

International Places & Spaces Exhibit Coming to Michigan

Mapping science like you've never seen

Ann Arbor, Michigan, February 8, 2011 – From March 7 through May 24, 2011, the University of Michigan Library will host the exhibit *Places & Spaces: Mapping Science* in the Hatcher Graduate Library Gallery. An opening reception will be held March 10 from 4:00-6:00 pm in the Library Gallery, with guest speaker Dr. Katy Börner speaking from 4:00-4:30 pm.

Are you interested in seeing science from above? Curious to see what impact one single person or invention can have? Keen to find pockets of innovation? Desperate for better tools to manage the information flood? Or are you simply fascinated by maps?

The *Places & Spaces: Mapping Science* exhibit was created to demonstrate the power of maps to navigate and manage physical places but also abstract topic spaces. It introduces knowledge mapping techniques to the general public. It is meant to inspire cross-disciplinary discussion on how to best track and communicate human activity and scientific progress on a global scale.

Several University of Michigan faculty created maps included in the exhibit: Santiago Schnell, Molecular and Integrative Physiology; Lada Adamic, School of Information; M. E. J. Newman, Physics; Jeff Horon, Medical School; Helena Buhr, Natalie Cotton, and Jason Owen-Smith, Sociology and Organizational Studies.

From March 7 through May 24 the Hatcher Graduate Library Gallery will display the exhibit, which has over 60 maps, interactive globes, illuminated diagrams, hands-on activities for children (and adults, too!), and a wealth of information for researchers and map enthusiasts, alike.

Places & Spaces: Mapping Science *Opening Reception at the University of Michigan*

Dr. Katy Börner

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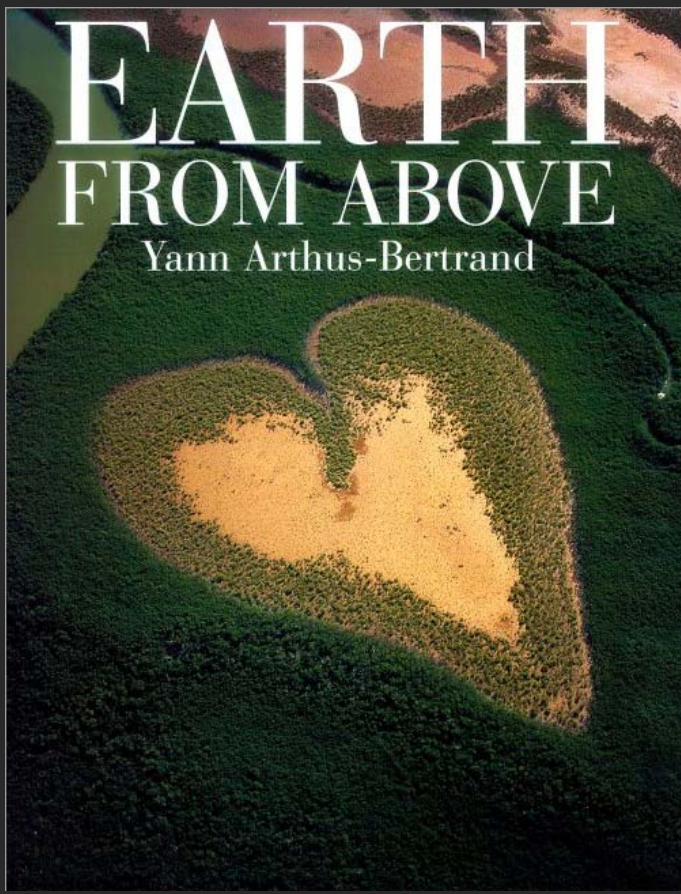
With special thanks to Michael J. Stamper (exhibit co-curator), members at the Cyberinfrastructure for Network Science Center, the Mapping Science exhibit map makers, and the exhibit advisory board.

*Hatcher Graduate Library Gallery, University of Michigan, Ann Arbor, MI
March 10, 2011*



EARTH FROM ABOVE

Yann Arthus-Bertrand



**How can we communicate the beauty,
structure, and dynamics of science to
a general audience?**

Milestones in Mapping Science



1934

2007

1982-1998

Algorithms

Visualizations

Tools

Books

Quantitative Validation
McCain
Central Analysis
Callan et al.

Cluster Tracking and Mapping
Garfield

Strong Graph Layout
Kahn

Self-Organizing Map (SOM)
Kohonen

Kamada-Kawai Graph Layout
Kamada and Kawai
Minimizing Scientific
Frontiers
Garfield and Small

Map of Information Science
Whinn and Griffith

Non-Circle
Hansen, Moore and Torgg @ Xerox PARC

Specialties in Sociology
Eaton

SOM of Newsgroup Postings
Kohonen

Binary Citation Browser
Mackinlay, Carl and Rao @ Xerox Research

Nipres Sanitron
Oculus Info, Inc.

Science and Technology
Dynamic Toolbox
Leyland

In Flow
Kahn

Flow Mapper
Tobler

The Discoveries
Borner

Foraigh in Science: Picking the Winners
Irvine and Martin

The Citation Process: The Role and Significance of Citations in Scientific Communication
Cowan

The Intellectual Organization of the Sciences
Whitley

ISI Atlas of Science - Bibliography and Molecular Genetics 1981/82 covering 127 Research Fronts
Specialties including 1982/84 Supplements
Garfield et al. (eds.)

Home: Academicus (French)
Borner

Little Science, Big Science and Beyond
Pico

Laboratory Life: The Construction of Scientific Facts
Latour and Woolgar

Making the Dynamics of Science and Technology: Sociology of Science in the Real World
Culnan, Law and Day

Emergy of an Information Science: Toward Scientography
Garfield

Mathematical Models - Ishikawa's Nishi
(Mathematical Models in the Exploration of Science)

Science in Action: How to Follow Scientists and Engineers through Society
Latour

Sci mash/mash kommunikation (Networks of Scientific Communication)
Dynamis

Scope

- Individual
- Local
- Global
- Mixture

Layout

- Manual
- Algorithmic

Type

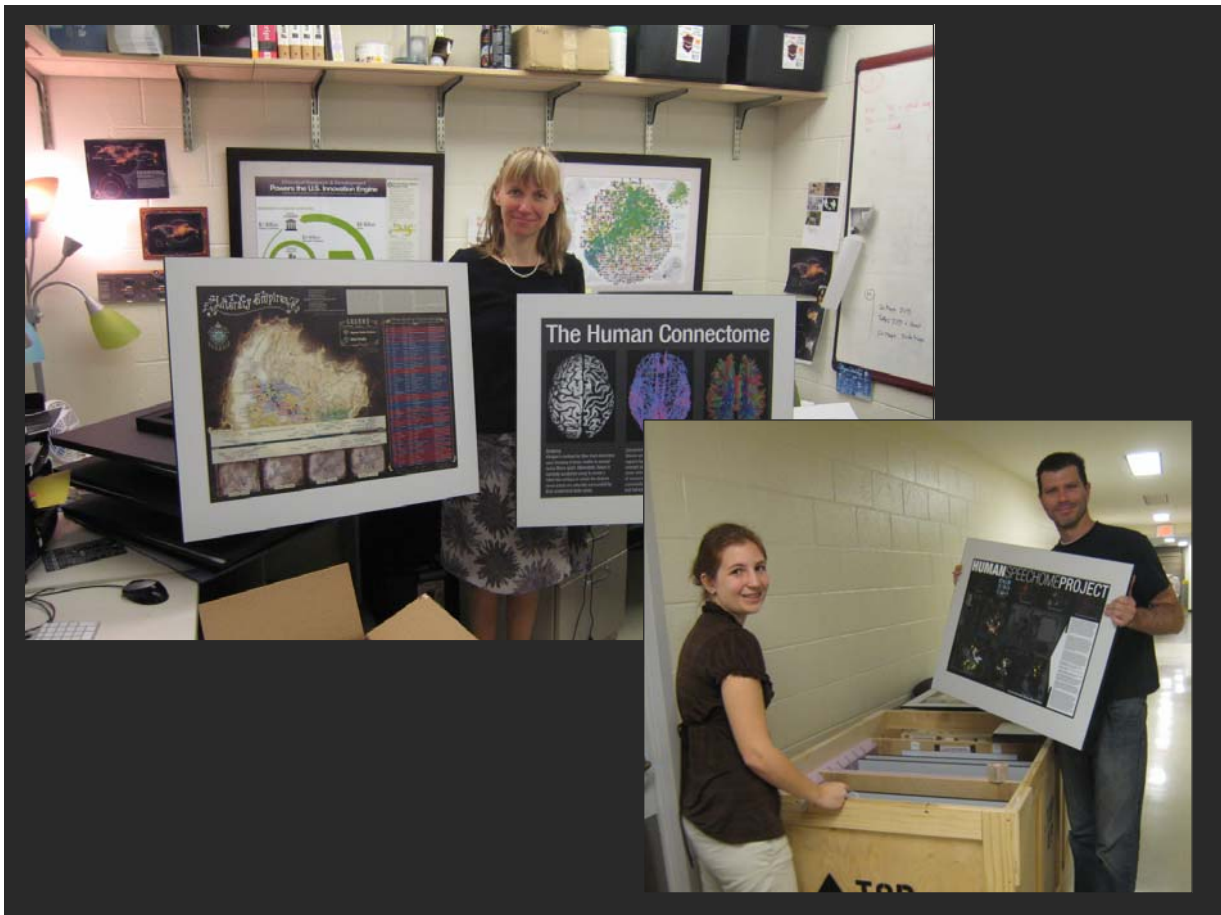
- Temporal
- Semantic
- Geographic
- Network
- Mixture

Exhibit Map

30 Part 2: The History of Science Maps



5 - 9, 2005: 101st Annual Meeting of the American Geographical Society, Denver, CO

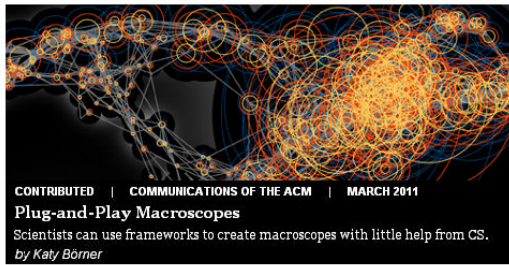




Debut of 5th Iteration of the Mapping Science Exhibit at MEDIA X was in 2009 at Wallenberg Hall, Stanford University, <http://mediax.stanford.edu>, <http://scaleindependentthought.typepad.com/photos/scimaps>



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



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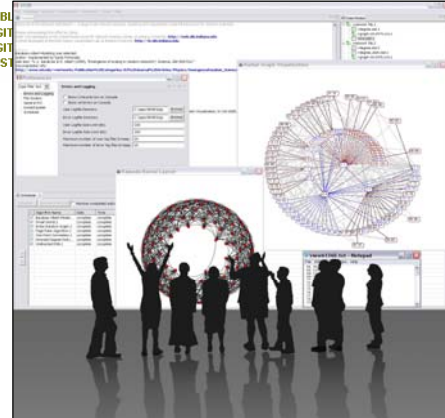


Fumbling the Future

Computer and Information Science and Engineering: One Discipline, Many Specialties

B.Y.O.C (1,342 Times and Counting)

