possible. This galaxy-like map of science (left) was generated at Sandia National Laboratories using an advanced graph layout routine (VxOrd) from the citation patterns in 800,000 scientific papers published in 2002. Each dot in the galaxy represents one of the 96,000 research communities active in science in 2002. A research community is a group of papers (9 on average) that are written on the same research topic in a given year. Over time, communities can be born, continue, split, merge, or die.
The map of science can be used as a tool for science strategy. This is the terrain in which organizations and institutions locate their scientific capabilities. Additional information about the scientific and economic impact of each research community allows policy makers to decide which areas to explore, exploit, abandon, or ignore.
We also envision the map as an educational tool. For children, the theoretical relationship between areas of science can be replaced with a concrete map showing how math, physics, chemistry, biology and social studies interact. For advanced students, areas of interest can be located and neighboring areas can be explored.
Nanotechnology
Most research communities in nanotechnology are concentrated in Physics, Chemistry, and Materials Science. However, many disciplines in the Life and Medical Sciences also have nanotechnology applications.
Proteomics
Research communities in proteomics are centered in Biochemistry. In addition, there is a heavy focus in the tools section of chemistry, such as Chromatography. The balance of the proteomics communities are widely dispersed among the Life and Medical Sciences.
Pharmacogenomics
Pharmacogenomics is a relatively new field with most of its activity in Medicine. It also has many communities in Biochemistry and two communities in the Social Sciences.

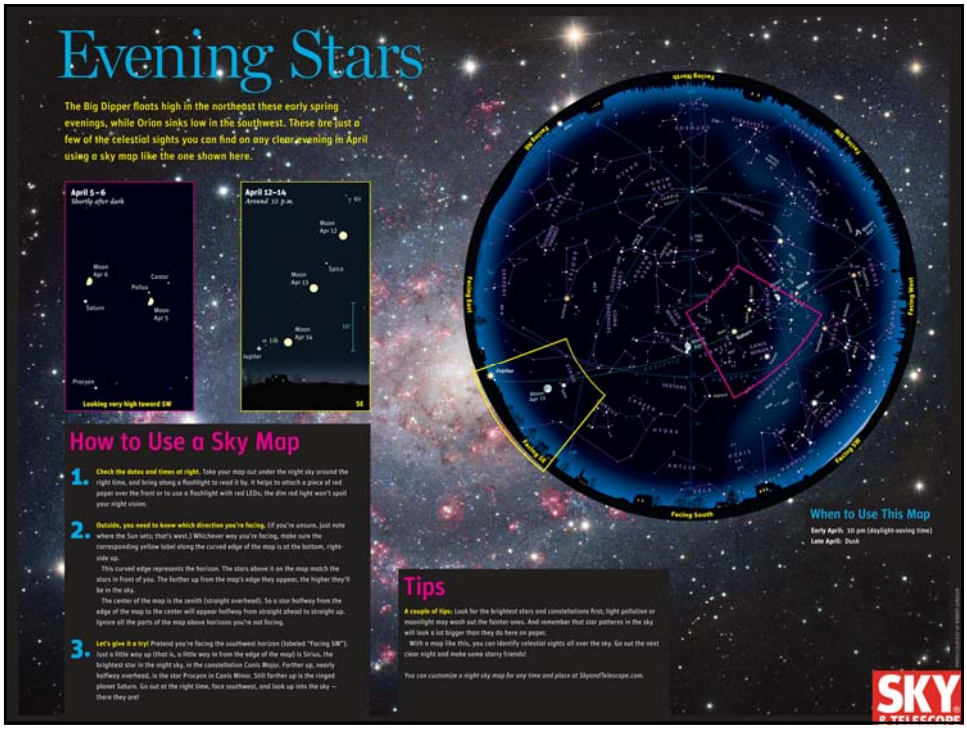
The Power of Reference Systems

Four Existing Reference Systems
VERSUS
Six Potential Reference Systems of Science



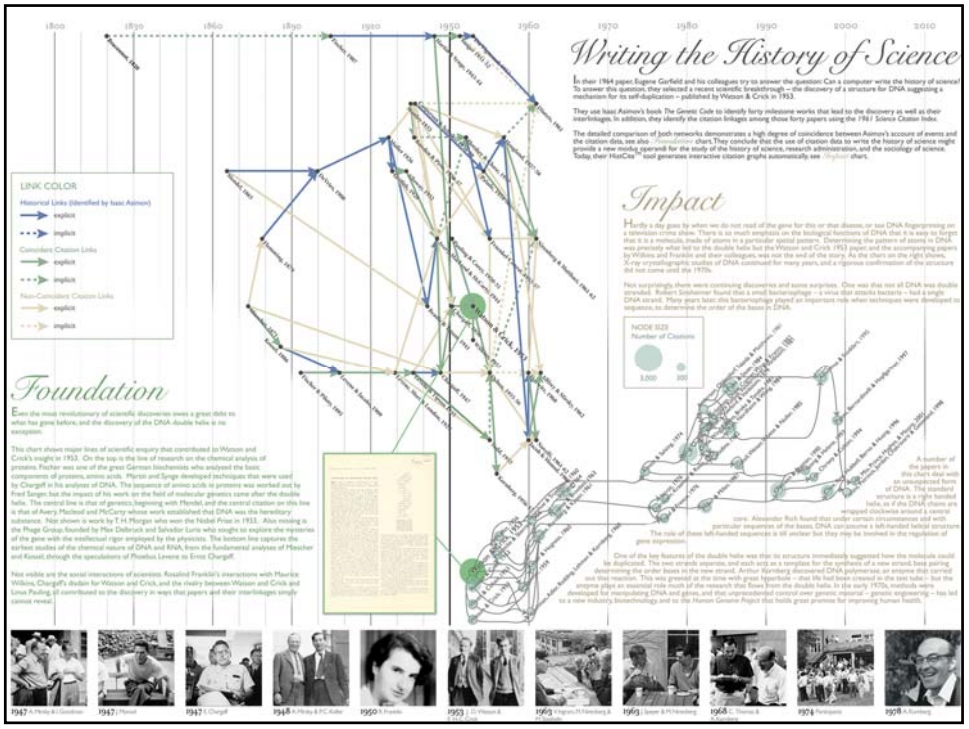
(2nd Iteration of Places & Spaces Exhibit - 2006)





How would a reference system for all of science look?

What dimensions would it have?


