Maps & Macroscopes: Drawing Actionable Insights From Data

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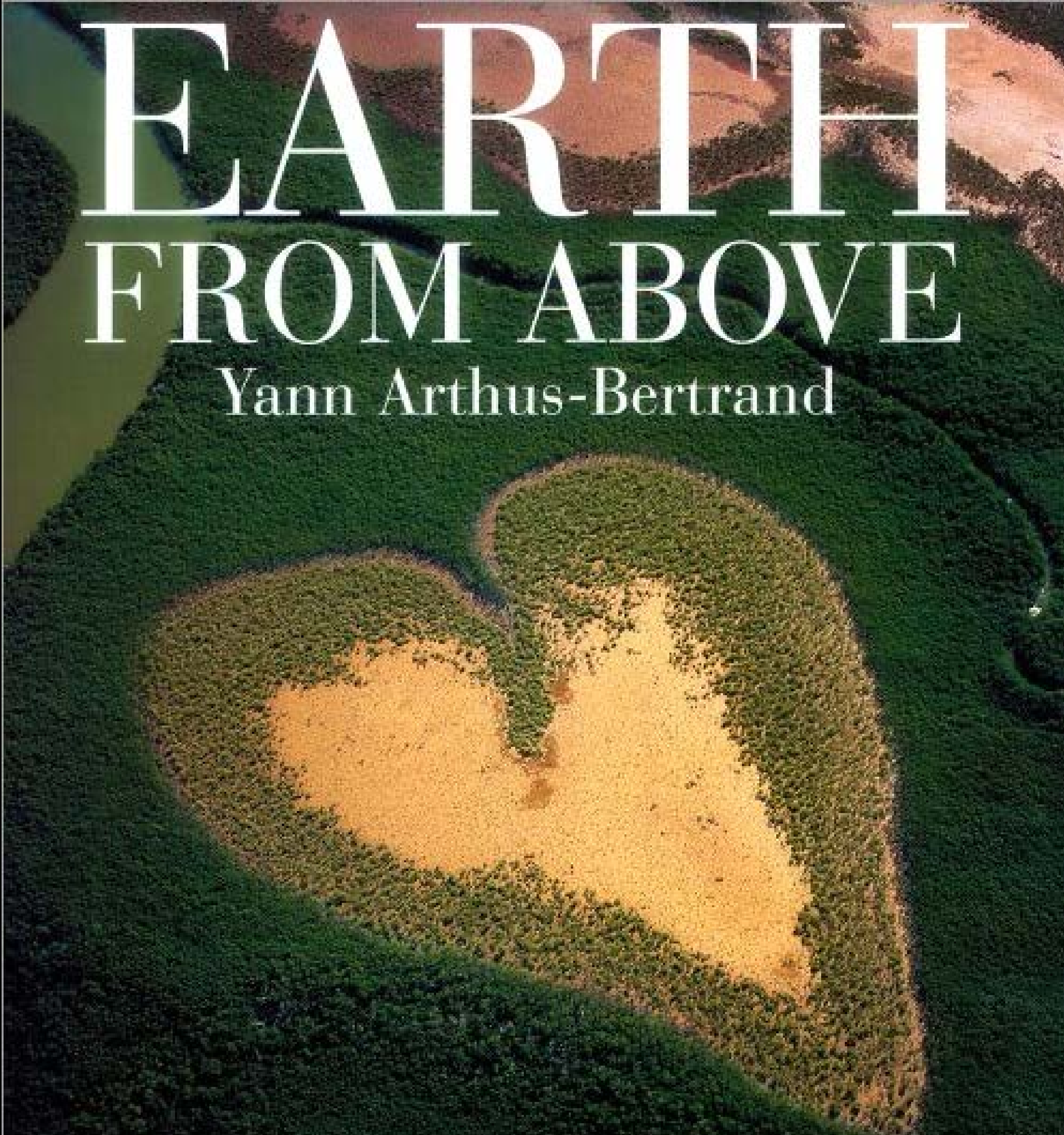
Opening Reception at Vanderbilt University, Nashville, TN

January 27, 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?

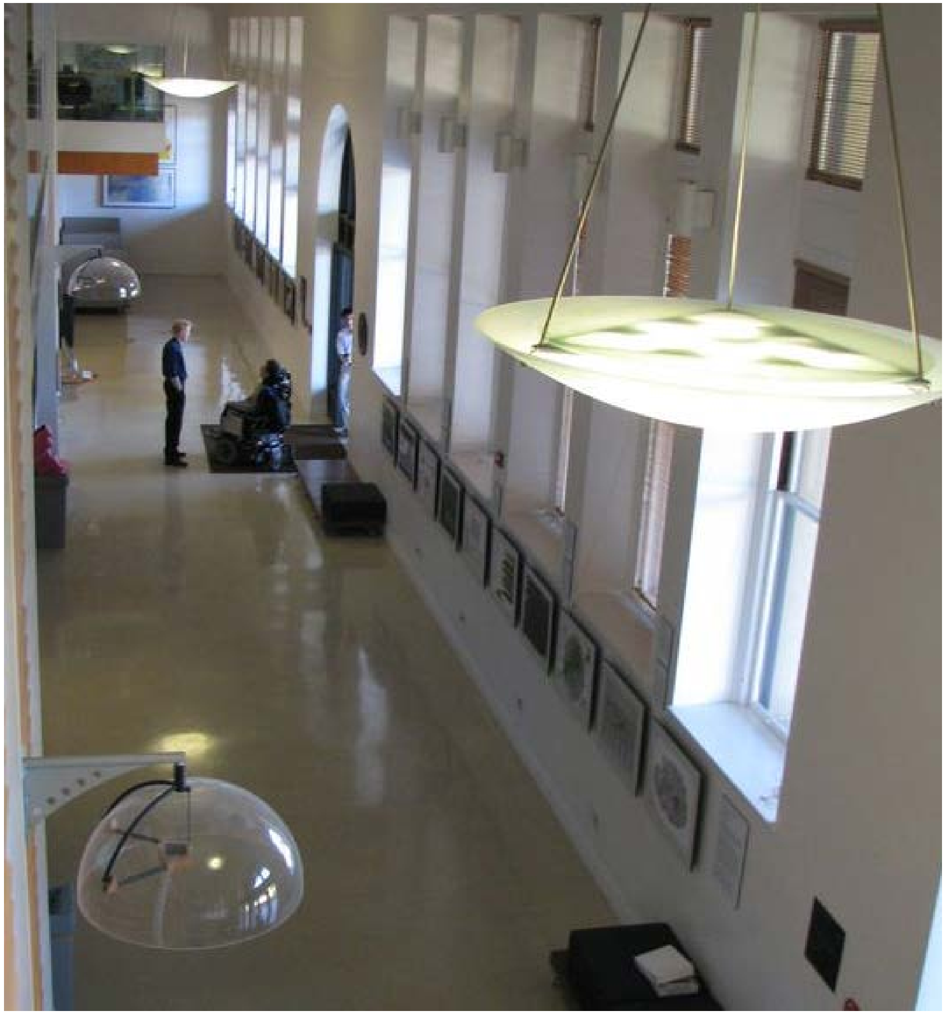
April, 2005: 101st Annual Meeting of the
Association of American Geographer, Denver, Colorado.

05: 101st Annual Meeting
American Geographer, De


INDIANA
UNIVERSITY
PLACES AND SPACES
EXHIBIT

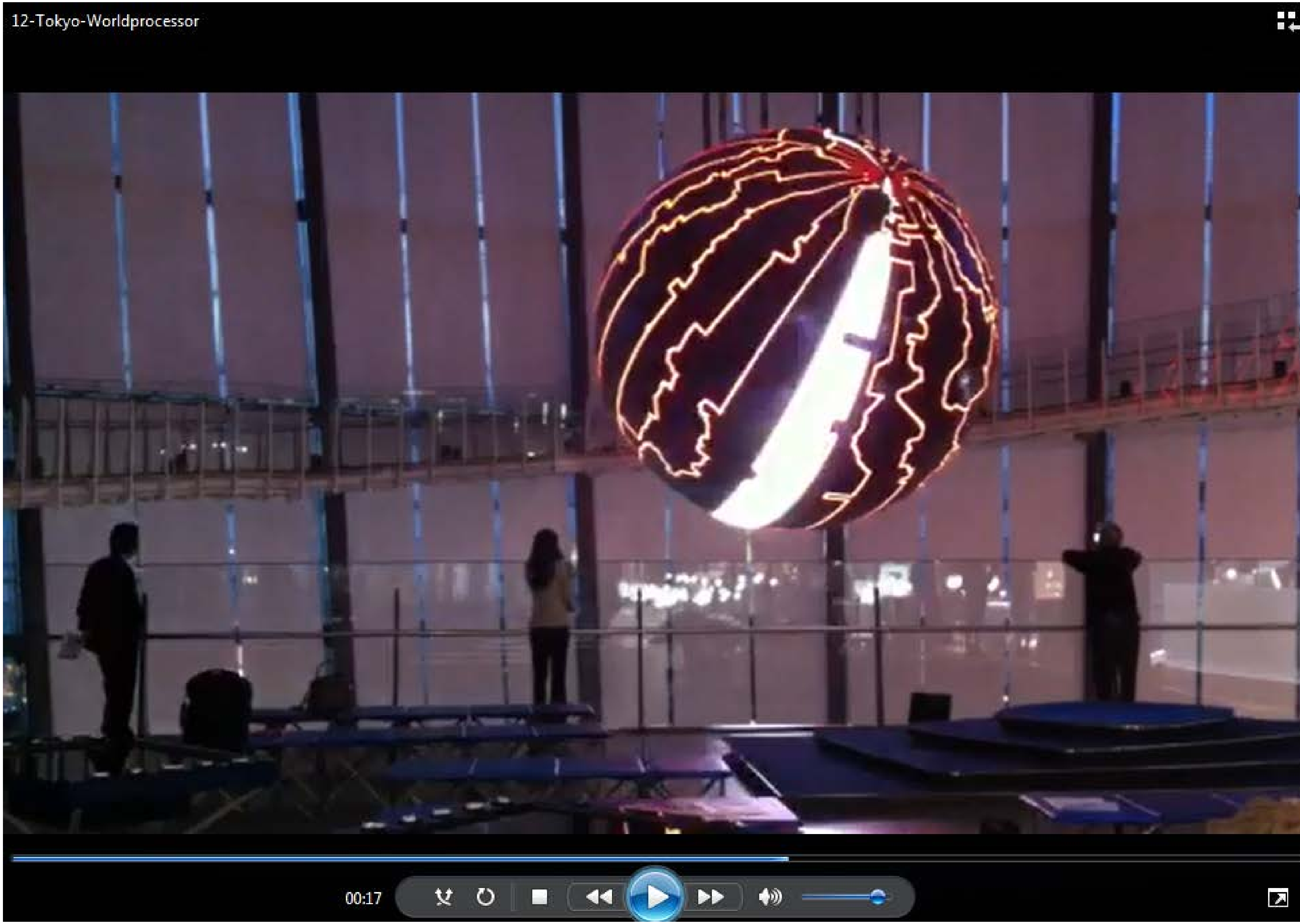

Chemical Research & Development
Powers the U.S. Innovation Engine
Literary Empires
LEGEND
The Human Connectome


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

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

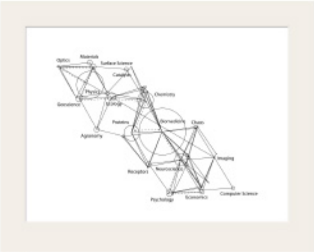
equal

10 x 10 = 100 maps!

The Power of Maps 2005

I.1

I.3



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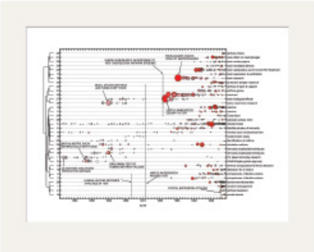

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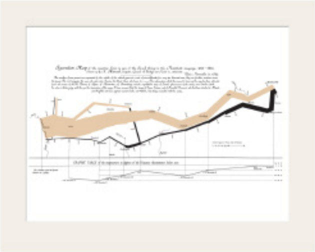

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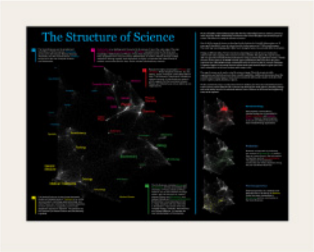


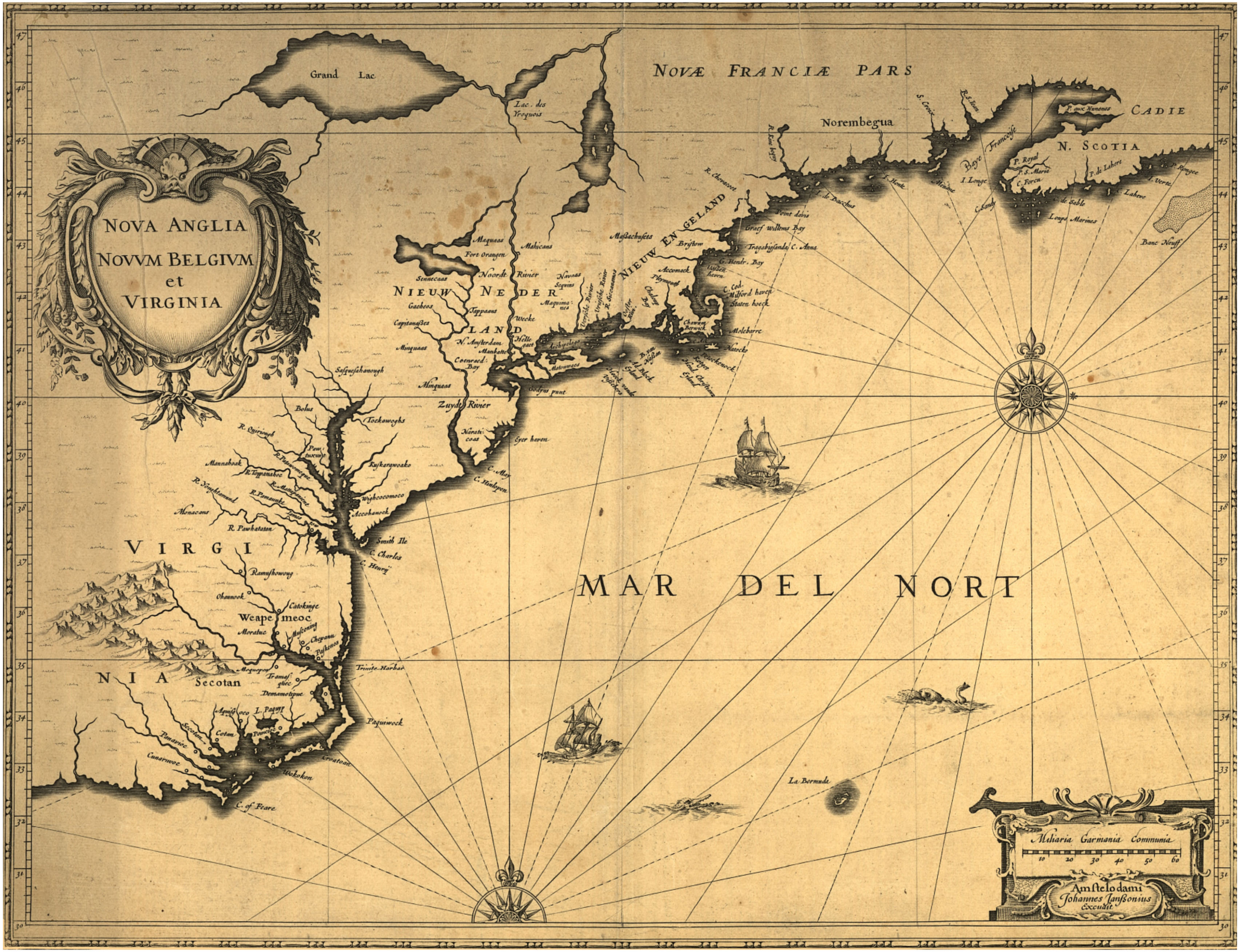
I.10

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

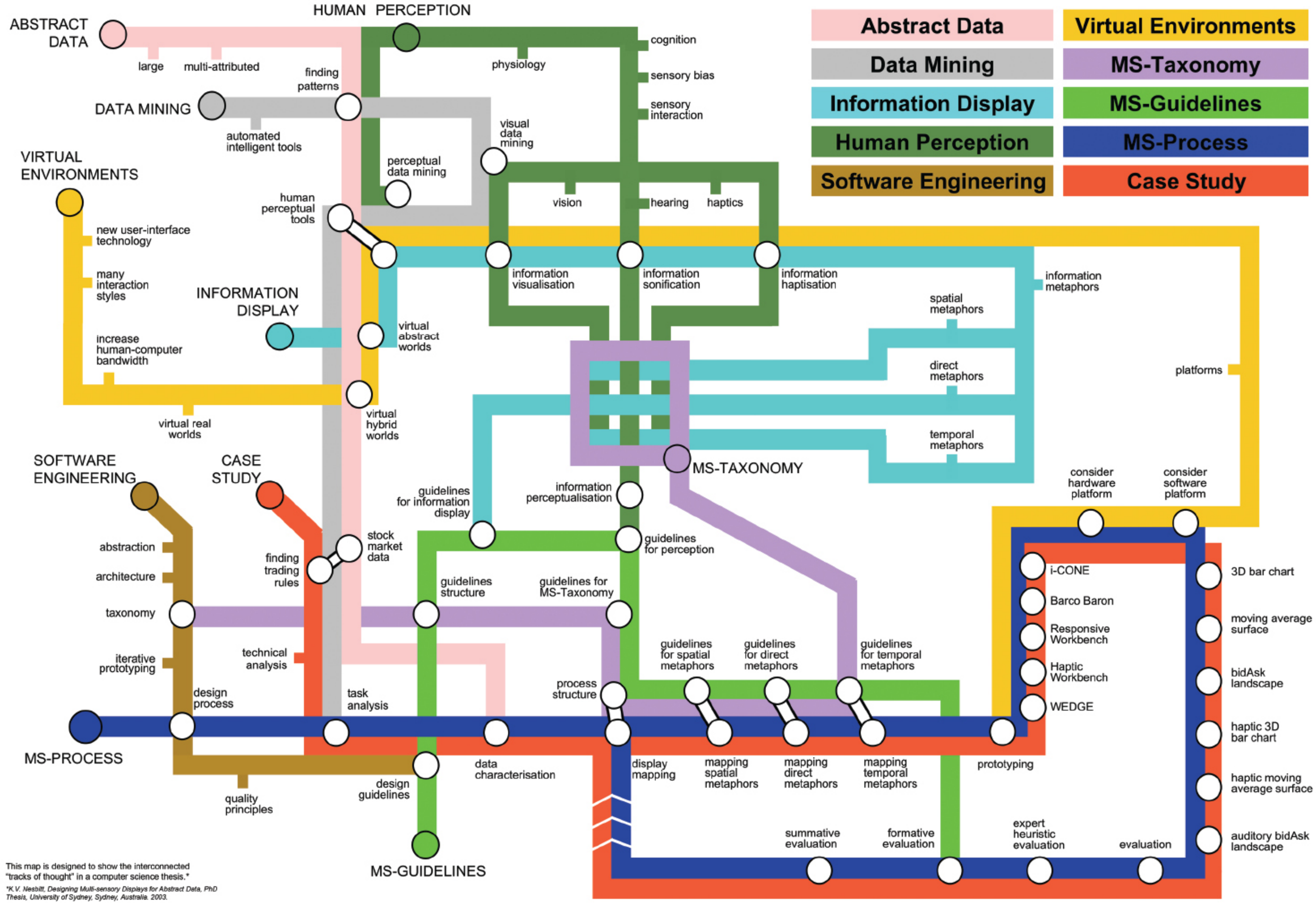


Nova Anglia, Novvm Belgivm et Virginia - Jan Jannson - 1642

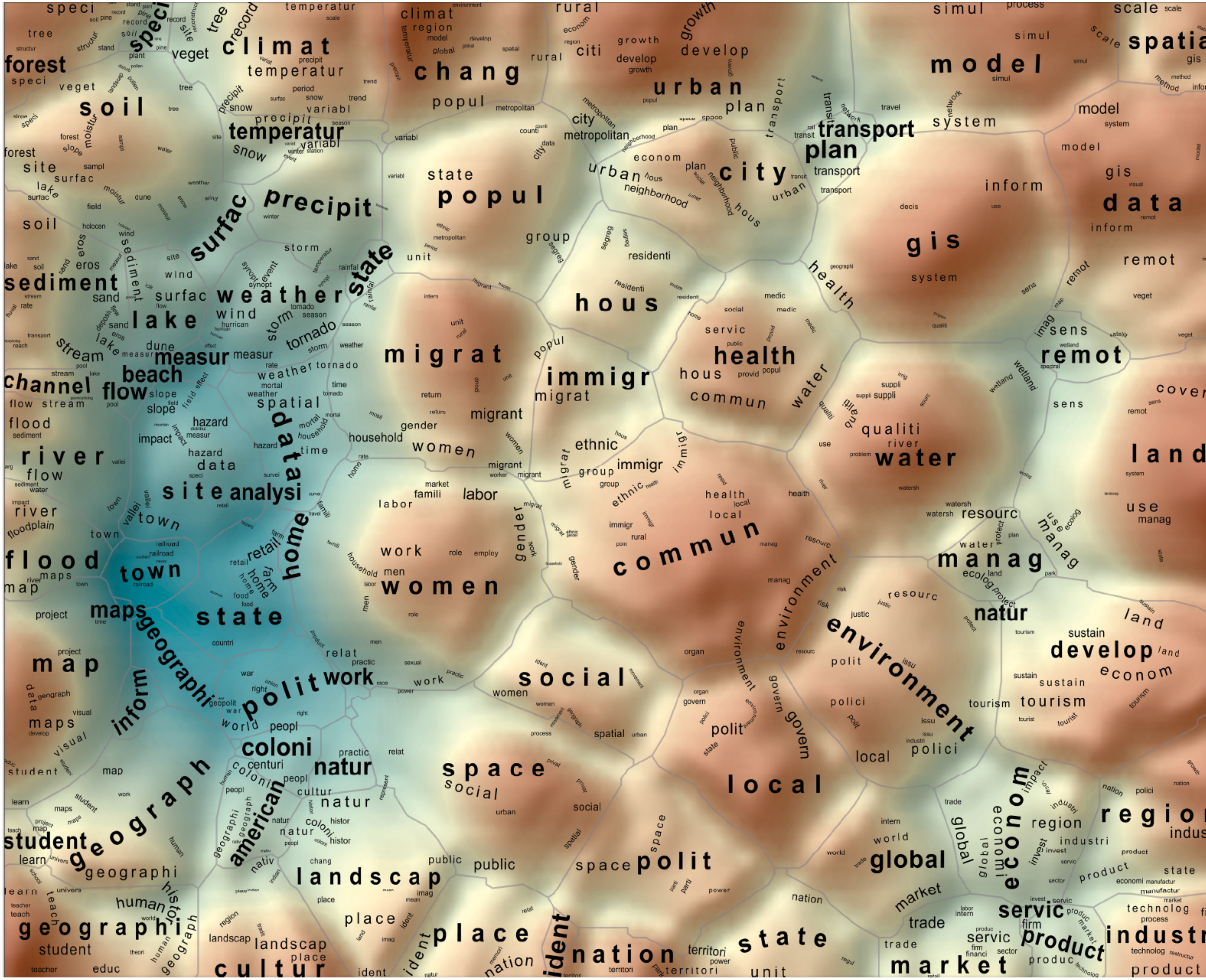
A New Map of the Whole World with Trade Winds According to the Latest and Most Exact Observations - Herman Moll - 1736

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

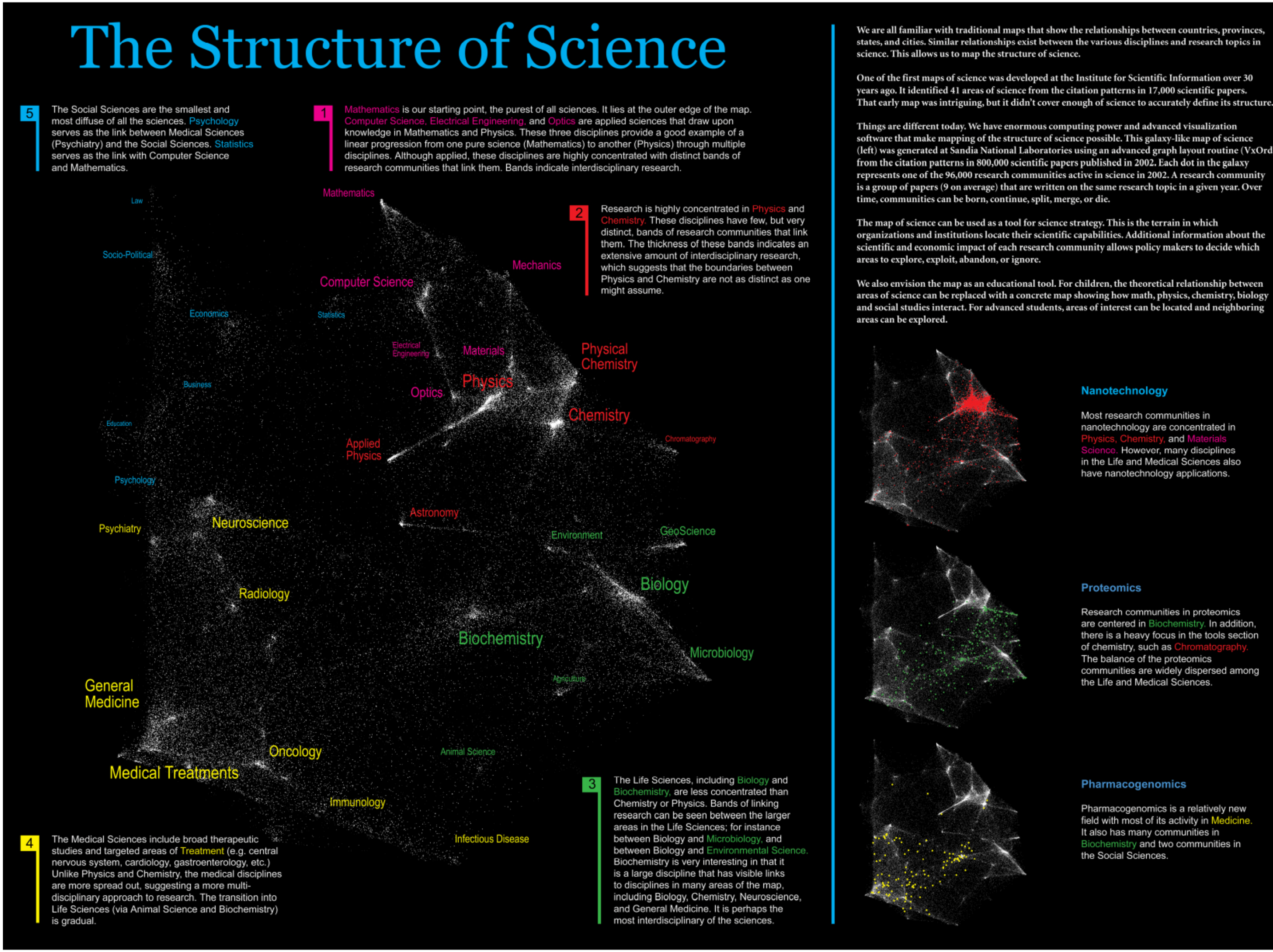
They can be used to identify objectively major experts, institutions, collections. They allow us to track the emergence, evolution, and disappearance of topics and help to identify the most promising areas of research.