TABLE OF CONTENTS



VIVO Research Networking

<http://vivoweb.org>



Network Workbench Tool & Community Wiki

<http://nwb.cns.iu.edu>



Science of Science (Sci²) Tool

<http://sci2.cns.iu.edu>



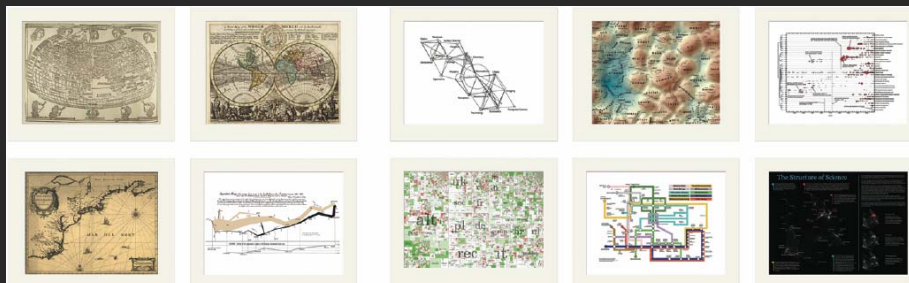
Epidemics Cyberinfrastructure

<http://epic.cns.iu.edu>



The Power of Maps

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

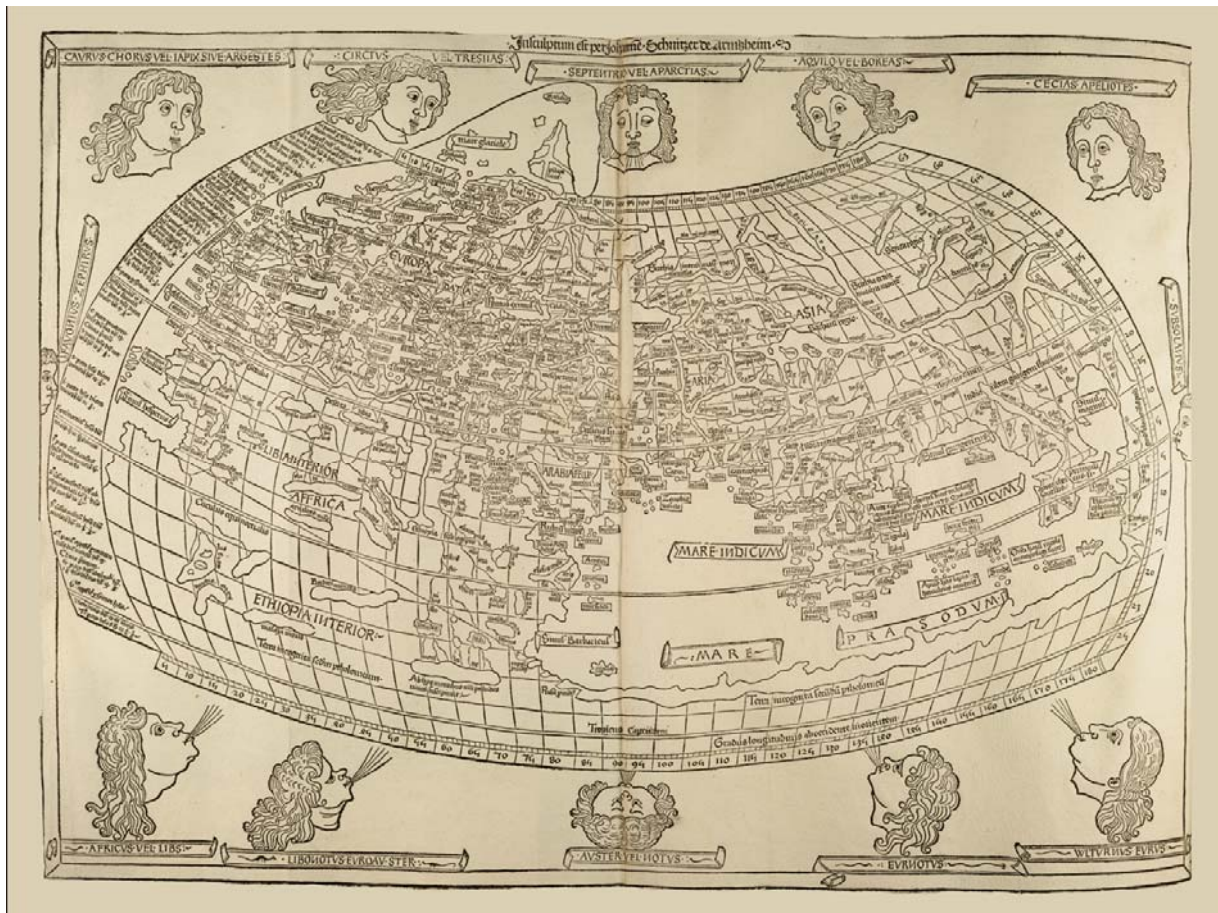


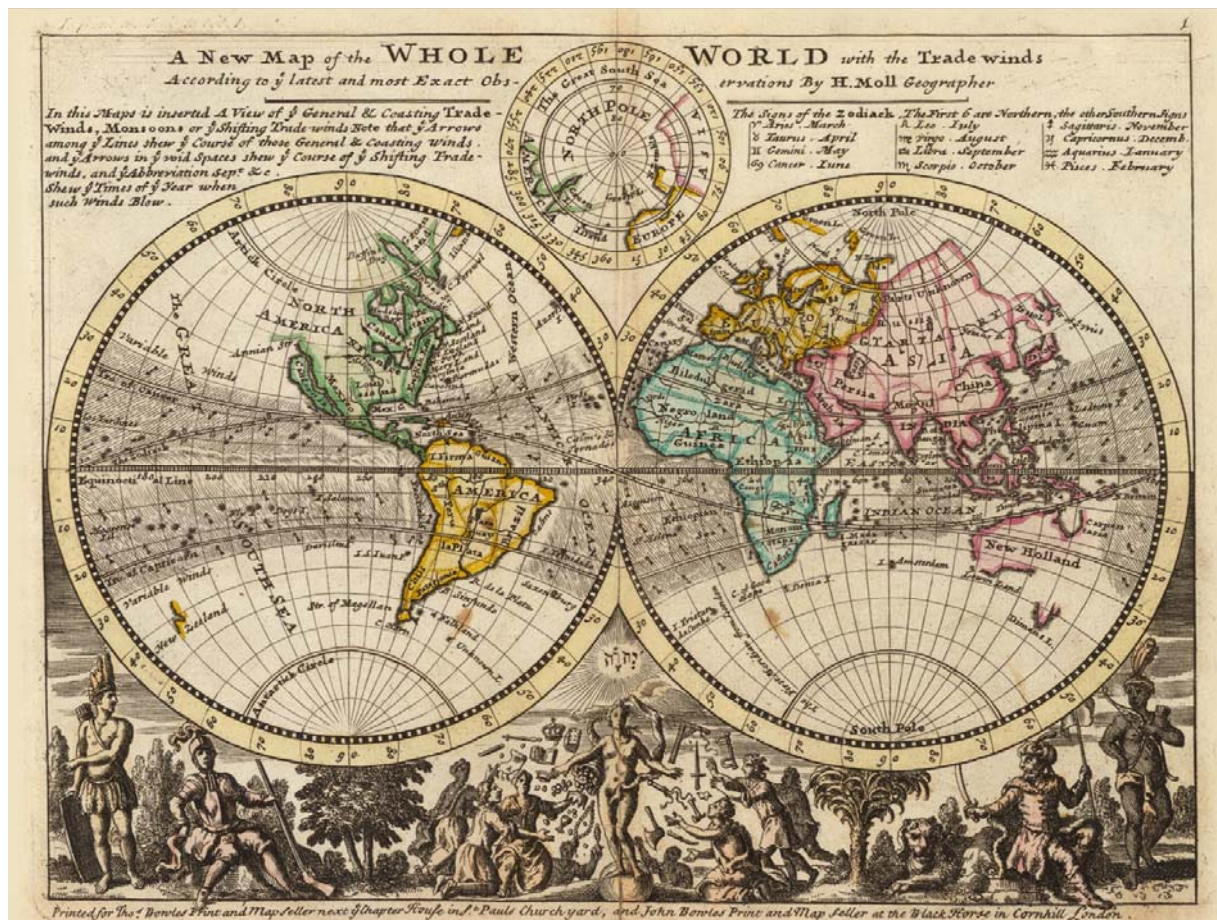
(1st Iteration of Places & Spaces Exhibit - 2005)

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

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

Without maps, we would be lost.

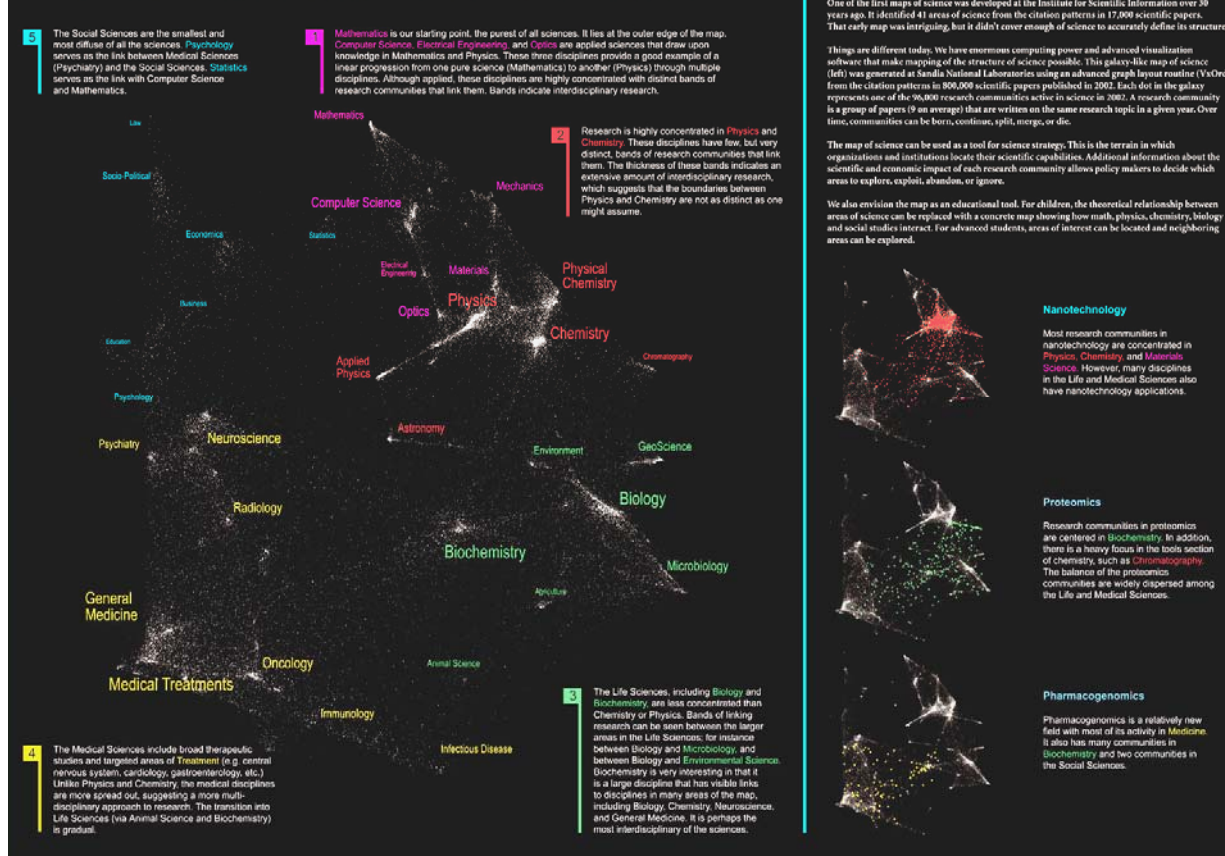




How would a map of science look?

What metaphors would work best?

The Structure of Science



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

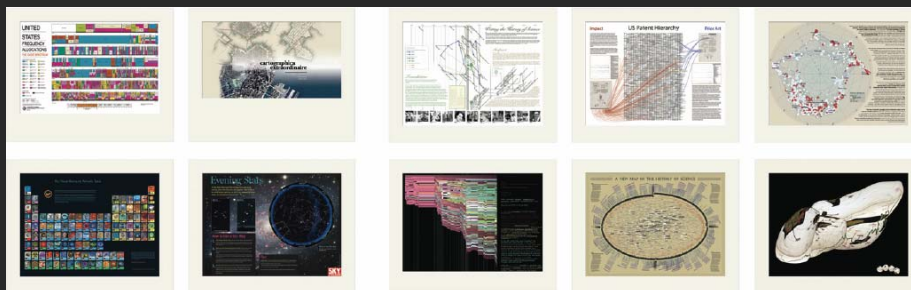
These maps are generated through a scientific analysis of large-scale scholarly datasets in an effort to connect and make sense of the bits and pieces of knowledge they contain.

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

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

The Power of Reference Systems

Four Existing Reference Systems VERSUS Six Potential Reference Systems of Science



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

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.

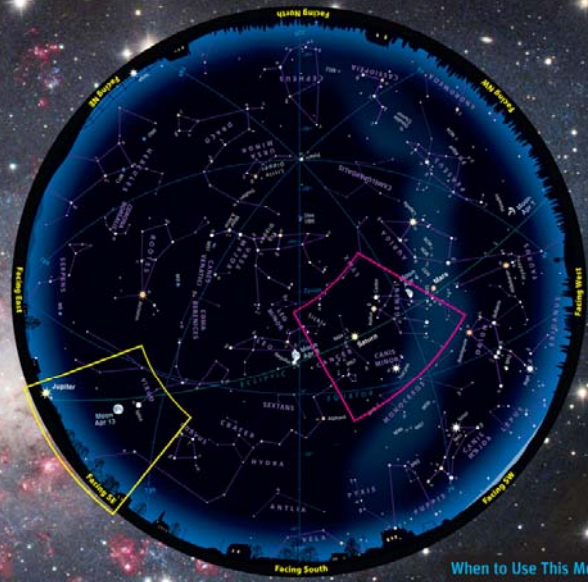
The Visual Elements Periodic Table is a grid of 111 elements, each represented by a small, colorful image. The elements are arranged in a standard periodic table layout. The images vary in style and content, representing the unique properties of each element. For example, Hydrogen is shown as a blue sphere, Helium as a yellow sun-like sphere, and Lithium as a red battery. The grid is set against a dark blue background.