Writing the History of Science
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Historical Links (identified by Isaac Asimov)
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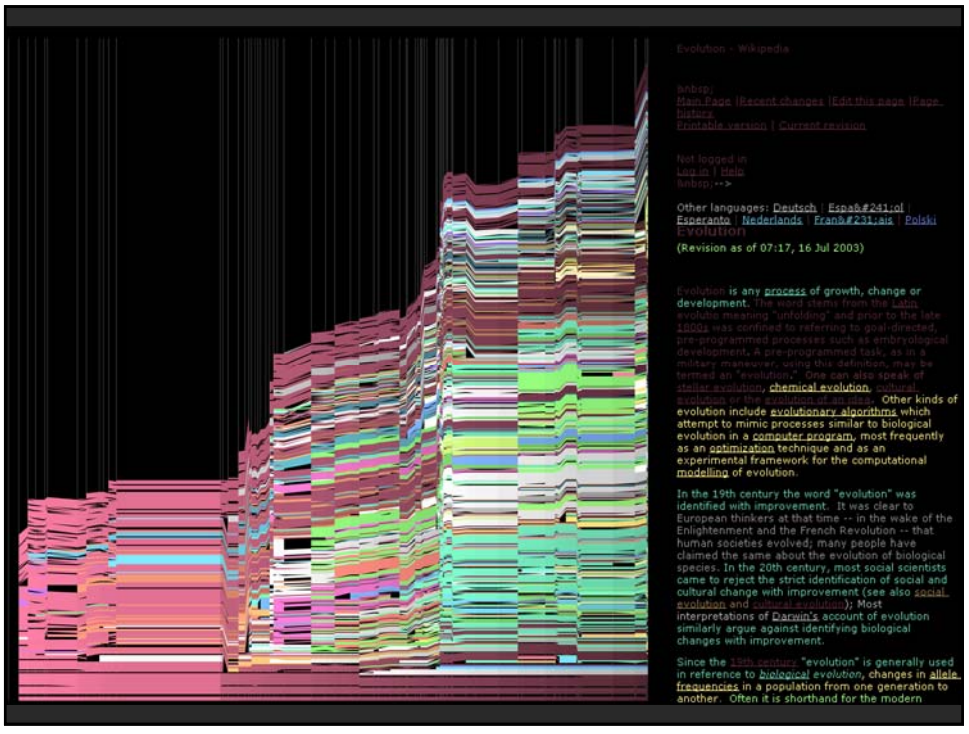
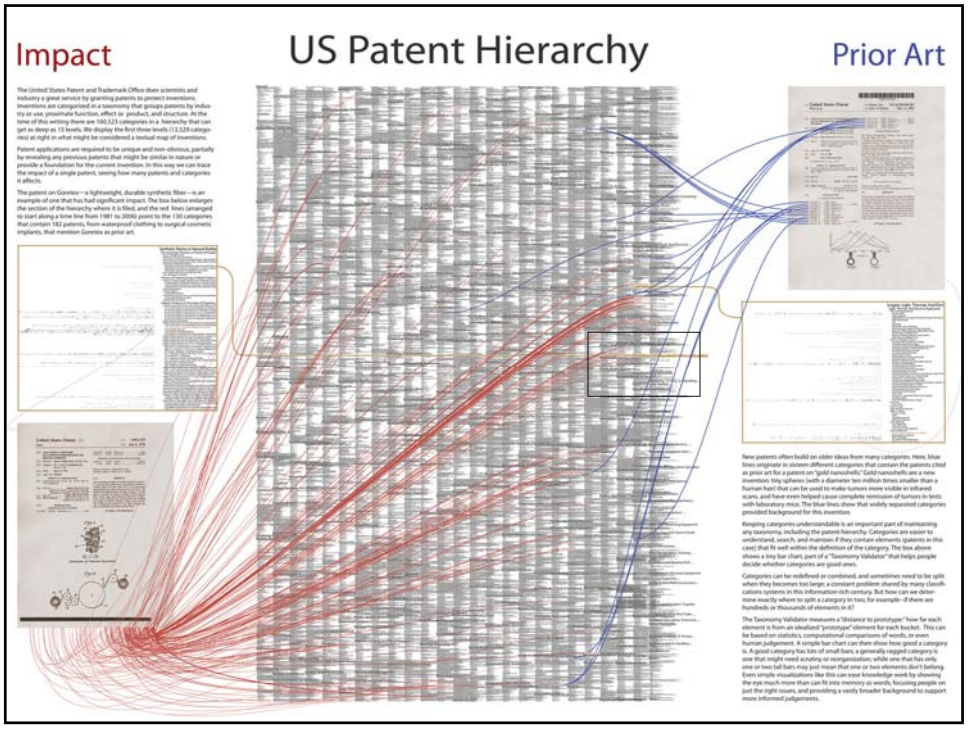
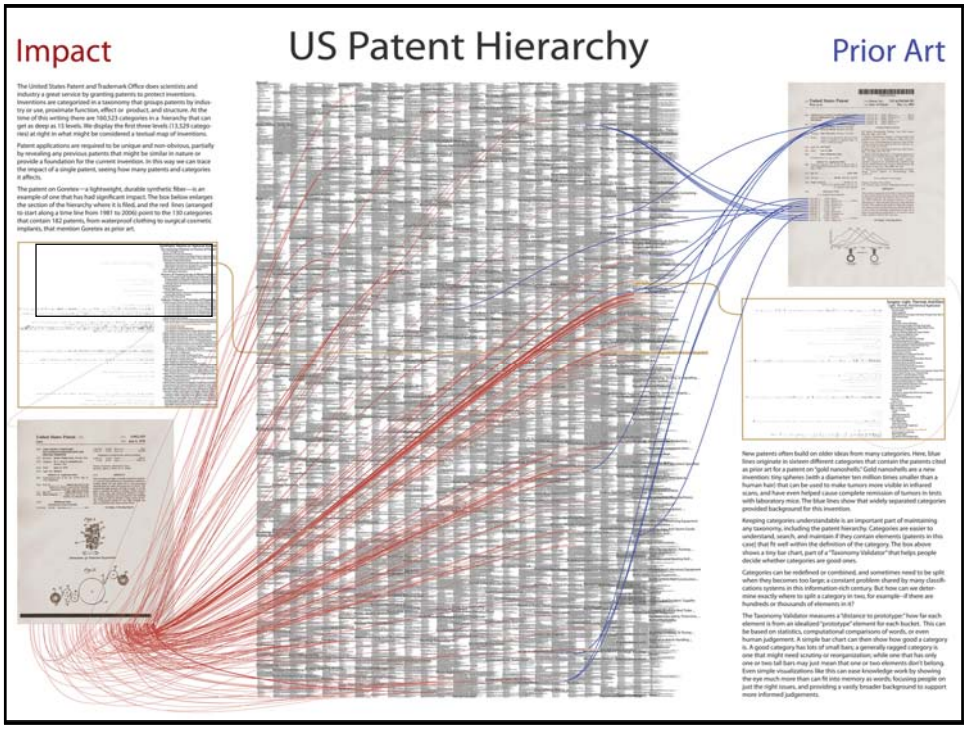

Evolution - Wikipedia
Main Page | Recent changes | Edit this page | Page history
Printable version | Current revision
Not logged in
Log in | Help
Other languages: Deutsch | Español | Esperanto | Nederlands | Français | Polski
Evolution
(Revision as of 07:17, 16 Jul 2003)
Evolution is any process of growth, change or development. The word stems from the Latin evolutio meaning "unfolding" and prior to the late 1800s was confined to referring to goal-directed, pre-programmed processes such as embryological development. A pre-programmed task, as in a military maneuver, using this definition, may be termed an "evolution." One can also speak of stellar evolution, chemical evolution, cultural evolution or the evolution of an idea. Other kinds of evolution include evolutionary algorithms which attempt to mimic processes similar to biological evolution in a computer program, most frequently as an optimization technique and as an experimental framework for the computational modelling of evolution.
In the 19th century the word "evolution" was identified with improvement. It was clear to European thinkers at that time -- in the wake of the Enlightenment and the French Revolution -- that human societies evolved; many people have claimed the same about the evolution of biological species. In the 20th century, most social scientists came to reject the strict identification of social and cultural change with improvement (see also social evolution and cultural evolution); Most interpretations of Darwin's account of evolution similarly argue against identifying biological changes with improvement.
Since the 19th century "evolution" is generally used in reference to biological evolution, changes in allele frequencies in a population from one generation to another. Often it is shorthand for the modern


