Places & Spaces: Mapping Science
An International Exhibit

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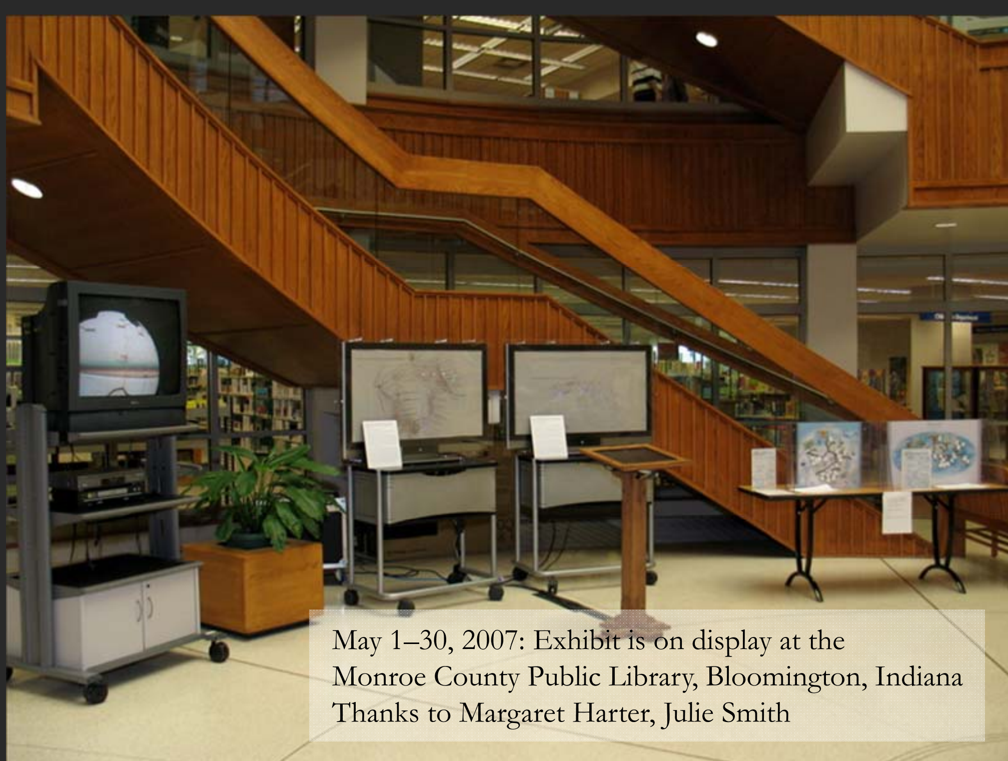
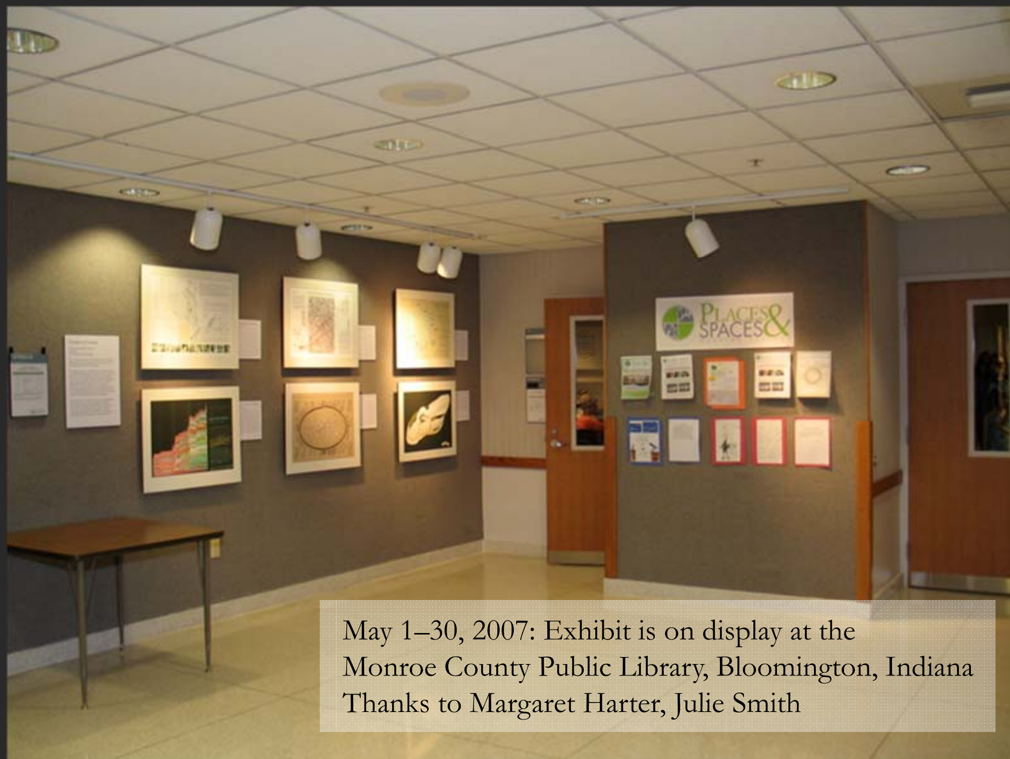


May 1–30, 2007: Exhibit is on display at the
Monroe County Public Library, Bloomington, Indiana
Thanks to Margaret Harter, Julie Smith



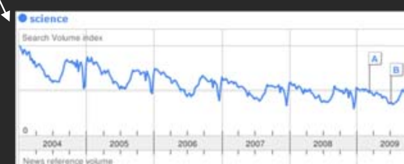
May 1–30, 2007: Exhibit is on display at the Monroe County Public Library, Bloomington, Indiana
Thanks to Margaret Harter, Julie Smith

Take terra bytes of data

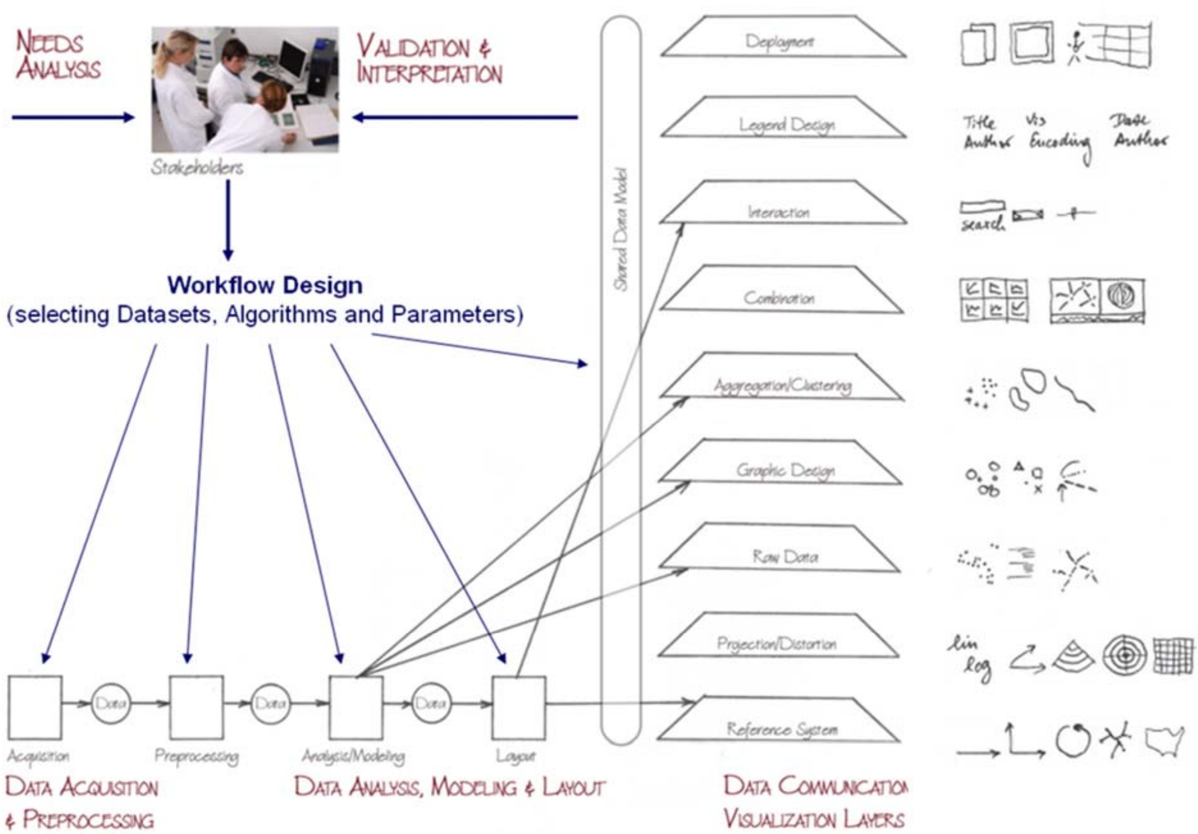
Black Box

Find your way

Find collaborators, friends



Identify trends



Temporal Analysis

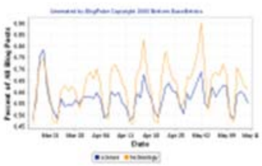
Science evolves over time. Attribute values of scholarly entities and their diverse aggregations increase and decrease at different rates and respond with different latency rates to internal and external events. Temporal analysis aims to identify the nature of phenomena represented by a sequence of observations such as patterns, trends, seasonality, outliers, and bursts of activity.

Data

A time series is a sequence of events or observations that are ordered in time. Time-series data can be continuous (there is an observation at every instant of time; see figure to the right) or discrete (observations exist for regularly or irregularly spaced intervals). Temporal aggregations—over journal volumes, years, or decades—are common.

Algorithms

Frequently, some form of filtering is applied to reduce noise and make patterns more salient. Smoothing (averaging using a smoothing window of a certain width) and curve approximation might be applied. The number of scholarly records is often plotted to get a first idea of the temporal distribution of a data set. It might be shown in total values or as a percentage of those. One may find out how long a scholarly entity was active; how old it was at a certain point; what growth, latency to peak, or decay rate it has; what correlations with other time series exist; or what trends are observable. Data models such as the least squares model (available in most statistical software packages) are applied to best fit a selected function to a data set and to determine if the trend is significant. Kleinberg's burst detection algorithm is commonly applied to identify words that have experienced a sudden change in frequency of occurrence.



Geographic Analysis

Geographic analysis aims to answer the question of where something happens and what impact it has on neighboring areas.

Data

Geographic analysis requires spatial attribute values or geolocations for authors and their papers, extracted from affiliation data or spatial positions of nodes, generated from layout algorithms. Geographic data can be continuous (each record has a specific position) or discrete (a position or area exists for sets of records, like the number of papers per country). Spatial aggregations (for example, merging data via postal codes, counties, states, countries, and continents) are common (see **page 66, Exemplification**).

Algorithms

Cartographic generalization refers to the process of abstraction. This includes (1) graphic generalization: the simplification, enlargement, displacement, merging, or selection of entities without enhancement or effect to their symbology and (2) conceptual symbolization: the merging, selection, and symbolization of entities, including enhancement (such as representing high-density areas with a city symbol).

Geometric generalization aims to solve the conflict between the number of visualized features, the size of symbols, and the size of the display surface. Cartographers dealt with this conflict intuitively in part until researchers like Friedrich Töpfer attempted to solve them with quantifiable expressions.

Flow maps use line thickness and direction to show the number of tangible or intangible entities that diffuse over a geographic location or science space (see CAS coauthor network, below, and **page 158, 113 Years of Physical Review**).

Topical Analysis

The topic coverage and topical similarity of basic and aggregate units of science (authors or institutions) can be derived from the units associated with them (papers, patents, or grants).

Data

The topic or semantic coverage of a unit of science can be derived from the text associated with it. Topical aggregations (for example, over journal volumes, scientific disciplines, or institutions) are common.

Algorithms

Topic analysis extracts the set of unique words or word profiles and their frequency from a text corpus. Stop words, such as "the" and "of," are removed. Stemming can be applied. Coword analysis identifies the number of times two words are used in the title, keyword set, abstract, or full text of a paper. The space of co-occurring words can be mapped, providing a unique view of the topic coverage of a data set (see **page 66, Exemplification**). Similarly, units of science can be grouped according to the number of words they have in common.

Salton's term frequency inverse document frequency (TFIDF) is a statistical measure used to evaluate the importance of a word in a corpus. The importance increases proportionally to the number of times a word appears in the paper but is offset by the frequency of the word in the corpus.

Dimensionality reduction techniques (see table on opposite page) are commonly used to project high-dimensional information spaces (for example, the matrix of all unique papers multiplied by their unique terms) into a low, typically two-dimensional space.

The SOM map below shows the topic landscape of geography abstracts; see **page 102, In Terms of Geography**.

Network Analysis

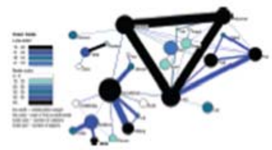
The study of networks aims to increase our understanding of natural and manmade networks. It builds on social network analysis, physics, information science, bibliometrics, scientometrics, informetrics, webometrics, communication theory, sociology of science, and several other disciplines.

Data

Authors, institutions, and countries, as well as words, papers, journals, patents, and funding, are represented as nodes and their complex interrelations as edges (see **Part 3: Toward a Science of Science/Conceptualizing Science: Basic Anatomy of Science**). Nodes and edges can have time-stamped attributes.

Algorithms

Diverse algorithms exist to calculate specific node, edge, and network properties (see "Network Science" review). Node properties include degree centrality, betweenness centrality, or hub and authority scores. Edge properties include durability, reciprocity, intensity (weak or strong), density (how many potential edges in a network actually exist), reachability (how many steps it takes to go from one "end" of a network to another), centrality (whether a network has a "center" point), quality (reliability or certainty), and strength. Network properties refer to the number of nodes and edges, network density, average path length, clustering coefficient, and distributions from which general properties such as "small-world," "scale-free," or "hierarchical" can be derived. Identifying major communities via community detection algorithms and calculating the "backbone" of a network via pathfinder network scaling or maximum flow algorithms helps to communicate and make sense of large-scale networks. See the coauthor network of information visualization researchers below.



First Iteration of Exhibit (2005): The Power of Maps

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

The first exhibit iteration on *The Power of Maps* demonstrates how maps help us to understand, navigate, and manage both physical places and abstract knowledge spaces.

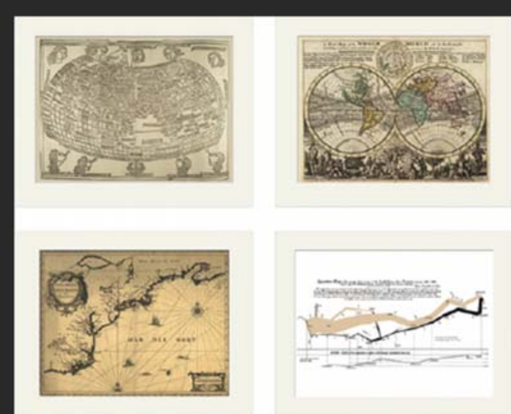
Early maps of our planet were certainly neither complete nor perfect, yet they proved invaluable for explorers. As keys to navigation, exploration, and communication, maps helped explorers find promising new lands while avoiding sea monsters.

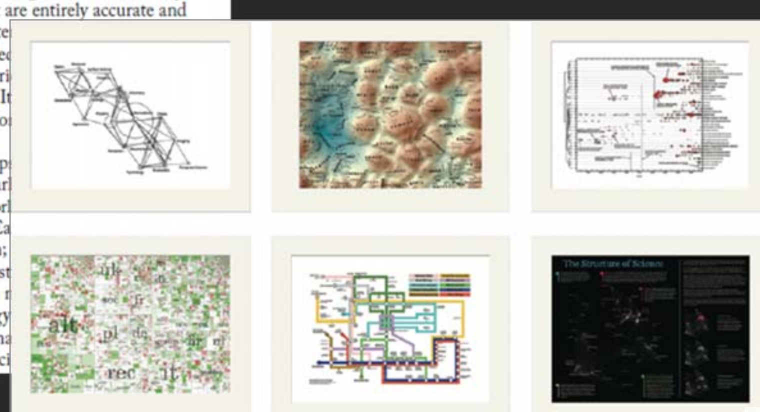
Maps of science today are based on limited knowledge and therefore imperfect. In order to generate comprehensive maps that are entirely accurate and reliable, we must first have proper coverage and inte
multidisciplinary, and multimedia scholarly knowled

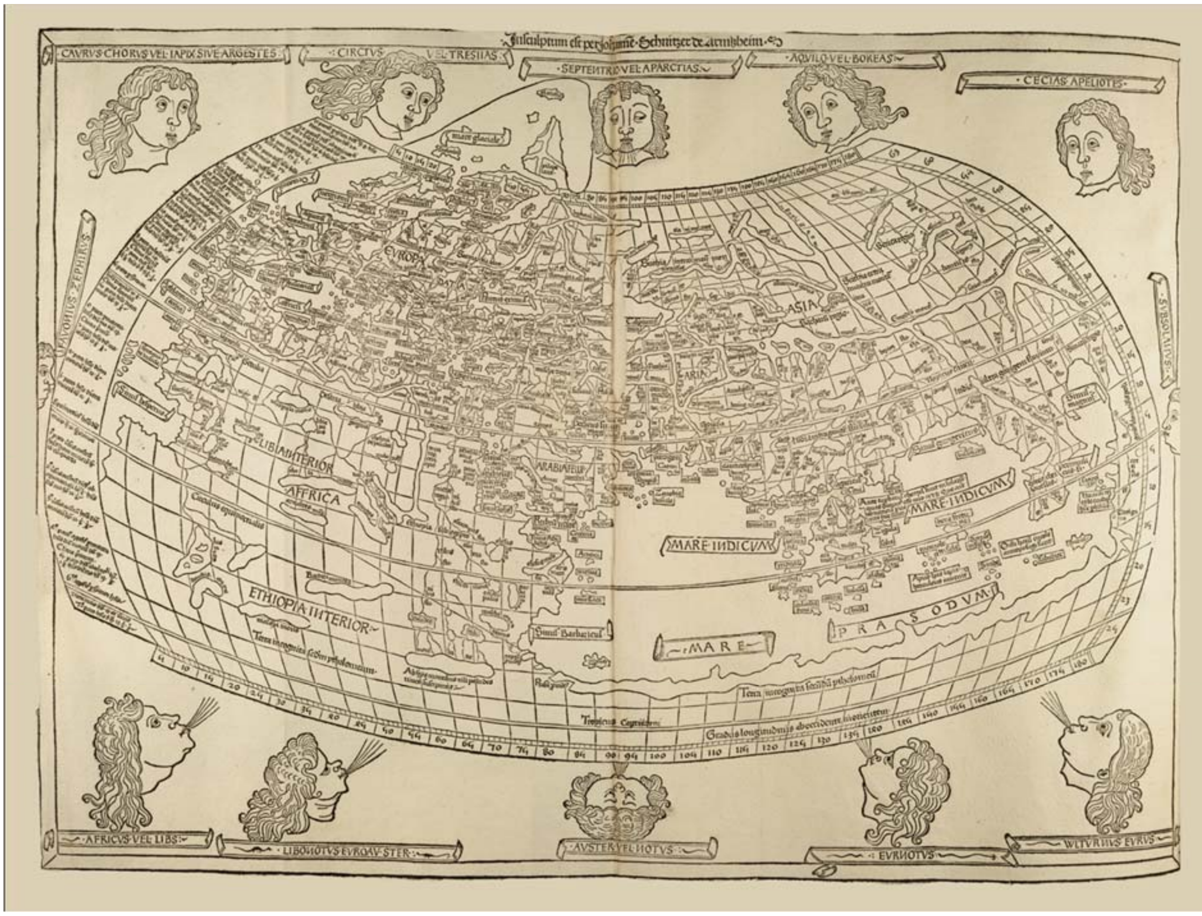
The first pictures of Earth from space were experi
mative of their perceptions of life and the cosmos. It
science will increase our appreciation and applicatio
serving as useful navigational tools.