Visit the periodic table on the web at:
www.chemsoc.org/visualelements

© Murrey Robertson/Royal Society of Chemistry 1999-2005

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.



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!

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 stargazing friends!

You can customize a night sky map for any time and place at SkymapTelescope.com.

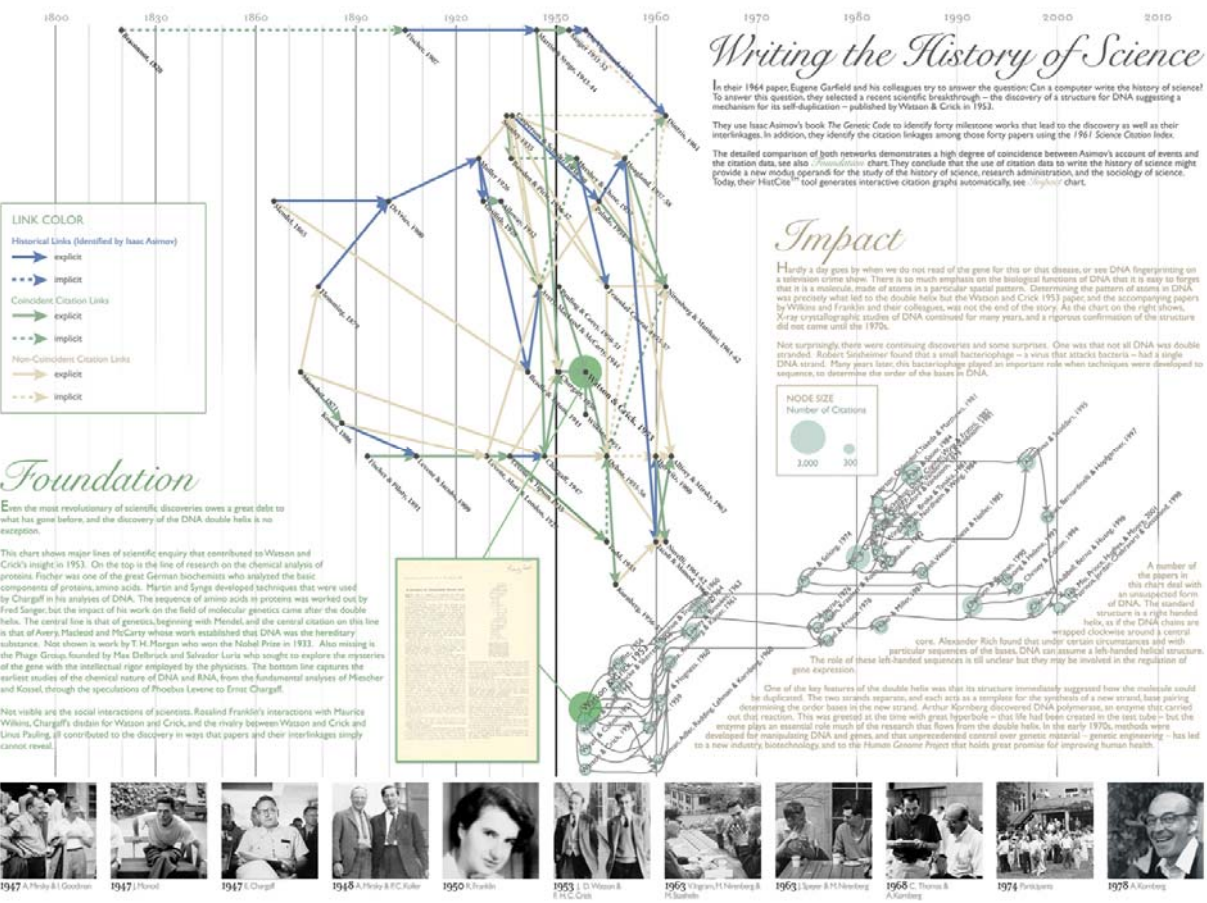
When to Use This Map

Early April: 10 pm (daylight-saving time)
Late April: Dark



How would a reference system for all of science look?

What dimensions would it have?



Foundation

Even the most revolutionary of scientific discoveries owes a great debt to what has gone before, and the discovery of the DNA double helix is no exception.

This chart shows major lines of scientific enquiry that contributed to Watson and Crick's insight in 1953. On the top is the line of research on the chemical analysis of proteins. Procter was one of the great German biochemists who analyzed the basic components of proteins, amino acids. Martin and Sings developed techniques that were used by Chargaff in his analyses of DNA. The sequence of amino acids in proteins was worked out by Fred Sanger, but the impact of his work on the field of molecular genetics came after the double helix. The central line is that of genetics, beginning with Mendel, and the central citation on this line is that of Avery, McClelland and McCarty whose work established that DNA was the hereditary substance. Note shown is work by T.H. Morgan who won the Nobel Prize in 1933. Also missing is the Pugs Group, founded by Max Delbrück and Salvador Luria who sought to explore the mysteries of the gene with the intellectual rigor employed by the physicists. The bottom line captures the earliest studies of the chemical nature of DNA and RNA, from the fundamental analyses of Mesrobian and Kossel, through the speculations of Phoebus Levene to Erwin Chargaff.

Not visible are the social interactions of scientists. Rosalind Franklin's interactions with Maurice Wilkins, Chargaff's disdain for Watson and Crick, and the rivalry between Watson and Crick and Linus Pauling, all contributed to the discovery in ways that papers and their interlinkages simply cannot reveal.



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 led 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 *Interlinkage* chart. They conclude that the use of citation data to write the history of science might provide a new modeling paradigm for the study of the history of science, research administration, and the sociology of science. Today, their *HarCon*™ tool generates interactive citation graphs automatically, see *Interlinkage* chart.

Impact

Hardly a day goes by when we do not read of the gene for this or that disease, or see DNA fingerprinting on a television crime show. There is so much emphasis on the biological functions of DNA that it is easy to forget that it is a molecule made of atoms in a particular spatial pattern. Describing the pattern of atoms in DNA was precisely what led to the double helix but the Watson and Crick 1953 paper, and the accompanying papers by Wilkins and Franklin and their colleagues, was not the end of the story. As the chart on the right shows, 47-year crystallographic studies of DNA continued for many years, and a rigorous confirmation of its structure did not come until the 1970s.

Not surprisingly, there were continuing discoveries and some surprises. One was that not all DNA was double stranded. Robert Sinsheimer found that a small bacteriophage—virus that attacks bacteria—had a single DNA strand. Many years later, this bacteriophage played an important role when techniques were developed to sequence, to determine the order of the bases in DNA.

A number of the papers in this chart deal with an unanticipated form of DNA. The standard structure is a right handed helix, so if the DNA strands are wrapped clockwise around a central core, Alexander Rich found that under certain circumstances and with particular sequences of the bases, DNA can assume a left handed helical structure. The role of these left-handed sequences is still unclear but they may be involved in the regulation of gene expression.

One of the key features of the double helix was that its structure immediately suggested how the molecule could be duplicated. The two strands separate, and each acts as a template for the synthesis of a new strand, base pairing determining the order bases in the new strand. Arthur Kornberg discovered DNA polymerase, an enzyme that carried out this reaction. This was greeted as the long with great hope—but that the helix was created in the test tube—but the enzyme plays an essential role much of the research that flows from the double helix. In the early 1970s, methods were developed for manipulating DNA and genes, and this unprecedented control over genetic material—genetic engineering—has led to a new industry, biotechnology and to the Human Genome Project that holds great promise for improving human health.

Impact

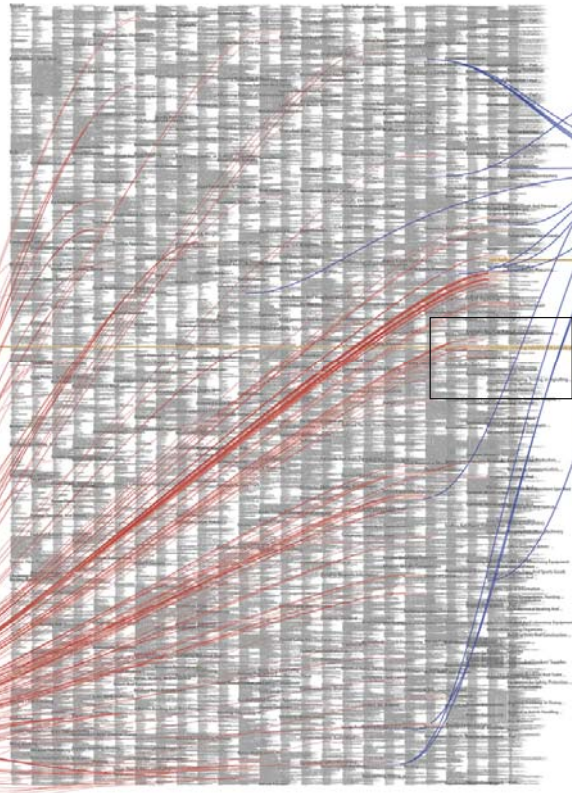
The United States Patent and Trademark Office does scientists and industry a great service by granting patents to protect inventions. Inventions are categorized in a taxonomy that groups patents by industry or use, preliminary function, effect or product, and structure. At the time of this writing there are 160,523 categories in a hierarchy that can get as deep as 15 levels. We display the first three levels (1,329 categories) at right in what might be considered a textual map of inventions.

Patent applications are required to be unique and non-obvious, partially by revealing any previous patents that might be similar in nature or provide a foundation for the current invention. In this way we can trace the impact of a single patent, seeing how many patents and categories it affects.

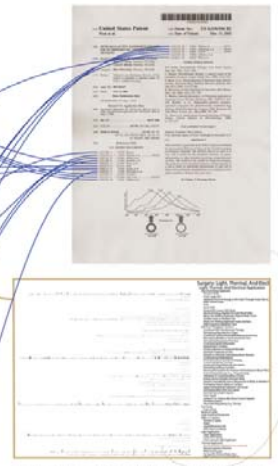
The patent on Gore-tex—a lightweight, durable synthetic fiber—is an example of one that has had significant impact. The box below enlarges the section of the hierarchy where it is filed, and the red lines (arranged to start along a time line from 1981 to 2000) point to the 130 categories that contain 182 patents, from waterproof clothing to surgical cosmetic implants, that mention Gore-tex as prior art.



