

Envisioning Digital Science

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Digital Studies of Digital Science (DS² 2021) | <https://pencelab.be/events/ds2-2021/>

March 15, 2021

Overview

Mapping Science: An Exhibit

Mapping SPOKE: 3M Nodes and 30M Edges

HuBMAP: Toward a Human Reference Map

Empower Yourself!

Mapping Science Exhibit

<http://scimaps.org>





101st Annual Meeting of the Association of American Geographers, Denver, CO.
April 5th - 9th, 2005 (First showing of Places & Spaces)



University of Miami, Miami, FL.
September 4 - December 11, 2014.



Duke University, Durham, NC.
January 12 - April 10, 2015

<http://scimaps.org>

The David J. Sencer CDC Museum, Atlanta, GA.
January 25 - June 17, 2016.

Places & Spaces: Mapping Science Exhibit

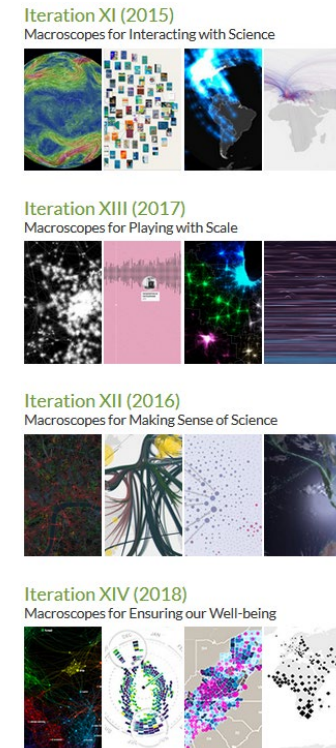
1st Decade (2005-2014)

Maps



2nd Decade (2015-2024)

Macroscopes

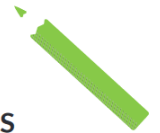


100

MAPS
in large format, full color, and
high resolution.

248

MAPMAKERS
from fields as disparate as art,
urban planning, engineering,
and the history of science.



43



MACROSCOPE MAKERS
including one whose job title is
"Truth and Beauty Operator."

20

MACROSCOPES
for touching all kinds of data.

382

DISPLAY VENUES
from the Cannes Film Festival
to the World Economic Forum.

354

PRESS ITEMS
including articles in *Nature*,
Science, *USA Today*, and *Wired*.



<http://scimaps.org>

Map of Scientific Collaborations from 2005-2009

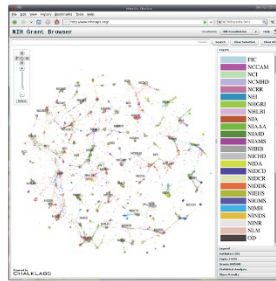


Computed Using Data from Elsevier's Scopus

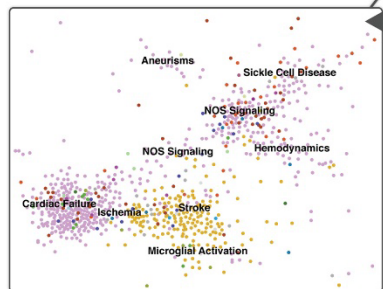
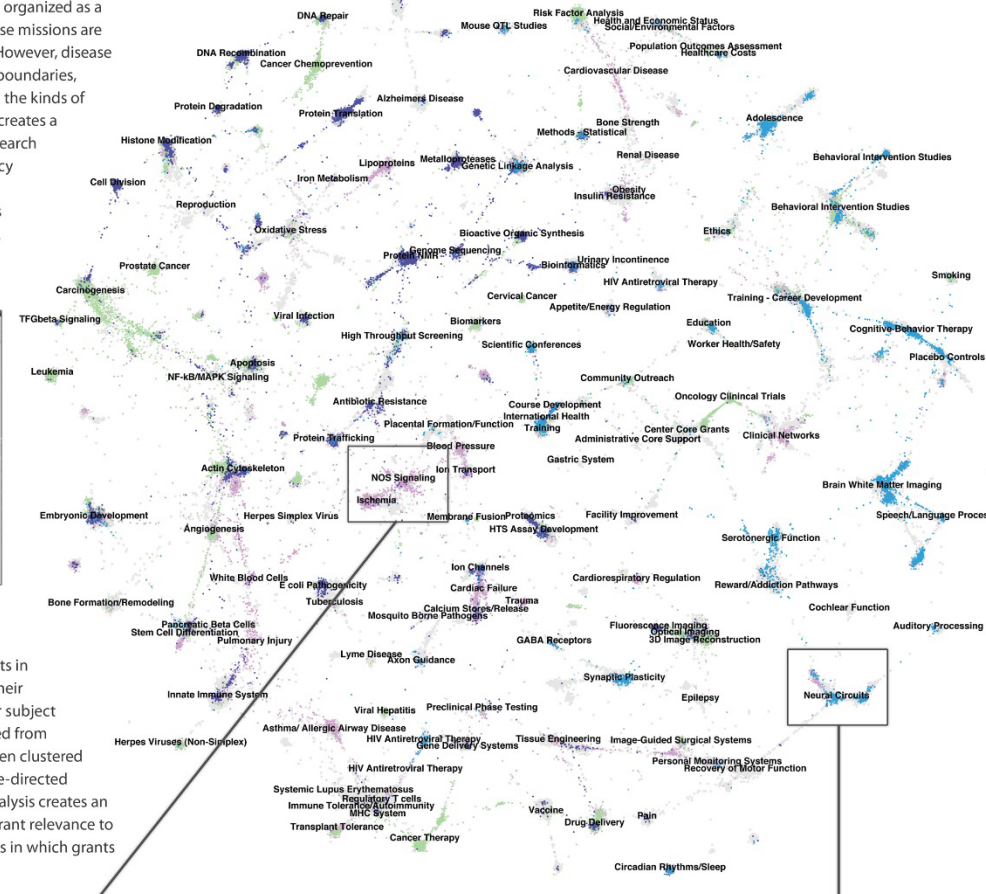
A Topic Map of NIH Grants 2007

Bruce W. Herr II (Chalklabs & IU), Gully Burns (ISI), David Newman (UCI), Edmund Talley (NIH)

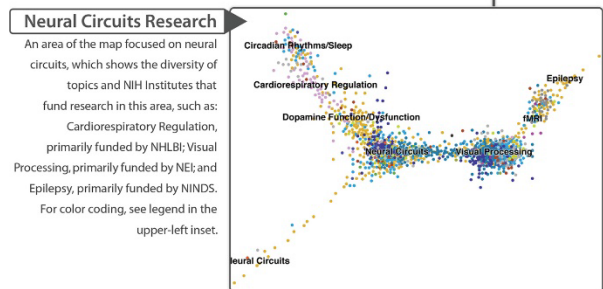
The National Institutes of Health (NIH) is organized as a multitude of Institutes and Centers whose missions are primarily focused on distinct diseases. However, disease etiologies and therapies flout scientific boundaries, and thus there is tremendous overlap in the kinds of research funded by each Institute. This creates a daunting landscape for decisions on research directions, funding allocations, and policy formulations. Shown here is devised an interactive topic map for navigating this landscape, online at www.nihmaps.org. Institute abbreviations can be found at www.nih.gov/icd.



Topic modeling, a statistical technique that automatically learns semantic categories, was applied to assess projects in terms used by researchers to describe their work, without the biases of keywords or subject headings. Grant similarities were derived from their topic mixtures, and grants were then clustered on a two-dimensional map using a force-directed simulated annealing algorithm. This analysis creates an interactive environment for assessing grant relevance to research categories and to NIH Institutes in which grants are localized.



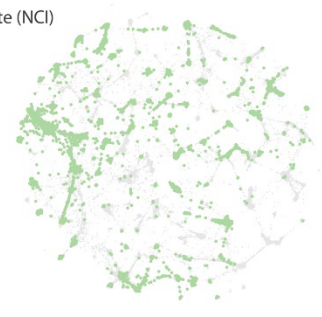
Cardiac Diseases Research
An area of the map focused on cardiovascular function and dysfunction. Cardiac Failure (primarily funded by NHLBI) is typically clustered next to Stroke (NINDS), since these are the two major medical emergencies associated with ischemia, which results from a restricted blood supply. Also localized in this area are grants focused on Nitric Oxide (NOS) Signaling, a major biochemical pathway for vasodilation, and grants on Hemodynamics, Sickle Cell Disease, and Aneurysms.



Neural Circuits Research
An area of the map focused on neural circuits, which shows the diversity of topics and NIH Institutes that fund research in this area, such as: Cardiorespiratory Regulation, primarily funded by NHLBI; Visual Processing, primarily funded by NEI; and Epilepsy, primarily funded by NINDS. For color coding, see legend in the upper-left inset.

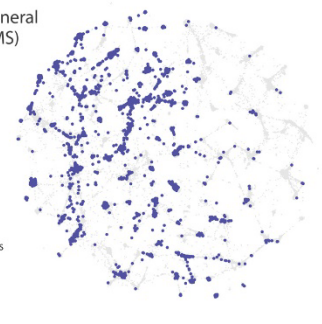
National Cancer Institute (NCI)

- TOP 10 TOPICS
- 1 Oncology Clinical Trials
 - 2 Cancer Treatment
 - 3 Cancer Therapy
 - 4 Carcinogenesis
 - 5 Risk Factor Analysis
 - 6 Cancer Chemotherapy
 - 7 Metastasis
 - 8 Leukemia
 - 9 Prediction/Prognosis
 - 10 Cancer Chemoprevention



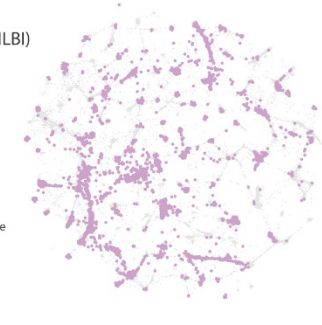
National Institute of General Medical Sciences (NIGMS)

- TOP 10 TOPICS
- 1 Bioactive Organic Synthesis
 - 2 X-ray Crystallography
 - 3 Protein NMR
 - 4 Computational Models
 - 5 Yeast Biology
 - 6 Metalloproteases
 - 7 Enzymatic Mechanisms
 - 8 Protein Complexes
 - 9 Invertebrate/Zebrafish Genetics
 - 10 Cell Division



National Heart, Lung, and Blood Institute (NHLBI)

- TOP 10 TOPICS
- 1 Cardiac Failure
 - 2 Pulmonary Injury
 - 3 Genetic Linkage Analysis
 - 4 Cardiovascular Disease
 - 5 Atherosclerosis
 - 6 Hemostasis
 - 7 Blood Pressure
 - 8 Asthma/ Allergic Airway Disease
 - 9 Gene Association
 - 10 Lipoproteins



National Institute of Mental Health (NIMH)

- TOP 10 TOPICS
- 1 Mood Disorders
 - 2 Schizophrenia
 - 3 Behavioral Intervention Studies
 - 4 Mental Health
 - 5 Depression
 - 6 Cognitive-Behavior Therapy
 - 7 AIDS Prevention
 - 8 Genetic Linkage Analysis
 - 9 Adolescence
 - 10 Childhood

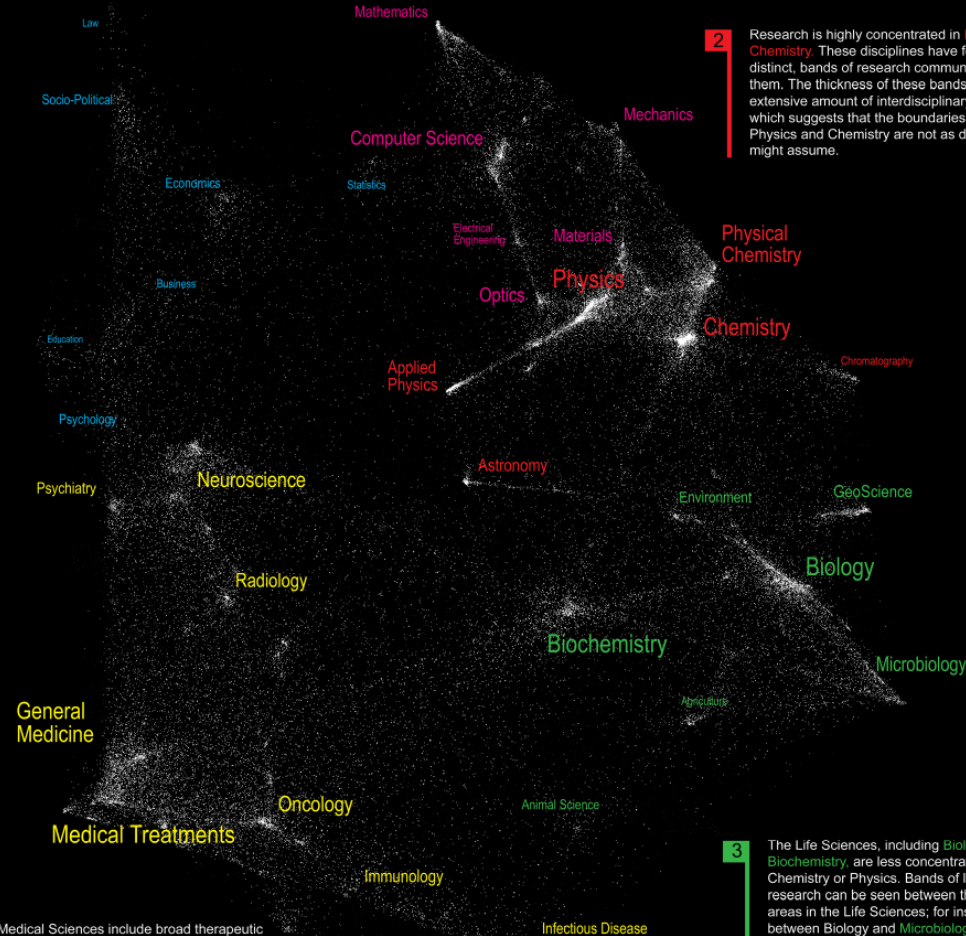


The Structure of Science

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.