Ph.D. Thesis Map - Keith B. Nesbitt - 2004



In Terms of Geography - Andre Skupin - 2005



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

The Power of Reference Systems 2006

II.1

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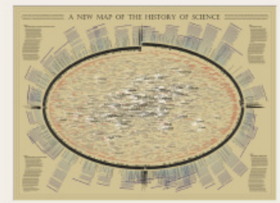

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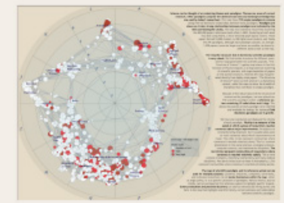

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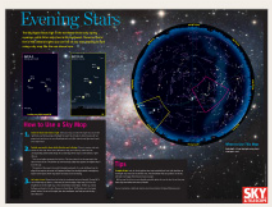

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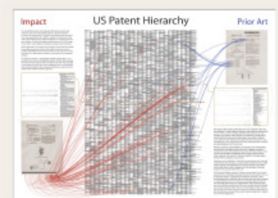

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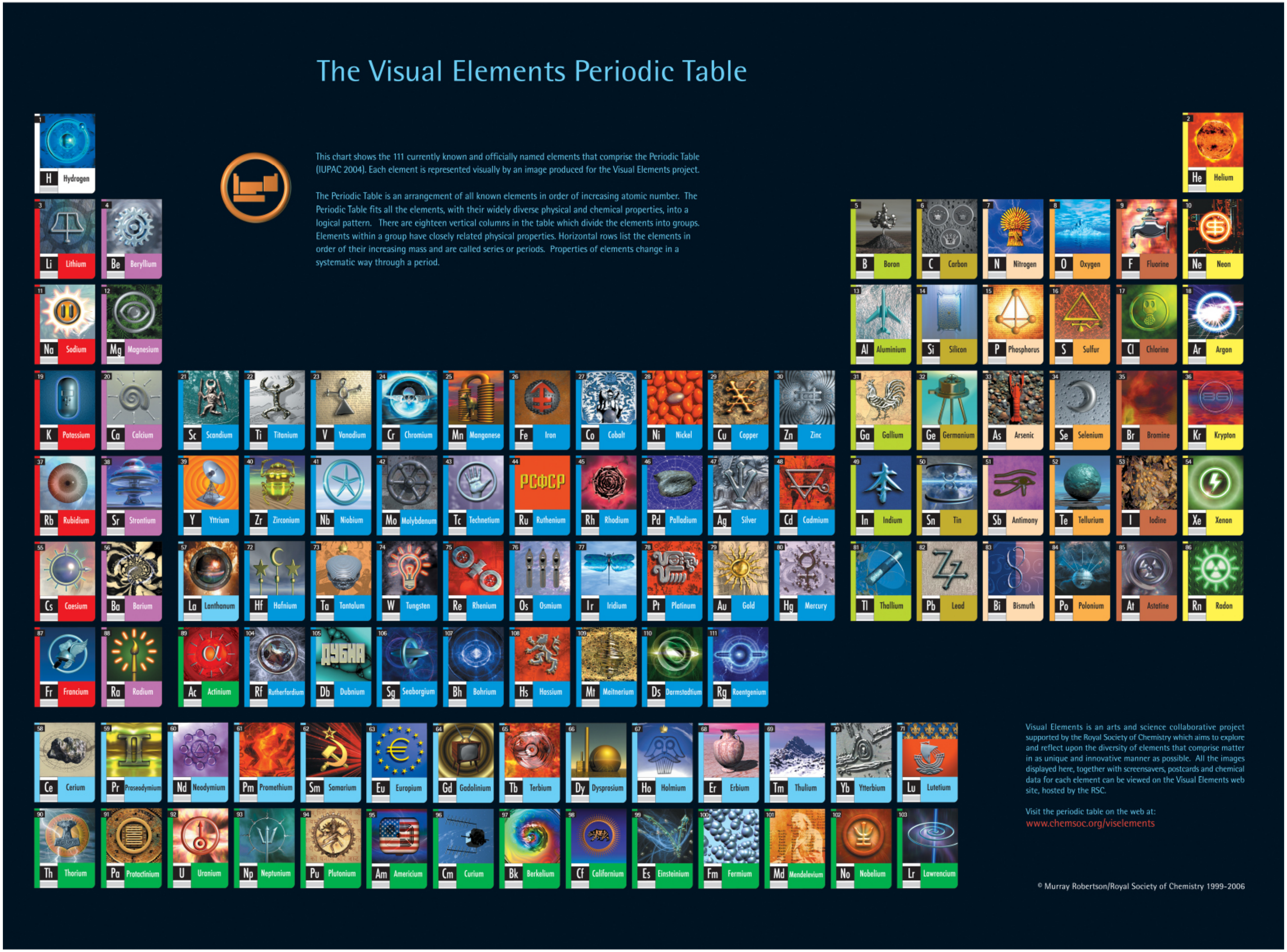
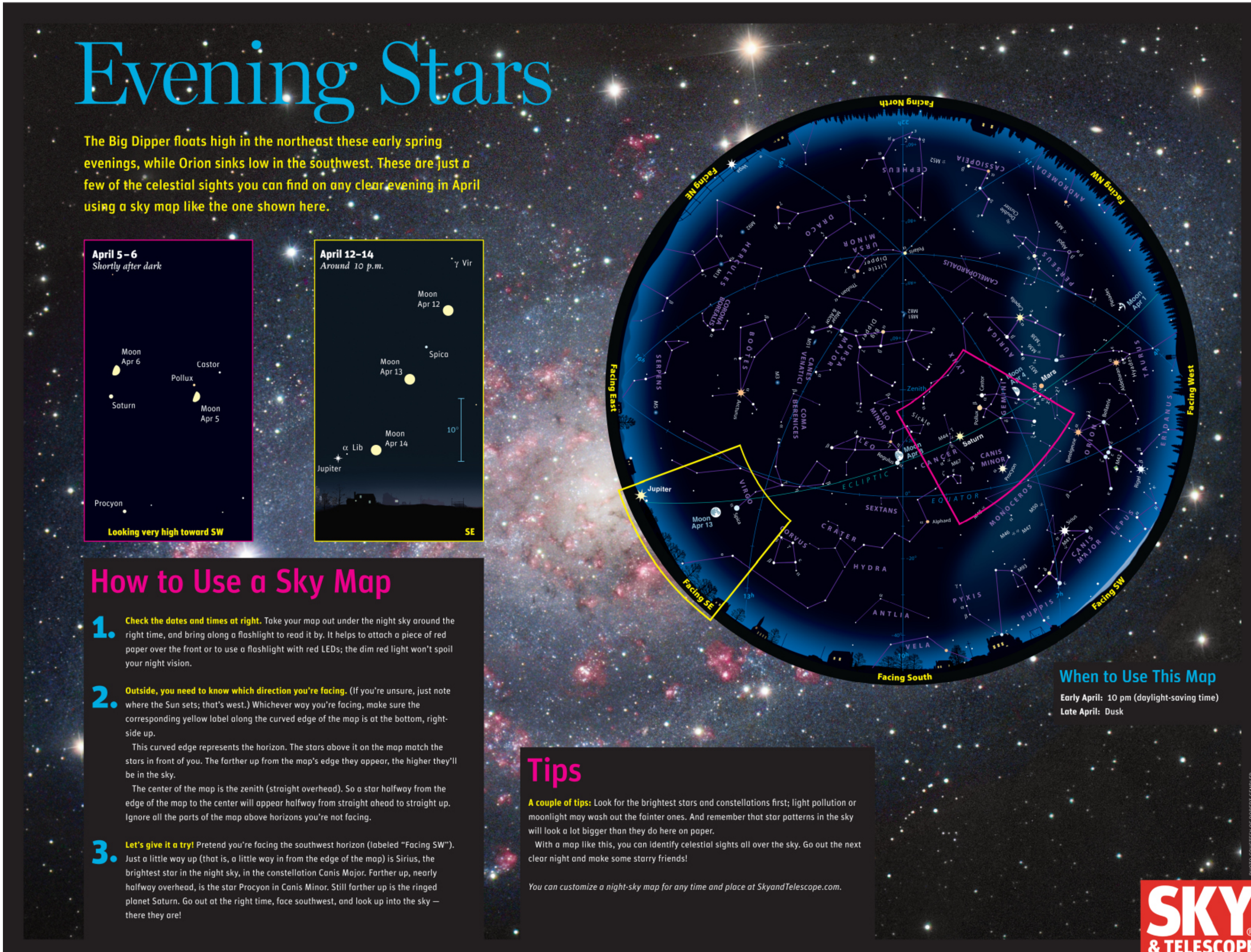


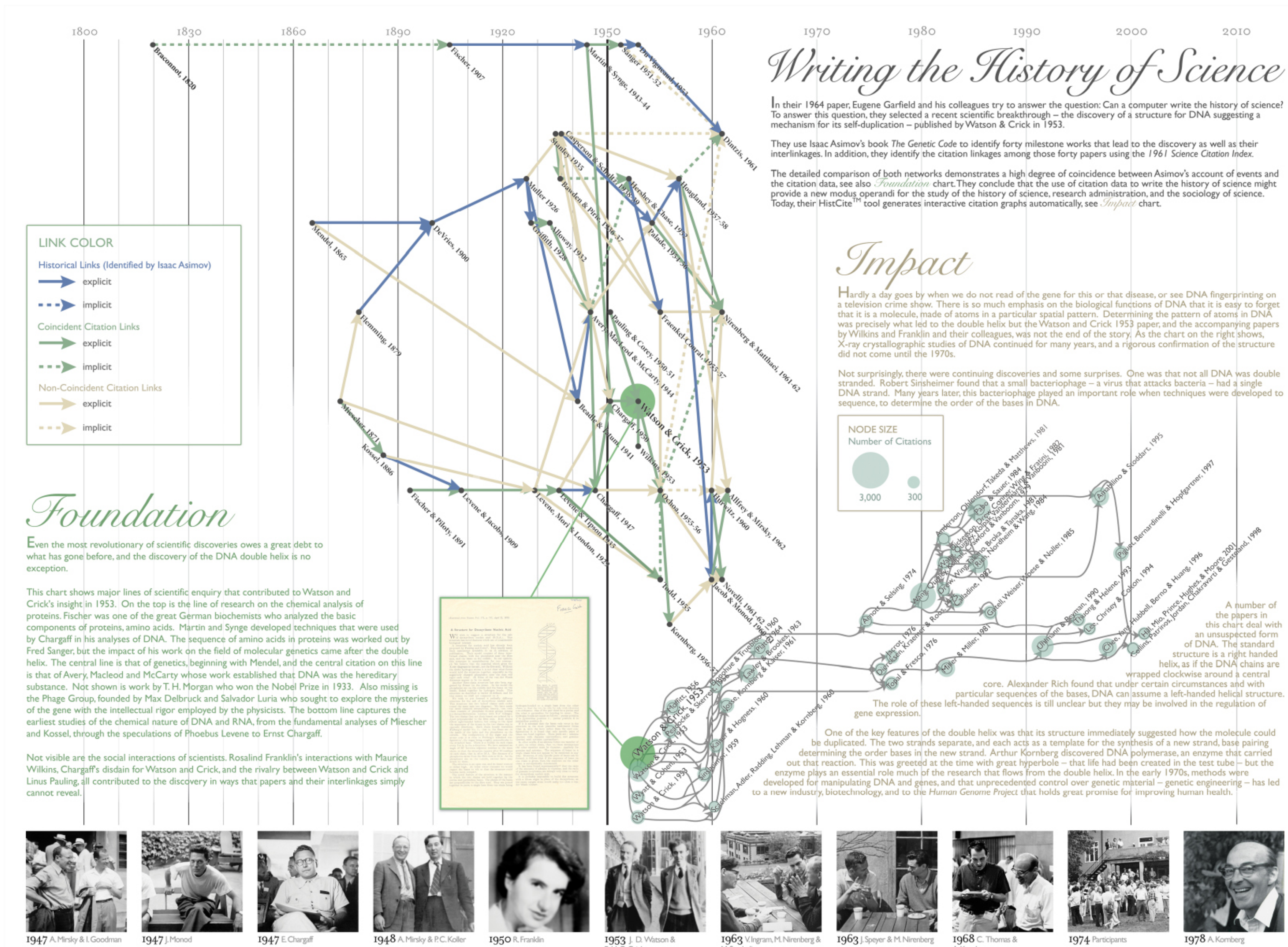
Visual Elements Periodic Table - Murray Robertson, John Emsley - 2005



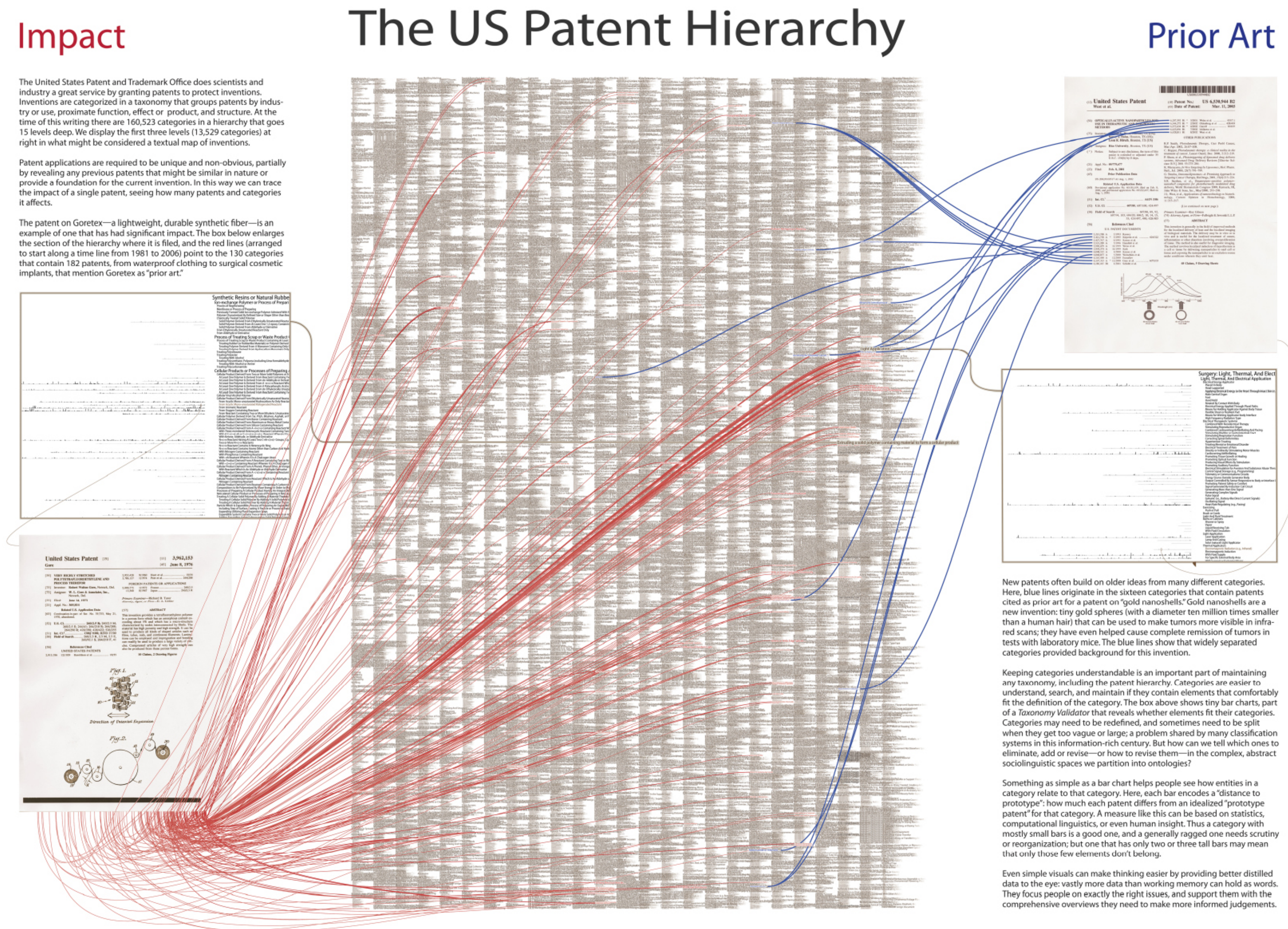
Sky Chart of New York City in April 2006 - Roger W. Sinnott, Interactive Factory - 2006

How would a reference system for all of science look?

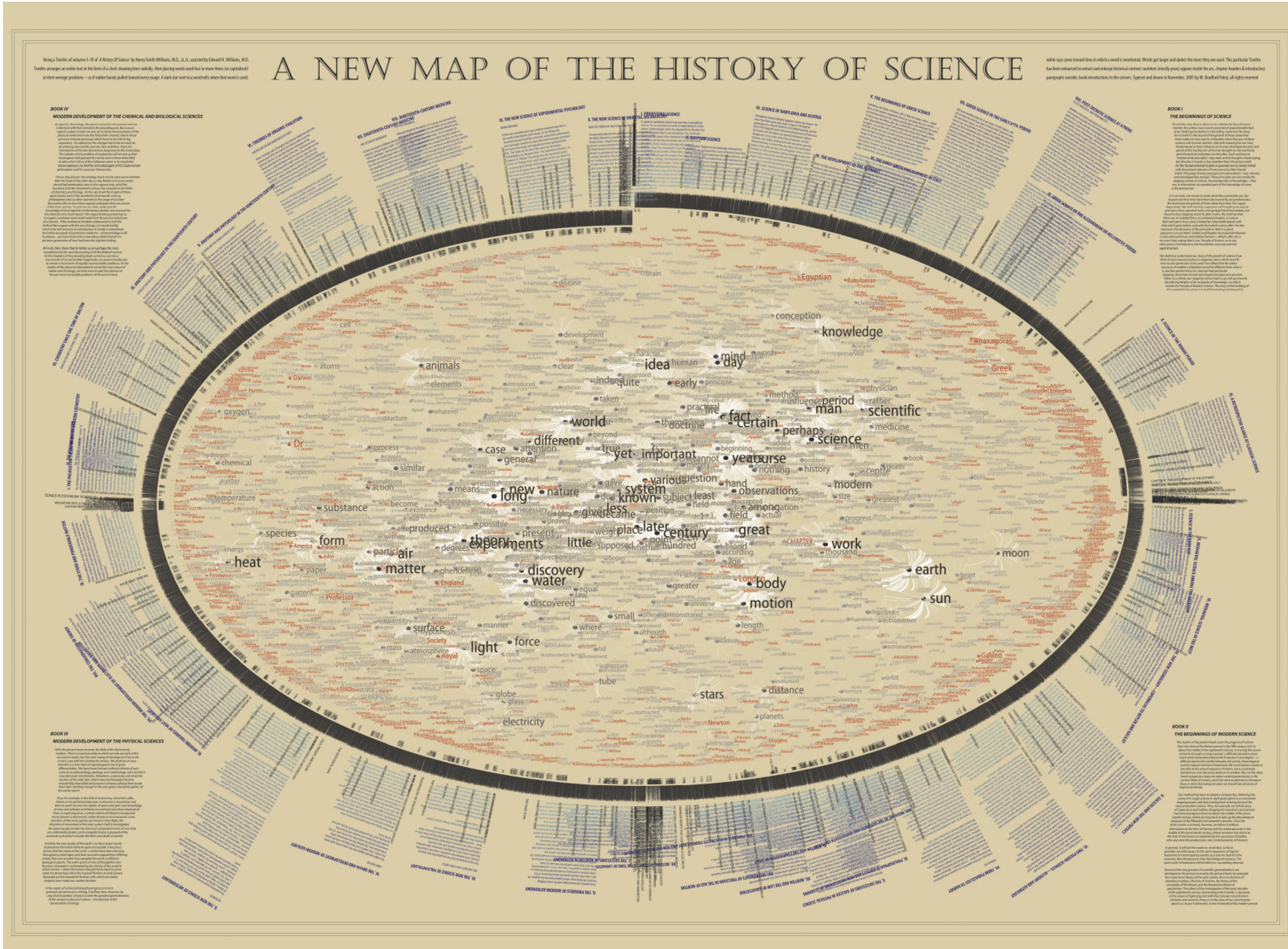
What dimensions would it have?



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

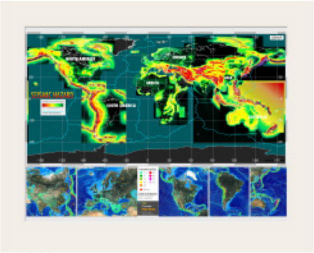


Taxonomy Visualization of Patent Data - Katy Borner, Elisha Hardy, Bruce Herr, Todd Holloway, Bradford Paley - 2006



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

The Power of Forecasts 2007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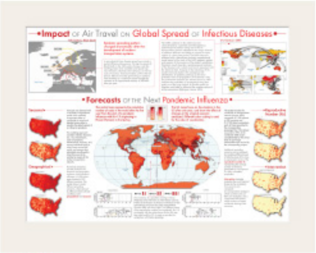

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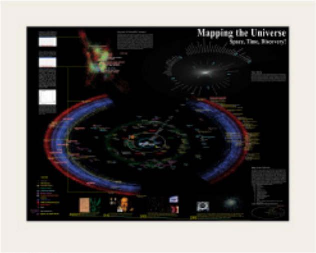

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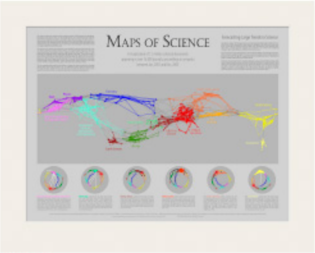

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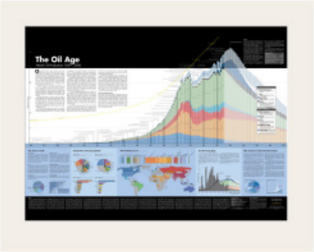

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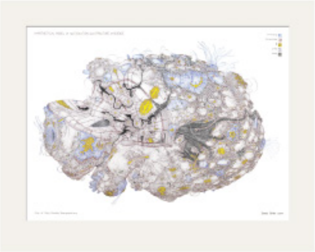
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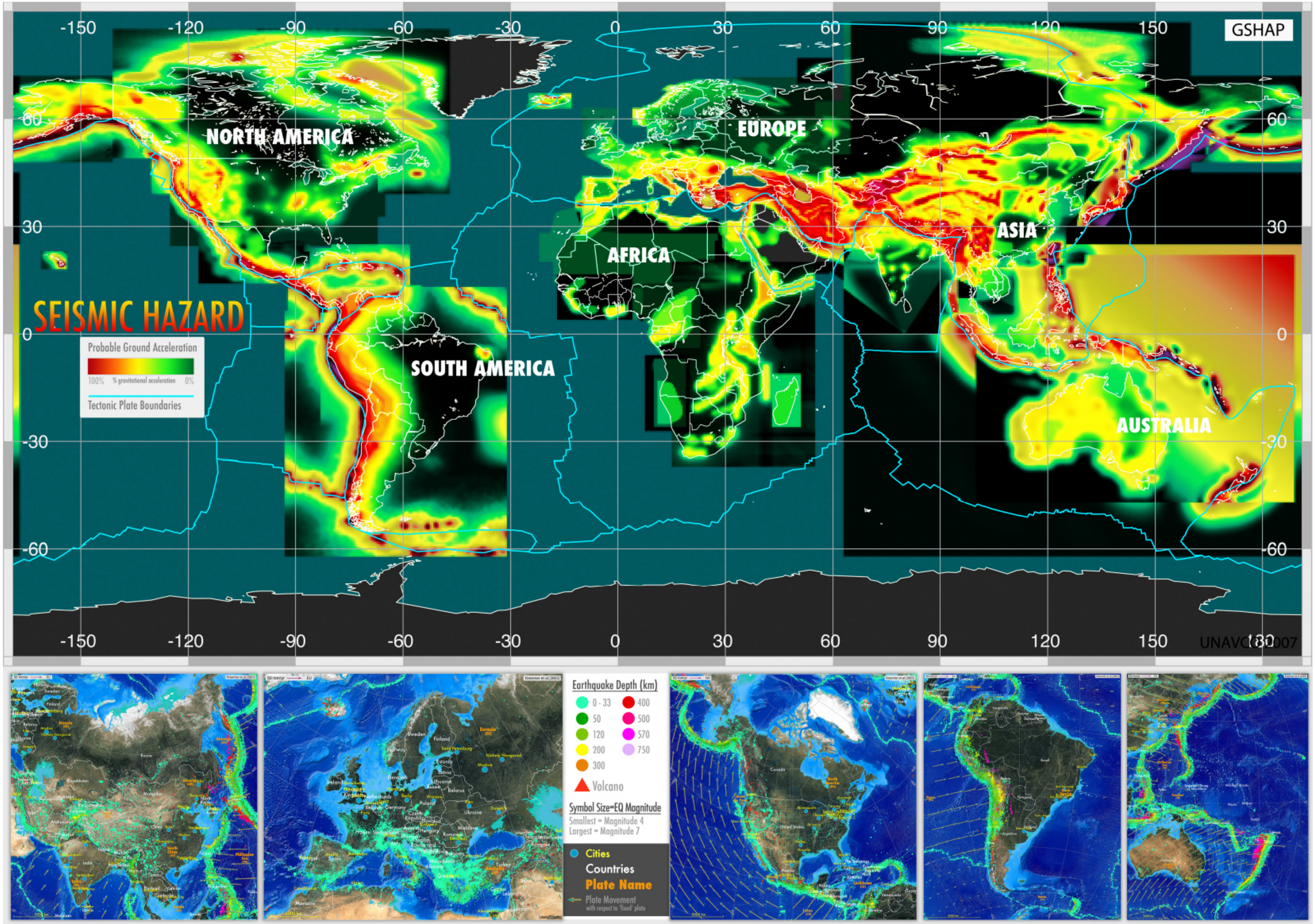
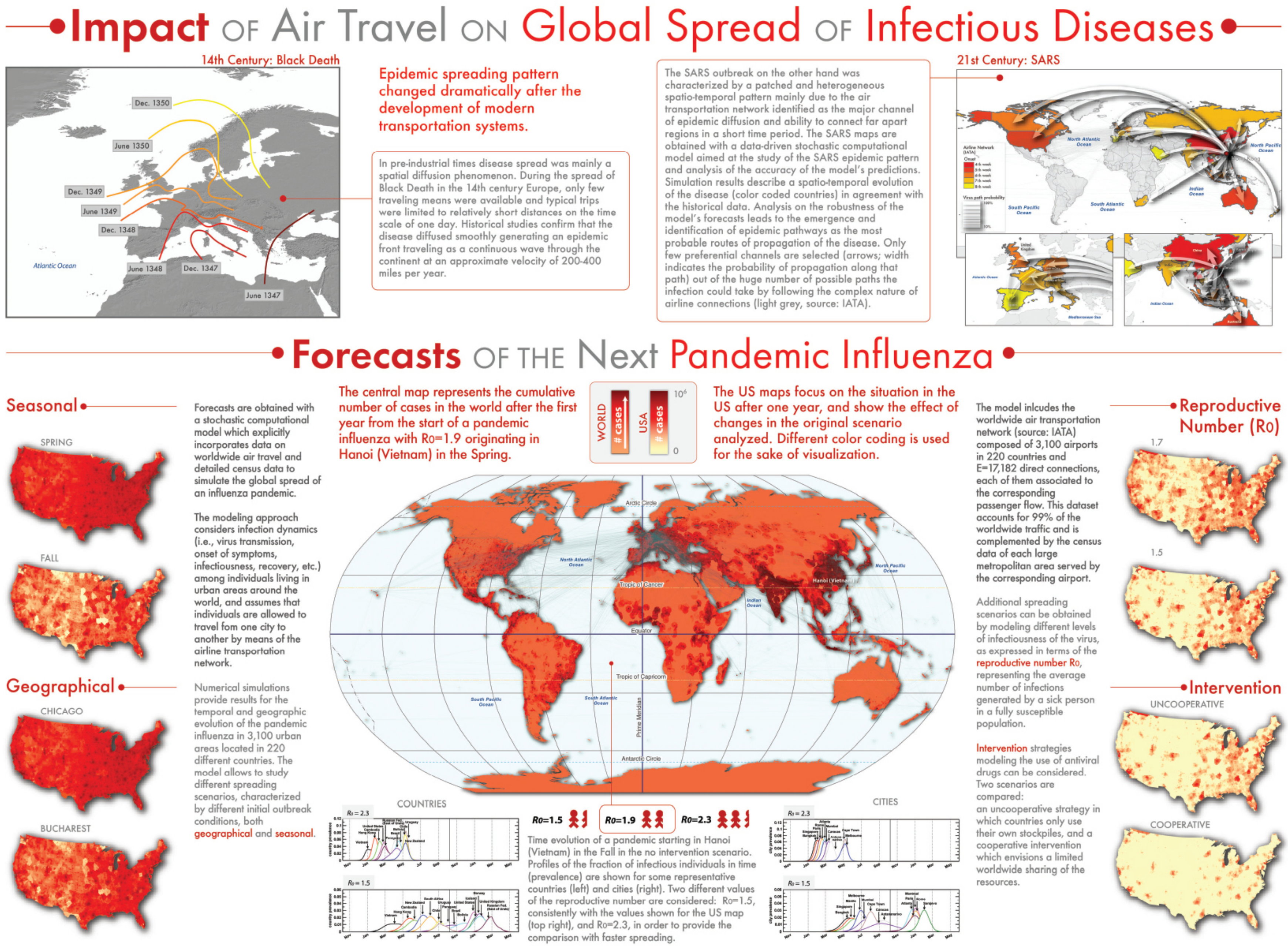


Tectonic Movements and Earthquake Hazard Predictions - Martin W. Hamburger, Lou Estey, Chuck Meertens, Elisha Hardy - 2005



Impact of Air Travel on Global Spread of Infectious Diseases - 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

Technology Horizons Program
Institute for the Future
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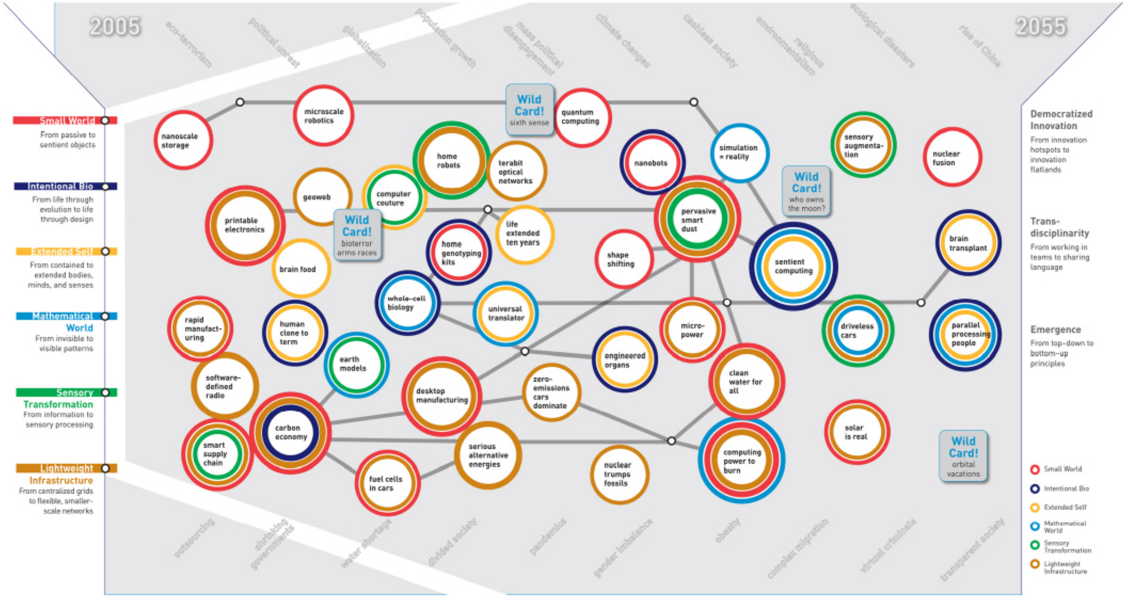


A map is a tool for navigating an unknown terrain. In the case of this map, Science & Technology Outlook: 2005–2055, the terrain we're navigating is the uncharted territory of science and technology (S&T) in the next 50 years. However, the map of the future is not a tool for prediction or, for that matter, 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 technologies, 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 respond 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.