US Patent Hierarchy



Prior Art



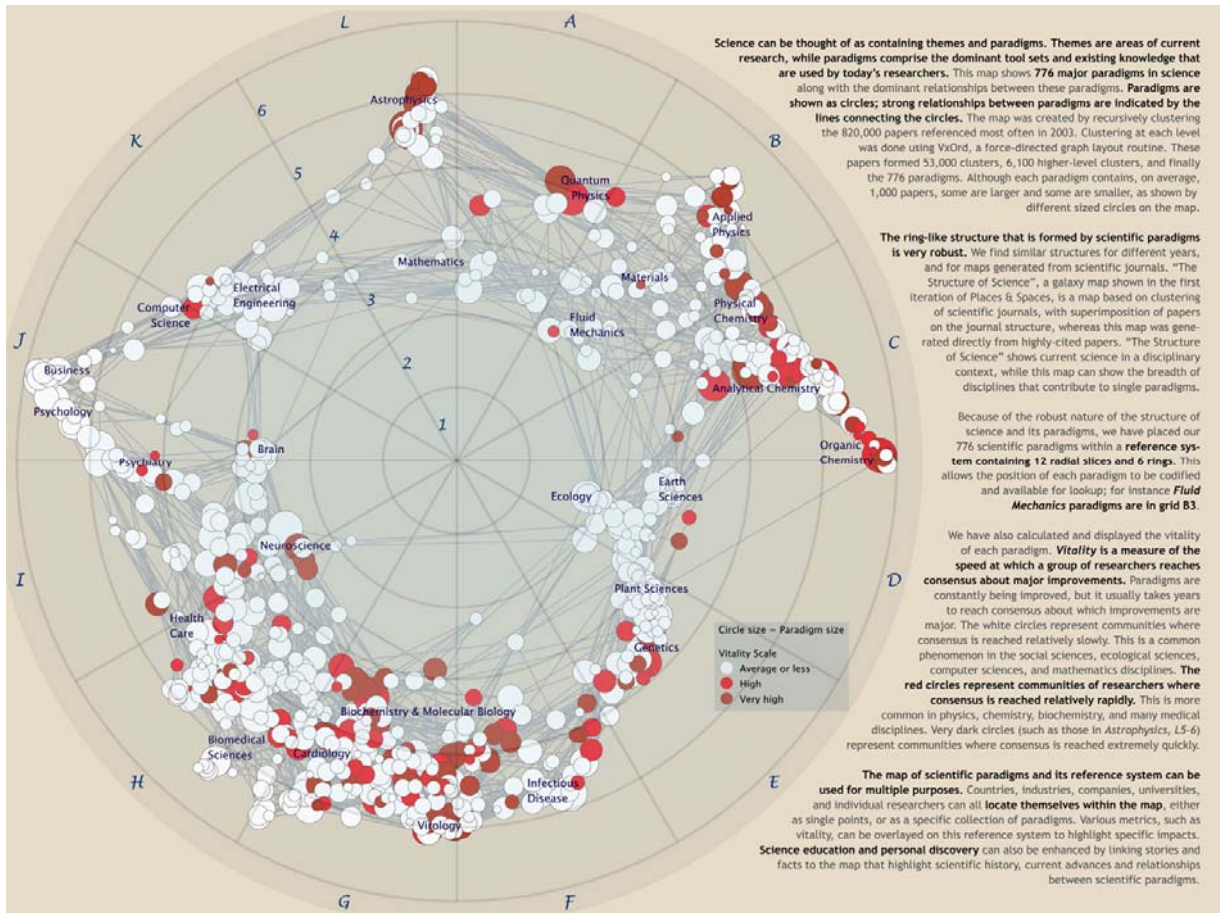
New patents often build on older ideas from many categories. Here, blue lines originate in sixteen different categories that contain the patents cited as prior art for a patent on "gold nanoshells." Gold nanoshells are a new invention. They are hollow shells a diameter ten million times smaller than a human hair) that can be used to detect tumors more visible in infrared scans, and have even helped cause complete remission of tumors in tests with laboratory mice. The blue lines show that widely separated categories provided background for this invention.

Keeping categories understandable is an important part of maintaining any taxonomy, including the patent hierarchy. Categories are easier to understand, search, and maintain if they contain elements (patents in this case) that fit well within the definition of the category. The box above shows a tiny bar chart, part of a "Taxonomy Validator" that helps people decide whether categories are good ones.

Categories can be redefined or combined, and sometimes need to be split when they become too large a constant problem shared by many classifications systems in this information-rich century. But how can we determine exactly where to split a category in two, for example—if there are hundreds or thousands of elements in it?

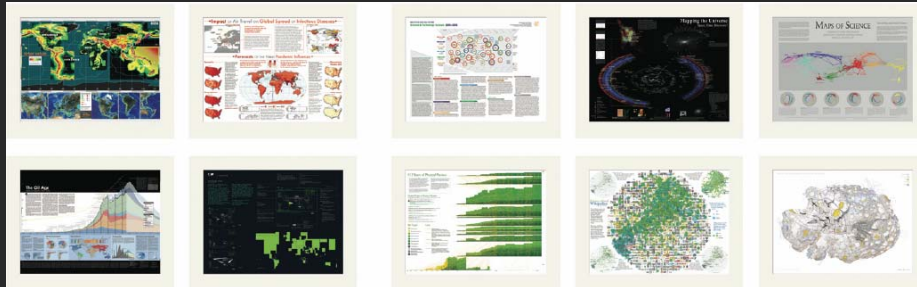
The Taxonomy Validator measures a "distance to prototype" how far each element is from an idealized "prototype" element for each bucket. This can be based on statistics, computational comparisons of words, or even human judgement. A simple bar chart can then show how good a category is. A good category has lots of small bars a generally ragged category is one that might need scrutiny or reorganization; while one that has only one or two tall bars may just mean that one or two elements don't belong. Even simple visualizations like this can ease knowledge work by showing the eye much more than can fit in memory as words, focusing people on just the right issues, and providing a vastly broader background to support more informed judgements.

	<h3>Synthetic Resins or Natural Rubbe</h3> <p>Ion-exchange Polymer or Process of Prepari</p> <p>Process of Regenerating</p> <p>Membrane or Process of Preparing</p> <p>Previously Formed Solid Ion-exchange Polymer Admixed With N</p> <p>Polymer Characterized By Defined Size or Shape Other than Bea</p> <p>Chemically Treated Solid Polymer</p> <p>Solid Polymer Derived From Ethylenically Unsaturated Reacta</p> <p>Solid Polymer Derived From At Least One 1,2-epoxy Containir</p> <p>Solid Polymer Derived From Aldehyde or Derivative</p> <p>From Ethylenically Unsaturated Reactant Only</p> <p>From Aldehyde or Derivative</p>
	<h3>Process of Treating Scrap or Waste Product (</h3> <p>Process of Treating Scrap or Waste Product Containing At Least</p> <p>Treating Rubber (or Rubberlike Materials) or Polymer Derived</p> <p>Treating Polymer Derived From A Monomer Containing Only (</p> <p>Treating Polymer Derived From Hydrocarbon Monomers Only</p> <p>Treating Polysiloxane</p> <p>Treating Polyester</p> <p>Treating With Alcohol</p> <p>Treating Polyurethane, Polyurea (excluding Urea-formaldehyde</p> <p>Treating With Alcohol or Amine</p> <p>Treating Polycarbonamide</p>
	<h3>Cellular Products or Processes of Preparing /</h3> <p>Cellular Product Derived From Two or More Solid Polymers or Fr</p> <p>At Least One Polymer Is Derived From Reactant Containing Tw</p> <p>At Least One Polymer Is Derived From An Aldehyde or Derivat</p> <p>At Least One Polymer Is Derived From A -n=c=x Reactant Whe</p>

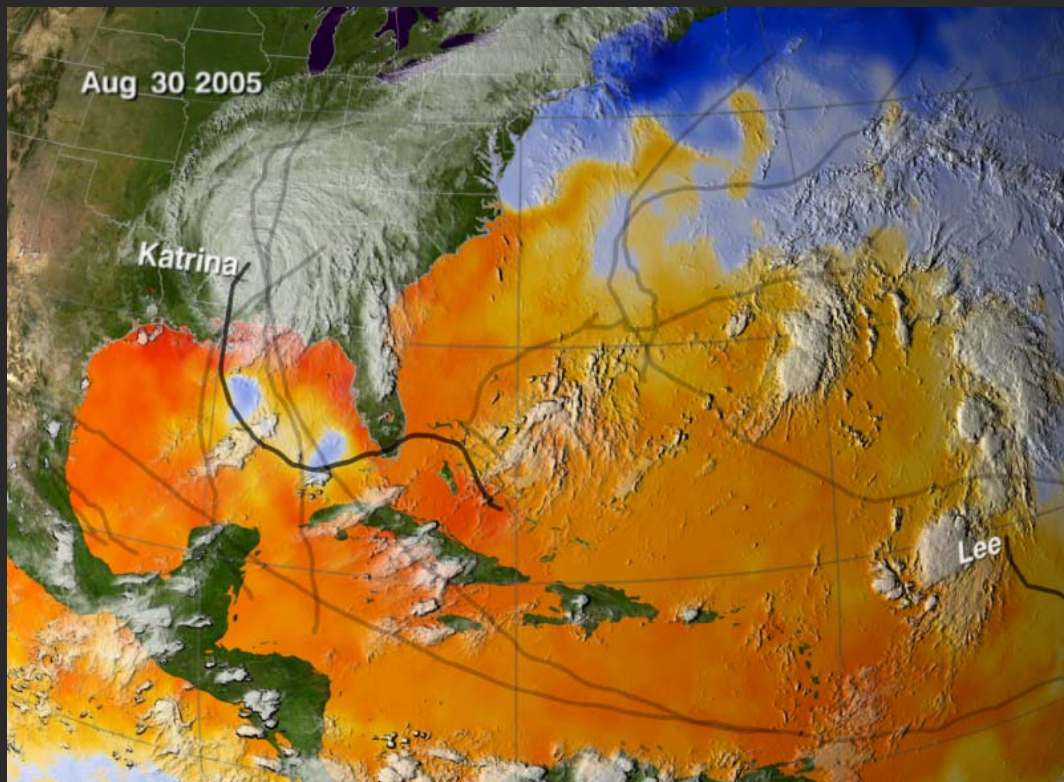


The Power of Forecasts

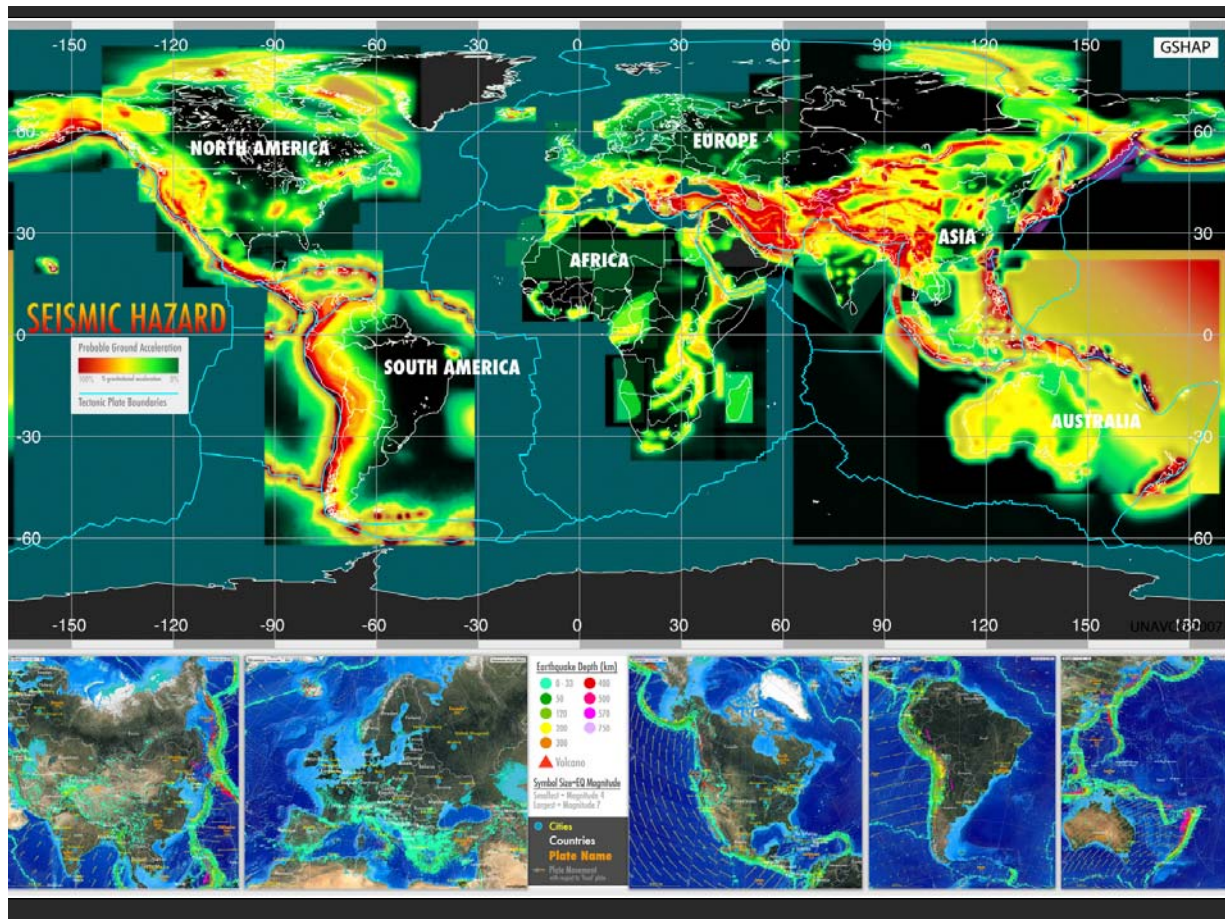
Four Existing Forecasts VERSUS Six Potential Science 'Weather' Forecasts



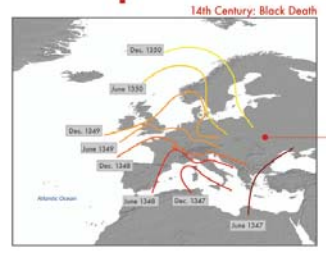
(3rd Iteration of Places & Spaces Exhibit - 2007)



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



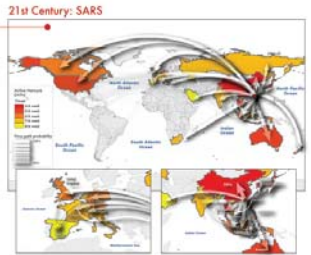
Impact of Air Travel on Global Spread of Infectious Diseases



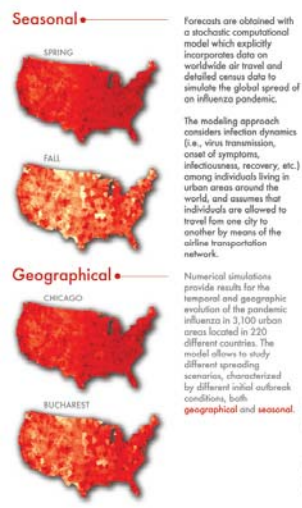
Epidemic spreading pattern changed dramatically after the development of modern transportation systems.