Impact
US Patent Hierarchy
Prior Art


Extruding a solid polymer containing material to
Synthetic Resins or Natural ...
Coating Processes
Rotary Shafts, Gudgeons, ...
Data Processing: Structural ...
Synthetic Resins or Natural ...
Measuring, Testing
Data Processing: Speech
Data Processing: Financial, ...
Jewelry, Symbolic
Threaded, Headed Fastener, ...
Synthetic Resins or Natural ...
Data Processing: Artificial ...
Data Processing: Database ...
Synthetic Resins or Natural ...
Electrical Computers: Arithmet
Amusement Devices
Electrical Computers And ...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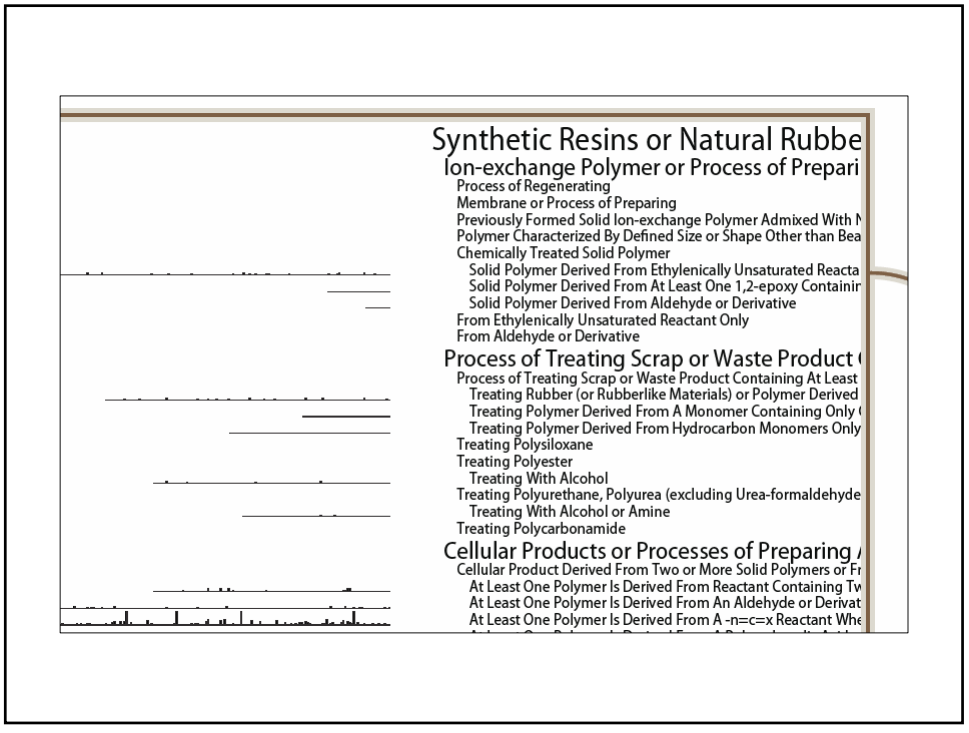
US Patent Hierarchy
Prior Art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Treating Polyester
Treating With Alcohol
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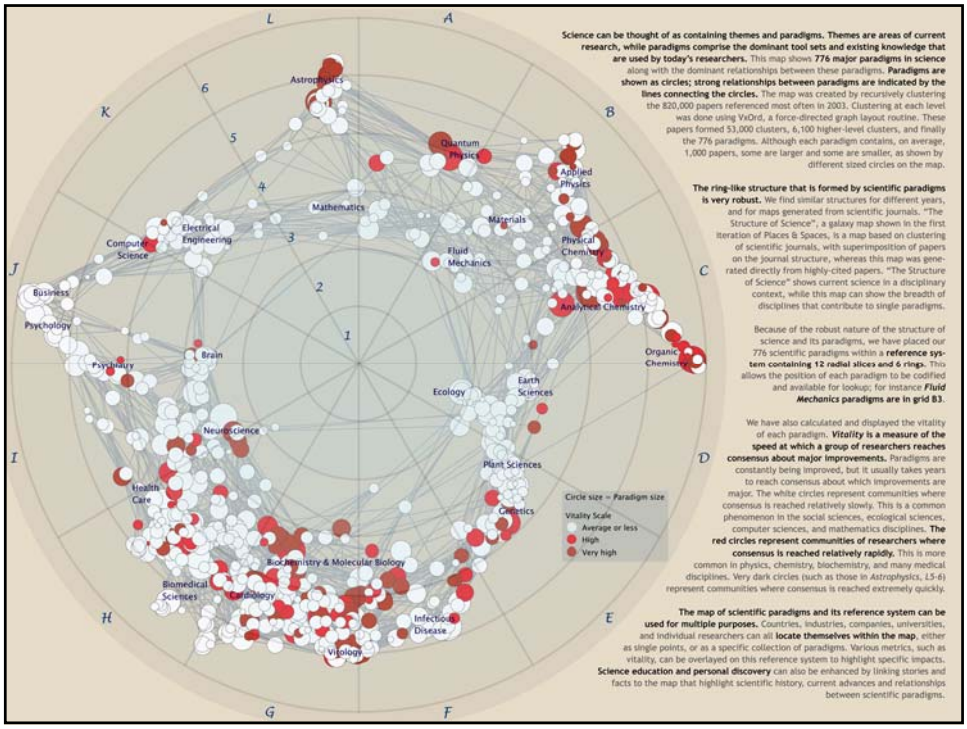
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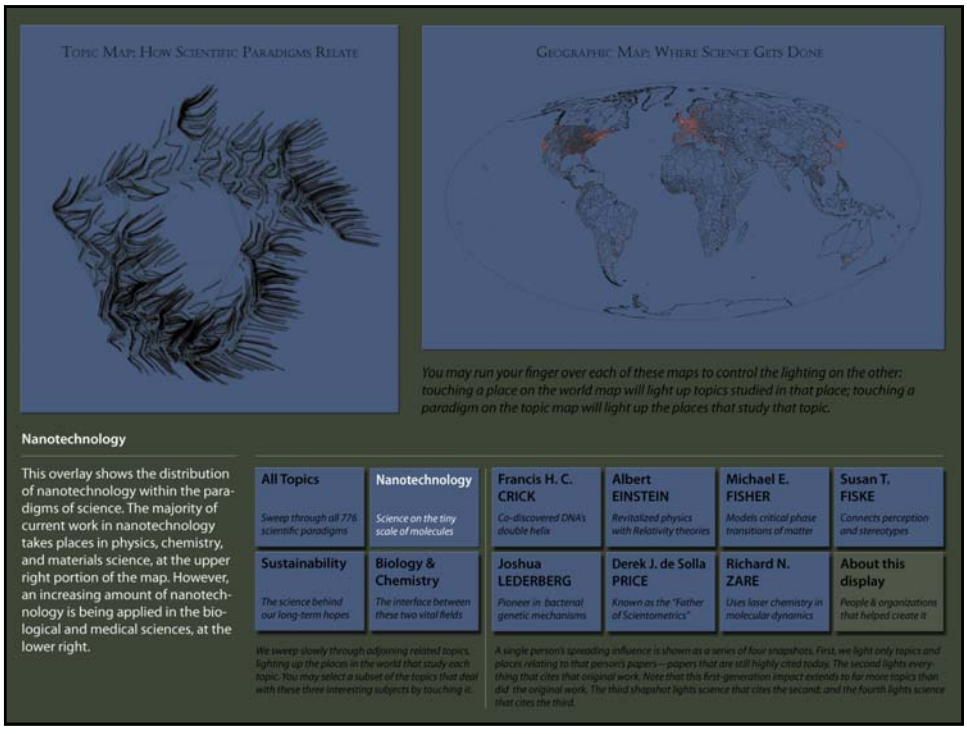
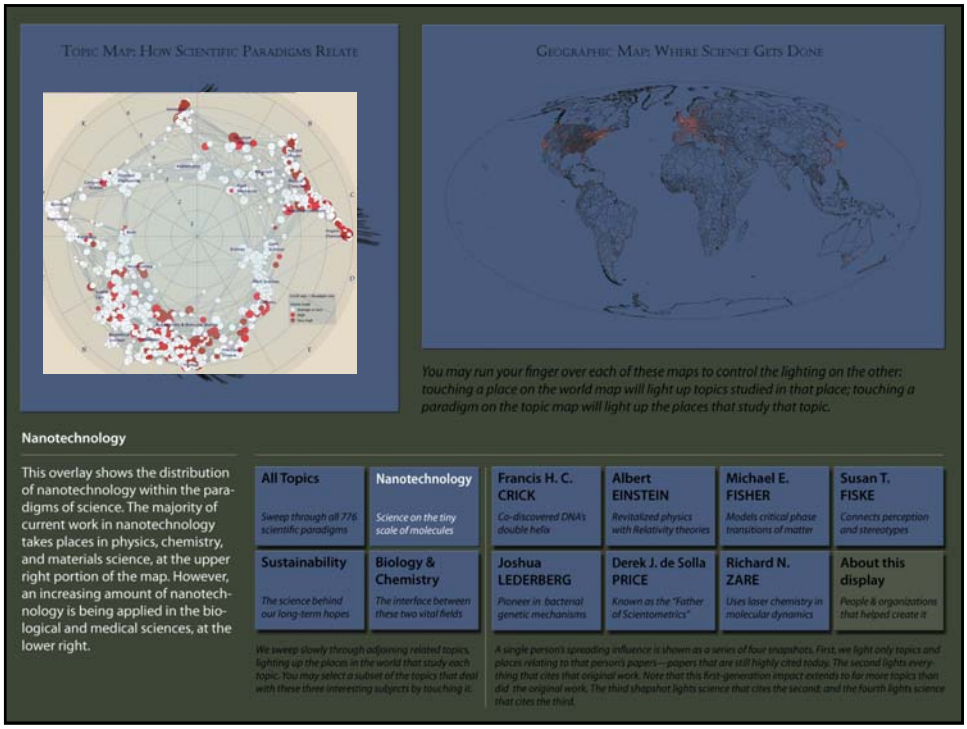
Applied Physics
Mathematics
Materials
Electrical Engineering
Computer Science
Fluid Mechanics
Physical Chemistry
Business
Psychology
Analytical Chemistry
Brain
Psychiatry
Organic Chemistry
Ecology
Earth Sciences
Neuroscience
Plant Sciences
Health Care
Genetics
Circle size = Paradigm size
Vitality Scale
Average or less
High
Very high
Biochemistry & Molecular Biology
Biomedical Sciences
Cardiology
Infectious Disease
Virology
Science can be thought of as containing themes and paradigms. Themes are areas of current research, while paradigms comprise the dominant tool sets and existing knowledge that are used by today's researchers. This map shows 776 major paradigms in science along with the dominant relationships between these paradigms. Paradigms are shown as circles; strong relationships between paradigms are indicated by the lines connecting the circles. The map was created by recursively clustering the 820,000 papers referenced most often in 2003. Clustering at each level was done using VxOrd, a force-directed graph layout routine. These papers formed 53,000 clusters, 6,100 higher-level clusters, and finally the 776 paradigms. Although each paradigm contains, on average, 1,000 papers, some are larger and some are smaller, as shown by different sized circles on the map.
The ring-like structure that is formed by scientific paradigms is very robust. We find similar structures for different years, and for maps generated from scientific journals. "The Structure of Science", a galaxy map shown in the first iteration of Places & Spaces, is a map based on clustering of scientific journals, with superimposition of papers on the journal structure, whereas this map was generated directly from highly-cited papers. "The Structure of Science" shows current science in a disciplinary context, while this map can show the breadth of disciplines that contribute to single paradigms.
Because of the robust nature of the structure of science and its paradigms, we have placed our 776 scientific paradigms within a reference system containing 12 radial slices and 6 rings. This allows the position of each paradigm to be codified and available for lookup; for instance Fluid Mechanics paradigms are in grid B3.
We have also calculated and displayed the vitality of each paradigm. Vitality is a measure of the speed at which a group of researchers reaches consensus about major improvements. Paradigms are constantly being improved, but it usually takes years to reach consensus about which improvements are major. The white circles represent communities where consensus is reached relatively slowly. This is a common phenomenon in the social sciences, ecological sciences, computer sciences, and mathematics disciplines. The red circles represent communities of researchers where consensus is reached relatively rapidly. This is more common in physics, chemistry, biochemistry, and many medical disciplines. Very dark circles (such as those in Astrophysics, L5-6) represent communities where consensus is reached extremely quickly.
The map of scientific paradigms and its reference system can be used for multiple purposes. Countries, industries, companies, universities, and individual researchers can all locate themselves within the map, either as single points, or as a specific collection of paradigms. Various metrics, such as vitality, can be overlayed on this reference system to highlight specific impacts. Science education and personal discovery can also be enhanced by linking stories and facts to the map that highlight scientific history, current advances and relationships between scientific paradigms.