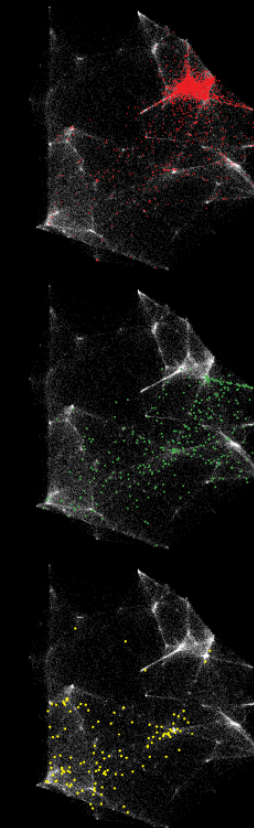
We are all familiar with traditional maps that show the relationships between countries, provinces, states, and cities. Similar relationships exist between the various disciplines and research topics in science. This allows us to map the structure of science.

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

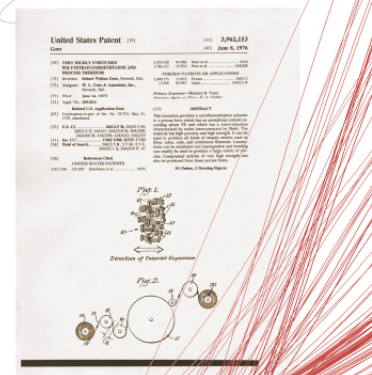
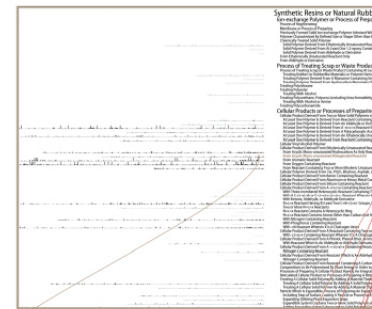
Pharmacogenomics is a relatively new field with most of its activity in **Medicine**. It also has many communities in **Biochemistry** and two communities in the Social Sciences.

Impact

The United States Patent and Trademark Office does scientists and industry a great service by granting patents to protect inventions. Inventions are categorized in a taxonomy that groups patents by industry or use, proximate function, effect or product, and structure. At the time of this writing there are 160,523 categories in a hierarchy that goes 15 levels deep. We display the first three levels (13,529 categories) at right in what might be considered a textual map of inventions.

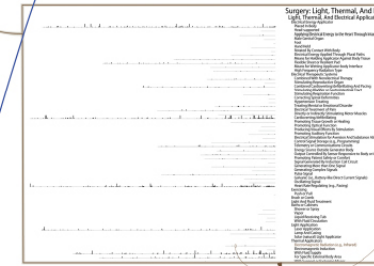
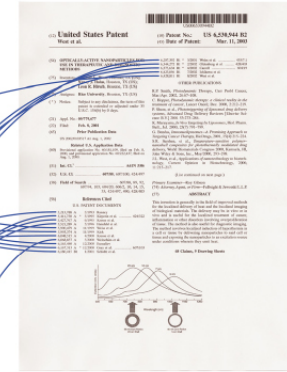
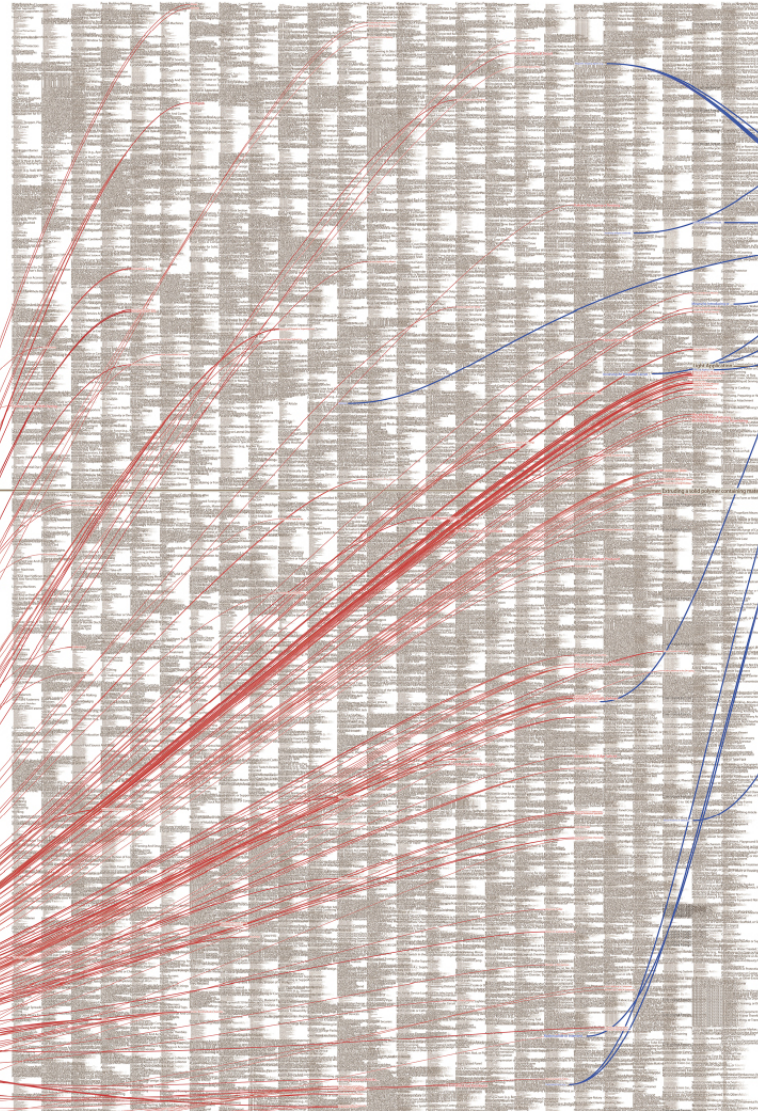
Patent applications are required to be unique and non-obvious, partially by revealing any previous patents that might be similar in nature or provide a foundation for the current invention. In this way we can trace the impact of a single patent, seeing how many patents and categories it affects.

The patent on Goretex—a lightweight, durable synthetic fiber—is an example of one that has had significant impact. The box below enlarges the section of the hierarchy where it is filed, and the red lines (arranged to start along a time line from 1981 to 2006) point to the 130 categories that contain 182 patents, from waterproof clothing to surgical cosmetic implants, that mention Goretex as "prior art."



The US Patent Hierarchy

Prior Art



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

Keeping categories understandable is an important part of maintaining any taxonomy, including the patent hierarchy. Categories are easier to understand, search, and maintain if they contain elements that comfortably fit the definition of the category. The box above shows tiny bar charts, part of a *Taxonomy Validator* that reveals whether elements fit their categories. Categories may need to be redefined, and sometimes need to be split when they get too vague or large; a problem shared by many classification systems in this information-rich century. But how can we tell which ones to eliminate, add or revise—or how to revise them—in the complex, abstract sociolinguistic spaces we partition into ontologies?

Something as simple as a bar chart helps people see how entities in a category relate to that category. Here, each bar encodes a "distance to prototype": how much each patent differs from an idealized "prototype patent" for that category. A measure like this can be based on statistics, computational linguistics, or even human insight. Thus a category with mostly small bars is a good one, and a generally ragged one needs scrutiny or reorganization; but one that has only two or three tall bars may mean that only those few elements don't belong.

Even simple visuals can make thinking easier by providing better distilled data to the eye: vastly more data than working memory can hold as words. They focus people on exactly the right issues, and support them with the comprehensive overviews they need to make more informed judgements.

Science related Wikipedian ACTIVITY

This visualization explores the activity of science, math, and technology (SMT) related articles in the English-language Wikipedia (<http://en.wikipedia.org>). The central image shows 659,388 articles (circles). Overlaid is a 37 x 37 grid of relevant half-inch sized images.

Blue, green, and yellow circles represent the 3,599 math, 6,474 science, and 3,164 technology related articles respectively. The larger the size of a circle the higher the likelihood it is that type of article. The four corners show activity patterns of SMT articles.

Article Edit Activity
Articles are size coded based on how frequently they have been edited from Feb. 6, 2001 to April 6, 2007. More consideration is given to current and major edits. Larger circles have been edited more frequently than smaller circles.

2007 Major Edits
Articles are size coded based on how many major edits they received from January 1st, 2007 to April 6th, 2007. Larger circles have received more edits than smaller circles. The highest number of major edits was 2,627.

For the central image, each article is size coded based on the likelihood that it is math, science, or technology related.

- 0%
- 50%
- 100%

All five images are color coded based on type. Transparency is used for legibility, and creates different colors when nodes overlap.

- Math
- Science
- Technology

Article Popularity
Articles are size coded based on the number of Wikipedia articles referencing it. Larger circles are receiving more links from other articles than smaller circles. The highest number of references to an article was 142,602.

Number of Bursts
Articles are size coded based on the number of bursts, i.e. sudden increases, of edit activity that occurred during the article's lifetime. Larger circles have had more bursts in activity than smaller circles. The most bursts an article had was 9.



Diseasome

The Human Disease Network

Explore online at <http://diseasome.eu>

Statistics

of Nodes: 516
 # of Edges: 1188
 Density: 0,0089
 Average Degree: 9,20
 Diameter: 15
 Average Shortest Path: 6,5

Disorder Class

- Cancer
- Endocrine
- Ear, Nose, Throat
- Ophthalmological
- Neurological
- Hematological
- Cardiovascular
- Muscular
- Immunological
- Dermatological
- Nutritional
- Connective Tissue Disorder
- Renal
- Psychiatric
- Metabolic
- Bone
- Skeletal
- Developmental
- Gastrointestinal
- Respiratory
- Multiple
- Unclassified

Top 5 Diseases

1. Deafness
2. Leukemia
3. Colon Cancer
4. Retinitis Pigmentosa
5. Diabetes Mellitus

Top 5 Genes

1. TP53
2. PAK6
3. FGFR2
4. RTN
5. MSH2

Description

The map presents a network of 516 diseases linked by 1188 known disorder-gene associations, indicating the common genetic origin of many diseases.

GENE NETWORK CLUSTER

This map offers a rapid visual reference of the genetic links between disorders and a valuable global perspective for physicians, genetic counselors, and biomedical researchers alike. This view appears only when the network is zoomed, revealing to their associated genes, together the understanding of the roots of disease, and the functions of particular genes.

NETWORK VISUALIZATION TECHNIQUES APPLIED

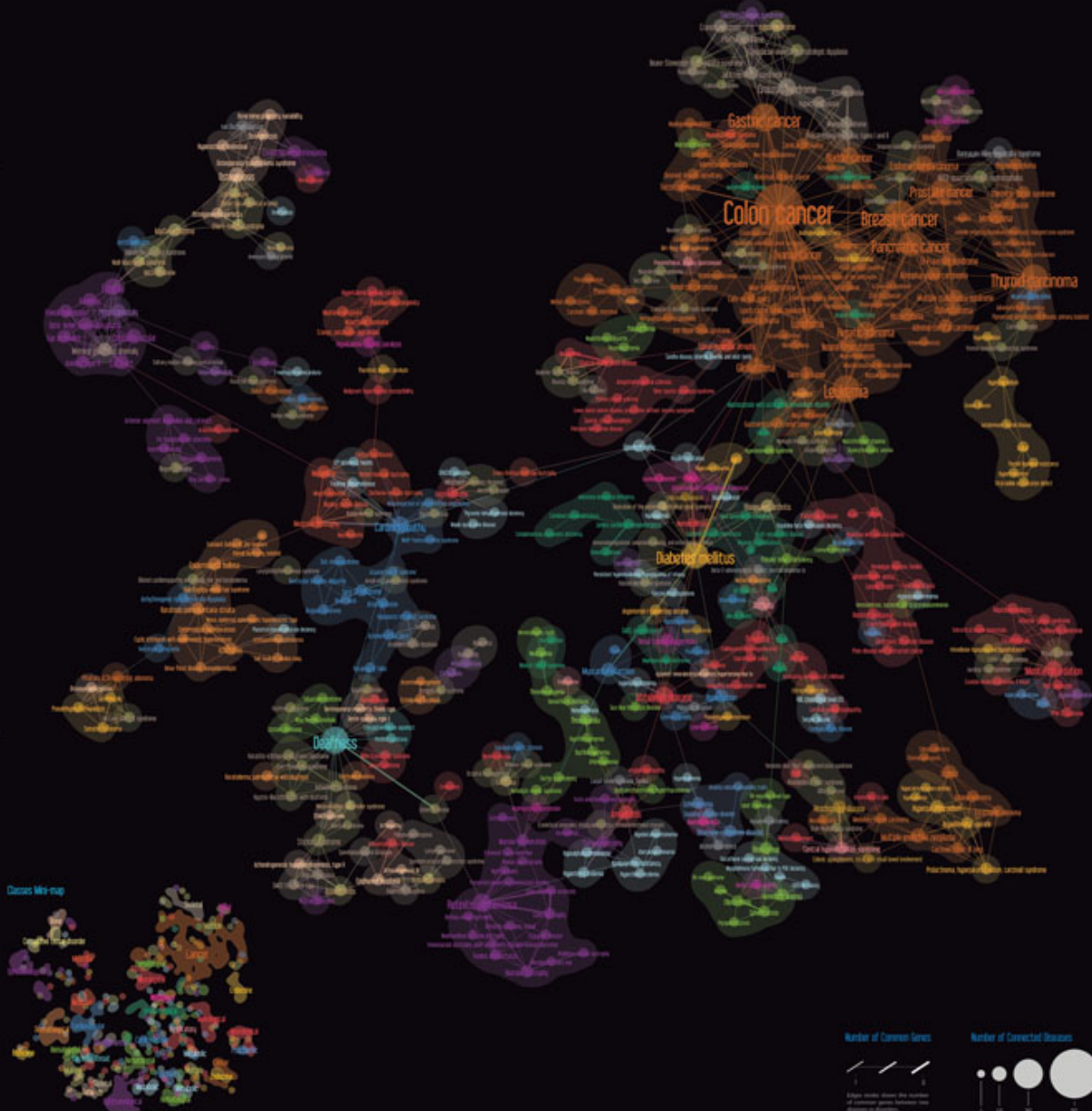
The map was done using the force-directed layout algorithm ForceAtlas in Gephi. Node sizes correspond to the disorder class to which the disease belongs, and the size is proportional to its node degree, the overall number of links. Link's width is proportional to the number of genes that are implicated in both disorders and colored with the average color between source and target nodes. Isolated diseases are not shown and only the giant component has been kept. The Clusters Mini-map shows more readable disorder classes and shows largest visual clusters.