In pre-industrial times disease spread was mainly a spatial diffusion phenomenon. During the spread of Black Death in the 14th century Europe, only few traveling means were available and typical legs were limited to relatively short distances on the time scale of one day. Historical studies confirm that the disease diffused smoothly generating an epidemic front traveling as a continuous wave through the continent at an approximate velocity of 200-400 miles per year.

The SARS outbreak on the other hand was characterized by a patched and heterogeneous spatiotemporal pattern mainly due to the air transportation network identified as the major channel of epidemic diffusion and ability to connect far apart regions in a short time period. The SARS maps are obtained with a date-driven stochastic computational model aimed at the study of the SARS epidemic pattern and analysis of the accuracy of the model's predictions. Simulation results describe a spatio-temporal evolution of the disease (color coded countries) in agreement with the historical data. Analysis on the robustness of the model's forecasts leads to the emergence and identification of epidemic pathways as the most probable routes of propagation of the disease. Only few preferential channels are selected (arrows; width indicates the probability of propagation along that path) out of the huge number of possible paths the infection could take by following the complex nature of airline connections (light grey; source: IATA).



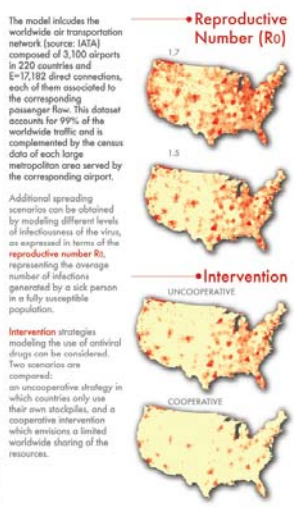
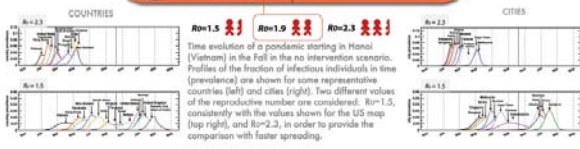
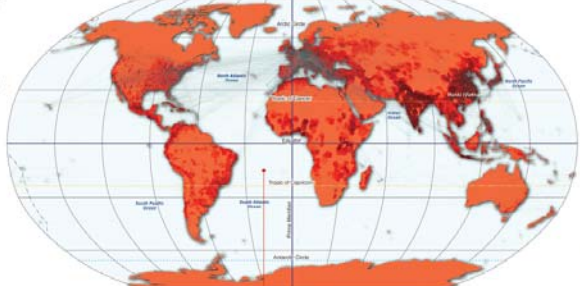
Forecasts of the Next Pandemic Influenza



The central map represents the cumulative number of cases in the world after the first year from the start of a pandemic influenza with $R_0=1.9$ 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.



Can one forecast science?

What 'science forecast language' will work?

INSTITUTE FOR THE FUTURE Science & Technology Outlook: 2005-2055

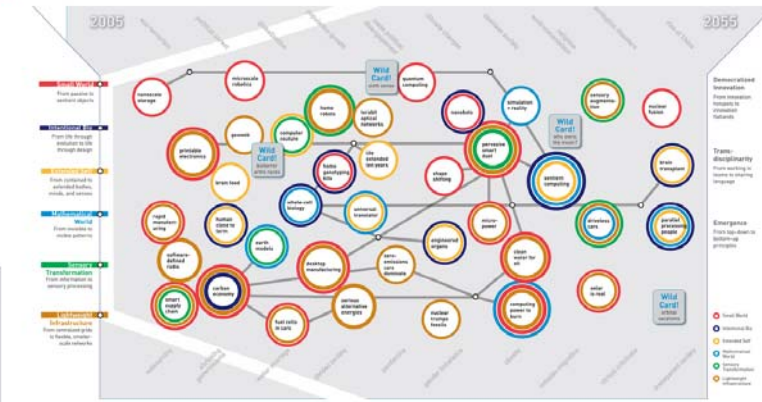
Technology Horizons Program
124 University Avenue, 2nd Floor, Palo Alto, CA 94301
1 650.854.6322 1 650.854.7859 www.iftf.org



A map is a tool for navigating an unknown terrain. In the case of this map, Science & Technology Outlook: 2005-2055, the terrain we're navigating is the uncharted territory of science and technology (SAT) in the next 50 years. However, the map of the future is not a tool for prediction or, for that matter, the product of predictors. Nor is it comparable to modern navigation techniques in which we rely on a shrinking number of strong signals, like GPS coordinates, to show the right path. Rather, it is here akin to classical low-tech navigational techniques with their reliance on an array of weak signals such as wind direction, the look and feel of the water, and the shape of cloud formations. Taken together, these signals often prove more useful for navigation than high-tech methods because, in addition to adding traction in selecting the "right" path, the signals contextualize information and reveal interdependencies and connections between seemingly unrelated events, thus enriching our understanding of the landscape. That's precisely the intention of this map of the future of SAT—to give the reader a deeper contextual understanding of the landscape and to point to the intricacies and interdependencies between trends.

While developing the map, the Institute for the Future (ITF) team listened for and connected a variety of weak signals, including those generated during interviews and working conversations involving more than 100 senior UK and U.S. experts in SAT—academics, policymakers, journalists, and corporate researchers. The ITF team also compiled a database of outputs on developments that are likely to impact the full range of SAT disciplines and practice areas over the next 50 years. We also relied on ITF's 42 years of experience in forecasting SAT developments to create the map and an accompanying set of SAT Perspectives that discuss issues emerging on the SAT horizon and are important for organizations, policymakers, and society-wide to understand.

On this map, six themes are woven together across the 50-year horizon, often resulting in important breakthroughs. These are supported by key technologies, innovations, and discoveries. In addition to the six themes, three meta-themes—democratized innovation, transdisciplinary, and emergence—will overlay the future SAT landscape influencing how we think about, learn about, and practice science. Finally, SAT trends won't operate in a vacuum. Wider social, demographic, political, economic, and environmental trends will both influence SAT trends and will be influenced by them. Some of these wider trends surround the map to remind us of the larger picture.



MAP THEMES

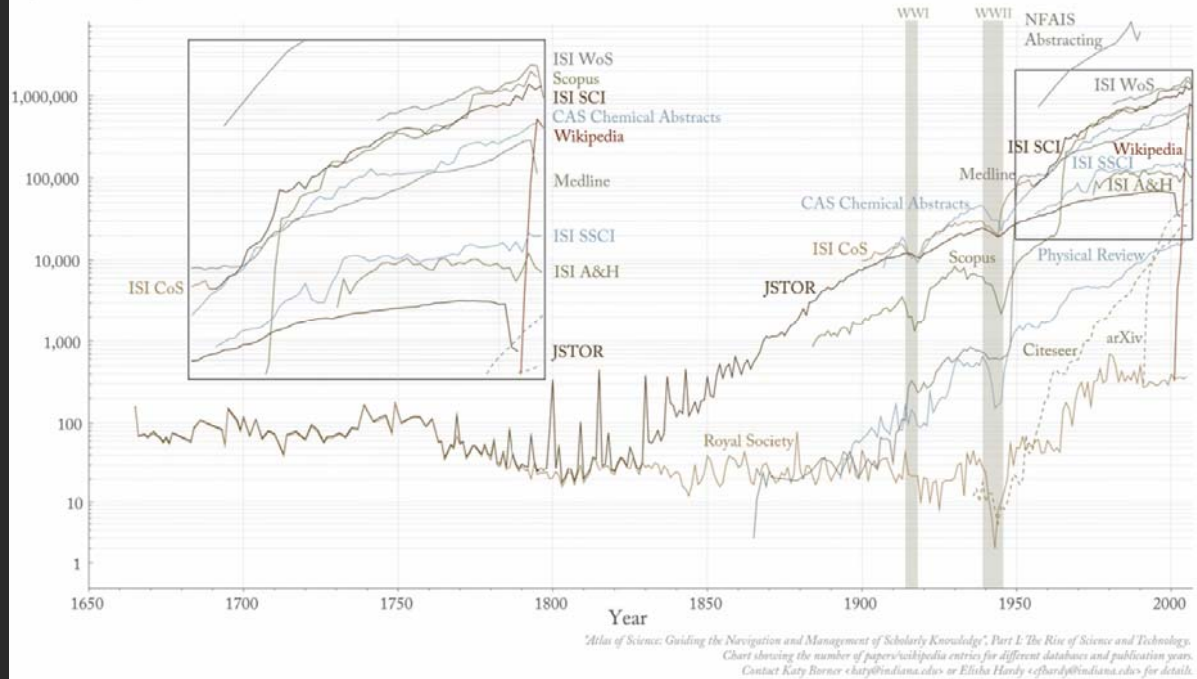
- Small World**
After 20 years of basic research and development at the 100-nanometer scale, the importance of nanotechnology as a source of innovations and new capabilities in everything from materials science to medicine is already well-understood. These results, however, will define how nanotechnology will unfold, and what impacts it will have. First, nanotechnology is not a single field with a coherent intellectual program; it's an opportunistic hybrid, shaped by a combination of fundamental research questions, promising technical applications, and venture and state capital. Second, nanotechnology is moving away from the original vision of small-scale mechanical engineering—in which assemblies build mechanical systems from individual atoms—toward one in which molecular biology and biochemistry contribute essential tools (such as proteins that build nanowires). Finally, nanotechnology will also serve as a model for transdisciplinary science. It will suggest both fundamental research and commercially oriented innovation, and it will be conducted not within the boundaries of conventional academic or corporate research departments, but in institutional and social milieu that emphasize heterogeneity.
- Mathematical World**
The ability to process, manipulate, and ultimately understand patterns in enormous amounts of data will allow decoding of previously mysterious processes in everything from biological to social systems. Scientists are learning that at the core of many biological phenomena—reproduction, growth, repair, and others—are computational processes that can be decoded and simulated. Using techniques of combinatorial science to uncover such patterns—whether these are physical, biological, or social—will likely occupy an increasing share of computing cycles in the next 50 years. Such massive computation will also make simulation widespread. Computer simulation will be used not only to help make decisions about large complex scientific and social problems but also to help individuals make better choices in their daily lives.
- Lightweight Infrastructure**
In the next few years, physical objects, plants, and men and women beings themselves will increasingly become embedded with computational devices that can sense, understand, and act upon their environment. They will be able to react to contextual clues about the physical, social, and even emotional state of people and things in their surroundings. As a result, increasing demands will be placed on our visual, auditory, and other sensory abilities. Information previously provided as text and numbers will be displayed in richer sensory forms—see graphics, pictures, patterns, sounds, smells, and tactile experiences. This enriched sensory environment will coincide with major breakthroughs in our understanding of the brain—its how and process, sensory information and connect various sensory functions.

- Transdisciplinary**
In the last few centuries, natural philosophy and natural history factored into the non-familiar disciplines of physics, chemistry, biology, and so on. The sciences evolved into their current form in response to industrial and professional opportunities, philanthropic priorities, and economic and state needs. Through most of the 20th century, the growth of the sciences, and academic and career pressures, encouraged ever greater specialization. In the coming decades, transdisciplinary research will become an imperative. According to Howard Thompson, a prominent forecaster and author, "transdisciplinarity goes beyond bringing together researchers from different disciplines to work in multidisciplinary teams. It means educating researchers who speak languages of multiple disciplines—biologists who have understanding of mathematics, mathematicians who understand biology."
- Emergence**
The phenomenon of self-organizing systems that generate complex behavior by hitting simple rules—will likely become an important research area, and an important model for understanding how the natural world works and how artificial worlds can be designed. Emergent phenomena have been observed across a variety of natural phenomena, from physics to biology to sociology. The concept has broad appeal due to the diversity of fields and problems to which it can be applied. It is proving useful for making sense of a very wide range of phenomena. Meanwhile, emergence can be modeled using relatively simple computational tools, although these models often require substantial processing power. More generally, it is a "richly regenerative" way of thinking about designing complex, robust technological systems. Finally, emergence is an accessible and vivid metaphor for understanding about designing complex, robust technologies from popular treatments of Newtonian mechanics, so too will scientific study and technical reproductions of emergent phenomena likely draw benefits from the popularization of its underlying concepts.

