MOOC and More

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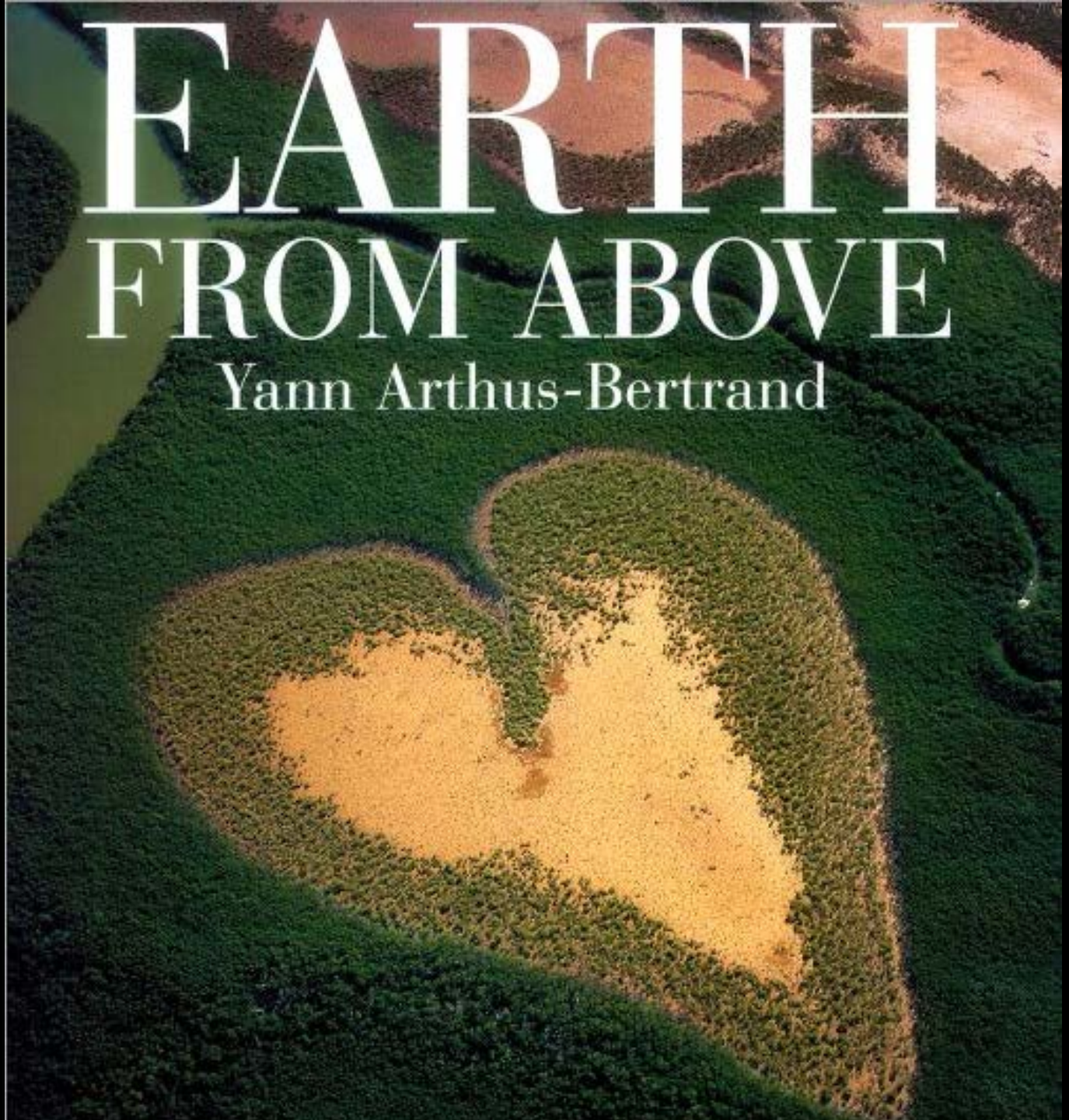
Talk at University of Applied Sciences Mittweida (Hochschule Mittweida), Germany
July 10, 2017

Places & Spaces

MAPPING SCIENCE

scimaps.org

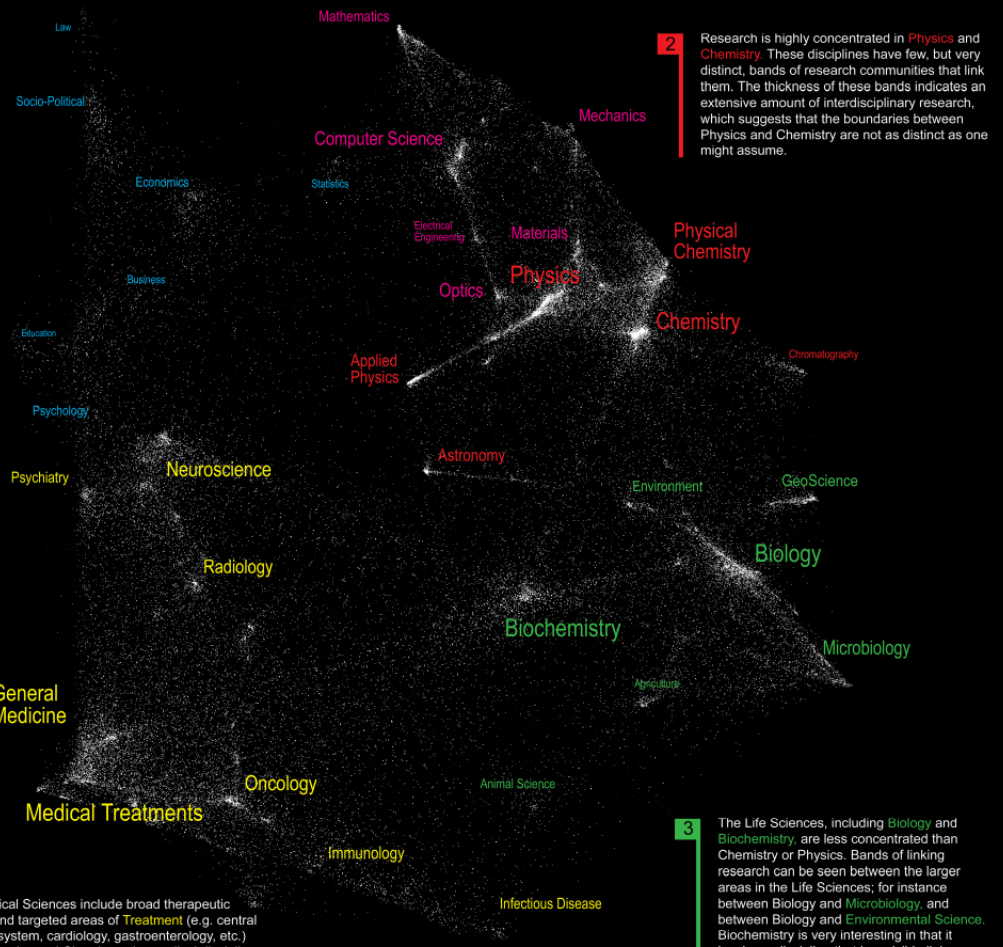

EARTH
FROM ABOVE
Yann Arthus-Bertrand

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

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.

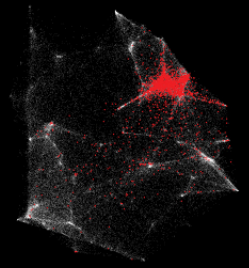
We are all familiar with traditional maps that show the relationships between countries, provinces, states, and cities. Similar relationships exist between the various disciplines and research topics in science. This allows us to map the structure of science.

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.

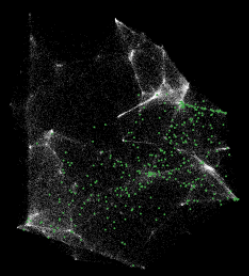
The map of science can be used as a tool for science strategy. This is the terrain in which organizations and institutions locate their scientific capabilities. Additional information about the scientific and economic impact of each research community allows policy makers to decide which areas to explore, 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.



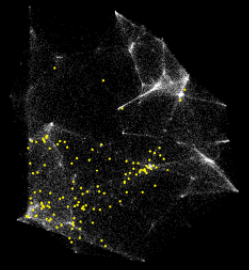
Nanotechnology

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.

The Structure of Science - Kevin Boyack, Richard Klavans - 2005

April, 2005: 101st Annual Meeting of the Association of American Geographer, Denver, Colorado.

05: 101st Annual Meeting

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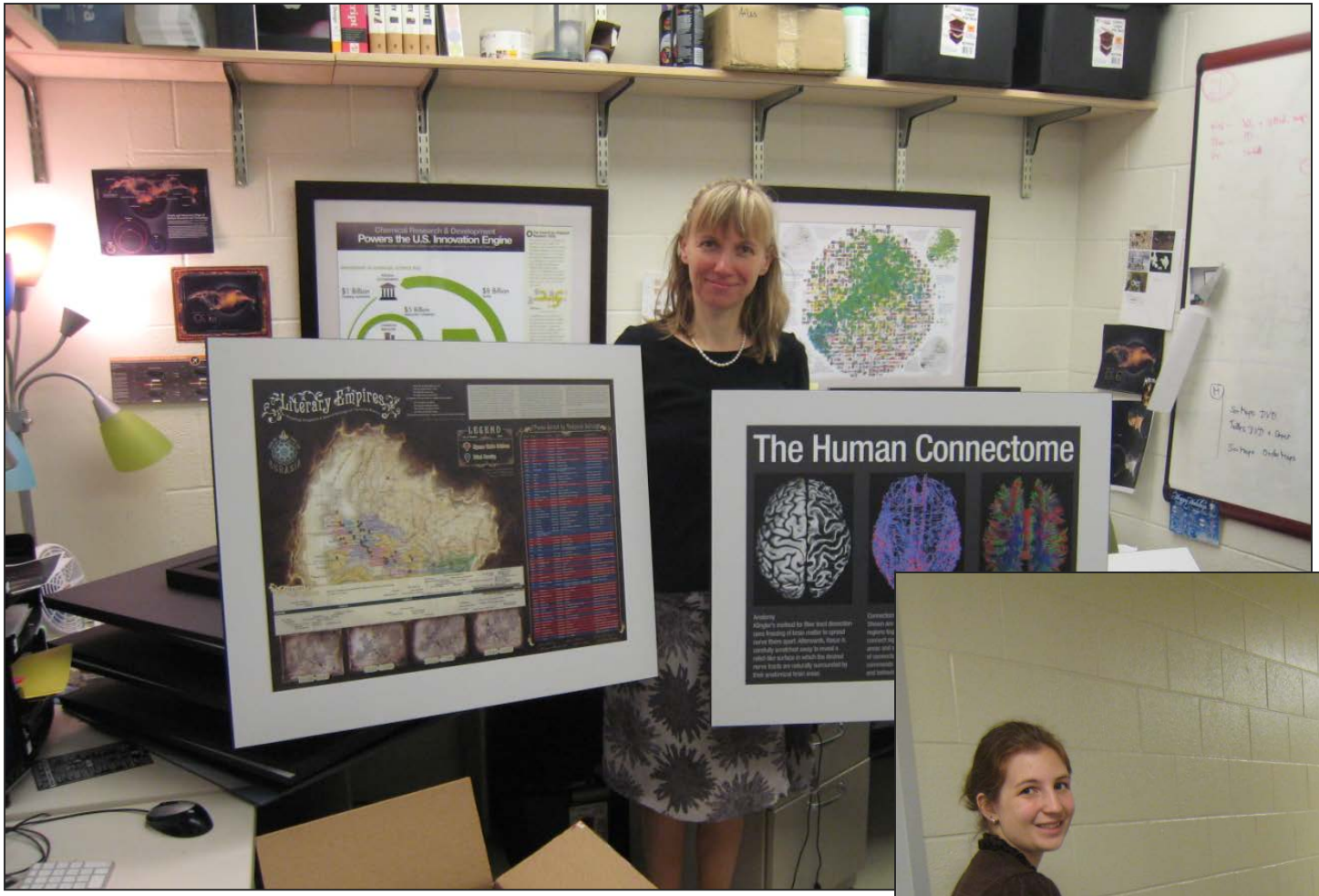
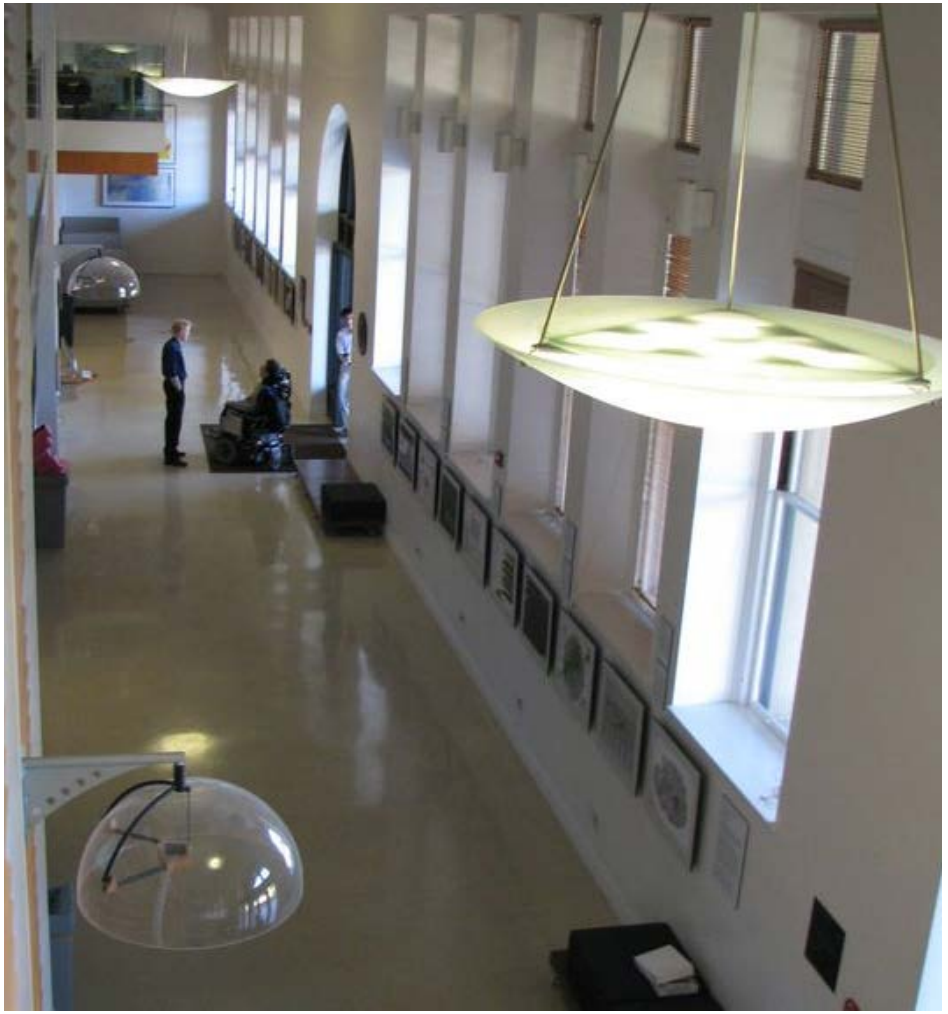
INDIANA
UNIVERSITY
PLACES AND SPACES
EXHIBIT

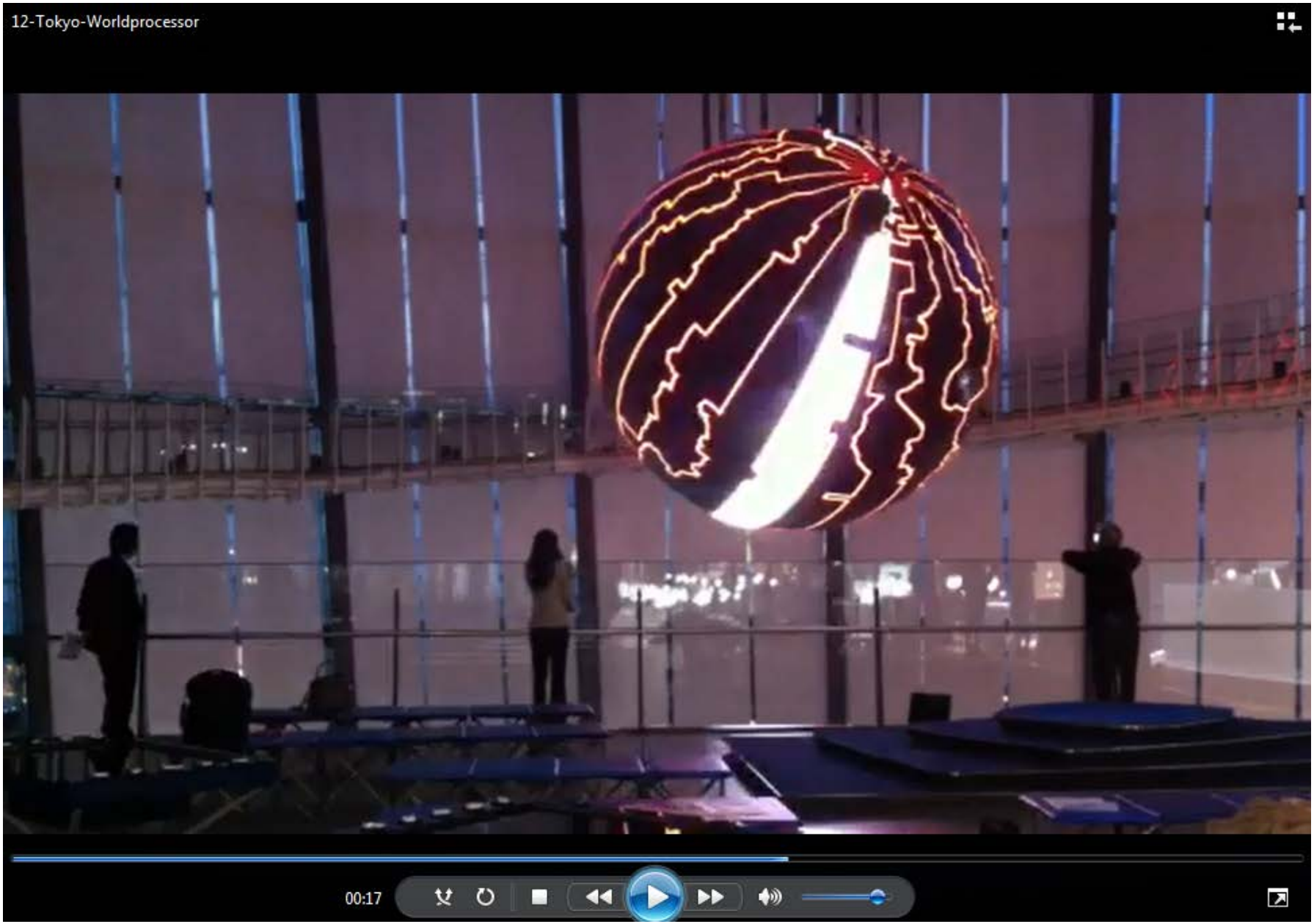

Chemical Research & Development
Powers the U.S. Innovation Engine
Literary Empires
LEGEND
The Human Connectome

HUMANSPEECHOMEPROJECT



Debut of 5th Iteration of the Mapping Science Exhibit at MEDIA X in 2009 at Wallenberg Hall, Stanford University.

Science Maps in "Expedition Zukunft" science train visited 62 cities in 7 months. Opening on April 23rd, 2009 by German Chancellor Merkel



Ingo Gunther's Worldprocessor globe design on display at the Museum of Emerging Science and Innovation in Tokyo, Japan.

Places & Spaces Digital Display in North Carolina State's Immersion Theater

Exhibit Advisors
and Ambassadors

Kristi Holmes @kristiholmes · Apr 30
Excited for @cnscenter Places&Spaces at @galterlibrary! @katycns @NUCATSInstitute #**unpackingcrates** #viz

Places & Spaces at Northwestern University
May 14 - September 23, 2015

Places & Spaces Exhibit at the David J. Sencer CDC Museum, Atlanta, GA January 25-June 17, 2016.

CDC Opening Event: Maps of Health

Tutorial and Symposium

February 4-5, 2016

Places & Spaces Exhibit at Vanderbilt University, Nashville, TN.
January 23-April 23, 2017 http://scimaps.org/vanderbilt

Maps

PLACES & SPACES

MAPPING SCIENCE

scimaps.org

10 iterations over 10 years

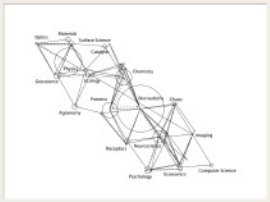
equal

10 x 10 = 100 maps!

The Power of Maps 2005

I.1

I.3



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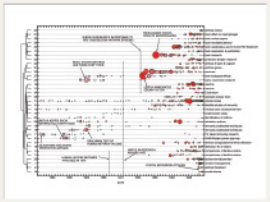

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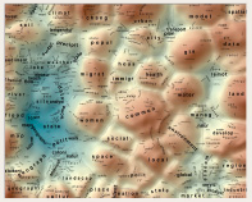

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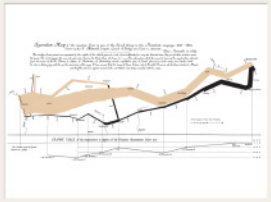

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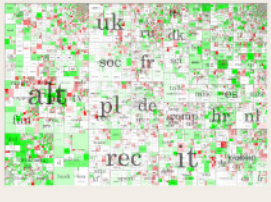

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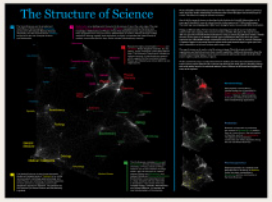


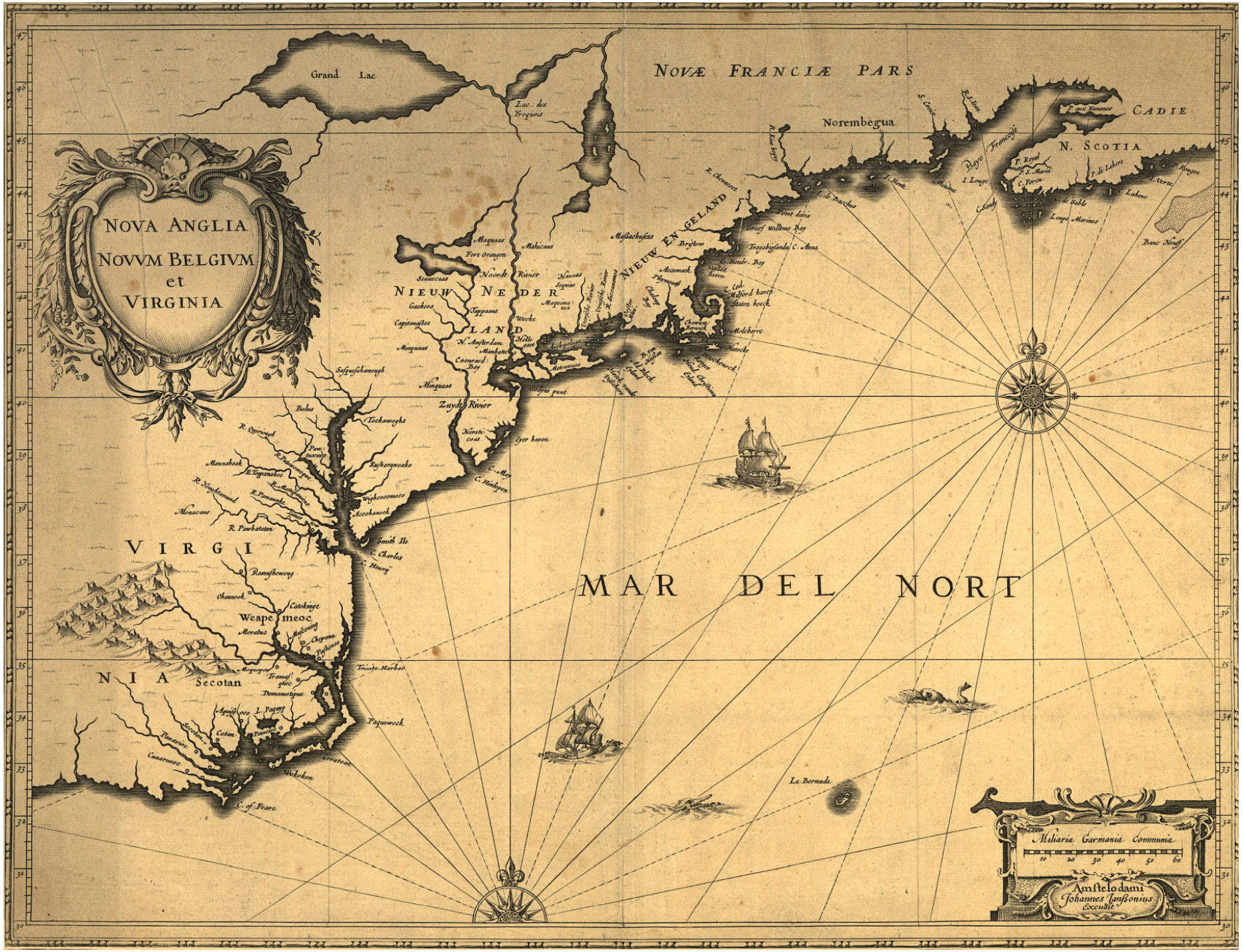
I.10

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.

Cosmographia World Map - Claudius Ptolemy - 1482

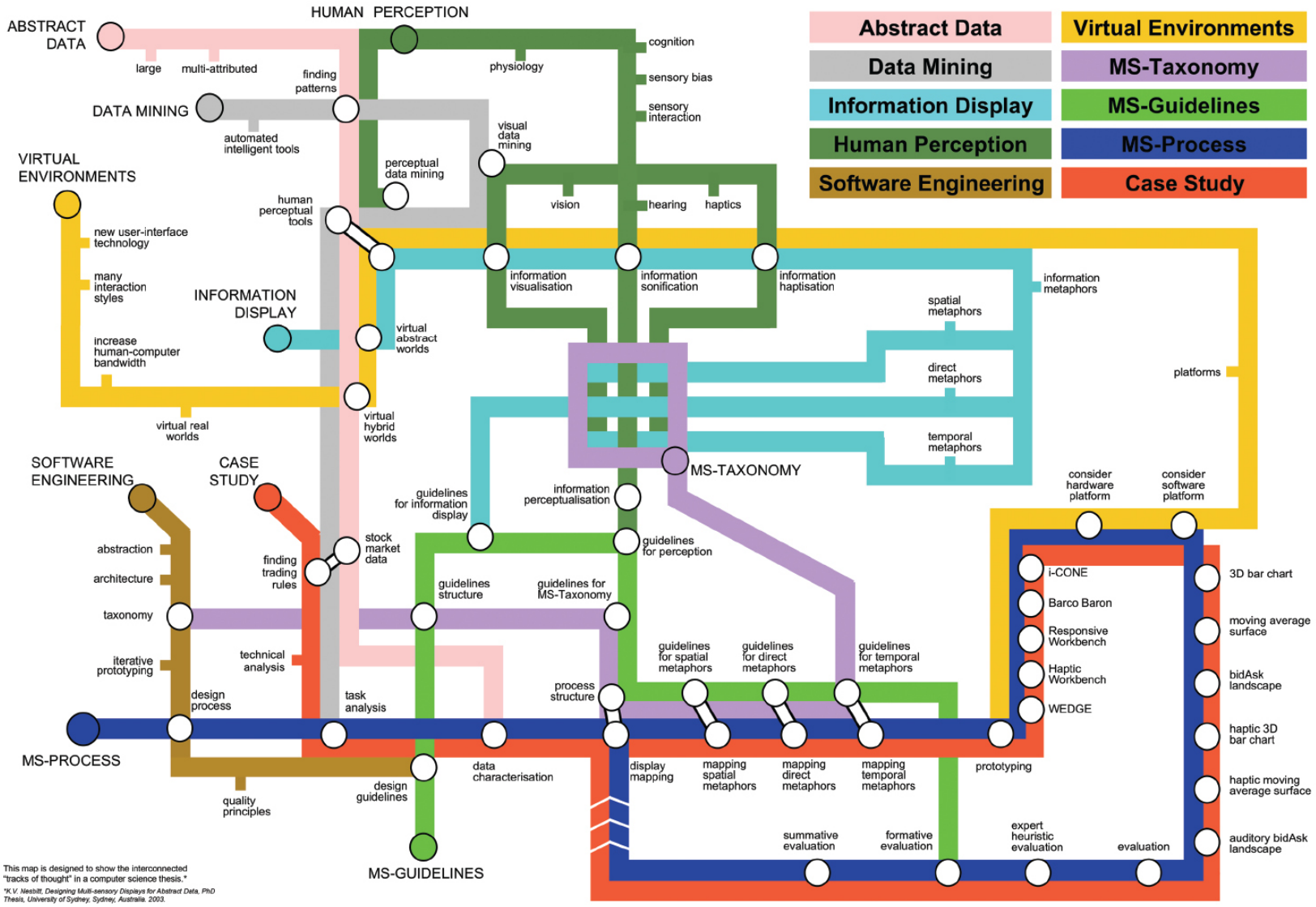


Nova Anglia, Novvm Belgivm et Virginia - Jan Jannson - 1642

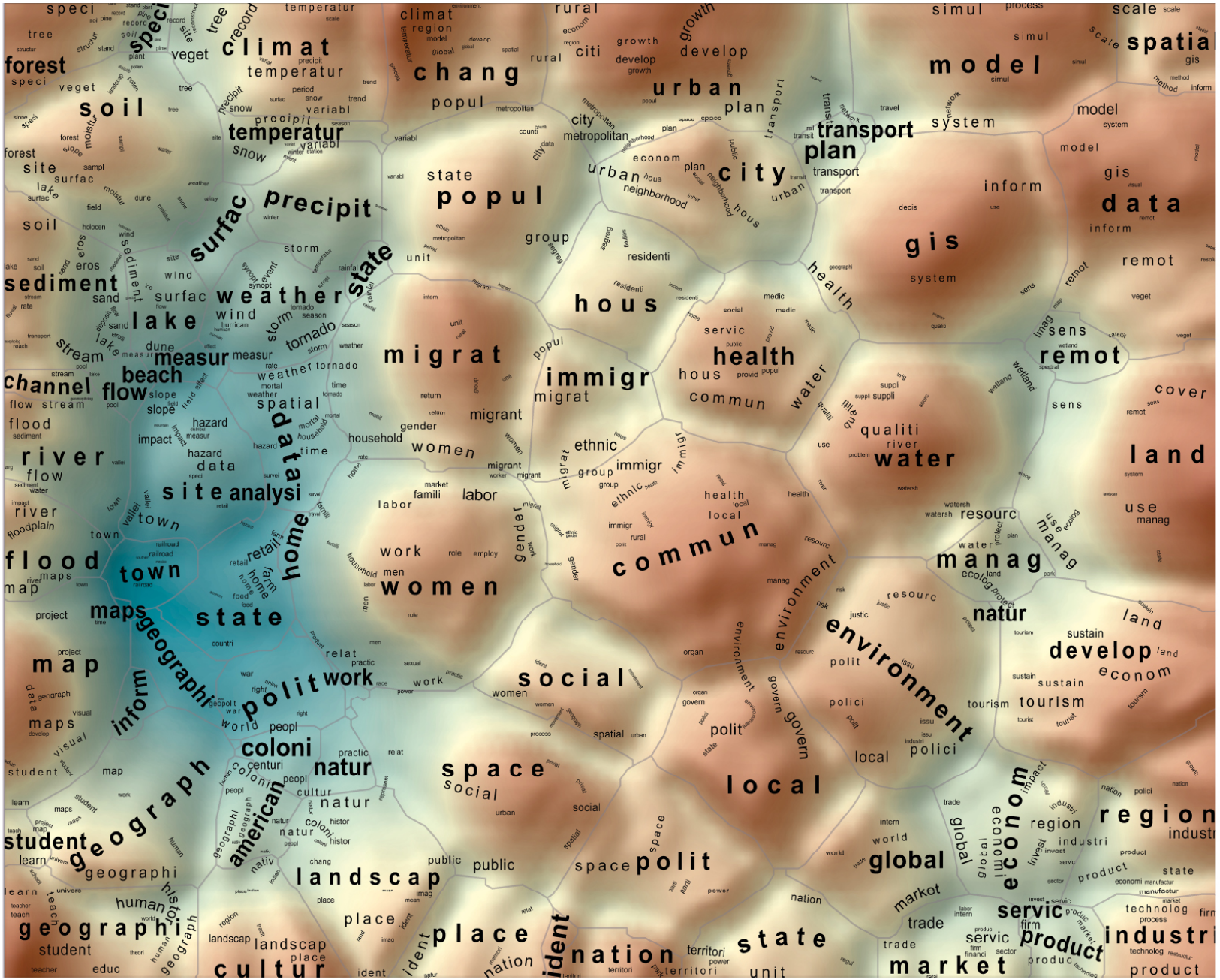
A New Map of the Whole World with Trade Winds According to the Latest and Most Exact Observations - Herman Moll - 1736

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

They can be used to identify objectively major experts, institutions, collections. They allow us to track the emergence, evolution, and disappearance of topics and help to identify the most promising areas of research.