The Disorder Class Interactivity graph below shows the interaction level between disorder classes, representing the number of shared genes, up to 80.

References

The Human Disease Network
 Bastin & Heymann 2009, *PLoS ONE*, 4(10): e8248

Disorder Class Interactions



Check out our **Zoom Maps** online!

VII.10
History of Science Fiction, by Ward Shulley

BROOKLYN, NY, 2011
Courtesy of Ward Shulley Studio

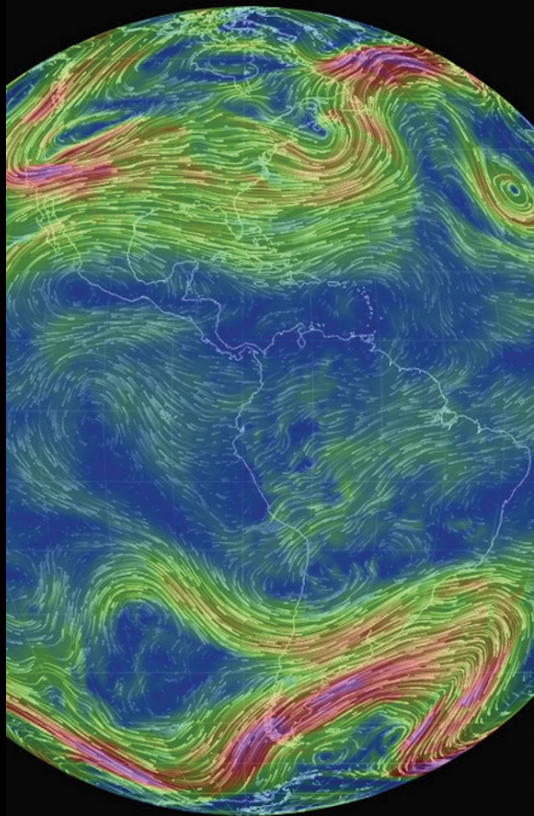
Ward Shulley is an artist identified with the Williamsburg scene in Brooklyn, New York. He is a writer, artist, and curator. This map plots the science fiction literary genre from its nascent beginnings in the late 18th century, through the Romantic period, and into the modern era. Emerging out of the data, here the narrative structure perceives and organizes the data. The map's structure is like a tree, tracing roots to pre-historical sources and whose body, the branches, are like the roots of the tree. The map is a complex network of colored lines and nodes, representing the evolution of science fiction literature. It branches into various sub-genres like 'SCIENCE ADVENTURE', 'FANTASY ADVENTURE', 'CYBER PUNK', and 'SPACE OPERA'. A zoomed-in inset shows a detailed section of the map, highlighting 'ENGLISH ROMANTIC POETS' (including S. Coleridge, Lord Byron, and Percy B. Shelley) and 'MARY SHELLY FRANKENSTEIN OR THE MODERN PROMETHEUS'. Other names like Jules Verne, Victor Hugo, and Mary Shelley are also visible. The map is presented in a browser window with navigation controls.

PLACES & SPACES
MAPPING & DESIGN

Visit scimaps.org and check out all our maps in stunning detail!



MACROSCOPES FOR INTERACTING WITH SCIENCE



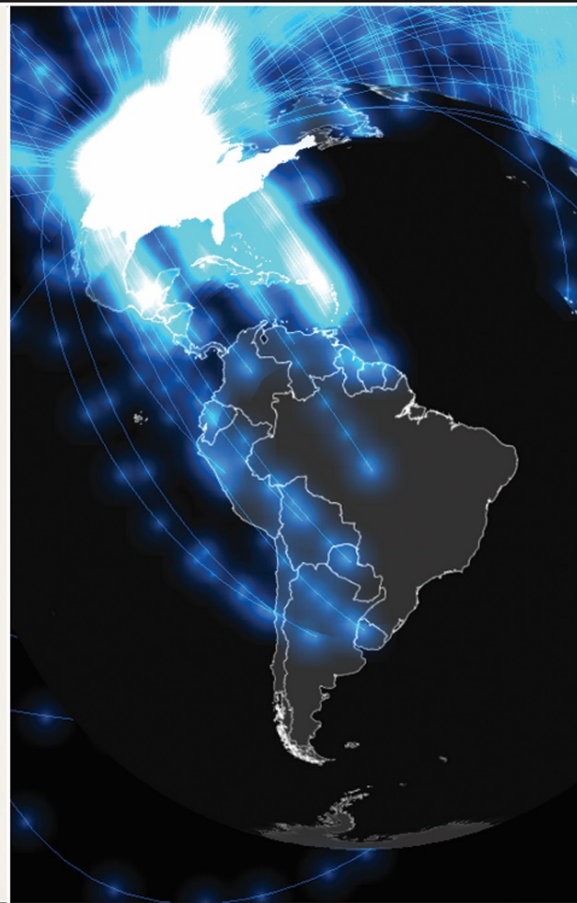
Earth

Weather on a worldwide scale



AcademyScope

Exploring the scientific landscape



Mapping Global Society

Local news from a global perspective

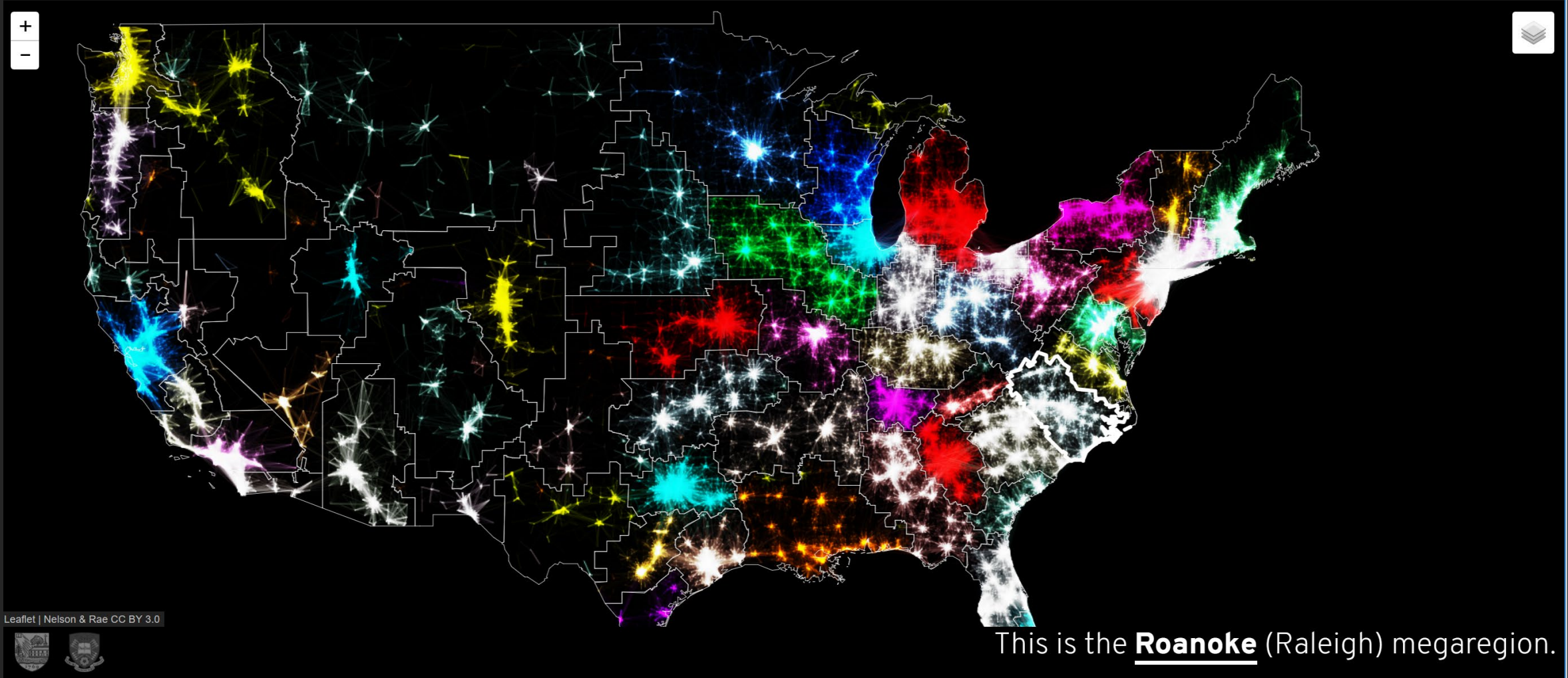


Charting Culture

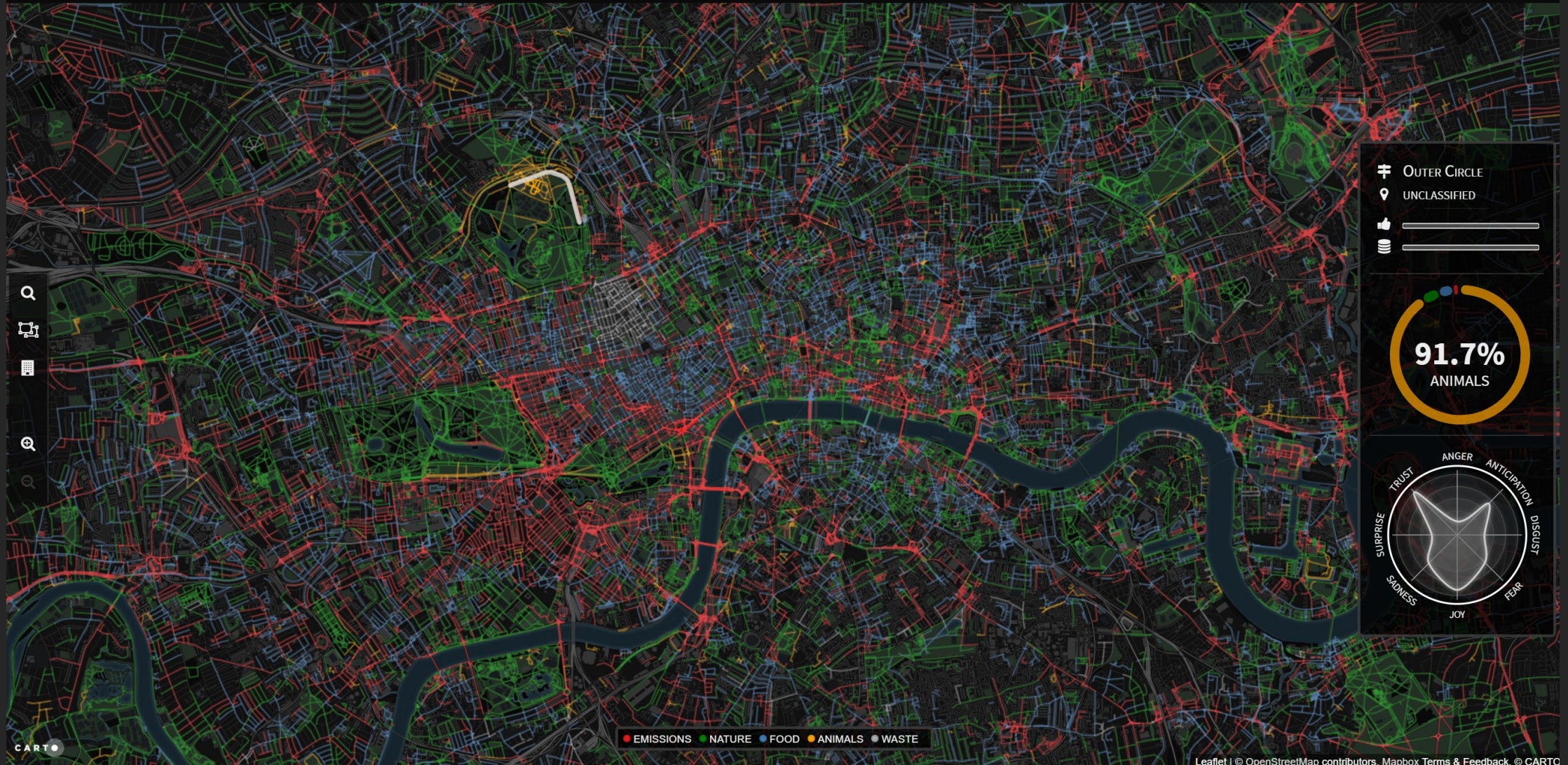
2,600 years of human history in 5 minutes

THE MEGAREGIONS OF THE US

Explore the new geography of commuter connections in the US.
Tap to identify regions. Tap and hold to see a single location's commuted.