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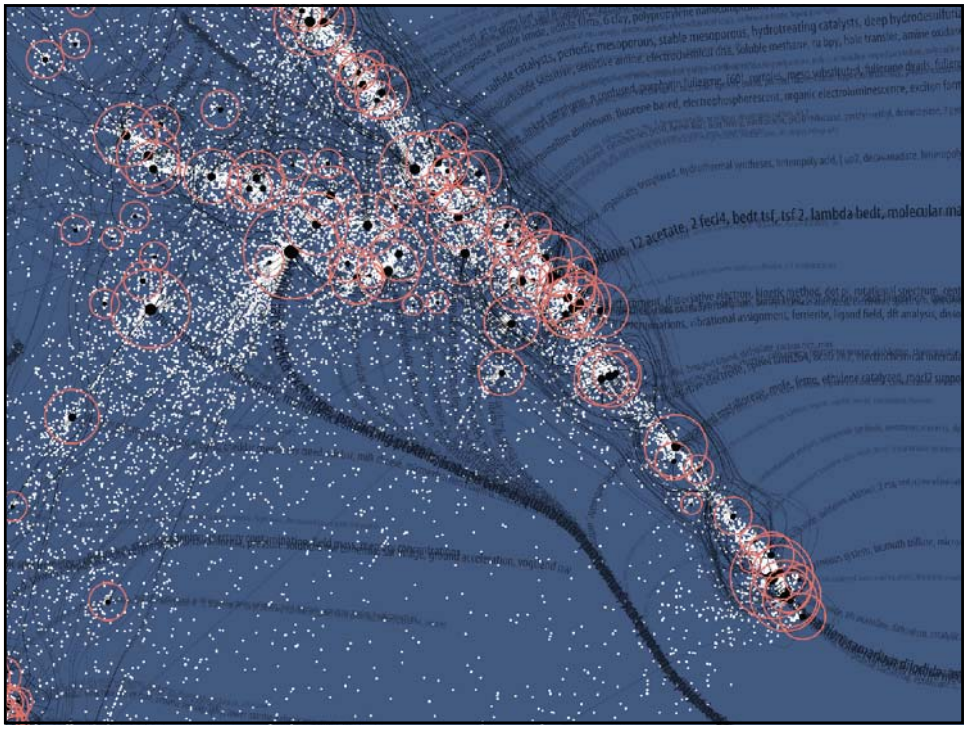
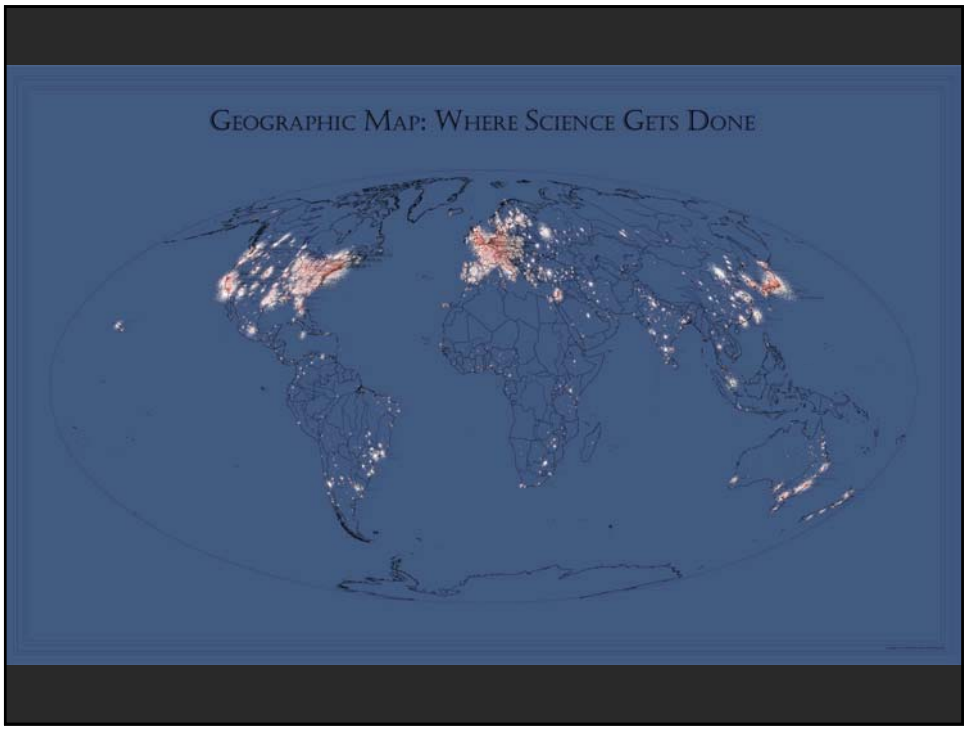
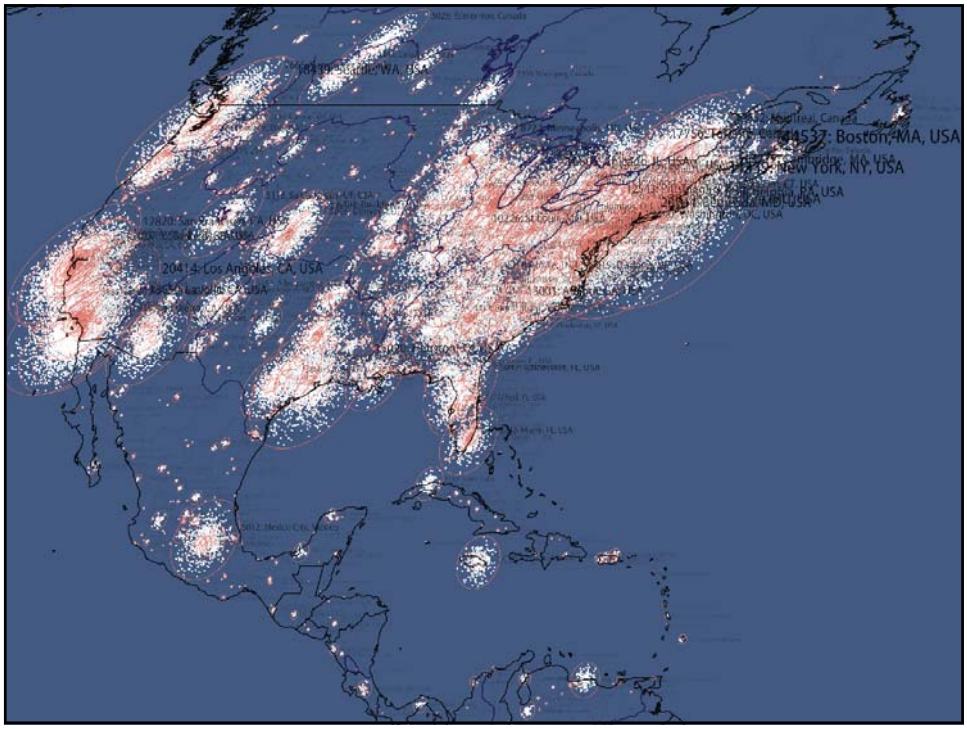
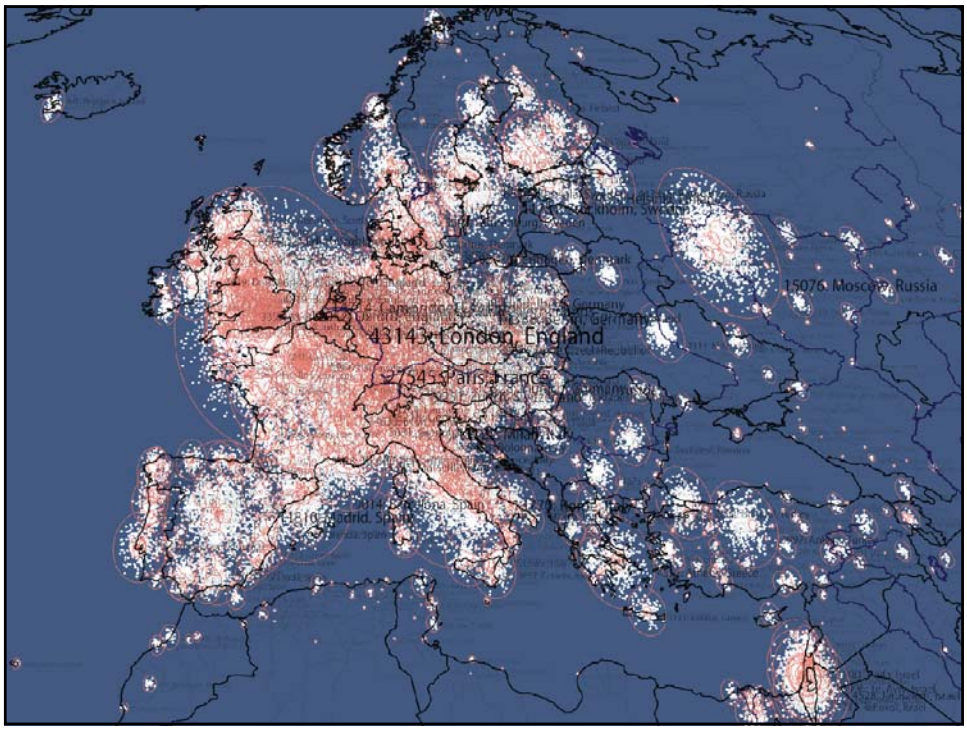
Topic Map: How Scientific Paradigms Relate