Ph.D. Thesis Map - Keith B. Nesbitt - 2004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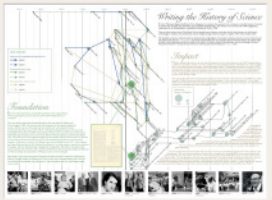
The Power of Reference Systems 2006

II.1

II.3



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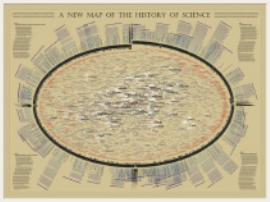

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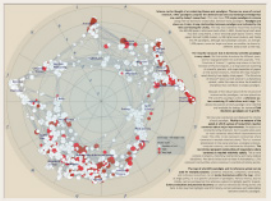

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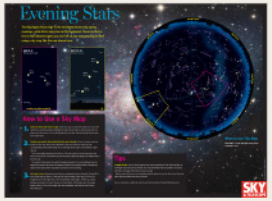

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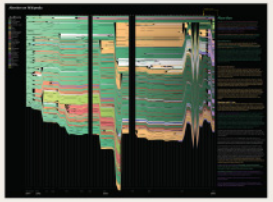

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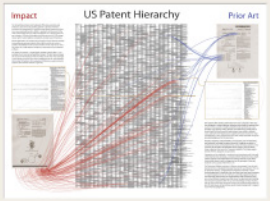

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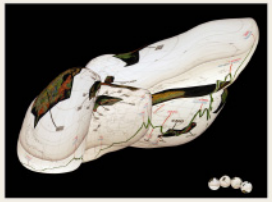

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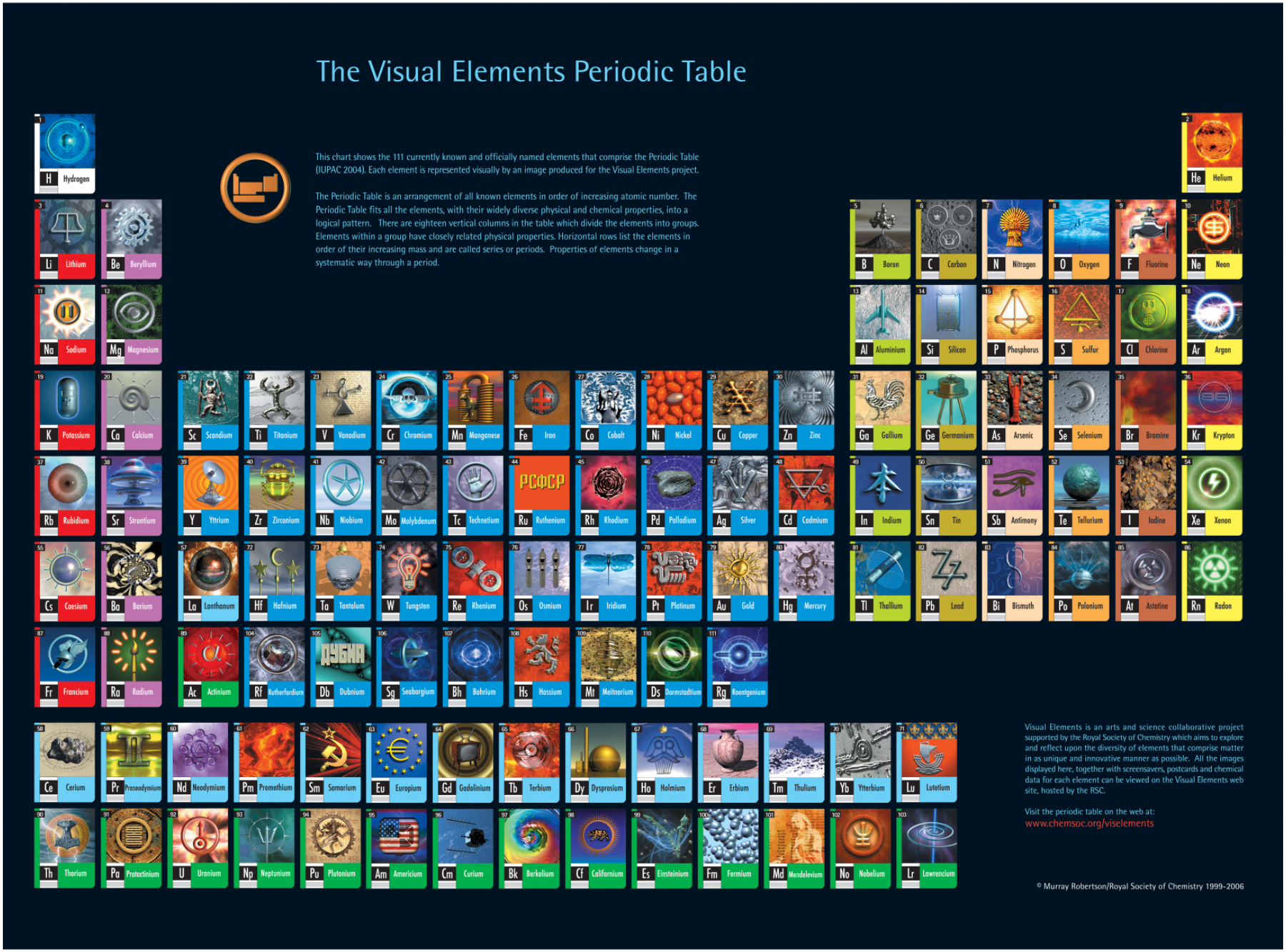
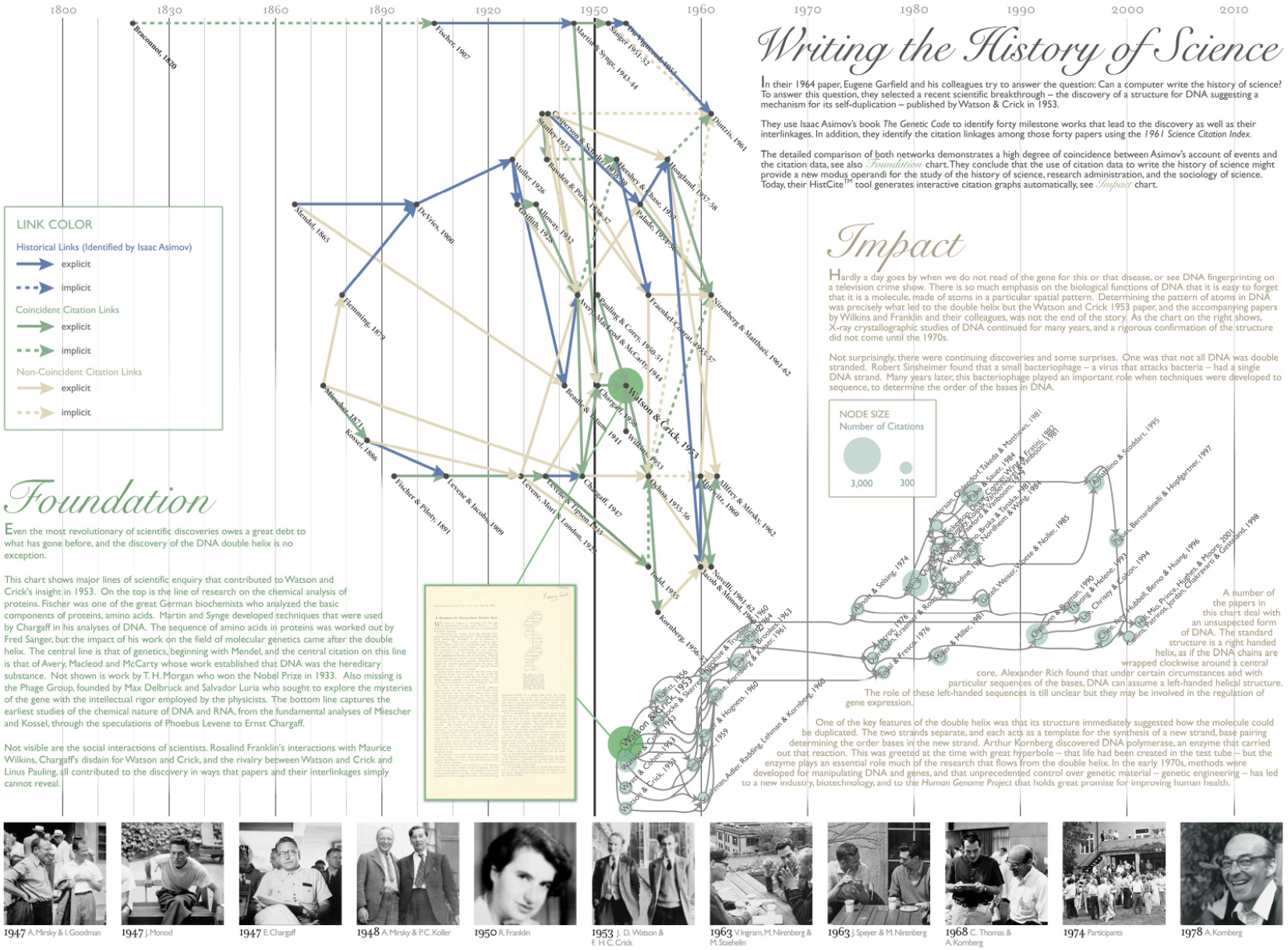


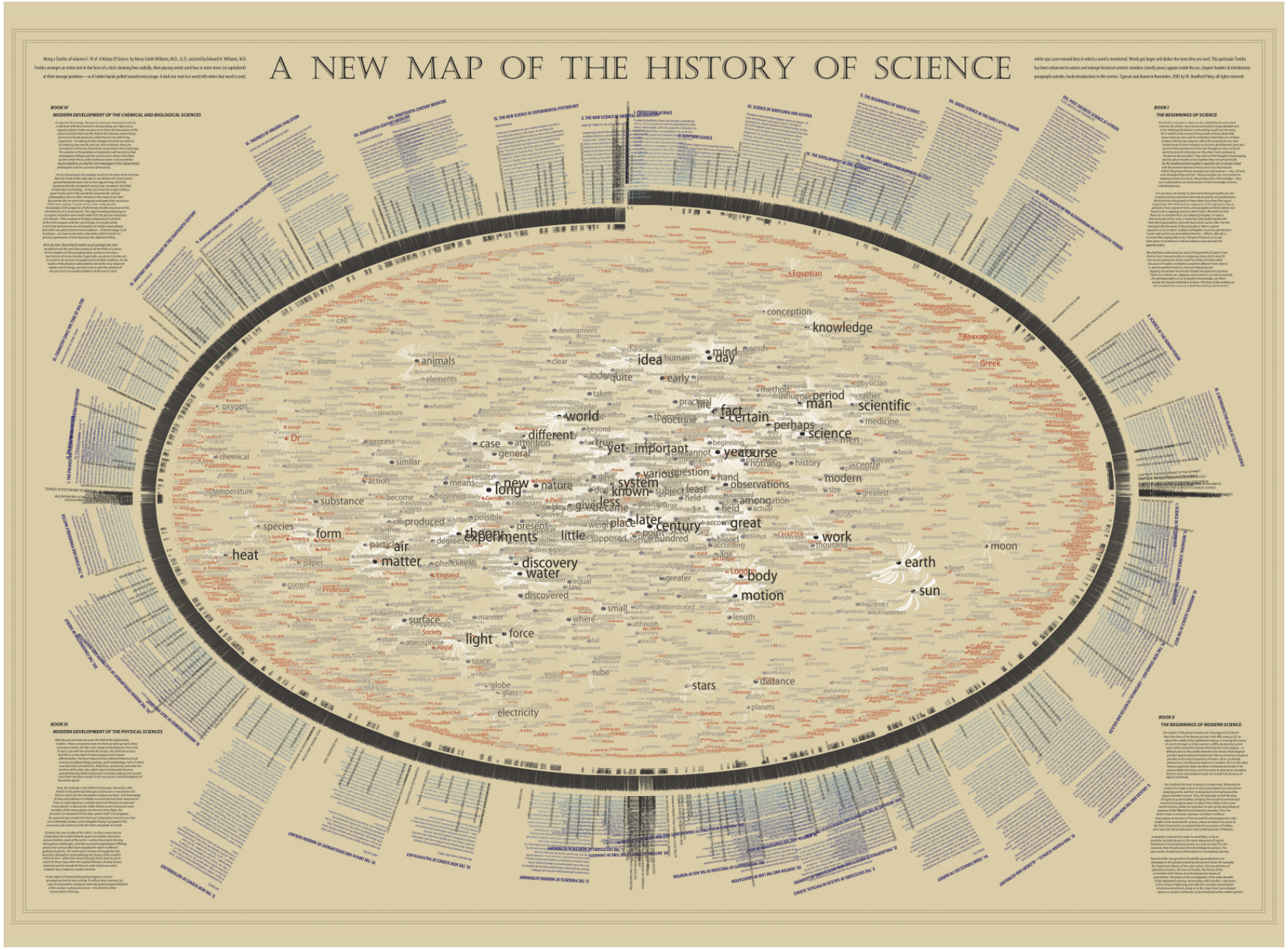
Visual Elements Periodic Table - Murray Robertson, John Emsley - 2005

How would a reference system for all of science look?

What dimensions would it have?

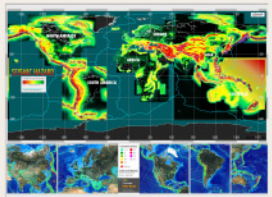


HistCiteTM Visualization of DNA Development - Eugene Garfield, Elisha Hardy, Katy Börner, Ludmila Pollock, Jan Witkowski - 2006



TexArc Visualization of "The History of Science" - W. Bradford Paley - 2006

The Power of Forecasts 2007



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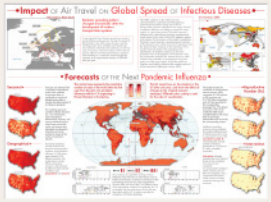

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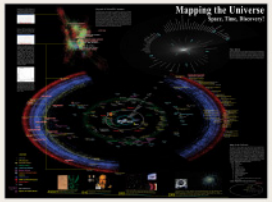

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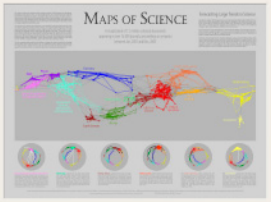

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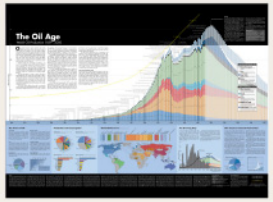

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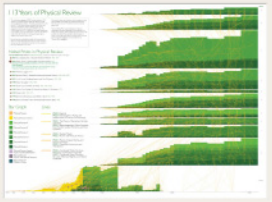

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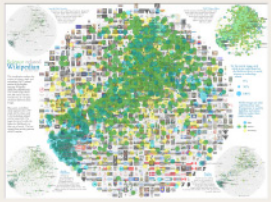

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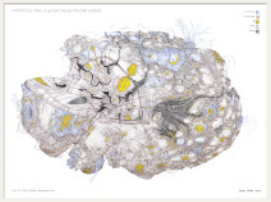

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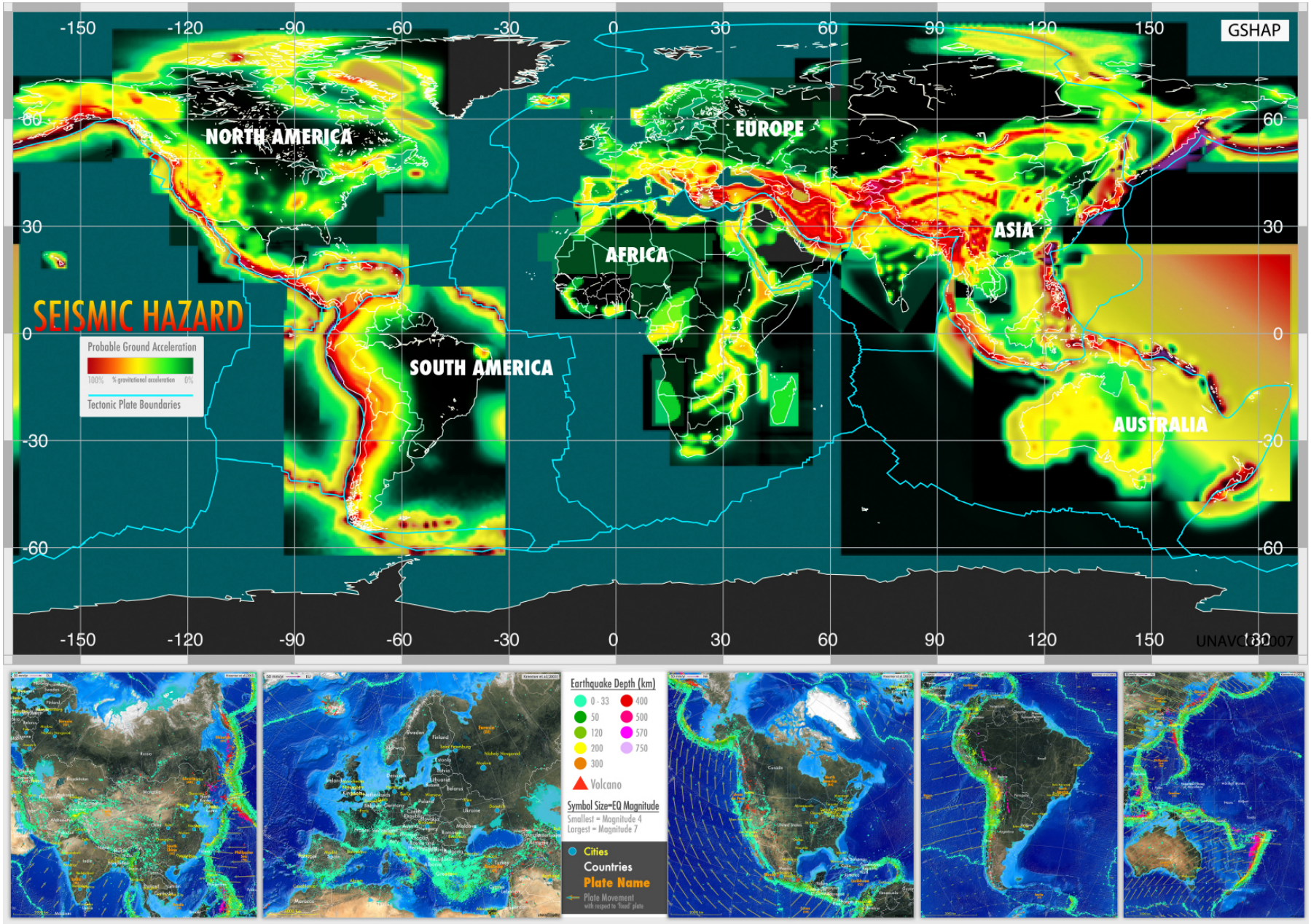
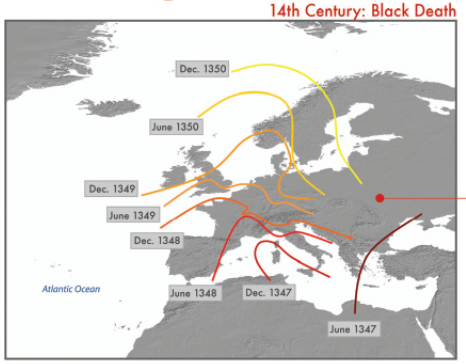


Tectonic Movements and Earthquake Hazard Predictions - Martin W. Hamburger, Lou Estey, Chuck Meertens, Elisha Hardy - 2005

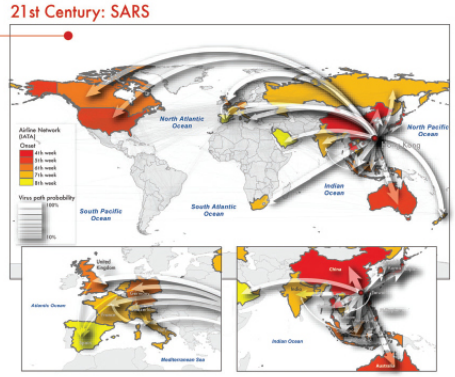
Impact of Air Travel on Global Spread of Infectious Diseases



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

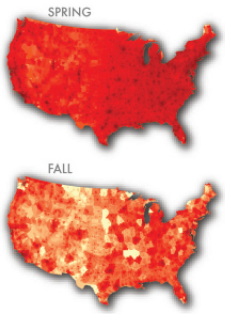
In pre-industrial times disease spread was mainly a spatial diffusion phenomenon. During the spread of Black Death in the 14th century Europe, only few traveling means were available and typical trips were limited to relatively short distances on the time scale of one day. Historical studies confirm 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 spatio-temporal 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 data-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

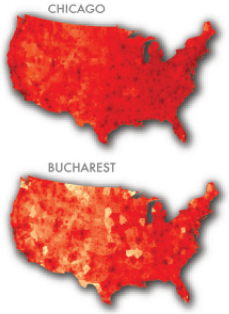
Seasonal



Forecasts are obtained with a stochastic computational model which explicitly incorporates data on worldwide air travel and detailed census data to simulate the global spread of an influenza pandemic.

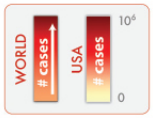
The modeling approach considers infection dynamics (i.e., virus transmission, onset of symptoms, infectiousness, recovery, etc.) among individuals living in urban areas around the world, and assumes that individuals are allowed to travel fom one city to another by means of the airline transportation network.

Geographical

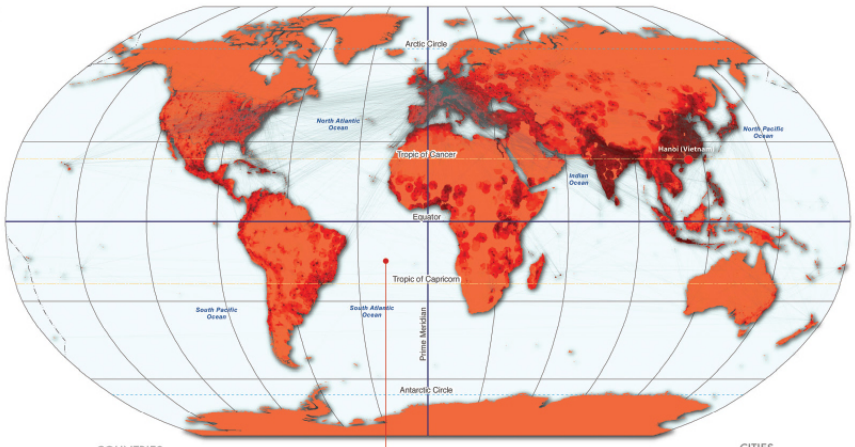


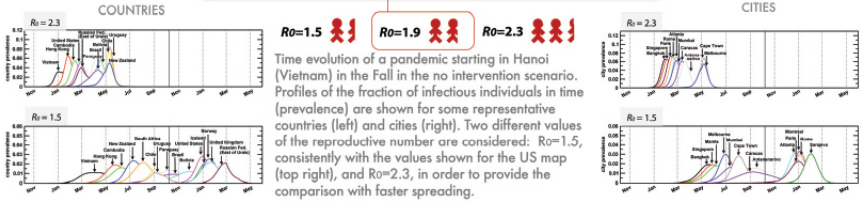
Numerical simulations provide results for the temporal and geographic evolution of the pandemic influenza in 3,100 urban areas located in 220 different countries. The model allows to study different spreading scenarios, characterized by different initial outbreak conditions, both geographical and seasonal.

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.





R0=1.5 R0=1.9 R0=2.3

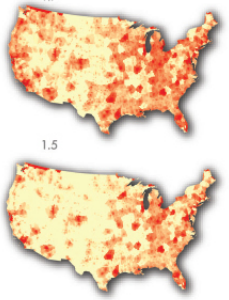
Time evolution of a pandemic starting in Hanoi (Vietnam) in the Fall in the no intervention scenario. Profiles of the fraction of infectious individuals in time (prevalence) are shown for some representative countries (left) and cities (right). Two different values of the reproductive number are considered: R0=1.5, consistently with the values shown for the US map (top right), and R0=2.3, in order to provide the comparison with faster spreading.

The model inlcudes the worldwide air transportation network (source: IATA) composed of 3,100 airports in 220 countries and E=17,182 direct connections, each of them associated to the corresponding passenger flow. This dataset accounts for 99% of the worldwide traffic and is complemented by the census data of each large metropolitan area served by the corresponding airport.

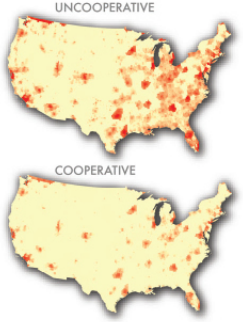
Additional spreading scenarios can be obtained by modeling different levels of infectiousness of the virus, as expressed in terms of the reproductive number R0, representing the average number of infections generated by a sick person in a fully susceptible population.

Intervention strategies modeling the use of antiviral drugs can be considered. Two scenarios are compared:
an uncooperative strategy in which countries only use their own stockpiles, and a cooperative intervention which envisions a limited worldwide sharing of the resources.

Reproductive Number (R0)



Intervention



Impact of Air Travel on Global Spread of Infectious Diseases - Vittoria Colizza, Alessandro Vespignani - 2007

Can one forecast science?

What ‘science forecast language’ will work to communicate results?

INSTITUTE FOR THE FUTURE

Science & Technology Outlook: 2005–2055

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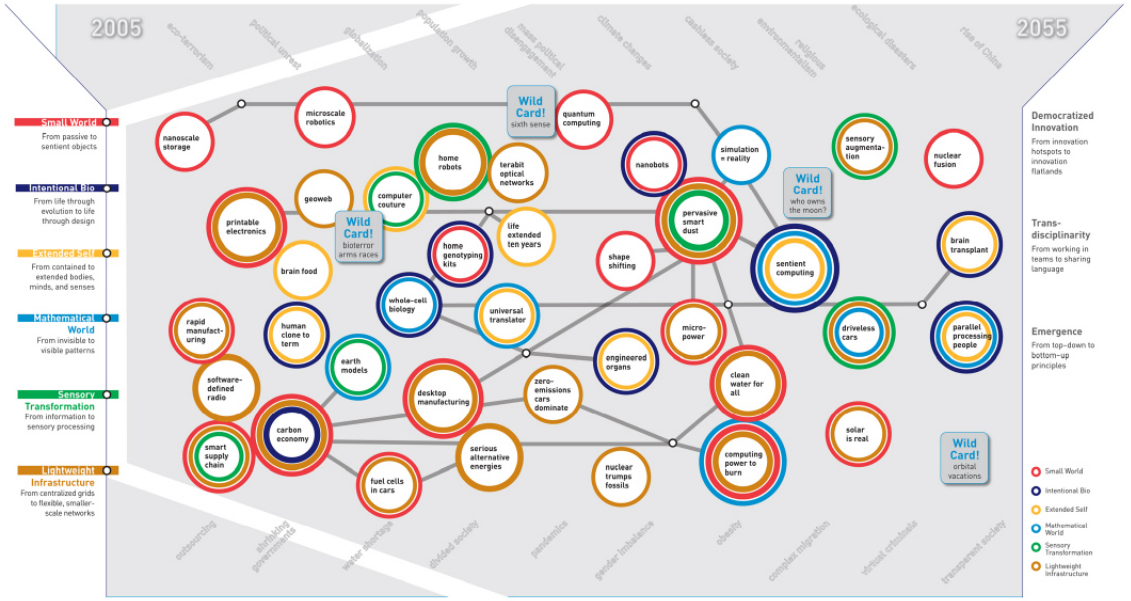

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A map is a tool for navigating an unknown terrain. In the case of this map, **Science & Technology Outlook: 2005–2055,** the terrain we're navigating is the uncharted territory of science and technology (S&T) in the next 50 years. However, the map of the future is not a tool for prediction or, for that matter, the product of predictions. 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's more 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 aiding travelers 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 S&T—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 (IFTF)** team listened for and connected a variety of weak signals, including those generated during interviews and workshop conversations involving more than 100 eminent U.K. and U.S. experts in S&T—academicians, policymakers, journalists, and corporate researchers. The IFTF team also compiled a database of outlooks on developments that are likely to impact the full range of S&T disciplines and practice areas over the next 50 years. We also relied on IFTF's 40 years of experience in forecasting S&T developments to create the map and an accompanying set of **S&T Perspectives** that discuss issues emerging on the S&T horizon and are important for organizations, policymakers, and society-at-large 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 technolgies, innovations, and discoveries. In addition to the six themes, three meta-themes—democratized innovation, transdisciplinarity, and emergence—will overlay the future S&T landscape influencing how we think about, learn about, and practice science. Finally, S&T trends won't operate in a vacuum. Wider social, demographic, political, economic, and environmental trends will both influence S&T 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. Three trends, 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 assemblers 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 support 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 milieux that emphasize heterogeneity.