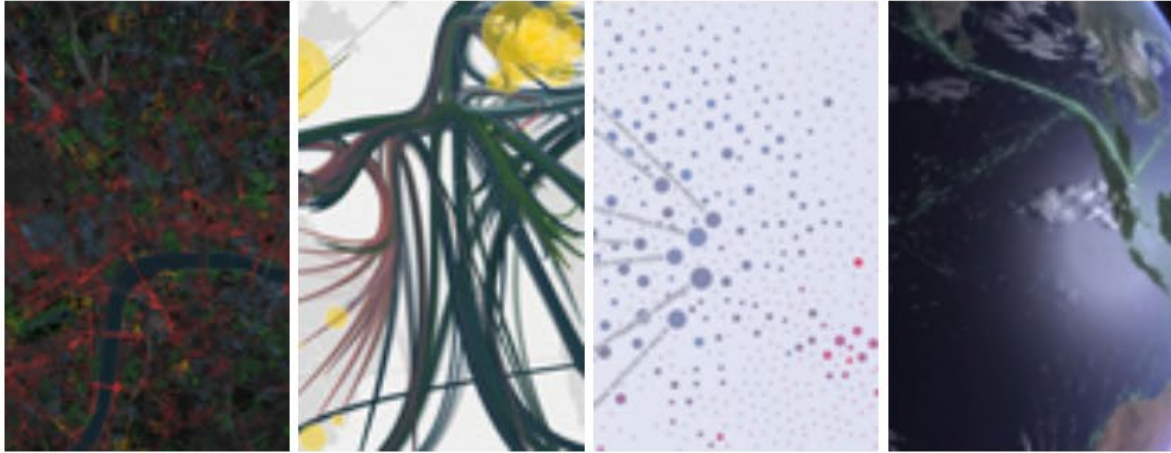


SMELLY
MAPS



Iteration XII (2016)

Macrosopes for Making Sense of Science



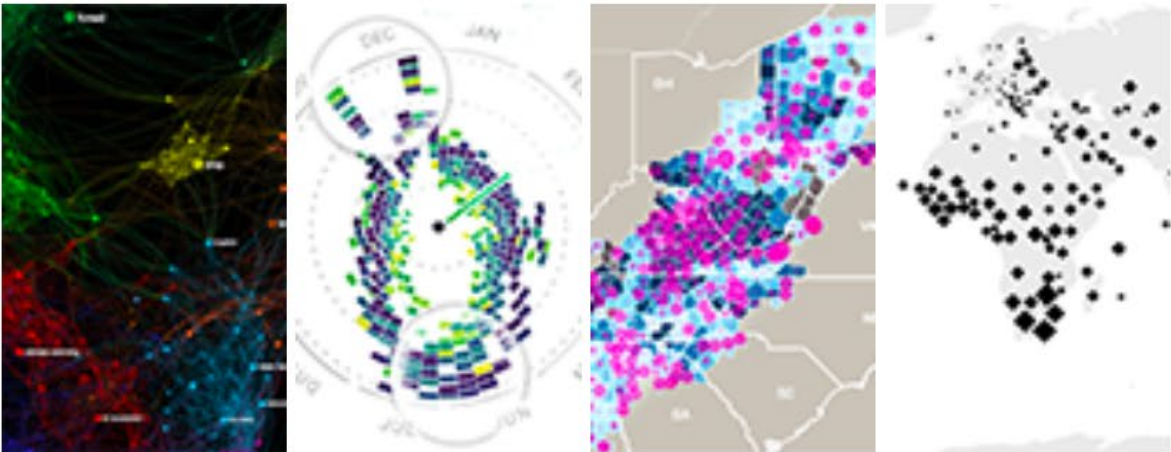
Iteration XIII (2017)

Macrosopes for Playing with Scale



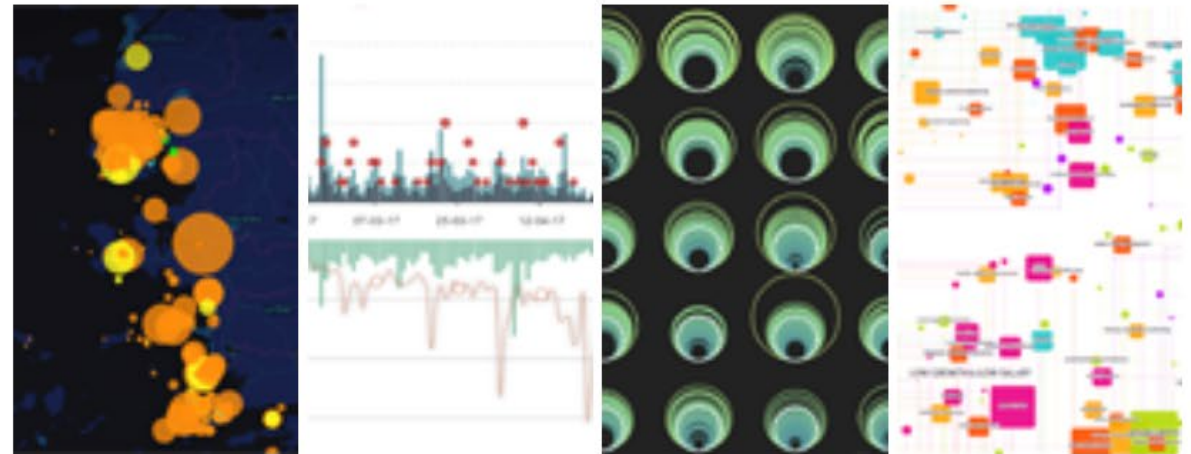
Iteration XIV (2018)

Macrosopes for Ensuring our Well-being



Iteration XV (2019)

Macrosopes for Tracking the Flow of Resources

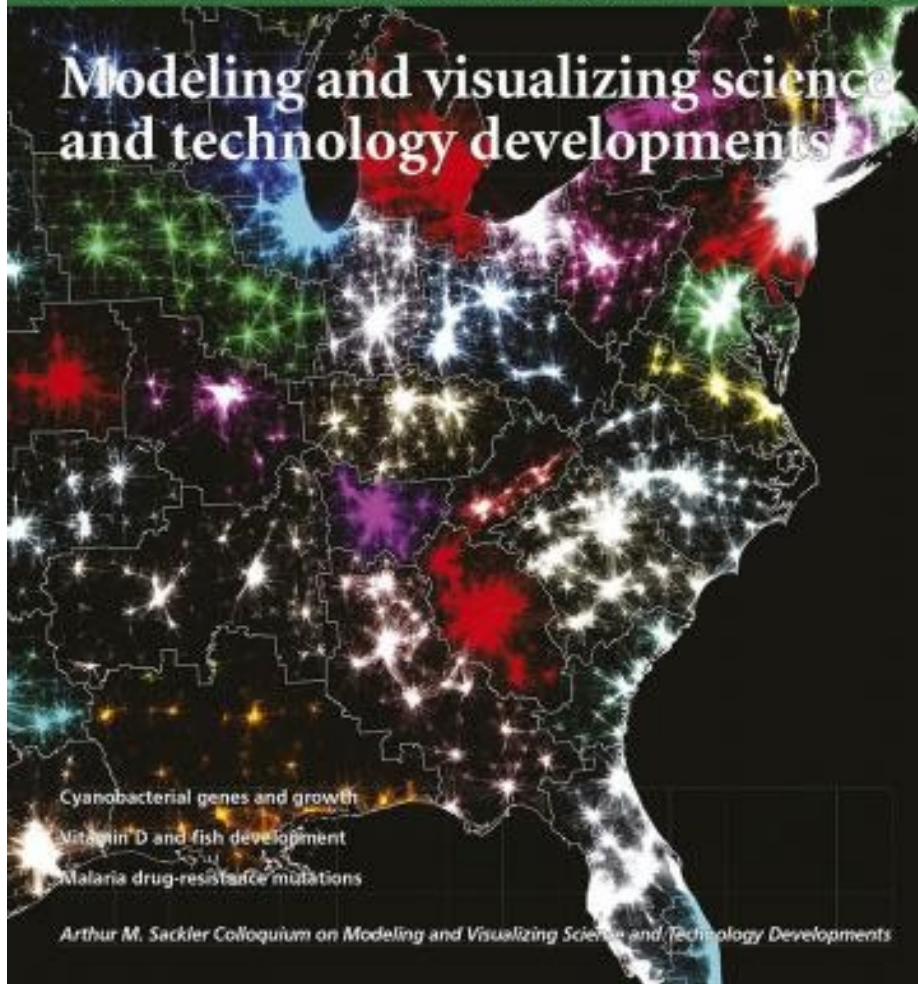


December 11, 2018 | vol. 115 | no. 50 | pp. 12537-12828

PNAS

Proceedings of the National Academy of Sciences of the United States of America www.pnas.org

Modeling and visualizing science and technology developments



<https://www.pnas.org/modeling>

Atlas of Forecasts

Modeling and Mapping Desirable Futures

Katy Börner



<https://mitpress.mit.edu/books/atlas-forecasts>

Acknowledgments

Exhibit Curators



The exhibit team: Lisel Record, Katy Börner, and Todd Theriault.

<http://scimaps.org>

Plus, we thank the more than 250 authors of the 100 maps and 16 interactive macroscopes.

Exhibit Advisory Board



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Vice President of Science and Technology for the **New York Hall of Science**



Benjamin Wiederkehr
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Visualizations of the Scalable Precision Medicine Knowledge Engine (SPOKE)

<https://spoke.ucsf.edu>



Scalable Precision
Medicine Knowledge
Engine

Search... 

Data & Tools

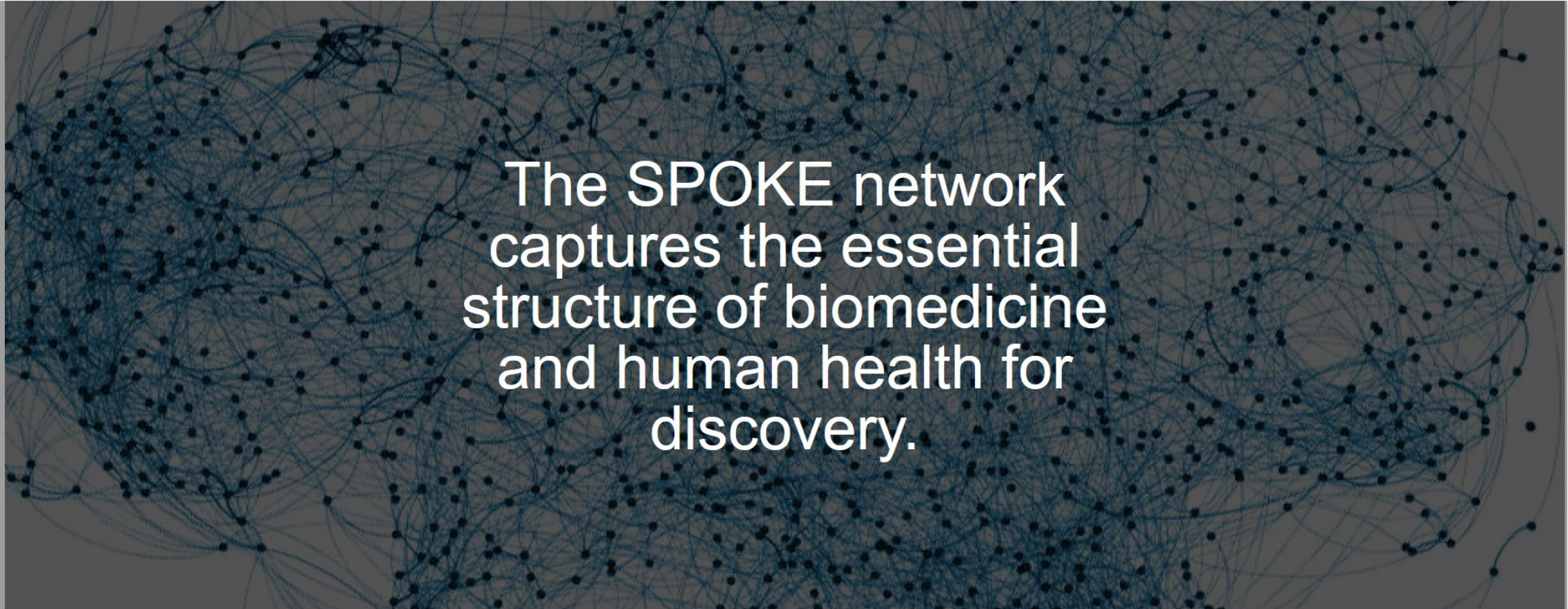
Neighborhood Explorer

Funding

Applications

People

Publications



The SPOKE network
captures the essential
structure of biomedicine
and human health for
discovery.

<https://spoke.ucsf.edu>

Lead Investigators



Sergio Baranzini, PhD
Principal Investigator



Sui Huang, MD, PhD (ISB)



Sharat Israni, PhD



Mike Keiser, PhD

SPOKE investigative teams

The SPOKE team members are from the following organizations. *Team members listed below are from UCSF, except when indicated.*

- [Google](#)
- [Indiana University \(IU\)](#)
- [Institute for Systems Biology \(ISB\)](#)
- [Lawrence Livermore National Lab \(LLNL\)](#)
- [Stanford University](#)
- [University of California, San Diego \(UCSD\)](#)
- [University of California, San Francisco \(UCSF\)](#)

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Scotter Morris, PhD

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Boris Oskotsky, PhD

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Mark Musen, MD, PhD (Stanford)

Camille Nebeker, EdD, MS (UCSD)

Roger Pearce, PhD (LNL)



Scalable Precision
Medicine Knowledge Engine

Envisioning SPOKE: 3M Nodes and 30M Edges

The Scalable Precision Medicine Oriented Knowledge Engine (SPOKE) graph federates about 19 open datasets into a public data commons of health relevant knowledge. This site lets users explore the massive SPOKE knowledge graph.

The site was designed for two user groups: (1) novice users interested to understand the coverage and quality of SPOKE data and (2) expert users interested to analyze and optimize the interlinked knowledge graphs in SPOKE.

The overview visualization shows the different entity type and their diverse interlinkages. Detail

SPOKE is a fully interactive tool for exploring the interconnections between data.