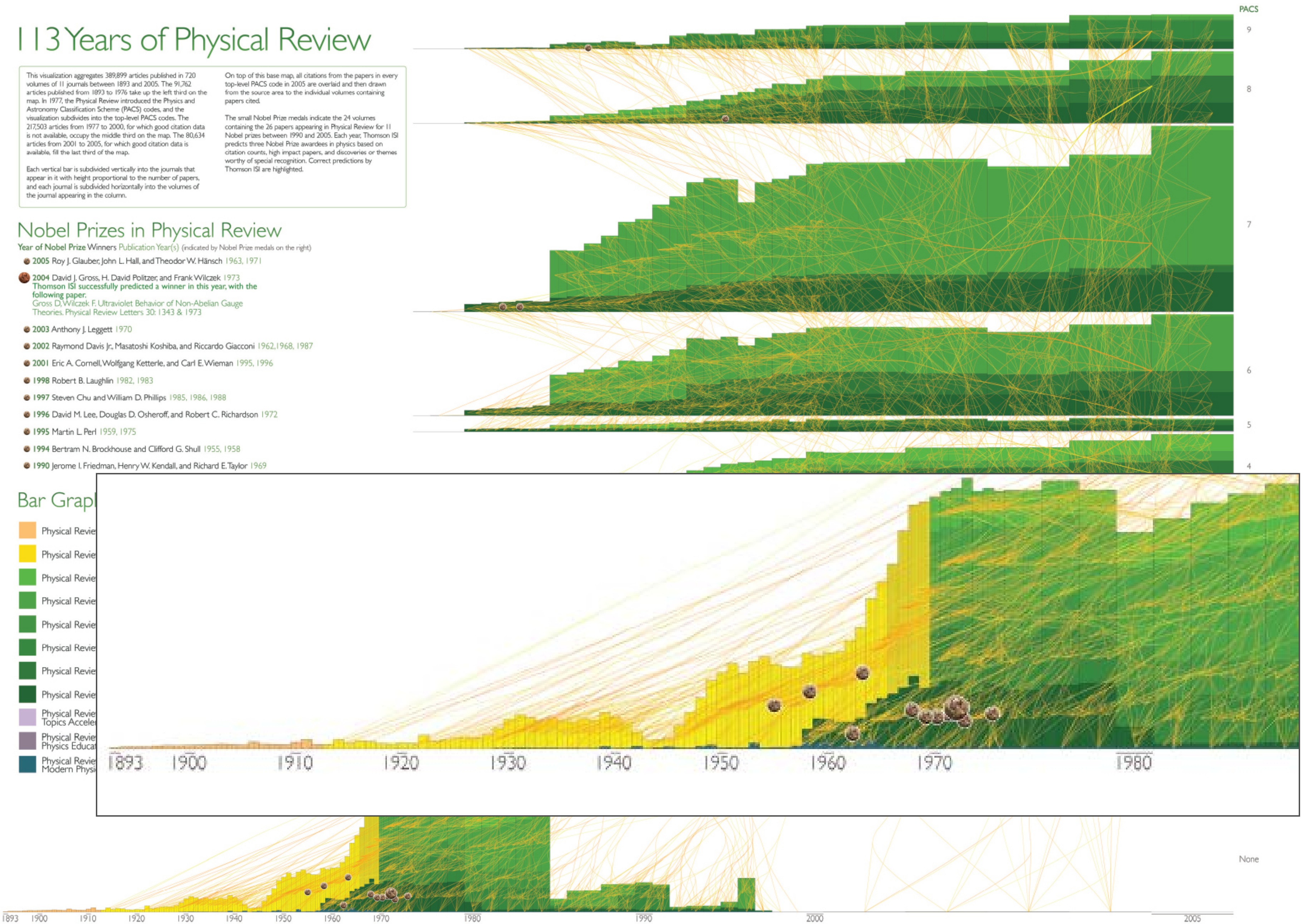
Transdisciplinarity

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."

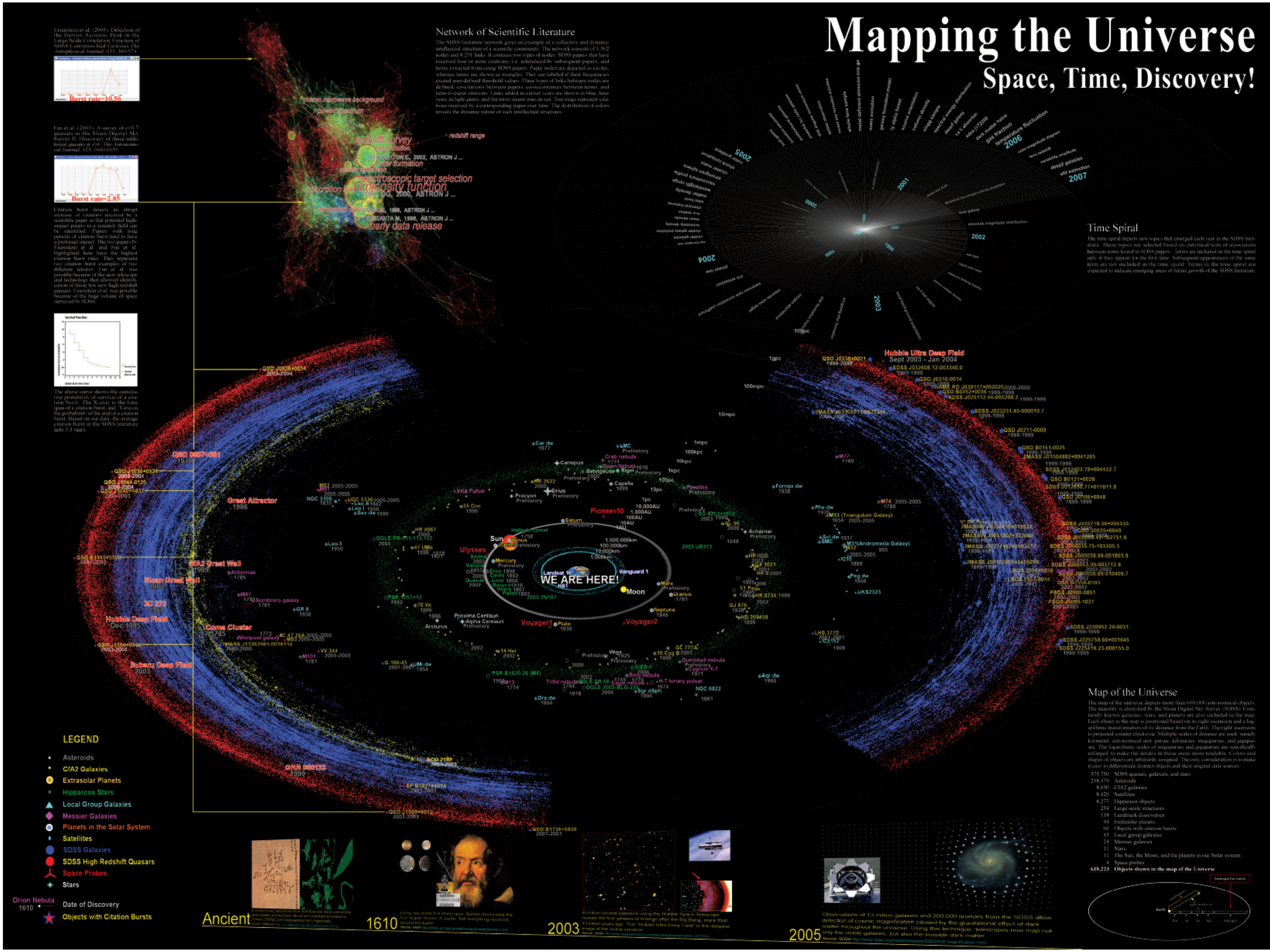
Emergence

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.

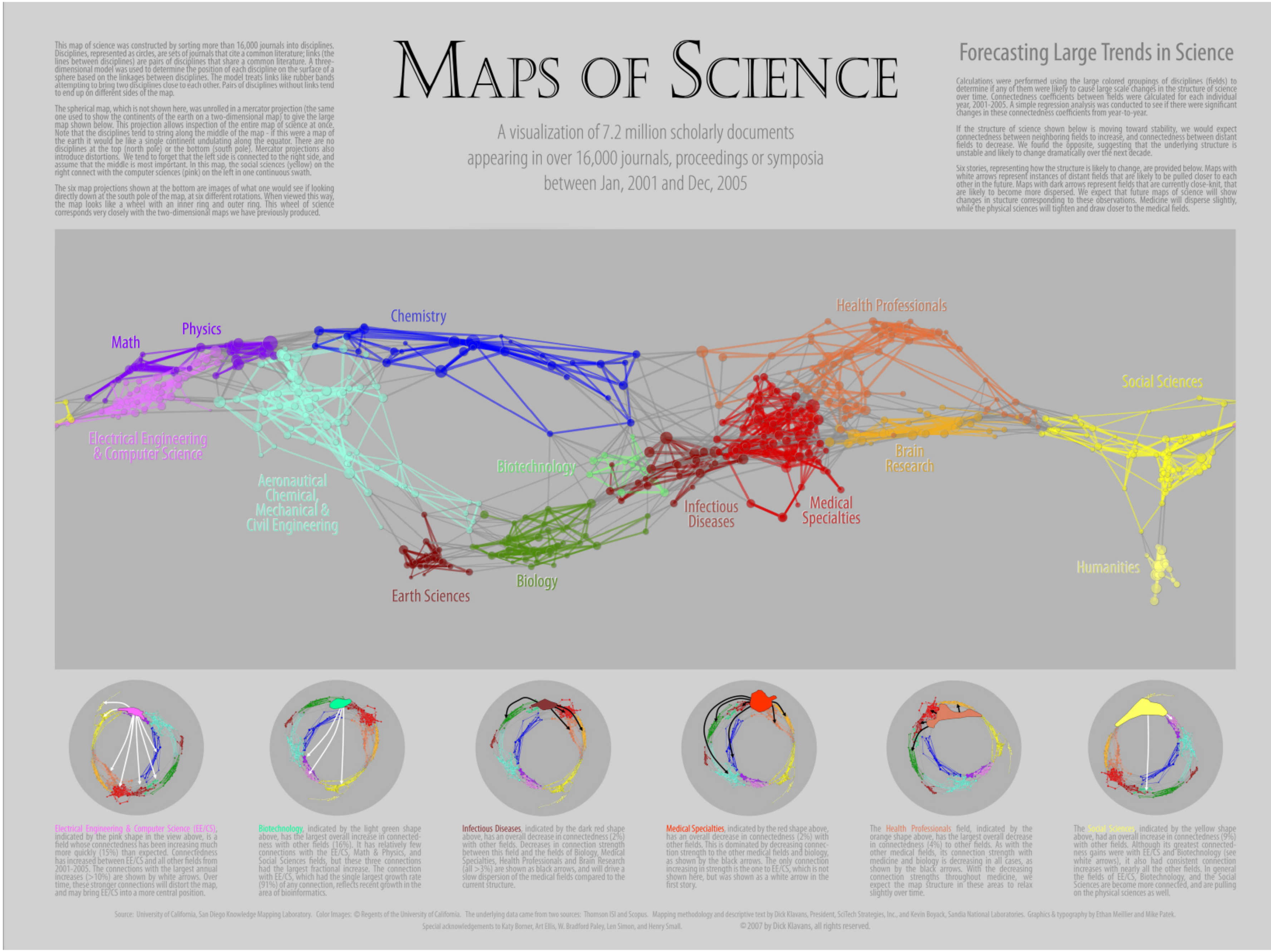
Science & Technology Outlook: 2005-2055 - Alex Soojung-Kim Pang, David Pescovitz, Marina Gorbis, Jean Hagan - 2006



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



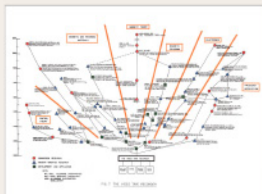
Mapping the Universe: Space, Time, Discovery! Chaomei Chen, Jian Zhang, Michael S. Vogeley, J. Richard Gott III, Mario Juric, Lisa Kershner - 2007



Maps of Science: Forecasting Large Trends in Science - Richard Klavans, Kevin Boyack - 2007

Science Maps for Economic Decision Makers 2008

IV.1



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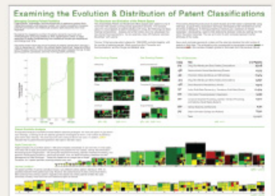

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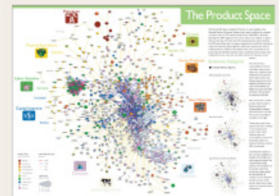

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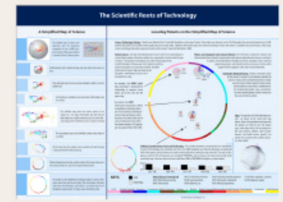

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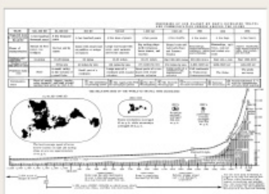

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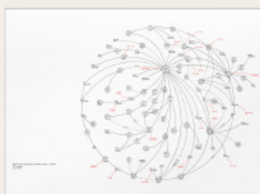

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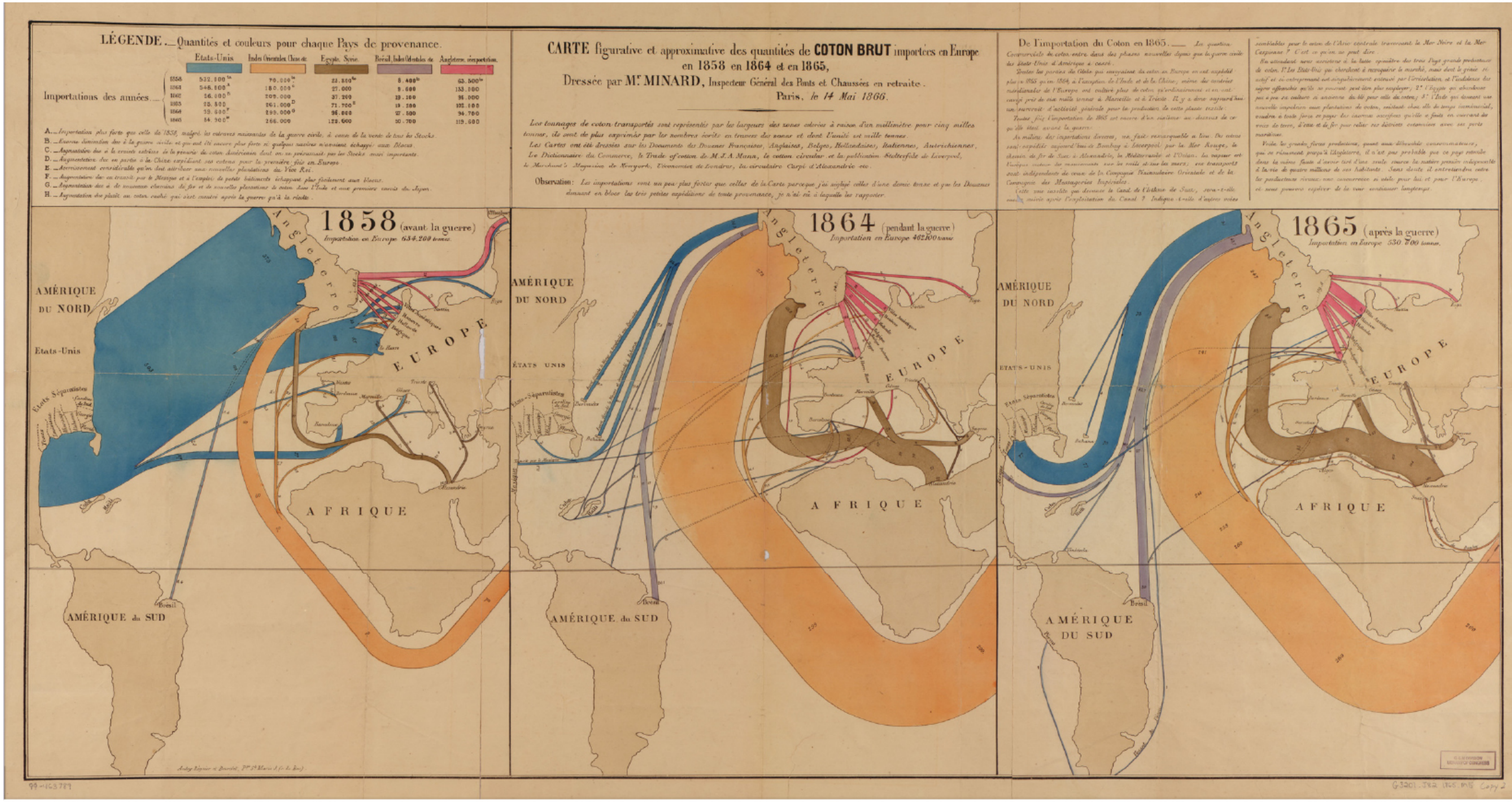
IV.10

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

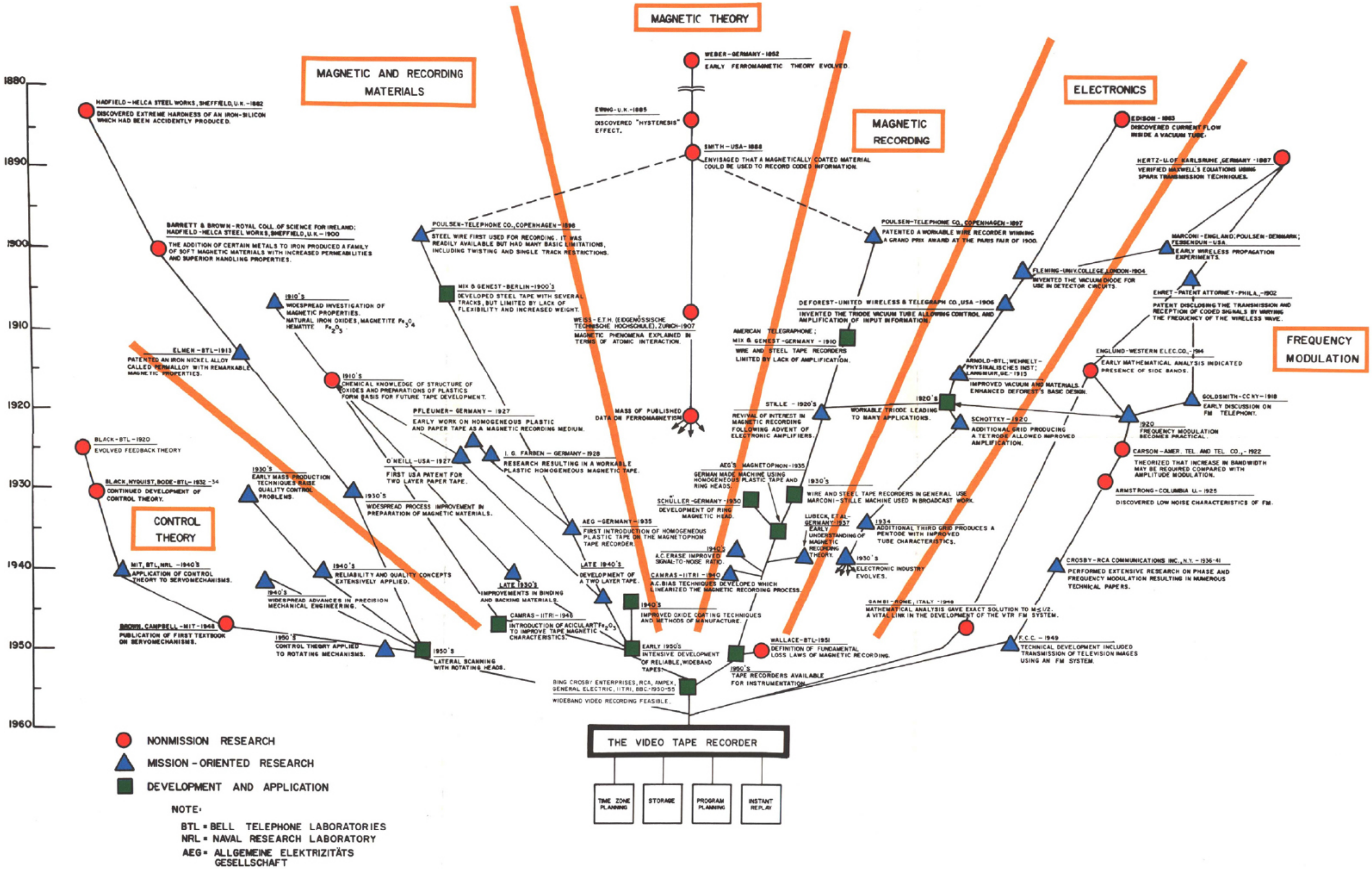
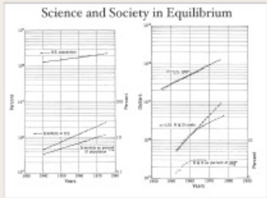


FIG. 7. THE VIDEO TAPE RECORDER

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

Science Maps for Science Policy Makers 2009



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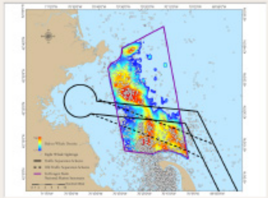

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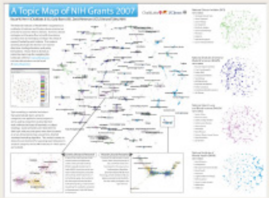

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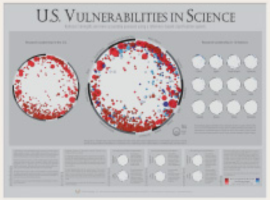
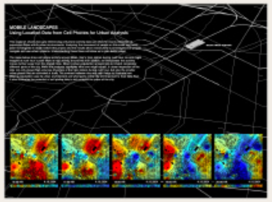


V.9

V.2



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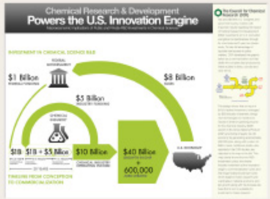

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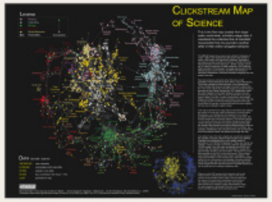
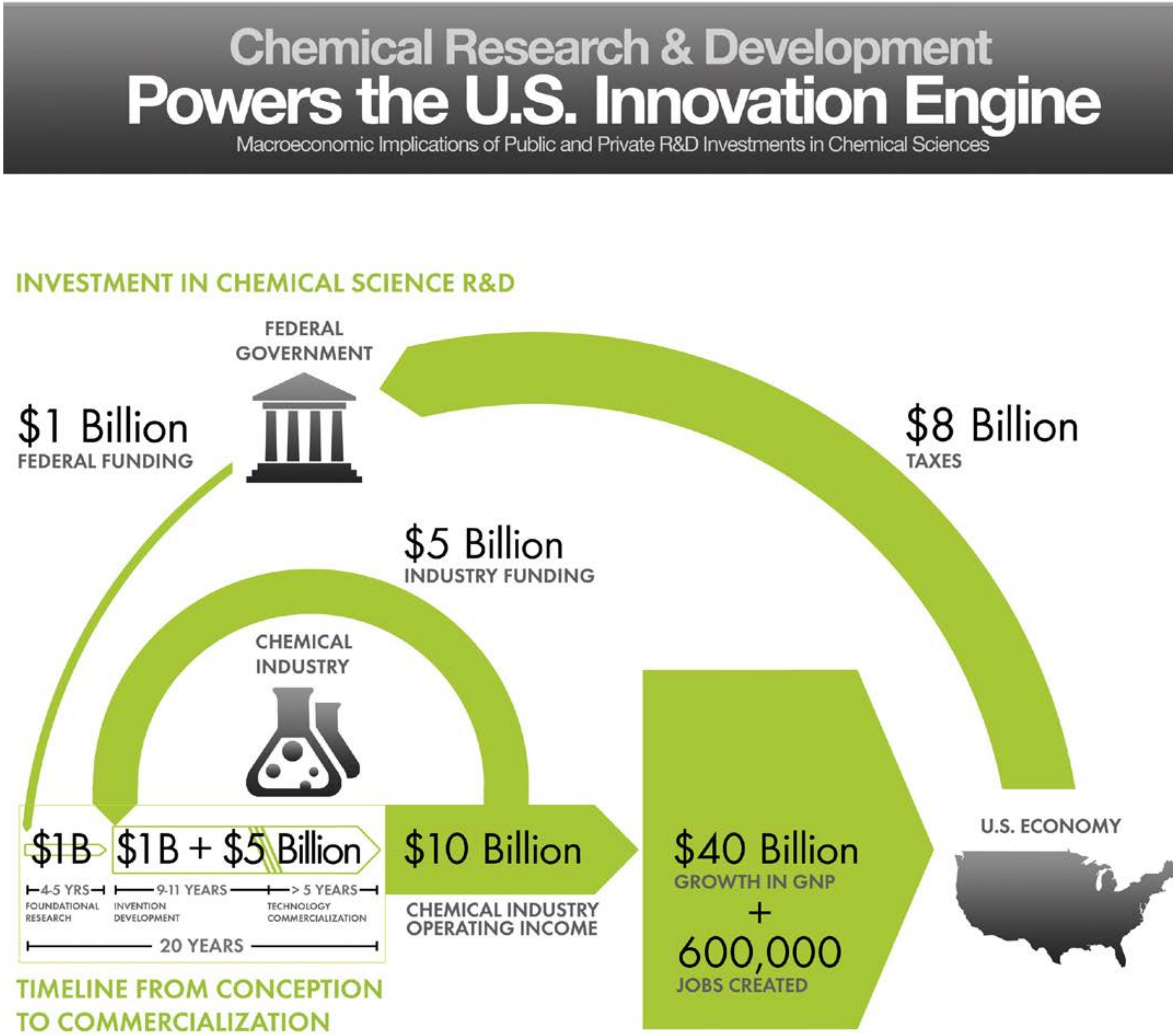