Intentional Biology

For 3.6 billion years, evolution has governed biology on this planet. But today, Mother Nature has a collaborator. Inexpensive tools to read and rewrite the genetic code of life will bootstrap our ability to manipulate biology from the bottom up. We'll not only genetically re-engineer existing life but actually create new life forms with purpose. Still, we will not be blind to what nature has to teach us. Evolution's elegant engineering at the smallest scales will be a rich source of inspiration as we build the bio-nanotechnology of the next 50 years.

Extended Self

In the next 50 years, we will be faced with broad opportunities to remake our minds and bodies in profoundly different ways. Advances in biotechnology, brain science, information technology, and robotics will result in an array of methods to dramatically alter, enhance, and extend the mental and physical hand that nature has dealt us. Wielding these tools on ourselves, humans will begin to define a variety of different "transhumanist" paths—that is, ways of being and living that extend beyond what we today consider natural for our species. In the very long term, following these paths could someday lead to an evolutionary leap for humanity.

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.

Sensory Transformation

In the next ten years, physical objects, places, and even human 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 encoded as text and numbers will be displayed in richer sensory formats—as graphics, pictures, patterns, sounds, smells, and tactile experiences. This enriched sensory environment will coincide with major breakthroughs in our understanding of the brain—in how we process sensory information and connect various sensory functions. Humans will become much more sophisticated in their ability to understand, create, and manage sensory information and ability to perform such tasks will become keys to success.

Lightweight Infrastructure

A confluence of new materials and distributed intelligence is pointing the way toward a new kind of infrastructure that will dramatically reshape the economics of moving people, goods, energy, and information. From the molecular level to the macro-economic level, these new infrastructure designs will emphasize smaller, smarter, more independent components. These components will be organized into more efficient, more flexible, and more secure ways than the capital-intensive networks of the 20th century. These lightweight infrastructures have the potential to boost emerging economies, improve social connectivity, mitigate the environmental impacts of rapid global urbanization, and offer new future paths in energy.

META-THEMES

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, pushed amateurs aside as a creative force. At the national scale, the capital-intensive character of scientific research made world-class research the property of prosperous advanced nations. In the new century, a number of trends and technologies will lower the barriers to participation in science and technology again, both for individuals and for emerging countries. The result will be a renaissance of the serious amateurs, the growth of new scientific and technical centres of excellence in developing countries, and a more global distribution of world-class scientists and technologists.

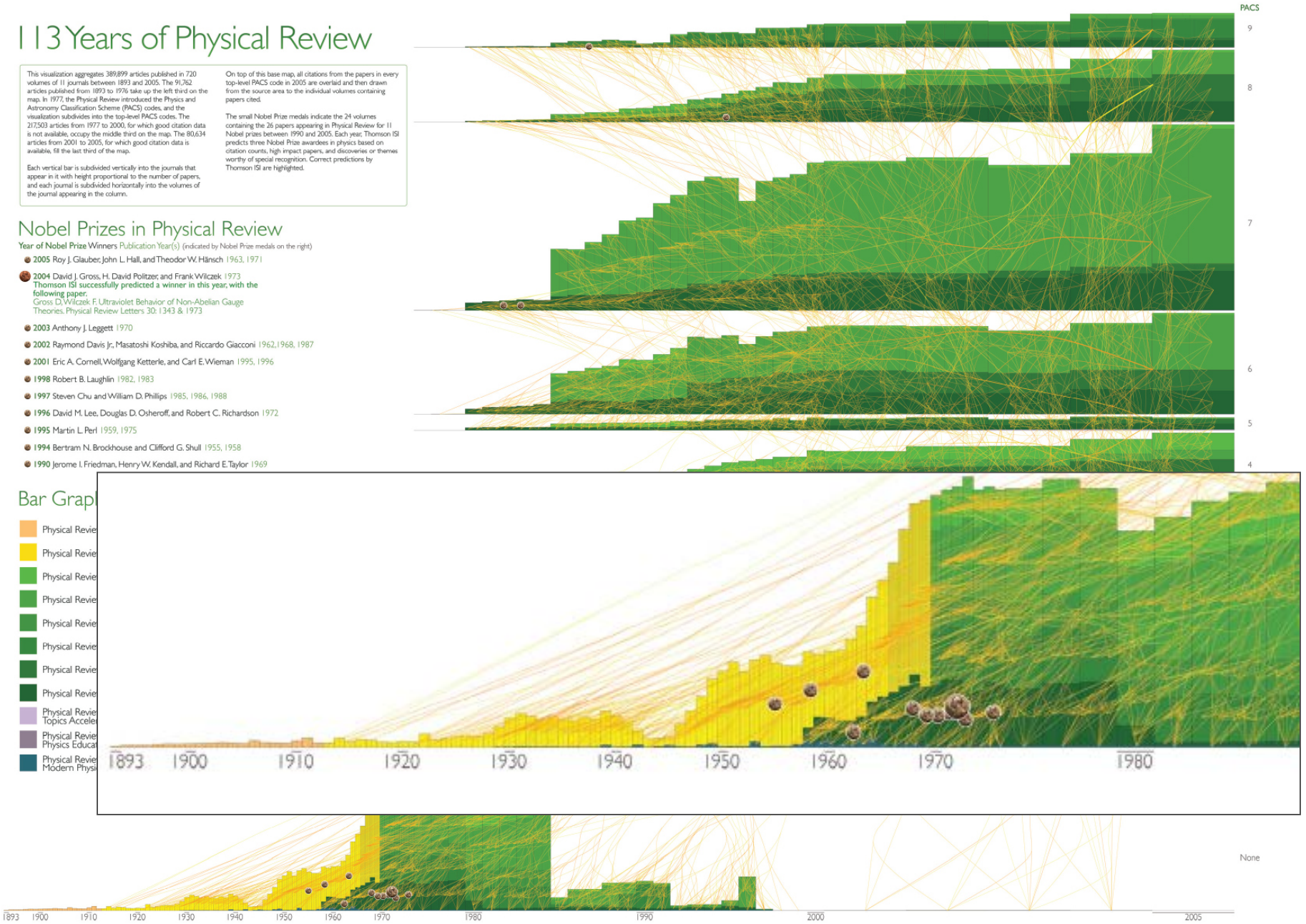
Transdisciplinarity

In the last two centuries, natural philosophy and natural history fractured into the now-familiar disciplines of physics, chemistry, biology, and so on. The sciences evolved into their current form in response to intellectual 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 Rheingold, a prominent forecaster and author, "transdisciplinarity goes beyond bringing together researchers from different disciplines to work in multidisciplinary teams. It means educating researchers who can speak languages of multiple disciplines—biologists who have understanding of mathematics, mathematicians who understand biology."

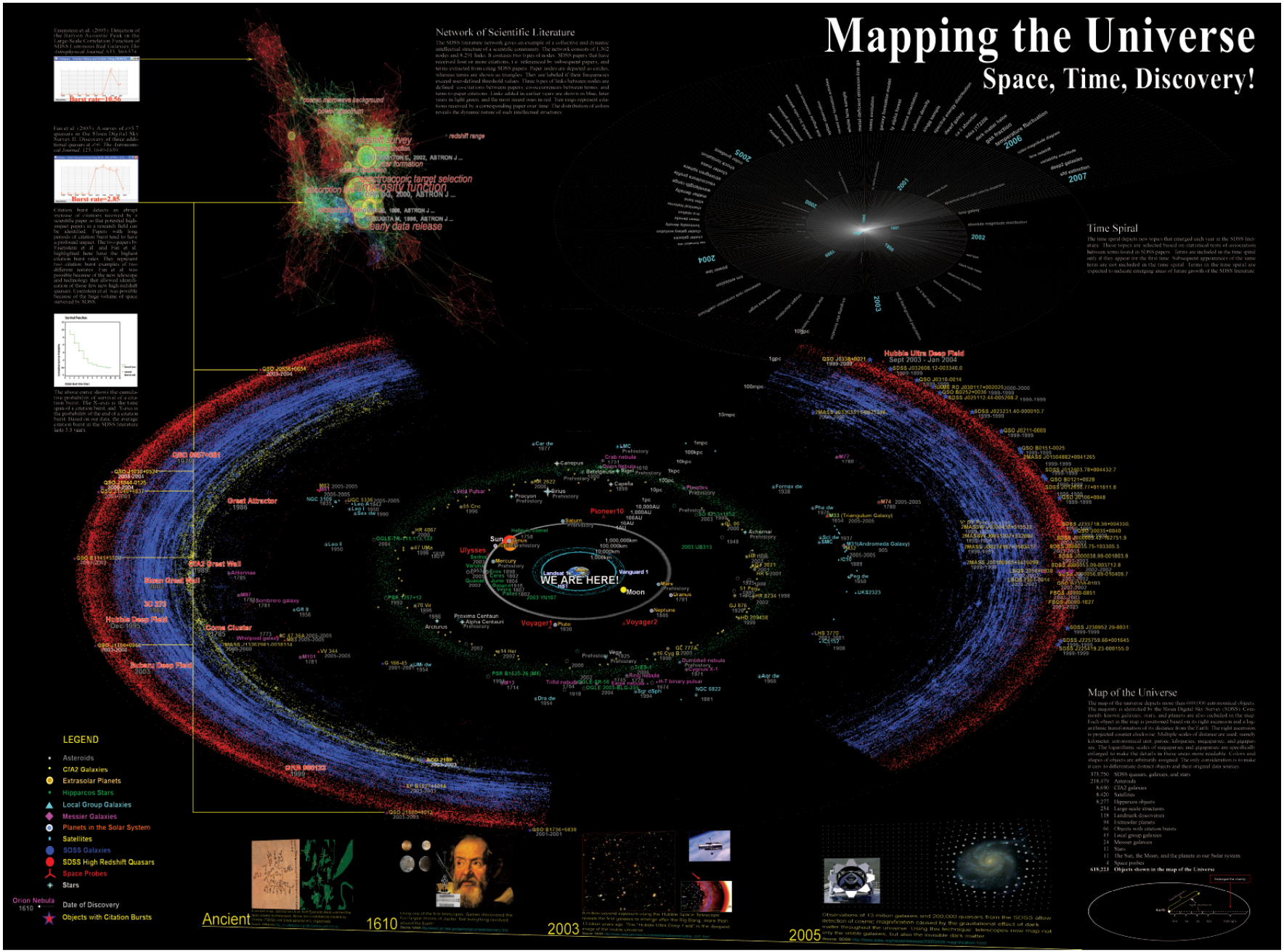
Emergence

The phenomenon of self-organizing swarms that generate complex behavior by following 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 those models often require substantial processing power. More generally, it is a richly suggestive as a way of thinking about designing complex, robust technological systems. Finally, emergence is an accessible and vivid a metaphor for understanding nature. Just as classical physics profited 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.

Science & Technology Outlook: 2005-2055 - Alex Soojung-Kim Pang, David Pescovitz, Marina Gorbis, Jean Hagan - 2006



114 Years of Physical Review - Bruce W. Herr II, Russell Duhon, Katy Borner, Elisha Hardy, Shashikant Penumarthy - 2007



Mapping the Universe: Space, Time, Discovery! Chaomei Chen, Jian Zhang, Michael S. Vogeley, J. Richard Gott III, Mario Juric, Lisa Kershner - 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

This map of science was constructed by sorting more than 16,000 journals into disciplines. Disciplines, represented as circles, are sets of journals that cite a common literature; links (the lines between disciplines) are pairs of disciplines 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 linkages between disciplines. The model treats links like rubber bands attempting to bring two disciplines close to each other. Pairs of disciplines without links tend to end up on different sides of the map.

The spherical map, which is not shown here, was unrolled in a mercator projection (the same one used to show the continents of the earth on a two-dimensional map) to give the large map shown below. This projection allows inspection of the entire map of science at once. Note that the disciplines tend to string along the middle of the map - if this were a map of the earth it would be like a single continent undulating along the equator. There are no disciplines at the top (north pole) or the bottom (south pole). Mercator projections also introduce distortions. We tend to forget that the left side is connected to the right side, and assume that the middle is most important. In this map, the social sciences (yellow) on the right connect with the computer sciences (pink) on the left in one continuous swath.

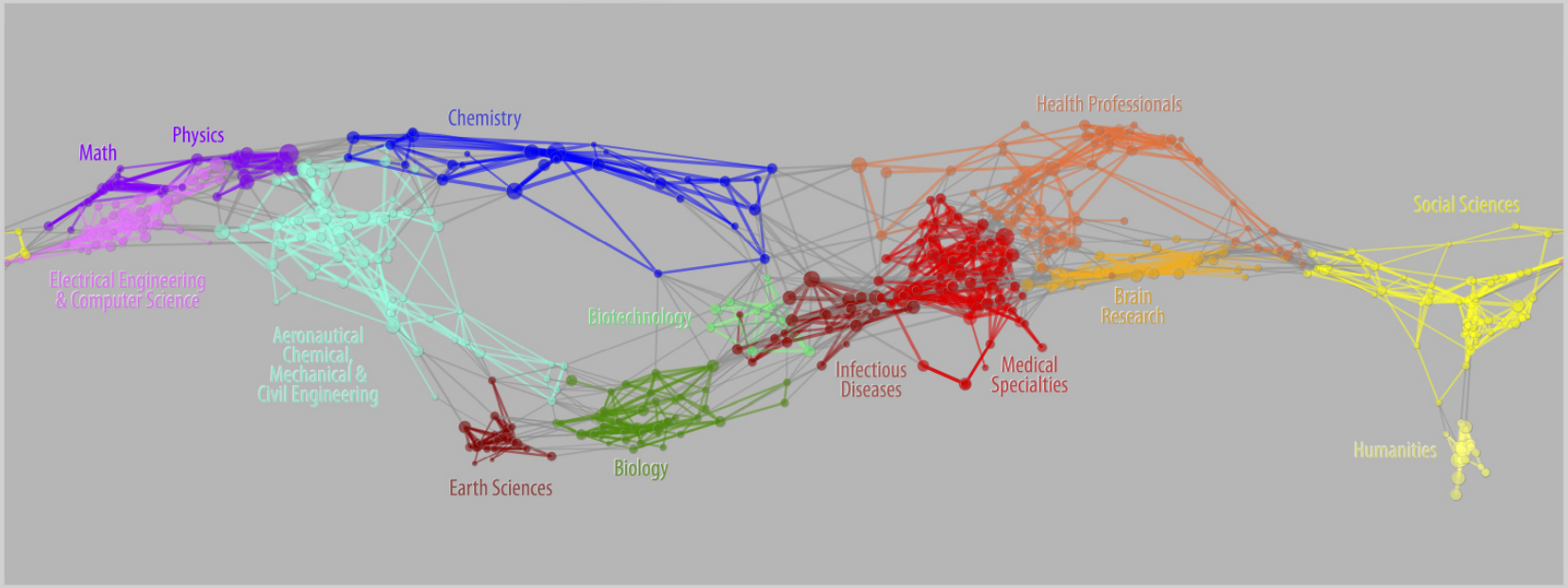
The six map projections shown at the bottom are images of what one would see if looking directly down at the south pole of the map, at six different rotations. When viewed this way, the map looks like a wheel with an inner ring and outer ring. This wheel of science corresponds very closely with the two-dimensional maps we have previously produced.

Forecasting Large Trends in Science

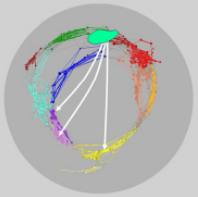
Calculations were performed using the large colored groupings of disciplines (fields) to determine if any of them were likely to cause large scale changes in the structure of science over time. Connectedness coefficients between fields were calculated for each individual year, 2001-2005. A simple regression analysis was conducted to see if there were significant changes in these connectedness coefficients from year-to-year.

If the structure of science shown below is moving toward stability, we would expect connectedness between neighboring fields to increase, and connectedness 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.

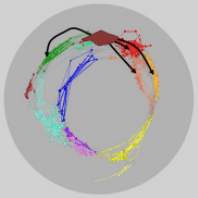
Six stories, representing how the structure is likely to change, are provided below. Maps with white arrows represent instances of distant fields that are likely to be pulled closer to each other in the future. Maps with dark arrows represent fields that are currently close-knit, that are likely to become more dispersed. We expect that future maps of science will show changes in stucture corresponding to these observations. Medicine will disperse slightly, while the physical sciences will tighten and draw closer to the medical fields.



Electrical Engineering & Computer Science (EE/CS), indicated by the pink shape in the view above, is a field whose connectedness has been increasing much more quickly (15%) than expected. Connectedness has increased between EE/CS and all other fields from 2001-2005. The connections with the largest annual increases (>10%) are shown by white arrows. Over time, these stronger connections will distort the map, and may bring EE/CS into a more central position.

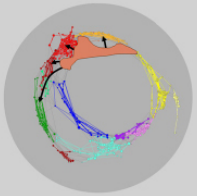


Biotechnology, indicated by the light green shape above, has the largest overall increase in connectedness with other fields (16%). It has relatively few connections with the EE/CS, Math & Physics, and Social Sciences fields, but these three connections had the largest fractional increase. The connection with EE/CS, which had the single largest growth rate (91%) of any connection, reflects recent growth in the area of bioinformatics.

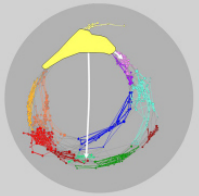


Infectious Diseases, indicated by the dark red shape above, has an overall decrease in connectedness (2%) with other fields. Decreases in connection strength between this field and the fields of Biology, Medical Specialties, Health Professionals and Brain Research (all >3%) are shown as black arrows, and will drive a slow dispersion of the medical fields compared to the current structure.

Medical Specialties, indicated by the red shape above, has an overall decrease in connectedness (2%) with other fields. This is dominated by decreasing connection strength to the other medical fields and biology, as shown by the black arrows. The only connection increasing in strength is the one to EE/CS, which is not shown here, but was shown as a white arrow in the first story.



The Health Professionals field, indicated by the orange shape above, has the largest overall decrease in connectedness (4%) to other fields. As with the other medical fields, its connection strength with medicine and biology is decreasing in all cases, as shown by the black arrows. With the decreasing connection strengths throughout medicine, we expect the map structure in these areas to relax slightly over time.



The Social Sciences, indicated by the yellow shape above, had an overall increase in connectedness (9%) with other fields. Although its greatest connectedness gains were with EE/CS and Biotechnology (see white arrows), it also had consistent connection increases with nearly all the other fields. In general the fields of EE/CS, Biotechnology, and the Social Sciences are become more connected, and are pulling on the physical sciences as well.

Source: University of California, San Diego Knowledge Mapping Laboratory. Color Images: © Regents of the University of California. The underlying data came from two sources: Thomson ISI and Scopus. Mapping methodology and descriptive text by Dick Klavans, President, SciTech Strategies, Inc., and Kevin Boyack, Sandia National Laboratories. Graphics & typography by Ethan Meillier and Mike Patek.
Special acknowledgements to Katy Borner, Art Ellis, W. Bradford Paley, Len Simon, and Henry Small.
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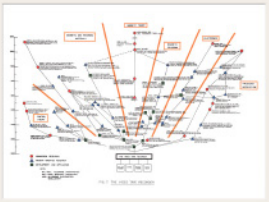
Maps of Science: Forecasting Large Trends in Science - Richard Klavans, Kevin Boyack - 2007

Science Maps for Economic Decision Makers 2008

IV.1



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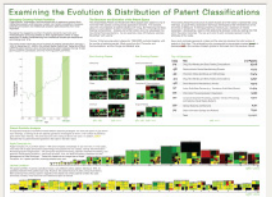

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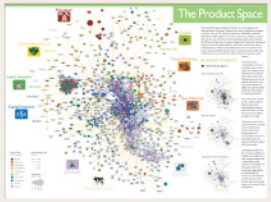

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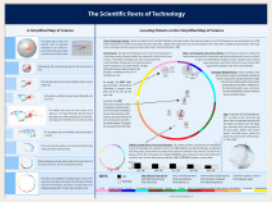

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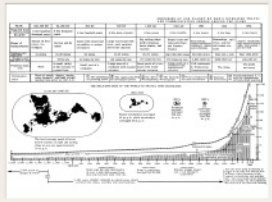

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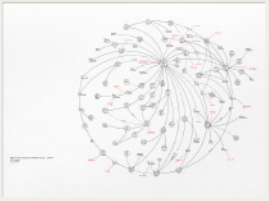

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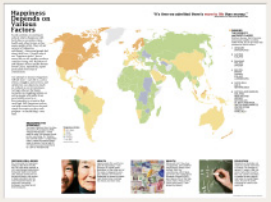
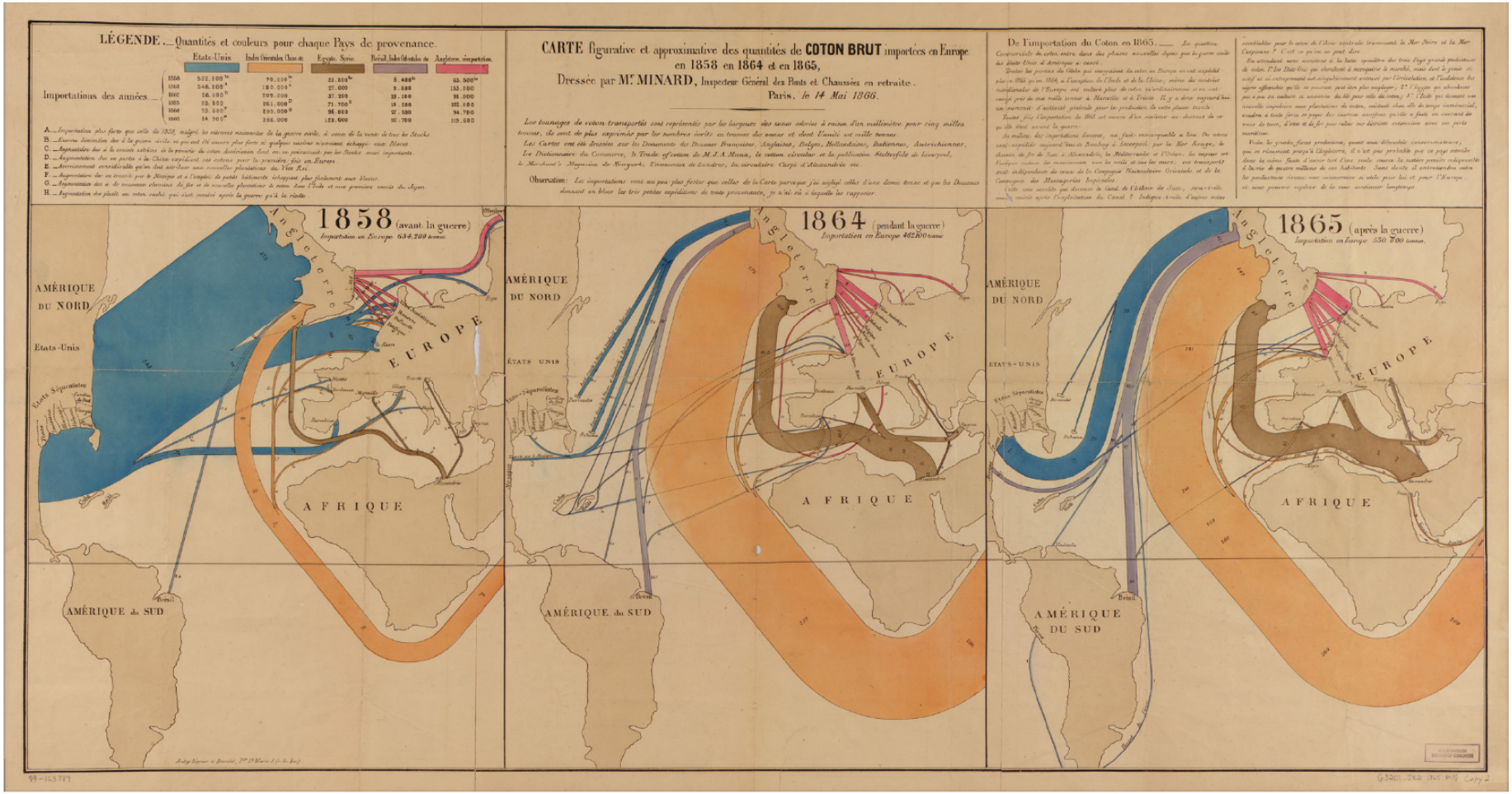
IV.8



IV.10

What insight needs do economic decision makers have?

What data views are most useful?



Europe Raw Cotton Imports in 1858, 1864 and 1865 - Charles Joseph Minard - 1866

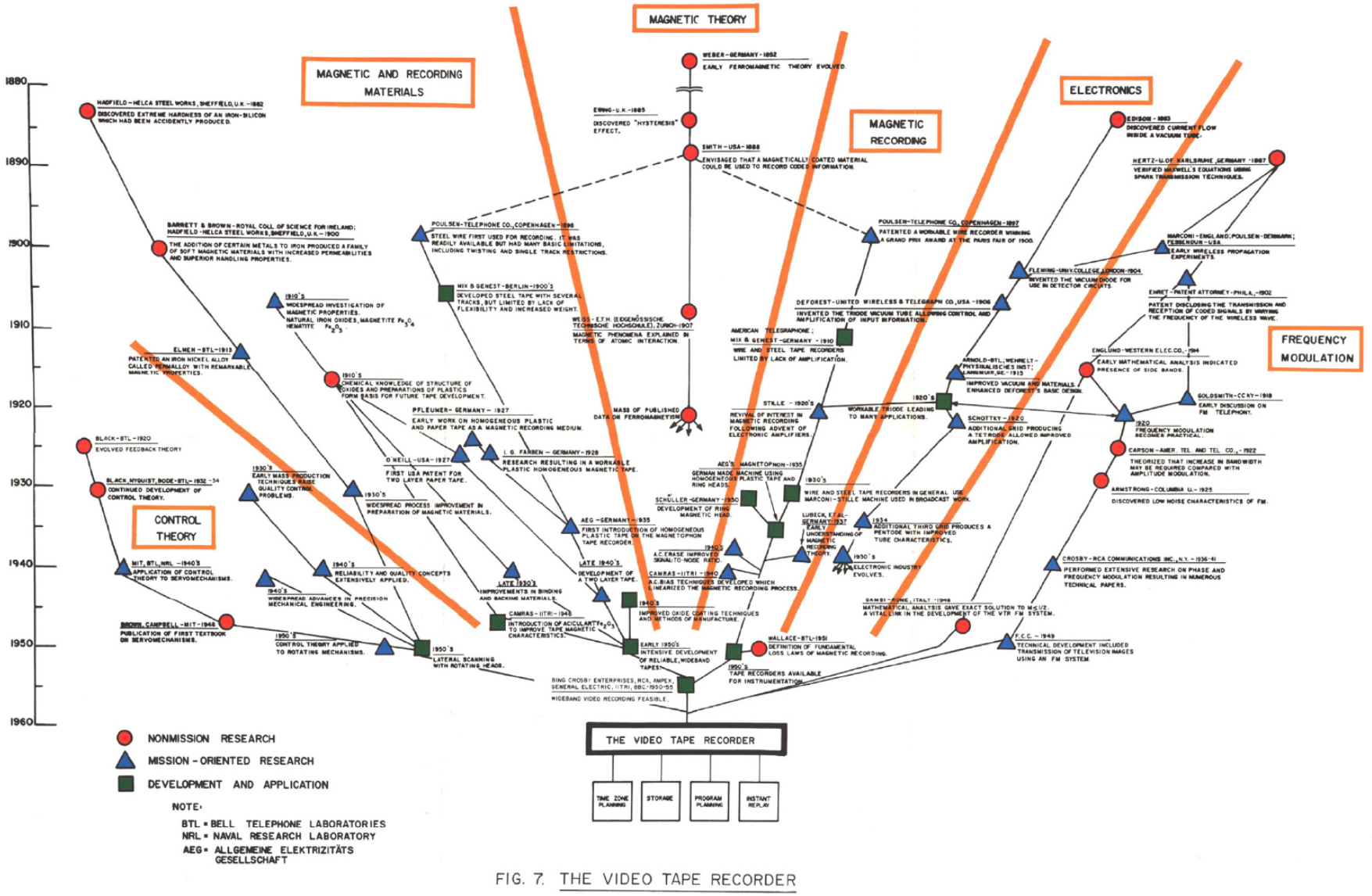


FIG. 7. THE VIDEO TAPE RECORDER

Tracing of Key Events in the Development of the Video Tape Recorder - Mr. G. Benn, Francis Narin - 1968

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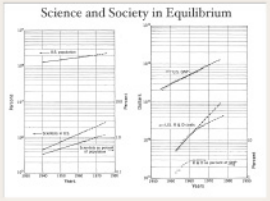
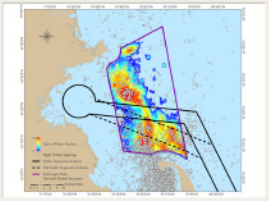


V.1



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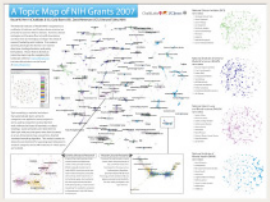
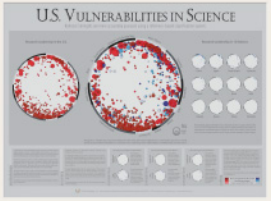


V.7



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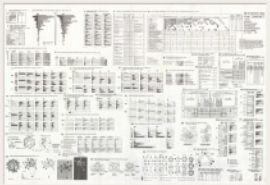

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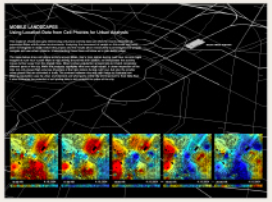

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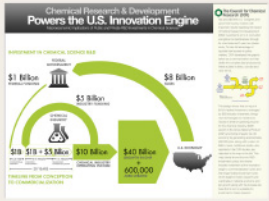