[Explore SPOKE](#)



NIH National Center
for Advancing
Translational Sciences

UCSF

CNS Cyberinfrastructure for
Network Science Center



A:0 1 2 3 4 5 6 7 8 9 10 11 12 A

B B

C C

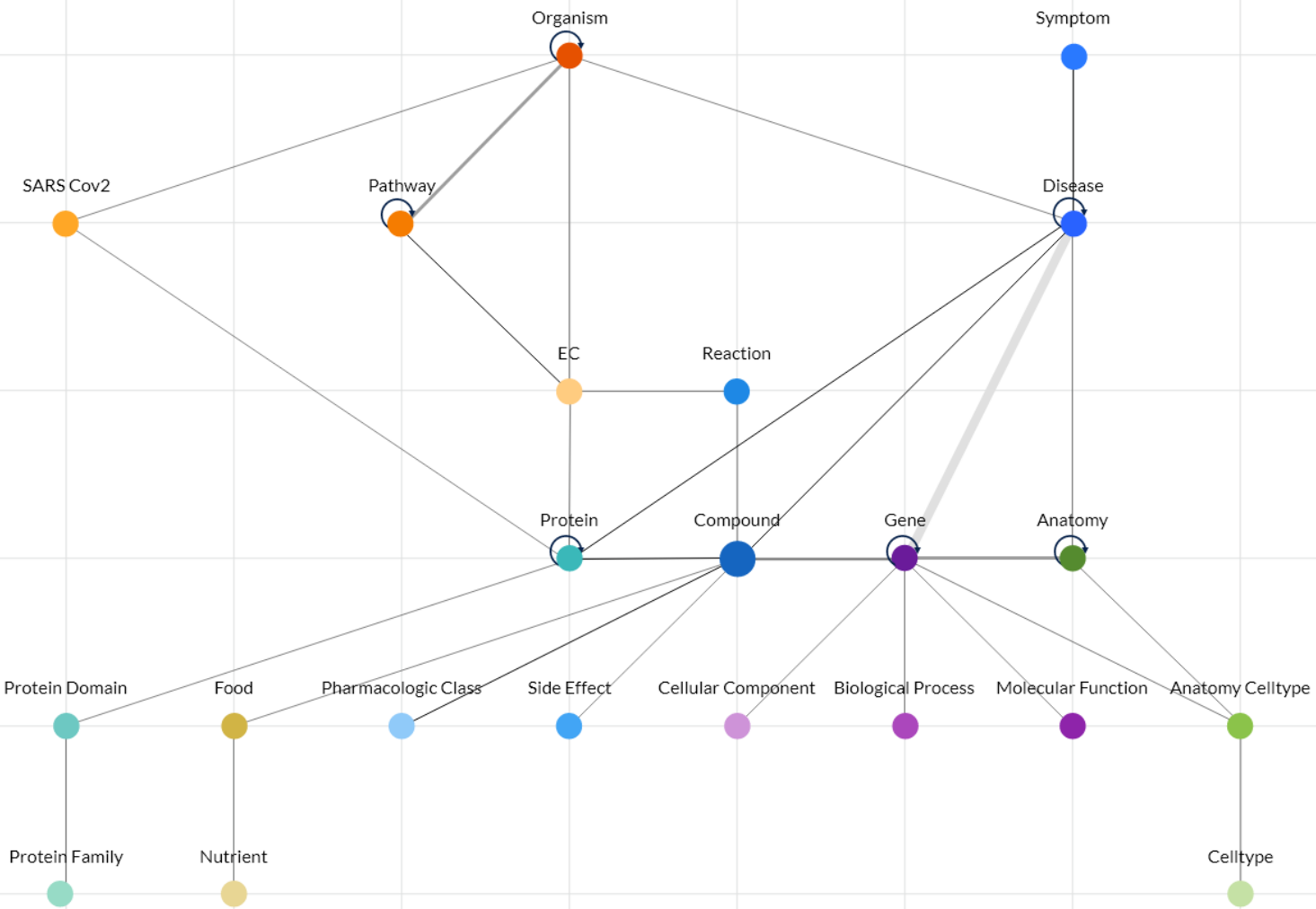
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E E

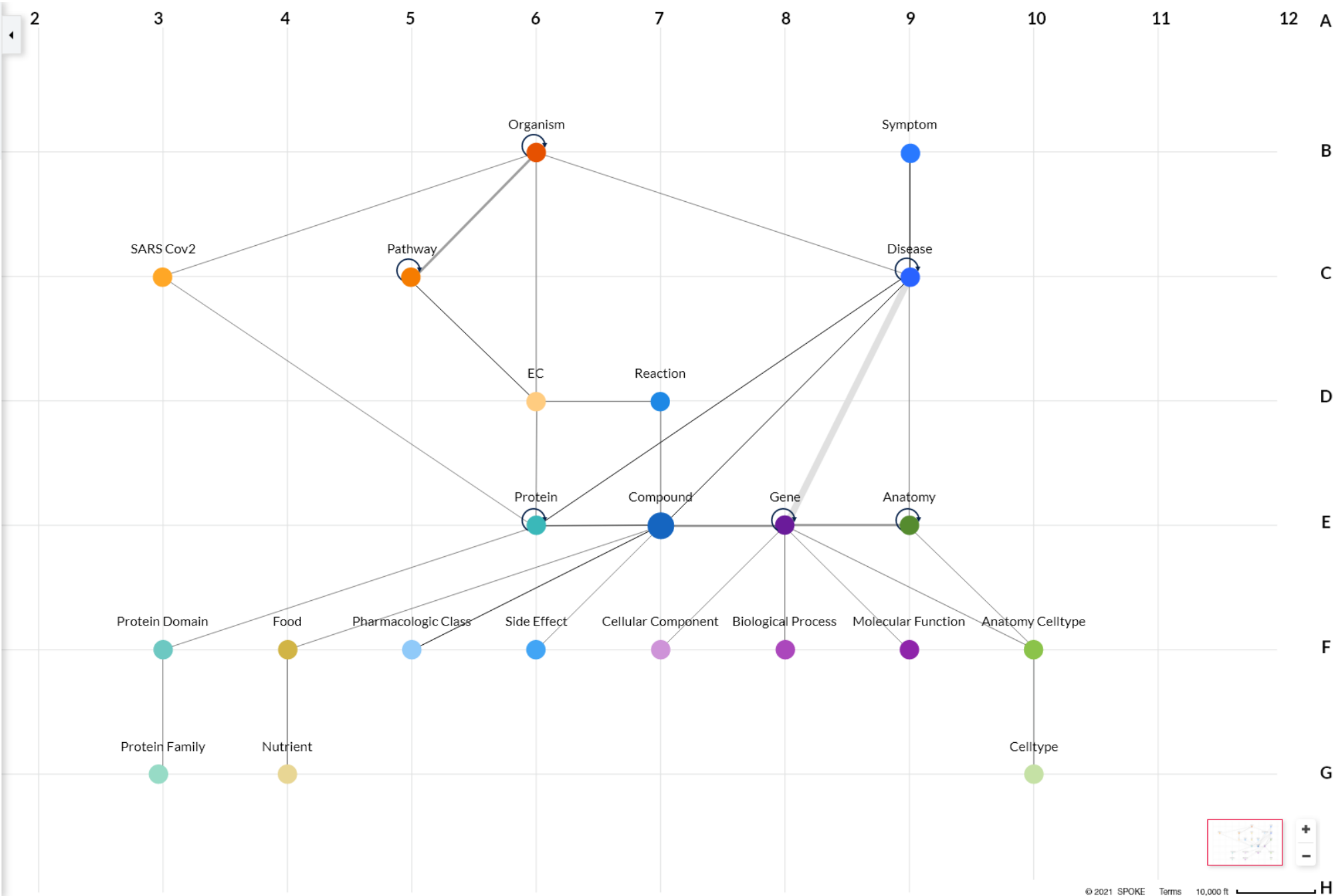
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G G

H H



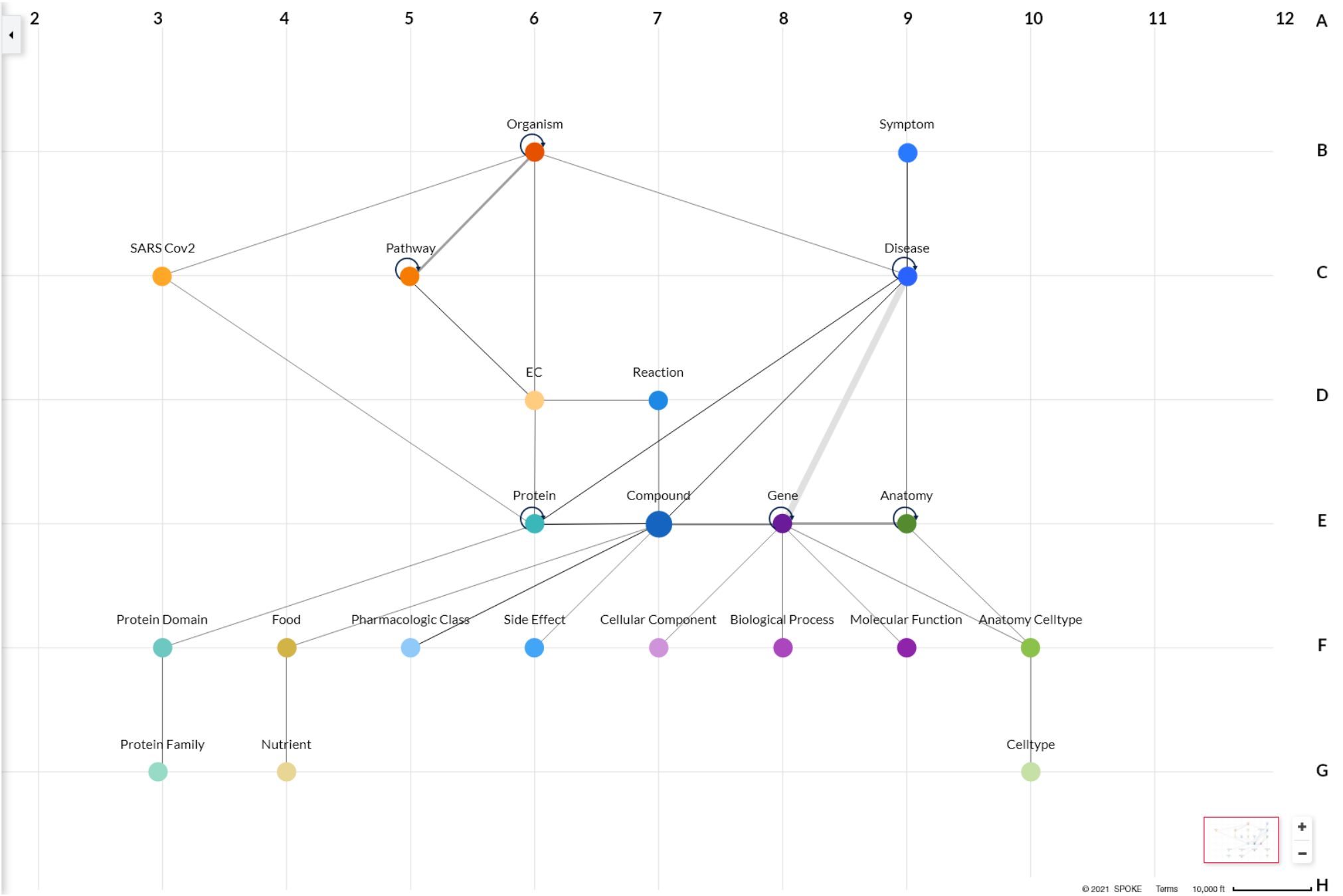
- potato
- heart
- alcoholic cardiomyopathy
- anterolateral myocardial infarction
- atrial fibrillation
- beta thalassemia
- brugada syndrome
- cardiac arrest
- cardiac tuberculosis
- coronary artery disease
- diabetic neuropathy
- diastolic heart failure
- ...



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- potato
- heart
- alcoholic cardiomyopathy
- anterolateral myocardial infarction
- atrial fibrillation
- beta thalassemia
- brugada syndrome
- cardiac arrest
- cardiac tuberculosis
- coronary artery disease**
- diabetic neuropathy
- diastolic heart failure
- ...



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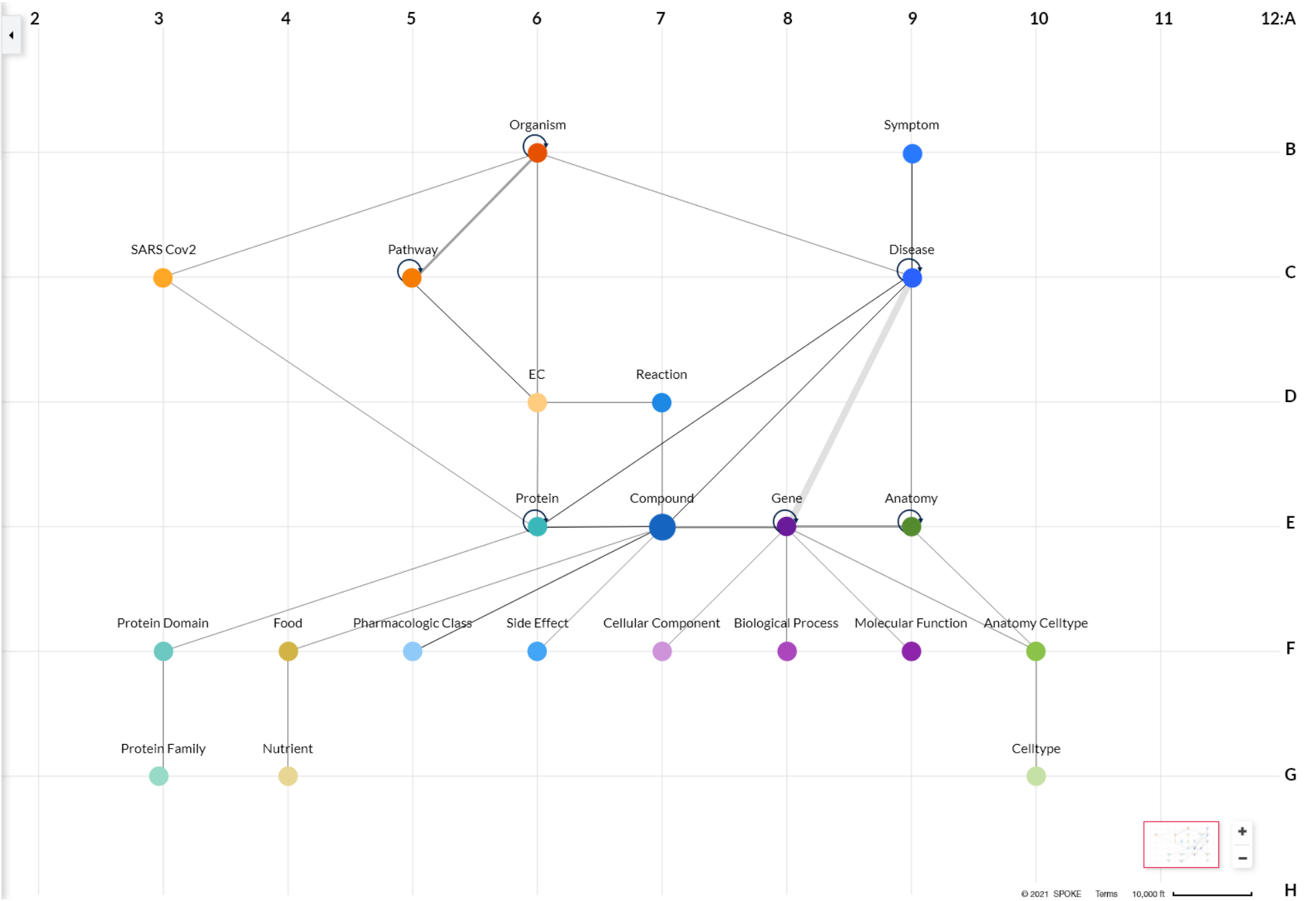