Geographic Map: Where Science Gets Done


20414 Los Angeles, CA, USA
New York, NY, USA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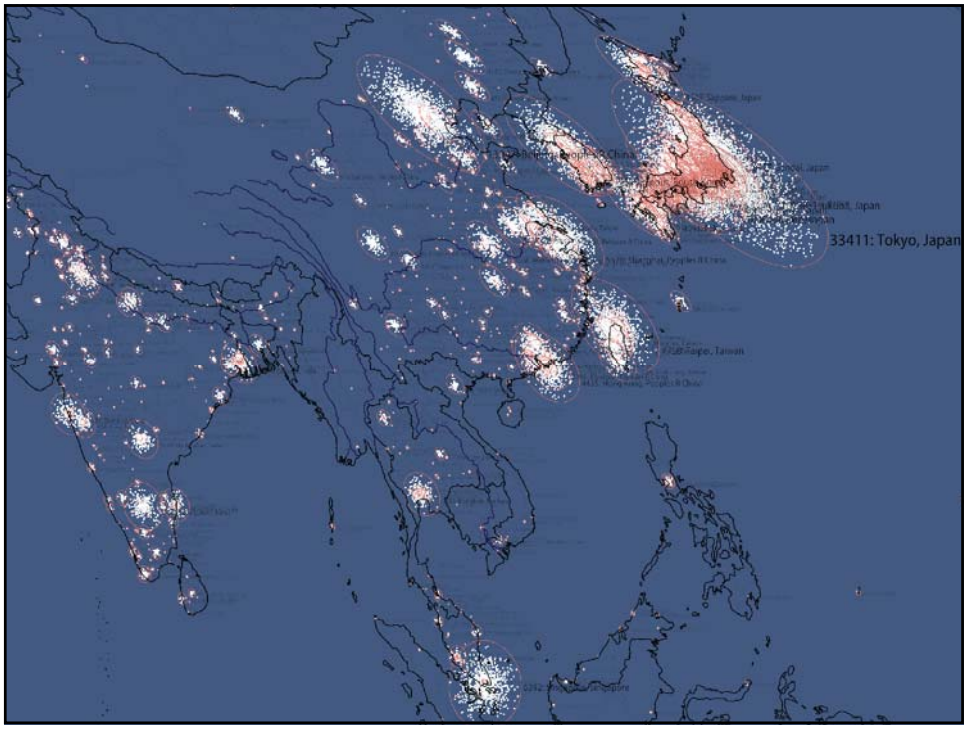
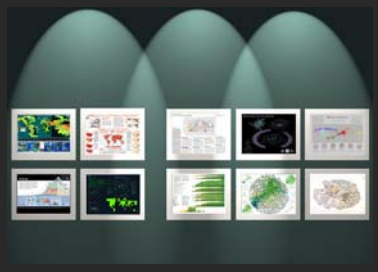
43143 London, England
27543 Paris, France



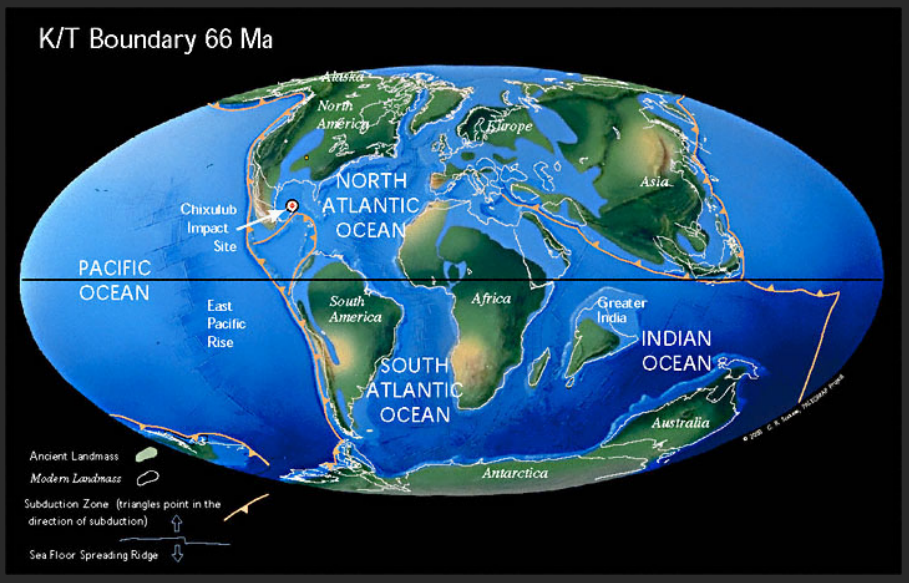
Illuminated Diagram Display
http://www.youtube.com/watch?v=bXABcOABG4E

The Power of Forecasts

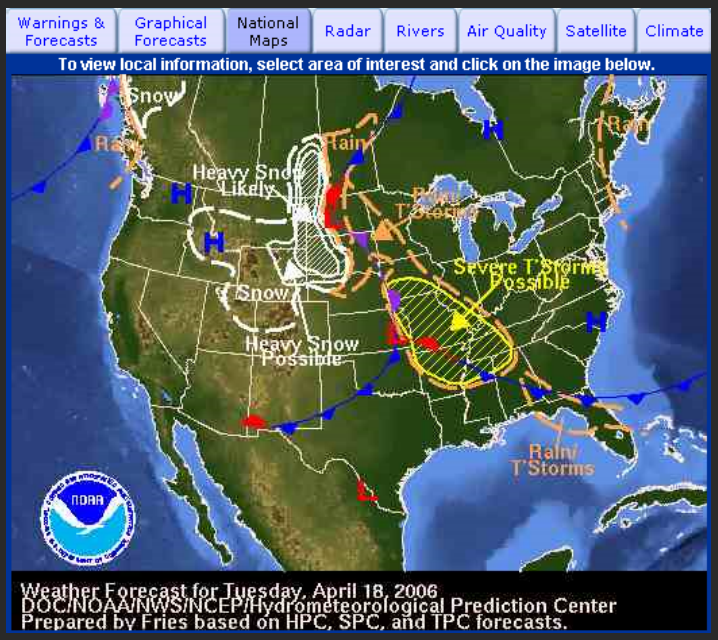
Four Existing Forecasts
VERSUS
Six Potential Science 'Weather' Forecasts



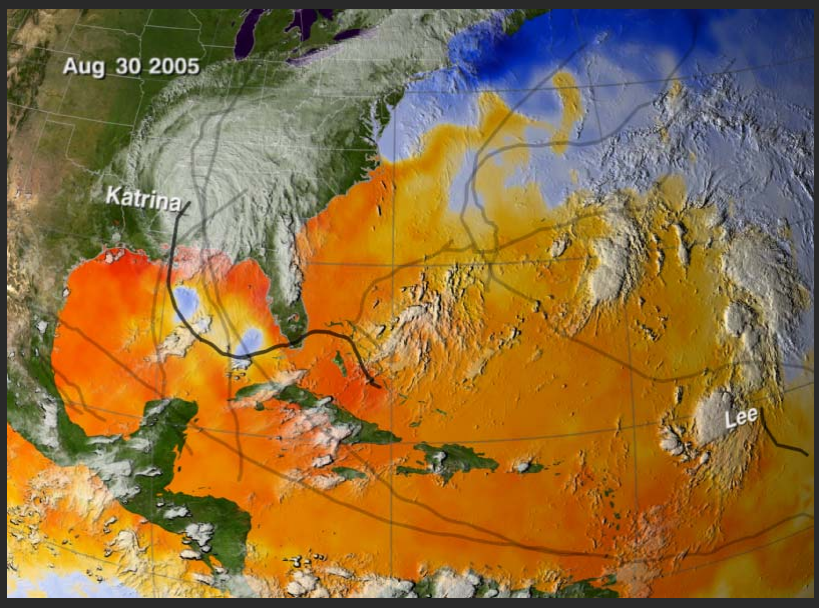
(3rd Iteration of Places & Spaces Exhibit - 2007)



http://www.scotese.com/



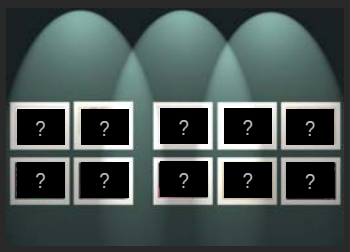
http://www.weather.gov



Named Storms, available online at http://svs.gsfc.nasa.gov/vis/a000000/a003200/a003279