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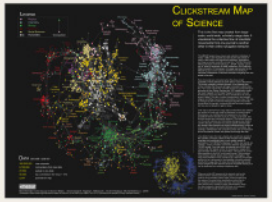
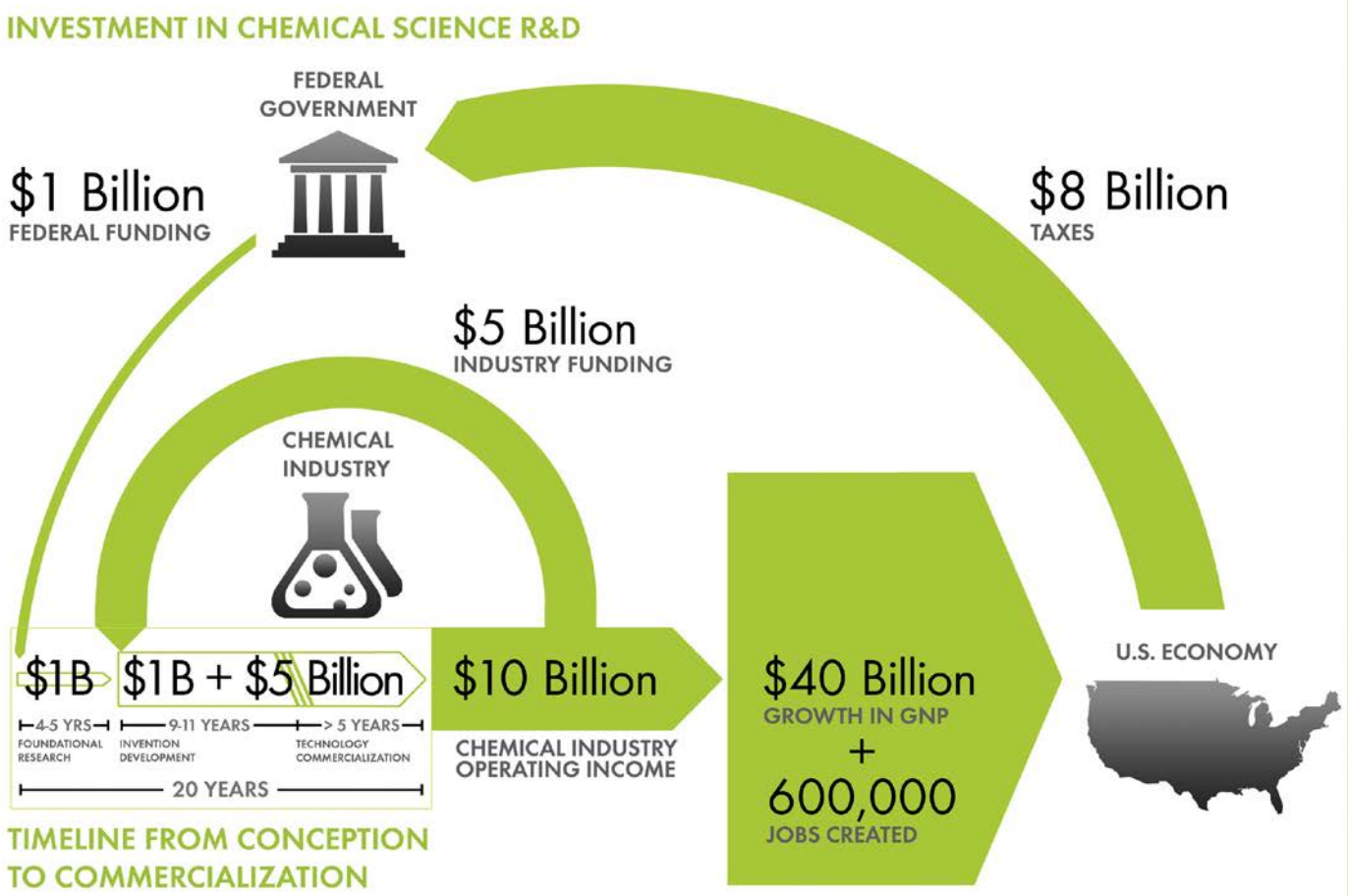


V.8

V.10

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

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



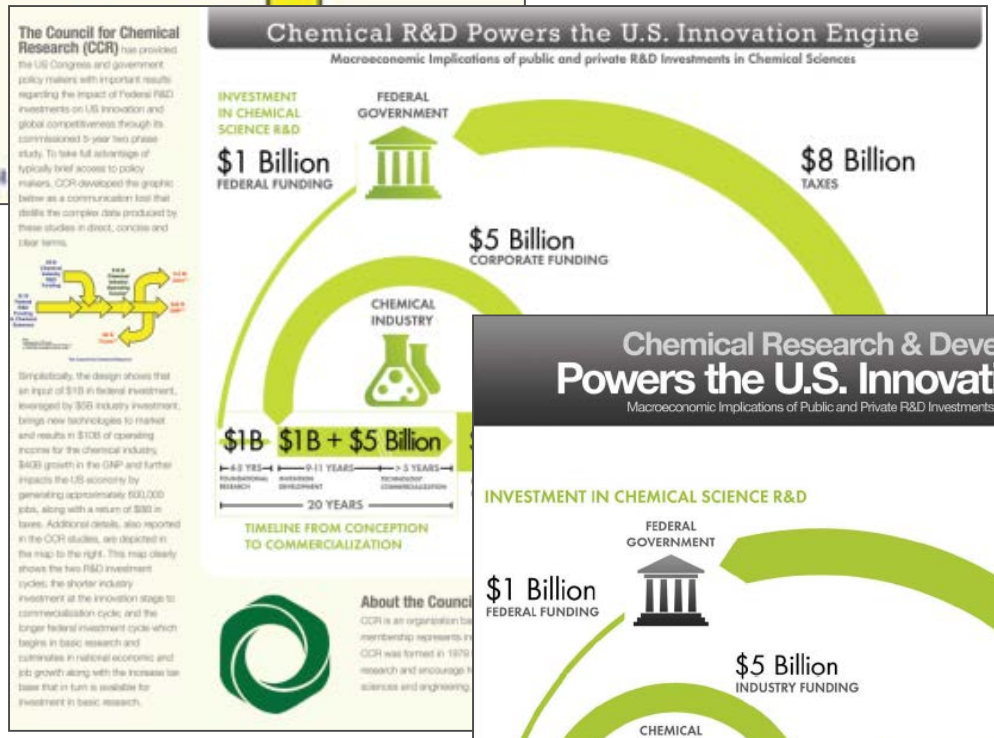
The Council for Chemical Research (CCR)

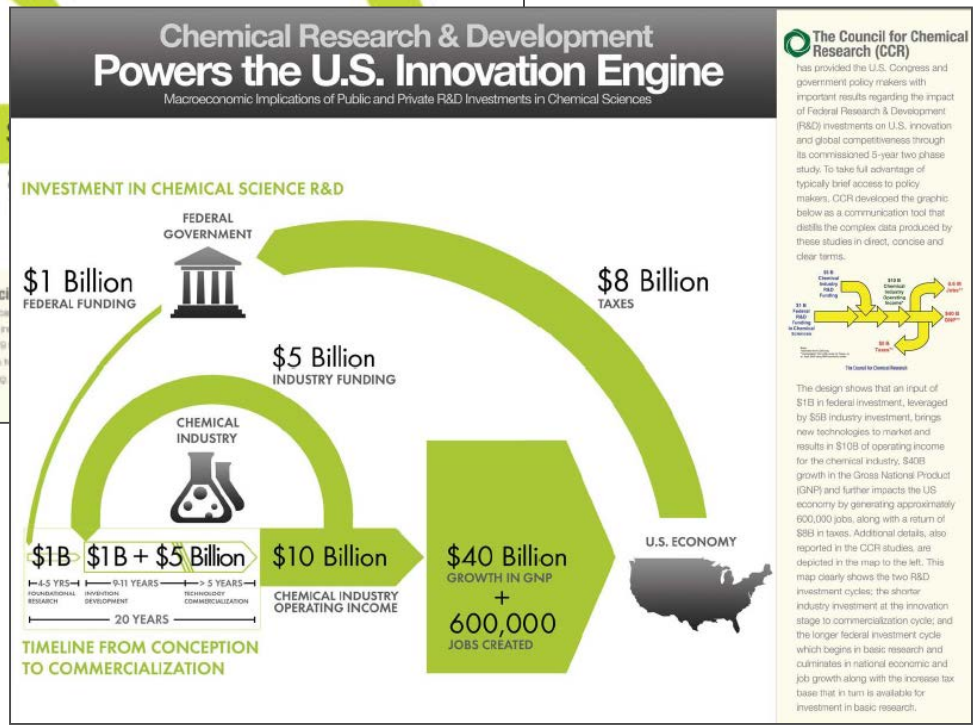
has provided the U.S. Congress and government policy makers with important results regarding the impact of Federal Research & Development (R&D) investments on U.S. innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to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

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

Chemical R&D Powers the U.S. Innovation Engine - The Council for Chemical Research - 2009

$5 B
Chemical
Industry
R&D
Funding
$1 B
Federal
R&D
Funding
In Chemical
Sciences
$10 B
Chemical
Industry
Operating
Income*
0.6 M
Jobs**
$40 B
GNP**


The Council for Chemical Research (CCR) has provided the US Congress and government policy makers with important results regarding the impact of Federal R&D investments on US innovation and global competitiveness through its commissioned 5-year two phase study. To take full advantage of typically brief access to policy makers, CCR developed the graphic below as a communication tool that distills the complex data produced by these studies in direct, concise and clear terms.
Chemical R&D Powers the U.S. Innovation Engine
Macroeconomic Implications of public and private R&D Investments in Chemical Sciences
INVESTMENT IN CHEMICAL SCIENCE R&D
FEDERAL GOVERNMENT
$1 Billion
FEDERAL FUNDING
$8 Billion
TAXES
$5 Billion
CORPORATE FUNDING
CHEMICAL INDUSTRY
$1B
$1B + $5 Billion
4-5 YRS
9-11 YEARS
> 5 YEARS
20 YEARS
TIMELINE FROM CONCEPTION TO COMMERCIALIZATION
About the Council


Chemical Research & Development
Powers the U.S. Innovation Engine
Macroeconomic Implications of Public and Private R&D Investments in Chemical Sciences
INVESTMENT IN CHEMICAL SCIENCE R&D
FEDERAL GOVERNMENT
$1 Billion
FEDERAL FUNDING
$8 Billion
TAXES
$5 Billion
INDUSTRY FUNDING
CHEMICAL INDUSTRY
$1B
$1B + $5 Billion
$10 Billion
CHEMICAL INDUSTRY OPERATING INCOME
4-5 YRS
FOUNDATIONAL RESEARCH
9-11 YEARS
INVENTION DEVELOPMENT
> 5 YEARS
TECHNOLOGY COMMERCIALIZATION
20 YEARS
TIMELINE FROM CONCEPTION TO COMMERCIALIZATION
$40 Billion
GROWTH IN GNP
+
600,000
JOBS CREATED
U.S. ECONOMY
The Council for Chemical Research (CCR)
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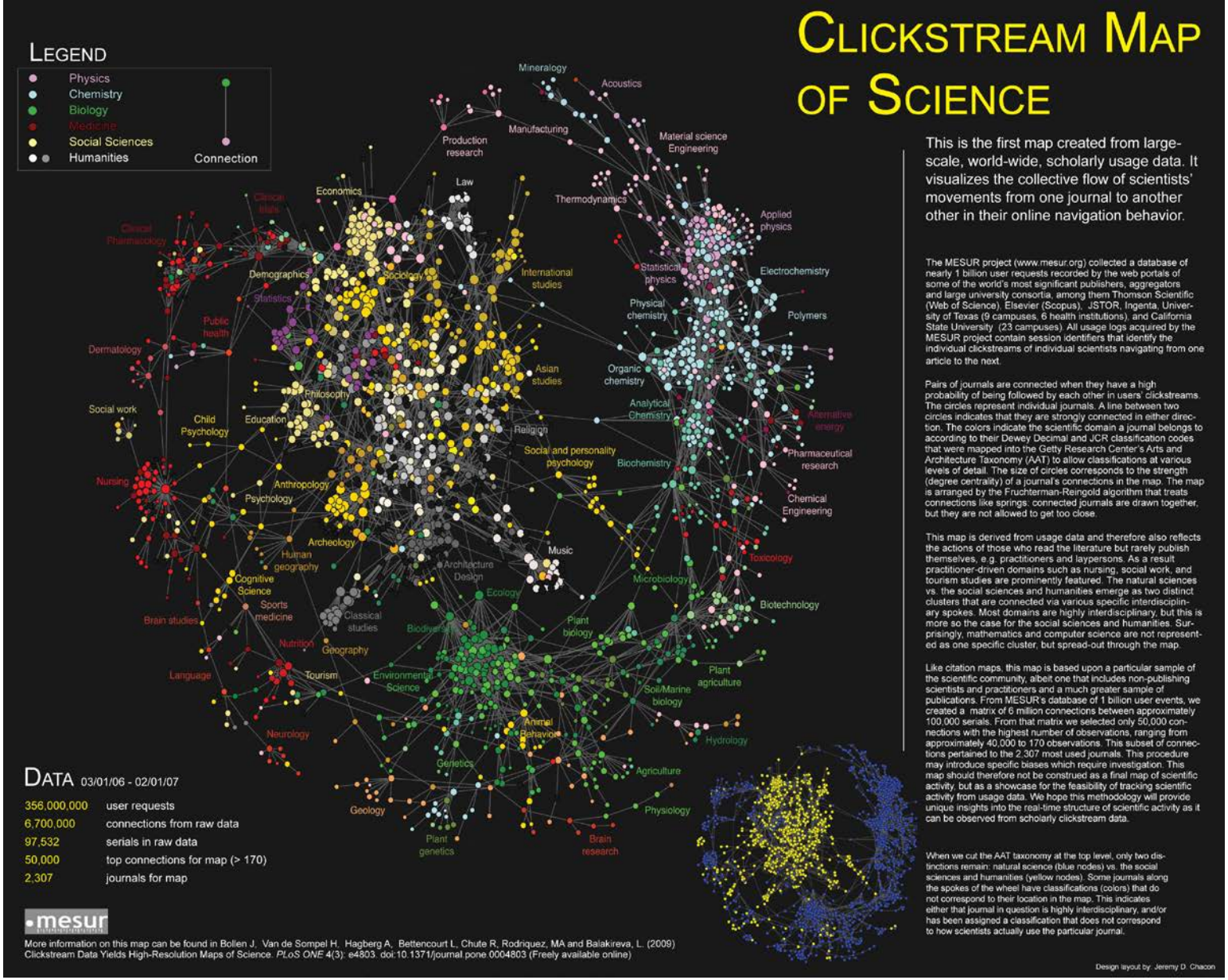
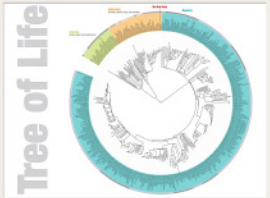


A Clickstream Map of Science. Johan Bollen, Herbert Van de Sompel, Aric Hagberg, Luís M. A. Bettencourt, Ryan Chute, Marko A. Rodriguez, and Lyudmila Balakireva - 2008

Science Maps for Scholars 2010



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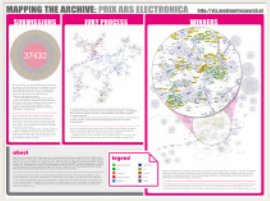

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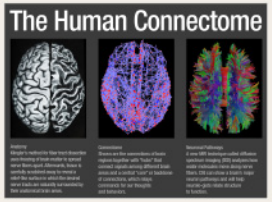

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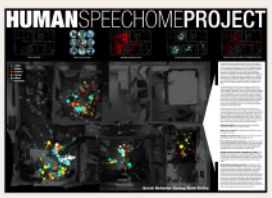

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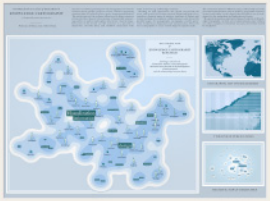

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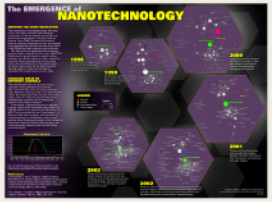

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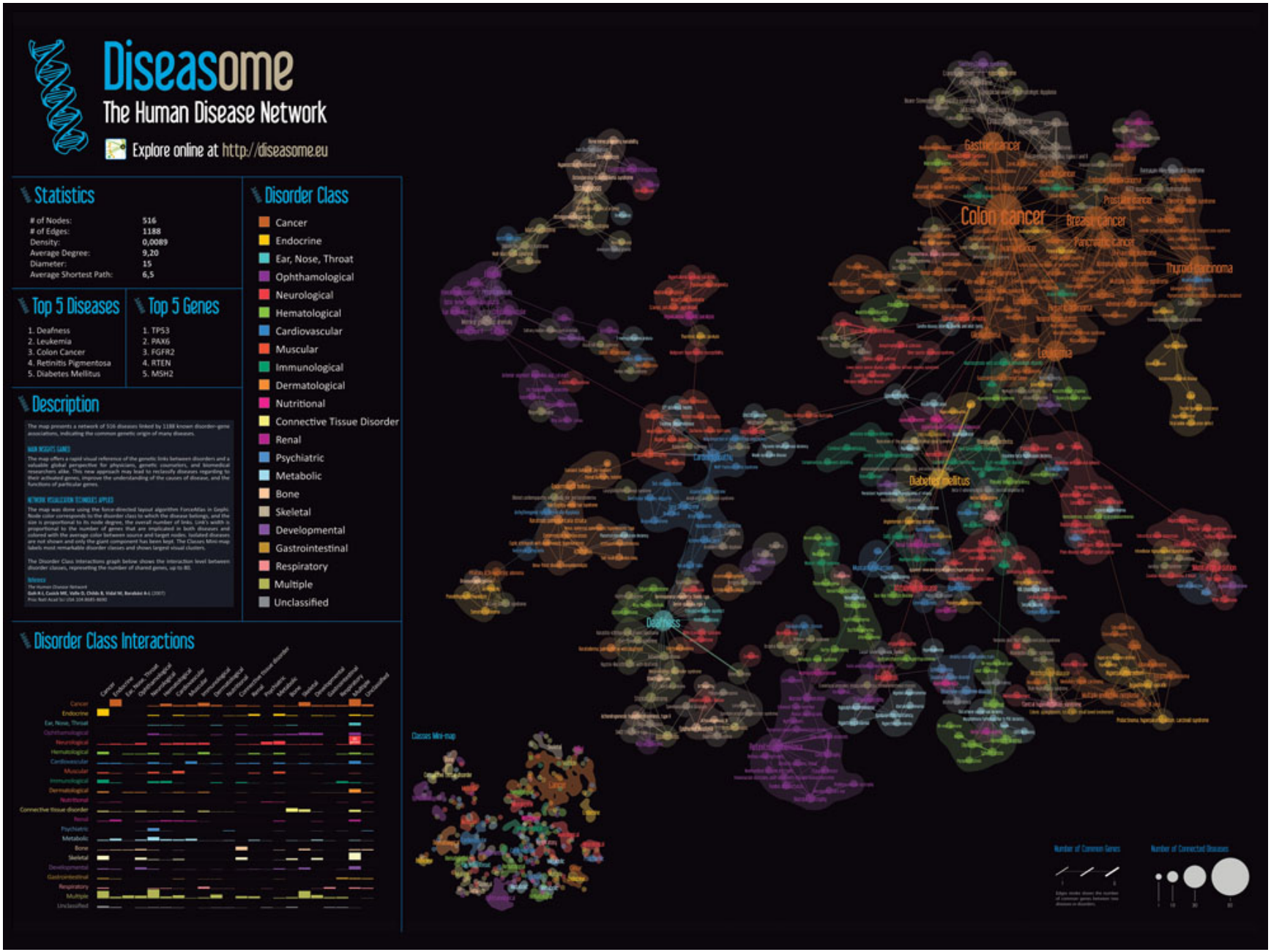
VI.10



Diseasome - Mathieu Bastian & Sebastien Heymann - 2009

The EMERGENCE of NANOTECHNOLOGY

MAPPING THE NANO REVOLUTION

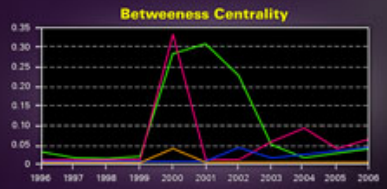
The emergence of nanotechnology has been one of the major scientific-technological revolutions in the last decade and it led to a structural reorganization of major fields of science. Price (1965) showed that fields of science and their development can be mapped using aggregated citations among the journals in the fields and their relevant environments.

The frames to the right show the evolving journal citation network for the years 1998-2003. Distances are proportional to cosine values between the citation patterns of the respective journals. Textual 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 betweeness 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. 2001. This is preceded by the "intervention" 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 specialty structure with low BC value journals results.

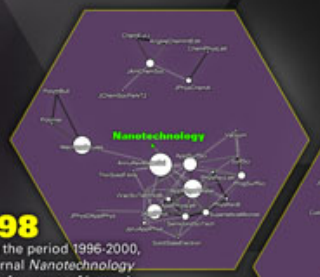


An animated sequence of this evolution is at: http://www.leydesdorff.net/journals/nanotech.

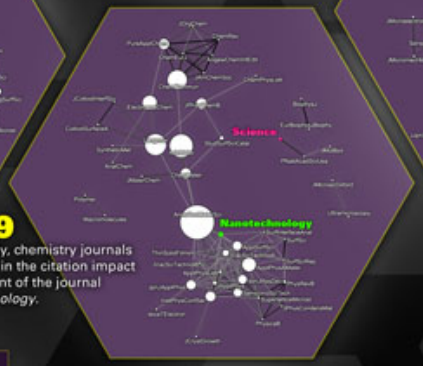
References

Leydesdorff, L. and T. Schank. 2008. Dynamic Animations of Journal Maps: Indicators of Structural Change and Interdisciplinary Developments. *Journal of the American Society for Information Science and Technology*, 59(11), 1810-1818.

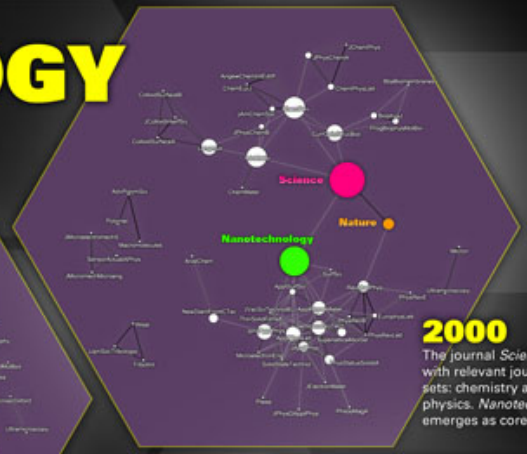
Price, Derek J. de Solla (1965). Networks of scientific papers. *Science*, 149, no. 3683, 510- 515.



1998
During the period 1996-2000, the journal *Nanotechnology* is part of a group of journals in applied physics.



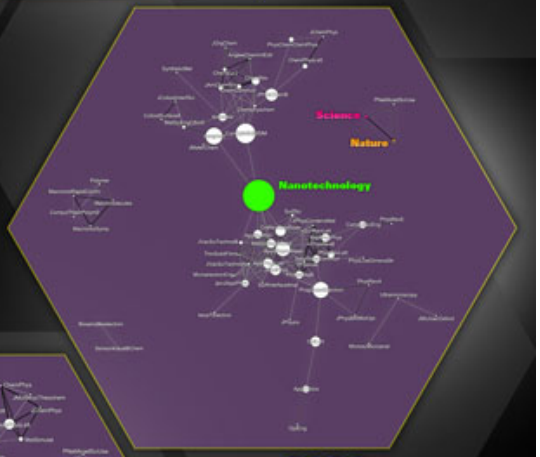
1999
Increasingly, chemistry journals play a role in the citation impact environment of the journal *Nanotechnology*.



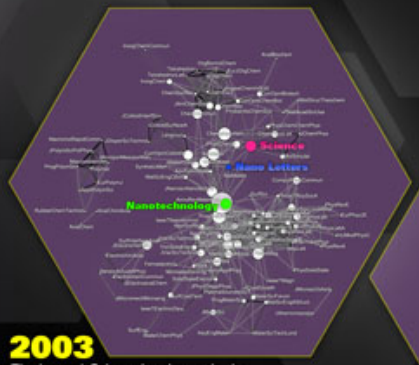
2000
The journal *Science* interfaces with relevant journals in both sets: chemistry and applied physics. *Nanotechnology* emerges as core journal.

LEGEND
- *Science*
- *Nature*
- *Nanotechnology*
- *Nano Letters*

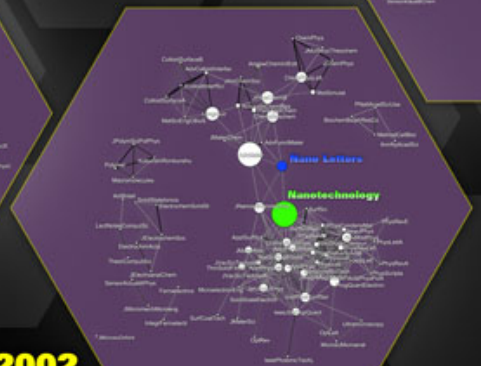
Values: 0.8, 0.22, 0.33



2001
The journal *Nanotechnology* now provides the interface between chemistry and physics. The "intervention" by *Science* is no longer needed.



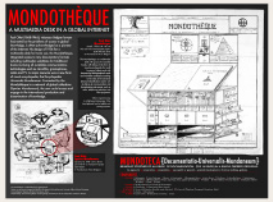
2003
The journal *Science* is relevant in the citation impact environment, but now functions as one of the specialist journals in nanotechnology. *Nanoscience* further develops as an increasingly integrated network of journals.



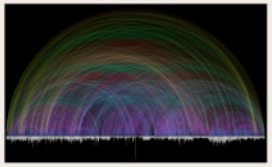
2002
Other journals in nanoscience and technology begin to emerge, and the bridging role of the journal *Nanotechnology* gradually subsides. *Nano Letters* and the *Journal of Nanoscience and Nanotechnology* join the new field of nanotechnology.

The Emergence of Nanoscience & Technology - Loet Leydesdorff - 2010

Science Maps as Visual Interfaces to Digital Libraries 2011



VII.1



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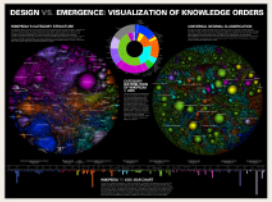

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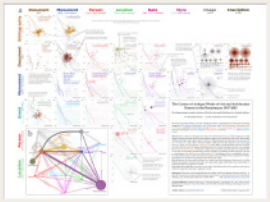

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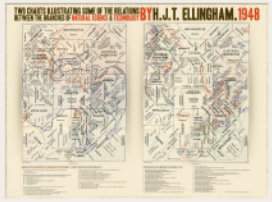

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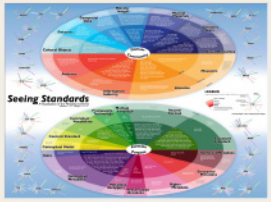
VII.6



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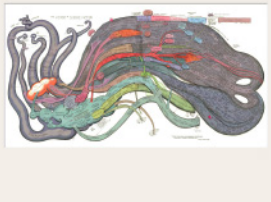

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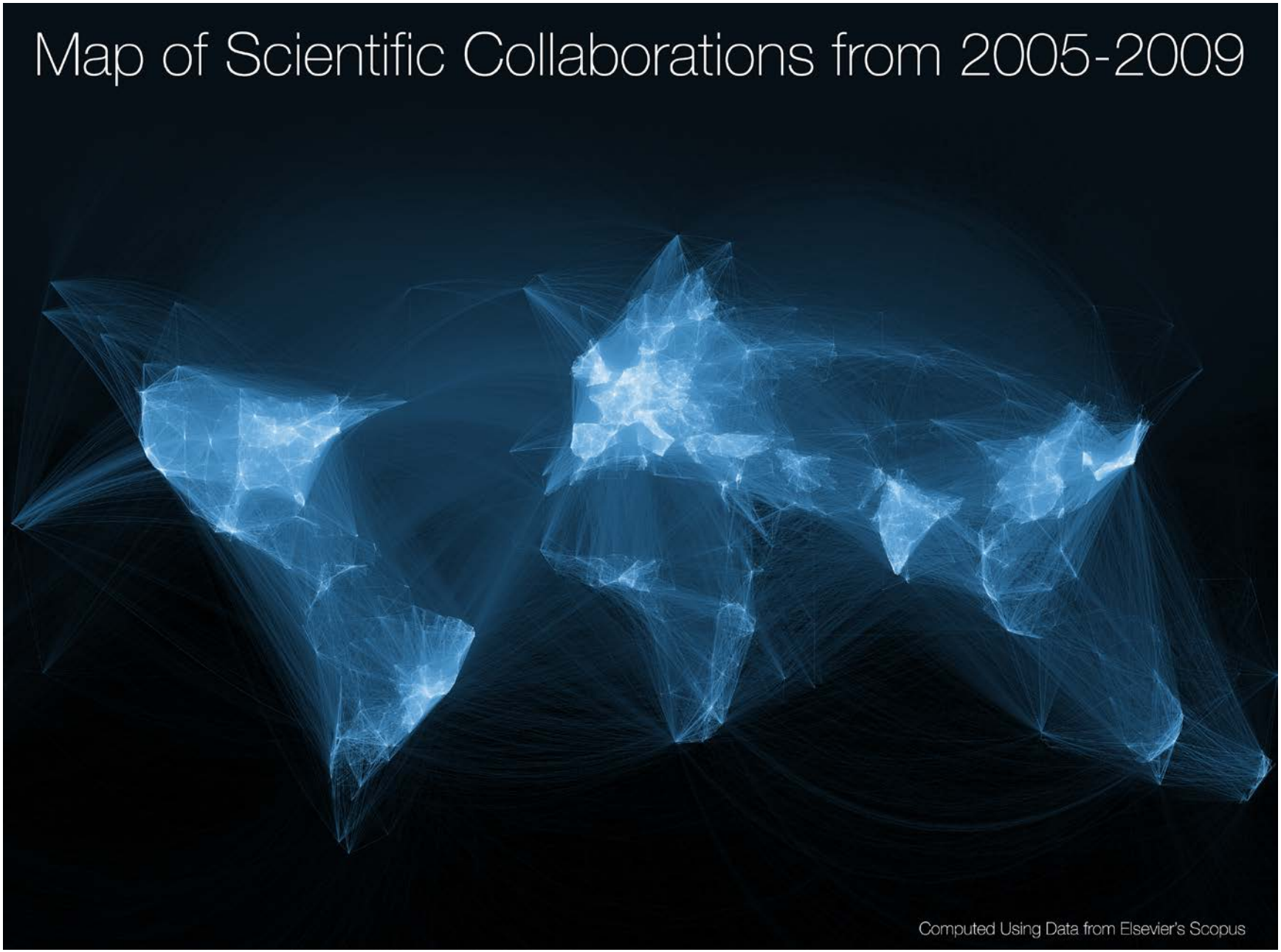
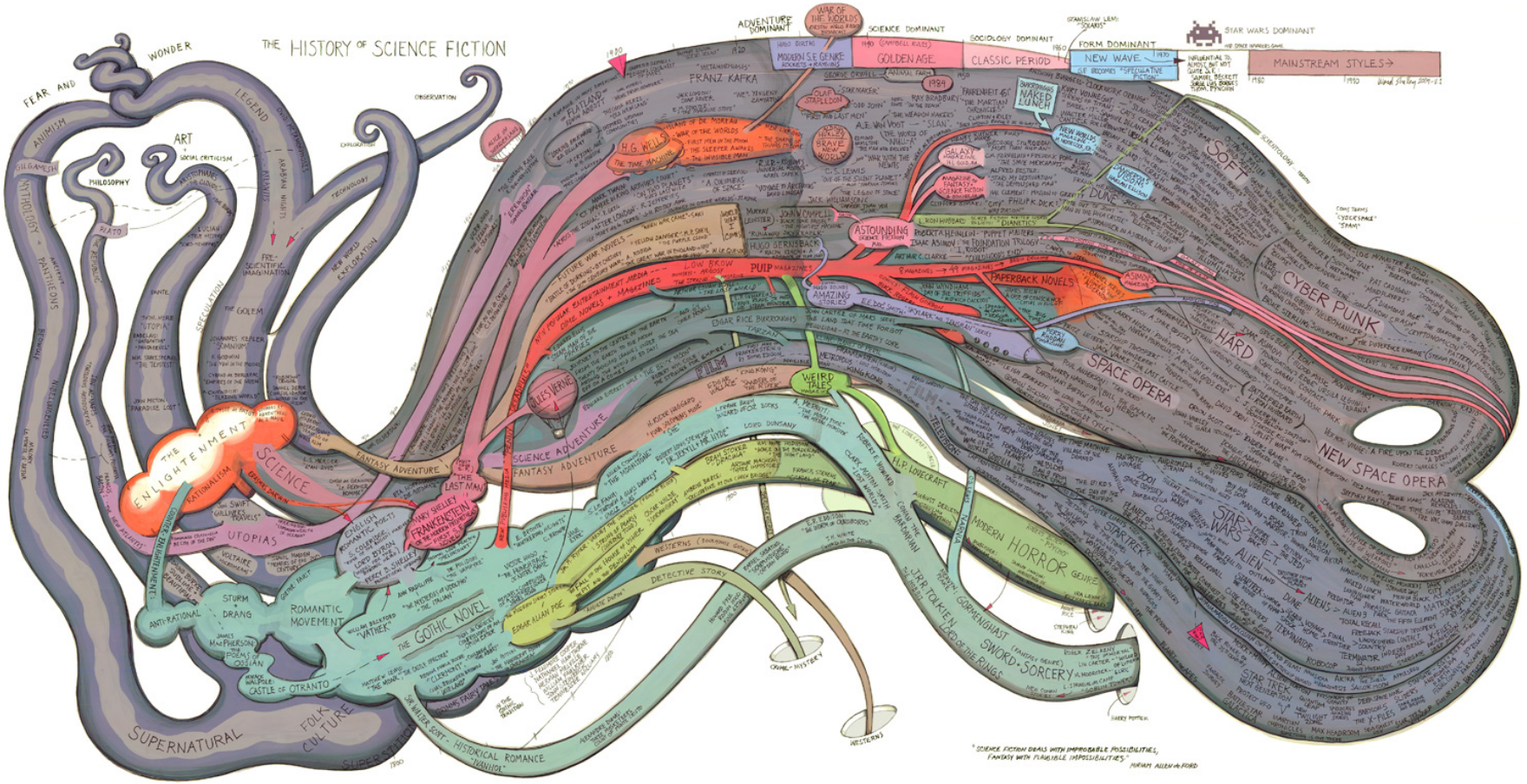