V.8

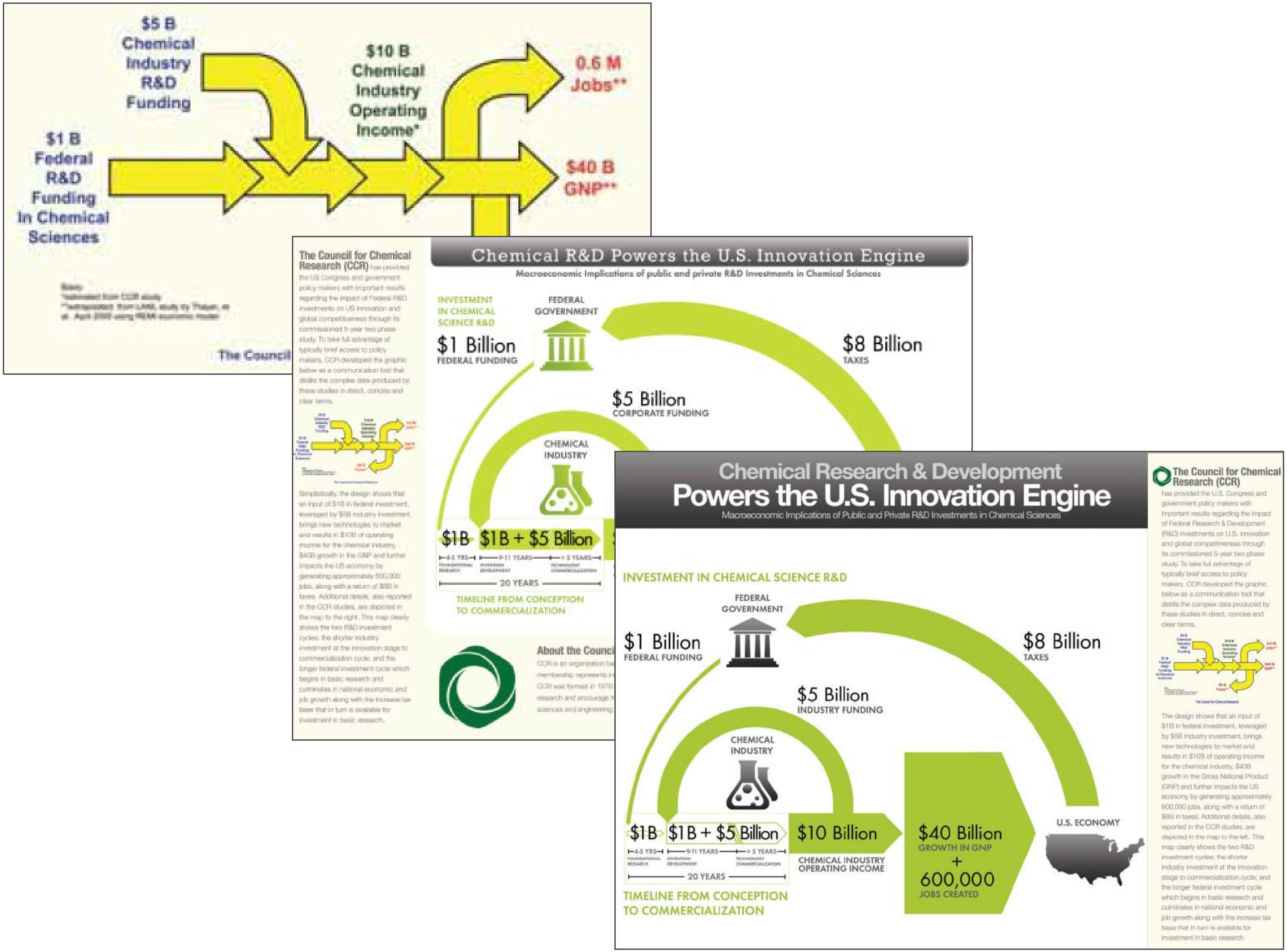
V.10



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
$10 B Chemical Industry Operating Income*
0.6 M Jobs**
$1 B Federal R&D Funding In Chemical Sciences
$40 B GNP**
The Council
The Council for Chemical Research (CCR)
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
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
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TAXES
$5 Billion
INDUSTRY FUNDING
CHEMICAL INDUSTRY
$1B
$1B + $5 Billion
4-5 YRS
9-11 YEARS
> 5 YEARS
FOUNDATIONAL RESEARCH
INVENTION DEVELOPMENT
TECHNOLOGY COMMERCIALIZATION
20 YEARS
TIMELINE FROM CONCEPTION TO COMMERCIALIZATION
$10 Billion
CHEMICAL INDUSTRY OPERATING INCOME
$40 Billion
GROWTH IN GNP
+
600,000
JOBS CREATED
U.S. ECONOMY
The Council for Chemical Research (CCR)
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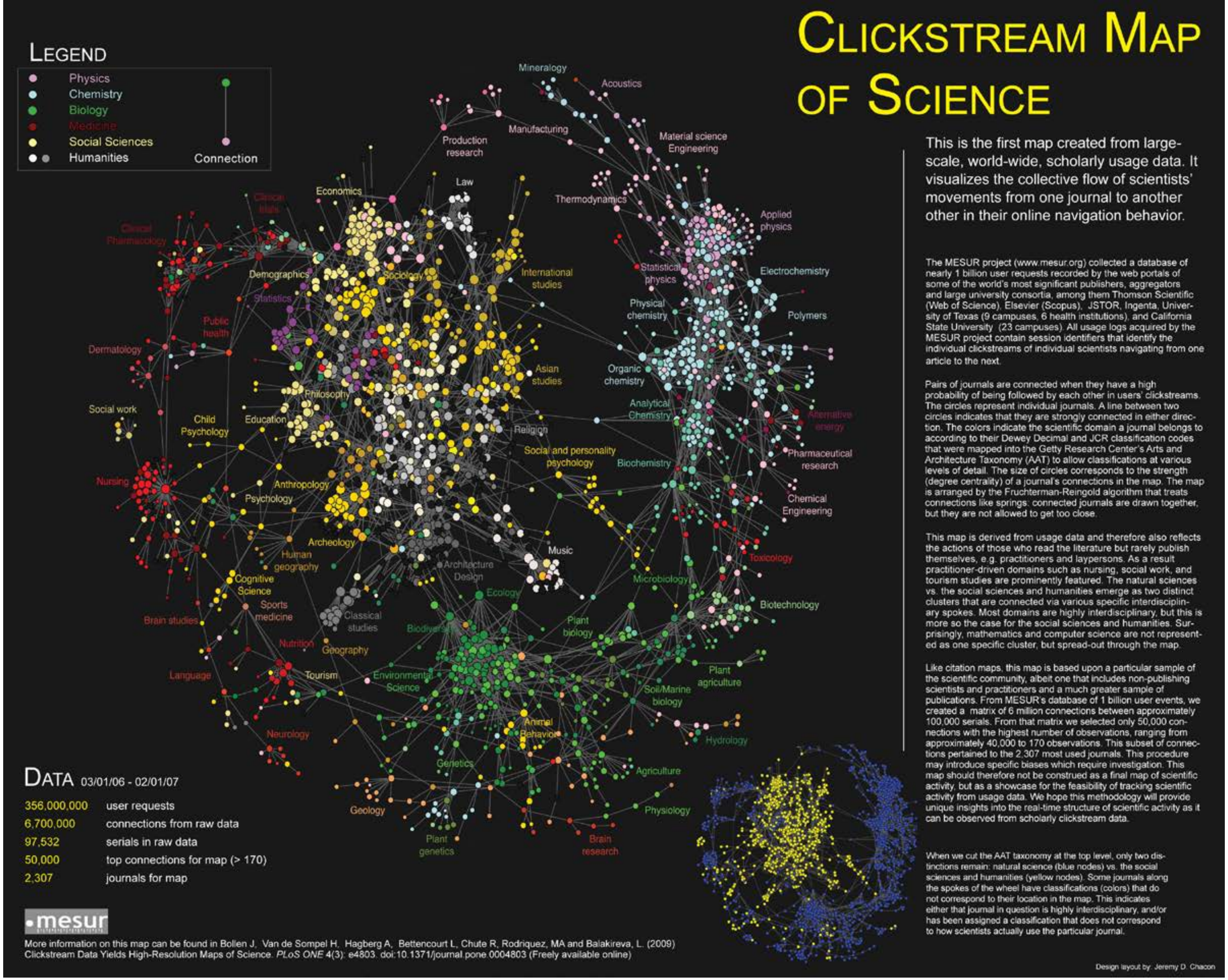
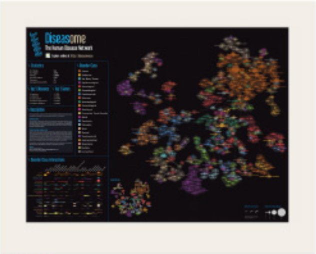


A Clickstream Map of Science. Johan Bollen, Herbert Van de Sompel, Aric Hagberg, Luís M. A. Bettencourt, Ryan Chute, Marko A. Rodriguez, and Lyudmila Balakireva - 2008

Science Maps for Scholars 2010

VI.1



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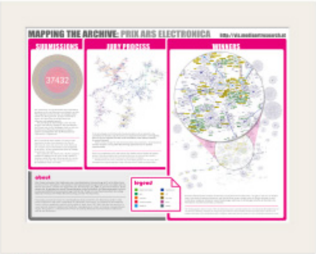
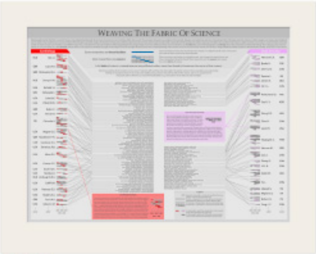


VI.5


VI.7



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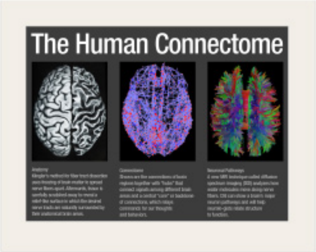
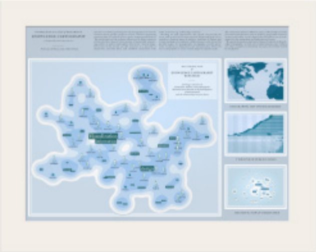


VI.2

VI.4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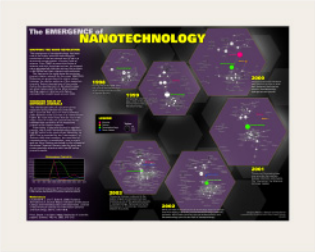
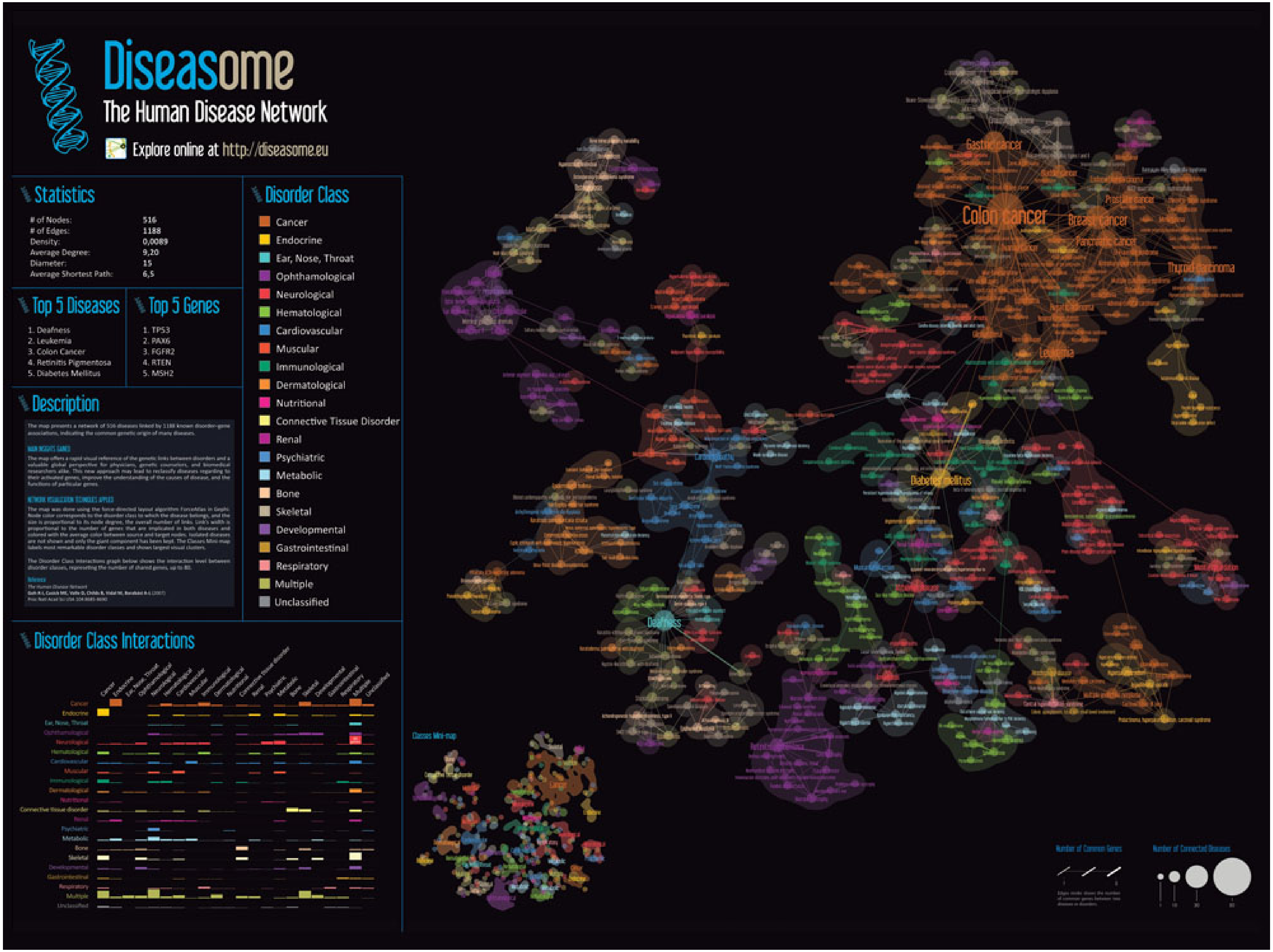
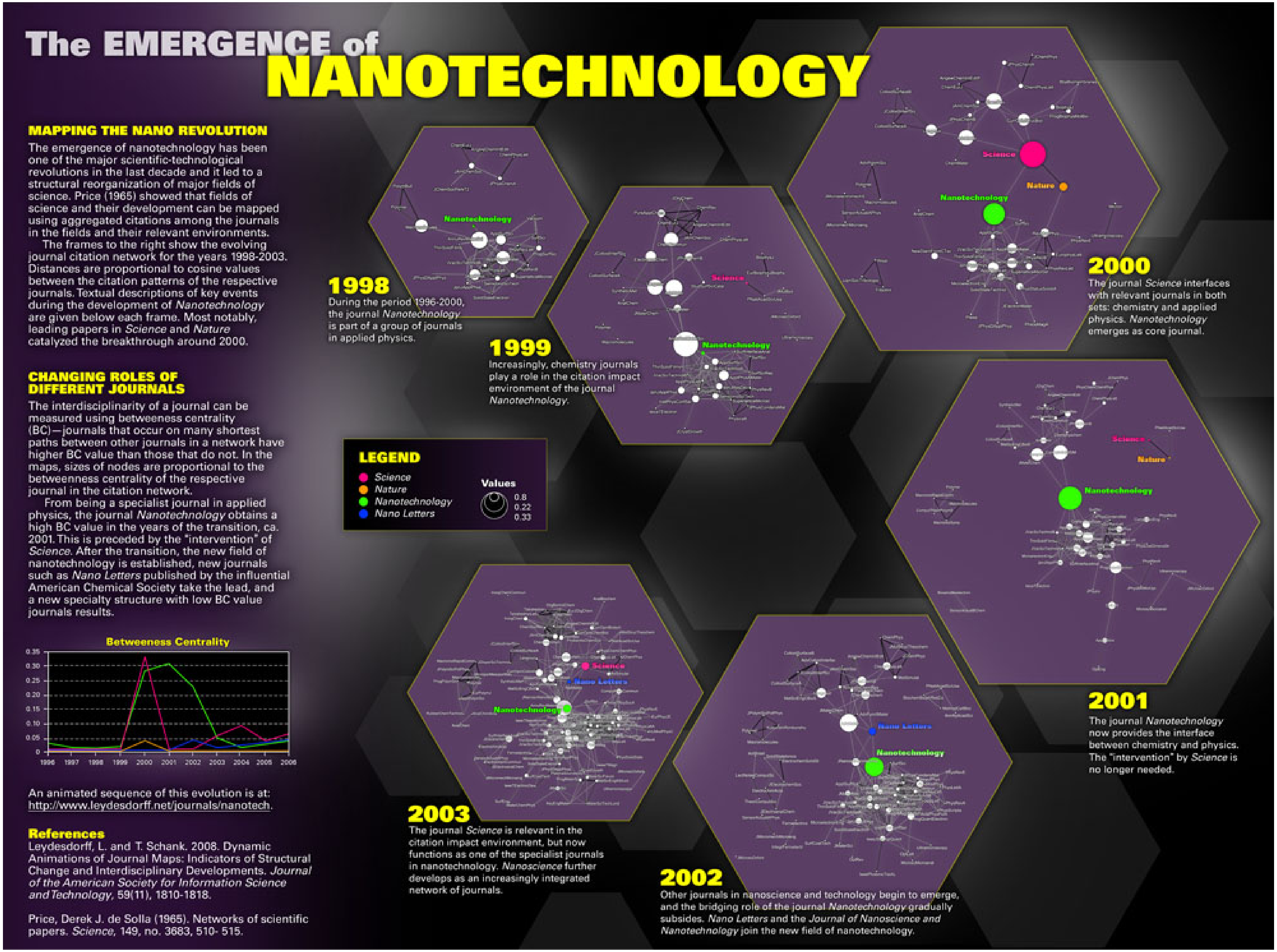


VI.8

VI.10



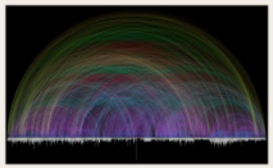
Diseasome - Mathieu Bastian & Sebastien Heymann - 2009



The Emergence of Nanoscience & Technology - Loet Leydesdorff - 2010

Science Maps as Visual Interfaces to Digital Libraries 2011

VII.1



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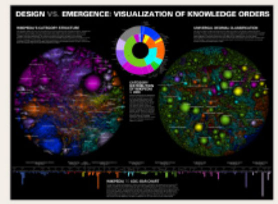

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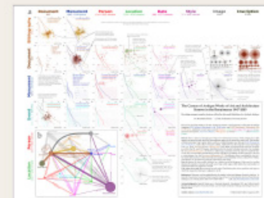
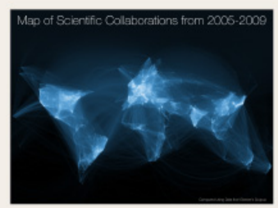


VII.7

VII.9

VII.2

VII.4



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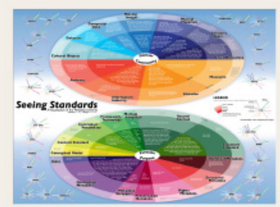

VII.8

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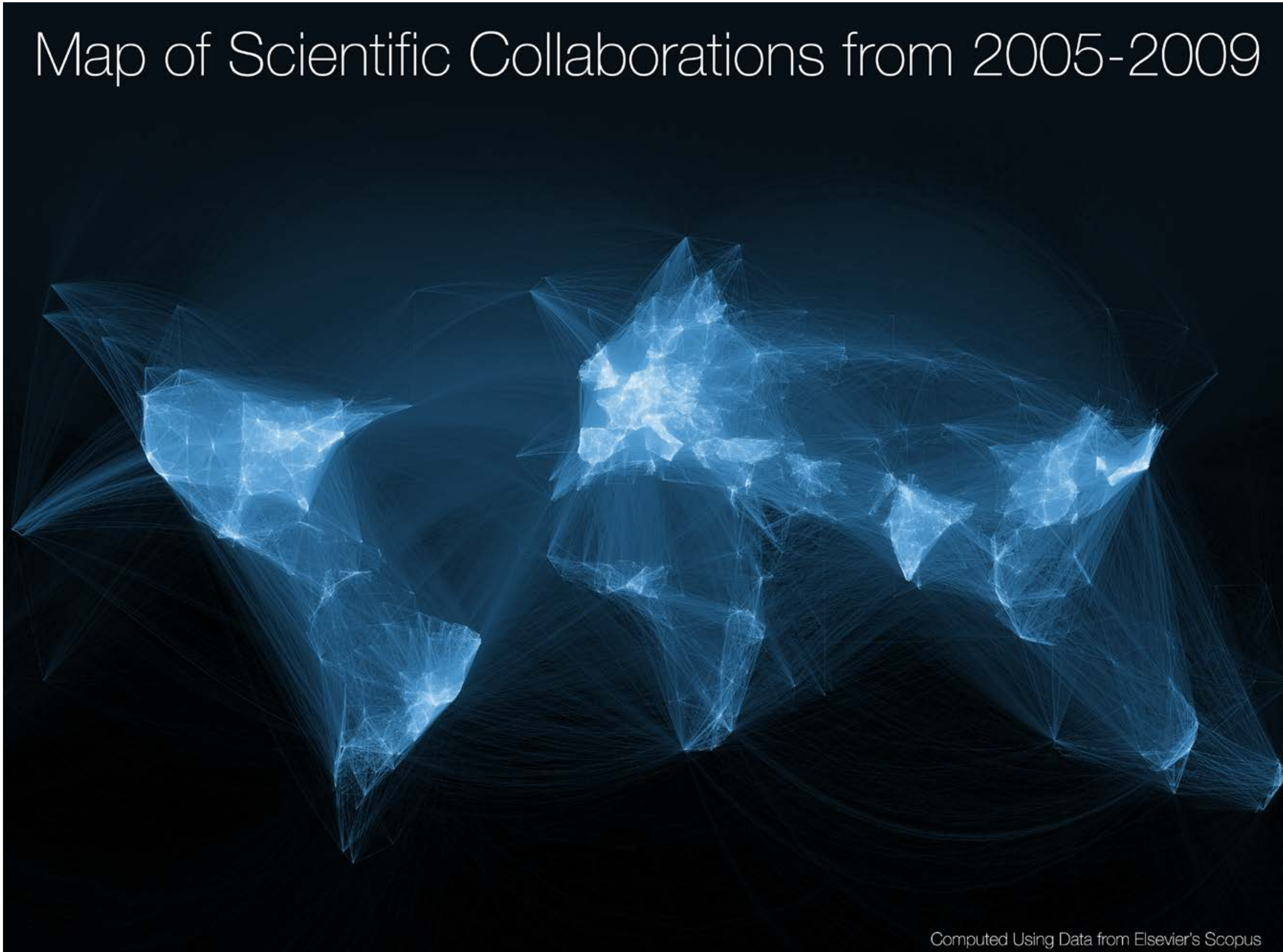
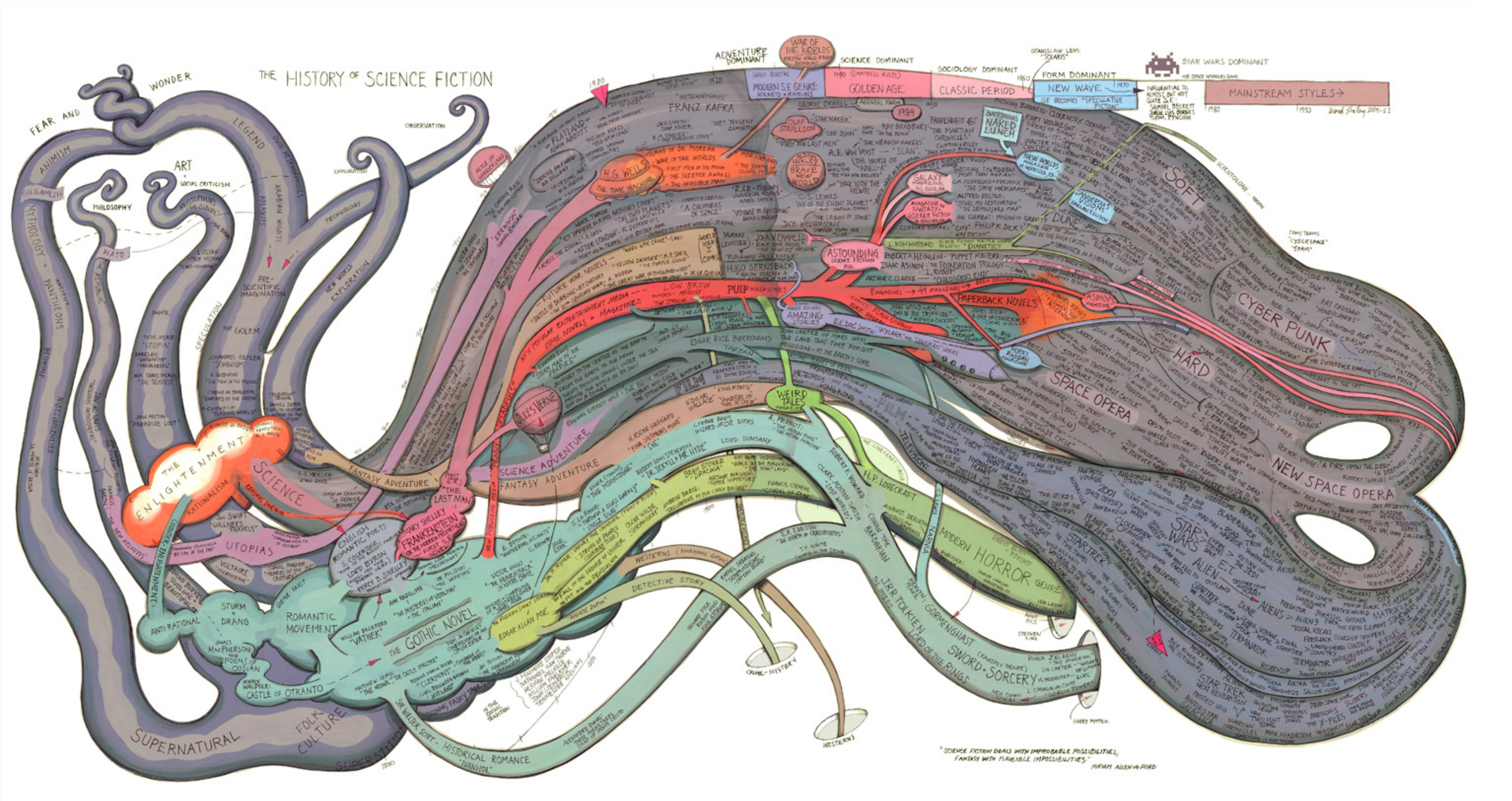


Stream of Scientific Collaborations Between World Cities - Olivier H. Beauchesne - 2012



History of Science Fiction - Ward Shelley - 2011

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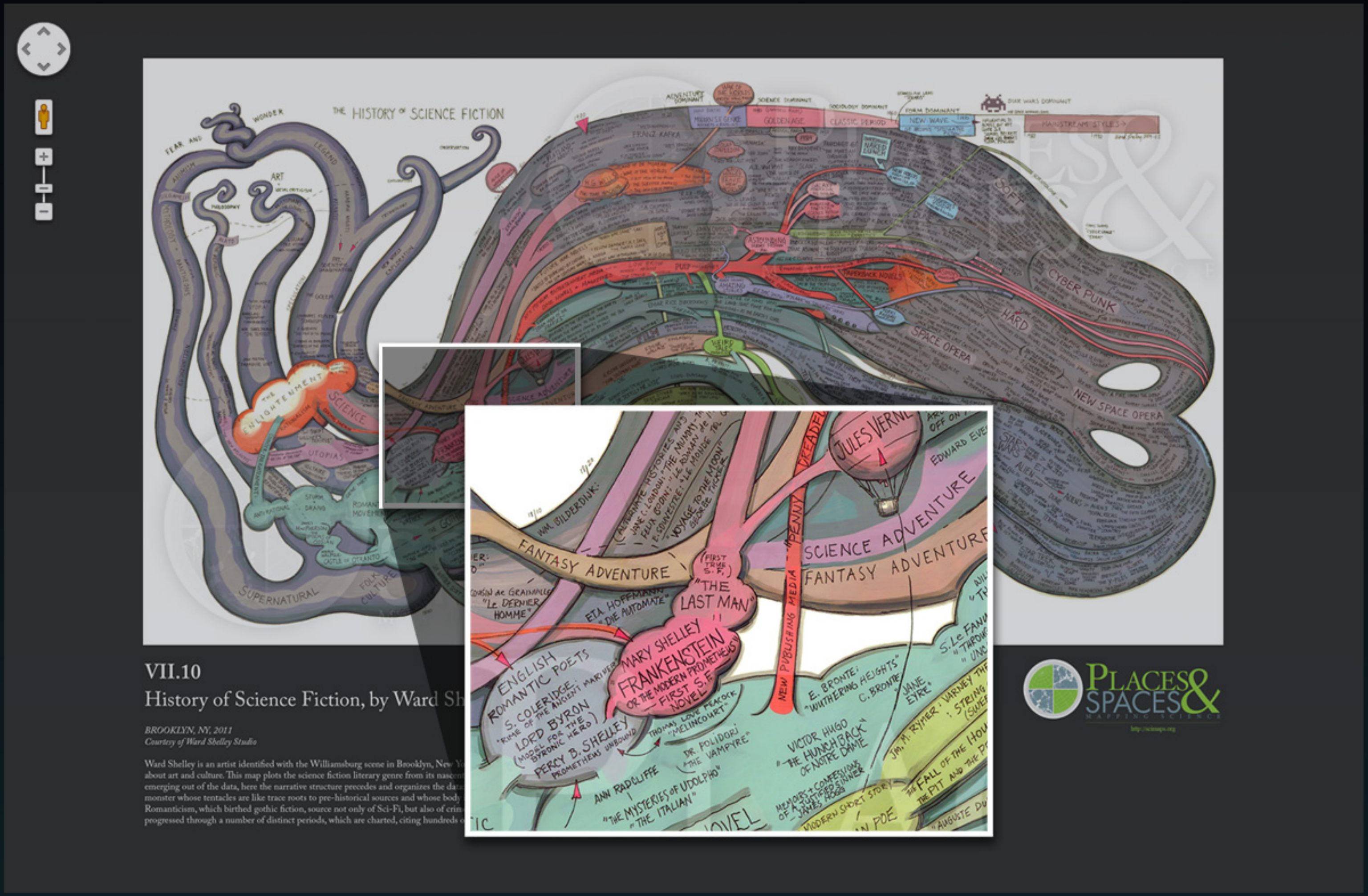