Science Maps for Economic Decision Making

Four Existing Maps
VERSUS
Six Science Maps



(4th Iteration of Places & Spaces Exhibit - 2008)

A Potential Future: Science Maps in Action

KIDS first …

All maps of science are on sale via
http://scimaps.org/ordermaps/


Inventors & Inventions
ASTRONOMY
PHYSICS
ENGINEERING
COMPUTER SCIENCE
MATH
SOCIAL SCIENCE
PHYSICAL CHEMISTRY
BRAIN
MENTAL HEALTH
EARTH SCIENCES
ORGANIC THEORY
ECOLOGY
HEALTH CARE
BIOLOGY
THERAPEUTIC RESEARCH
INFECTIOUS DISEASE
CELL BIOLOGY
VIRUSES


Inventors
ASTRONOMY
PHYSICS
ENGINEERING
COMPUTER SCIENCE
MATH
SOCIAL SCIENCE
PHYSICAL CHEMISTRY
BRAIN
MENTAL HEALTH
EARTH SCIENCES
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INFECTIOUS DISEASE
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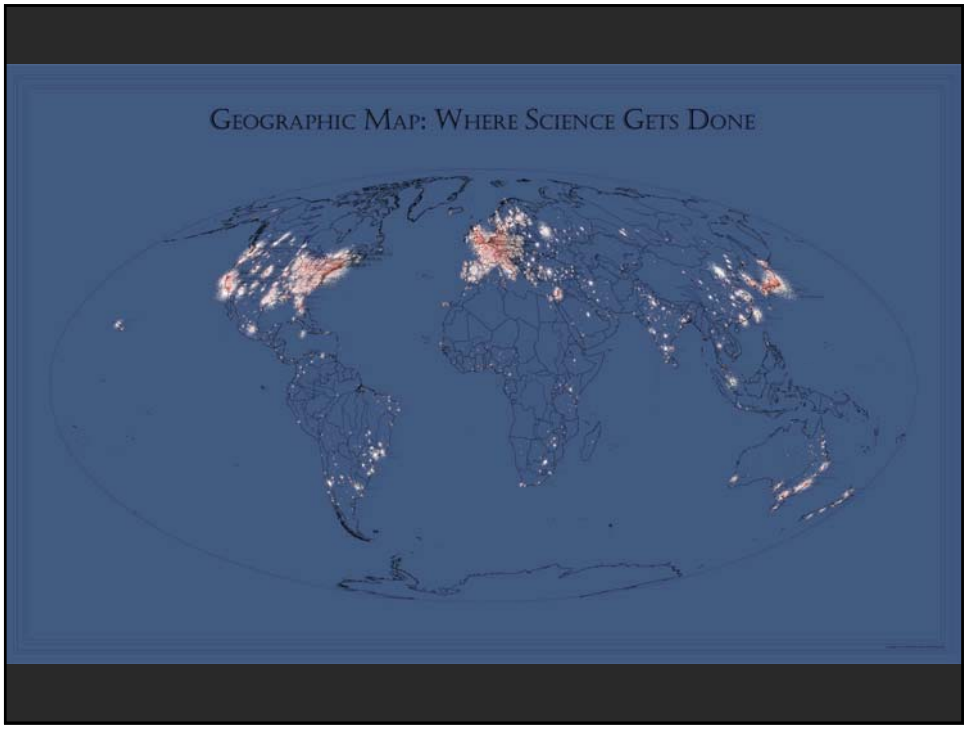
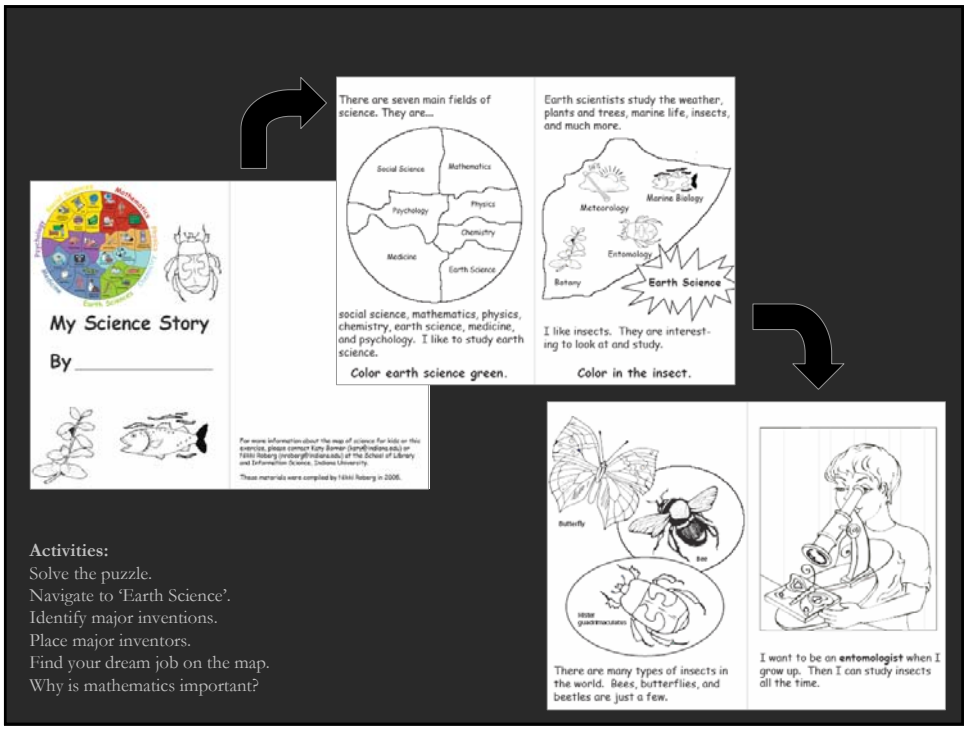
VIRUSES

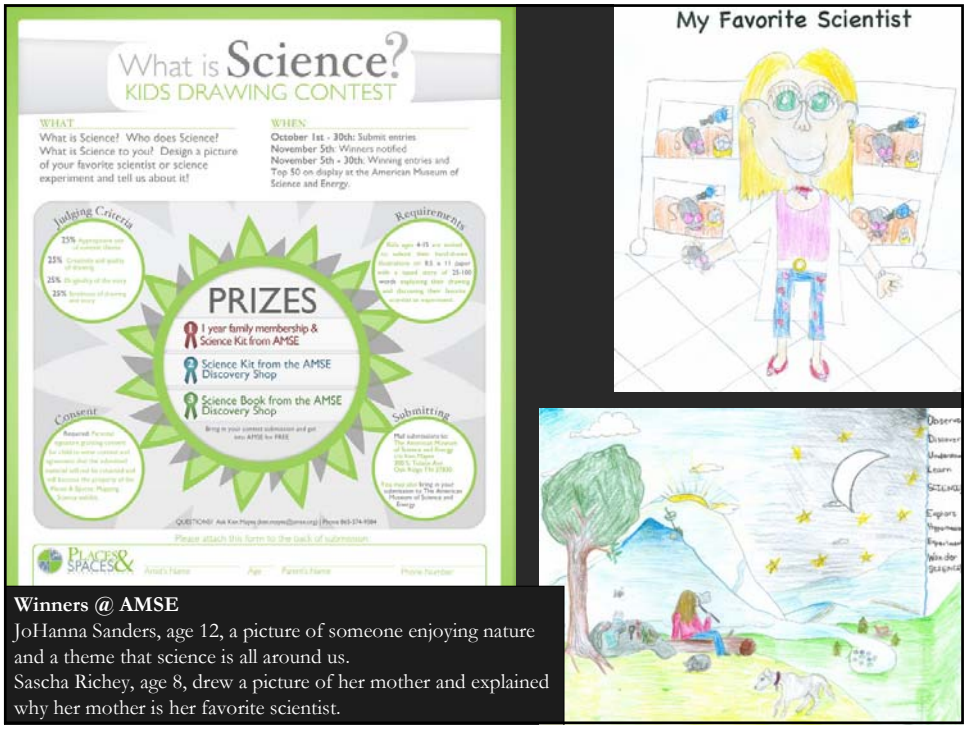


Science Puzzle Map for Kids by Fileve Palmer, Julie Smith, Elisha Hardy and Katy Börner, Indiana University, 2006. (Base map taken from Illuminated Diagram display by Kevin Boyack, Richard Klavans, and W. Bradford Paley.)


Inventors



Activities:
Solve the puzzle.
Navigate to 'Earth Science'.
Identify major inventions.
Place major inventors.
Find your dream job on the map.
Why is mathematics important?