Stream of Scientific Collaborations Between World Cities - Olivier H. Beauchesne - 2012



History of Science Fiction - Ward Shelley - 2011

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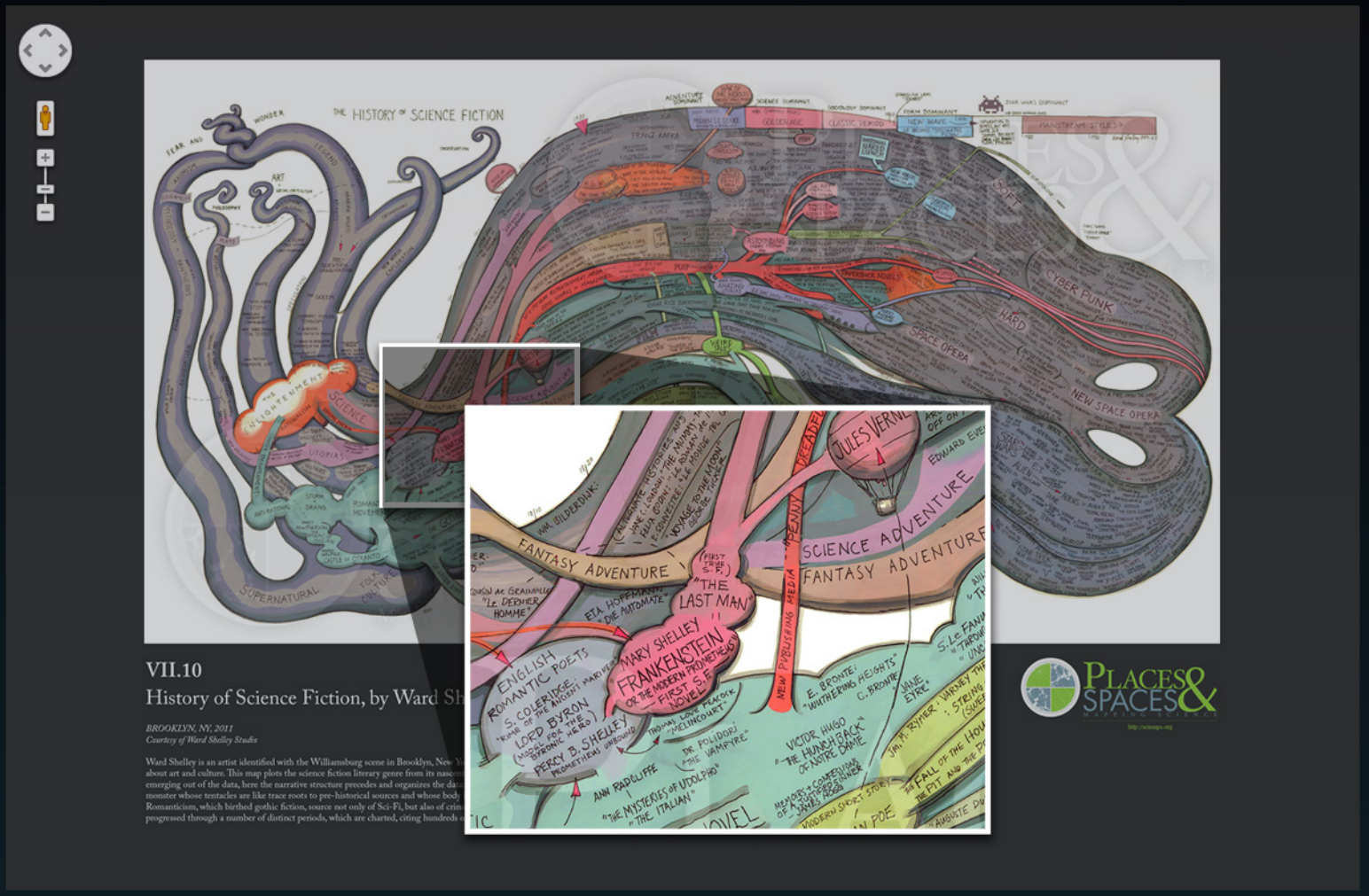

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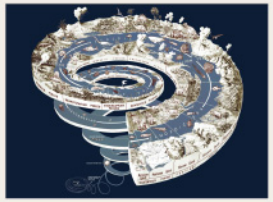
Science Maps for Kids 2012



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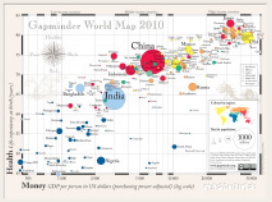

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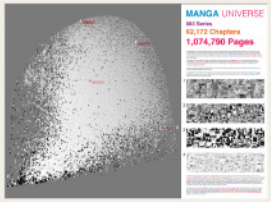

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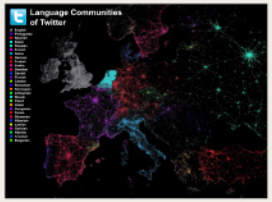

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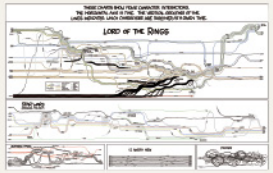

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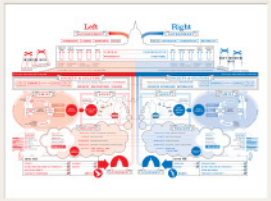

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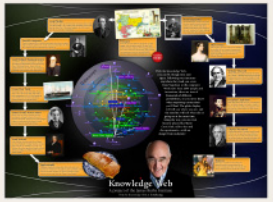
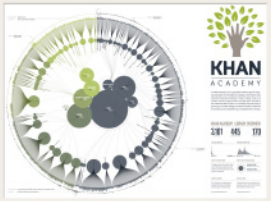
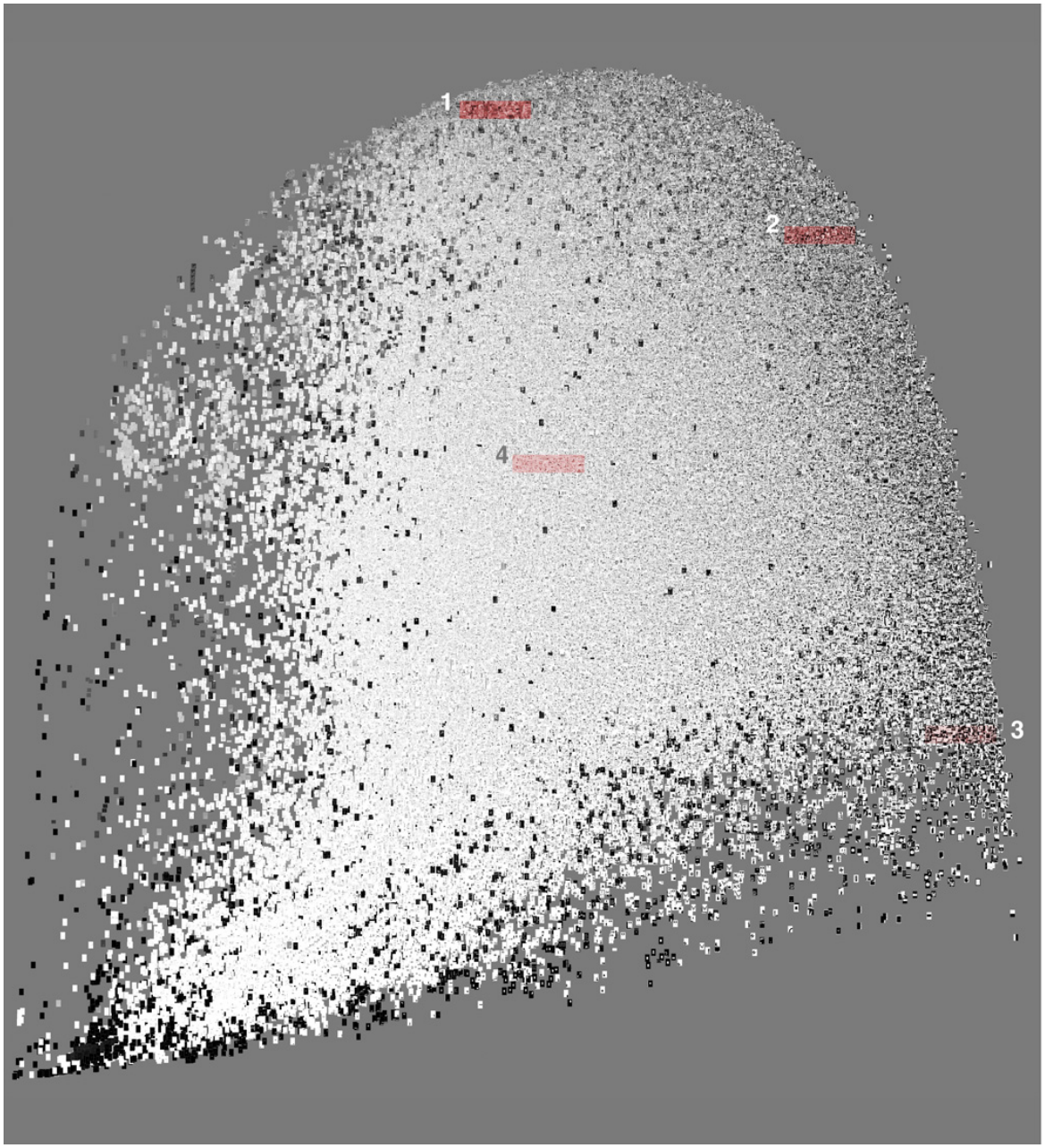


VIII.6

VIII.8



VIII.10



MANGA UNIVERSE

883 Series

62,172 Chapters

1,074,790 Pages

The digitization of cultural artifacts and the rise of social media create unprecedented opportunities for the study of visual culture. But how can we explore patterns and relations between sets of photographs, designs, or videos which may number in hundreds of thousands, millions, or billions? In 2007, we set up the Software Studies Initiative (www.softwarestudies.com) at University of California, San Diego (UCSD) and California Institute for Telecommunication and Information (Calit2) to address these challenges.

In fall 2009, we downloaded all pages of 883 different manga series from OneManga.com, the most popular web site for "scanlations," which refer to manga publications that are digitized and translated by fans. The resulting data set contains 1,074,790 manga pages. Each page is in the form of a JPEG image; average image resolution is 850 x 1150 pixels. The complete image set is 100 GB.

The map on the left shows the complete set of over one million pages organized according to contrast (horizontal axis) and amount of detail and texture (vertical axis).

The pages in the lower left of the map consist of a small number of flat areas, with minimum detail and no texture. The pages situated in the top part have lots of detail and texture. Pages with the lowest contrast are on the extreme left; pages with the highest contrast are on the extreme right.

1

2

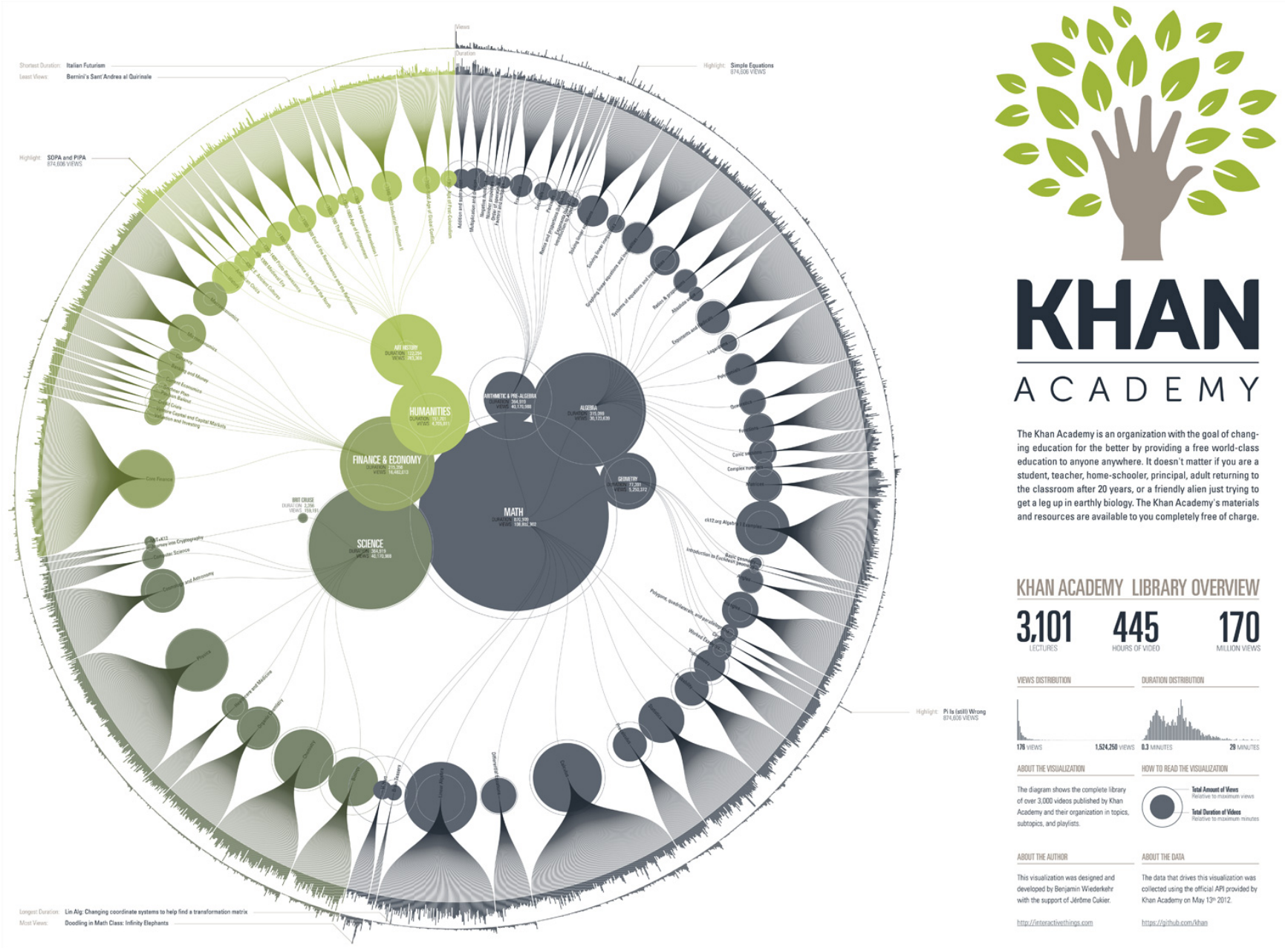
3

4

In between the four graphical extremes corresponding to the left, right, top, and bottom edges of the pages "cloud" we see practically infinite graphic variations. The density of this map suggests that the concept of style as it is normally used may become problematic when we consider very large cultural data sets. The concept assumes that we can partition a set of works into a small number of discrete categories. However, if we find a very large set of variations with very small differences between them, any attempt to divide this space into discrete stylistic categories will be arbitrary. It is important to keep in mind that this map only shows graphic variations along two dimensions—mapping other visual characteristics such as composition or representation of characters and their faces might split the cloud into distinct clusters.

Our map also shows which graphical choices are more commonly used by manga artists (the central part of the cloud of pages) and which appear much more rarely (bottom and left parts). If you are a beginning manga artist and want to establish a unique style, you may want to position yourself in either bottom or left parts of the map, which so far have not been explored by other artists. To see other visualizations and read papers about the one million manga pages project, visit www.softwarestudies.com.
Credits: Lev Manovich, Jay Chow.

Manga Universe - Lev Manovich and Jay Chow - 2012



KHAN ACADEMY

The Khan Academy is an organization with the goal of changing education for the better by providing a free world-class education to anyone anywhere. It doesn't matter if you are a student, teacher, home-schooler, principal, adult returning to the classroom after 20 years, or a friendly alien just trying to get a leg up in earthly biology. The Khan Academy's materials and resources are available to you completely free of charge.

KHAN ACADEMY LIBRARY OVERVIEW

3,101 LECTURES

445 HOURS OF VIDEO

170 MILLION VIEWS

VIEWS DISTRIBUTION

176 VIEWS — 1,524,250 VIEWS

DURATION DISTRIBUTION

0.3 MINUTES — 29 MINUTES

ABOUT THE VISUALIZATION

The diagram shows the complete library of over 3,000 videos published by Khan Academy and their organization in topics, subtopics, and playlists.

HOW TO READ THE VISUALIZATION

Total Amount of Views
Relative to maximum views

Total Duration of Videos
Relative to maximum minutes

ABOUT THE AUTHOR

This visualization was designed and developed by Benjamin Wiederkehr with the support of Jérôme Cukier.

http://interactivethings.com

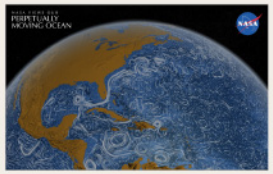
ABOUT THE DATA

The data that drives this visualization was collected using the official API provided by Khan Academy on May 13th 2012.

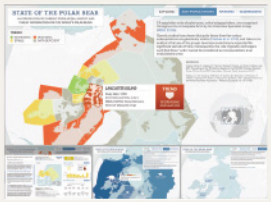
https://github.com/khan

Khan Academy Library Overview - Benjamin Wiederkehr and Jérôme Cukier - 2012

Science Maps Showing Trends and Dynamics 2013



IX.1



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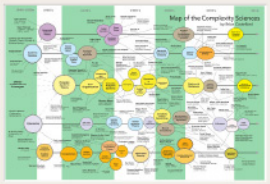

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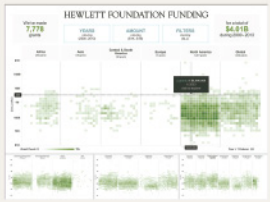

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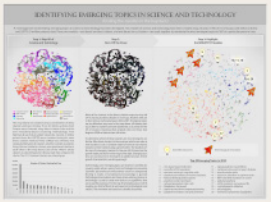

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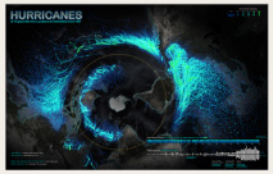
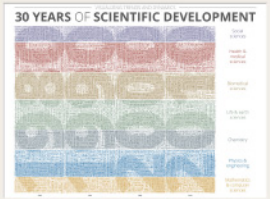


IX.2

IX.4



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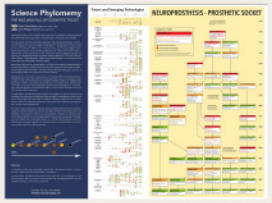

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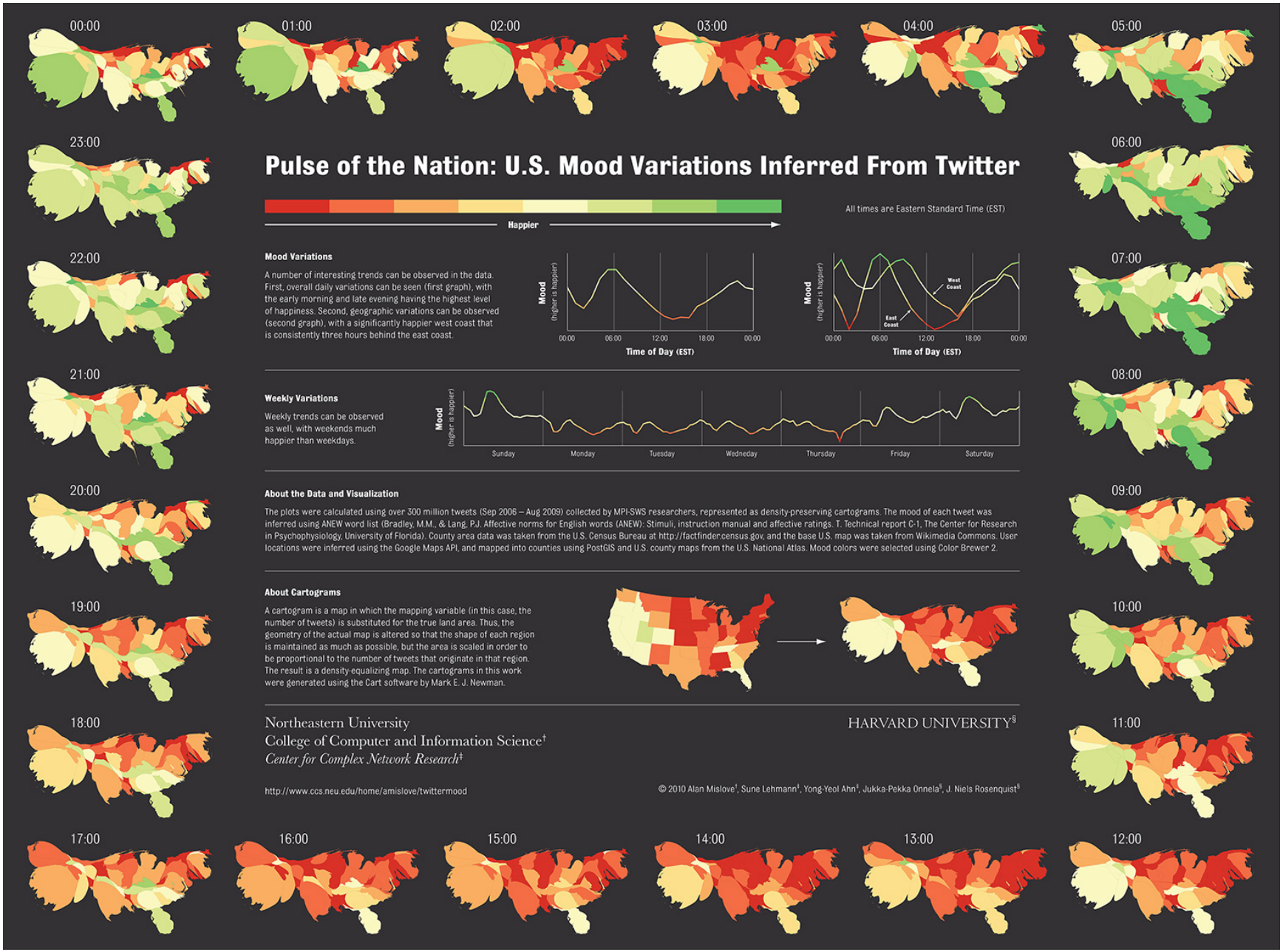
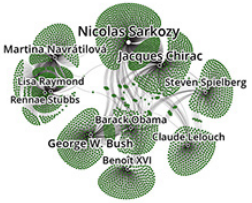


Pulse of the Nation - Alan Mislove, Sune Lehmann, Yong-Yeol Ahn, Jukka-Pekka Onnela, and James Niels Rosenquist - 2010

Who Really Matters in the World

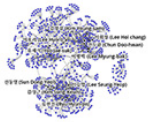
LEADERSHIP NETWORKS IN DIFFERENT-LANGUAGE WIKIPEDIAS

CHINESE 2011
Threshold of 30



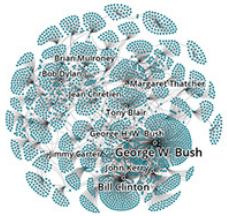
FRENCH 2011
Threshold of 250

ARABIC 2011
Threshold of 10

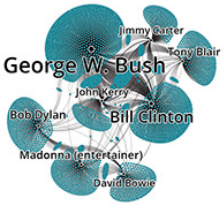


KOREAN 2011
Threshold of 10

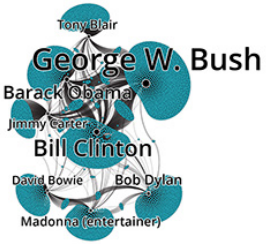
ENGLISH 2003
Threshold of 10



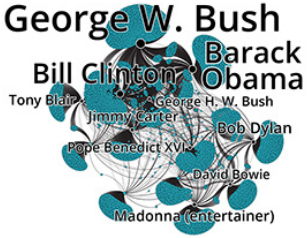
ENGLISH 2005
Threshold of 30



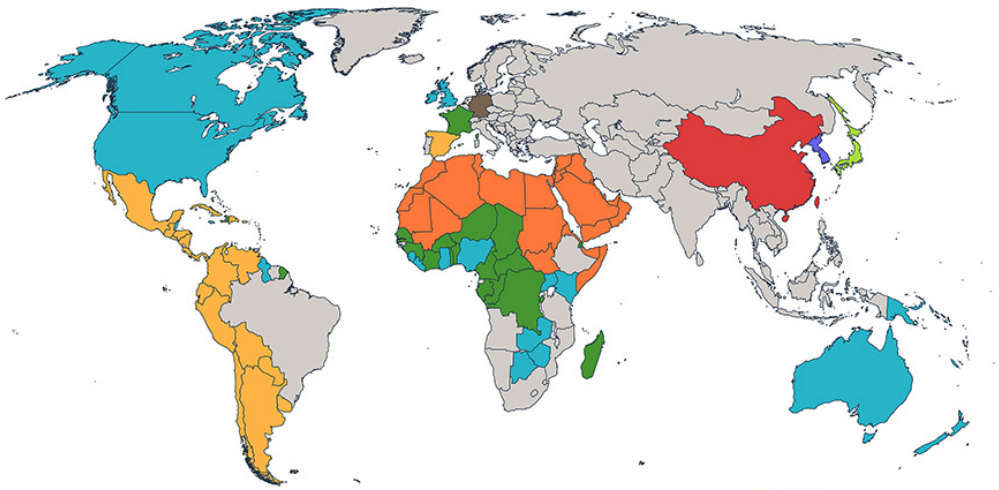
ENGLISH 2007
Threshold of 300



ENGLISH 2009
Threshold of 500



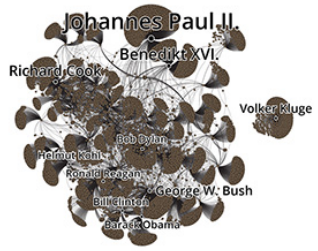
ENGLISH 2011
Threshold of 500



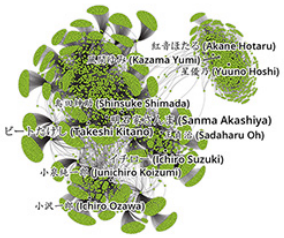
Shown are the networks of living people and their friendship, business, and animosity links retrieved from eight different-language Wikipedias. Network nodes, geospatial regions in which the languages are spoken, and the tabular listing of the number of living people in 2011 are color-coded. The networks show living people interconnection for eight different languages. Because the size of the complete networks was too large, different thresholds were applied (see numbers on map). Native language names and English translations are listed for key people nodes. Different networks have rather different global and local structures revealing the (dis)connectedness of politicians, musicians, athletes, and others. The lower five figures showcase the evolution of the English network between 2003-2011. For example, the U.S. President Barack Obama node becomes dominant when he is elected in 2009 and shows a major increase in importance in 2011, providing a near real-time window into current history and culture through the lens of Wikipedians.