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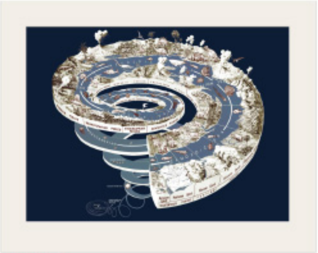
Science Maps for Kids 2012



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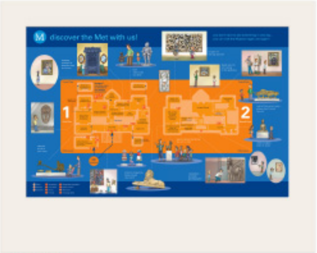
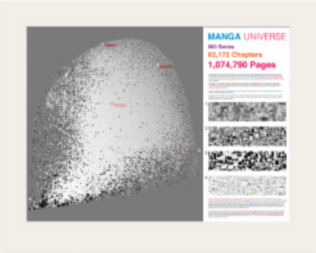


VIII.3

VIII.5



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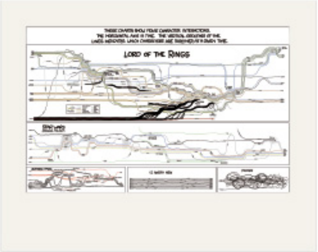

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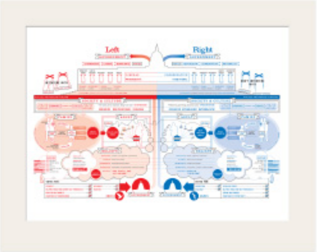

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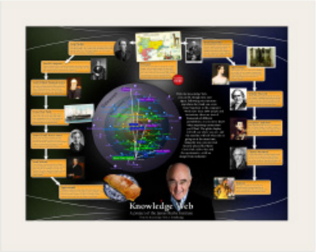

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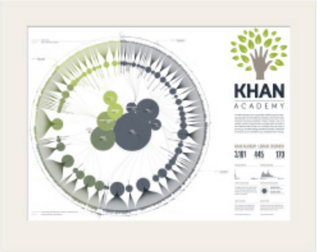

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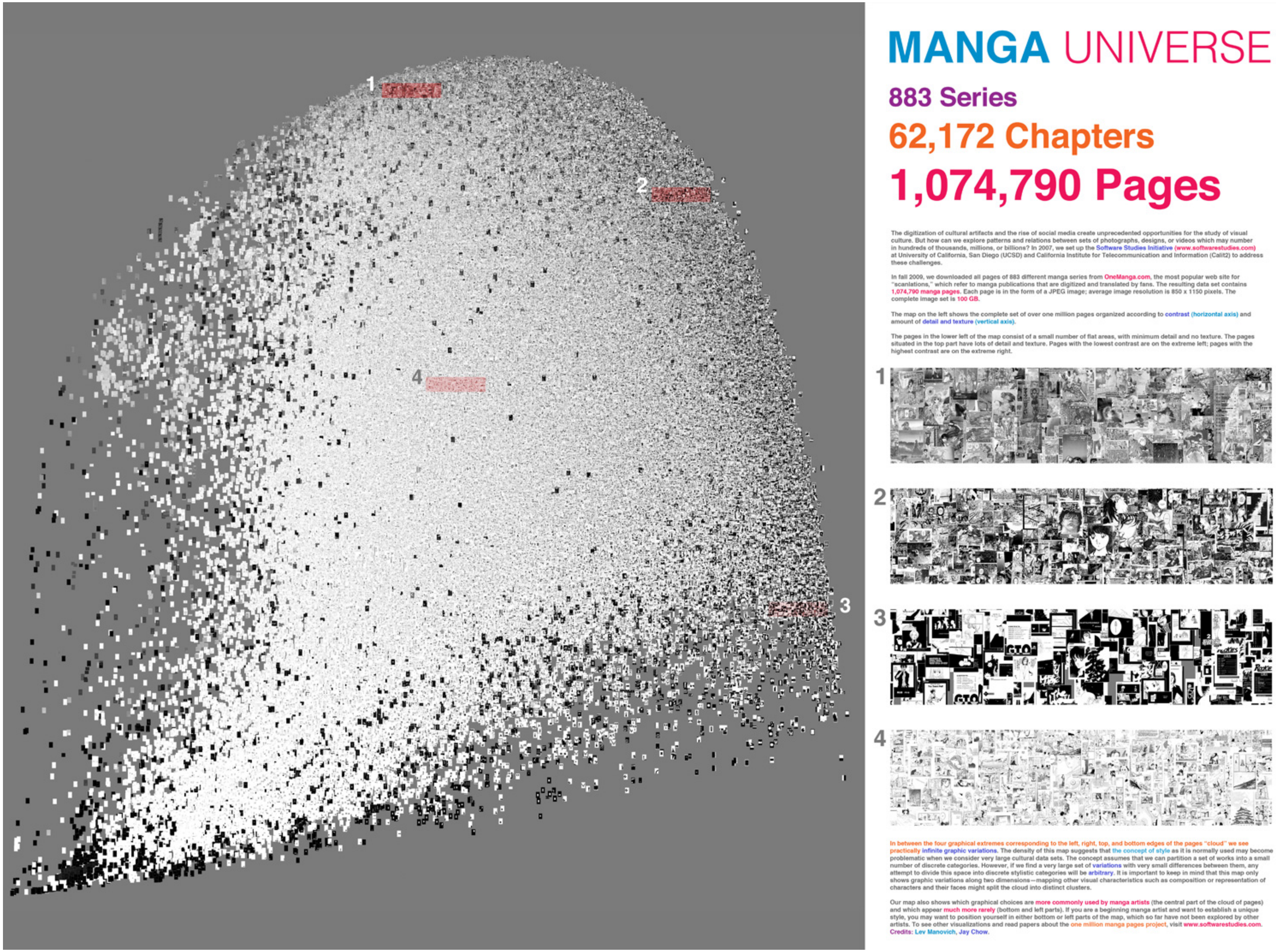
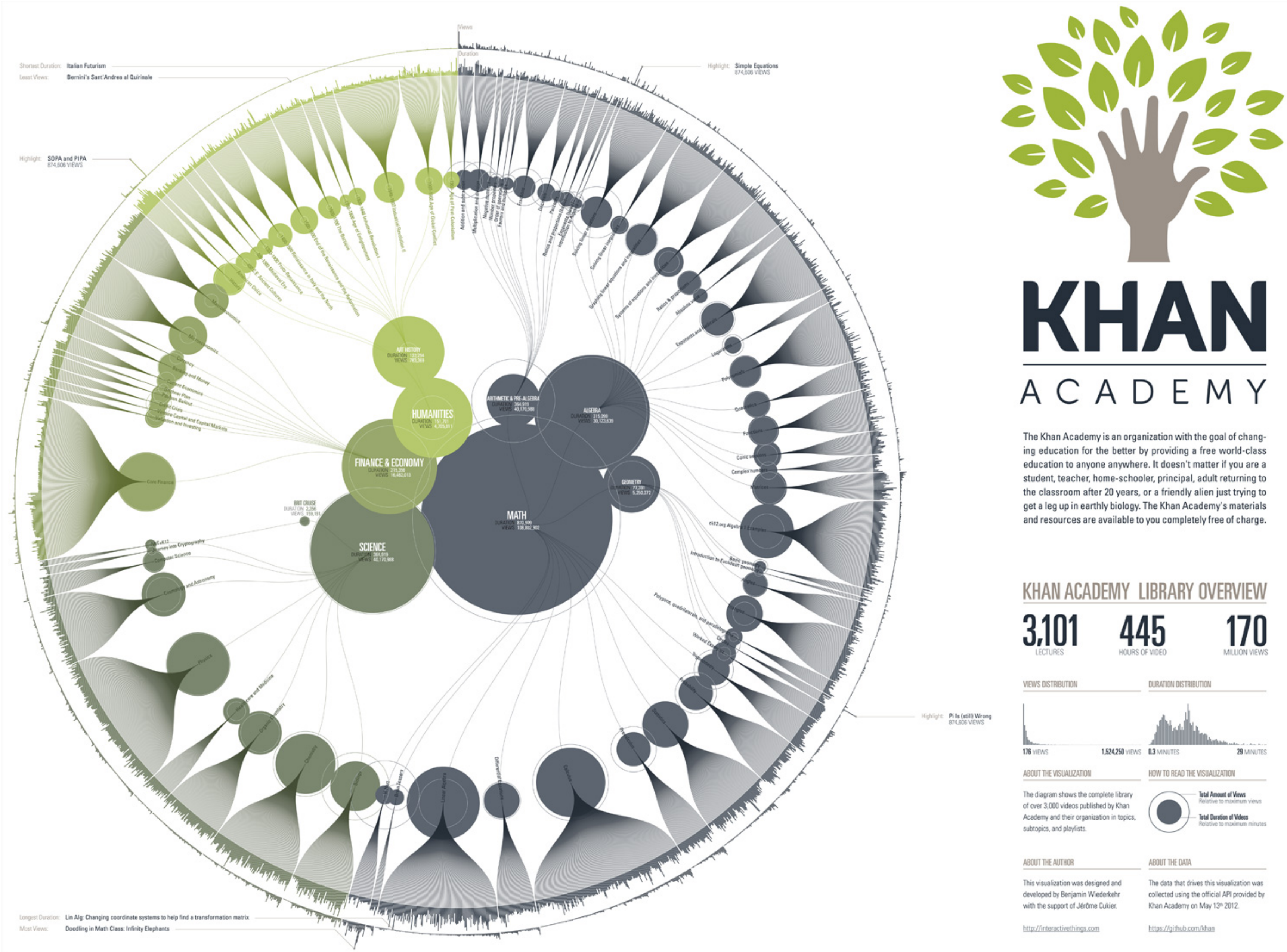
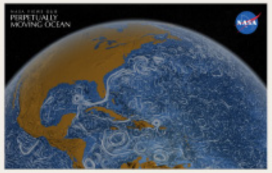


Manga Universe - Lev Manovich and Jay Chow - 2012



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

Science Maps Showing Trends and Dynamics 2013



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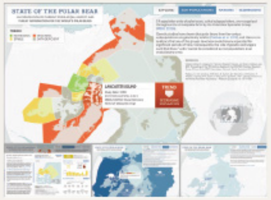

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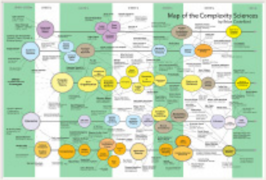

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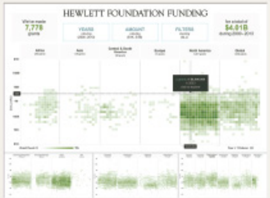

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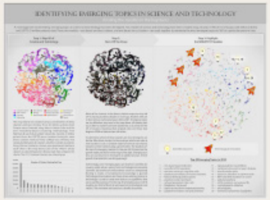

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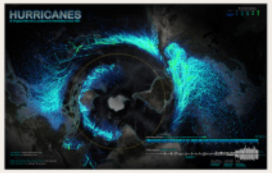

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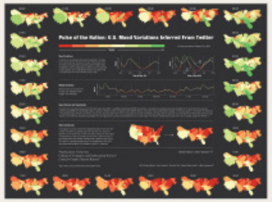

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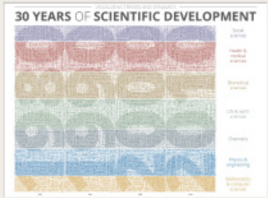

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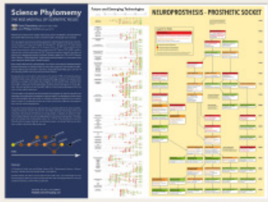

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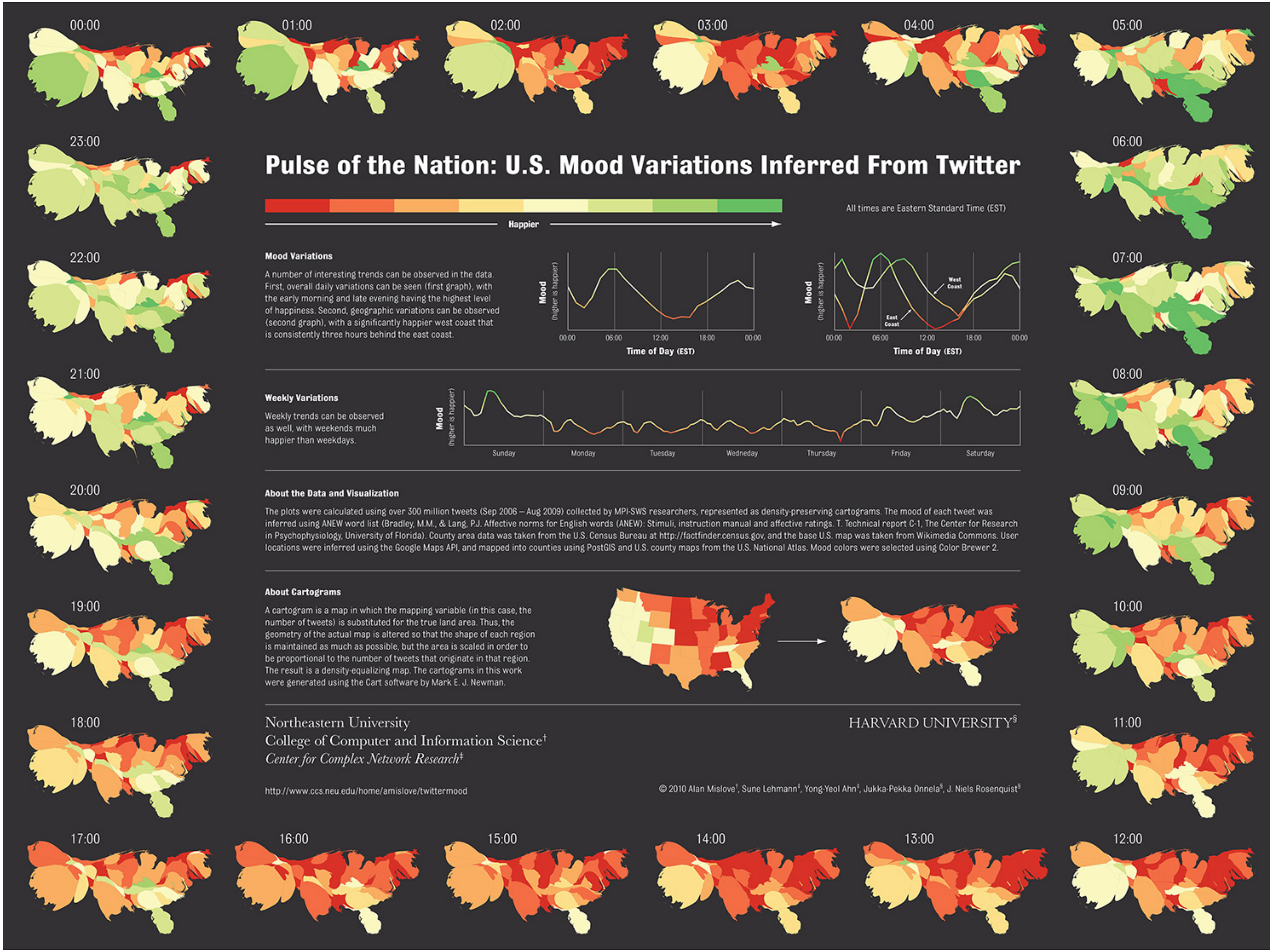
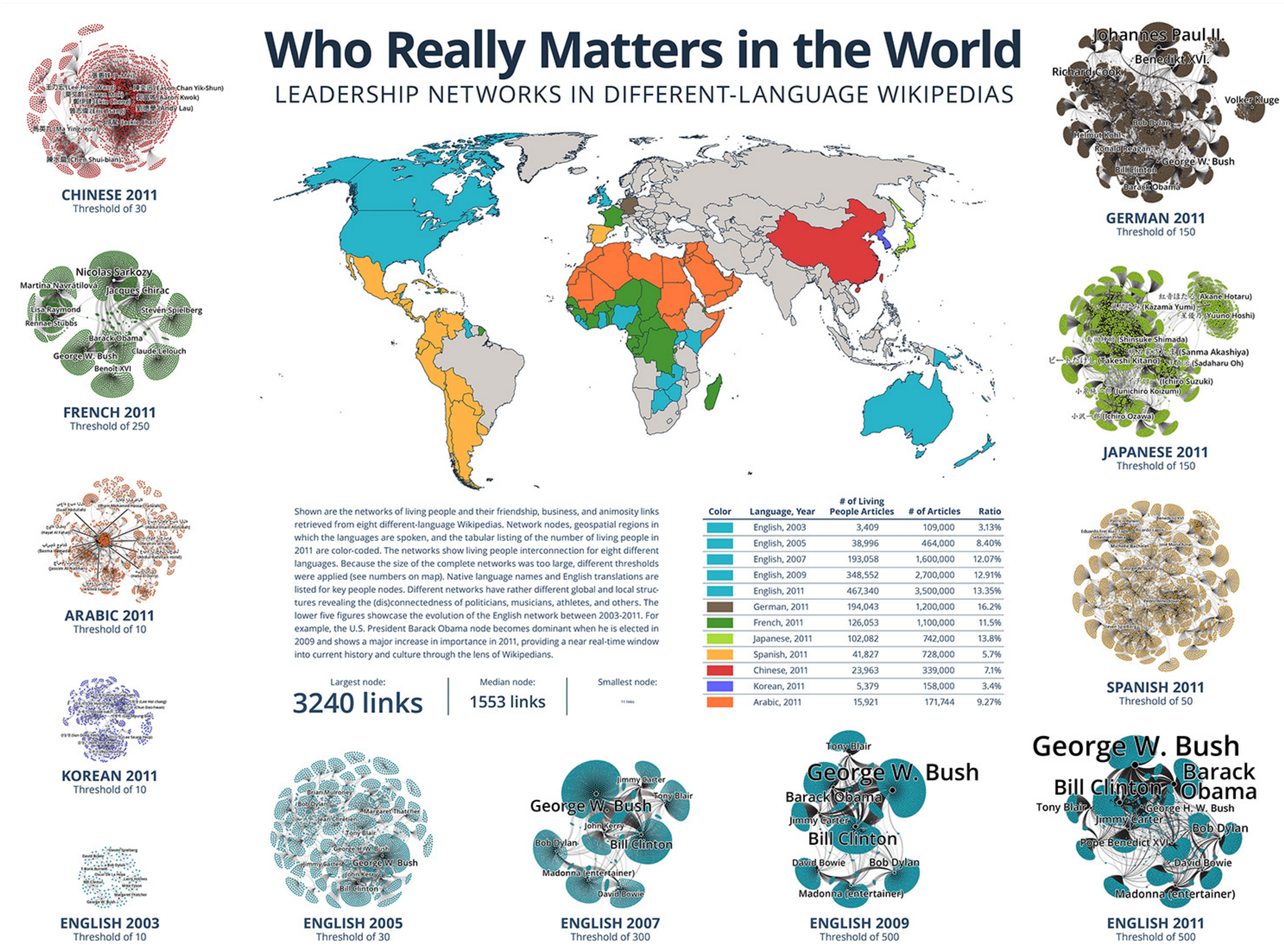


Pulse of the Nation - Alan Mislove, Sune Lehmann, Yong-Yeol Ahn, Jukka-Pekka Onnela, and James Niels Rosenquist - 2010



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%

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

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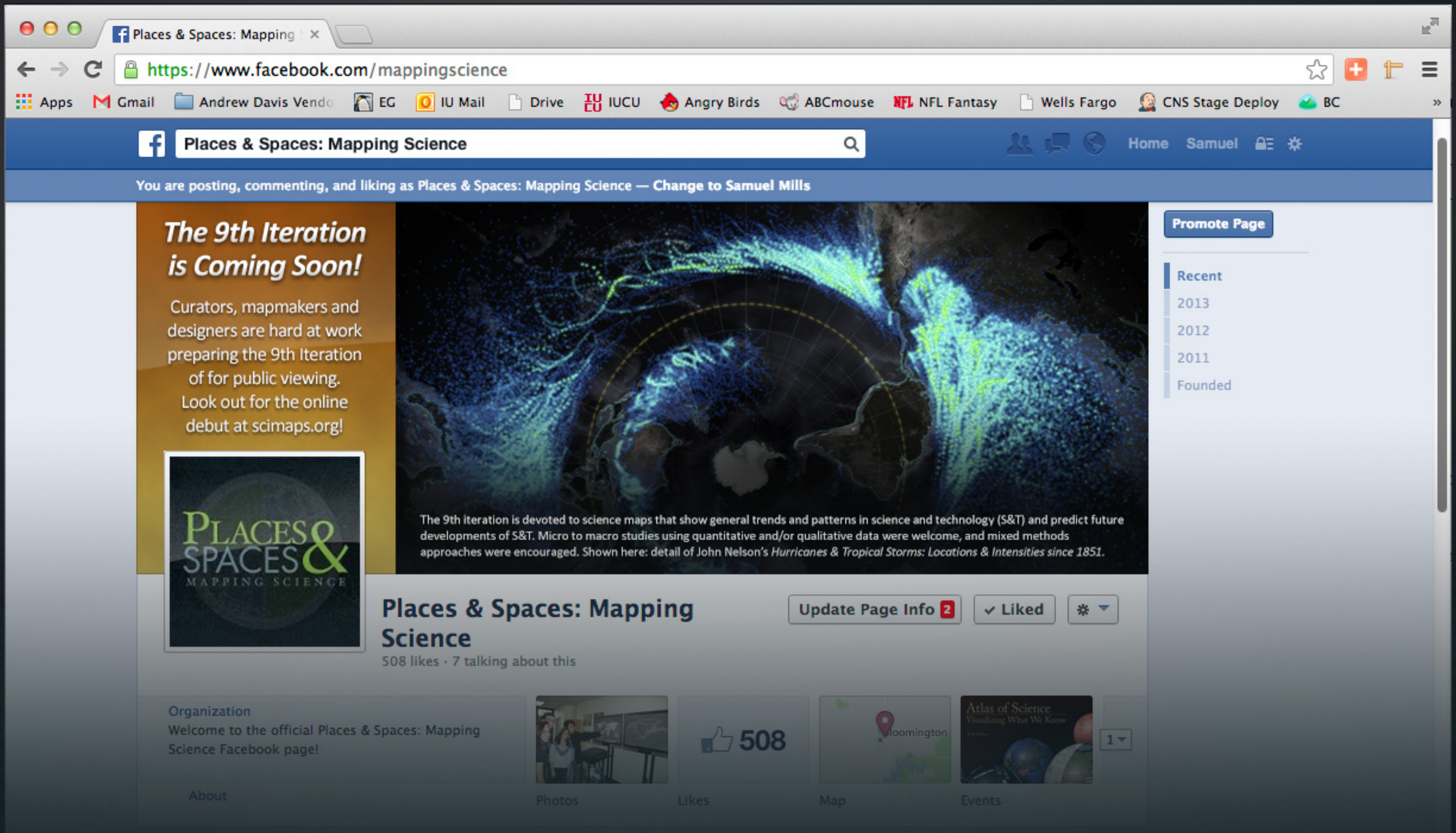

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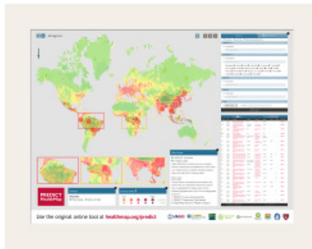
X.1



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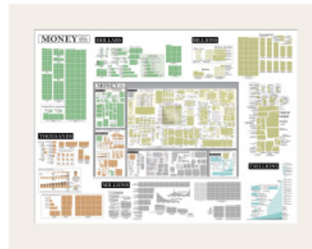

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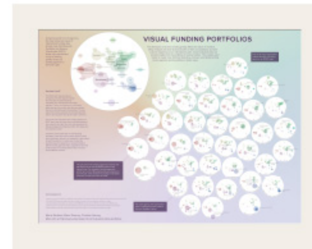

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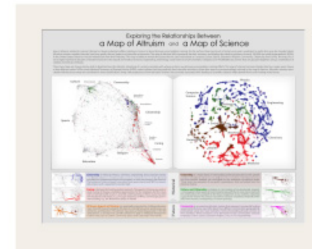

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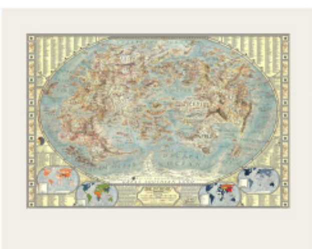

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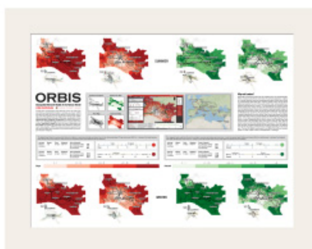

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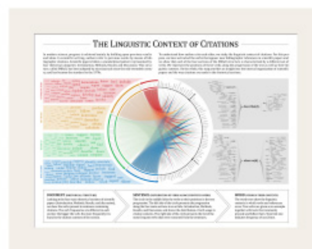

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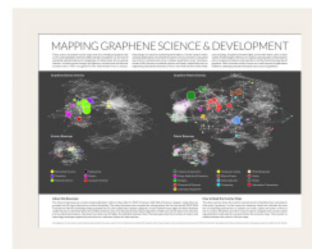

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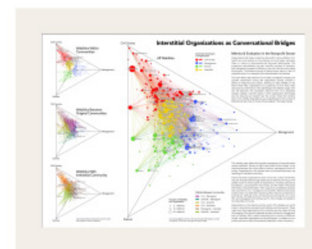