potato ✕

coronary artery disease ✕

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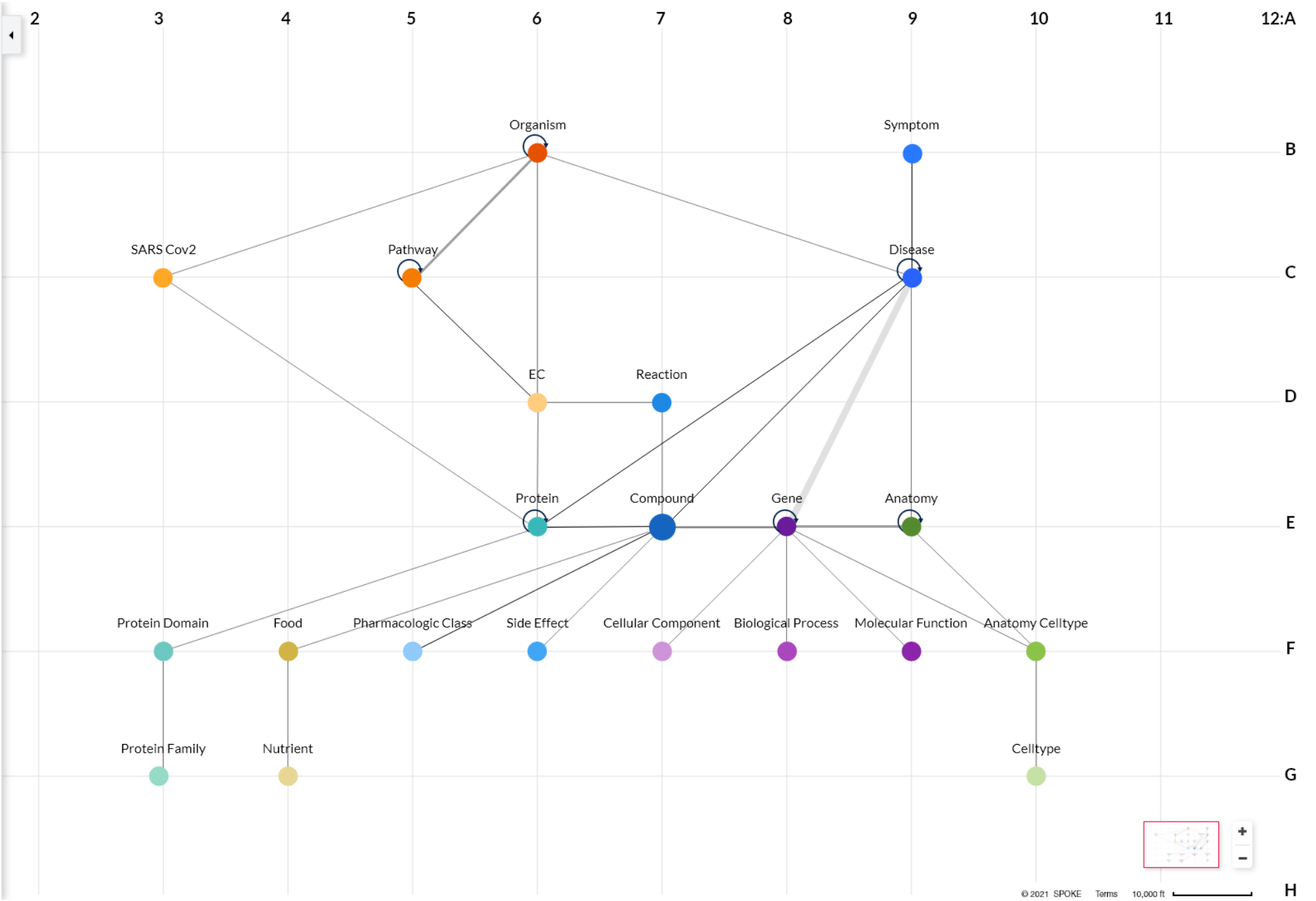
potato ✕

coronary artery disease ✕

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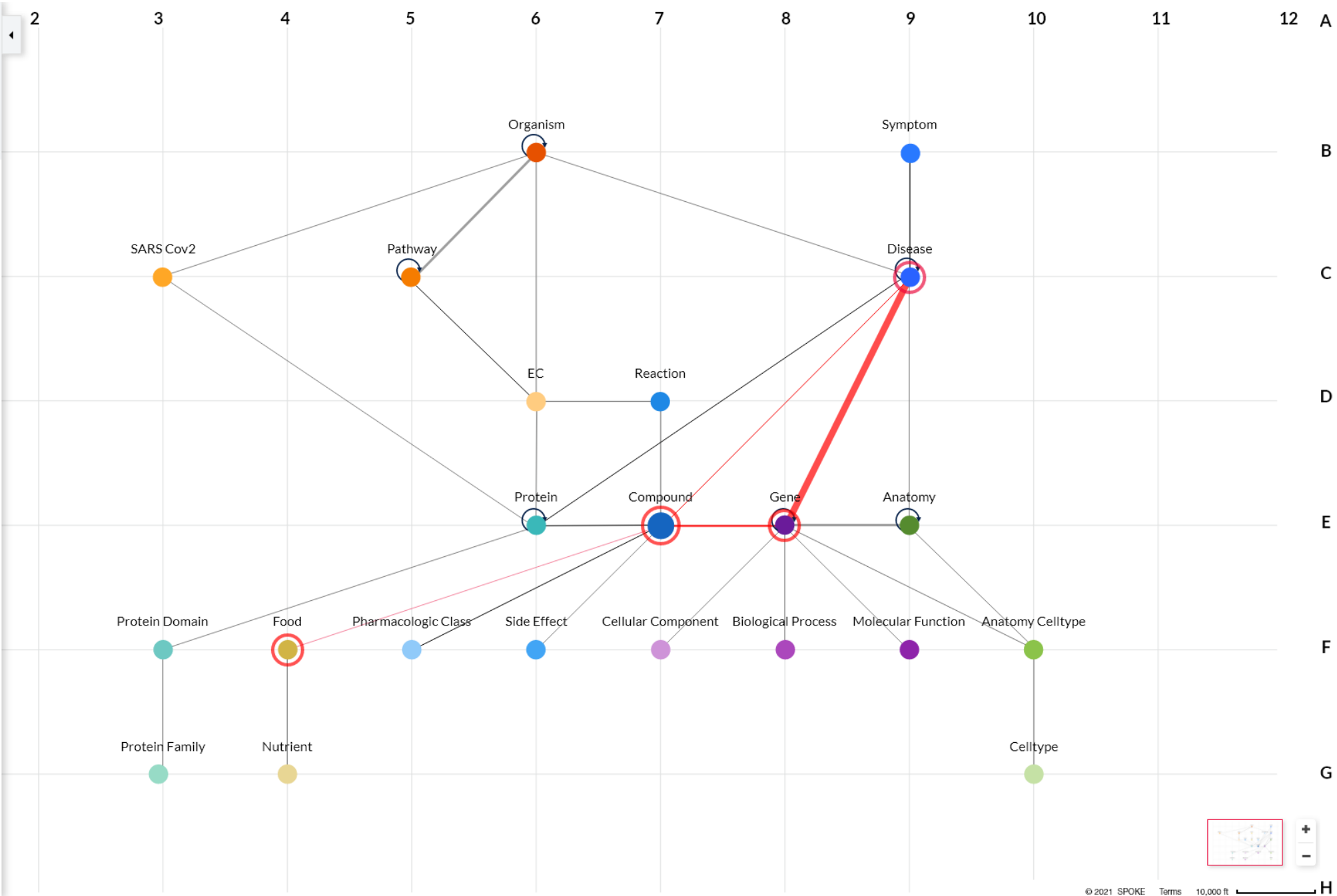
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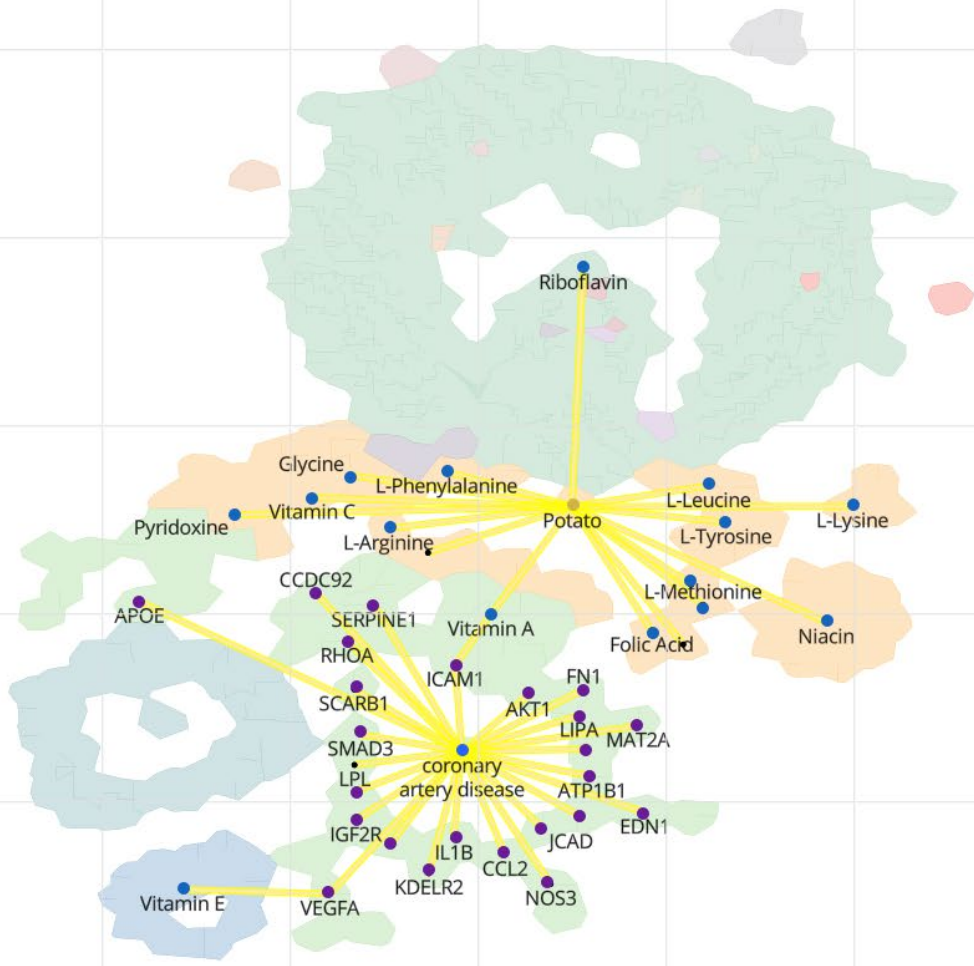
potato ✕

coronary artery disease ✕

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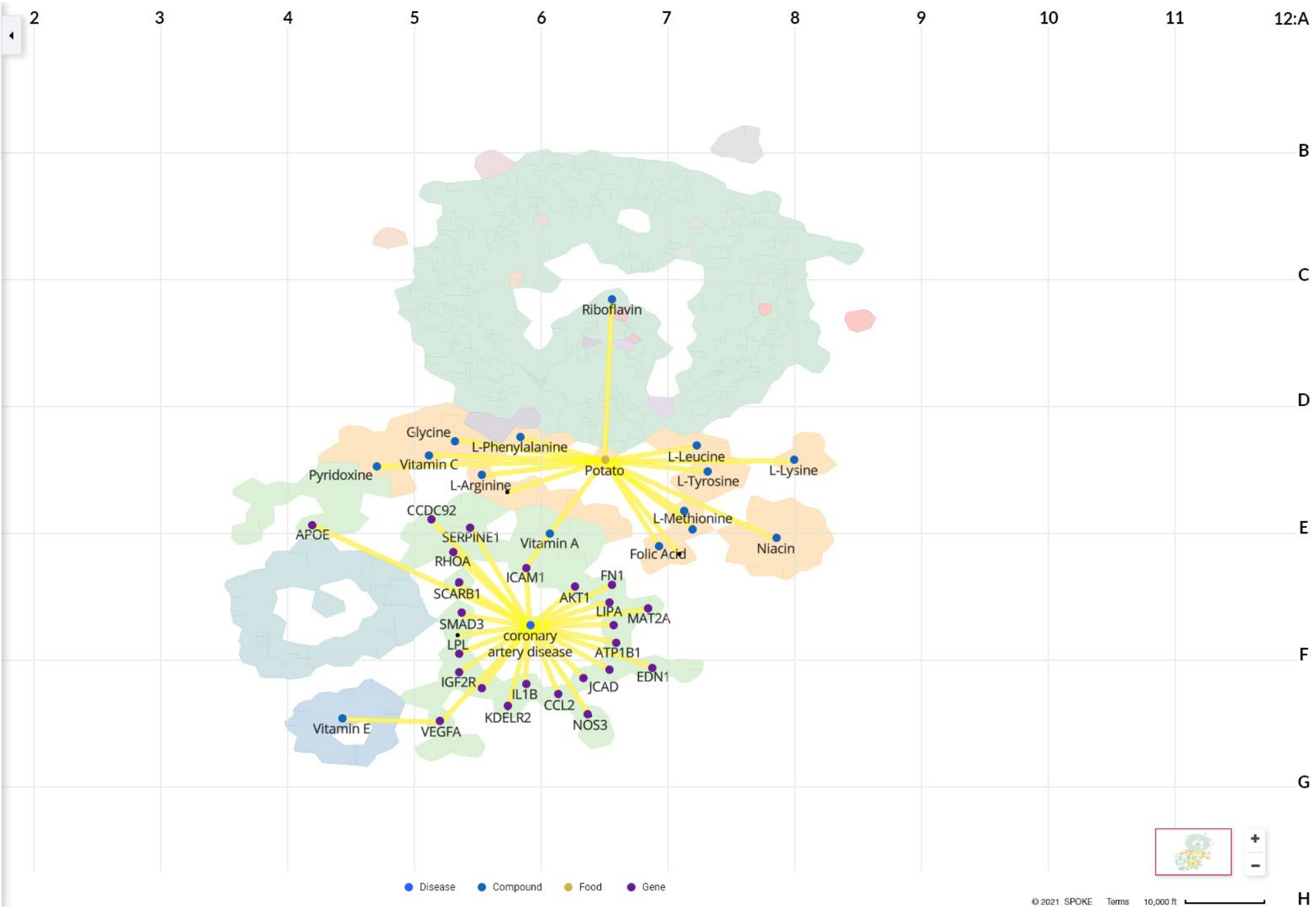
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● Disease ● Compound ● Food ● Gene