Largest node: **3240 links** | Median node: **1553 links** | Smallest node:

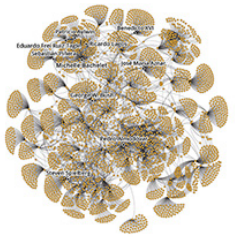
Color	Language, Year	# of Living People Articles	# of Articles	Ratio
	English, 2003	3,409	109,000	3.13%
	English, 2005	38,996	464,000	8.40%
	English, 2007	193,058	1,600,000	12.07%
	English, 2009	348,552	2,700,000	12.91%
	English, 2011	467,340	3,500,000	13.35%
	German, 2011	194,043	1,200,000	16.2%
	French, 2011	126,053	1,100,000	11.5%
	Japanese, 2011	102,082	742,000	13.8%
	Spanish, 2011	41,827	728,000	5.7%
	Chinese, 2011	23,963	339,000	7.1%
	Korean, 2011	5,379	158,000	3.4%
	Arabic, 2011	15,921	171,744	9.27%



GERMAN 2011
Threshold of 150



JAPANESE 2011
Threshold of 150



SPANISH 2011
Threshold of 50

Who Really Matters in the World—Leadership Networks in Different-Language Wikipedias

Peter A. Gloor, Keiichi Nemoto, Samuel T. Mills, and David E. Polley - 2013

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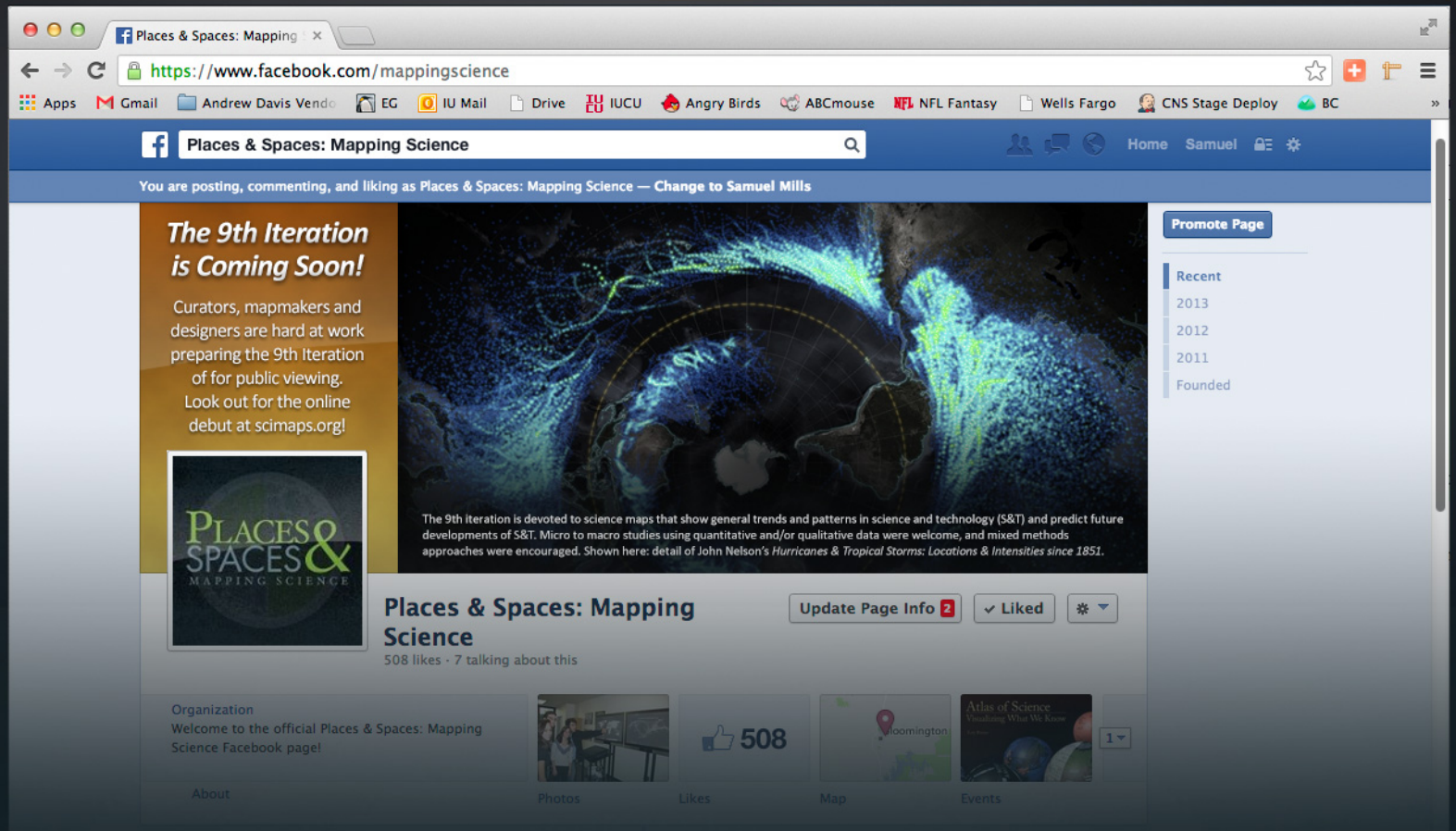

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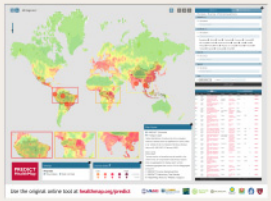
The Future of Science Mapping 2014

X.1

X.2



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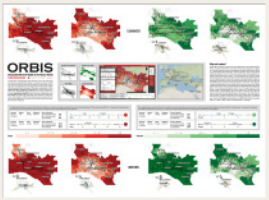

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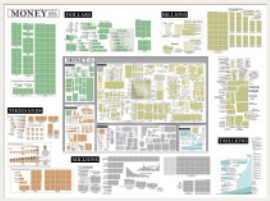

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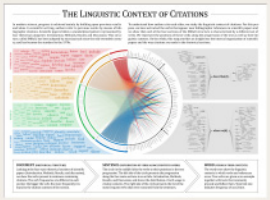

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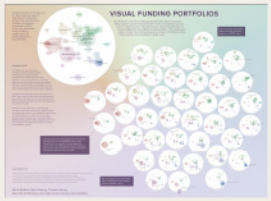

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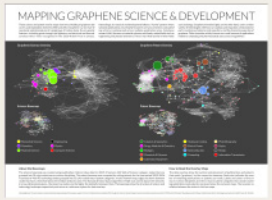

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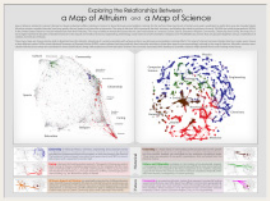

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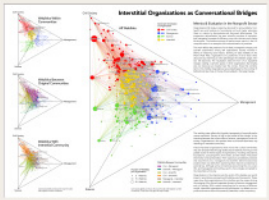

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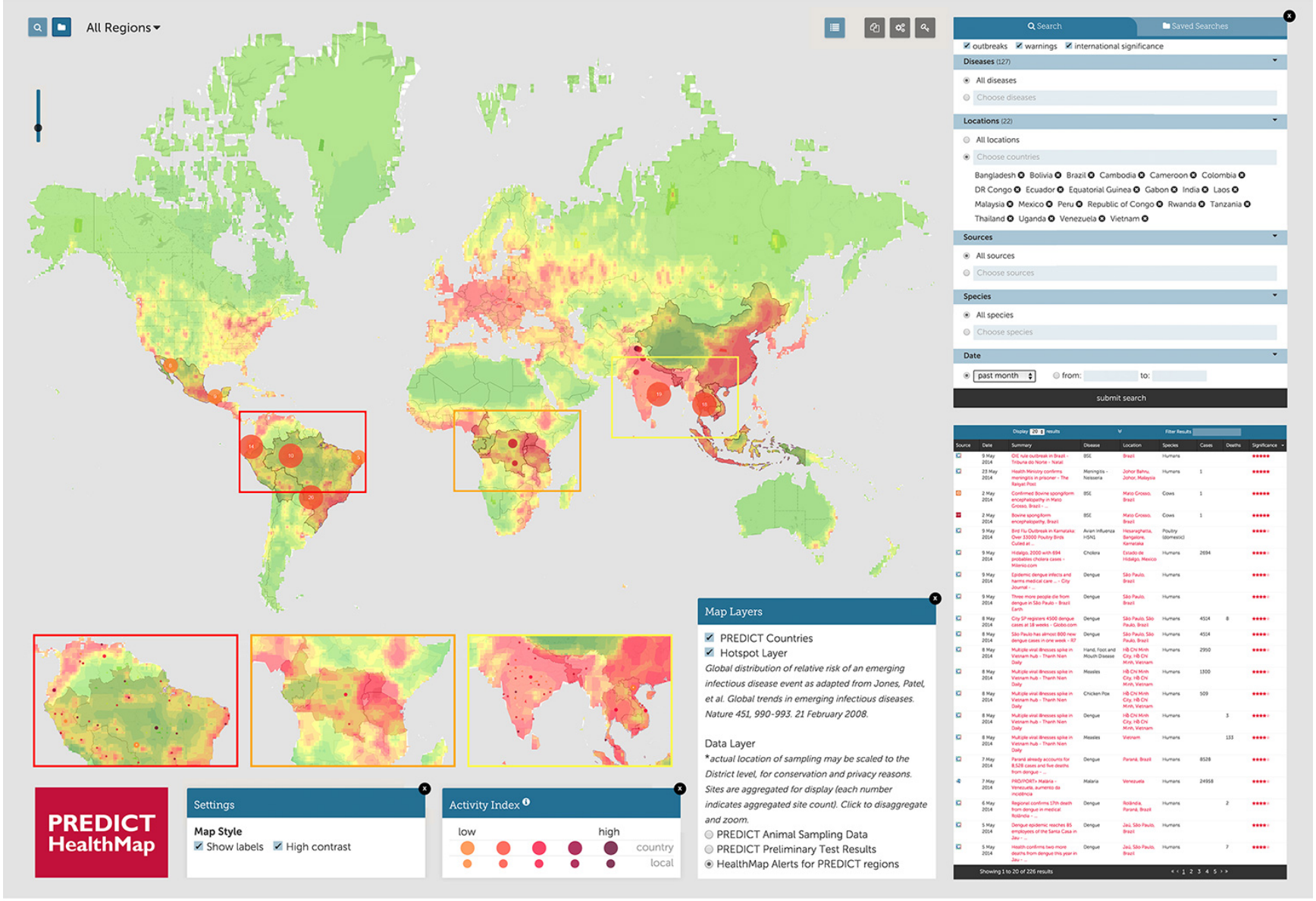


Use the original online tool at **healthmap.org/predict**

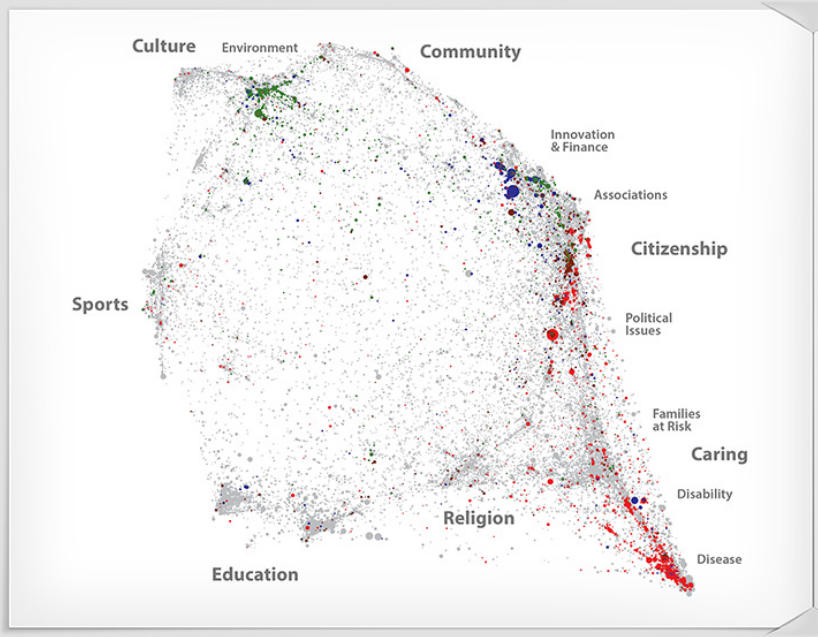
PREDICT: HealthMap - John Brownstein, Damien Joly, William Karesh, Peter Daszak, Nathan Wolfe, Tracey Goldstein, Susan Aman, Clark Freifeld, Sumiko Mekaru, Tammie O'Rourke, Stephen Morse, Christine Kreuder Johnson, Jonna Mazet, and the PREDICT Consortium - 2014

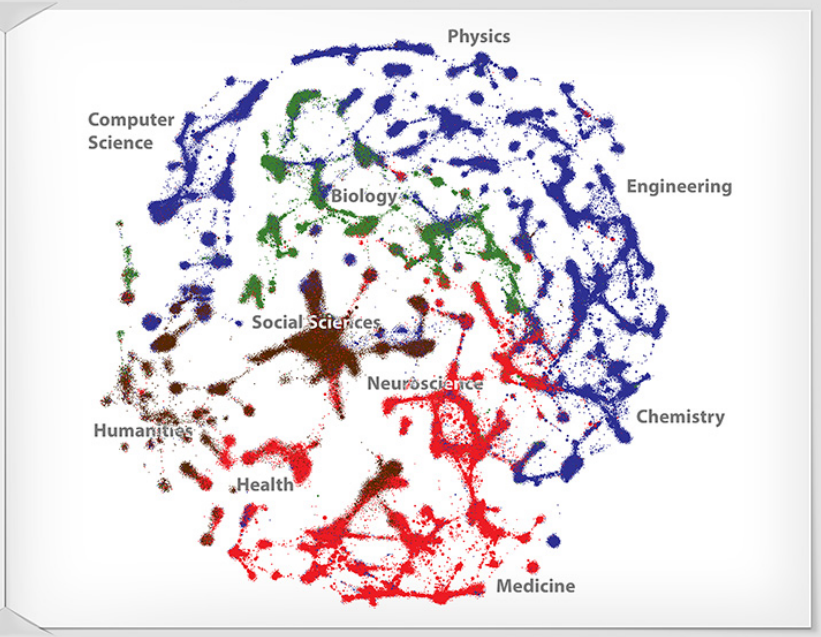
Map of the Internet - Martin Vargic - 2014

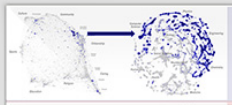
Exploring the Relationships Between
a Map of Altruism and a Map of Science

How is altruism related to science? Altruism is about individual selfless intentions. Science is about discovery and problem solving. On the surface these two facets of society may seem unrelated. In reality they may be strongly linked. Altruistic missions explain historical (and may predict future) patterns of scientific investments. The map of altruism (left) represents altruistic missions, and displays the relative positions of nearly 100,000 non-profit organizations (NPOs) in the United States based on mission-related text from their websites. This map of altruism reveals the issues that we care most about as a society: *Culture*, *Sports*, *Education*, *Religion*, *Community*, *Citizenship*, and *Caring*. The map of science (right) represents decades of funded research in the natural and medical sciences, engineering, technology, social sciences and humanities. It displays over 43,000,000 documents that are grouped together using a combination of citation and textual similarity.

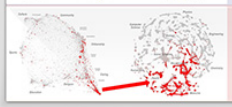
These two maps are shown side-by-side to illustrate how the altruistic intentions of a society correlate with where we focus our discovery and problem solving efforts. The map of science has been divided into four major areas, shown in four different colors. NPOs whose National Taxonomy of Exempt Entities (NTEE) codes indicate that they explicitly fund scientific activities in these four areas are correspondingly colored in the map of altruism. Altruistic missions associated with these four areas are considered in more detail below, along with projections of how altruistic missions not currently associated with funding of scientific research might benefit from such funding in the future.





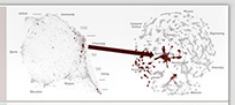


Citizenship is linked to *Physics*, *Chemistry*, *Engineering* and *Computer Science*. The specific aspect of *Citizenship* active here is the belief that funding should be provided for entrepreneurship and innovation so that the economy can flourish. The funding of science-based innovation from governments and NPOs is reasonably mature and is expected to remain high.

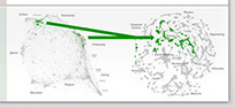


Caring is the basis for funding medical research. The aspects of *Caring* vary, and include curing of disease, providing opportunities for the disabled, and the treatment of mental health issues. A scientific understanding of these issues has been well funded by individuals, e.g., through donations to NPOs; and through government funding, e.g., the National Institutes of Health.

Historical



Citizenship is a major factor in the funding of the *Social Sciences*. The specific aspect of *Citizenship* active here is aligned with the belief that rational analysis and the scientific method can contribute to the resolution of political issues. 'Think tanks' are examples of non-profit organizations that are funded from this altruistic motive.



Culture and Citizenship contribute to the funding of environmental research. *Culture* supports that aspect of environmental research that is more concerned with the preservation of our planet for the future enjoyment of our children. *Citizenship* supports the research focusing on innovative solutions and political tradeoffs which arise from the toxic consequences of current practices.

All Seven Aspects of Altruism are potentially important for childhood development. Scientific research related to this topic is currently focused on social issues, e.g., risk factors, and *Education*. The altruism map raises an interesting question: Is this the right balance, or should more scientific attention be paid to childhood development in other areas, such as *Culture*, *Community*, *Sports*, and *Citizenship*? Time will tell.

Future

Community is an important altruistic mission that represents a potential funding opportunity. We know very little about how different communities (geographical, professional, social, etc.) have evolved in terms of providing altruistic services to their members. There are lessons to be learned from how communities variously emphasize *Culture*, *Sports*, *Education*, *Religion*, *Care*, or *Civic* responsibility.

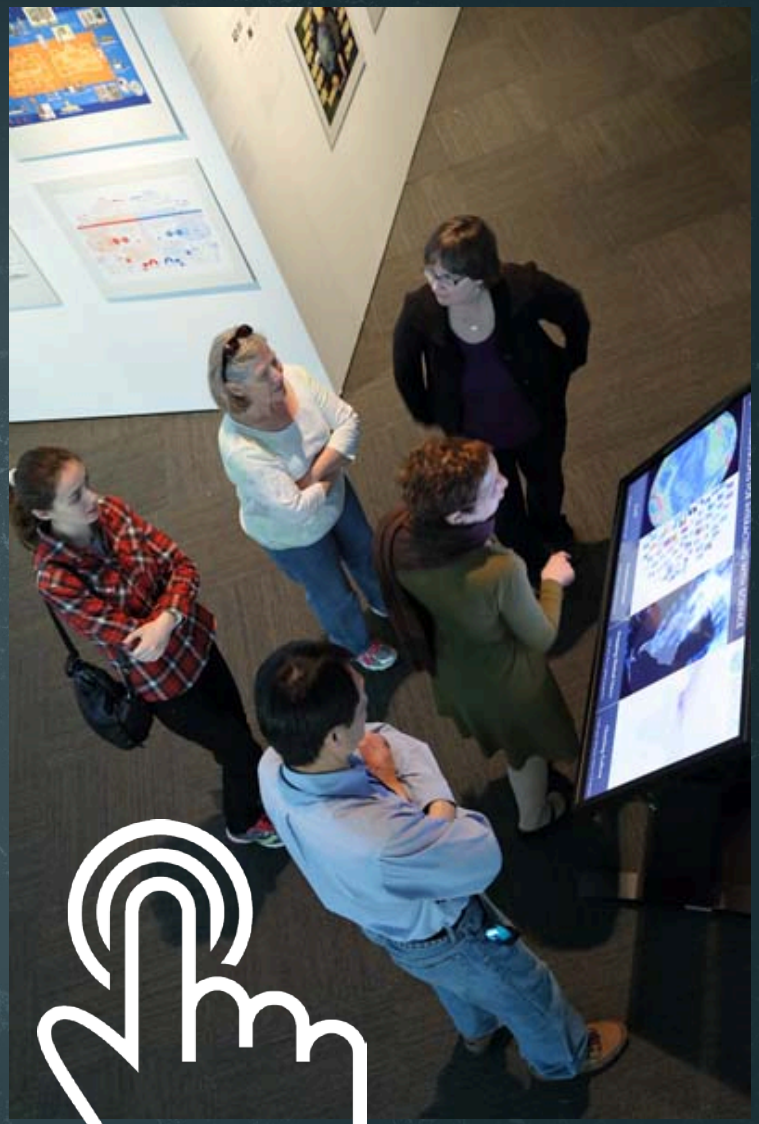
Exploring the Relationships between a Map of Altruism and a Map of Science - Richard Klavans and Kevin W. Boyack - 2014