The Power of Maps features four cartographic map
earliest global maps of our world by Ptolemy, an earl
Johannes Janssonius, an early map of the whole wor
early statistical graph by Charles Joseph Minard. Ea
employs a different metaphor: a node-link diagram;
ing map rendered using geographic information syst
a crossmap; and a galaxy view. Which metaphor is r
visual index of our collective science and technology

Note that the makers of the early cartographic ma
ing presses, while the makers of the first maps of sci






Insculptum est per Johannē Schnitzer de Armßheim
CAVRVS CHORVS VEL IAPIX SIVE ARGESTES
CIRCIVS VEL TRESIAS
SEPTENTRIO VEL APARCTIAS
AQVILO VEL BOREAS
CECIAS APELIOTES
EVROPA
ASIA
AFRICA
LIBIA INTERIOR
ARABIA FELIX
MARE INDICVM
ETHIOPIA INTERIOR
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AFRICVS VEL LIBS
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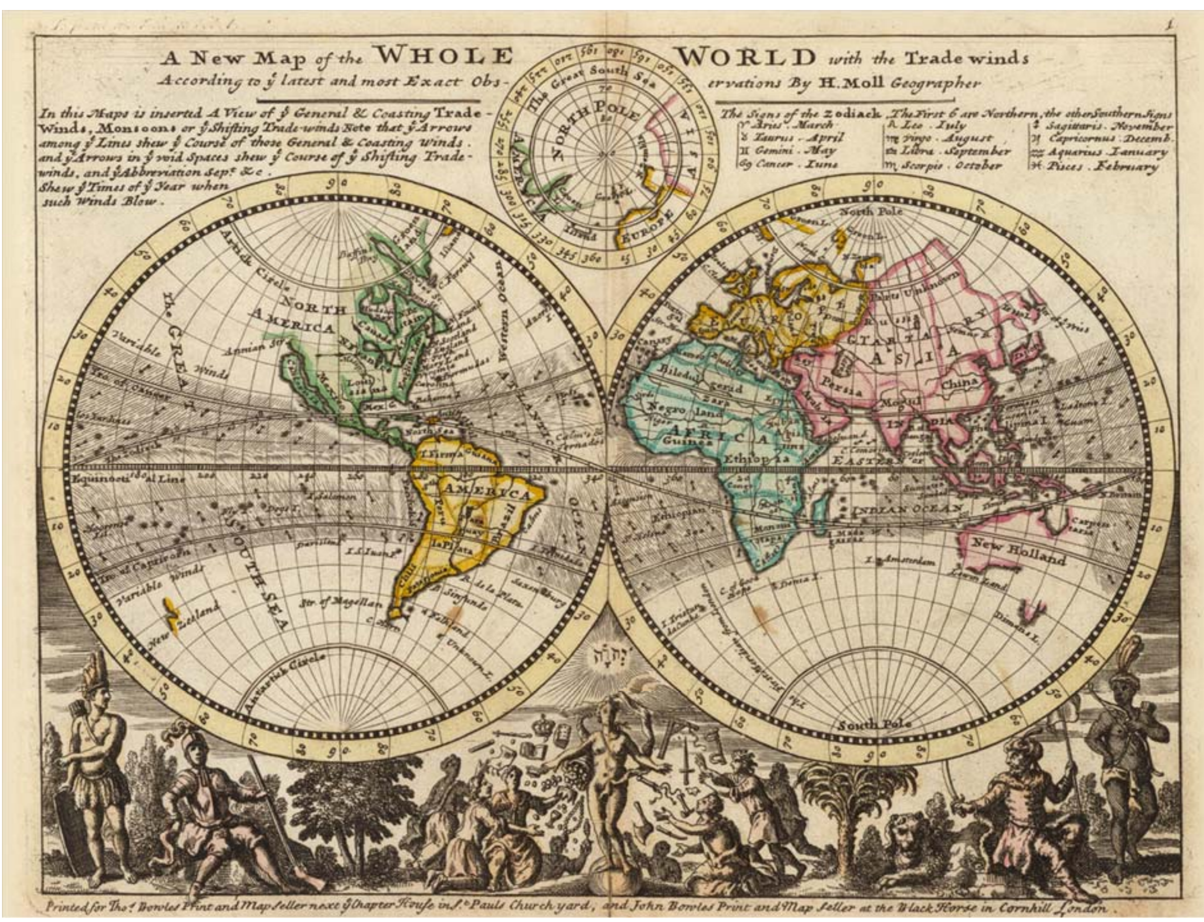
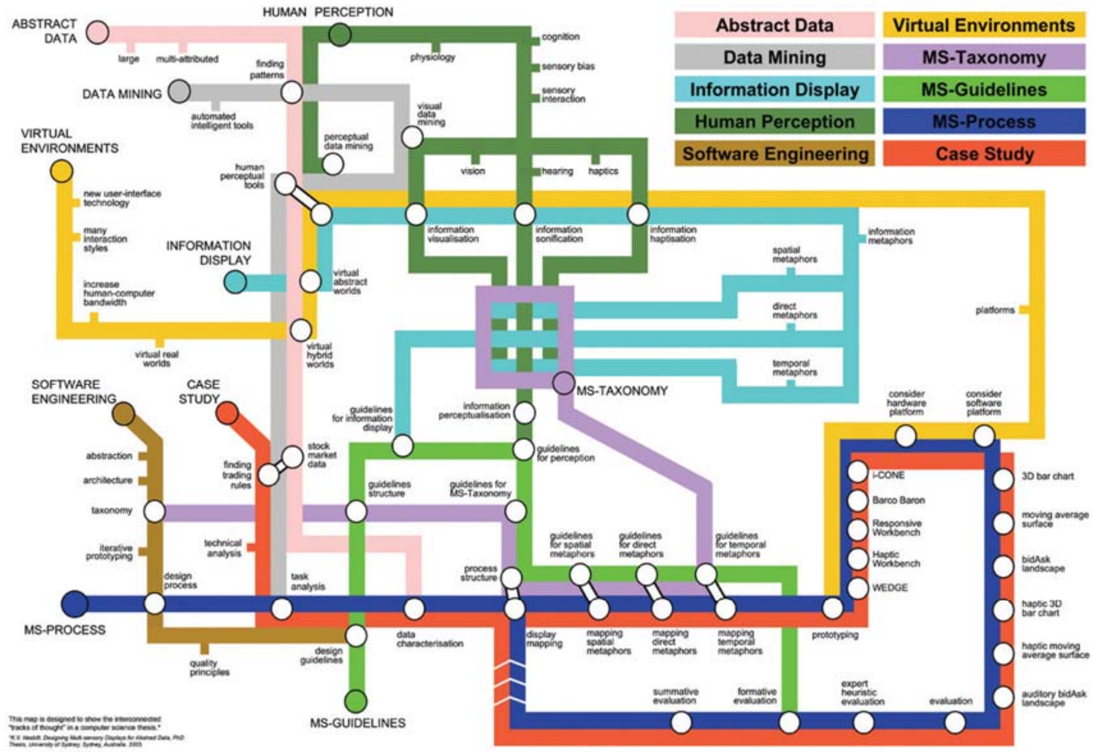
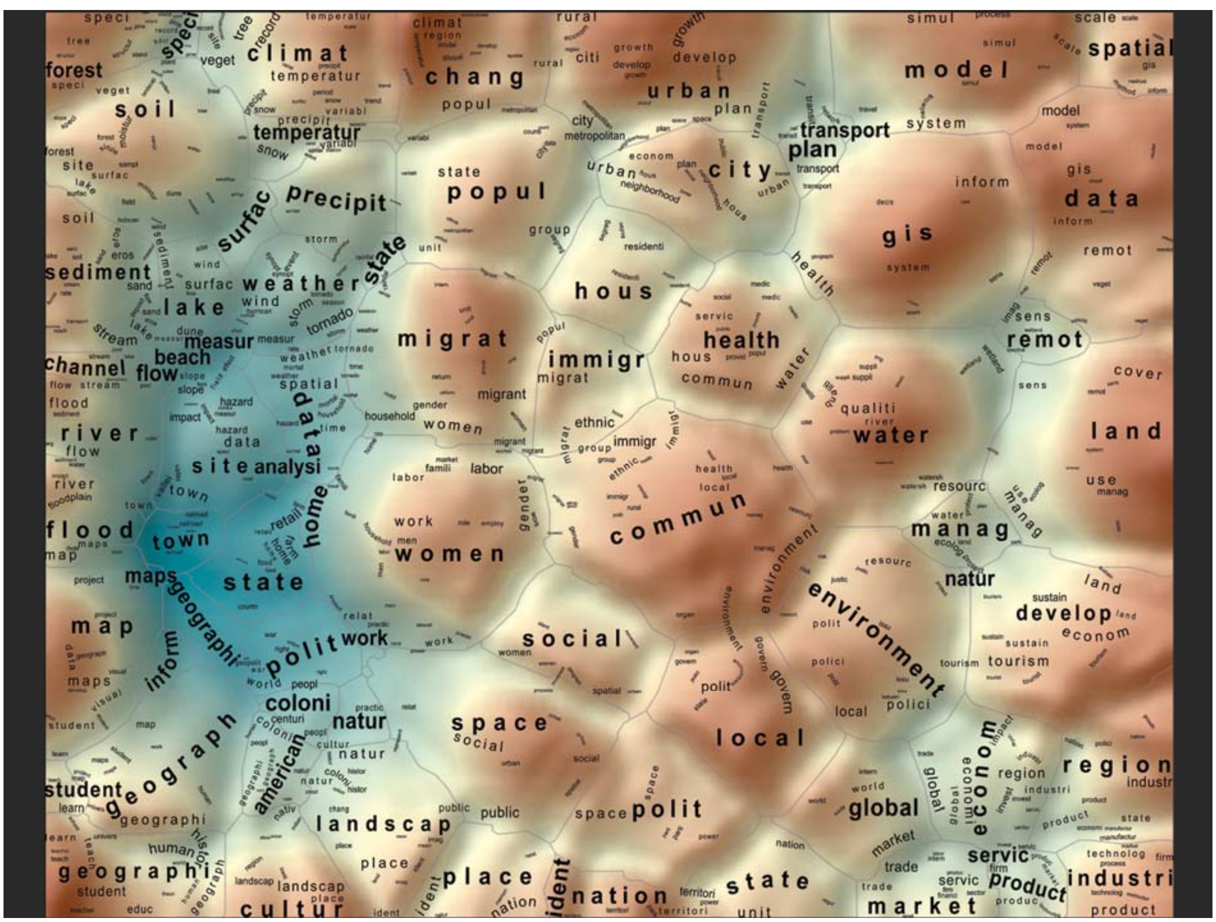
VVLTVRNVS EVRVS


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 Maps is inserted A View of ye General & Coasting Trade-Winds, Monsoons or ye Shifting Trade-winds Note that ye Arrows among ye Lines shew ye Course of those 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 6 are Northern, the other Southern Signs
Aries . March
Taurus . April
Gemini . May
Cancer . June
Leo . July
Virgo . August
Libra . September
Scorpio . October
Sagittaris . November
Capricornus . Decemb.
Aquarius . January
Pisces . February
The Great South Sea
NORTH POLE
AMERICA
ASIA
EUROPE
North Pole
NORTH AMERICA
AMERICA
SOUTH SEA
AFRICA
ASIA
INDIAN OCEAN
New Holland
South Pole
Printed for Thos. Bowles Print and Map seller next ye Chapter House in St. Pauls Church yard, and John Bowles Print and Map seller at the Black Horse in Cornhill London.



Abstract Data
Virtual Environments
Data Mining
MS-Taxonomy
Information Display
MS-Guidelines
Human Perception
MS-Process
Software Engineering
Case Study
ABSTRACT DATA
large
multi-attributed
HUMAN PERCEPTION
physiology
cognition
sensory bias
sensory interaction
finding patterns
DATA MINING
automated intelligent tools
visual data mining
perceptual data mining
VIRTUAL ENVIRONMENTS
new user-interface technology
many interaction styles
increase human-computer bandwidth
virtual real worlds
human perceptual tools
vision
hearing
haptics
INFORMATION DISPLAY
virtual abstract worlds
virtual hybrid worlds
information visualisation
information sonification
information haptisation
information metaphors
spatial metaphors
direct metaphors
temporal metaphors
platforms
MS-TAXONOMY
SOFTWARE ENGINEERING
CASE STUDY
abstraction
architecture
taxonomy
iterative prototyping
design process
finding trading rules
stock market data
technical analysis
task analysis
guidelines for information display
information perceptualisation
guidelines for perception
guidelines structure
guidelines for MS-Taxonomy
guidelines for spatial metaphors
guidelines for direct metaphors
guidelines for temporal metaphors
process structure
consider hardware platform
consider software platform
i-CONE
Barco Baron
Responsive Workbench
Haptic Workbench
WEDGE
3D bar chart
moving average surface
bidAsk landscape
haptic 3D bar chart
haptic moving average surface
auditory bidAsk landscape
MS-PROCESS
quality principles
design guidelines
data characterisation
display mapping
mapping spatial metaphors
mapping direct metaphors
mapping temporal metaphors
prototyping
summative evaluation
formative evaluation
expert heuristic evaluation
evaluation
MS-GUIDELINES
This map is designed to show the interconnected "tracks of thought" in a computer science thesis.*



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home
flood
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maps
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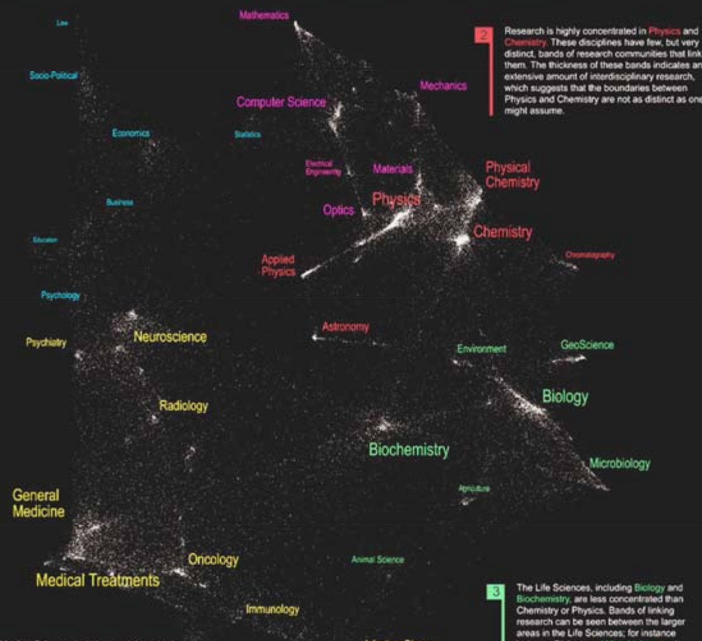
The Structure of Science

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.



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.

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.

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.