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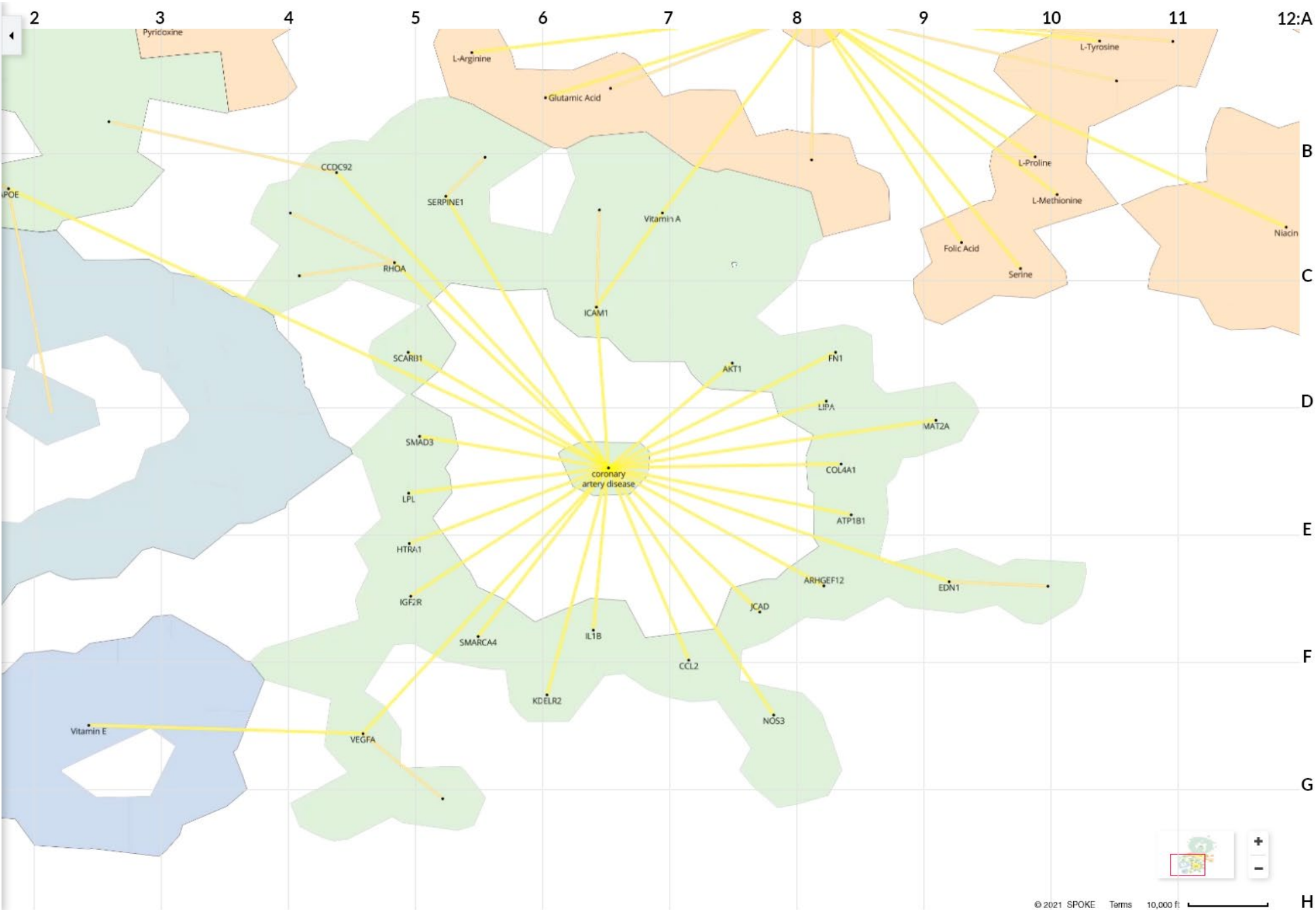
potato ×

coronary artery disease ×

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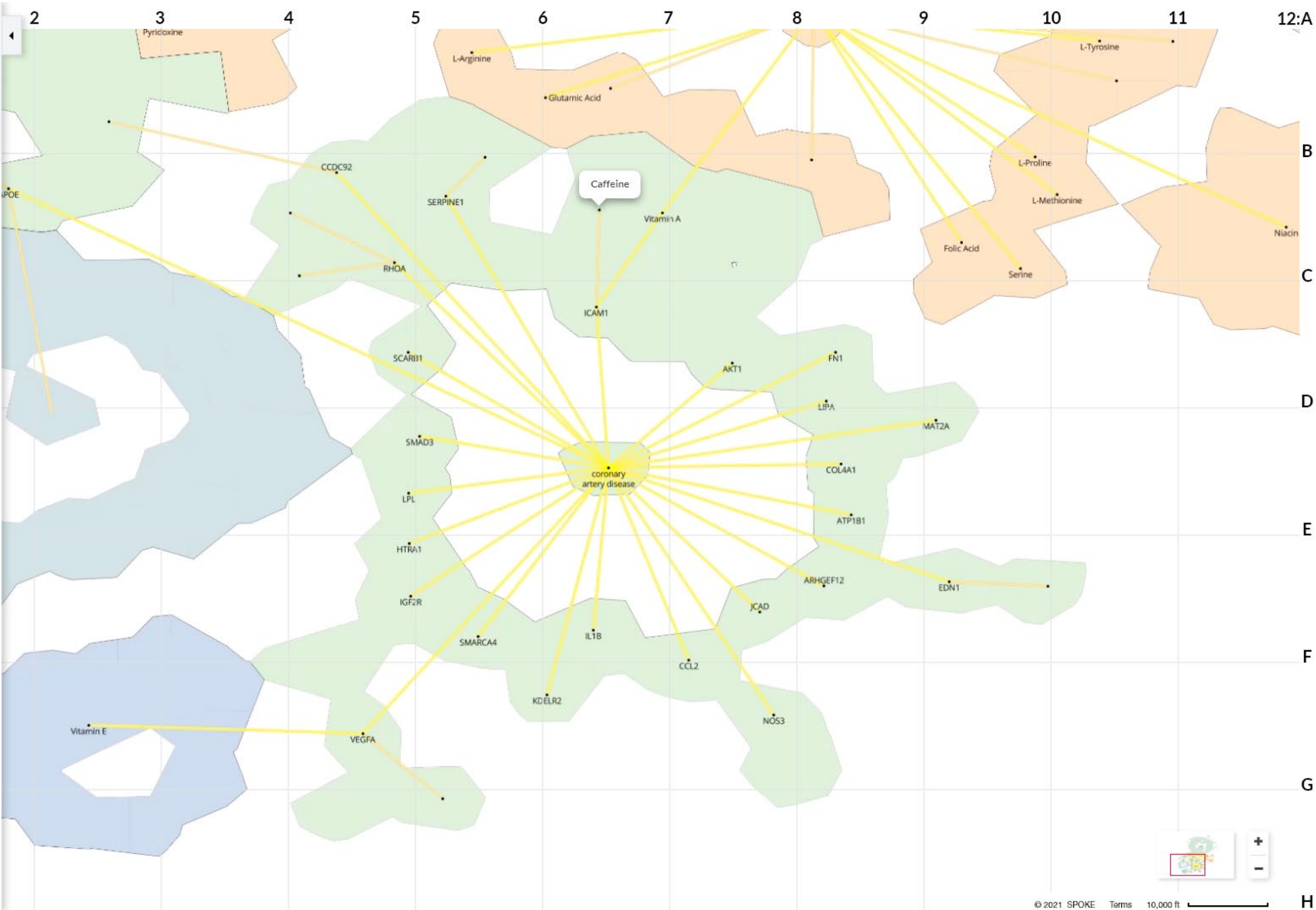
potato ×

coronary artery disease ×

SEARCH

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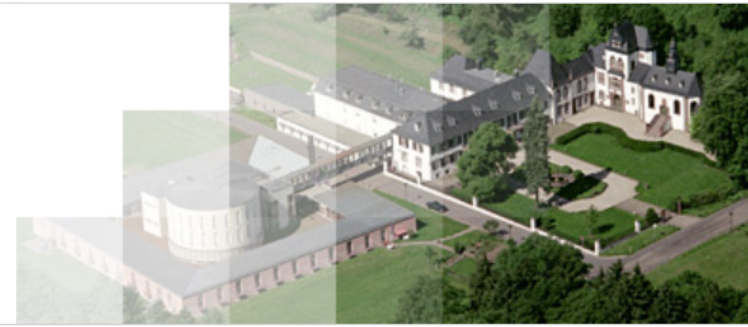
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April 11 – 16 , 2021, **Dagstuhl Seminar 21152**

Multi-Level Graph Representation for Big Data Arising in Science Mapping

Organizers

Katy Börner (Indiana University – Bloomington, US)

Stephen G. Kobourov (University of Arizona – Tucson, US)

For support, please contact

Susanne Bach-Bernhard for administrative matters

Shida Kunz for scientific matters

Documents

List of Participants

Shared Documents

Dagstuhl Seminar Wiki

Dagstuhl Seminar Schedule ([Upload here](#))

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Documentation

In the series **Dagstuhl Reports** each Dagstuhl Seminar and Dagstuhl Perspectives Workshop is documented. The seminar organizers, in cooperation with the collector, prepare a report that includes contributions from the participants' talks together with a summary of the seminar.

Download [📄 overview leaflet \(PDF\)](#).

Publications

Furthermore, a comprehensive peer-reviewed collection of research papers can be published in the series **Dagstuhl Follow-Ups**.

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Places & Spaces: Mapping Science

Drawing from across cultures and across scholarly disciplines, the Places & Spaces: Mapping Science traveling exhibit demonstrates the power of maps (visualizations) to address vital questions about the contours and content of scientific knowledge. As of December 2020, the exhibit features 100 framed maps, 24 macrosopes, an award-winning short film, touch screen interactives, and sculptural elements created by more than 230 leading experts in the natural, physical, and social sciences, scientometrics, visual arts, science policy, and the humanities.

The maps have been displayed in 30 countries on six continents. Places & Spaces showcases innovative approaches to data visualization, critical for making sense of the large streams of data we confront on a daily basis. Ranging from reproductions of early maps of our planet, to the first maps showing the terrain of science, to maps showing the national mood through tweets over the course of a day, the exhibit touches on subject matter as diverse as polar bear habitat, forecasting epidemics, and the settings of Victorian poems.

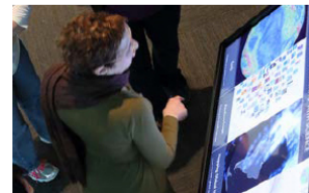
In 2015 Places & Spaces expanded from exhibiting static maps of science to include interactive data visualizations we call macrosopes. Macrosopes are software tools that help one focus on patterns in data that are too large or complex to view unaided. Interactive by nature, one can use them to visually explore data and to ask and answer new questions.



Maps

Maps serve as navigational tools, documenting the landscape, warning of hazards, and highlighting potential routes of travel. Science maps chart the more abstract spaces of data and knowledge, helping forecast new fields of inquiry. Individually and as a whole, the science maps in Places & Spaces: Mapping Science use data to tell meaningful stories that both the scientist and the layperson can understand and appreciate.

[show Gallery](#)



Macrosopes

Macrosopes are software tools that help us focus on patterns in data that are too large or complex to see with the naked eye. Interactive by nature, they are best used to visually explore data and to ask and answer new questions. Each macroscope featured was selected as an outstanding example of how visualization can reveal trends and patterns in data.

[show Gallery](#)

Call for Papers: Special Issue on Multi-level Graph Representations for Big Data in Science

CG&A seeks submissions for this upcoming special issue.

The July/Aug 2022 special issue in *IEEE Computer Graphics and Applications* on “Multi-Level Graph Representations for Big Data in Science”

Articles due for review:
December 29, 2021

Guest editors:

- Katy Börner, Indiana University, Bloomington, US
- Stephen G. Kobourov, University of Arizona, Tucson, US

<https://www.computer.org/digital-library/magazines/cg/call-for-papers-special-issue-on-multi-level-graph-representations-for-big-data-in-science>

For centuries, cartographic maps have guided human exploration. While being rather imperfect initially, they helped explorers find promised lands and return home safely. Recent advances in data, algorithms, and computing infrastructures make it possible to map humankind’s collective scholarly knowledge and technology expertise by using topic maps on which “continents” represent major areas of science (e.g., mathematics, physics, or medicine) and zooming reveals successively more detailed subareas. Basemaps of science and technology are generated by analyzing citations links between millions of publications and/or patents. “Data overlays” (e.g., showing all publications by one scholar, institution, or country or the career trajectory of a scholar as a pathway) are generated by science-locating relevant publication records based on topical similarity. Despite the demonstrated utility of such maps, current approaches do not scale to the hundreds of millions of data records now available. The main challenge is designing efficient and effective methods to visualize and interact with more than 100 million scholarly publications at multiple levels of resolution.

This special issue invites researchers in cartography, data visualization, science of science, graph drawing, and other domains to submit novel and promising new research on graph mining and layout algorithms and their application to the development of science mapping standards and services. Topics of interest include:

- Science of science user needs and applications
- Efficient multi-level graph algorithms
- Network visualizations
- Effective user interfaces to large-scale data visualizations

Deadlines

Submissions due: 29 December 2021

Preliminary notification: 2 March 2022

Revisions due: 6 April 2022

Final notification: 11 May 2022

Final version due: 25 May 2022

Publication: July/August 2022

HuBMAP: Mapping 30+ Trillion Cells

Michael P. Snyder, et al. 2019. The human body at cellular resolution: The NIH Human Biomolecular Atlas Program. *Nature*. 574, p. 187-192.