Explore the maps and background information at http://scimaps.org

Macroscopes

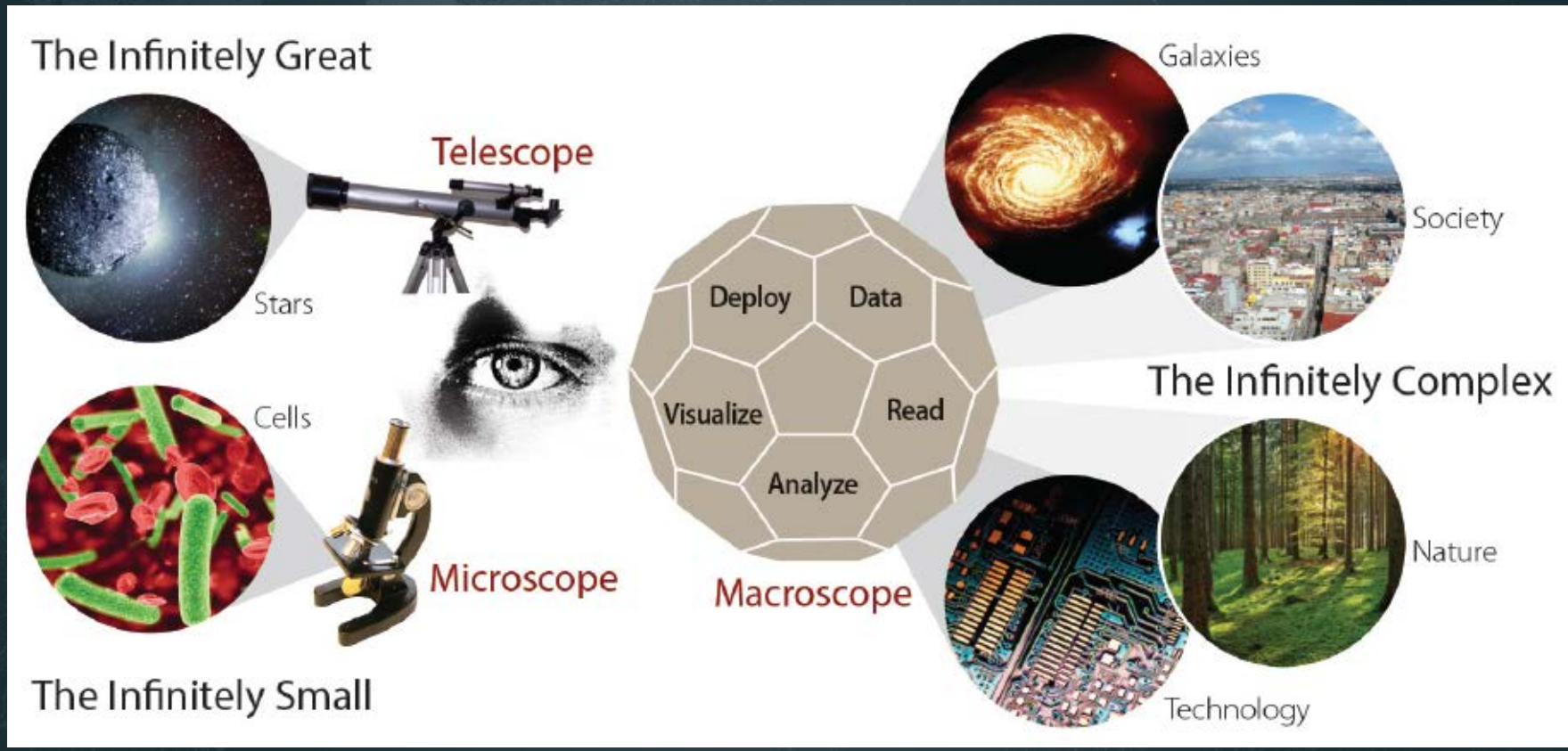
PLACES & SPACES
MAPPING SCIENCE

scimaps.org



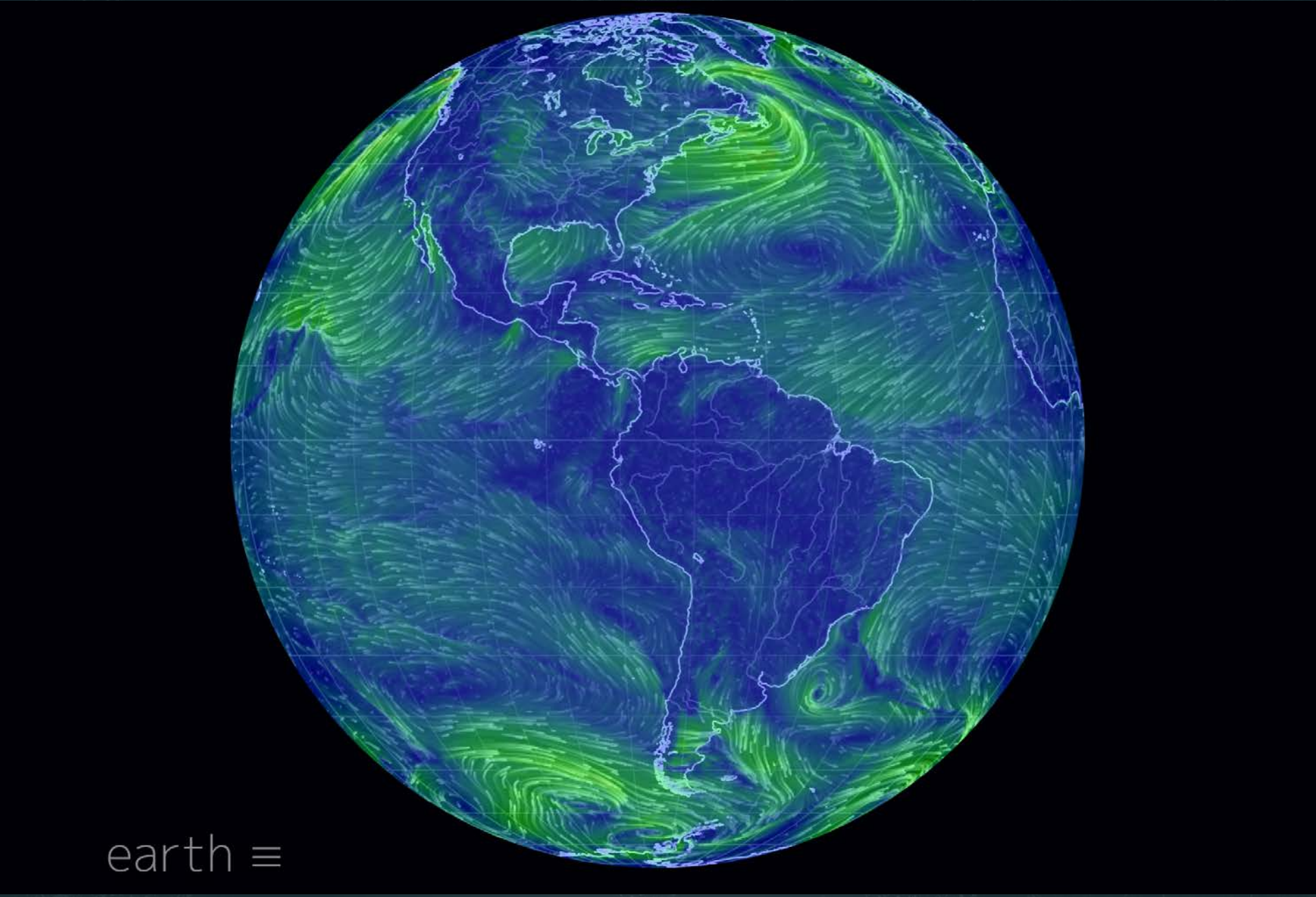
MAPS
vs.
MACROSCOPES

Microscopes & Telescopes vs. MACROSCOPES

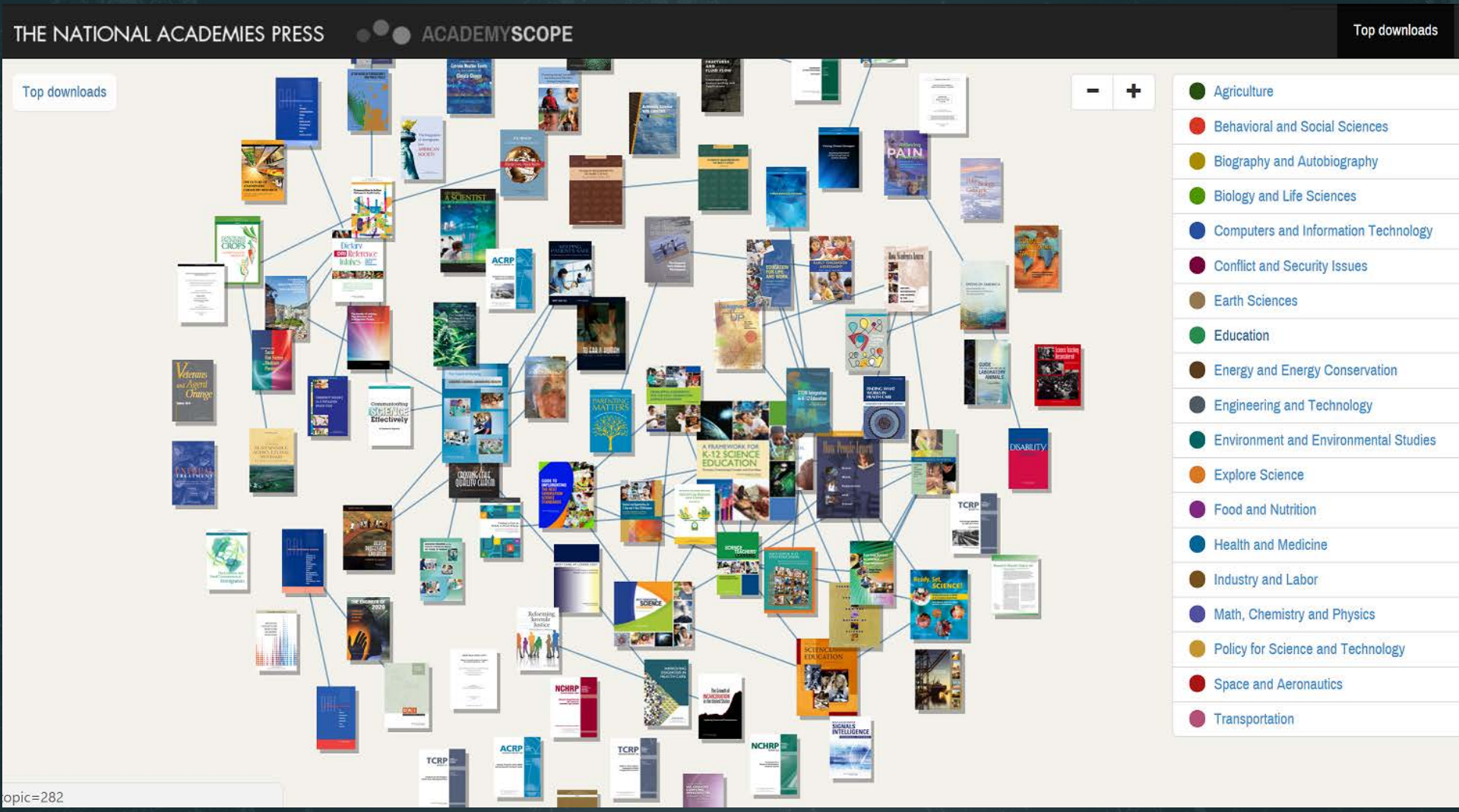


Iteration XI (2015): Macroscopes for Interacting with Science

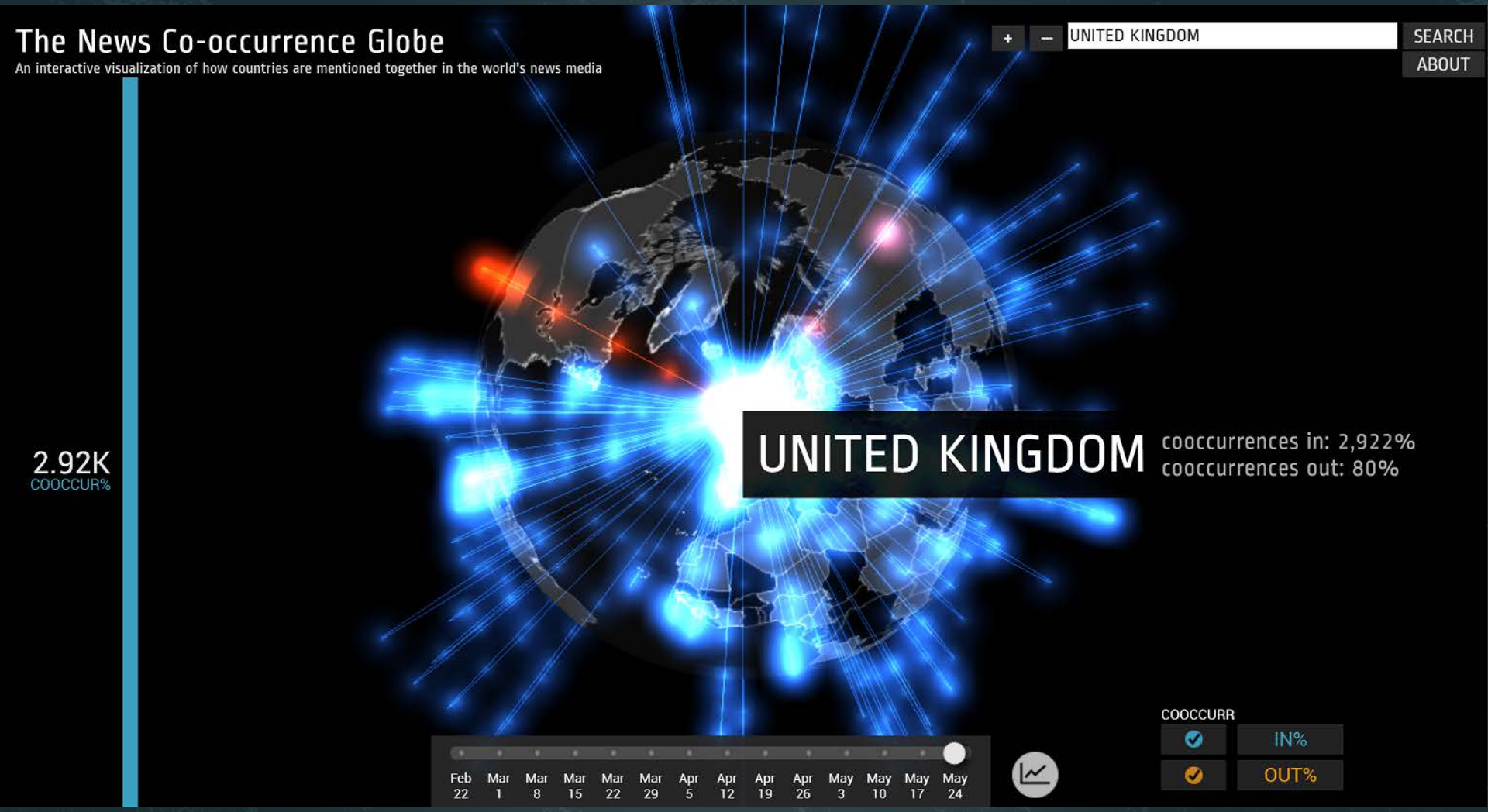
http://scimaps.org/iteration/11



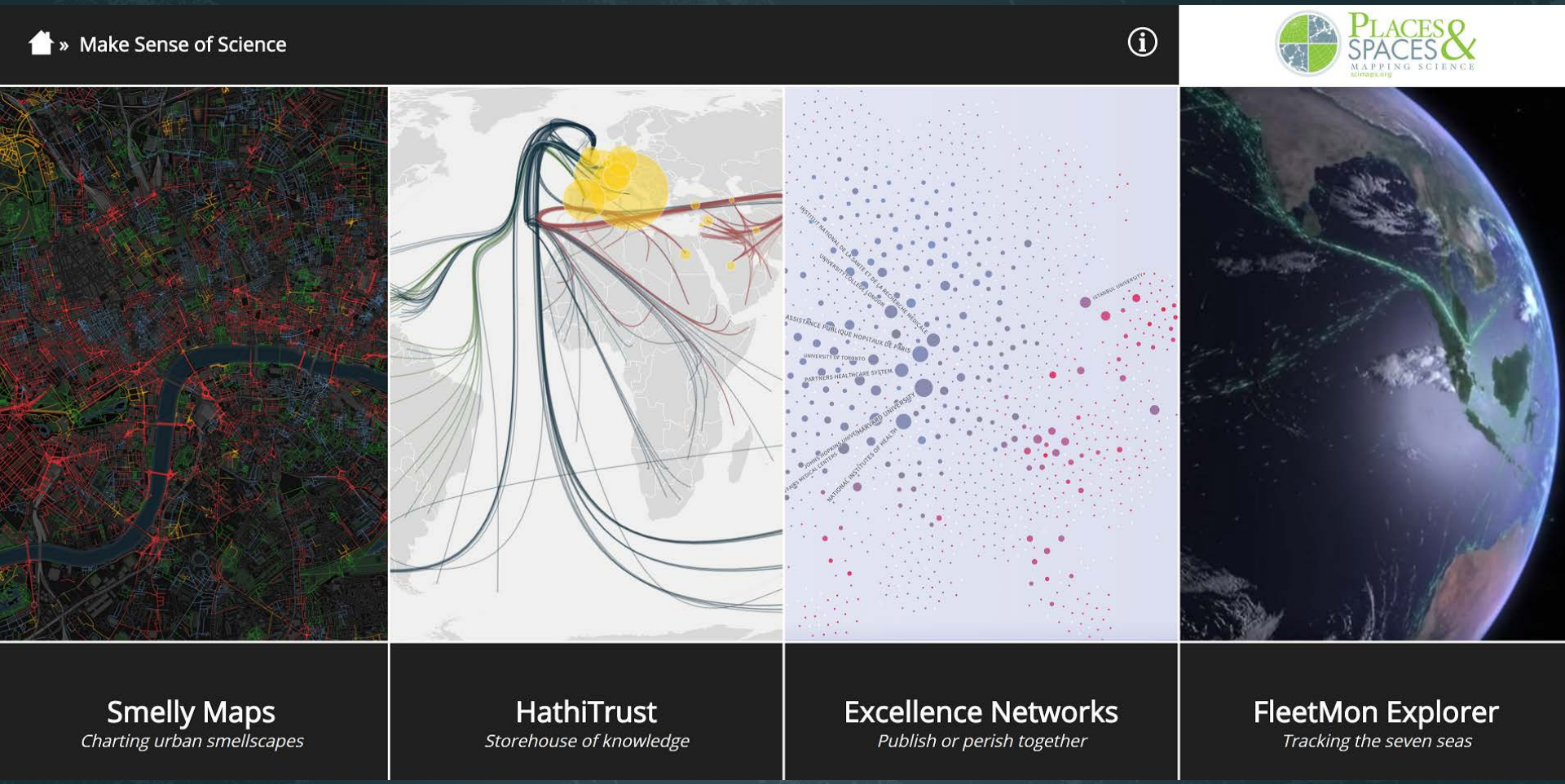
Earth – Cameron Beccario



AcademyScope – National Academy of the Sciences & CNS

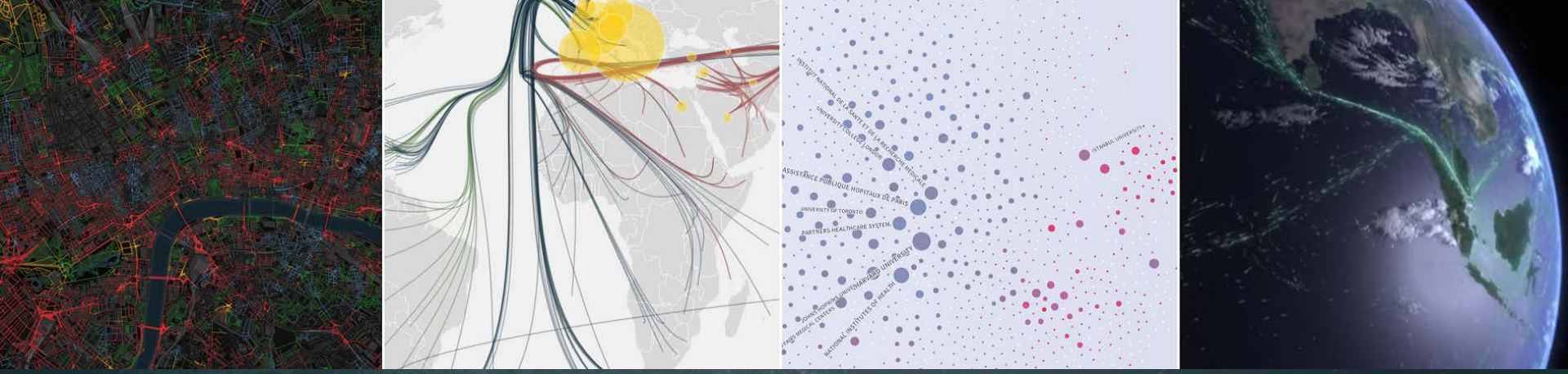


Mapping Global Society –Kalev Leetaru



Iteration XII (2016): Macroscopes for Making Sense of Science

http://scimaps.org/iteration/12



Four new macroscopes debut at Vanderbilt University:

1. **Smelly Maps:** Features a "smellscape" of 12 cities mapped by smell using social media
2. **HathiTrust:** Highlights the diversity of publications collected in digital form by HathiTrust.
3. **Excellence Networks:** Compares how research institutions, such as Indiana and Vanderbilt universities, collaborate with one another.
4. **FleetMon:** Shows how the amount of shipping traffic that navigates the Strait of Malacca compared to other major shipping lanes of the world.

http://scimaps.org/vanderbilt

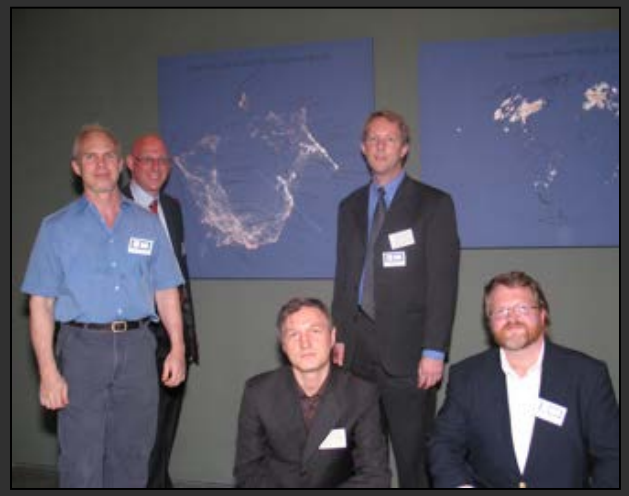
A visitor explores the macroscope kiosk at the Eskenazi Museum of Art at Indiana University.

Call for Macroscope Tools for the *Places & Spaces: Mapping Science* Exhibit (2017) http://scimaps.org/call

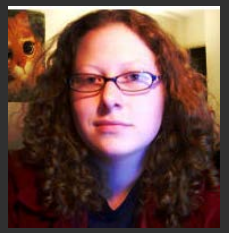
Background and Goals

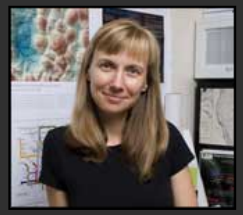
The *Places & Spaces: Mapping Science* exhibit is designed to open people's hearts and minds to the value, complexity, and beauty of maps of science and technology.

Drawing from across cultures and across scholarly disciplines, the *Places & Spaces: Mapping Science* exhibit demonstrates the



Join the map makers & exhibit ambassadors.

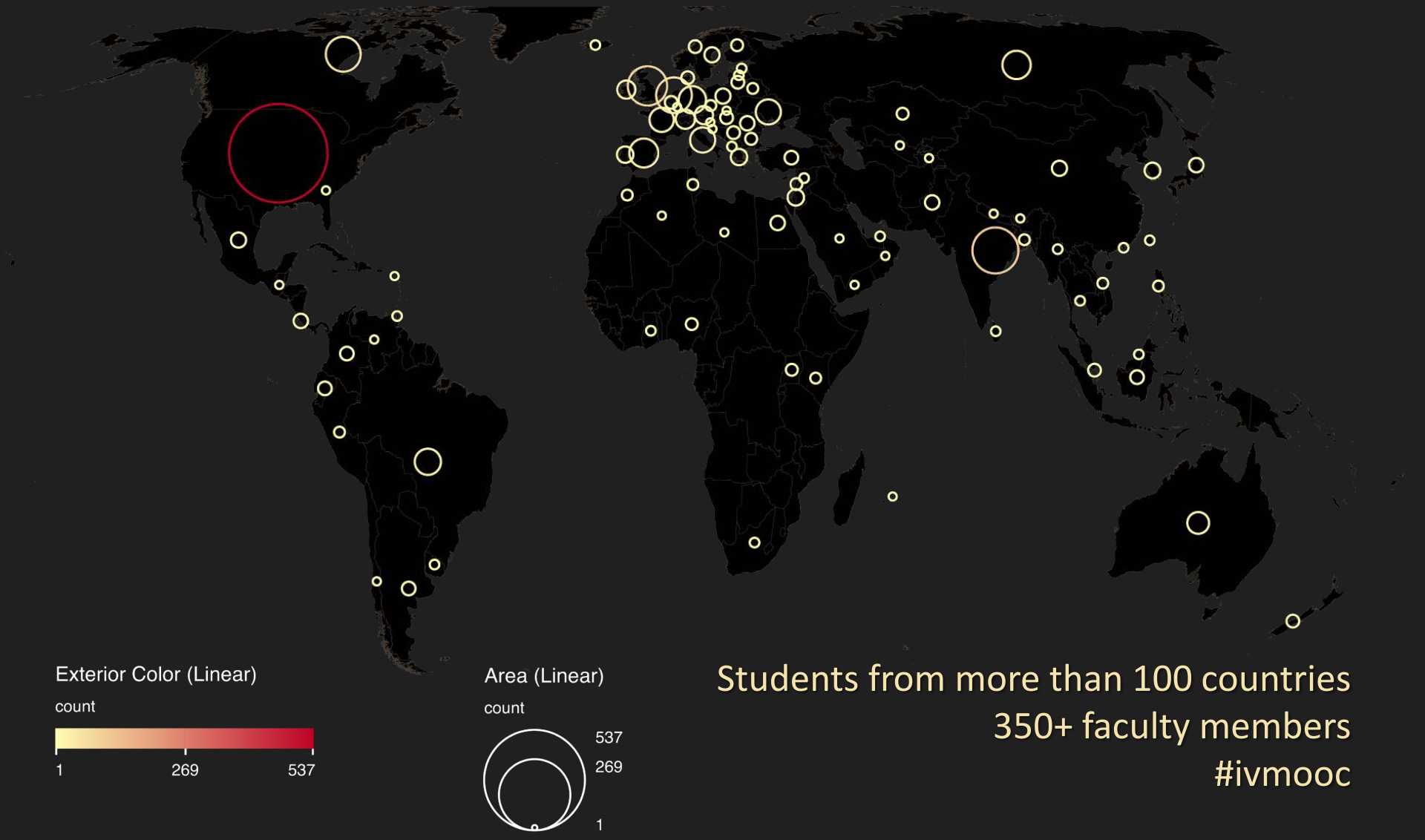




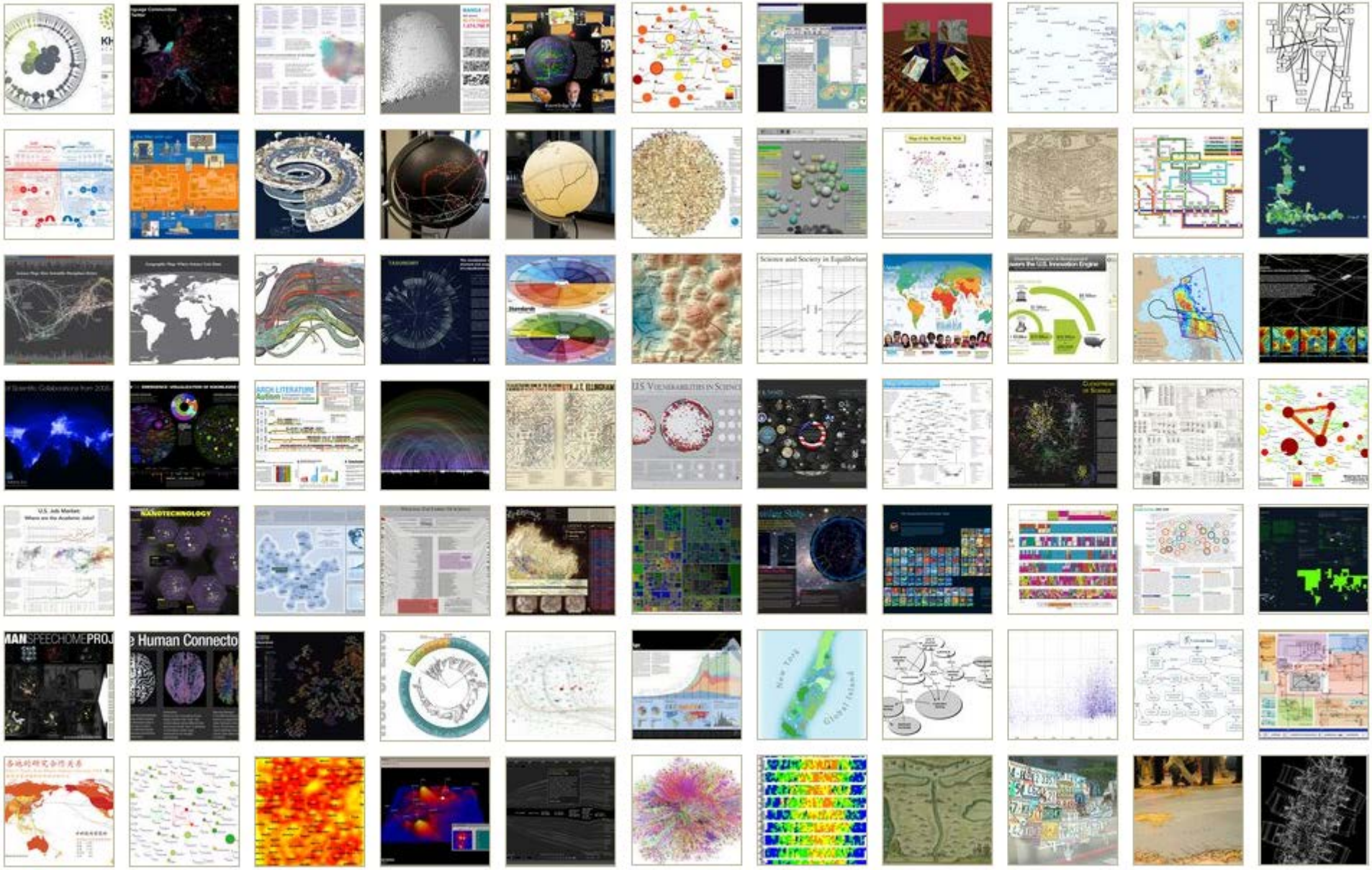
Data Visualization Literacy: Teaching

Register for free: http://ivmooc.cns.iu.edu. Class started Jan 10, 2017.

The Information Visualization MOOC
ivmooc.cns.iu.edu



Students from more than 100 countries
350+ faculty members
#ivmooc


Science and Society in Equilibrium
U.S. Vulnerabilities in Science
NANOTECHNOLOGY
Human Connecto

How to Classify Different Visualizations?

By

- User insight needs?
- User task types?

- Data to be visualized?
- Data transformation?

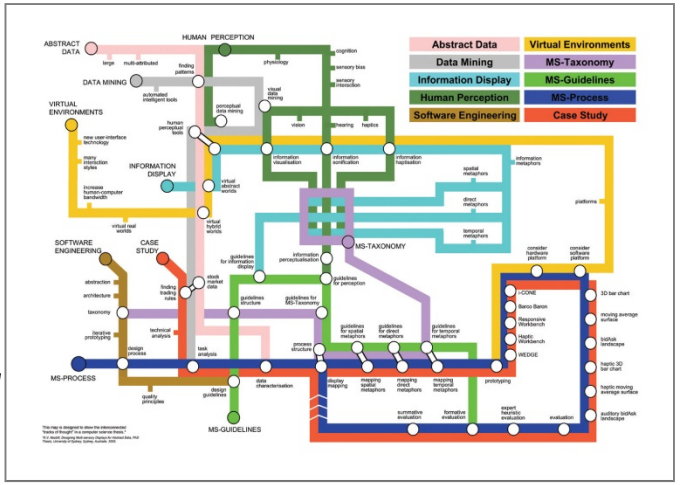
- Visualization technique?
- Visual mapping transformation?
- Interaction techniques?

- Or ?

Different Question Types

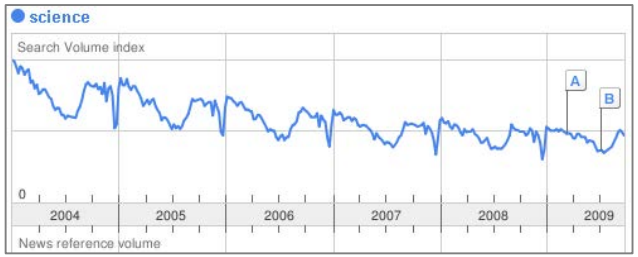
Terabytes of data

Descriptive & Predictive Models



Find your way

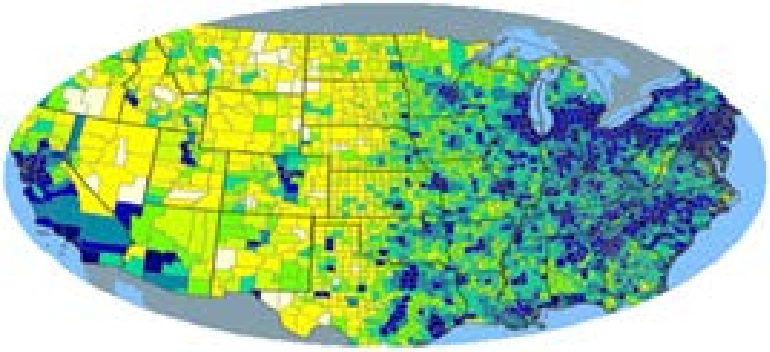
Find collaborators, friends



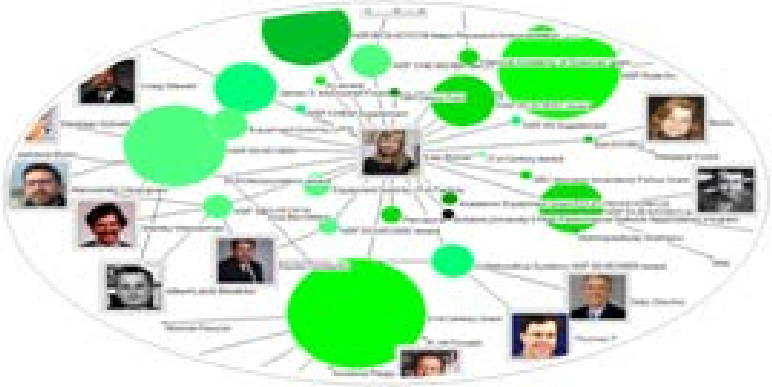
Identify trends

Different Levels of Abstraction/Analysis

Macro/Global
Population Level

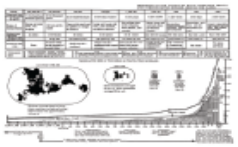
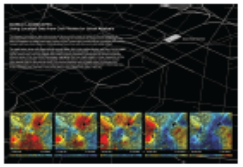
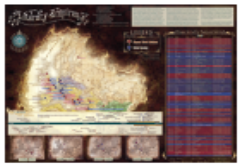
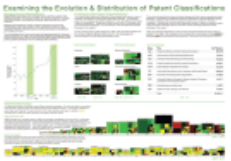


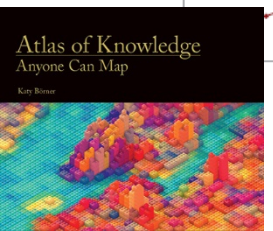
Meso/Local
Group Level



Micro
Individual Level

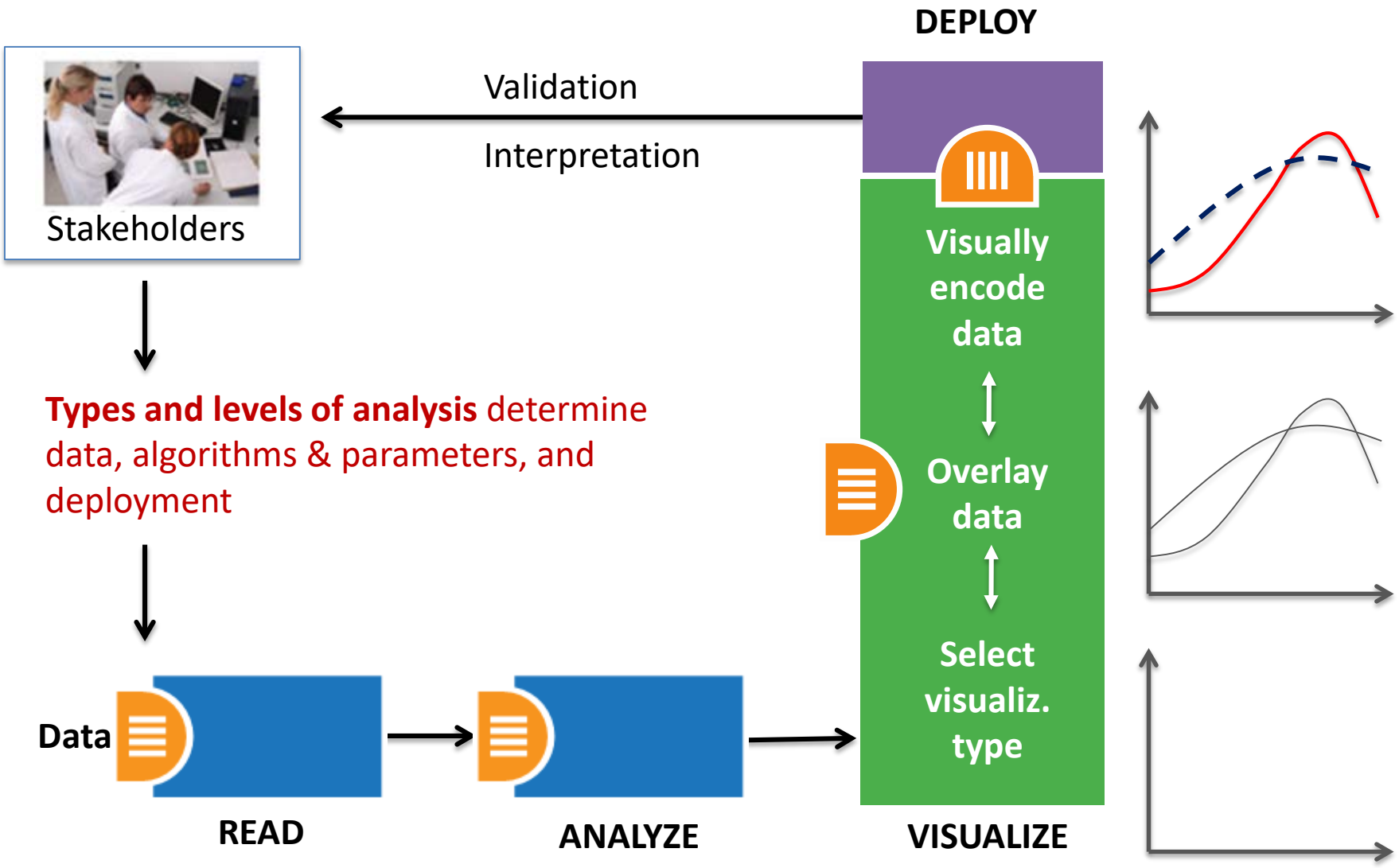
Tasks

TYPES	LEVELS		
	MICRO: Individual Level about 1–1,000 records page 6	**MESO: Local Level** about 1,001–100,000 records page 8	**MACRO: Global Level** more than 100,000 records page 10
Statistical Analysis page 44	Knowledge Cartography page 135	Productivity of Russian life sciences research teams page 105	Number of scientists versus population and R&D costs versus GNP. page 103
WHEN: Temporal Analysis page 48	Visualizing decision-making processes page 95	Key events in the development of the video tape recorder page 85	 Increased travel and communication speeds page 83
WHERE: Geospatial Analysis page 52	 Cell phone usage in Milan, Italy page 109	 Victorian poetry in Europe page 137	Ecological footprint of countries page 99
WHAT: Topical Analysis page 56	 Evolving patent holdings of Apple Computer, Inc. and Jerome Lemelson page 89	Evolving journal networks in nanotechnology page 139	Product space showing co-export patterns of countries page 93
WITH WHOM: Network Analysis page 60	World Finance Corporation network page 87	Electronic and new media art networks page 133	World-wide scholarly collaboration networks page 157