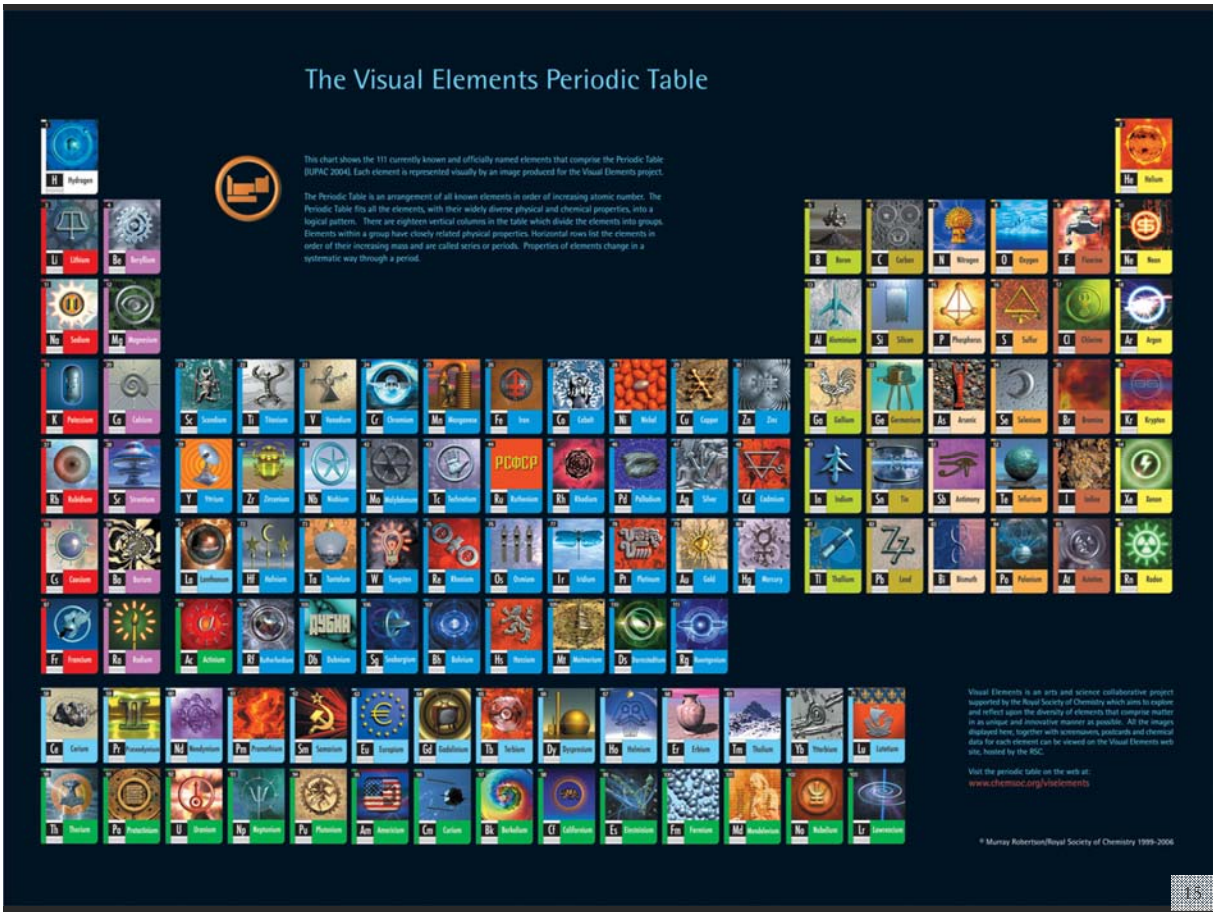
Second Iteration of Exhibit (2006): The Power of Reference Systems

Four Existing Reference Systems
Versus
Six Potential Reference Systems

This iteration aims to inspire discussion about a common reference system for all existing scholarly knowledge. Throughout history, scientists have battled to agree on standardized reference systems for their respective fields of research. These standards are invaluable for indexing, storing, accessing, and managing scientific data efficiently.

Results include the description of the electromag
odic table of elements, geographic projections, and
systems, shown here. Note that the geographic ma
from paper to geographic information systems (GI
for public use and consumption.

In comparison to these four existing systems are
systems for scholarly knowledge. Each reference sy
sional timeline and the geographic system to the se
used to identify the location of an author, paper, pa
tory or contribution.


The Visual Elements Periodic Table
This chart shows the 111 currently known and officially named elements that comprise the Periodic Table (IUPAC 2004). Each element is represented visually by an image produced for the Visual Elements project.
The Periodic Table is an arrangement of all known elements in order of increasing atomic number. The Periodic Table fits all the elements, with their widely diverse physical and chemical properties, into a logical pattern. There are eighteen vertical columns in the table which divide the elements into groups. Elements within a group have closely related physical properties. Horizontal rows list the elements in order of their increasing mass and are called series or periods. Properties of elements change in a systematic way through a period.
Visual Elements is an arts and science collaborative project supported by the Royal Society of Chemistry which aims to explore and reflect upon the diversity of elements that comprise matter in as unique and innovative manner as possible. All the images displayed here, together with screensavers, postcards and chemical data for each element can be viewed on the Visual Elements web site, hosted by the RSC.
Visit the periodic table on the web at:
www.chemsoc.org/viselements
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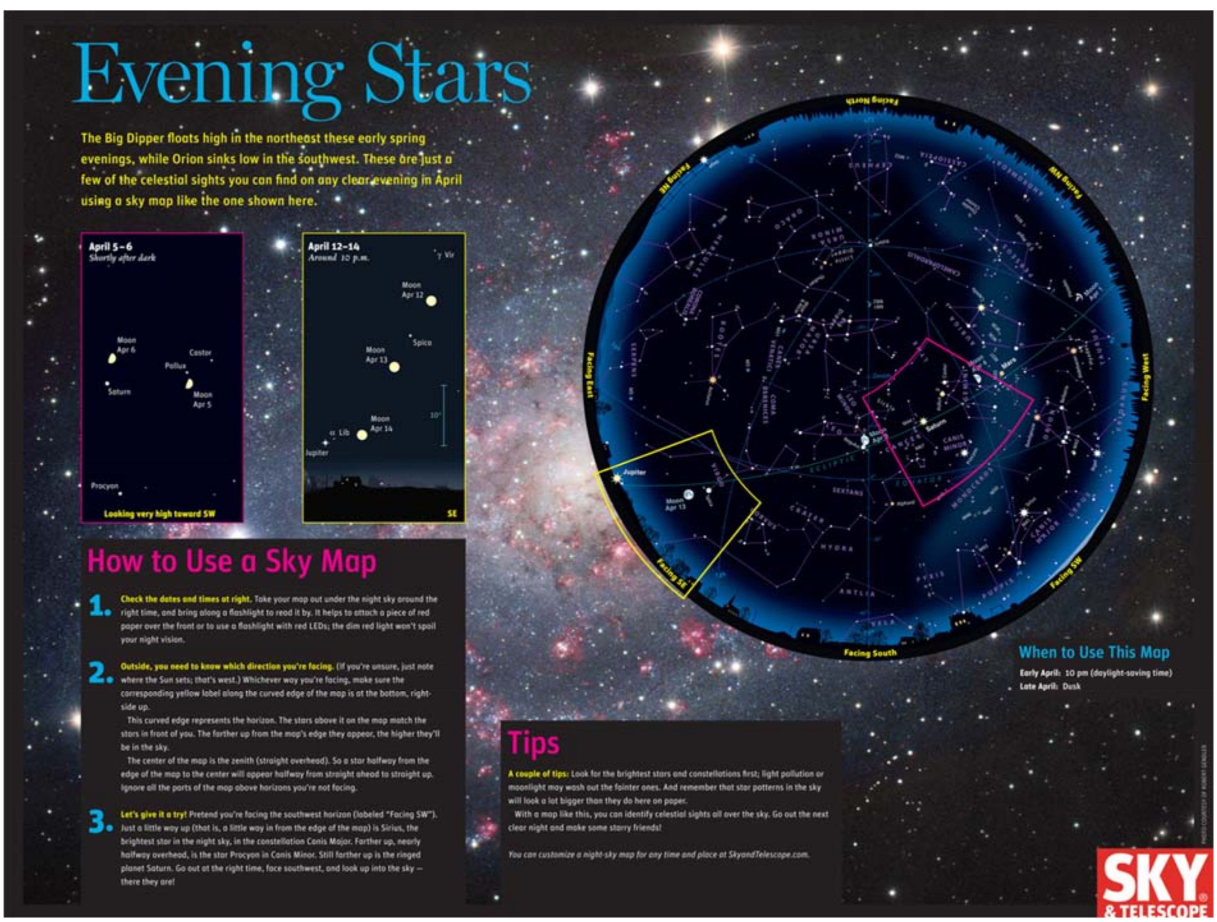
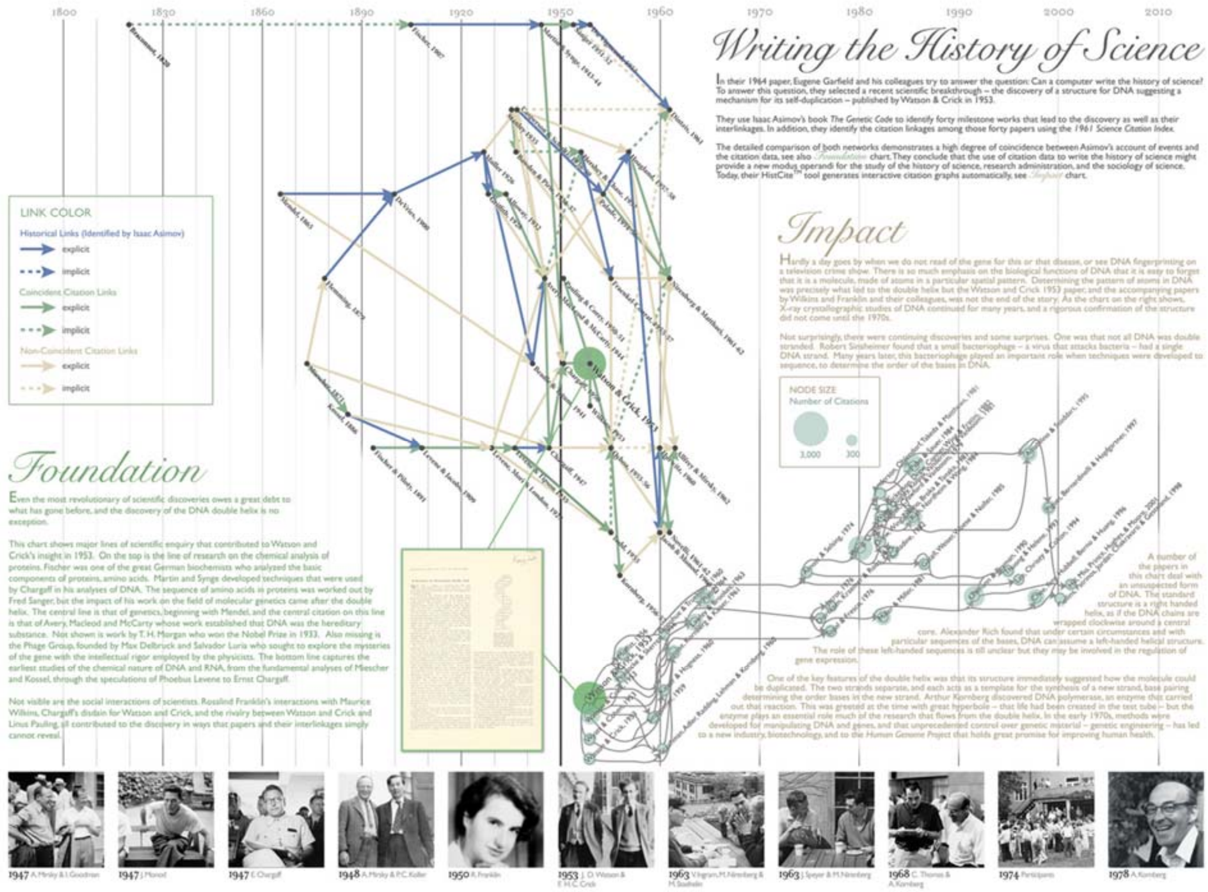

Evening Stars
The Big Dipper floats high in the northeast these early spring evenings, while Orion sinks low in the southwest. These are just a few of the celestial sights you can find on any clear evening in April using a sky map like the one shown here.
April 5–6
Shortly after dark
Moon Apr 6
Castor
Pollux
Saturn
Moon Apr 5
Procyon
Looking very high toward SW
April 12–14
Around 10 p.m.
Moon Apr 12
Spica
Moon Apr 13
Moon Apr 14
α Lib
Jupiter
10°
SE
How to Use a Sky Map
1. Check the dates and times at right. Take your map out under the night sky around the right time, and bring along a flashlight to read it by. It helps to attach a piece of red paper over the front or to use a flashlight with red LEDs; the dim red light won't spoil your night vision.
2. Outside, you need to know which direction you're facing. (If you're unsure, just note where the Sun sets; that's west.) Whichever way you're facing, make sure the corresponding yellow label along the curved edge of the map is at the bottom, right-side up.
This curved edge represents the horizon. The stars above it on the map match the stars in front of you. The farther up from the map's edge they appear, the higher they'll be in the sky.
The center of the map is the zenith (straight overhead). So a star halfway from the edge of the map to the center will appear halfway from straight ahead to straight up. Ignore all the parts of the map above horizons you're not facing.
3. Let's give it a try! Pretend you're facing the southwest horizon (labeled "Facing SW"). Just a little way up (that is, a little way in from the edge of the map) is Sirius, the brightest star in the night sky, in the constellation Canis Major. Farther up, nearly halfway overhead, is the star Procyon in Canis Minor. Still farther up is the ringed planet Saturn. Go out at the right time, face southwest, and look up into the sky — there they are!
Facing North
Facing NE
Facing NW
Facing East
Facing West
Facing SE
Facing SW
Facing South
Jupiter
Moon Apr 13
Saturn
Mars
When to Use This Map
Early April: 10 pm (daylight-saving time)
Late April: Dusk
Tips
A couple of tips: Look for the brightest stars and constellations first; light pollution or moonlight may wash out the fainter ones. And remember that star patterns in the sky will look a lot bigger than they do here on paper.
With a map like this, you can identify celestial sights all over the sky. Go out the next clear night and make some starry friends!
You can customize a night-sky map for any time and place at SkyandTelescope.com.
SKY & TELESCOPE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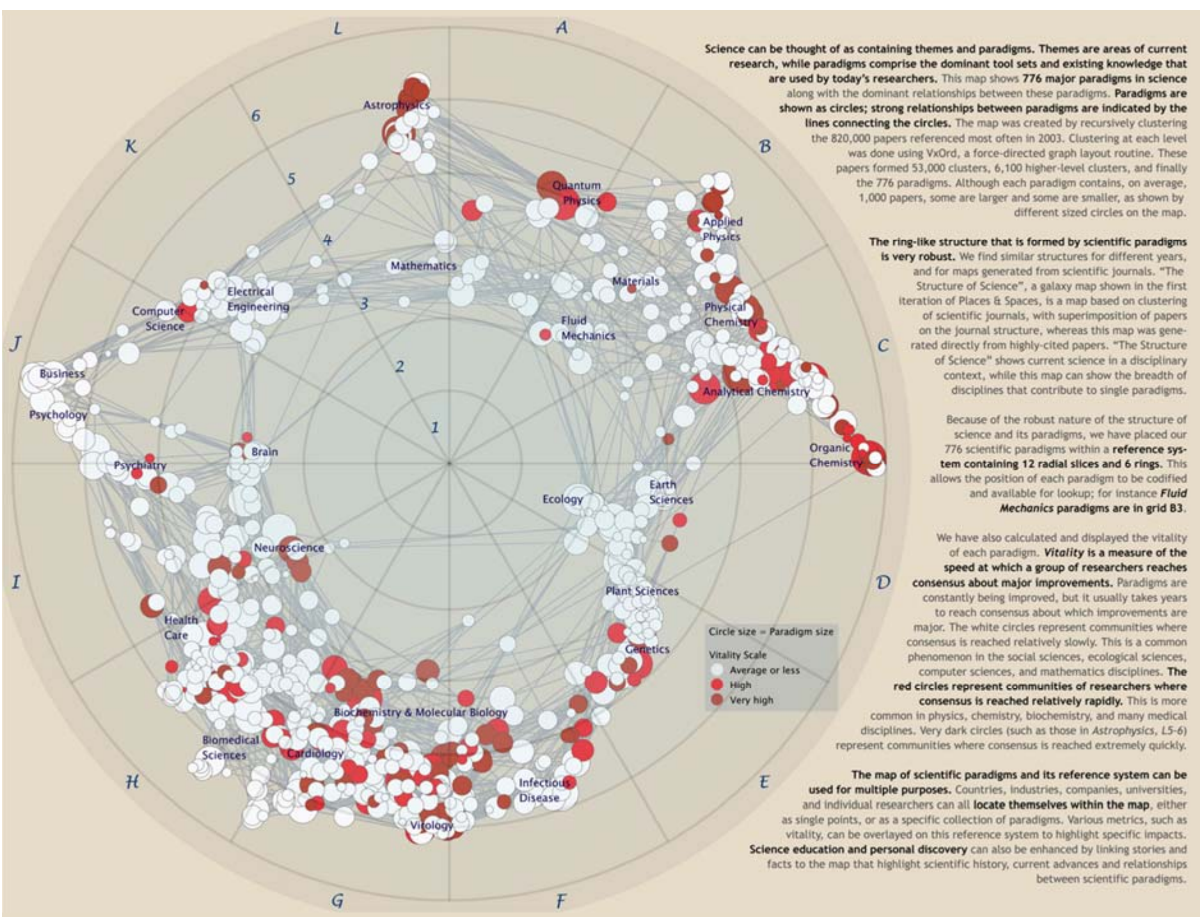
Writing the History of Science
In their 1964 paper, Eugene Garfield and his colleagues try to answer the question: Can a computer write the history of science? To answer this question, they selected a recent scientific breakthrough – the discovery of a structure for DNA suggesting a mechanism for its self-duplication – published by Watson & Crick in 1953.
They use Isaac Asimov's book The Genetic Code to identify forty milestone works that lead to the discovery as well as their interlinkages. In addition, they identify the citation linkages among those forty papers using the 1961 Science Citation Index.
The detailed comparison of both networks demonstrates a high degree of coincidence between Asimov's account of events and the citation data, see also Foundation chart. They conclude that the use of citation data to write the history of science might provide a new modus operandi for the study of the history of science, research administration, and the sociology of science. Today, their HistCite™ tool generates interactive citation graphs automatically, see Impact chart.
LINK COLOR
Historical Links (Identified by Isaac Asimov)
explicit
implicit
Coincident Citation Links
explicit
implicit
Non-Coincident Citation Links
explicit
implicit
Impact
NODE SIZE
Number of Citations
3,000
300
Foundation
Watson & Crick, 1953
1947 A. Mirsky & I. Goodman
1947 J. Monod
1947 E. Chargaff
1948 A. Mirsky & P.C. Koller
1950 R. Franklin
1953 J. D. Watson & F. H.C. Crick
1974 Participants
1978 A. Kornberg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Astrophysics
Quantum Physics
Applied Physics
Mathematics
Materials
Electrical Engineering
Computer Science
Physical Chemistry
Fluid Mechanics
Analytical Chemistry
Business
Psychology
Organic Chemistry
Brain
Psychiatry
Ecology
Earth Sciences
Neuroscience
Plant Sciences
Health Care
Genetics
Biochemistry & Molecular Biology
Biomedical Sciences
Cardiology
Infectious Disease
Virology
Circle size = Paradigm size
Vitality Scale
Average or less
High
Very high
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.