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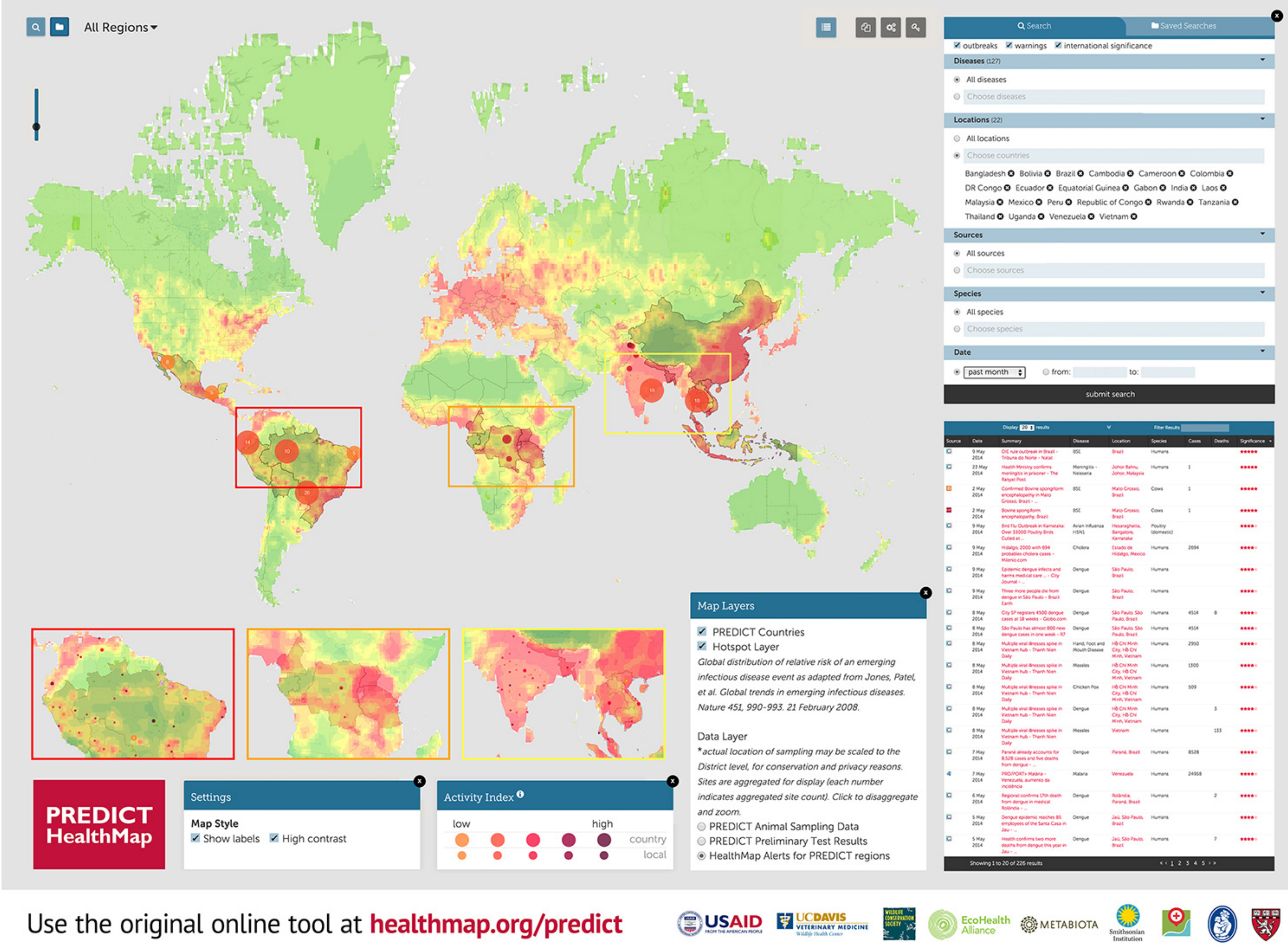
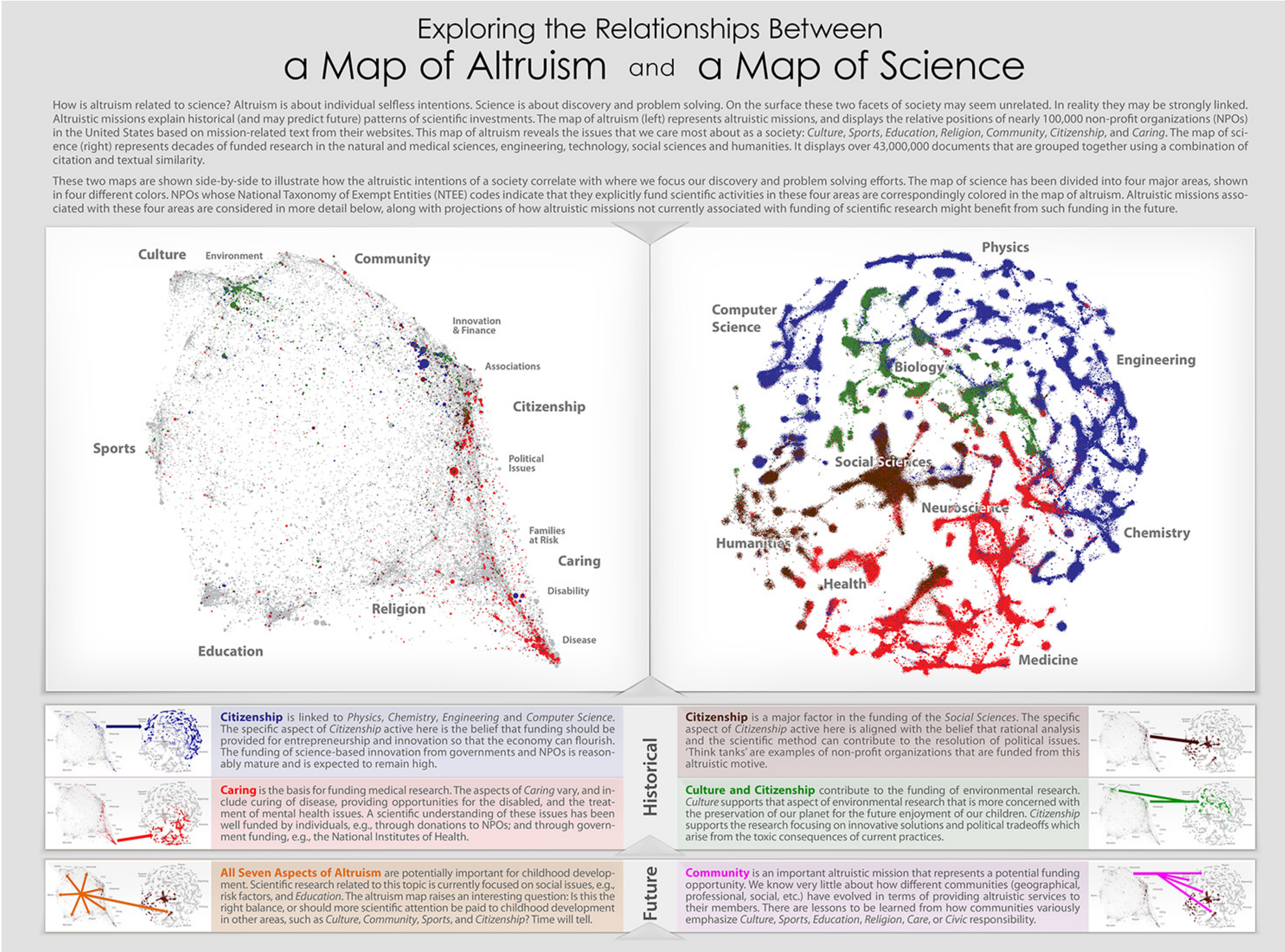


PREDICT: HealthMap - John Brownstein, Damien Joly, William Karesh, Peter Daszak, Nathan Wolfe, Tracey Goldstein, Susan Aman, Clark Freifeld, Sumiko Mekaru, Tammie O'Rourke, Stephen Morse, Christine Kreuder Johnson, Jonna Mazet, and the PREDICT Consortium - 2014

Map of the Internet - Martin Vargic - 2014



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

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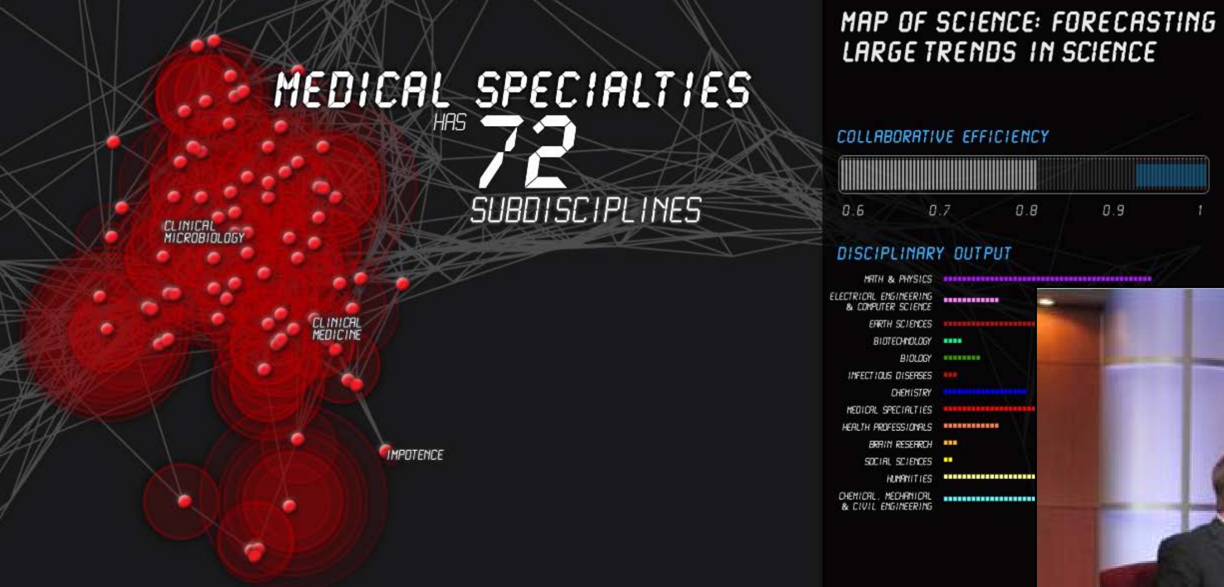

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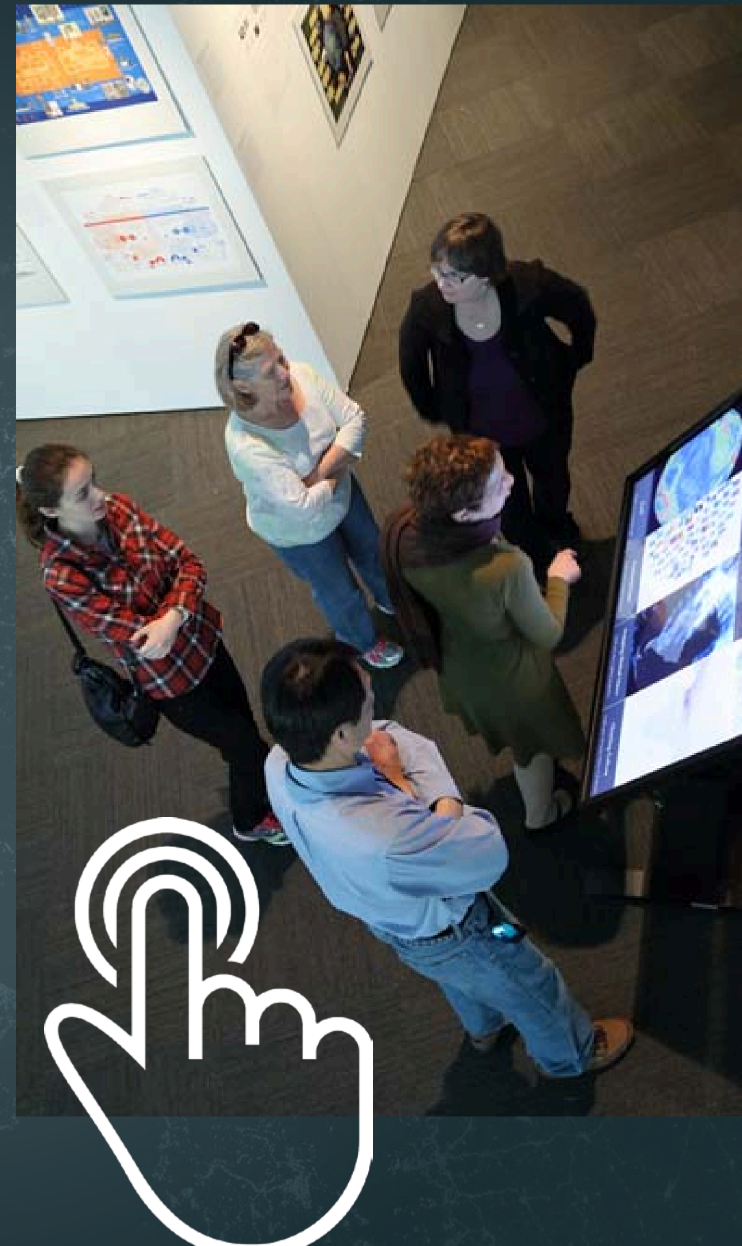
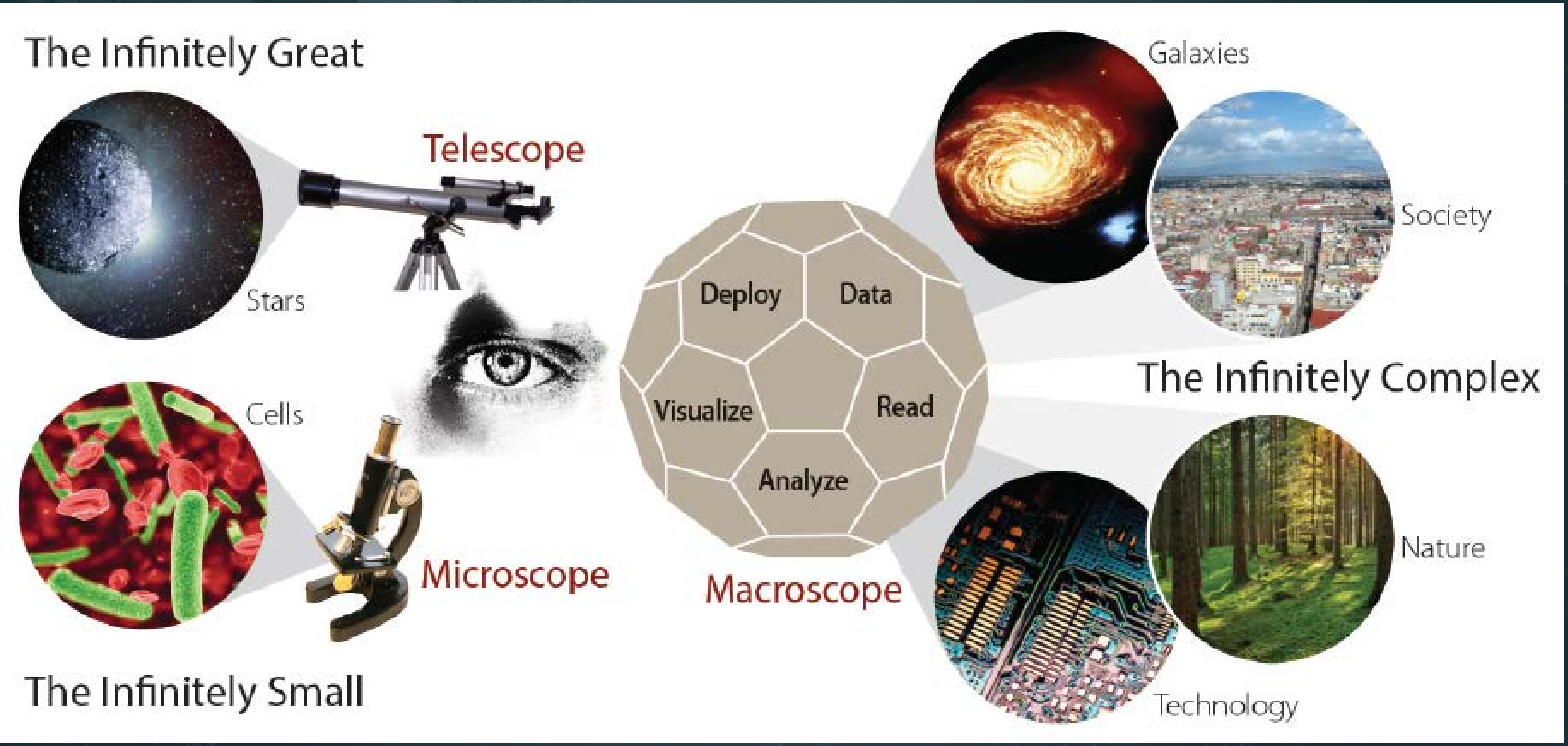


MAPS

vs.

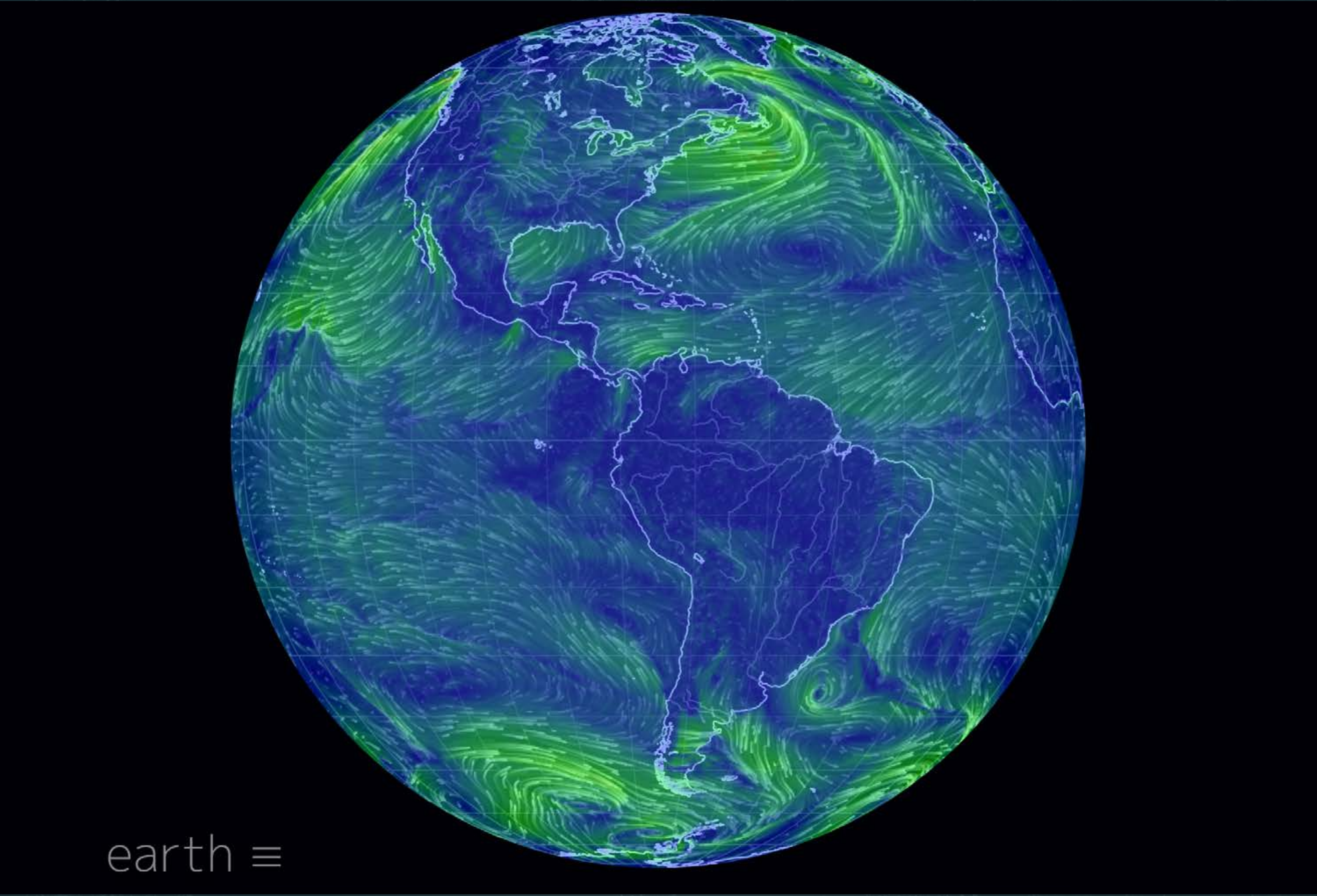
MACROSCOPES

Microscopes & Telescopes vs. MACROSCOPES

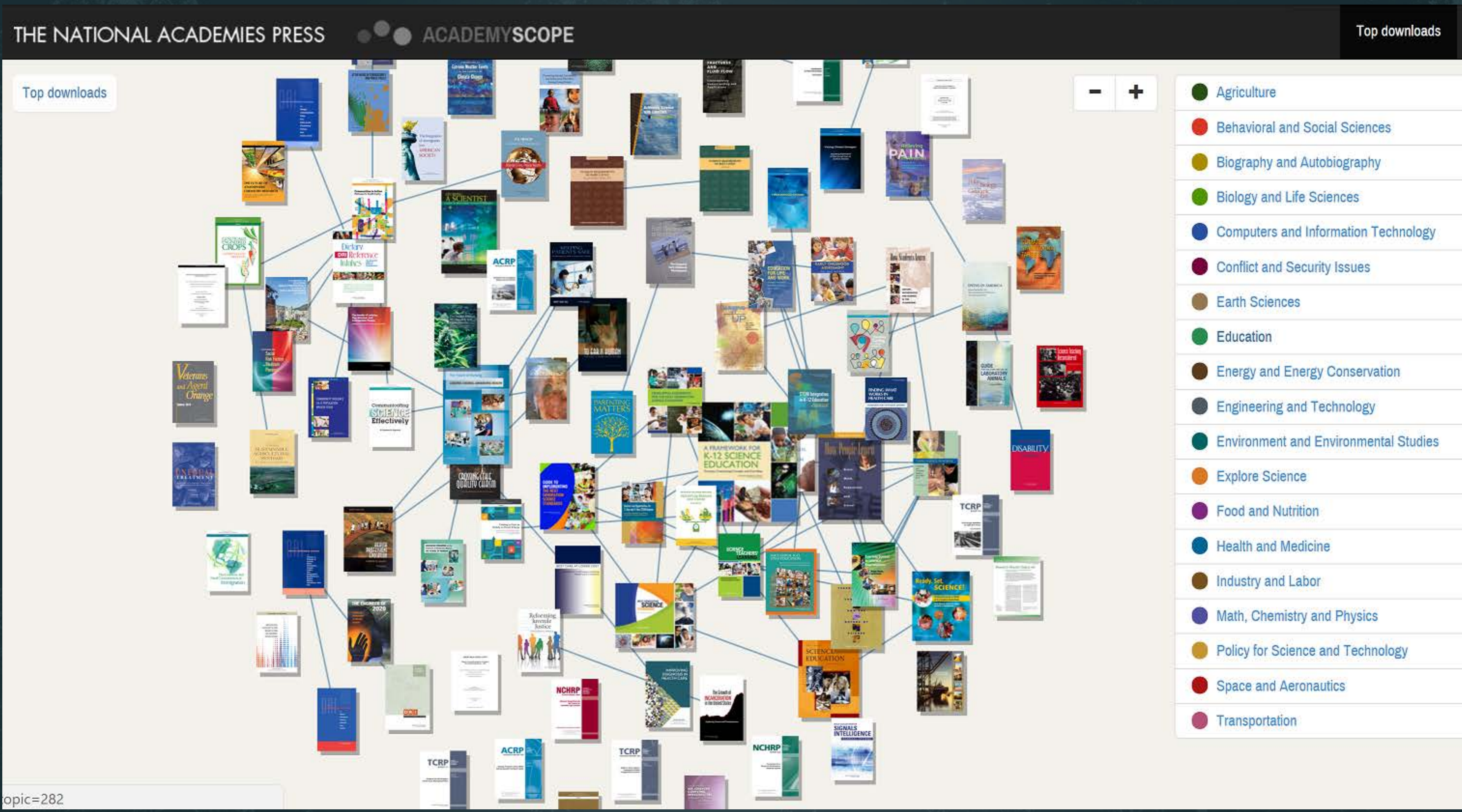


Iteration XI (2015): Macroscopes for Interacting with Science

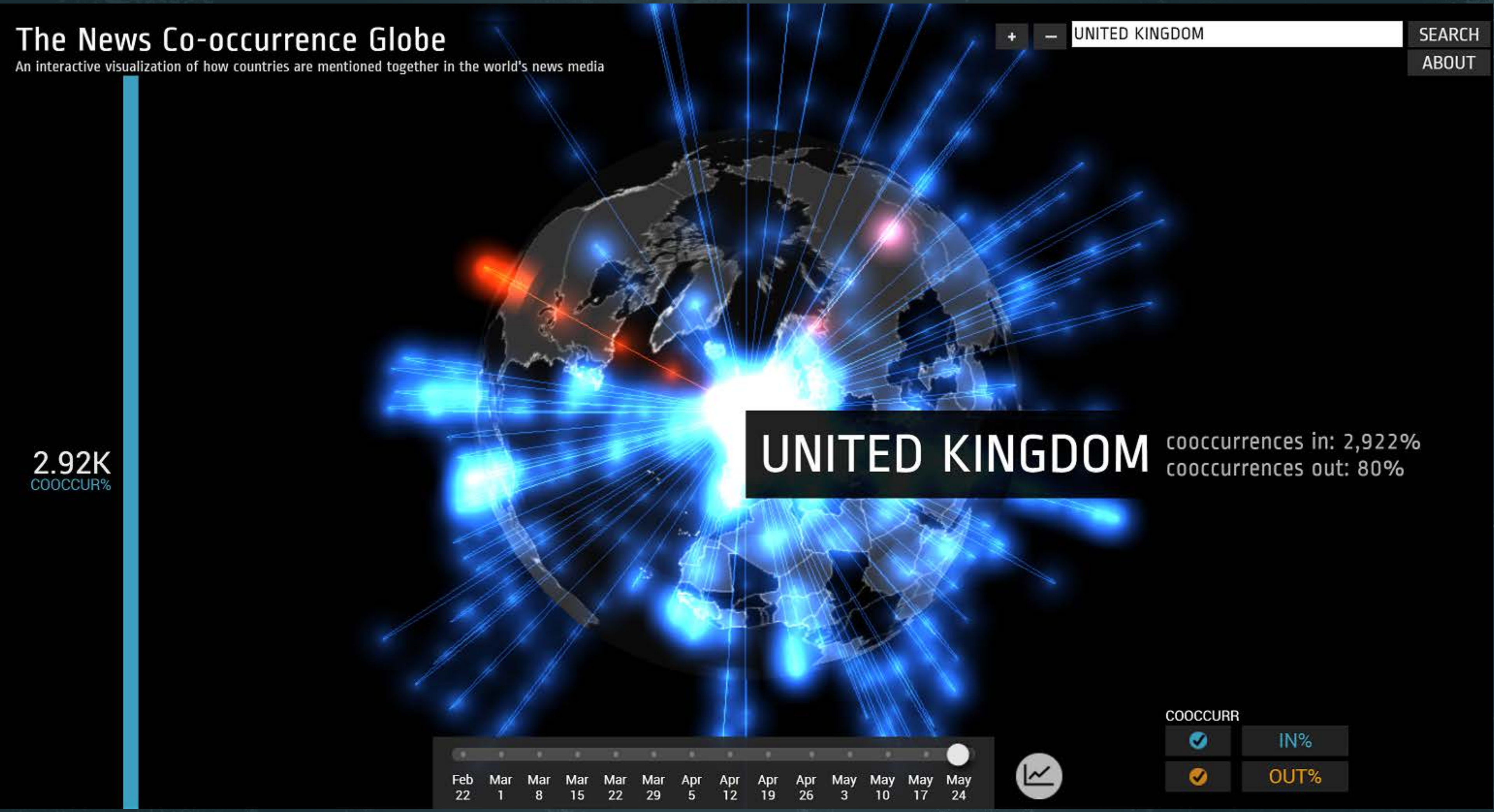
http://scimaps.org/iteration/11



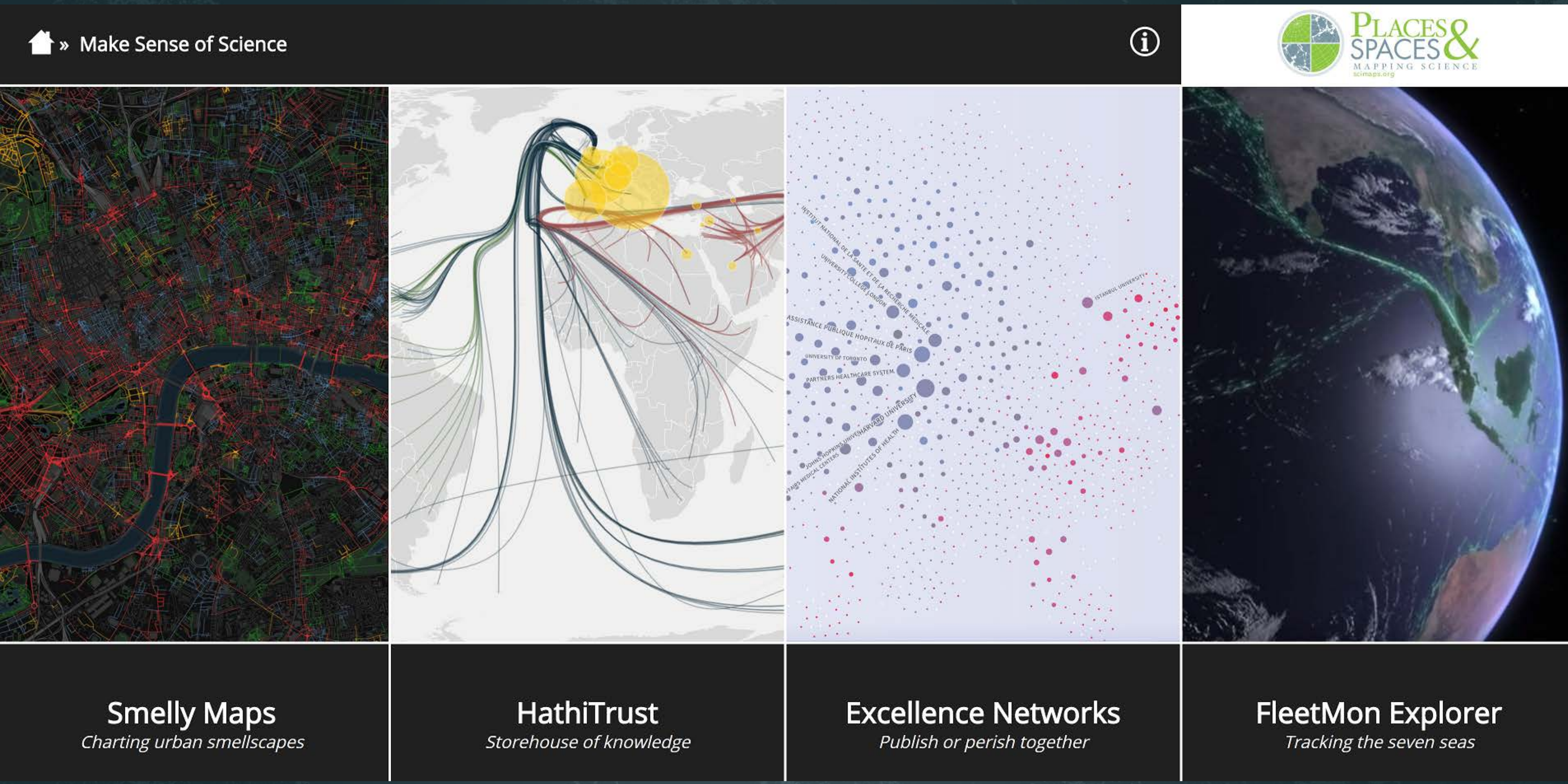
Earth – Cameron Beccario



AcademyScope – National Academy of the Sciences & CNS

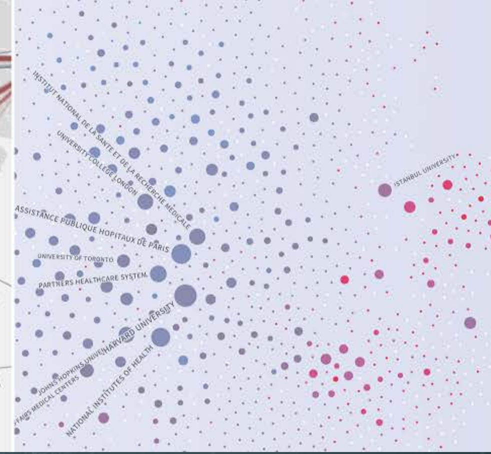


Mapping Global Society –Kalev Leetaru – 201XXXX



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

http://scimaps.org/iteration/12

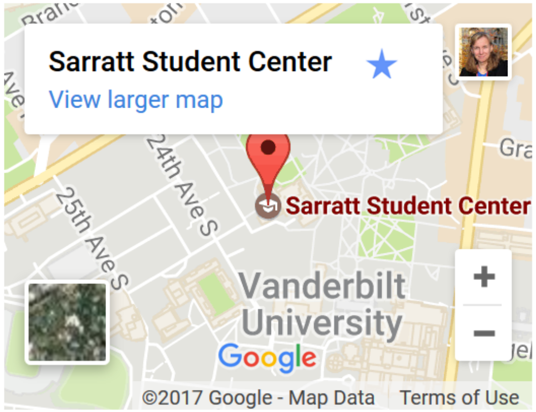
  

Four new macroscopes debut at Vanderbilt University:

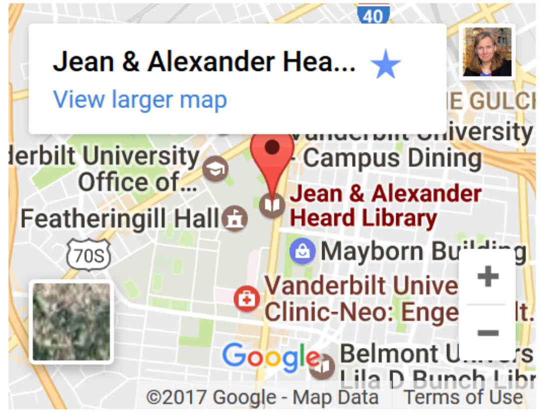
1. **Smelly Maps:** Features a "smellscape" of 12 cities mapped by smell using social media
2. **HathiTrust:** Highlights the diversity of publications collected in digital form by HathiTrust.
3. **Excellence Networks:** Compares how research institutions, such as Indiana and Vanderbilt universities, 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

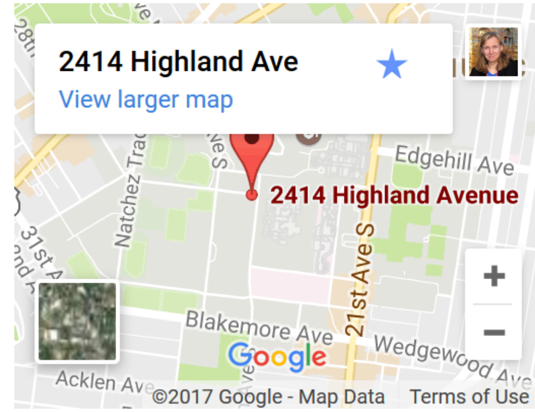
Sarratt Student Center | Rand Hall
West Side Row
Nashville TN 37240



Central Library
419 21st Ave S
Nashville, TN 37240



The Wond'ry
2414 Highland Avenue, Suite 102
Nashville, TN 37240



Special Events:

- **Friday, January 27** - Reception. Katy Börner, curator of *Places & Spaces* will deliver the inaugural lecture, "Maps & Macroscopes" in the Central Library Community Room, 3-4 p.m.

Workshops held at the Wond'ry at the Innovation Pavilion

- **Tuesday, February 7** - Creating Illustrations and Figures with Inkscape, 11 a.m.
- **Wednesday, February 8** - Interactive Data Analysis with R & ggvis, 11 a.m.
- **Thursday, February 9** - Visualizing Data with Tableau, 11 a.m.
- **Thursday, March 16** - Using a GoPro Camera, 11 a.m.
- **Wednesday, March 22** - The Artistic, Scientific, and Political Impact of Drone Technology: A Panel Discussion with Artist Tivon Rice, 11 a.m

Competition

- **April 2017** - Undergraduate, graduate, and professional students compete for the best data visualization.

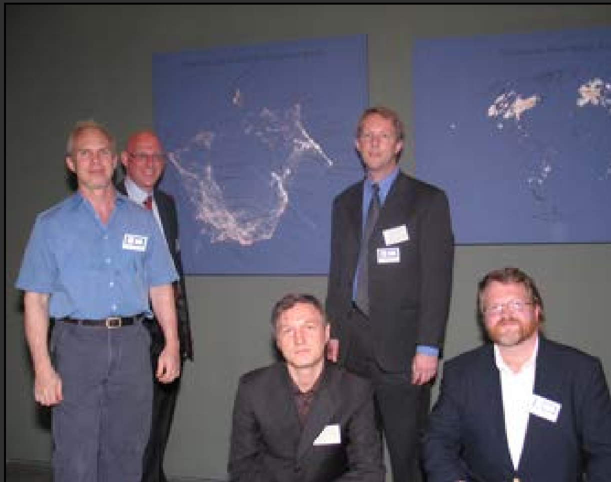
A visitor explores the macroscope kiosk at the Eskenazi Museum of Art at Indiana University.

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

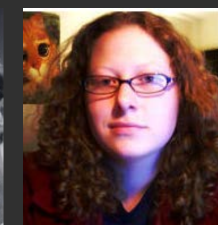
Background and Goals

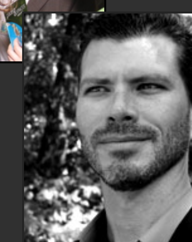
The *Places & Spaces: Mapping Science* exhibit is designed to open people's hearts and minds to the value, complexity, and beauty of maps of science and technology.

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



Join the map makers & exhibit ambassadors.





IVMOOC.cns.iu.edu

PLACES & SPACES

MAPPING SCIENCE

scimaps.org

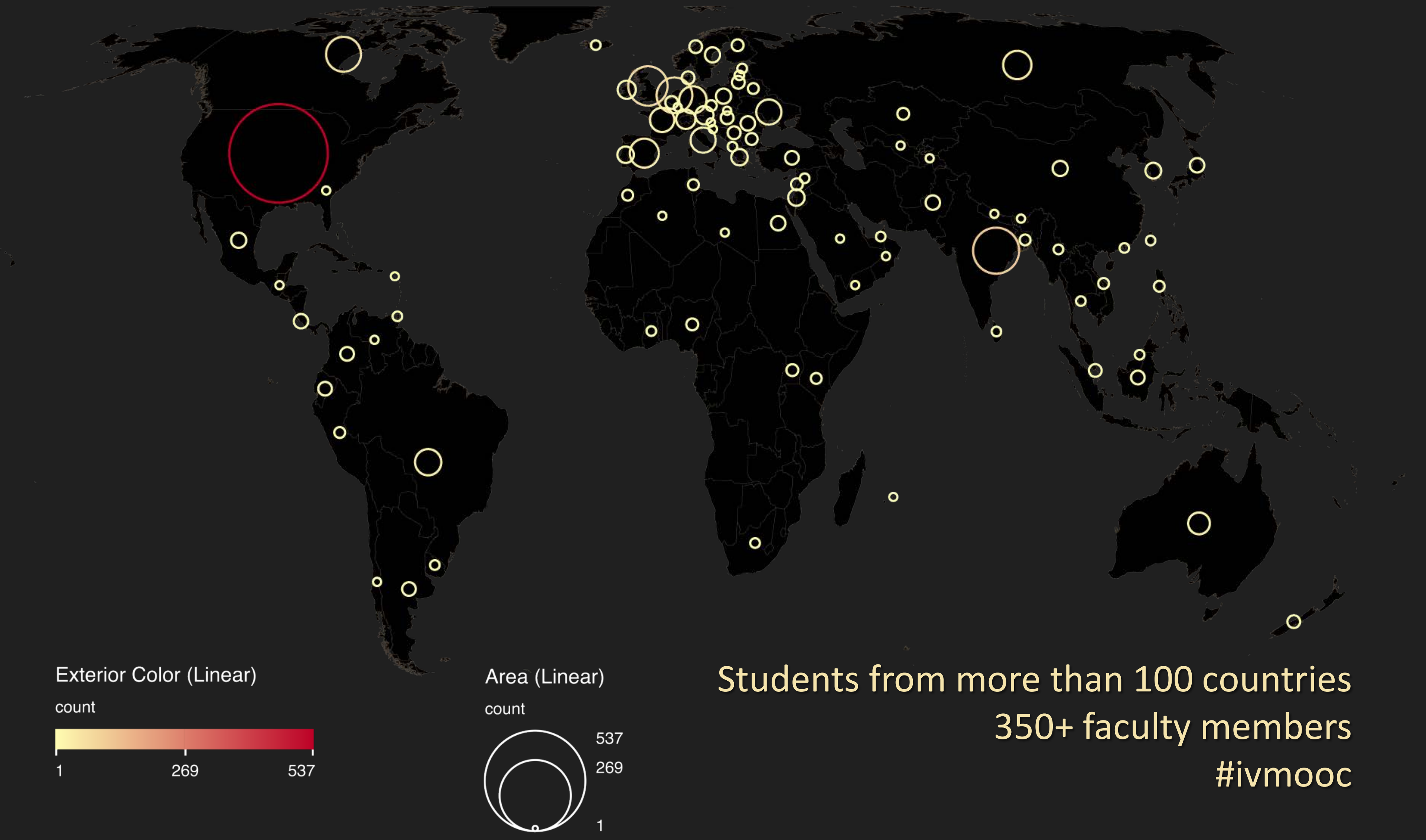
IVMOOC 2017

MENU

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

The Information Visualization MOOC

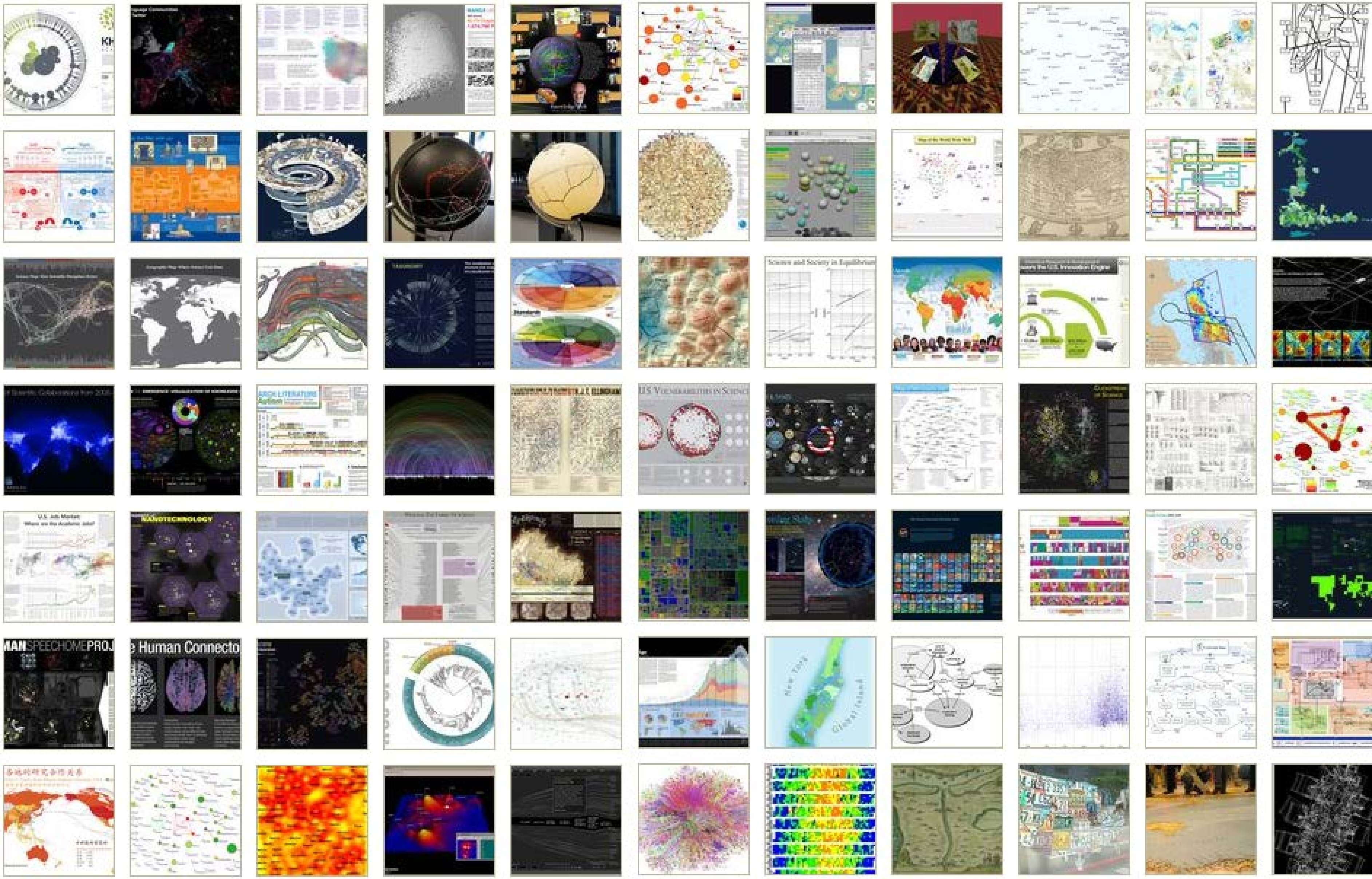
ivmooc.cns.iu.edu



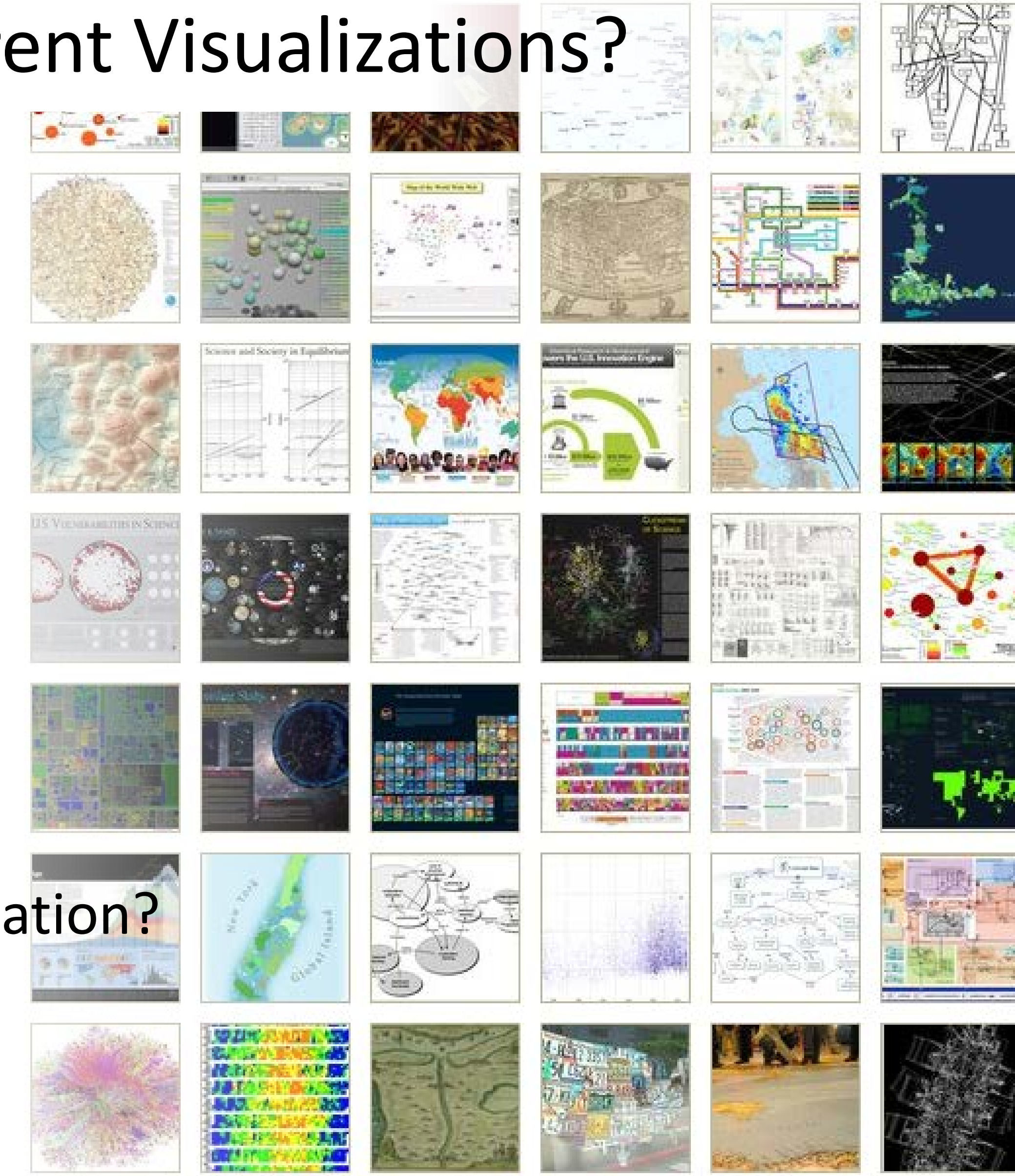
Students from more than 100 countries

350+ faculty members

#ivmooc


Science and Society in Equilibrium
U.S. Job Market: Where are the Academic Jobs?
NANOTECHNOLOGY
MANSPEECHOMEPROJ
e Human Connecto

How to Classify Different Visualizations?



By

- User insight needs?
- User task types?

- Data to be visualized?
- Data transformation?

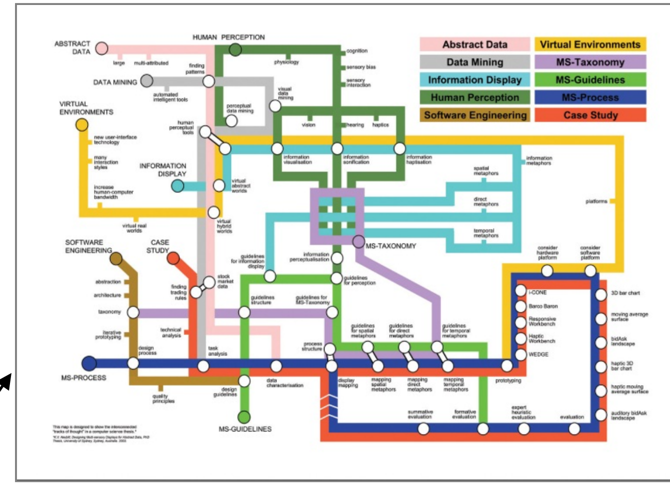
- Visualization technique?
- Visual mapping transformation?
- Interaction techniques?

- Or ?

Different Question Types

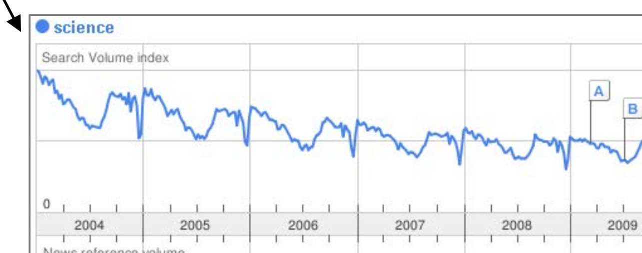
Terabytes of data

Descriptive & Predictive Models



Find your way

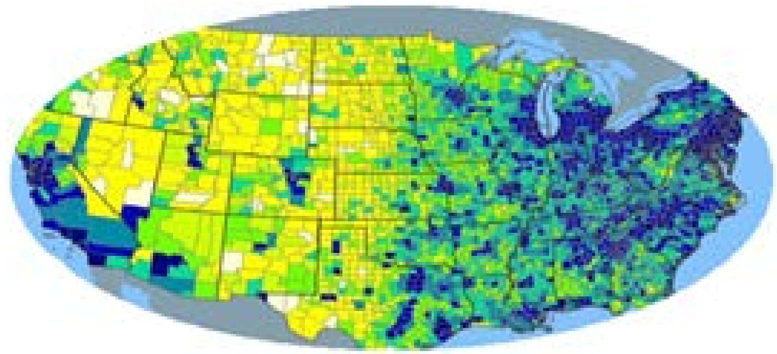
Find collaborators, friends



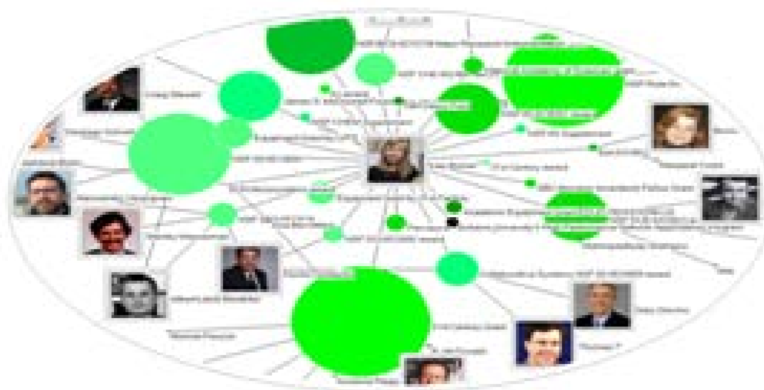
Identify trends

Different Levels of Abstraction/Analysis

Macro/Global
Population Level

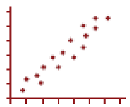
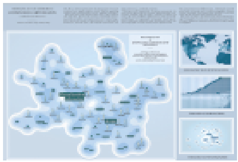
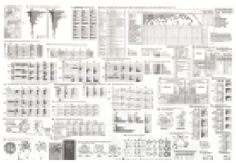
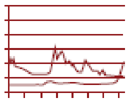
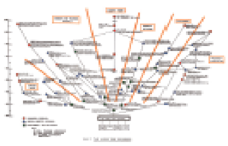
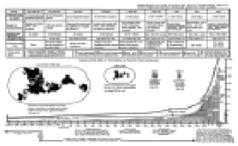
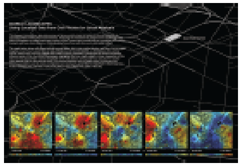
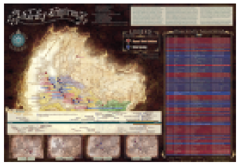
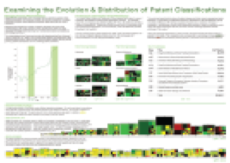
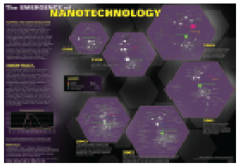
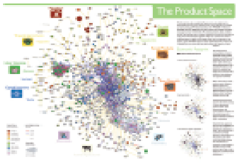
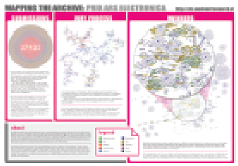