- Democratized Innovation**
Before the 20th century, many of the greatest scientific discoveries and technical inventions were made by amateur scientists and independent inventors. In the last 100 years, a professional class of scientists and engineers, supported by universities, industry, and the state, poured resources into a creative force. At the national scale, the capital-intensive character of scientific research made world-class research the property of program advanced nations. In the new century, a number of trends and technologies will lower the barriers to participation in science and technology alike, both for individuals and for emerging countries. The result will be a renaissance of the serious amateur, the growth of new scientific and technical centers of excellence in developing countries, and a more global distribution of world-class scientists and technologists.

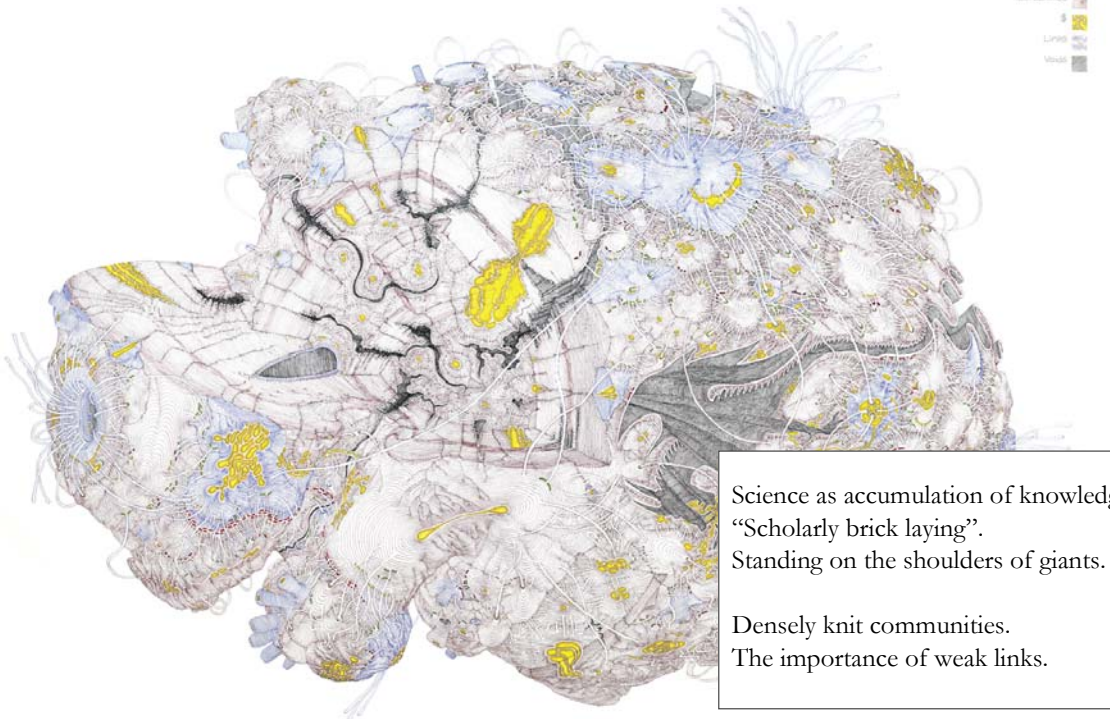
- Meta-Themes**
- Democratized Innovation**
- Emergence**

Papers & Wikipedia Entries



Atlas of Science - Katy Borner - 2010

HYPOTHETICAL MODEL of the EVOLUTION and STRUCTURE of SCIENCE



Science as accumulation of knowledge.
 "Scholarly brick laying".
 Standing on the shoulders of giants.

Densely knit communities.
 The importance of weak links.

One of Many Possible Interpretations

Daniel Zeller 2007

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

MAPS OF SCIENCE

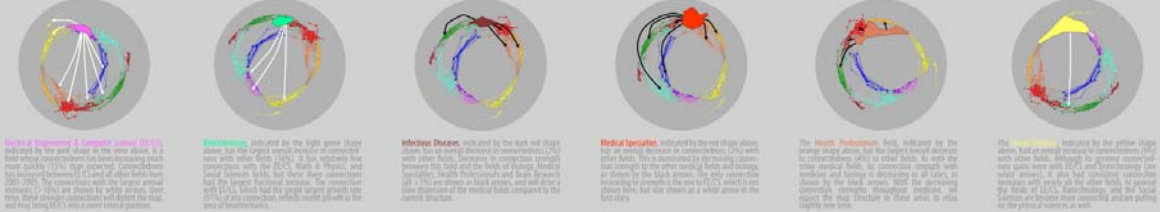
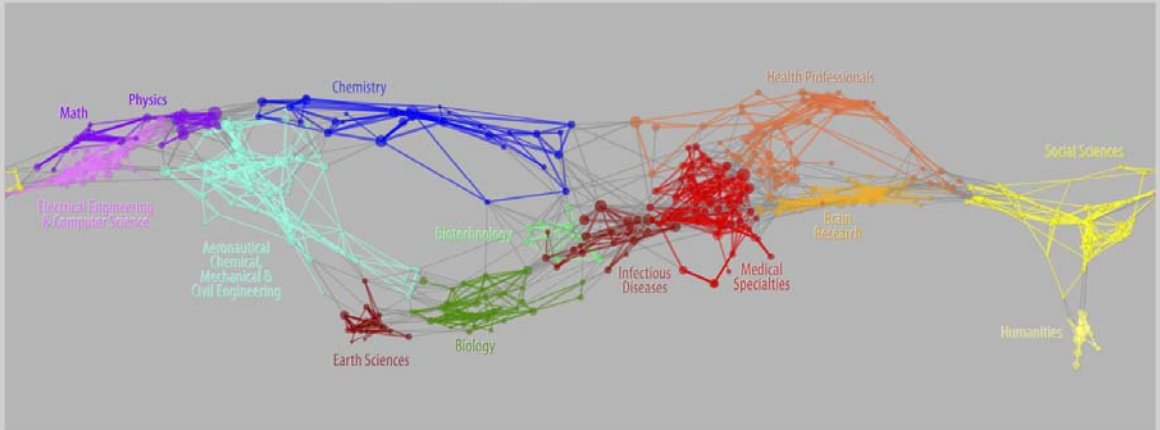
A visualization of 7.2 million scholarly documents
appearing in over 16,000 journals, proceedings or symposia
between Jan, 2001 and Dec, 2005

Forecasting Large Trends in Science

Calculations were performed using the large dataset processing of algorithms (which to determine if any of them were likely to cause large scale change in the structure of science over time. Correlation coefficients between fields were calculated for each individual year, 2001-2005. A simple regression analysis was conducted to see if there were significant changes in these correlation coefficients from year to year.

If the structure of science shown below is moving toward stability, we would expect correlations between publishing fields to increase, and connections between distant fields to decrease. We found the opposite, suggesting that the underlying structure is unstable and likely to change dramatically over the next decade.

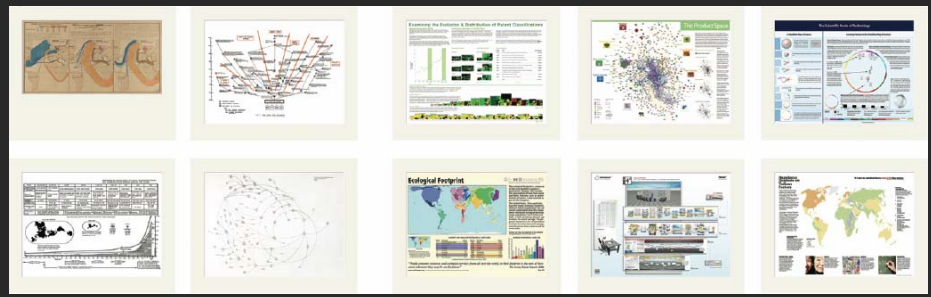
This map of science was constructed by starting with more than 16,000 journals into disciplines. Disciplines, represented as nodes, are sets of journals that share a common literature. Links (the lines between disciplines) are pairs of journals that share a common literature. A three-dimensional model was used to determine the position of each discipline on the surface of a sphere based on the language keywords it contains. The model used links (the edges) to determine the position of each discipline. The model used links (the edges) to determine the position of each discipline. The model used links (the edges) to determine the position of each discipline. The model used links (the edges) to determine the position of each discipline.



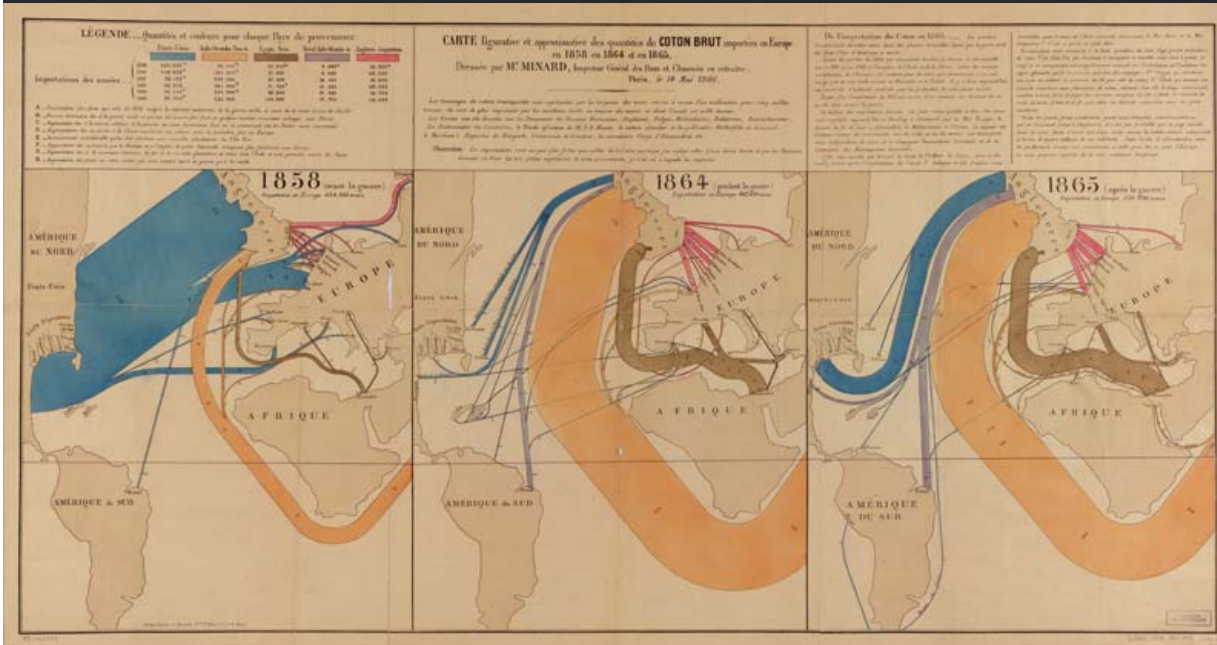
Source: University of California, San Diego Knowledge Mapping Laboratory. Color images © Department of the University of California. The authors: Eds. Lynn H. Lee, Steven D. Iyengar, Mapping technology and algorithms used by Dirk Kosch, President, Tech Systems, Inc., and Anne Rosen, Santa Barbara University. Copyright © by Dirk Kosch, all rights reserved. Special acknowledgment to Edy Benzer, MIT, B. Bradford Perry, Los Alamos, and Henry J. Smith. © 2007 by Dirk Kosch, all rights reserved.