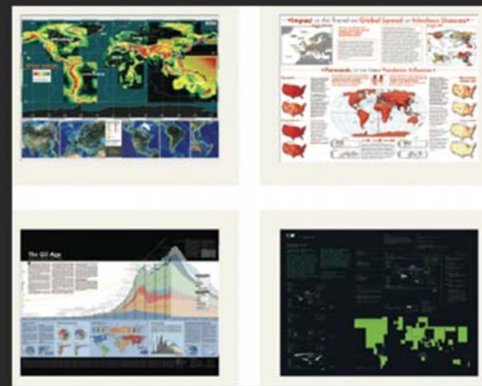
Third Iteration of Exhibit (2007): The Power of Forecasts

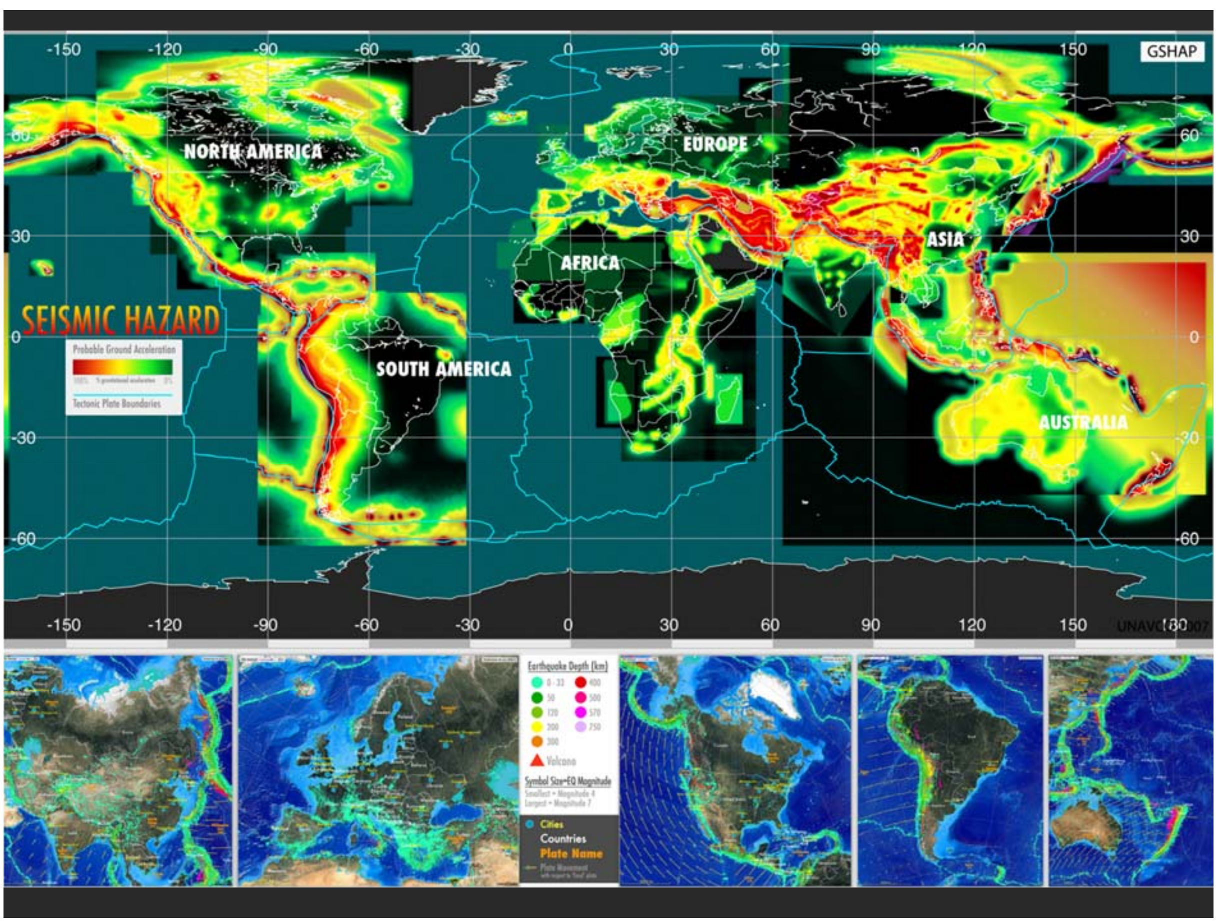
Four Existing Forecasts
Versus
Six Science Forecasts

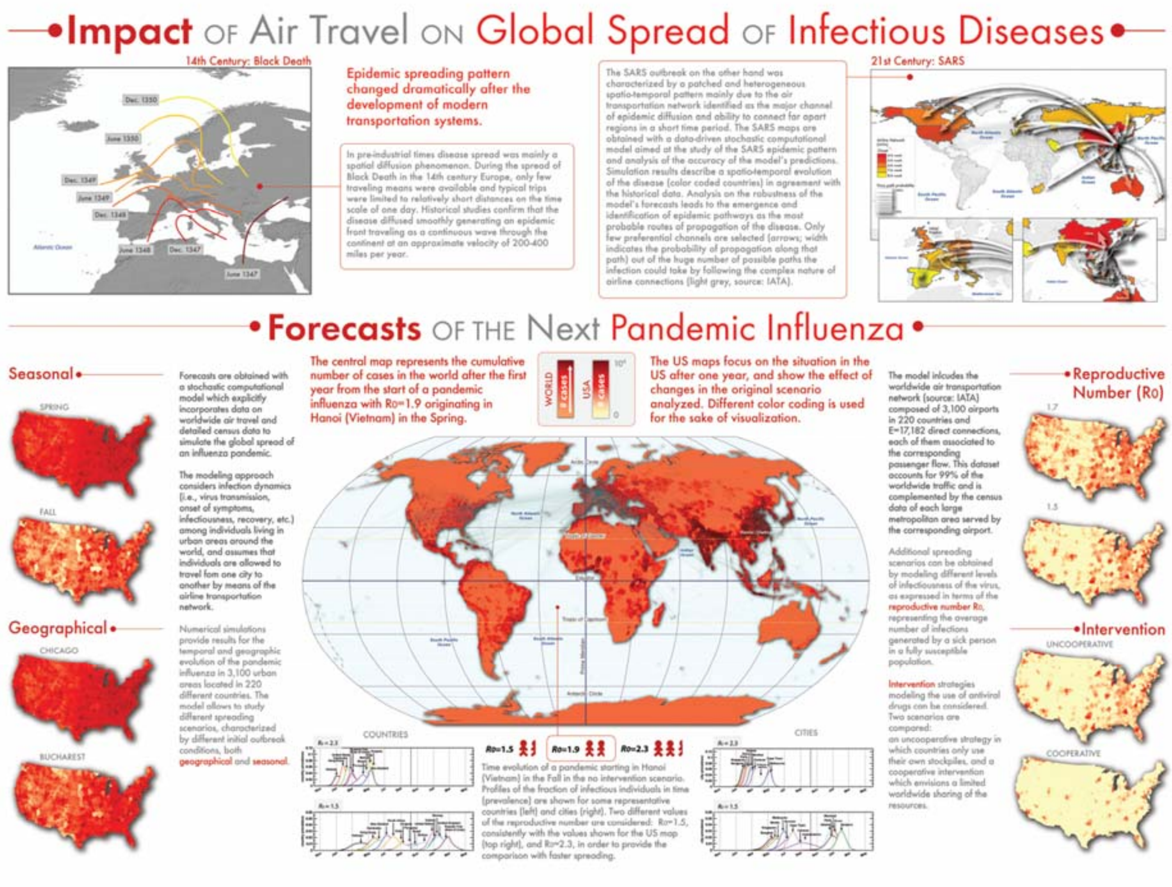
The third iteration of the exhibit compares and contrasts seismic hazard, economic, resource depletion, and epidemic forecast maps with maps forecasting the structure and evolution of science.

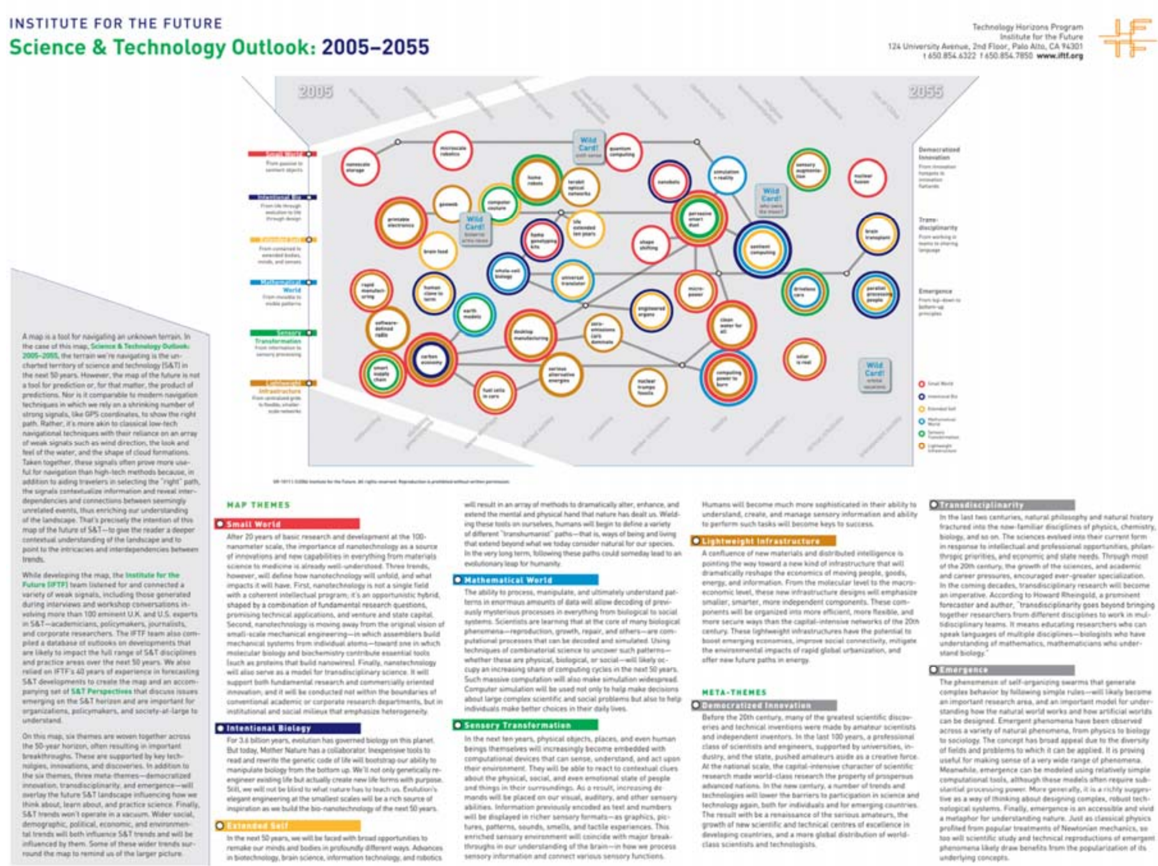
Real-time weather forecasts are served by the National Oceanic and Atmospheric Administration (NOAA) or the National Aeronautics and Space Administration (NASA). Computational models of the movements of tectonic plates help reduce losses due to earthqual
tsunamis. Epidemic models make us understand
and how actions far away affect us right here. Ecc
catastrophic and sustainable futures for mankind.

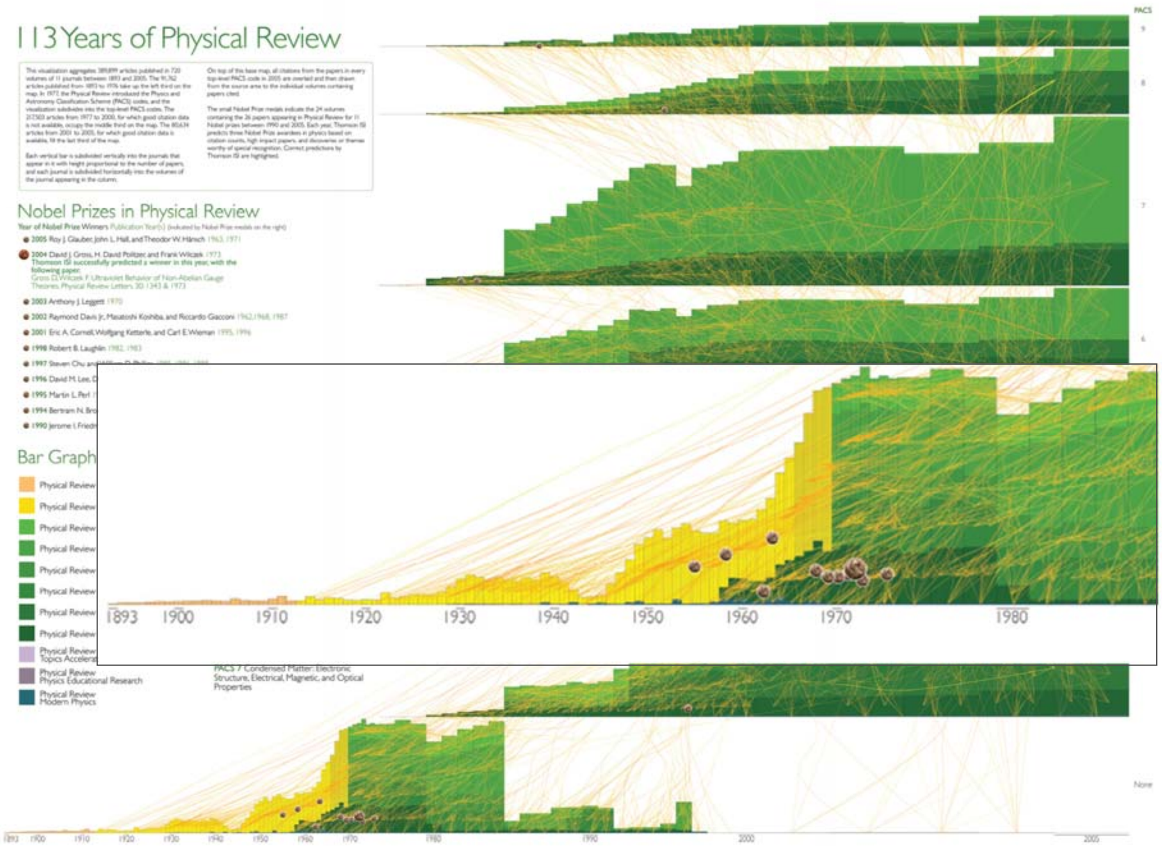
Daily science and technology forecasts would s
of top experts/institutions/countries, major activit
frontiers, augmenting our knowledge and decisio
available on TV, in the press, and online?

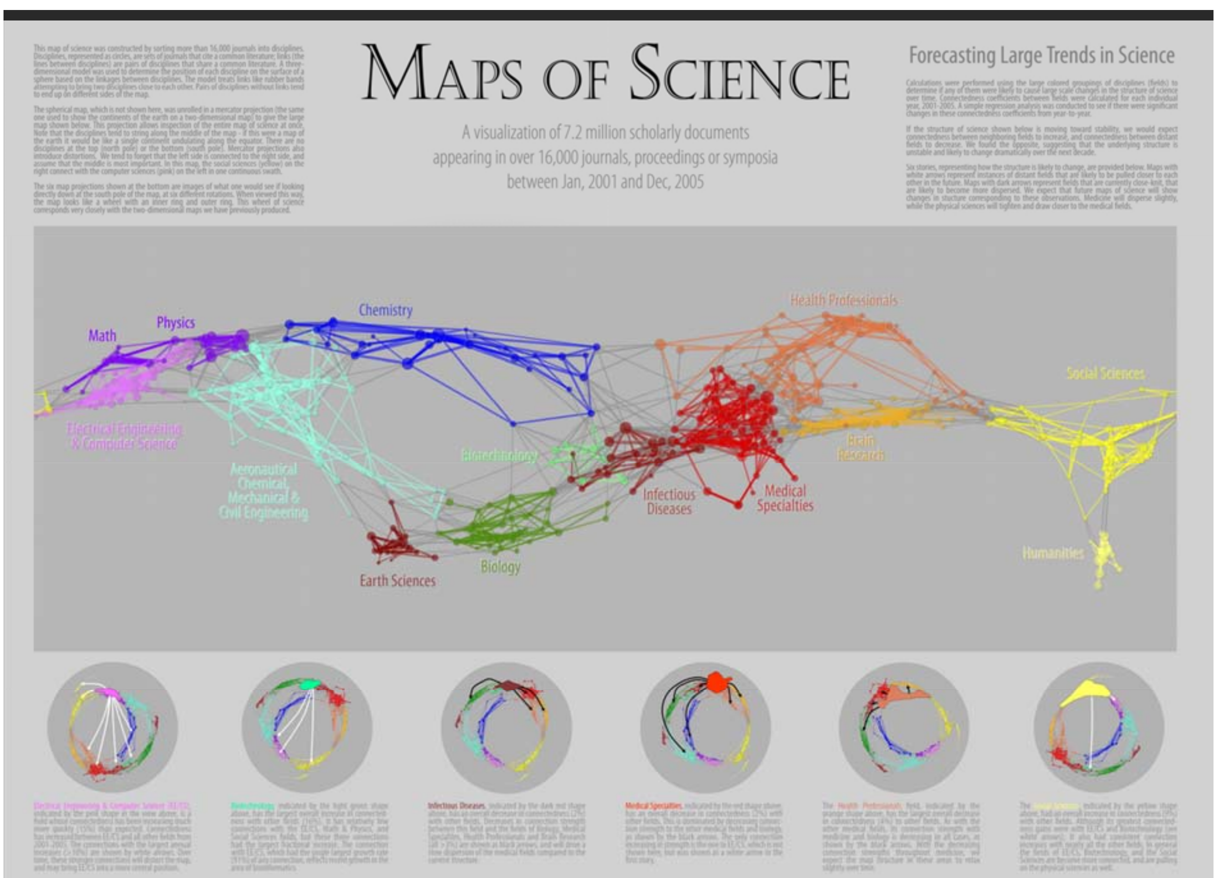





Impact OF Air Travel ON Global Spread OF Infectious Diseases
14th Century: Black Death
Epidemic spreading pattern changed dramatically after the development of modern transportation systems.
21st Century: SARS
Forecasts OF THE Next Pandemic Influenza
Seasonal
Geographical
Reproductive Number (R0)
Intervention
The central map represents the cumulative number of cases in the world after the first year from the start of a pandemic influenza with R0=1.9 originating in Hanoi (Vietnam) in the Spring.
The US maps focus on the situation in the US after one year, and show the effect of changes in the original scenario analyzed. Different color coding is used for the sake of visualization.