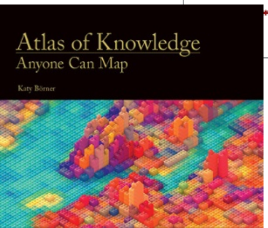
Meso/Local
Group Level



Micro
Individual Level

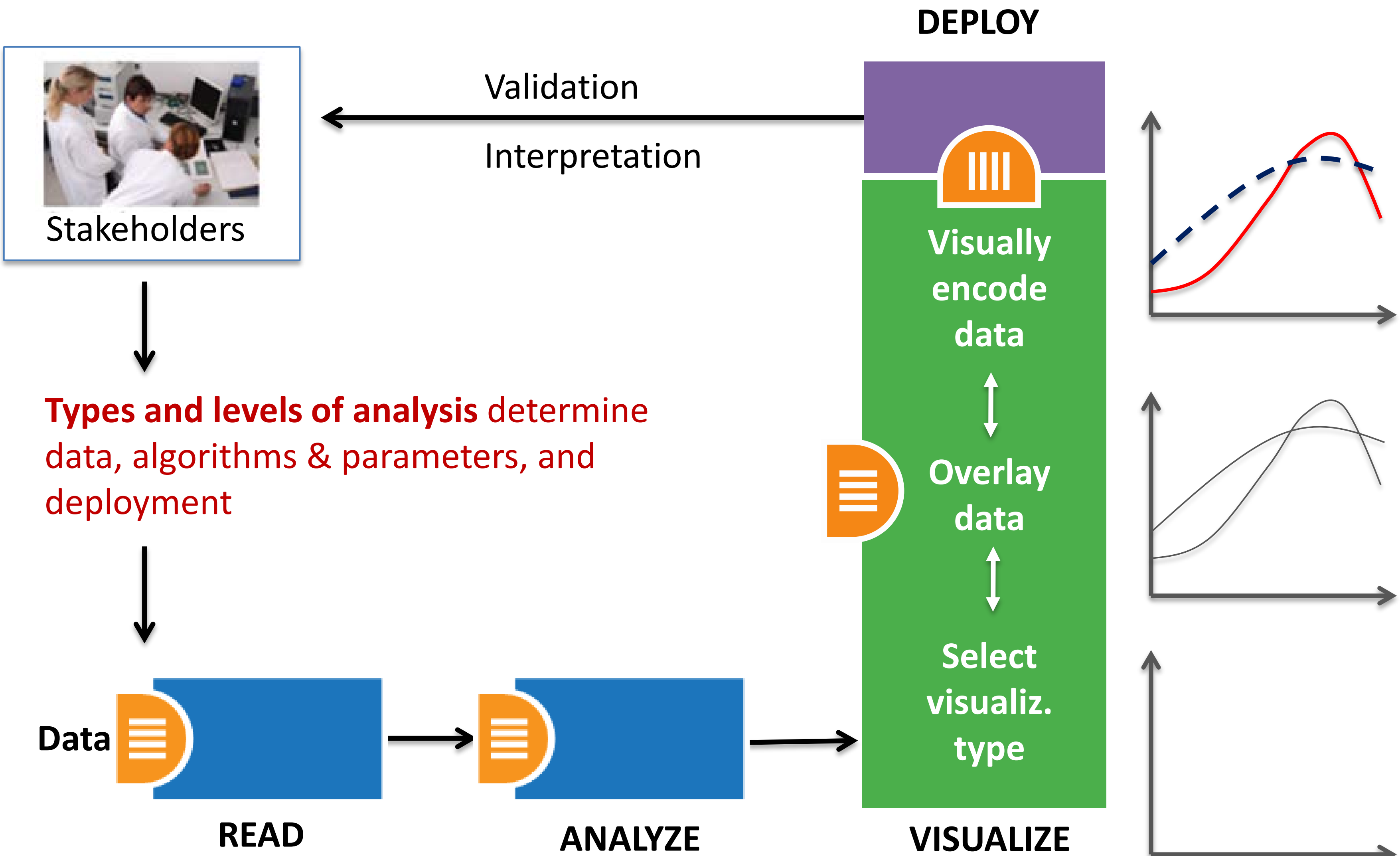
Tasks

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

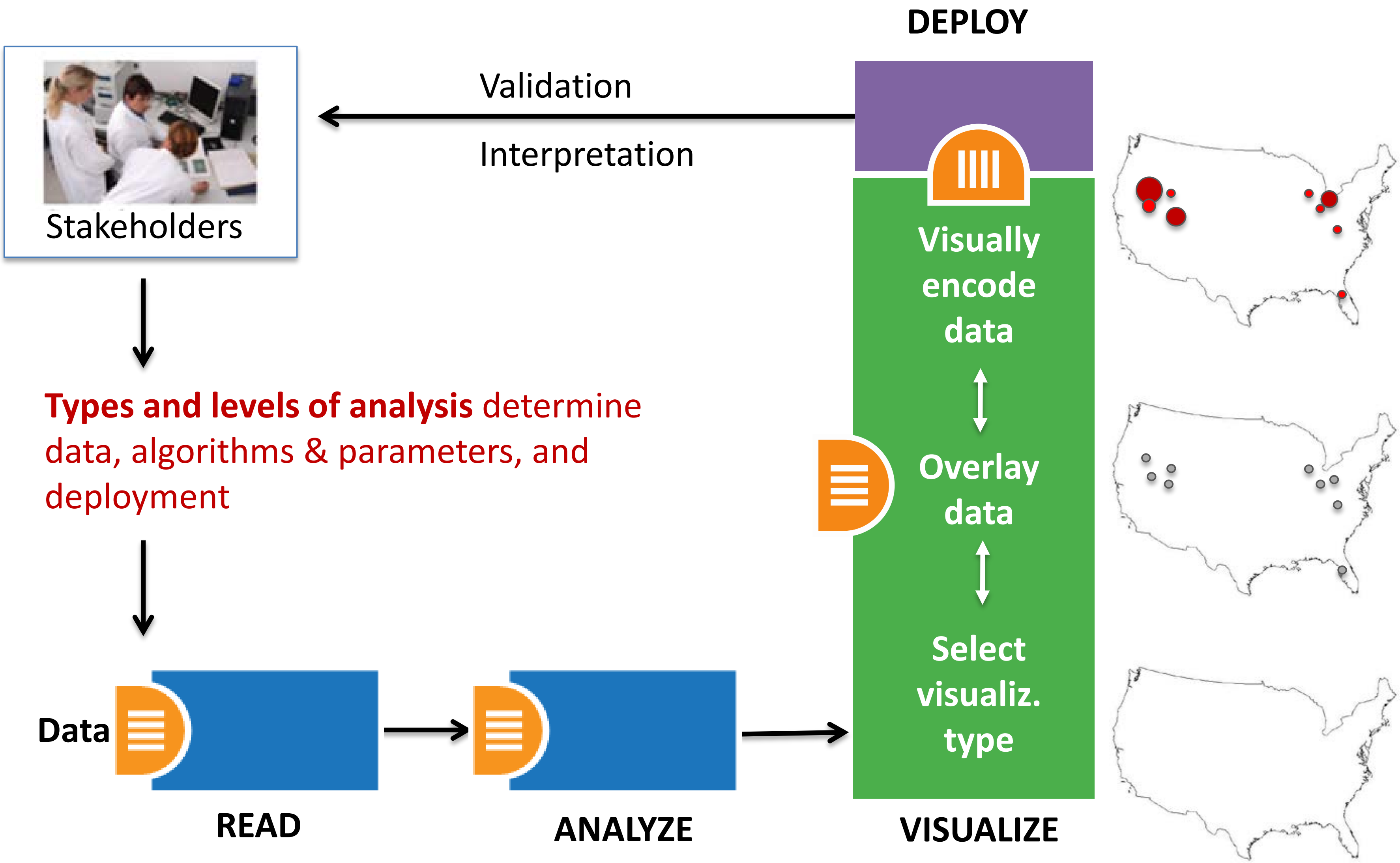


See page 5

Needs-Driven Workflow Design

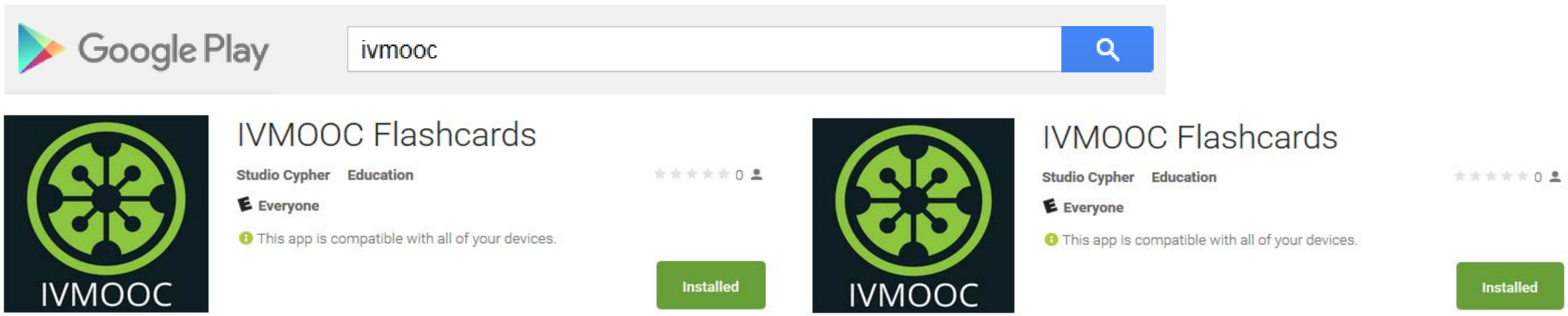


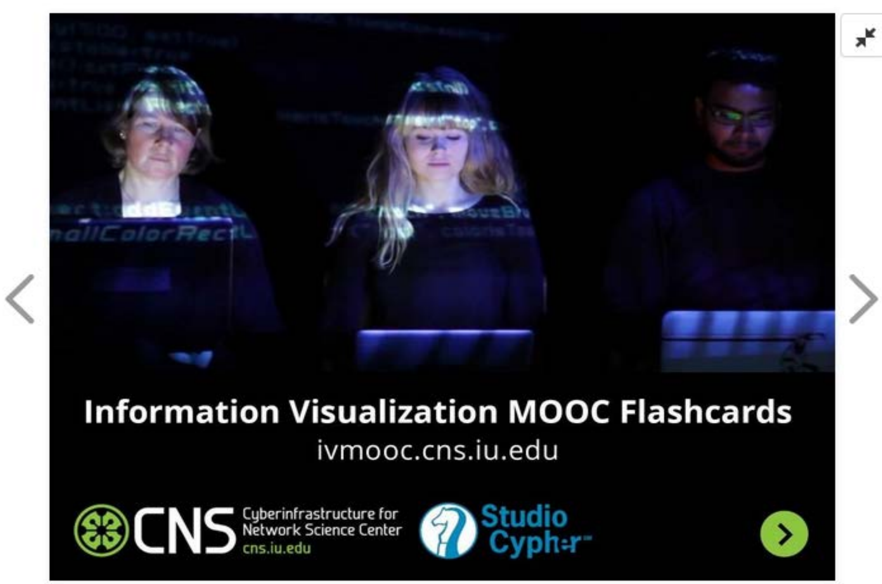
Needs-Driven Workflow Design

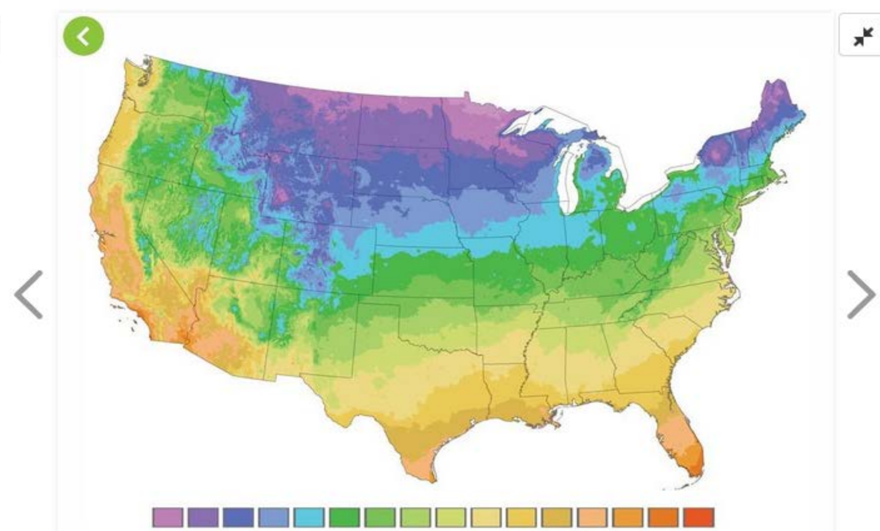


IVMOOC App – More than 60 visualizations

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

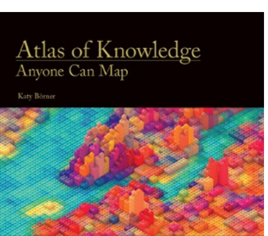






Visualization Framework

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



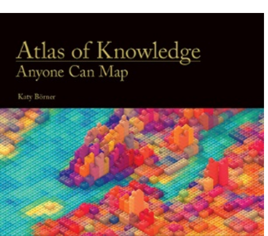
See page 24

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

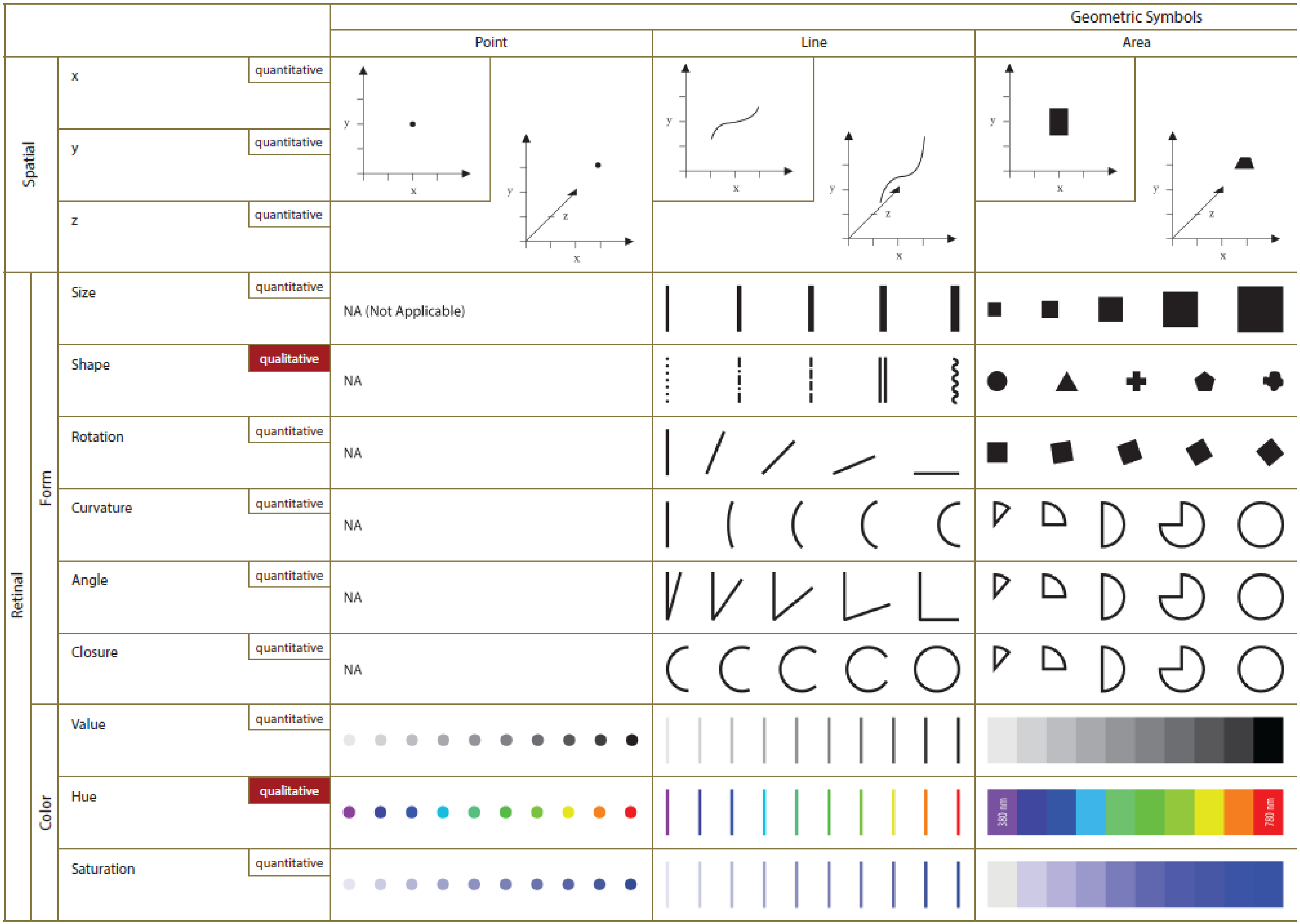
Visualization Framework

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	• nominal	• table	• geometric symbols	• spatial	• overview
• order/rank/sort	• ordinal	• chart	point	position	• zoom
• distributions	• interval	• graph	line	• retinal	• search and locate
(also outliers, gaps)	• ratio	• map	area	form	• filter
• comparisons		• network layout	surface	color	• details-on-demand
• trends			volume	optics	• history
(process and time)			• linguistic symbols	motion	• extract
• geospatial			text		• link and brush
• compositions			numerals		• projection
(also of text)			punctuation marks		• distortion
• correlations/relationships			• pictorial symbols		
			images		
			icons		
			statistical glyphs		

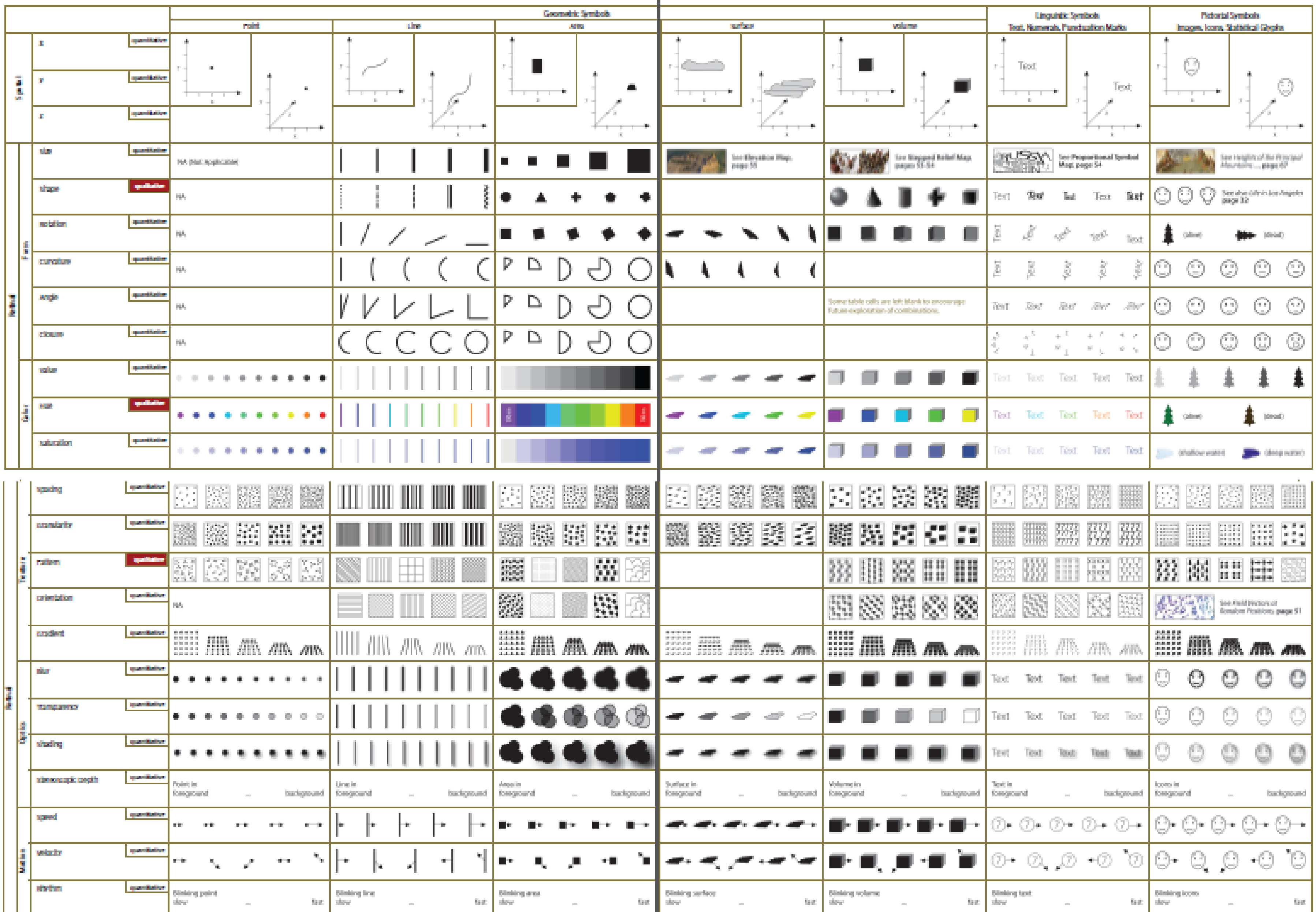


See page 24

Graphic Variable Types Versus Graphic Symbol Types



Graphic Variable Types Versus Graphic Symbol Types



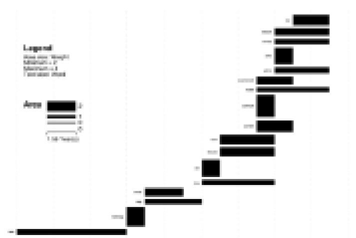
Load **One** File and Run **Many** Analyses and Visualizations

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

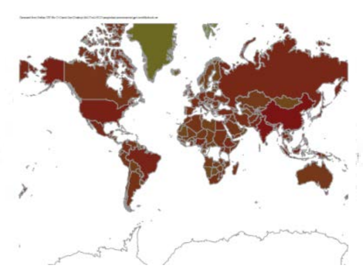
Location	*Count*	*# Citations*
Netherlands	13	292
United States	9	318
Germany	11	36
United Kingdom	1	2

Temporal Burst Analysis—p. 48



Geospatial Analysis—p. 52

Geospatial Analysis—p. 52



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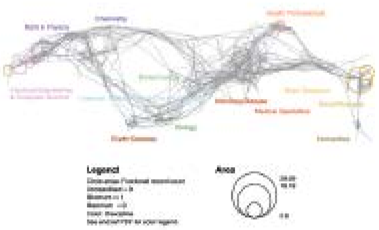
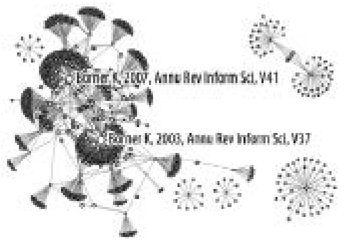
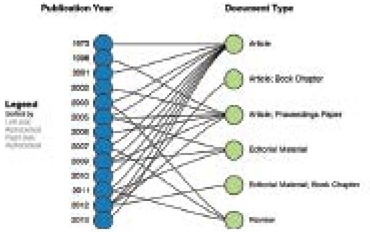
Topical Analysis–p. 56



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

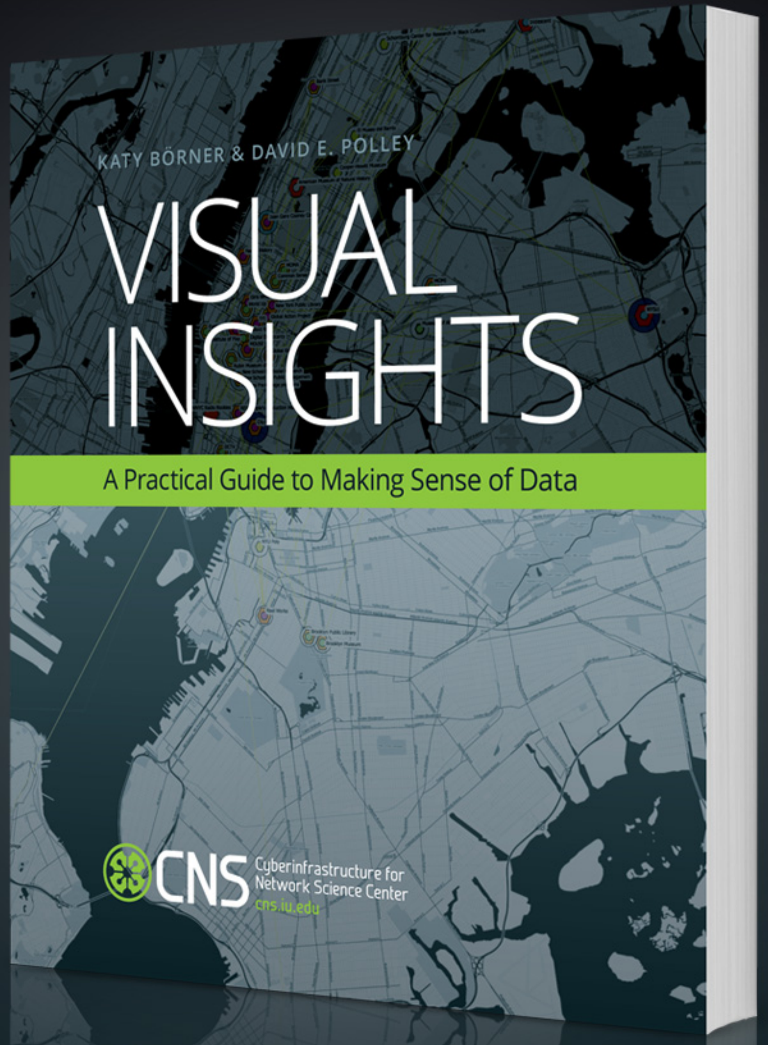
Part 2: Students work in teams on client projects.

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.



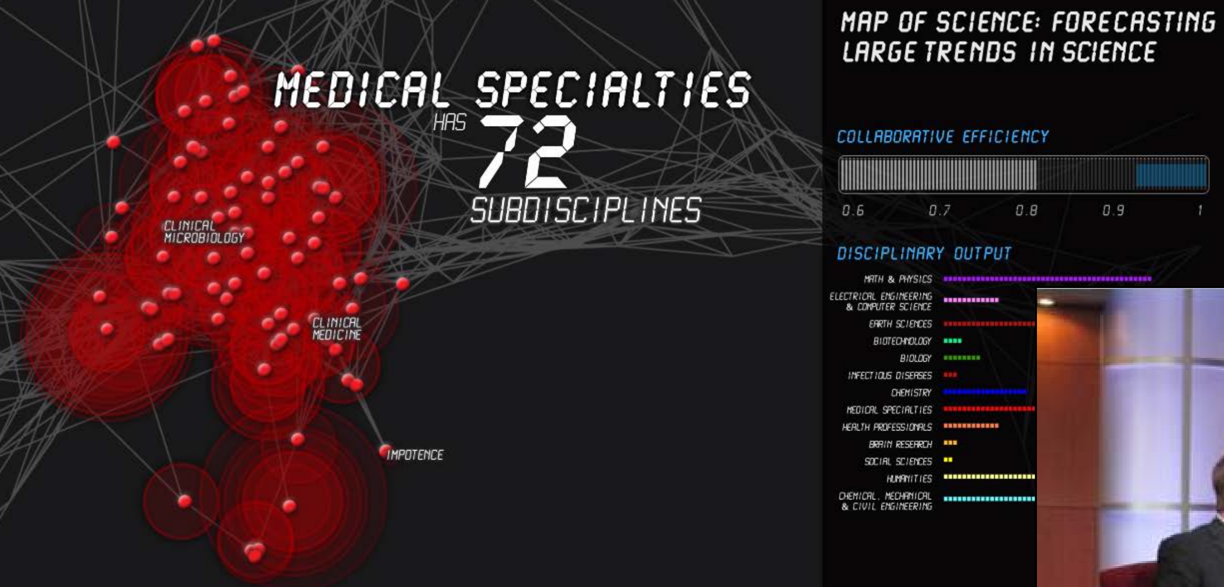
cns.iu.edu/ivmoocbook14.html

Forecasting S&T

PLACES & SPACES

MAPPING SCIENCE

scimaps.org



Science Forecast S1:E1, 2015

Government, academic, and industry leaders discussed challenges and opportunities associated with using big data, visual analytics, and computational models in STI decision-making.

Conference slides, recordings, and report are available via http://modsti.cns.iu.edu/report

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  - 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

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

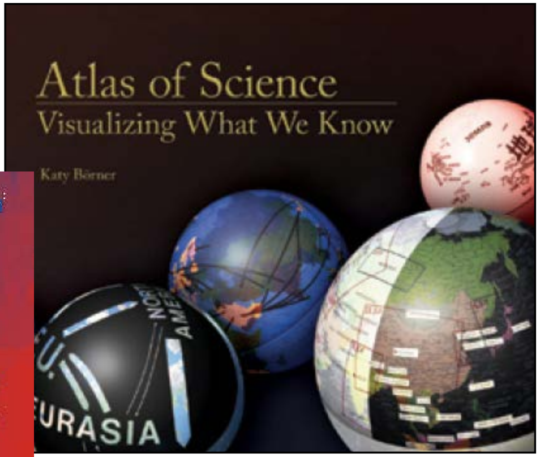
Börner, Katy (2010) **Atlas of Science: Visualizing What We Know**. The MIT Press. http://scimaps.org/atlas

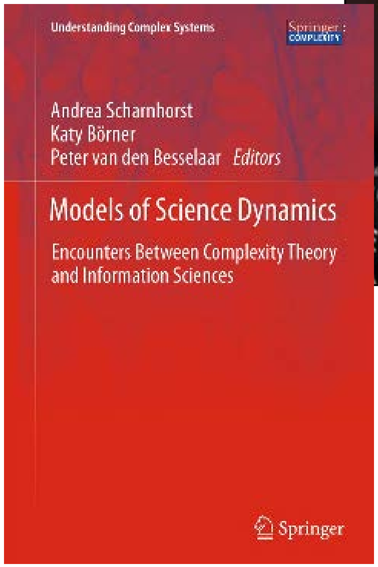
Scharnhorst, Andrea, Börner, Katy, van den Besselaar, Peter (2012) **Models of Science Dynamics**. Springer Verlag.

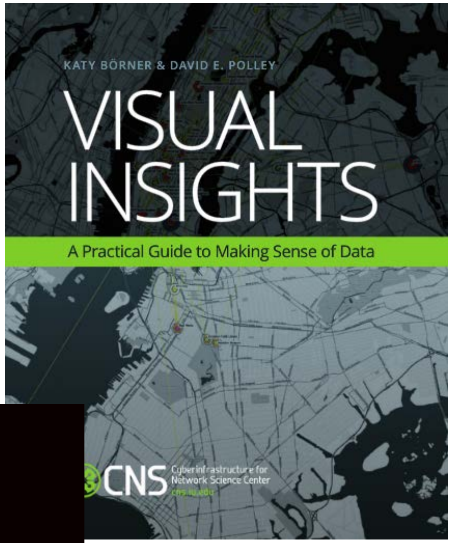
Katy Börner, Michael Conlon, Jon Corson-Rikert, Cornell, Ying Ding (2012) **VIVO: A Semantic Approach to Scholarly Networking and Discovery**. Morgan & Claypool.

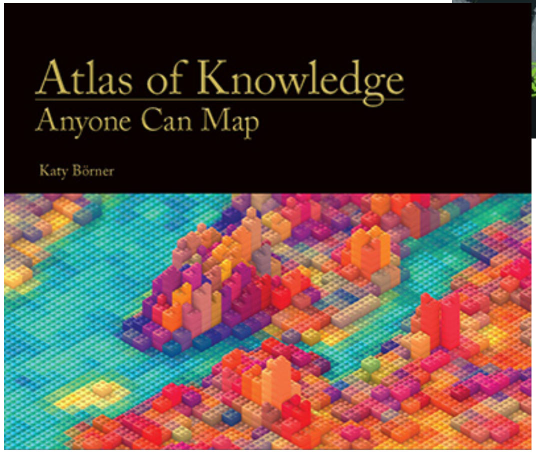
Katy Börner and David E Polley (2014) **Visual Insights: A Practical Guide to Making Sense of Data**. The MIT Press.

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









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