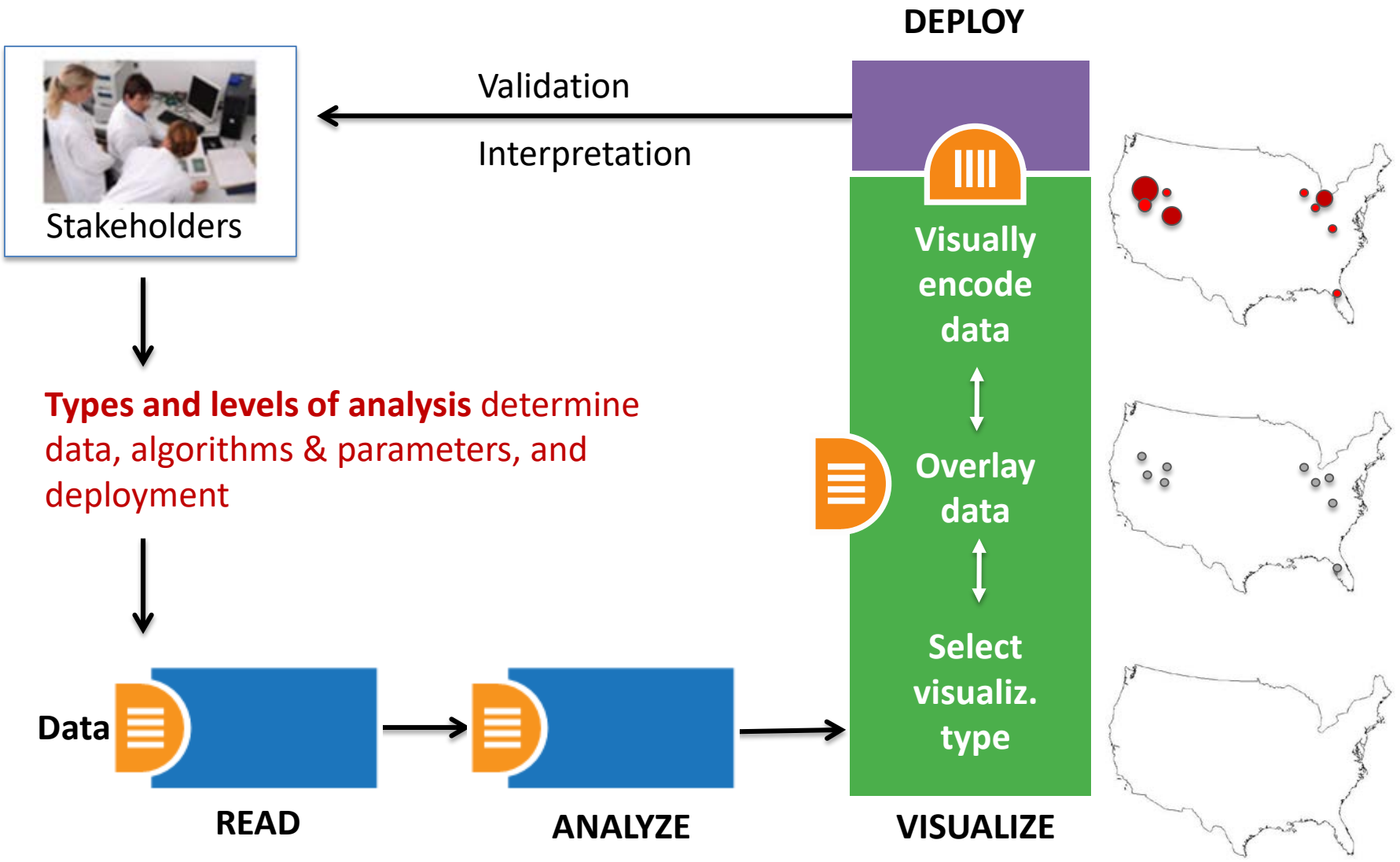


See page 5

Needs-Driven Workflow Design

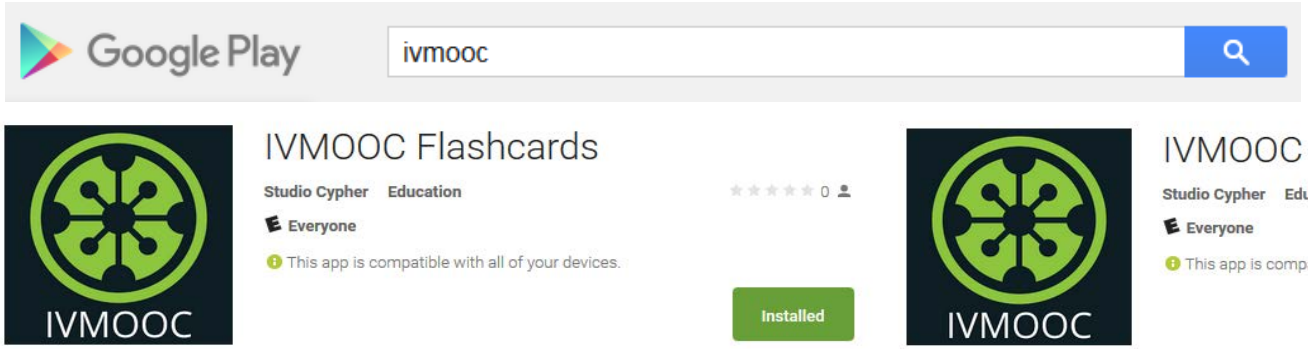


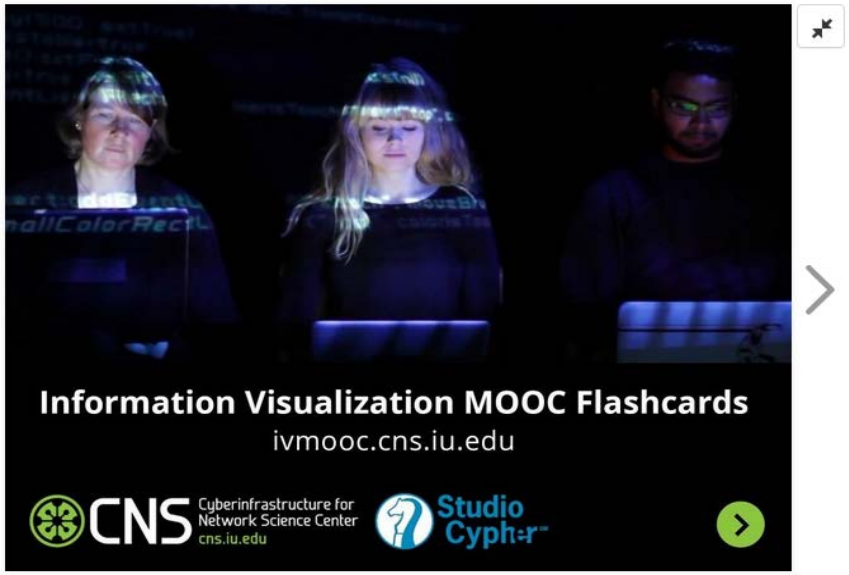
Needs-Driven Workflow Design

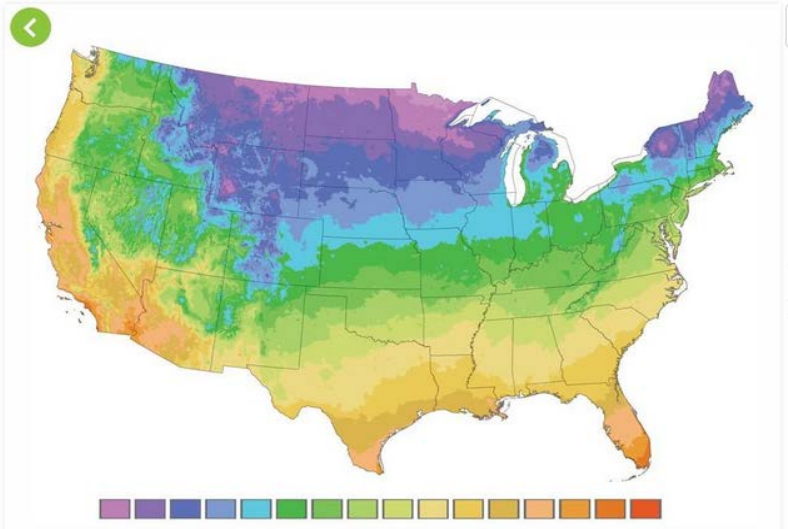


IVMOOC App – More than 60 visualizations

The “IVMOOC Flashcards” app can be downloaded from Google Play and Apple iOS stores.

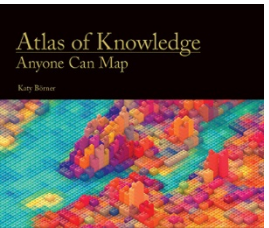






Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
• categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships	• nominal • ordinal • interval • ratio	• table • chart • graph • map • network layout	• geometric symbols point line area surface volume • linguistic symbols text numerals punctuation marks • pictorial symbols images icons statistical glyphs	• spatial position • retinal form color optics motion	• overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion



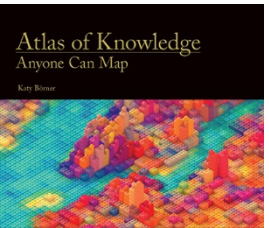
See page 24

Visualization Framework

Basic Task Types								
Bertin, 1967	**Wehrend & Lewis, 1996**	**Few, 2004**	**Yau, 2011**	**Rendgen & Wiedemann, 2012**	**Frankel, 2012**	**Tool: Many Eyes**	**Tool: Chart Chooser**	**Börner, 2014**
selection	categorize			category				categorize/ cluster
order	rank	ranking					table	order/rank/ sort
	distribution	distribution					distribution	distributions (also outliers, gaps)
	compare	nominal comparison & deviation	differences		compare and contrast	compare data values	comparison	comparisons
		time series	patterns over time	time	process and time	track rises and falls over time	trend	trends (process and time)
		geospatial	spatial relations	location		generate maps		geospatial
quantity		part-to-whole	proportions		form and structure	see parts of whole, analyze text	composition	compositions (also of text)
association	correlate	correlation	relationships	hierarchy		relations between data points	relationship	correlations/ relationships

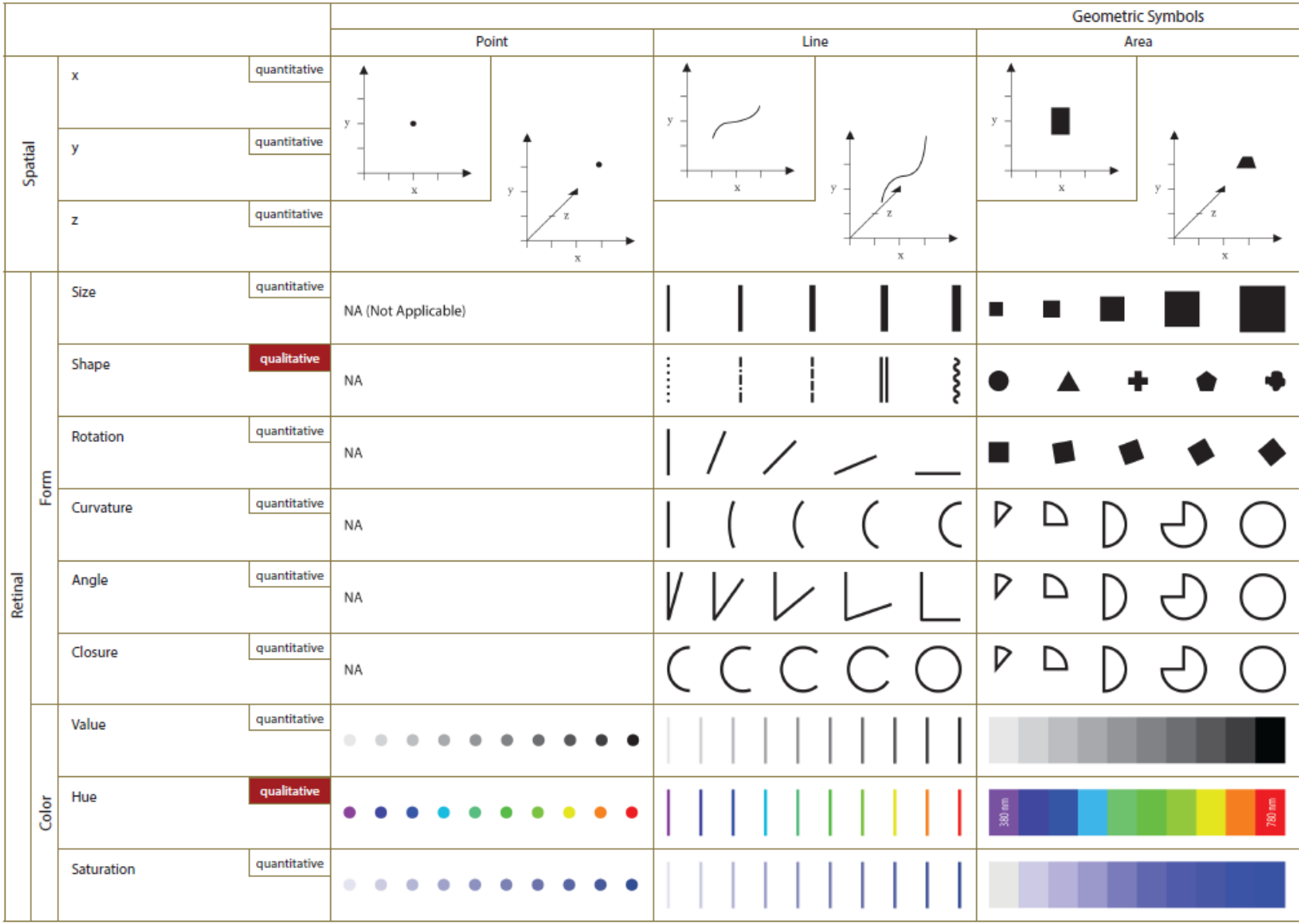
Visualization Framework

Insight Need Types page 26	Data Scale Types page 28	Visualization Types page 30	Graphic Symbol Types page 32	Graphic Variable Types page 34	Interaction Types page 26
• categorize/cluster • order/rank/sort • distributions (also outliers, gaps) • comparisons • trends (process and time) • geospatial • compositions (also of text) • correlations/relationships	• nominal • ordinal • interval • ratio	• table • chart • graph • map • network layout	• geometric symbols point line area surface volume • linguistic symbols text numerals punctuation marks • pictorial symbols images icons statistical glyphs	• spatial position • retinal form color optics motion	• overview • zoom • search and locate • filter • details-on-demand • history • extract • link and brush • projection • distortion

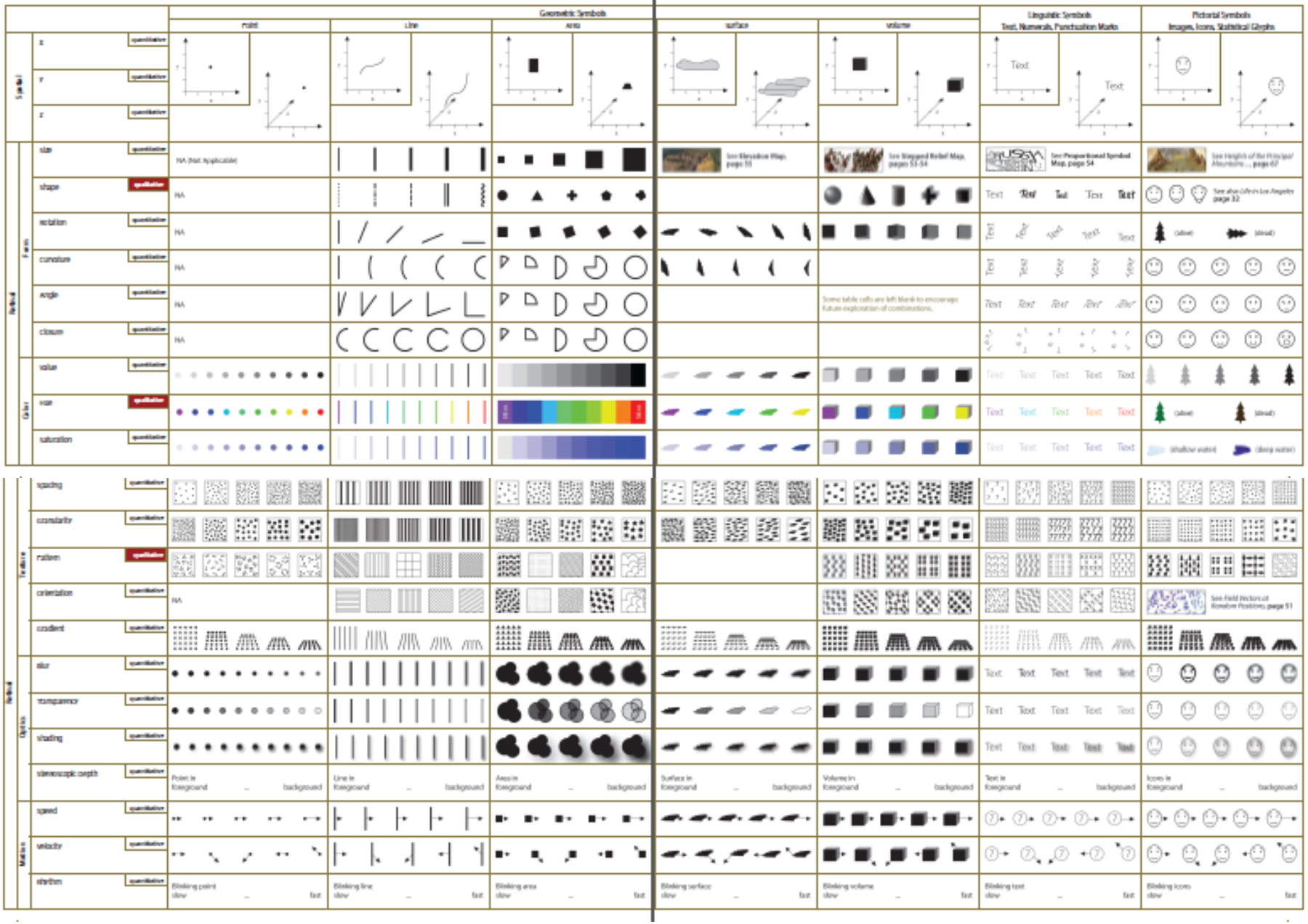


See page 24

Graphic Variable Types Versus Graphic Symbol Types



Graphic Variable Types Versus Graphic Symbol Types



Load **One** File and Run **Many** Analyses and Visualizations

Times Cited	Publication Year	City of Publisher	Country	Journal Title (Full)	Title	Subject Category	Authors
12	2011	NEW YORK	USA	COMMUNICATIONS OF THE ACM	Plug-and-Play Macroscopes	Computer Science	Borner, K
18	2010	MALDEN	USA	CTS-CLINICAL AND TRANSLATIONAL SCIENCE	Advancing the Science of Team Science	Research & Experimental Medicine	Falk-Krzesinski, HJ|Borner, K|Contractor, N|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B
13	2010	WASHINGTON	USA	SCIENCE TRANSLATIONAL MEDICINE	A Multi-Level Systems Perspective for the Science of Team Science	Cell Biology |Research & Experimental Medicine	Borner, K|Contractor, N|Falk-Krzesinski, HJ|Fiore, SM|Hall, KL|Keyton, J|Spring, B|Stokols, D|Trochim, W|Uzzi, B

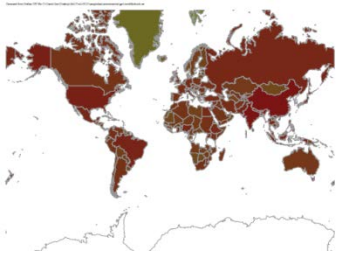
Statistical Analysis–p. 44

Location	*Count*	*# Citations*
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

Temporal Burst Analysis–p. 48

Geospatial Analysis–p. 52

Geospatial Analysis–p. 52



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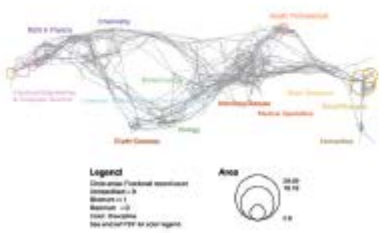
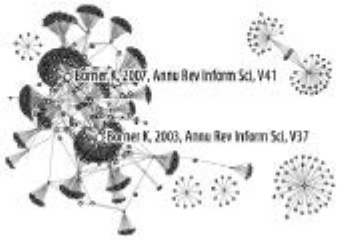
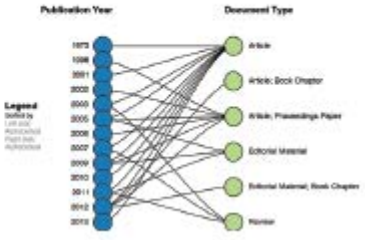
Topical Analysis–p. 56



Paper Citation Network–p. 60



Bi-Modal Network–p. 60



Co-author and many other bi-modal networks.

Course Schedule

Part 1: Theory and Hands-On

- **Session 1** – Workflow Design and Visualization Framework
- **Session 2** – "When:" Temporal Data
- **Session 3** – "Where:" Geospatial Data
- **Session 4** – "What:" Topical Data

Mid-Term

- **Session 5** – "With Whom:" Trees
- **Session 6** – "With Whom:" Networks
- **Session 7** – Dynamic Visualizations and Deployment

Final Exam

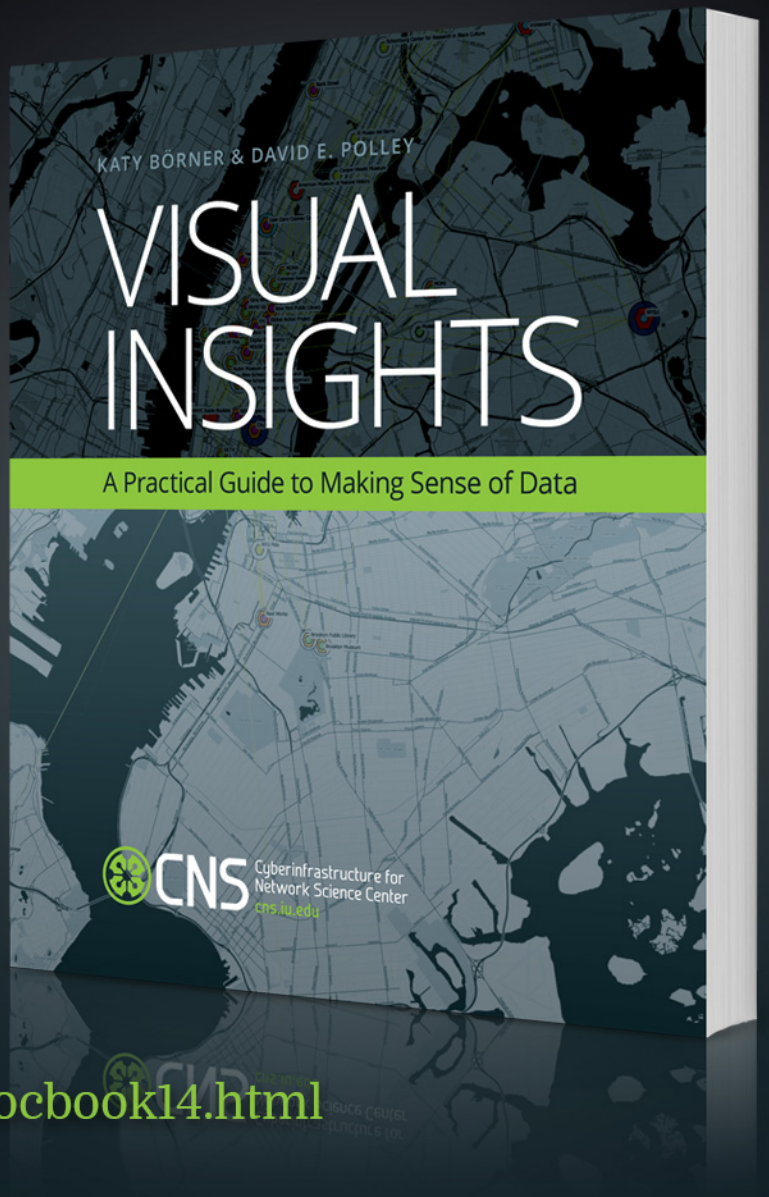
Part 2: Students work in teams on client projects.

Final grade is based on Homework and Quizzes (**10%),** Midterm (**20%**), Final (**30%**), Client Project (**30%**), and Class Participation (**10%**).

The IVMOOC Companion Textbook

This textbook offers a gentle introduction to the design of insightful visualizations. It seamlessly blends theory and practice, giving readers both the theoretical foundation and the practical skills necessary to render data into insights.

The book accompanies the Information Visualization MOOC that attracted students, scholars, and practitioners from many fields of science and more than 100 different countries.



cns.iu.edu/ivmoocbook14.html

Data Visualization Literacy: Outlook

Dagstuhl Seminar 18482

Network Visualization in the Humanities

November 25 – 30, 2018, Schloss Dagstuhl, Wadern, Germany

Organizers:
Katy Börner (Indiana University – Bloomington, US)
Dan Edelstein (Stanford University, US)
Tamara Mchedlidze (KIT – Karlsruher Institut für Technologie, DE)
Gerik Scheuermann (Universität Leipzig, DE)
Raymond G. Siemens (University of Victoria, CA)

Digital humanities have seen fast growth in the last ten years. Digital humanities scholars of all fields extract data from their object of study and apply computational methods to answer research questions and to gain new insights. Much of the data collected from, e.g., books, historical texts, publications, dialogs, speeches, archaeological databases, and art pieces can be modeled as networks. Existing network analysis and visualization techniques have already proven themselves useful in analyzing these data and providing new discoveries.

The central goal of the network visualization field is the development of techniques and algorithms for effective network visualization. While network visualization strongly impacts a variety of different major research areas (incl. social science, bioinformatics, neuroscience, electronics, software engineering, business informatics, etc.), the humanities fields use only a tiny portion of the existing network visualization methods. On the other hand, network visualization scholars have not made an extensive attempt to develop and adapt techniques to be used by humanities researchers. Besides the general force-directed algorithm, there is a very limited number of other types of network visualization techniques that have been

PROGRAMS

- Awards
- Koshland Science Museum
- Cultural Programs
- Sackler Colloquia
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  - Upcoming Colloquia
  - Completed Colloquia
  - Video Gallery
  - Connect with Sackler Colloquia
  - Give to Sackler Colloquia
- Kavli Frontiers of Science
- Distinctive Voices

Arthur M. Sackler COLLOQUIA

Upcoming Colloquia

Unless otherwise indicated, most Sackler colloquia are held at the Arnold and Mabel Beckman Center, in Irvine, California.

Reproducibility of Research: Issues and Proposed Remedies

March 8-10, 2017; Washington, D.C.
Organized by David B. Allison, Richard Shiffrin and Victoria Stodden
Registration now open

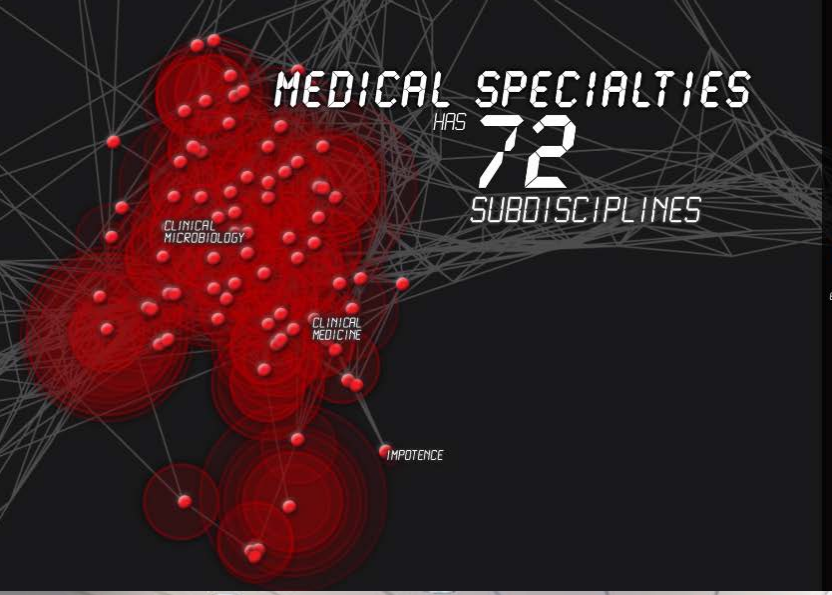
Science of Science Communication III

November 15-16, 2017; Washington, D.C.
Organized by Karen Cook, Baruch Fischhoff, Alan I. Leshner and Dietram A. Scheufele
Registration will open May 2017

Modelling and Visualizing Science and Technology Developments

December 4-5, 2017; Irvine, CA
Organized by Katy Börner, William Rouse and H. Eugene Stanley
Registration will open August 2017

http://www.nasonline.org/programs/sackler-colloquia/upcoming-colloquia



Science Forecast S1:E1, 2015

CSWS Session: Visualizing STEAM Data in Support of Smart Decision Making
November 15-17, 2017, Tokyo, Japan.

References

Börner, Katy, Chen, Chaomei, and Boyack, Kevin. (2003). **Visualizing Knowledge Domains.** In Blaise Cronin (Ed.), *ARIST*, Medford, NJ: Information Today, Volume 37, Chapter 5, pp. 179-255. http://ivl.slis.indiana.edu/km/pub/2003-borner-arist.pdf

Shiffrin, Richard M. and Börner, Katy (Eds.) (2004). **Mapping Knowledge Domains**. *Proceedings of the National Academy of Sciences of the United States of America*, 101(Suppl_1). http://www.pnas.org/content/vol101/suppl_1

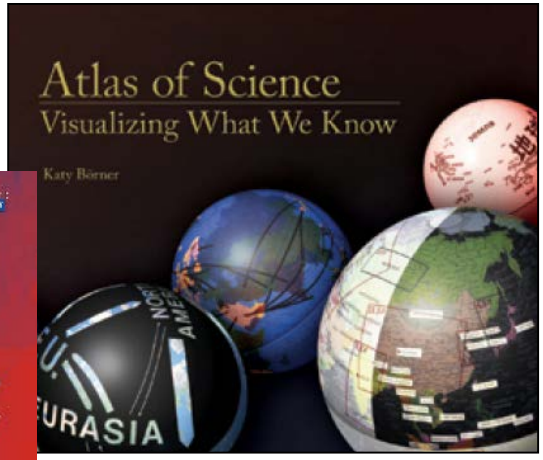
Börner, Katy (2010) **Atlas of Science: Visualizing What We Know**. The MIT Press. http://scimaps.org/atlas

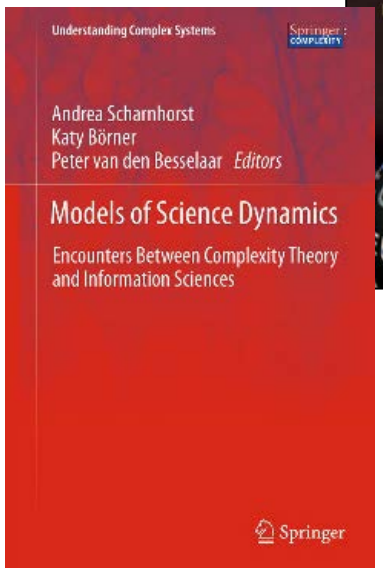
Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

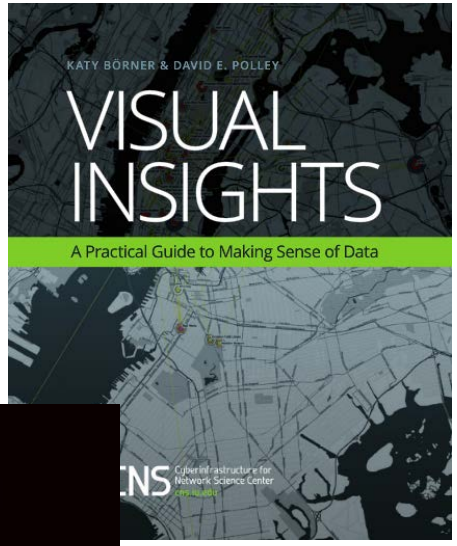
Katy Börner, Michael Conlon, Jon Corson-Rikert, Cornell, Ying Ding (2012) **VIVO: A Semantic Approach to Scholarly Networking and Discovery**. Morgan & Claypool.

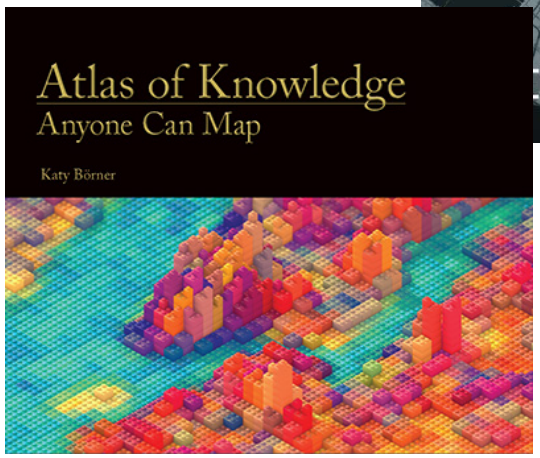
Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

Börner, Katy (2015) **Atlas of Knowledge: Anyone Can Map**. The MIT Press. http://scimaps.org/atlas2









All papers, maps, tools, talks, press are linked from http://cns.iu.edu
These slides are at http://cns.iu.edu/presentations.html

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