INSTITUTE FOR THE FUTURE
Science & Technology Outlook: 2005–2055
2005
2055
MAP THEMES
Small World
Intentional Biology
Extended Self
Mathematical World
Sensory Transformation
Lightweight Infrastructure
META-THEMES
Democratized Innovation
Transdisciplinarity
Emergence


113 Years of Physical Review
Nobel Prizes in Physical Review
Bar Graph
PACS
1893
1900
1910
1920
1930
1940
1950
1960
1970
1980
1990
2000
2005
None


Maps of Science
A visualization of 7.2 million scholarly documents appearing in over 16,000 journals, proceedings or symposia between Jan, 2001 and Dec, 2005
Forecasting Large Trends in Science
Math
Physics
Chemistry
Health Professionals
Social Sciences
Electrical Engineering & Computer Science
Aeronautical Chemical, Mechanical & Civil Engineering
Biotechnology
Infectious Diseases
Medical Specialties
Brain Research
Humanities
Earth Sciences
Biology


Additional Elements of the Exhibit

Certainly science maps and data graphs work to engage viewers intellectually—but can they also capture the imagination, as did the early maps of the world? Is it possible to involve viewers in a more dynamic way that heightens both their awareness and appreciation of data, information, and knowledge? What can be learned from theater, movies, and art exhibits—as well as science displays—to improve the ability of science maps to entertain while educating, to inspire while being true to facts, and
ers to engage in scienc
Additional exhibit e
and interact with scien
exceptional high data
and a map of today's s
drives a touch panel di
the touch panel display
on any given topic are
given geographic locat
The *Hands-On Scien*
stand science from ab
color drawings. Childr
placing images of maj
appropriate places on t
of various countries fo
patents. **Shape of Scie**
The **Video of the Exhi**
Public Library (NYPL
NYPL officials, who

Illuminated Diagram Display

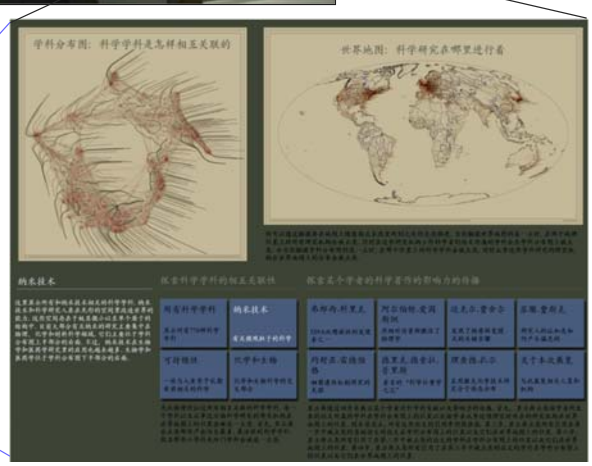
W. Bradford Paley, Kevin W. Boyack, Richard Kalvans, and Katy Börner (2007) Mapping, Illuminating, and Interacting with Science. SIGGRAPH 2007.

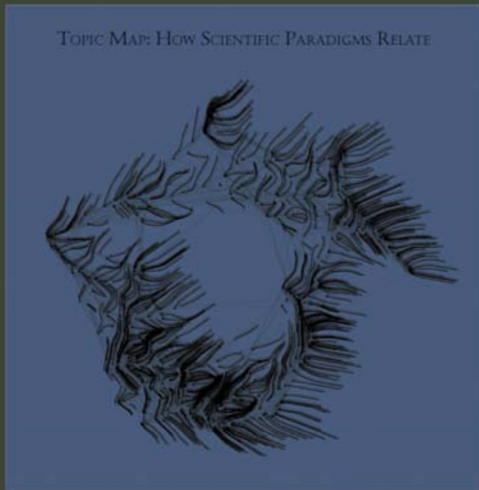
Large-scale, high resolution prints illuminated via projector or screen.

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.





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*

Sustainability — *The science behind our long-term hopes*

Biology & Chemistry — *The interface between these two vital fields*

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.

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*

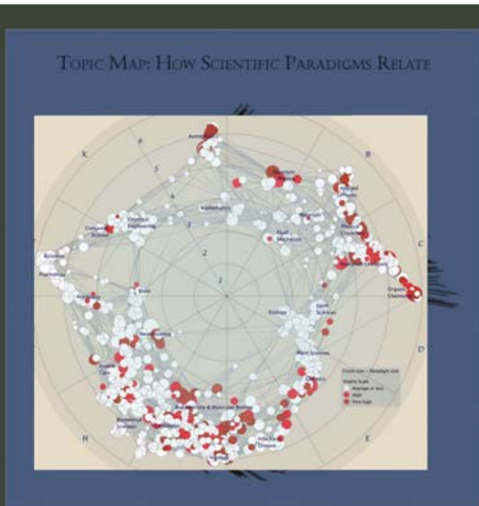
Joshua LEDERBERG — *Pioneer in bacterial genetic mechanisms*

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*

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 shapshot lights science that cites the second; and the fourth lights science that cites the third.



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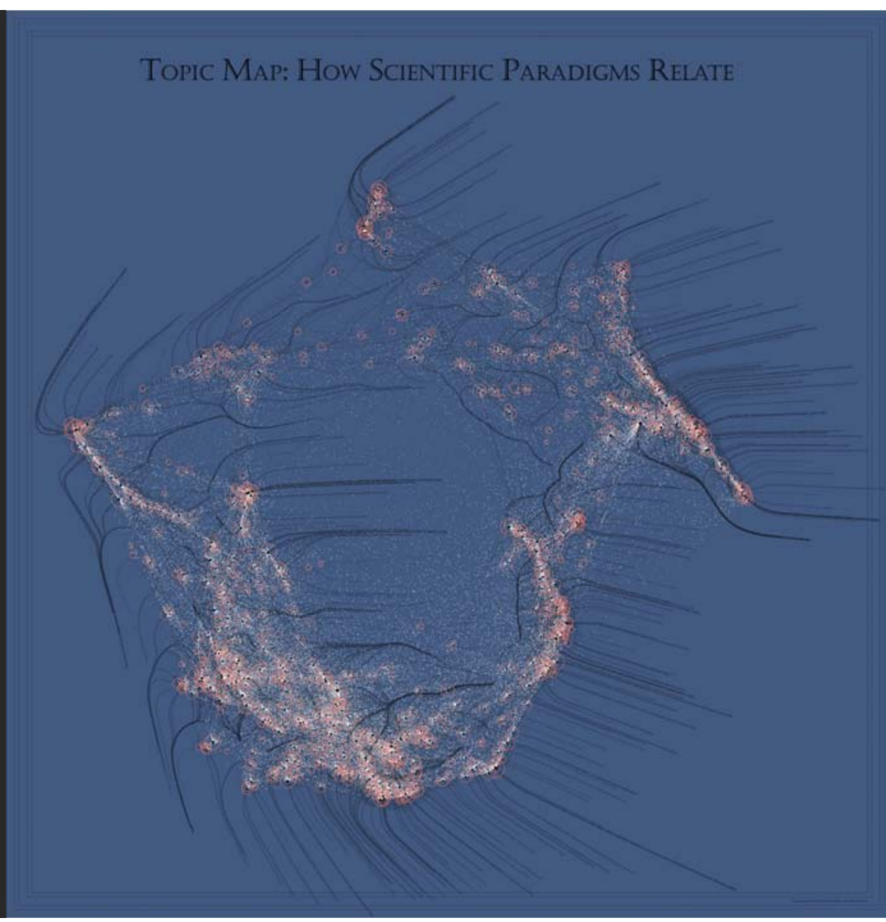
Science Maps in "Expedition Zukunft" science train visiting 62 cities in 7 months 12 coaches, 300 m long
Opening was on April 23rd, 2009 by German Chancellor Merkel
http://www.expedition-zukunft.de




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
Hands-On Science Maps for Kids, by Fileve Palmer (Painting), Julie Smith (Data Acquisition), Elisha Hardy and Katy Börner (Graphic Design), BLOOMINGTON, IN, 2006, Courtesy of Indiana University. Learn more at www.scimaps.org. This map plots the locations of where scientific papers were published: each light green dot represents 10 or fewer papers; they are scattered around the exact location for visibility, within a labelled green circle whose size is proportional to the number of papers published in that place. The base map is part of an "illuminated diagram" display which used a computer and two projectors, projecting spots of light on the prints to highlight different kinds of scientific research (on a sibling map of scientific paradigms) and the areas in the world where such

31


Inventors
ASTRONOMY
PHYSICS
ENGINEERING
COMPUTER SCIENCE
MATH
SOCIAL SCIENCE
PHYSICAL CHEMISTRY
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MENTAL HEALTH
EARTH SCIENCES
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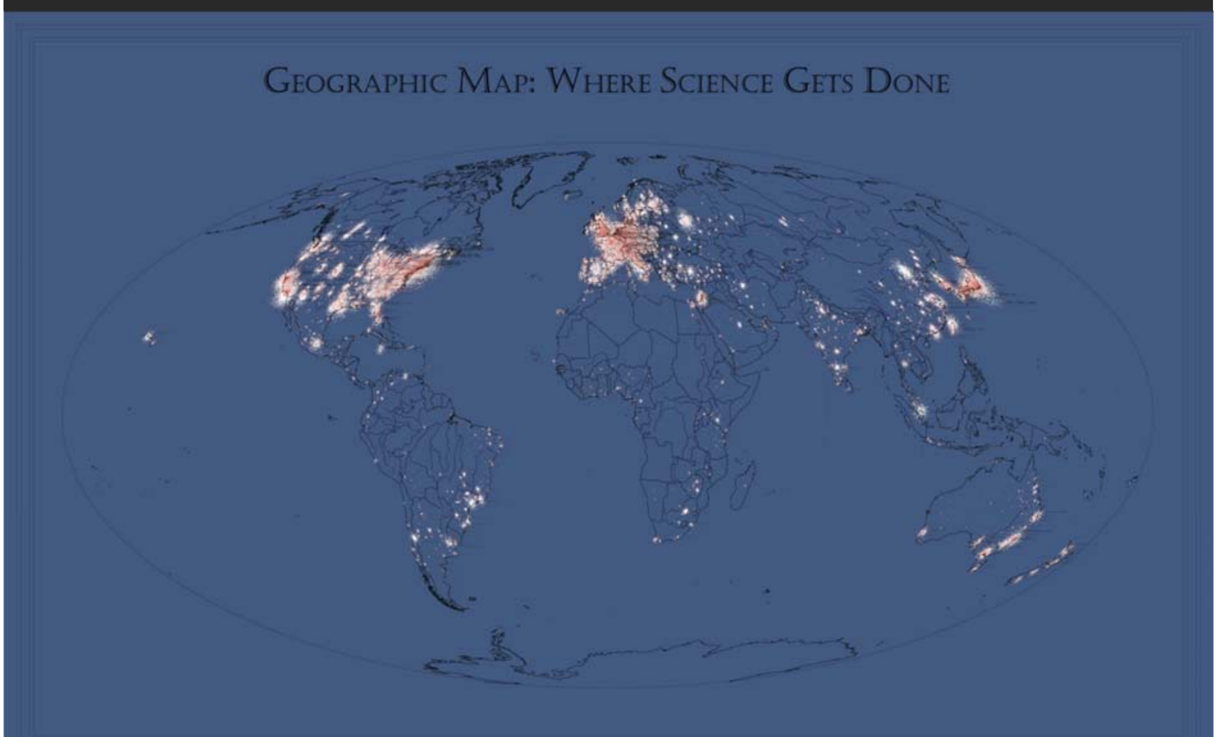
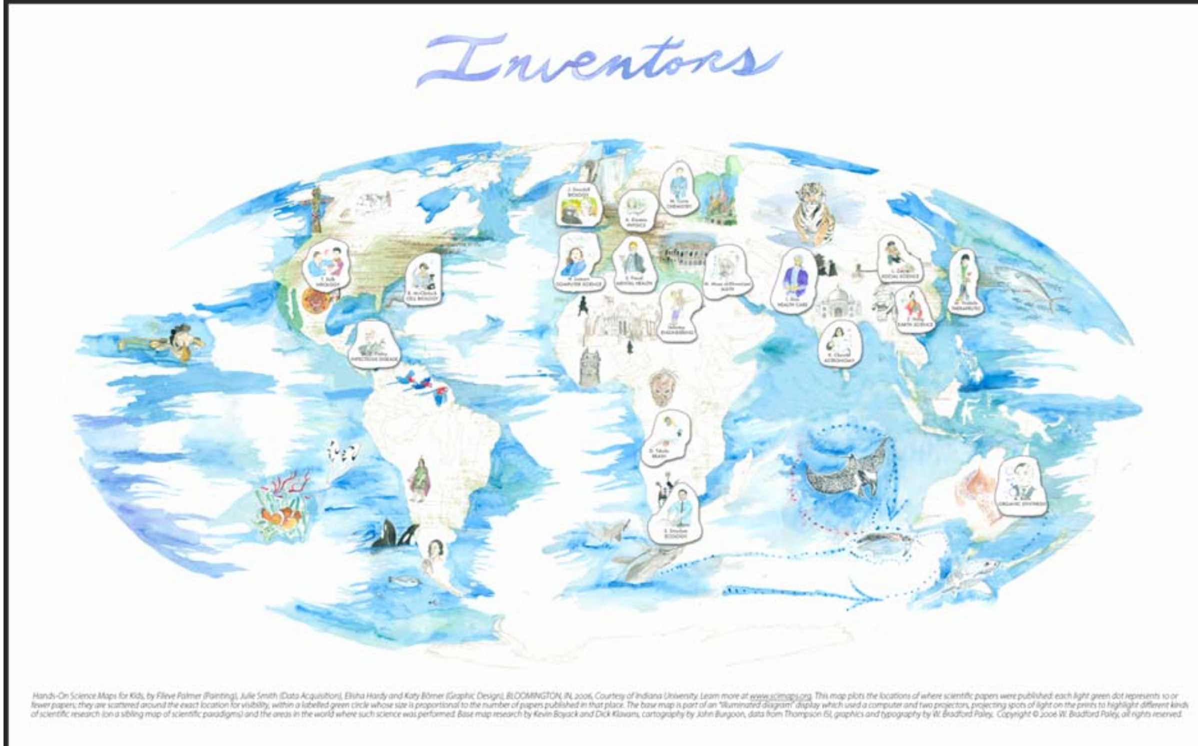
32



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
Hands-On Science Maps for Kids, by Fileve Palmer (Painting), Julie Smith (Data Acquisition), Elisha Hardy and Katy Börner (Graphic Design), BLOOMINGTON, IN, 2006, Courtesy of Indiana University. Learn more at www.scimaps.org. This map plots the locations of where scientific papers were published: each light green dot represents 10 or fewer papers; they are scattered around the exact location for visibility, within a labelled green circle whose size is proportional to the number of papers published in that place. The base map is part of an "illuminated diagram" display which used a computer and two projectors, projecting spots of light on the prints to highlight different kinds of scientific research (on a sibling map of scientific paradigms) and the areas in the world where such science was performed. Base map research by Kevin Boyack and Dick Klavans, cartography by John Burgoon, data from Thompson ISI, graphics and typography by W. Bradford Paley. Copyright © 2006 W. Bradford Paley, all rights reserved.