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)

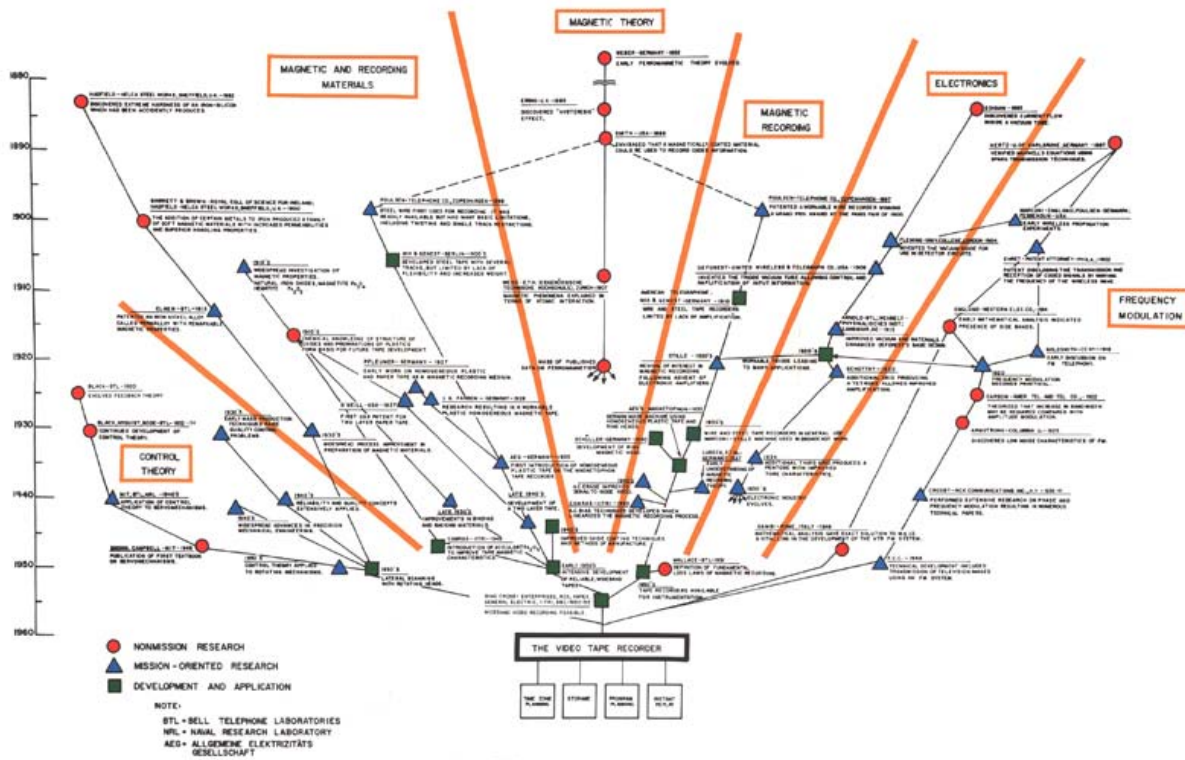
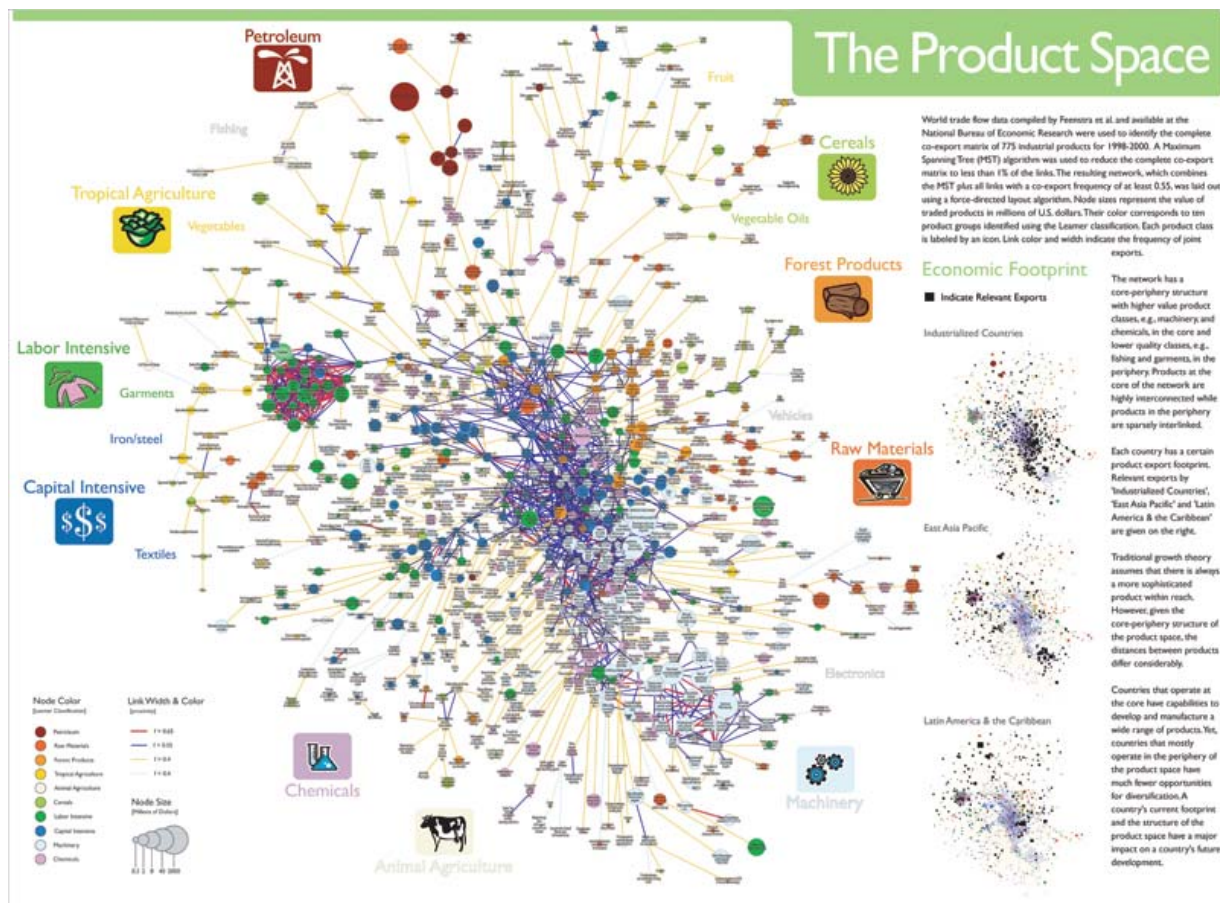


FIG. 7. THE VIDEO TAPE RECORDER

What insight needs to economic decision makers have?

What data views are most useful?



Happiness Depends on Various Factors

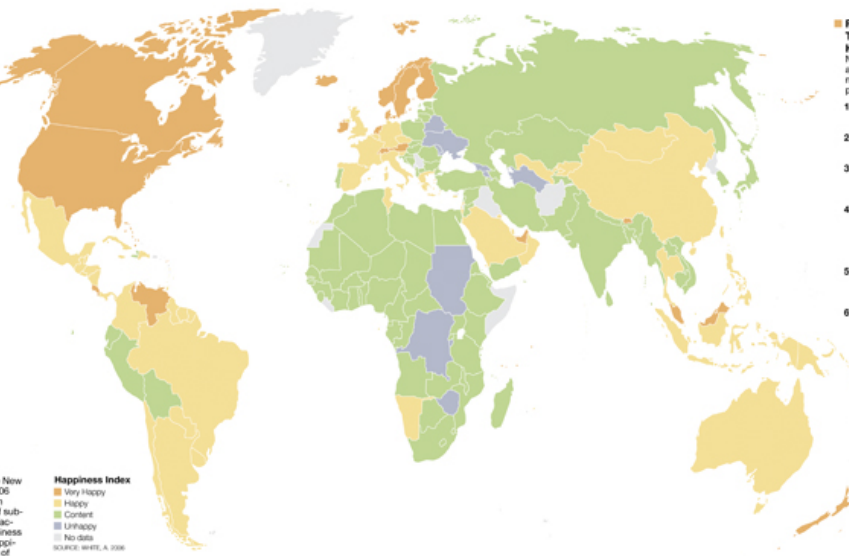
Social scientists are starting to include relative happiness with hard data on economic status, health, and other factors as they assess quality of life. They rely on surveys of "subjective well-being"—how good people feel about their lives. A world map of one "happiness index" shows many, but not all, 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.

MEASURING THE INTANGIBLE

The map is derived from the New Economics Foundation's 2008 "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).

Happiness Index
 ■ Very Happy
 ■ Happy
 ■ Content
 ■ Unhappy
 ■ No data
SOURCE: WRIE, A, 2008



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

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.



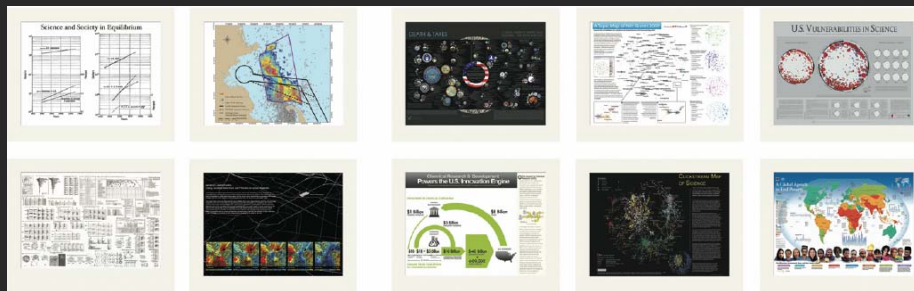
EDUCATION

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.

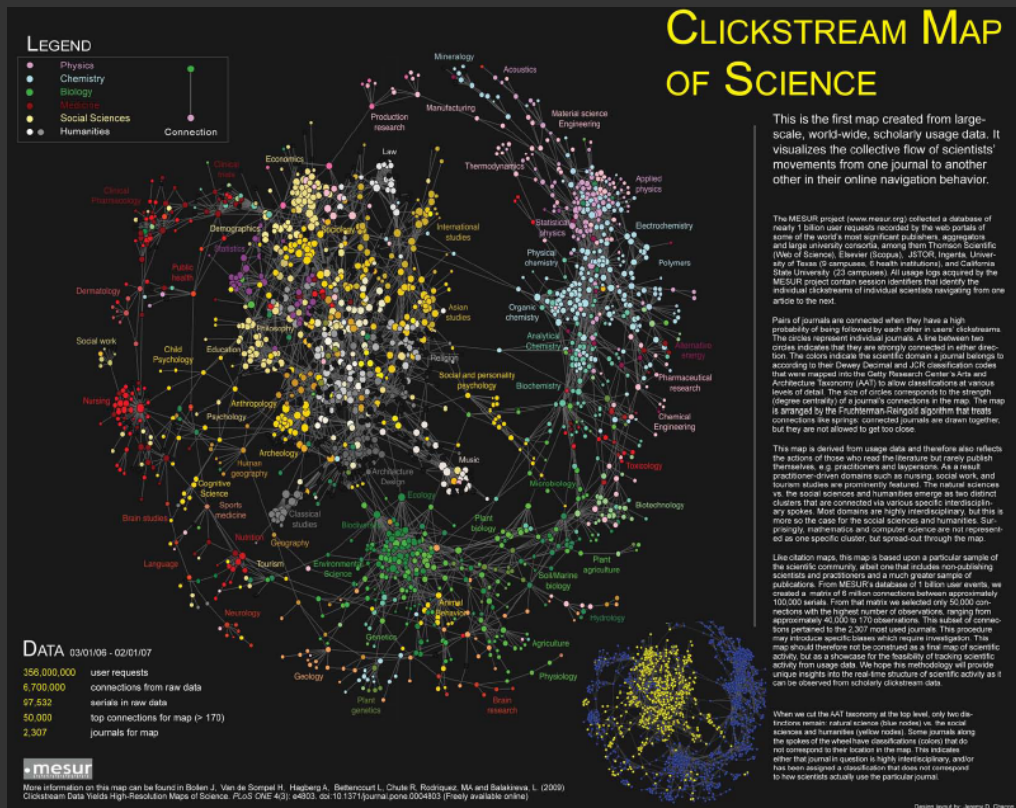
Photos: Robert Ross; Photo used in EarthPlace publication