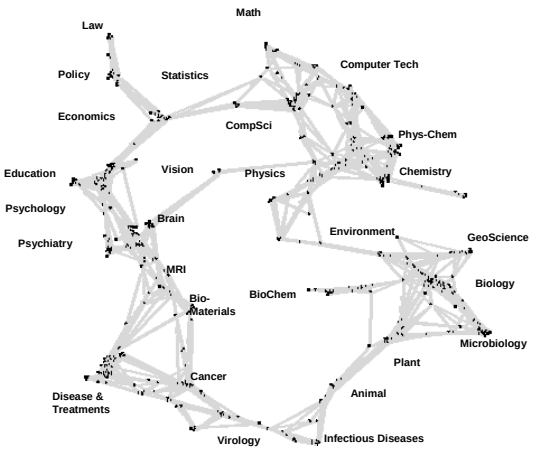
Winners @ AMSE
JoHanna Sanders, age 12, a picture of someone enjoying nature and a theme that science is all around us.
Sascha Richey, age 8, drew a picture of her mother and explained why her mother is her favorite scientist.

… my SPONSORS next …

Latest 'Base Map' of Science

Kevin W. Boyack & Richard Klavans, unpublished work.

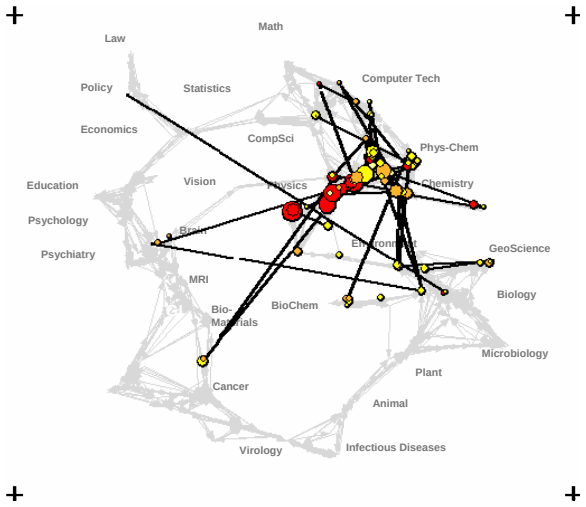
- Uses combined SCI/SSCI from 2002
  - 1.07M papers, 24.5M references, 7,300 journals
  - Bibliographic coupling of papers, aggregated to journals
- Initial ordination and clustering of journals gave 671 clusters
- Coupling counts were reaggregated at the journal cluster level to calculate the
  - (x,y)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



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

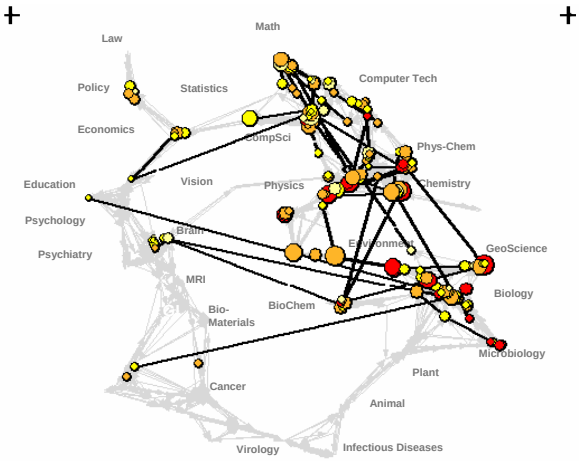
Funding patterns of the US Department of Energy (DOE)



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

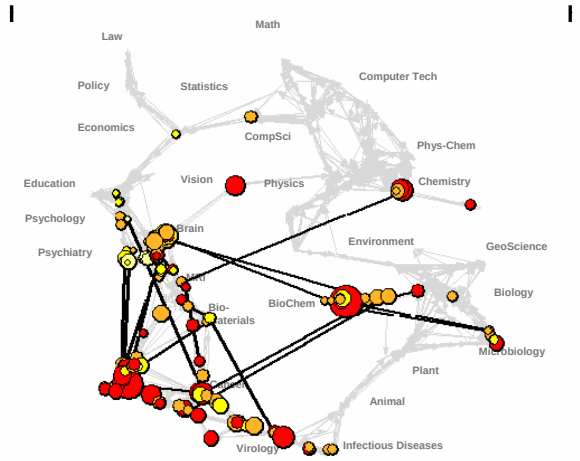
Funding Patterns of the National Science Foundation (NSF)



Science map applications: Identifying core competency

Kevin W. Boyack & Richard Klavans, unpublished work.

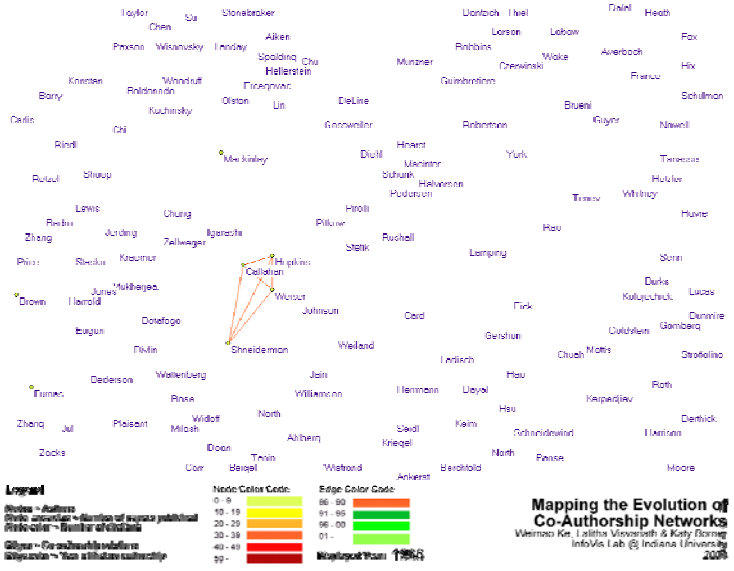
Funding Patterns of the National Institutes of Health (NIH)



… then SCIENTISTS …

Mapping the Evolution of Co-Authorship Networks

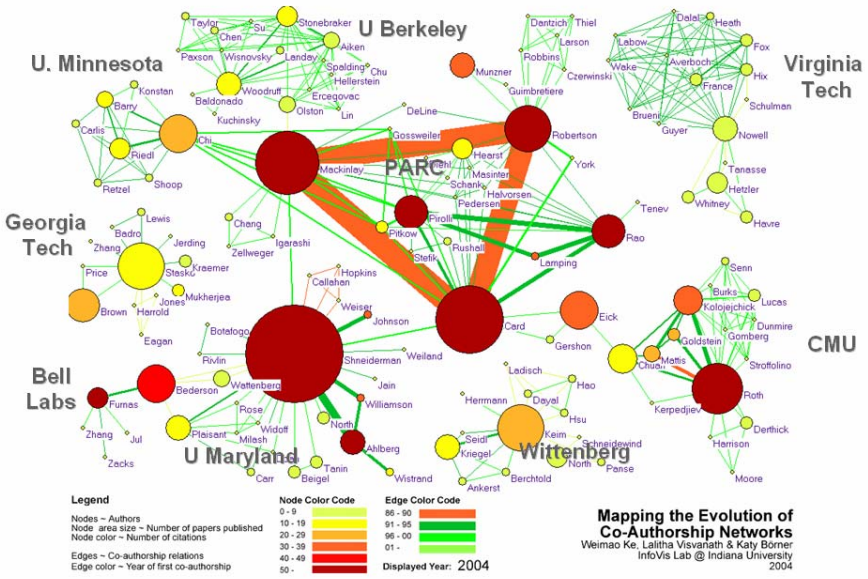
Ke, Visvanath & Börner, (2004) Won 1st price at the IEEE InfoVis Contest.



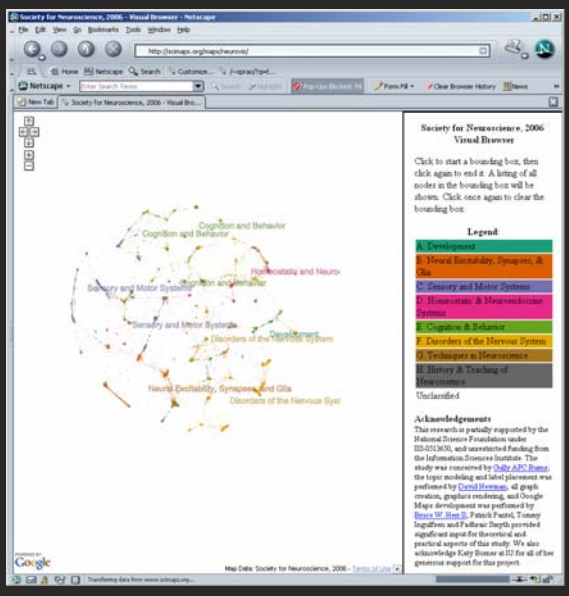
62

Mapping the Evolution of Co-Authorship Networks

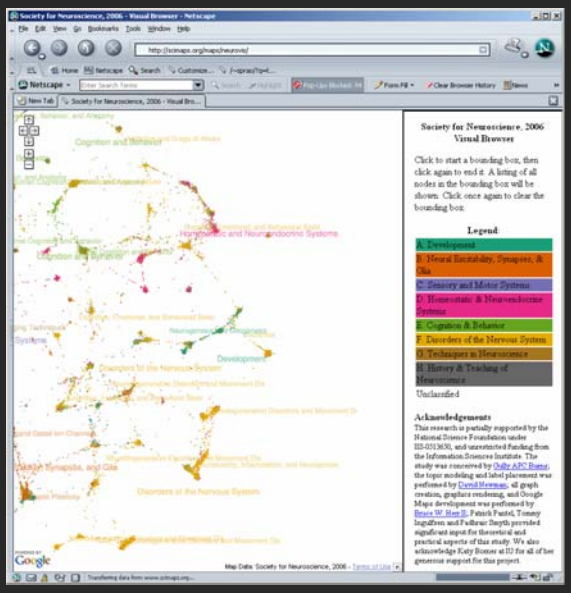
Ke, Visvanath & Börner, (2004) Won 1st price at the IEEE InfoVis Contest