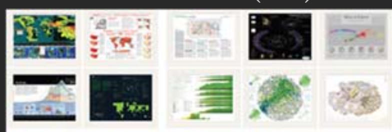
Mapping Science Exhibit – 10 Iterations in 10 years

http://scimaps.org/

The Power of Maps (2005)

The Power of Reference Systems (2006)

The Power of Forecasts (2007)



Science Maps for Economic Decision Makers (2008)

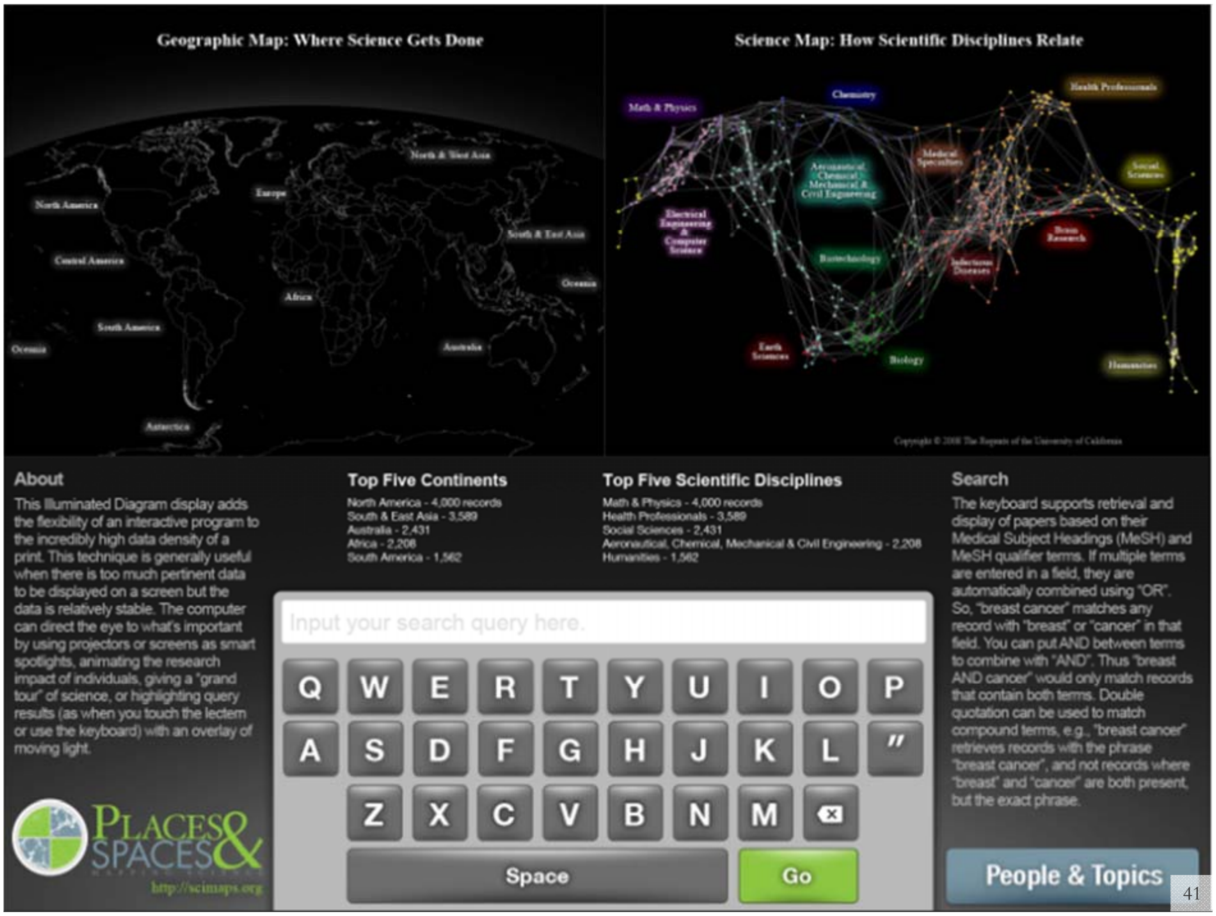
Science Maps for Science Policy Makers (2009)

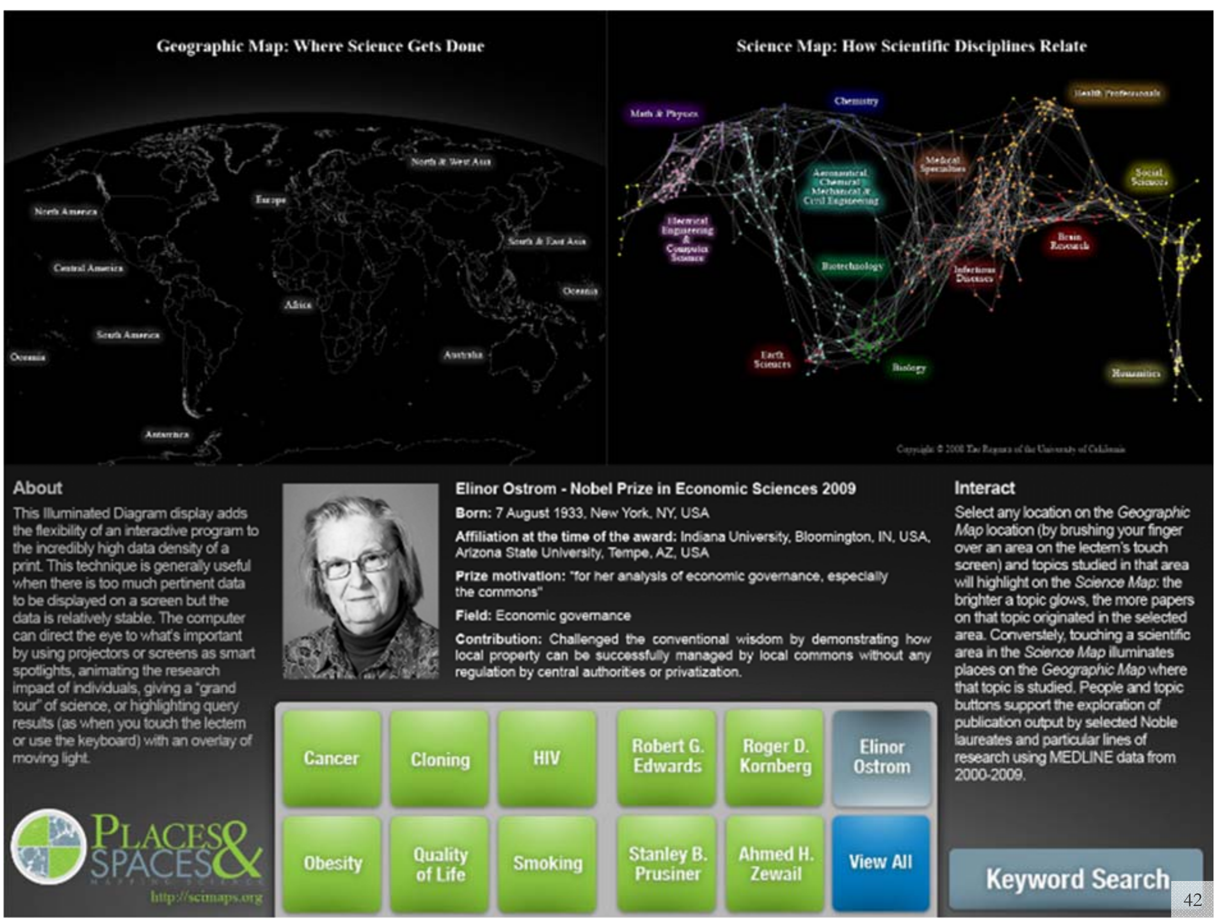
Science Maps for Scholars (2010)
Science Maps as Visual Interfaces to Digital Libraries (2011)
Science Maps for Kids (2012)
Science Forecasts (2013)
How to Lie with Science Maps (2014)

Exhibit has been shown in 72 venues on four continents. Currently at
- NSF, 10th Floor, 4201 Wilson Boulevard, Arlington, VA
- Center of Advanced European Studies and Research, Bonn, Germany
- Science Train, Germany
- Cultural Dimensions of Innovation, UCD Conference, Dublin, Ireland

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

Illuminated Diagram Display
on display at the Smithsonian in DC.
http://scimaps.org/exhibit_info/#ID


Geographic Map: Where Science Gets Done
Science Map: How Scientific Disciplines Relate
About
This Illuminated Diagram display adds the flexibility of an interactive program to the incredibly high data density of a print. This technique is generally useful when there is too much pertinent data to be displayed on a screen but the data is relatively stable. The computer can direct the eye to what's important by using projectors or screens as smart spotlights, animating the research impact of individuals, giving a "grand tour" of science, or highlighting query results (as when you touch the lectern or use the keyboard) with an overlay of moving light.
Top Five Continents
North America - 4,000 records
South & East Asia - 3,589
Australia - 2,431
Africa - 2,208
South America - 1,562
Top Five Scientific Disciplines
Math & Physics - 4,000 records
Health Professionals - 3,589
Social Sciences - 2,431
Aeronautical, Chemical, Mechanical & Civil Engineering - 2,208
Humanities - 1,562
Search
The keyboard supports retrieval and display of papers based on their Medical Subject Headings (MeSH) and MeSH qualifier terms. If multiple terms are entered in a field, they are automatically combined using "OR". So, "breast cancer" matches any record with "breast" or "cancer" in that field. You can put AND between terms to combine with "AND". Thus "breast AND cancer" would only match records that contain both terms. Double quotation can be used to match compound terms, e.g., "breast cancer" retrieves records with the phrase "breast cancer", and not records where "breast" and "cancer" are both present, but the exact phrase.
Input your search query here.
Space
Go
People & Topics
PLACES & SPACES
http://scimaps.org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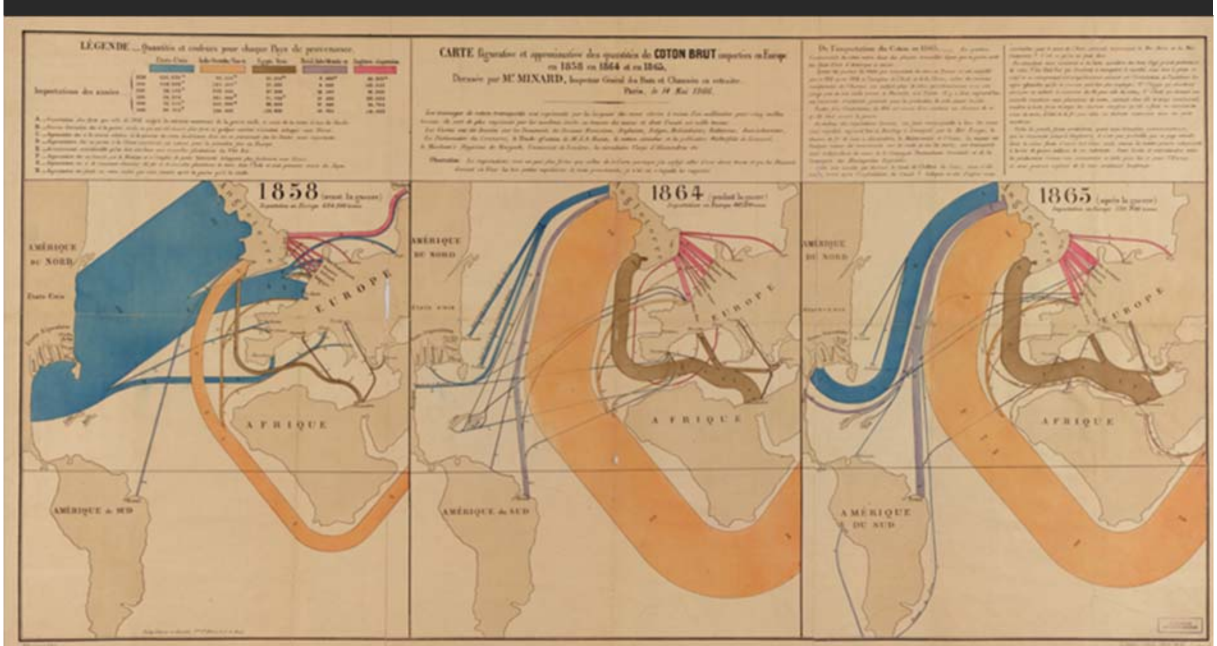
Elinor Ostrom - Nobel Prize in Economic Sciences 2009
Born: 7 August 1933, New York, NY, USA
Affiliation at the time of the award: Indiana University, Bloomington, IN, USA, Arizona State University, Tempe, AZ, USA
Prize motivation: "for her analysis of economic governance, especially the commons"
Field: Economic governance
Contribution: Challenged the conventional wisdom by demonstrating how local property can be successfully managed by local commons without any regulation by central authorities or privatization.
Interact
Select any location on the Geographic Map location (by brushing your finger over an area on the lectern's touch screen) and topics studied in that area will highlight on the Science Map: the brighter a topic glows, the more papers on that topic originated in the selected area. Conversely, touching a scientific area in the Science Map illuminates places on the Geographic Map where that topic is studied. People and topic buttons support the exploration of publication output by selected Noble laureates and particular lines of research using MEDLINE data from 2000-2009.
Cancer
Cloning
HIV
Robert G. Edwards
Roger D. Kornberg
Elinor Ostrom
Obesity
Quality of Life
Smoking
Stanley B. Prusiner
Ahmed H. Zewail
View All
Keyword Search
PLACES & SPACES
http://scimaps.org

Science Maps for Economic Decision Making

Four Existing Maps
VERSUS
Six Science Maps

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



Joseph Minard, Title: Europe Raw Cotton Imports in 1858, 1864 and 1865 (1866)

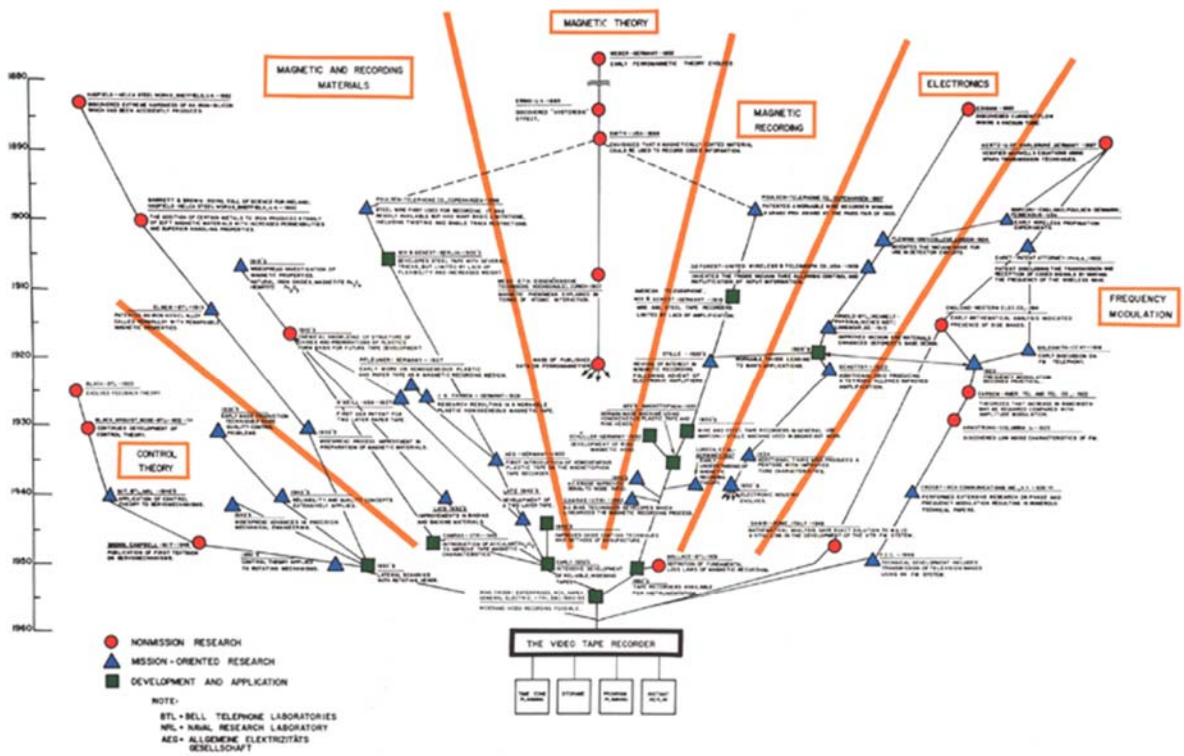
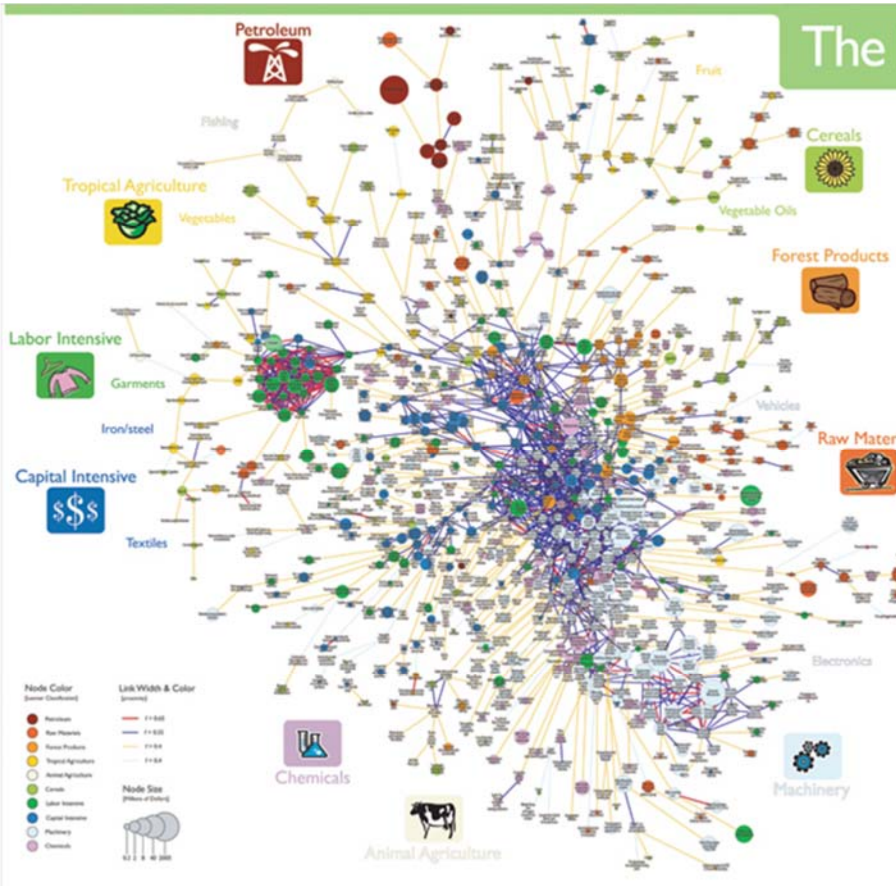


FIG. 7. THE VIDEO TAPE RECORDER

What insight needs to economic decision makers have?

What data views are most useful?

The Product Space



World trade flow data compiled by Feenstra et al. and available at the National Bureau of Economic Research were used to identify the complete co-export matrix of 775 industrial products for 1998-2000. A Maximum Spanning Tree (MST) algorithm was used to reduce the complete co-export matrix to less than 1% of the links. The resulting network, which combines the MST plus all links with a co-export frequency of at least 0.55, was laid out using a force-directed layout algorithm. Node sizes represent the value of traded products in millions of U.S. dollars. Their color corresponds to ten product groups identified using the Leamer classification. Each product class is labeled by an icon. Link color and width indicate the frequency of joint exports.