Science Maps for Science Policy Making

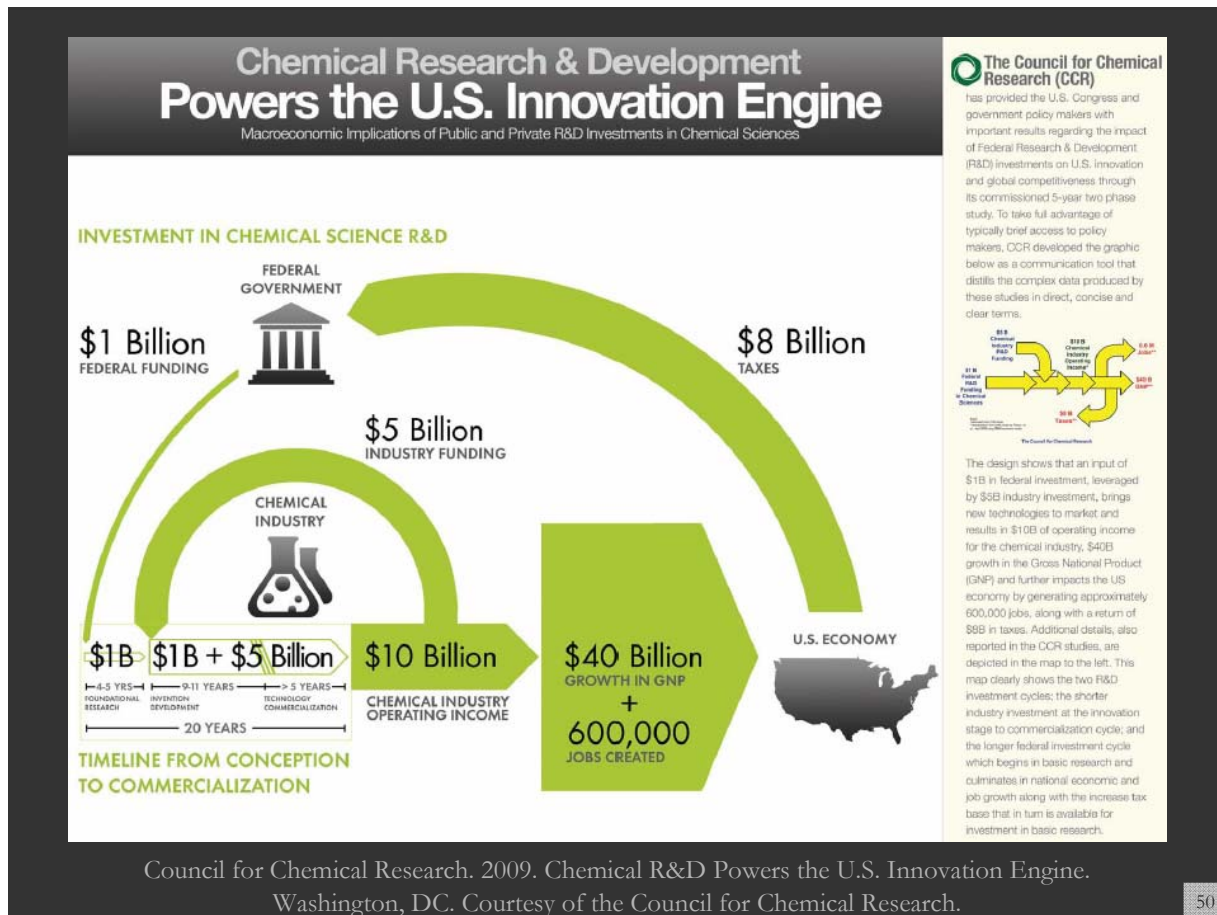
Four Existing Maps
VERSUS
 Six Science Maps

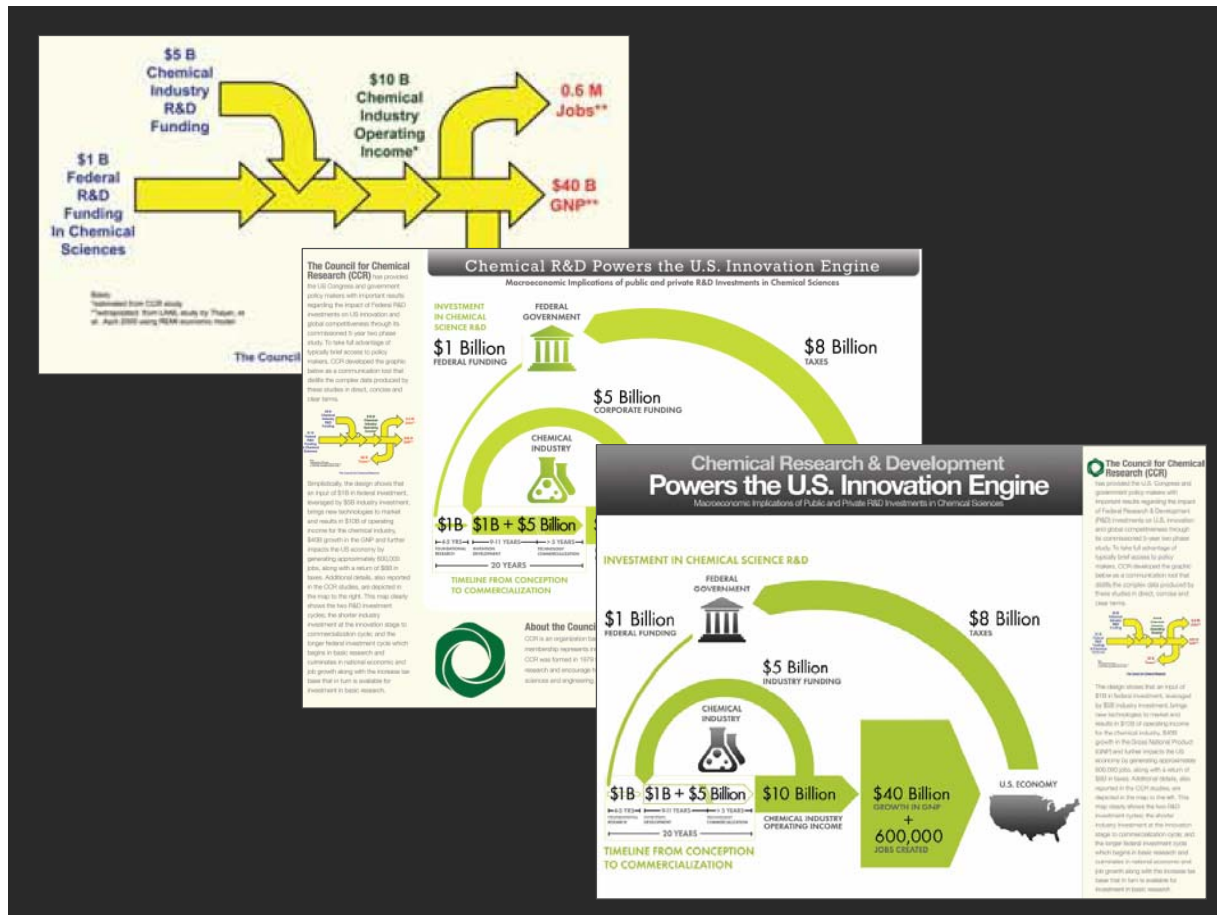


(5th Iteration of Places & Spaces Exhibit - 2009)



Bollen, Johan, Herbert Van de Sompel, Aric Hagberg, Luis M.A. Bettencourt, Ryan Chute, Marko A. Rodriguez, Lyudmila Balakireva. 2008. A Clickstream Map of Science. 49





Science Maps for Scholars

Four Existing Maps
VERSUS
 Six Science Maps



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

The EMERGENCE of NANOTECHNOLOGY

MAPPING THE NANO REVOLUTION

The emergence of nanotechnology has been one of the major scientific-technological revolutions in the last decade and it led to a structural reorganization of major levels of science. Price (1995) showed that fields of science and their development can be mapped using aggregated citations among the journals in the fields and their relevant environments. The frames to the right show the evolving journal citation networks for the years 1998-2003. Distances are proportional to cosine values between the citation patterns of the respective journals. Typical descriptions of key events during the development of nanotechnology are given below each frame. Most notably, leading papers in Science and Nature catalyzed the breakthrough around 2000.

CHANGING ROLES OF DIFFERENT JOURNALS

The interdisciplinarity of a journal can be measured using betweenness centrality (BC) — journals that occur on many shortest paths between other journals in a network have higher BC value than those that do not. In the maps, sizes of nodes are proportional to the betweenness centrality of the respective journal in the citation network.

From being a specialist journal in applied physics, the journal Nanotechnology obtains a high BC value in the years of the transition, ca. 2000. This is preceded by the "invention" of Science after the transition, the new field of nanotechnology is established, new journals such as Nano Letters published by the influential American Chemical Society take the lead, and a new spacy structure with low BC value journals results.



An animated sequence of this evolution is at <http://www.lloydsof.com/journals/nanotech>

References

Lloydsof, L. and T. Schank, 2006. Dynamic Animations of Journal Maps: Indicators of Structural Change and Interdisciplinary Developments. *Journal of the American Society for Information Science and Technology*, 57(11), 1810-1818.

Price, Daise J. de Solla (1965). Networks of scientific papers. *Science*, 146, no. 3682, 610-613.

1998

During the period 1998-2003, the journal Nanotechnology is part of a group of journals in applied physics.

1999

Increasingly, chemistry journals play a role in the citation impact assessment of the journal Nanotechnology.

LEGEND



Values
0.5
0.22
0.38

2000

The natural Science interfaces with relevant journals in nano-arts; chemistry and applied physics. Nanotechnology emerges as core journal.

2001

The journal Nanotechnology now provides the interface between chemistry and physics. The "iron revolution" for Science is no longer needed.

2003

The journal Science is relevant in the citation impact environment, but now functions as one of the specialist journals in nanotechnology. Nanotechnology further develops as an increasingly integrated network of journals.

2002

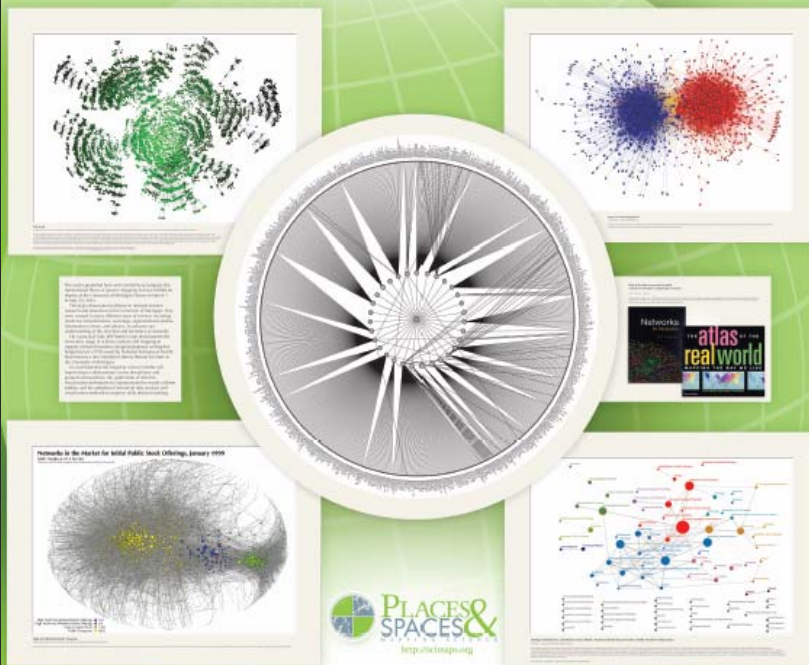
Other journals in nanoscience and technology begin to emerge, and the budding field of the journal Nanotechnology gradually substitutes Nano Letters and the Journal of Nanoscience and Nanotechnology for the new field of nanotechnology.

Loet Leydesdorff, Thomas Schank and the Journal of the American Society for Information Science and Technology. 2010. The Emergence of Nanoscience & Technology.

55

Network Science Research

by Faculty at the University of Michigan



Several University of Michigan faculty created maps included in the exhibit: Santiago Schnell, Molecular and Integrative Physiology; Lada Adamic, School of Information; M. E. J. Newman, Physics; Jeff Horon, Medical School; Helena Buhr, Natalie Cotton, and Jason Owen-Smith, Sociology and Organizational Studies.

Upcoming Iterations

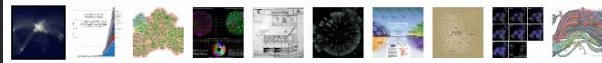
- Science Maps as Visual Interfaces to Digital Libraries (2011)
- Science Maps for Kids (2012)
- Science Forecasts (2013)
- How to Tell Lies with Science Maps (2014)



Data as Art: 10 Striking Science Maps

By Dave Mosher | March 8, 2011 | 7:00 am | Categories: Art, Tech

<< Previous | Next >>



The computer age triggered a seemingly endless stream of scientific data, but such incoming mountains of information come at a cost. The more data you amass, the tougher it is to comprehend what you're dealing with.

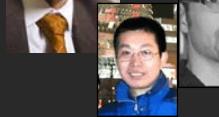
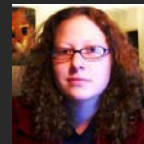
In a push for better perspective, a group of information scientists in 2005 created a decade-long competitive art exhibit called *Places & Spaces: Mapping Science*. From artistic pop-culture plots to illustrations of the state of scientific collaboration (above), the founders hope winning entries inspire researchers to present their troves of data in clever and digestible ways.

"Good science maps give you a holistic understanding of how the data is structured," said information scientist Katy Börner of Indiana University, a founder and curator of the exhibit. She is also author of the *Atlas of Science*, a collection of the maps gathered over the years. "You don't just have to use maps to find your way home. They can be ways to get global overviews on topics."



Contact the map makers or the exhibit curators:

Katy Börner (katy@indiana.edu) and Michael J. Stammer (mstammer@indiana.edu)



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Places & Spaces: Mapping Science

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Places & Spaces: Mapping Science

New Illuminated Diagram setup in action.



4 minutes ago · Like · Comment