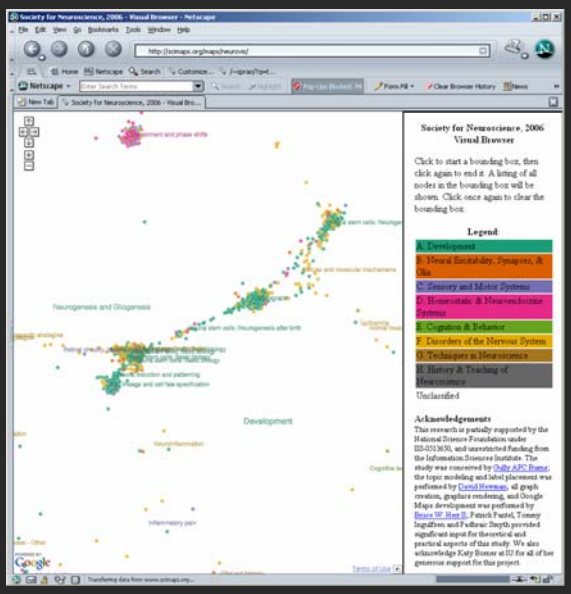
63



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/



Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

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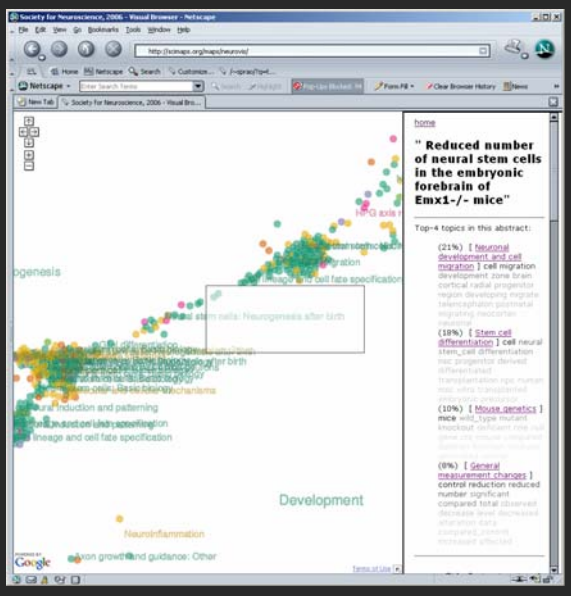

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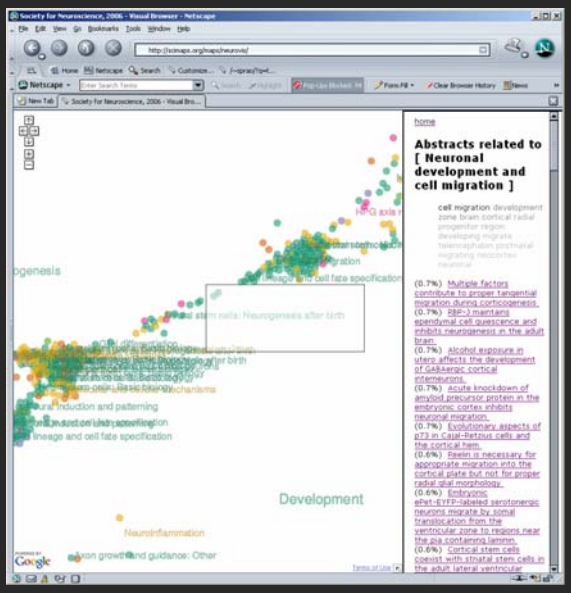
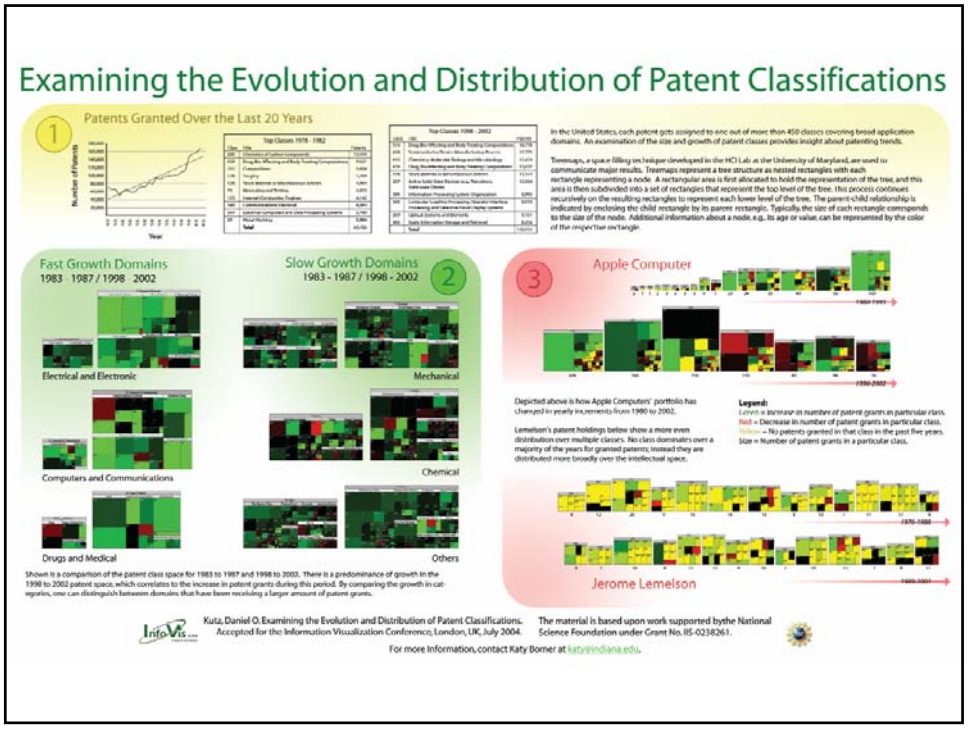
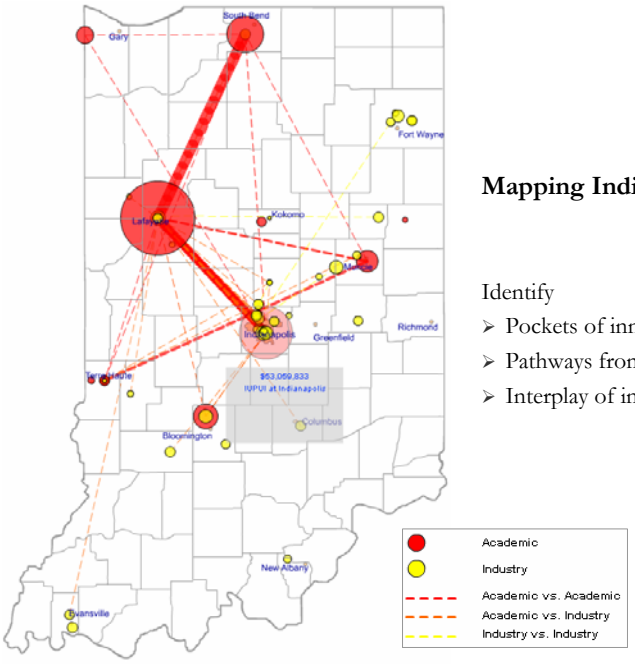


Bruce W. Herr II, Gully Burns (USC), David Newman (UCI), Society for Neuroscience, 2006 Visual Browser, 2007, http://scimaps.org/maps/neurovis/

… and INDUSTRY too.





Mapping Indiana's Intellectual Space

Identify

- Pockets of innovation
- Pathways from ideas to products
- Interplay of industry and academia


Interested to get your own science map?
Contact the map makers!
katy@indiana.edu


Merry Christmas
and Happy New Year!
2008
Jon Burgoyne
Katy Börner
Russell J. Duhon
Shravan Rajagopal
Heng (Michael) Zhang
Bruce W. Herr II
Julie M. Smith
Chung-Yang (Kenneth) Lee
Kristin E. Reed
Stacy Kowalczyk
Micah Linnemeier
Bryan J. Hook
Nianli Ma
Carol Walter
Renpeng Hu
Richard Pinapati
Todd Holloway
Peter A. Hook
Weixia (Bonnie) Huang
Elisha F. Hardy
Fileve Palmer
Benjamin Ray Gonzalez
cyberinfrastructure for
NETWORK SCIENCE CENTER
Cake created by Kristin Reed and Lydia Nichols. They insisted on having a legend!
http://ella.slis.indiana.edu/~katy
http://scimaps.org
http://ivl.slis.indiana.edu

The End.