Economic Footprint

■ Indicate Relevant Exports

The network has a core-periphery structure with higher value product classes, e.g., machinery, and chemicals, in the core and lower quality classes, e.g., fishing and garments, in the periphery. Products at the core of the network are highly interconnected while products in the periphery are sparsely interlinked.

Each country has a certain product export footprint. Relevant exports by 'Industrialized Countries', 'East Asia Pacific' and 'Latin America & the Caribbean' are given on the right.

Traditional growth theory assumes that there is always a more sophisticated product within reach. However, given the core-periphery structure of the product space, the distances between products differ considerably.

Countries that operate at the core have capabilities to develop and manufacture a wide range of products. Yet, countries that mostly operate in the periphery of the product space have much fewer opportunities for diversification. A country's current footprint and the structure of the product space have a major impact on a country's future development.

Happiness Depends on Various Factors

"It's time we admitted there's more to life than money."
- David Cameron, U.K. leader of the opposition, 2006

Social scientists are starting to include relative happiness with hard data on economic status, health, and other factors as they assess quality of life. They rely on surveys of "subjective well-being"—how good people feel about their lives. A world map of one "happiness index" shows many, but not all, wealthy northern countries faring well. Residents of sub-Saharan Africa and the former Soviet Union, meanwhile, report particularly low levels of contentment.

Any attempt to measure happiness will fall short—each life is a series of joys, struggles, and sorrows, and satisfaction can depend as much on outlook as on circumstances. Averages obscure the happy moments in struggling nations, as well as people who suffer from poor health, poverty, or discrimination in countries that rank high. Still, happiness indices can help researchers move beyond simple economics as they track progress—or backsliding—over time.

RANKING THE WORLD'S HAPPIEST PLACES
Northern Europe, North America, and several wealthy countries make the list, but so do many less prosperous island nations.

1. DENMARK, SWITZERLAND
2. AUSTRIA, ICELAND
3. BAHAMAS, FINLAND, SWEDEN
4. BHUTAN, BRUNEI, CANADA, IRELAND, LUXEMBOURG
5. COSTA RICA, MALTA, NETHERLANDS
6. ANTIGUA AND BARBUDA, MALAYSIA, NEW ZEALAND, NORWAY, SEYCHELLES, ST. KITTS AND NEVIS, UNITED ARAB EMIRATES, UNITED STATES, VANUATU, VENEZUELA

MEASURING THE INTANGIBLE
The map is derived from the New Economics Foundation's 2006 "Happy Planet Index," which drew on over 100 surveys of subjective well-being. Its "satisfaction with life scale"—a happiness index—ranks the relative happiness of nations, from a high of 273 (Denmark and Switzerland) to a low of 100 (Burundi).

DEFINING WELL-BEING
By comparing the happiness index to data from the UN, the CIA, and other sources, a U.K. psychologist determined that good health and health care, enough money for fundamental needs, and access to basic education are the most important factors for subjective well-being. European countries top all three measures.

HEALTH
Japan boasts the world's longest life expectancy—one measure of overall health. Swaziland, at the other end of the scale, is plagued by poverty, disease, and violence. Disparities in access to health care divide many countries into haves and have-nots.

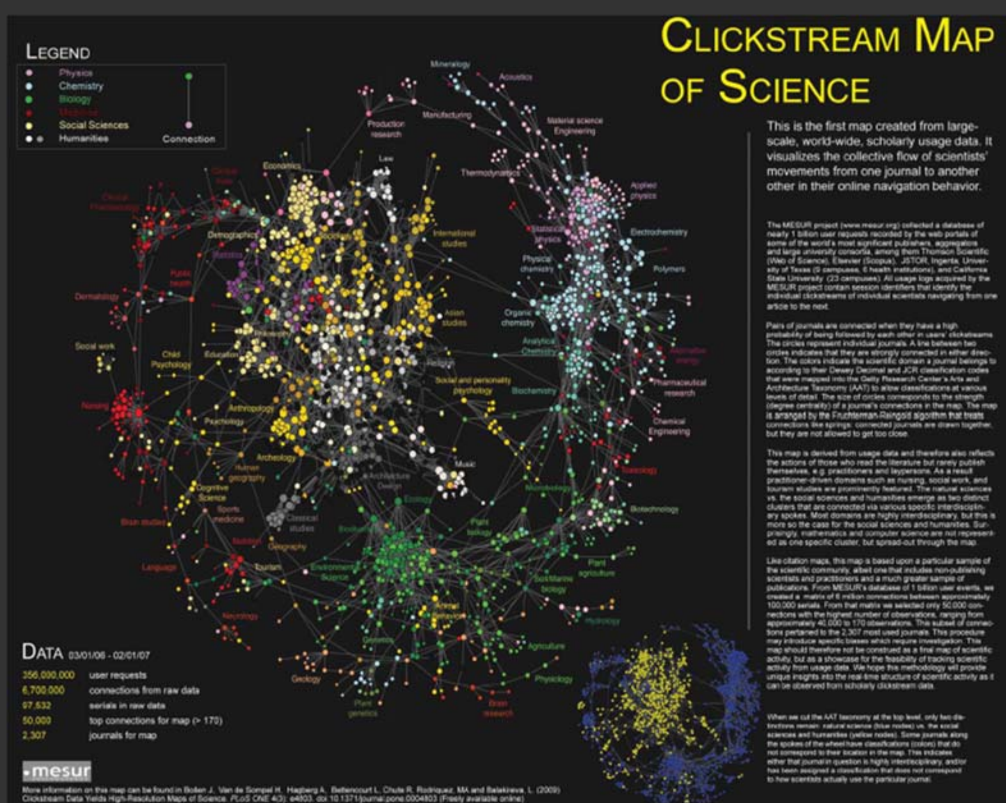
WEALTH
Money still can't buy love, or happiness, and wealthier people aren't always more content. Still, tiny Luxembourg, which takes top rank in per capita Gross Domestic Product (GDP), also rates a 253 on the happiness index. Real poverty means real misery, a fate shared by billions.

EDUCATION
Residents of Australia can expect to spend more time in school—an average of almost 21 years—than citizens of any other country. But only a basic education is needed to see a significant jump in overall happiness. Around the world, hundreds of millions lack even that.

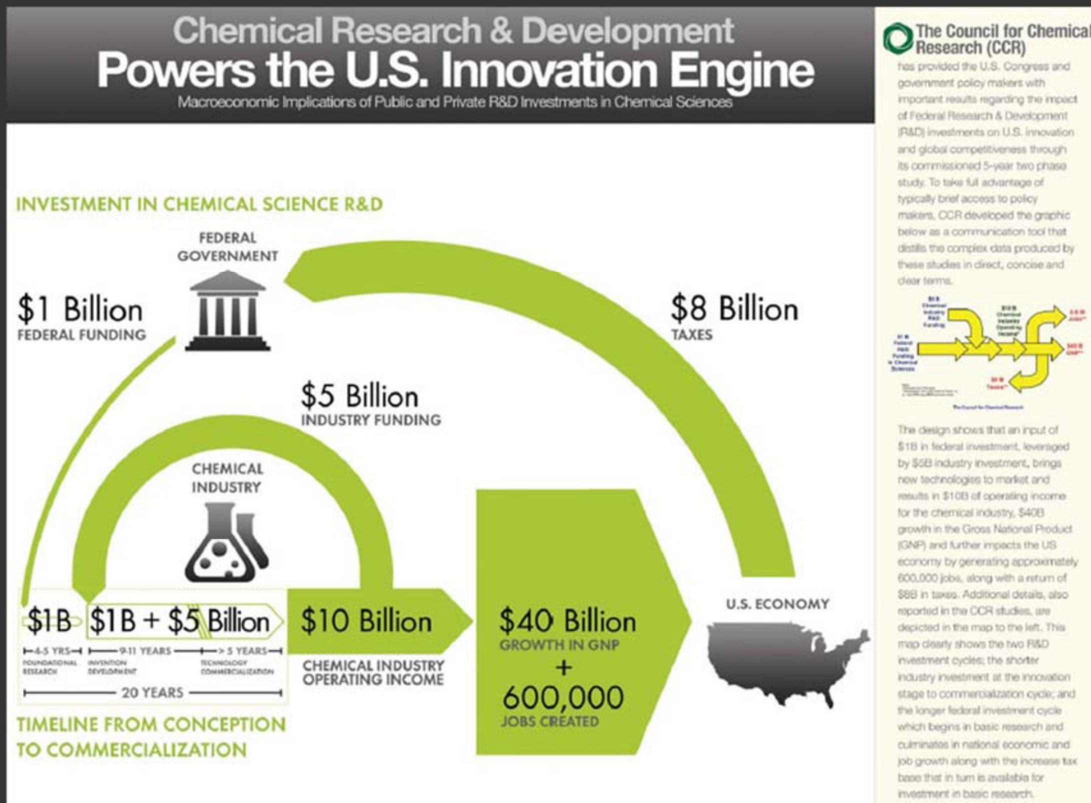
Science Maps for Science Policy Making

Four Existing Maps
VERSUS
Six Science Maps

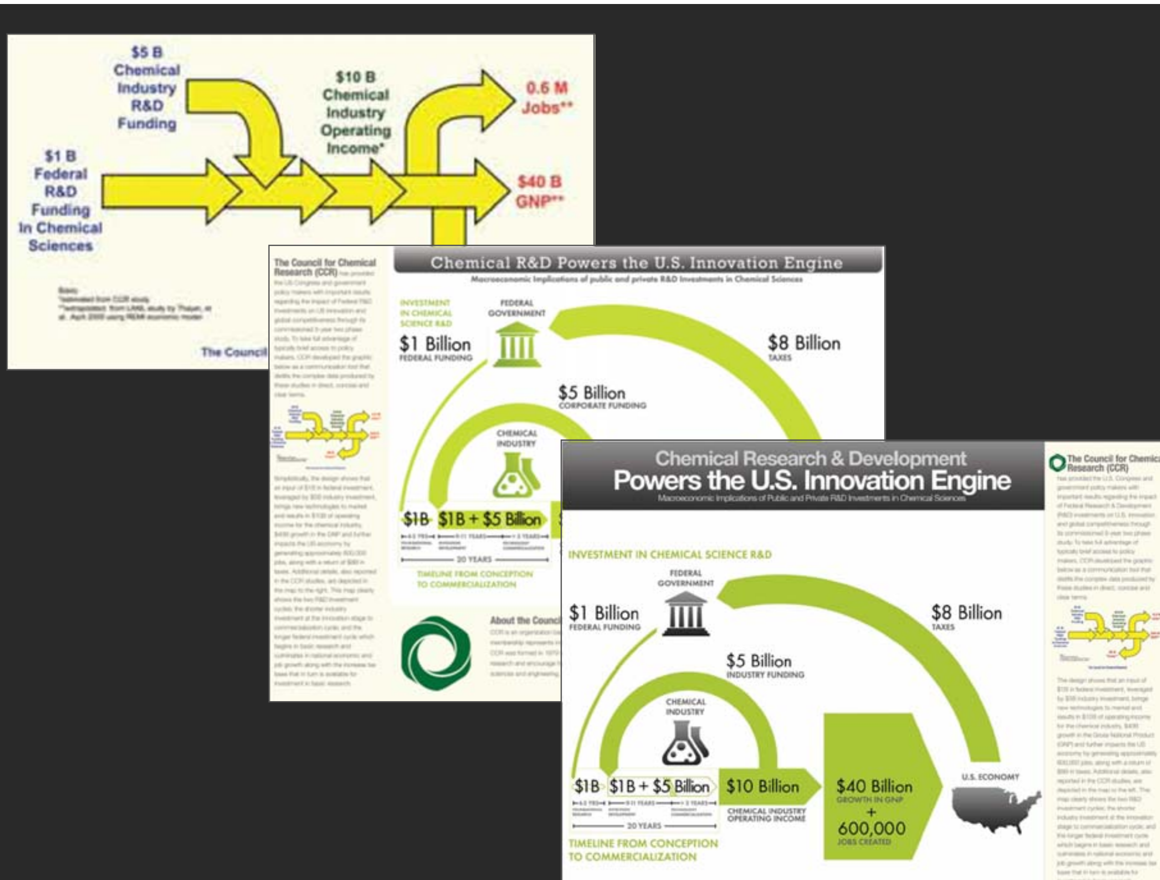
(5th Iteration of Places & Spaces Exhibit - 2009)



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



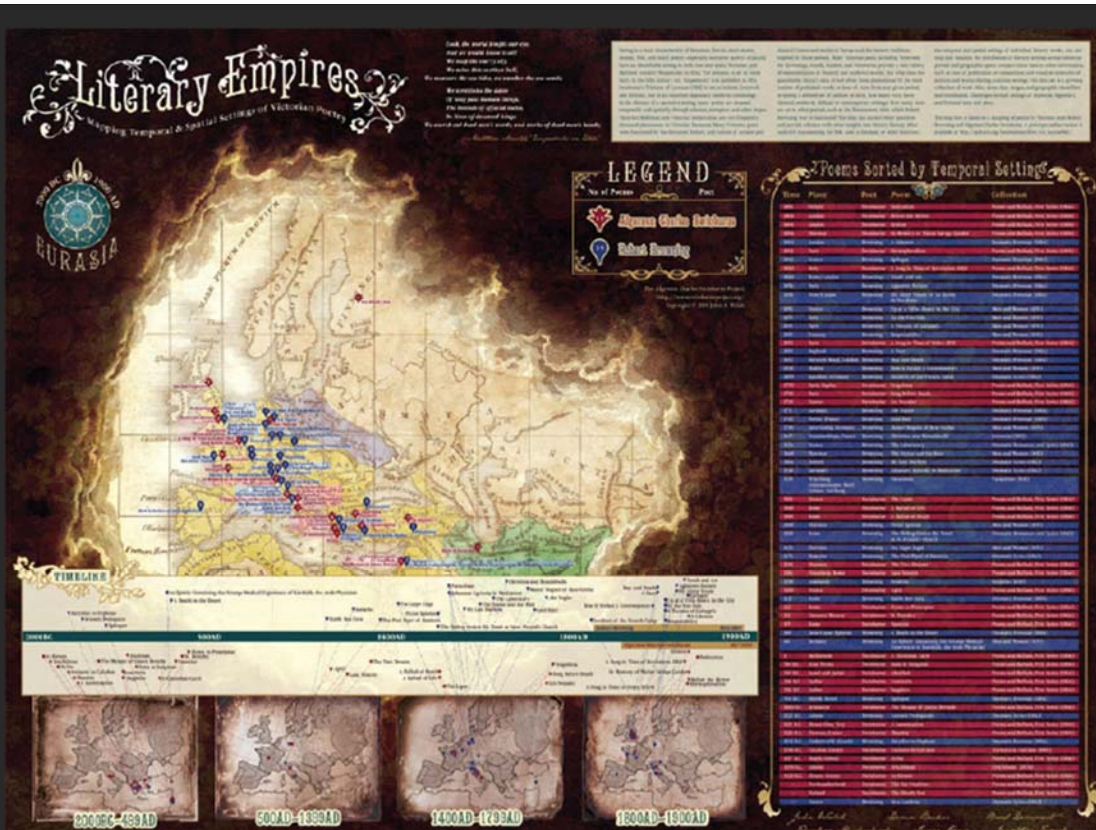
Council for Chemical Research. 2009. Chemical R&D Powers the U.S. Innovation Engine. Washington, DC. Courtesy of the Council for Chemical Research.



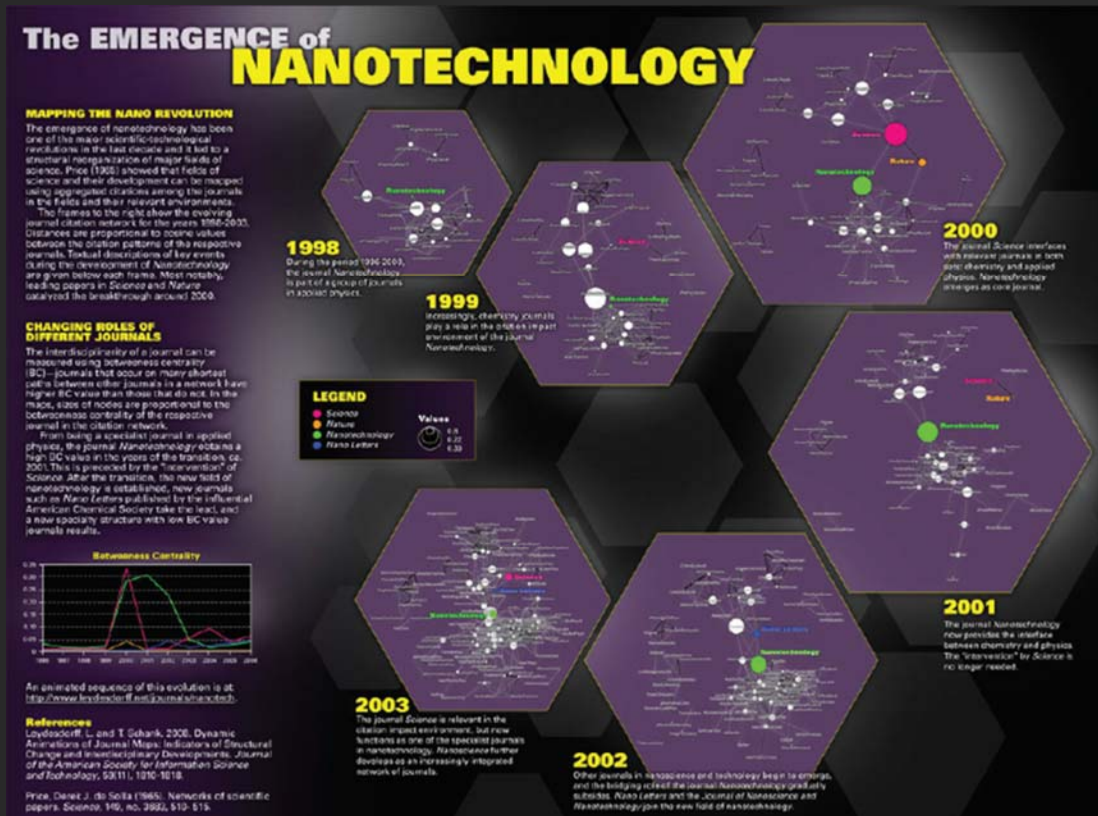
Science Maps for Scholars

Four Existing Maps
VERSUS
Six Science Maps

(6th Iteration of Places & Spaces Exhibit – 2010)



John A. Walsh, Devin Becker, Bradford Demarest, Jonathan Tweedy, Theodora Michaelidou, and Laura Pence (2010) Map of Literary Empires: Mapping Temporal and Spatial Settings of Victorian Poetry.



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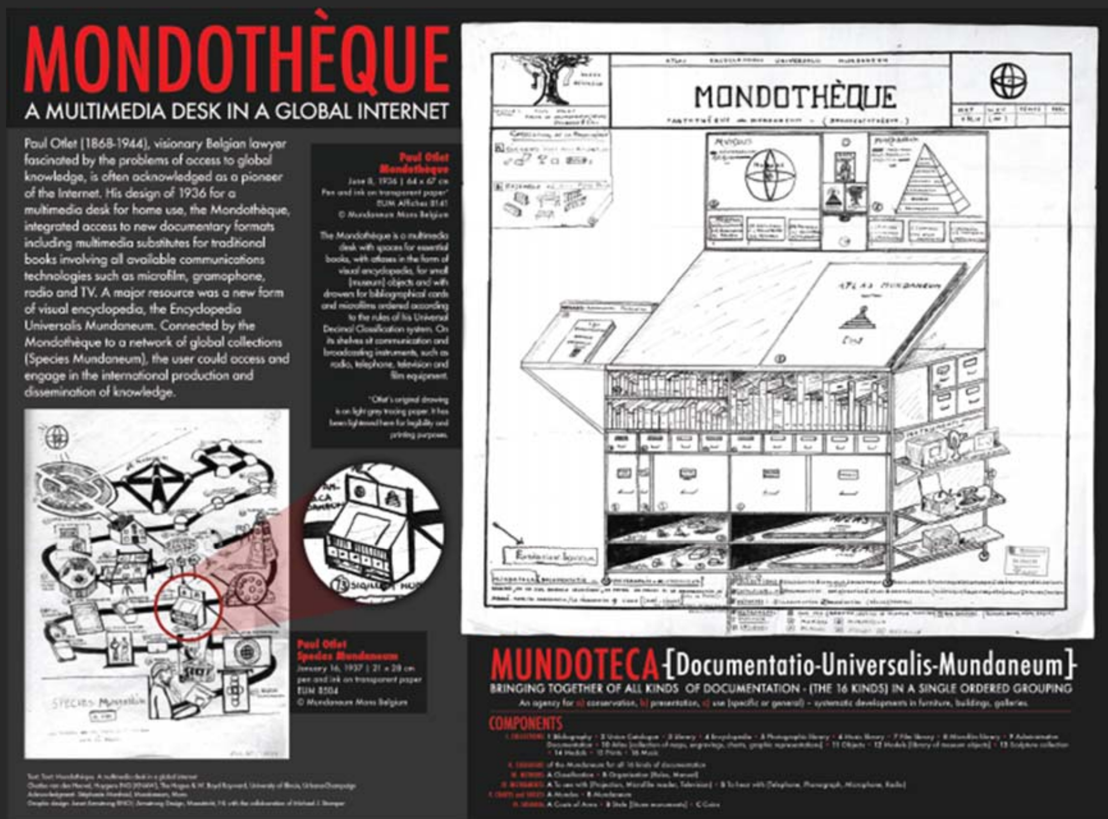
Science Maps as Visual Interfaces to Digital Libraries

Four Existing Maps
VERSUS
Six Science Maps

(7th Iteration of Places & Spaces Exhibit – 2011)



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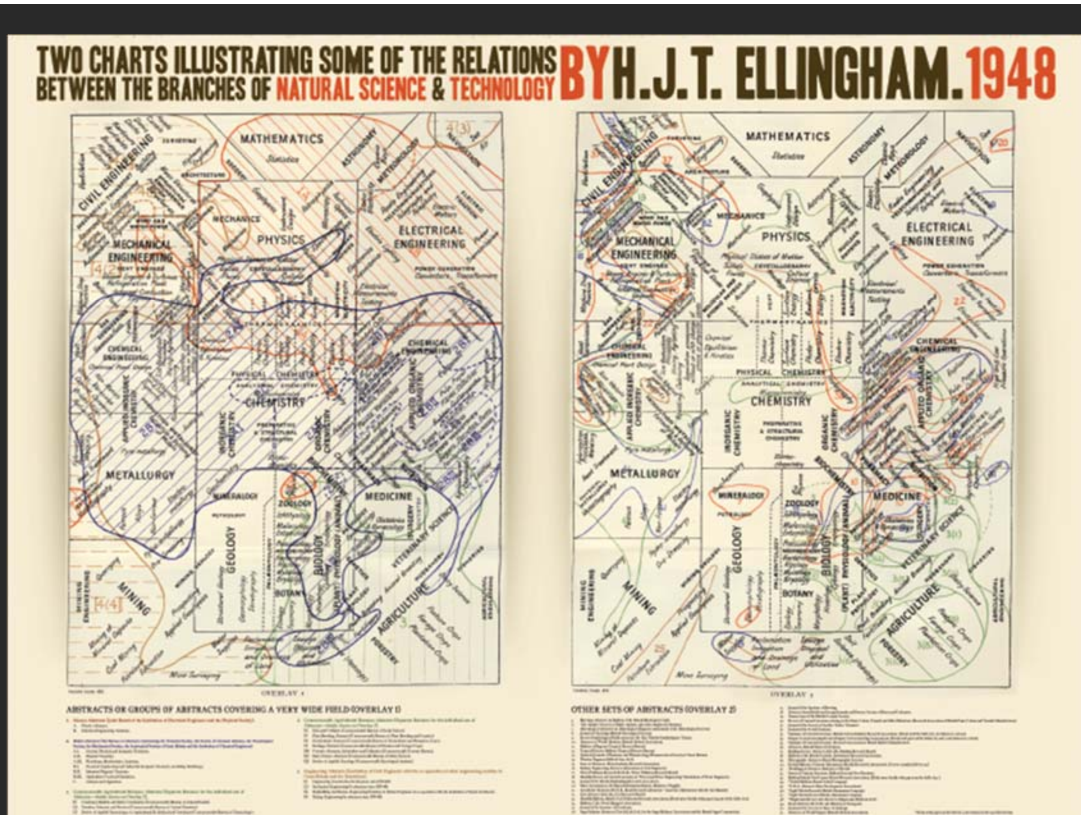

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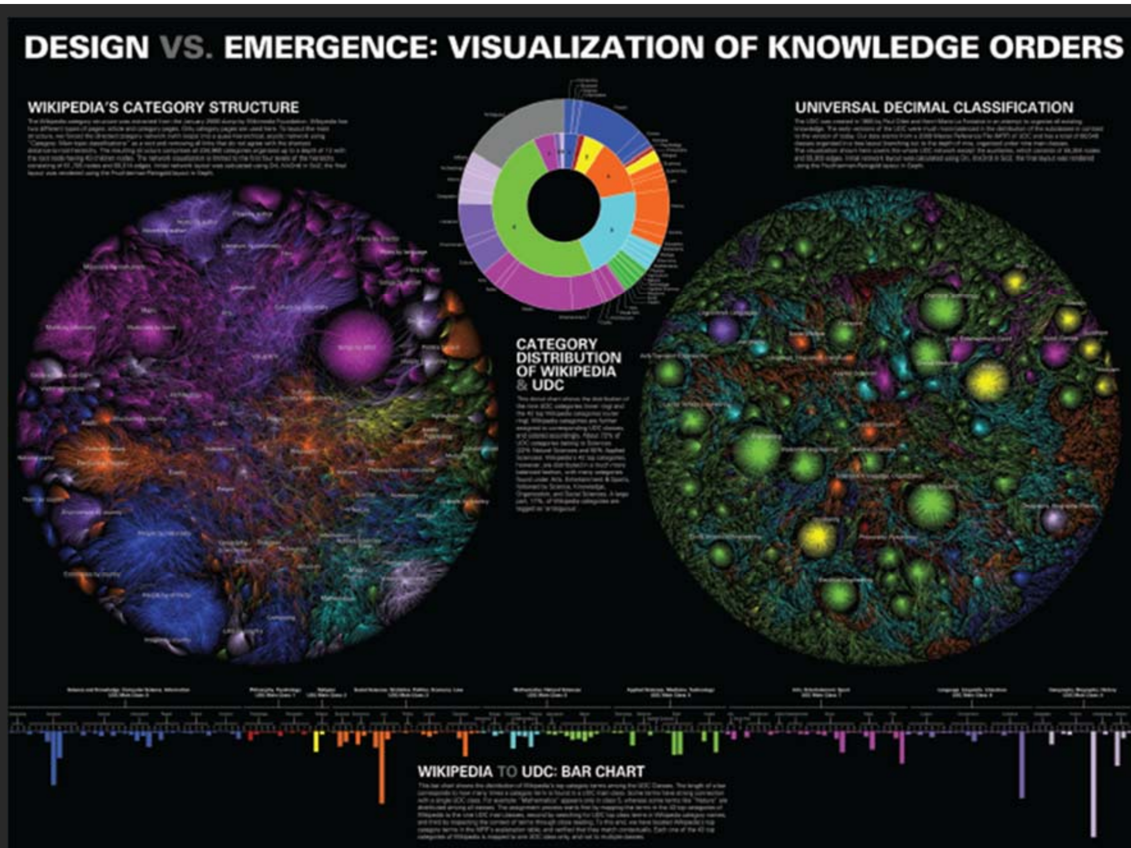

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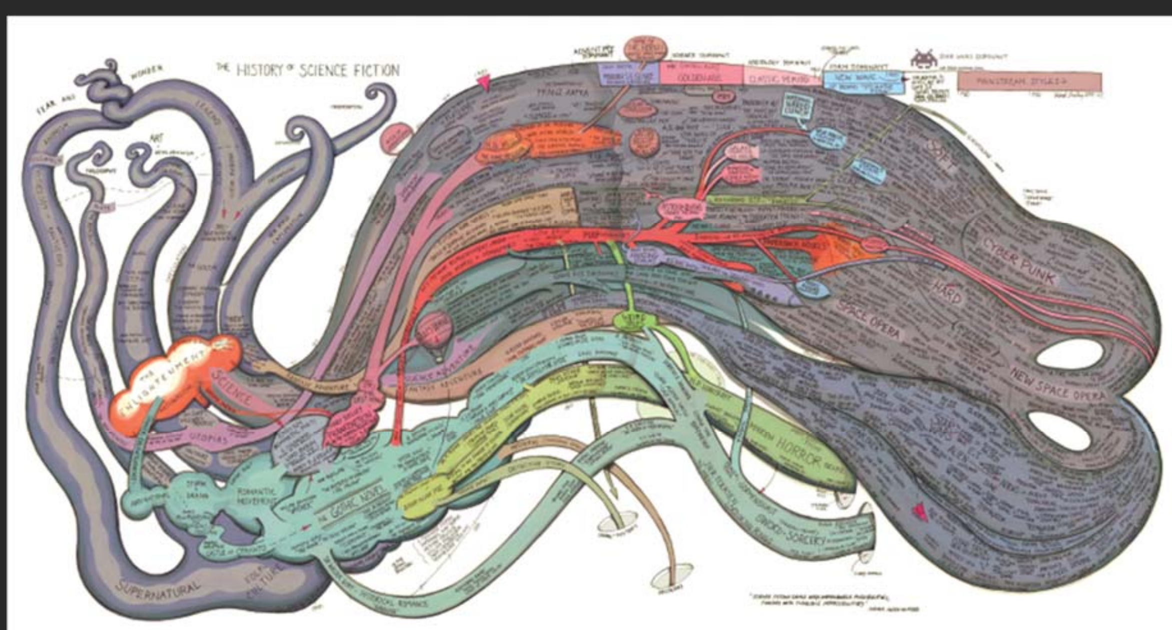

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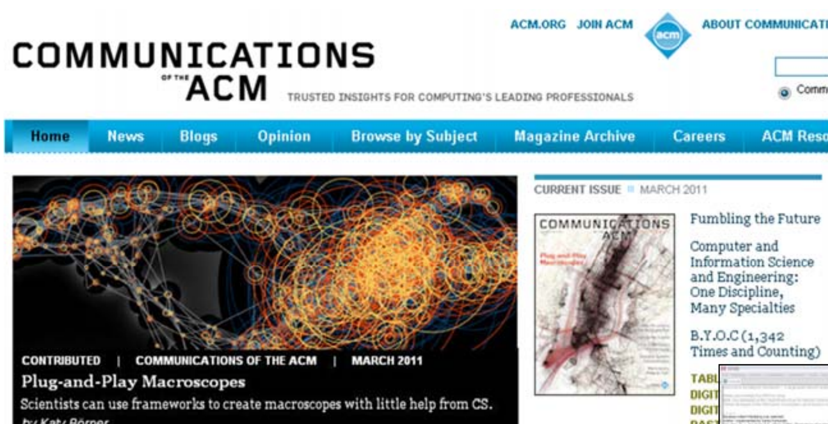

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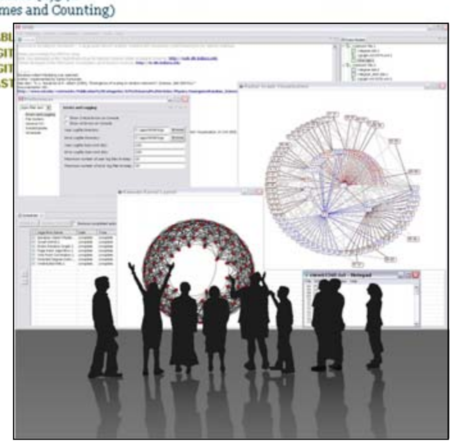
VIVO Research Networking
http://vivoweb.org

Network Workbench Tool & Community Wiki
http://nwb.cns.iu.edu

Science of Science (Sci^2) Tool
http://sci2.cns.iu.edu

Epidemics Cyberinfrastructure
http://epic.cns.iu.edu



OSGi Alliance CIShell cyberinfrastructure shell

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Related Talks

Monday

3:30pm
Online Interactive Map: Say goodbye to tabular representation
Chin Hua Kong and Katy Börner
The Research Superhighway | Oak room | Monday 3:30 – 4pm

5pm
Places & Spaces: Mapping Science
Katy Börner, Michael Stamper, and Samantha Hale
The Human Element | Oak room | Monday 5 – 5:30pm

Tuesday

9:30am
Plug-and-play visualization with the Science of Science Tool
David Polley, Chin Hua Kong, and Katy Börner
The Research Superhighway | Walnut room | Tuesday 9:30 – 10am

11:30am
VIVO@IU: An overview
Robert Light, Chin Hua Kong, and Katy Börner
The Research Superhighway | Oak room | Tuesday 11:30 – 12pm

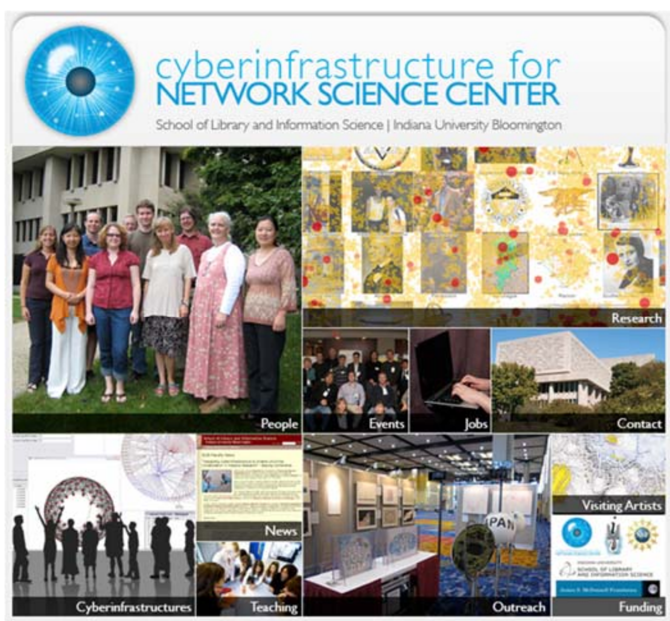
We are Hiring!

Senior Software Engineer/Research Analyst (3IT) **IU Job #6839**

As Senior Software Engineer, you will perform research and programming for current and future externally funded research projects at the CNS Center. These projects include tools powered by the Cyberinfrastructure Shell (CIShell, http://cishell.org), an open-source software platform that supports the interchange of datasets and algorithms; MapIN, a map of Indiana's expertise and resources; and other online interactive maps and web sites. You will participate in the entire software development process, from the collection of user stories through planning, implementation, testing, deployment, and documentation. You will also be expected to participate in the training new developers, and the creation of educational material for workshops. As Senior Software Engineer, you will have a chance to help set the standards of our team in many areas, including code, teamwork, product direction, and process.

Software Developer (2IT) **IU Job #6862**

As a Software Developer, you will work in a team of four to perform research and programming for current and future externally funded research projects at the CNS Center. The main focus will be on tools powered by the Cyberinfrastructure Shell (CIShell, http://cishell.org). CIShell is an open-source software platform, built on Java and OSGi that allows developers and scientists to easily exchange datasets and algorithms, and bundle them into custom tools that serve the particular needs of research communities. You will participate in the entire software development process, from the collection of user stories through planning, implementation, testing, deployment, and documentation.



All papers, maps, tools, talks, press are linked from http://cns.iu.edu

CNS Facebook: http://www.facebook.com/cnscenter
Mapping Science Exhibit Facebook: http://www.facebook.com/mappingscience