<https://www.nature.com/articles/s41586-019-1629-x.pdf>



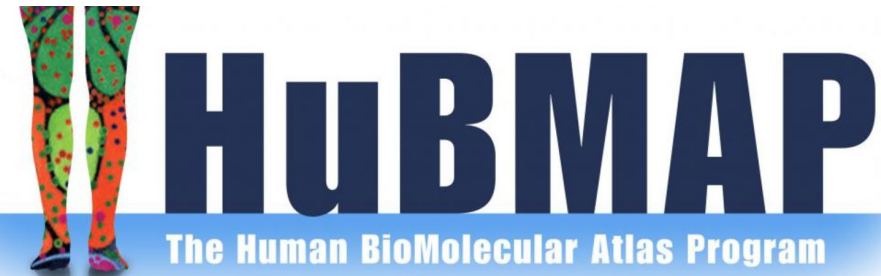
HuBMAP

Vision

Catalyze the development of an open, global framework for comprehensively mapping the human body at cellular resolution.

Goals

1. Accelerate the development of the next generation of tools and techniques for constructing high resolution spatial tissue maps
2. Generate foundational 3D tissue maps
3. Establish an open data platform
4. Coordinate and collaborate with other funding agencies, programs, and the biomedical research community
5. Support projects that demonstrate the value of the resources developed by the program



<https://commonfund.nih.gov/HuBMAP>

The Human Body at Cellular Resolution: The NIH Human Biomolecular Atlas Program.

Snyder et al. *Nature*. 574, p. 187-192.

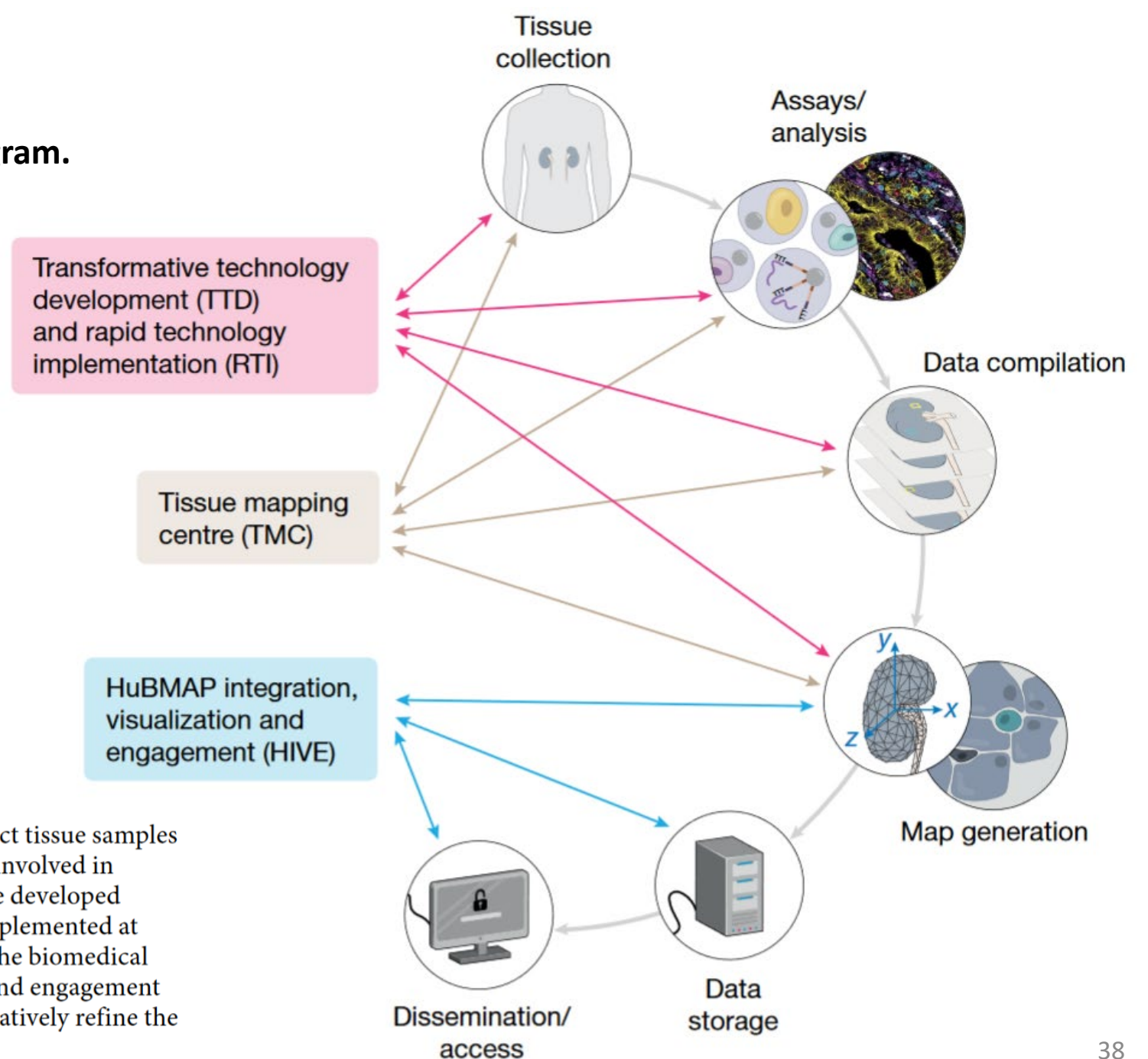


Fig. 1 | The HubMAP consortium. The TMCs will collect tissue samples and generate spatially resolved, single-cell data. Groups involved in TTD and RTI initiatives will develop emerging and more developed technologies, respectively; in later years, these will be implemented at scale. Data from all groups will be rendered useable for the biomedical community by the HuBMAP integration, visualization and engagement (HIVE) teams. The groups will collaborate closely to iteratively refine the atlas as it is gradually realized.

The Human Body at Cellular Resolution: The NIH Human Biomolecular Atlas Program.

Snyder et al. *Nature*. 574, p. 187-192.

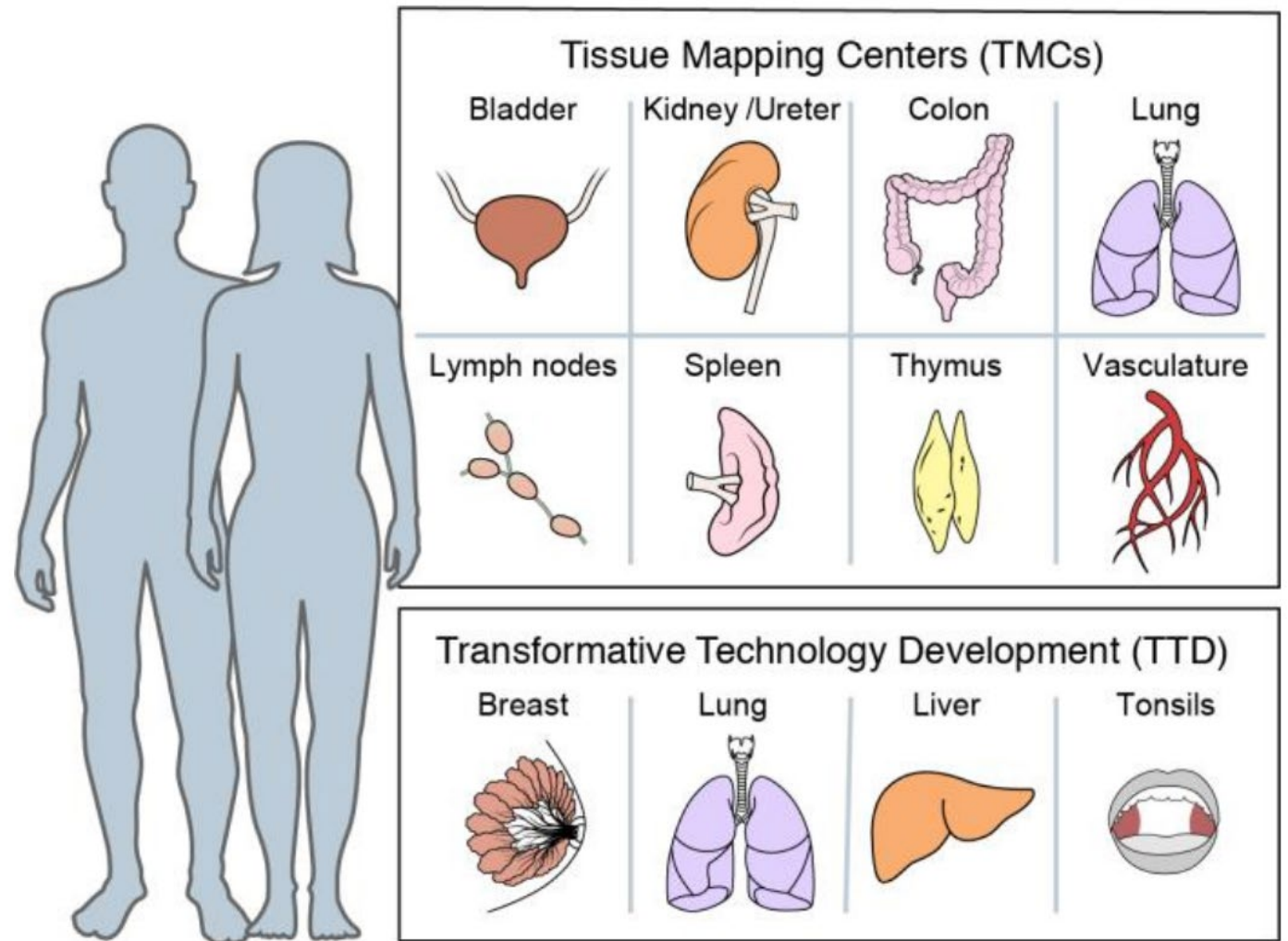


Fig. 2 | Key tissues and organs initially analysed by the consortium.

Using innovative, production-grade ('shovel ready') technologies, HuBMAP TMCs will generate data for single-cell, three-dimensional maps of various human tissues. In parallel, TTD projects (and later RTI projects) will refine assays and analysis tools on a largely distinct set of human tissues. Samples from individuals of both sexes and different ages will be studied. The range of tissues will be expanded throughout the program.

The Human Body at Cellular Resolution: The NIH Human Biomolecular Atlas Program.
 Snyder et al. *Nature*. 574, p. 187-192.

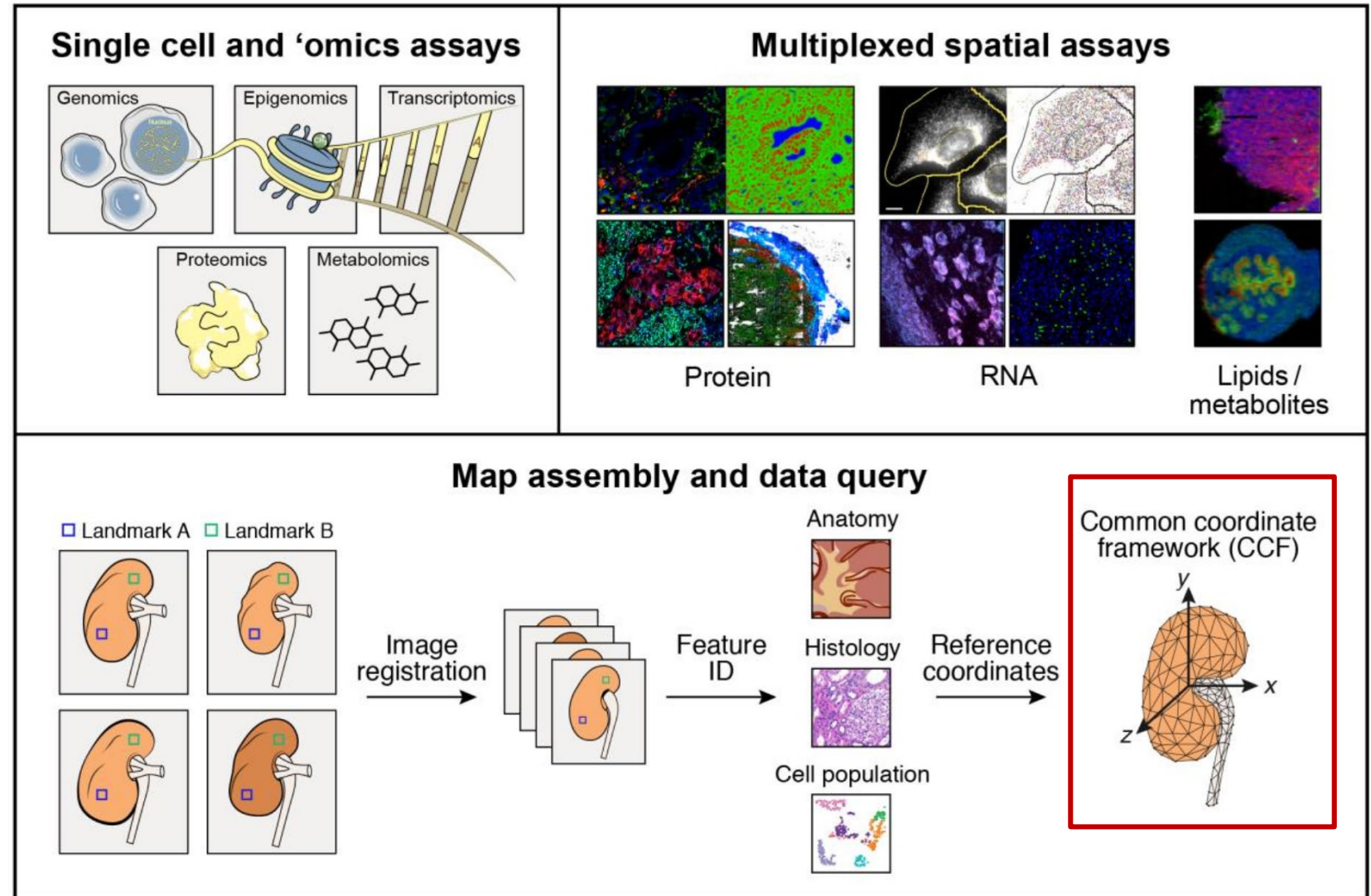


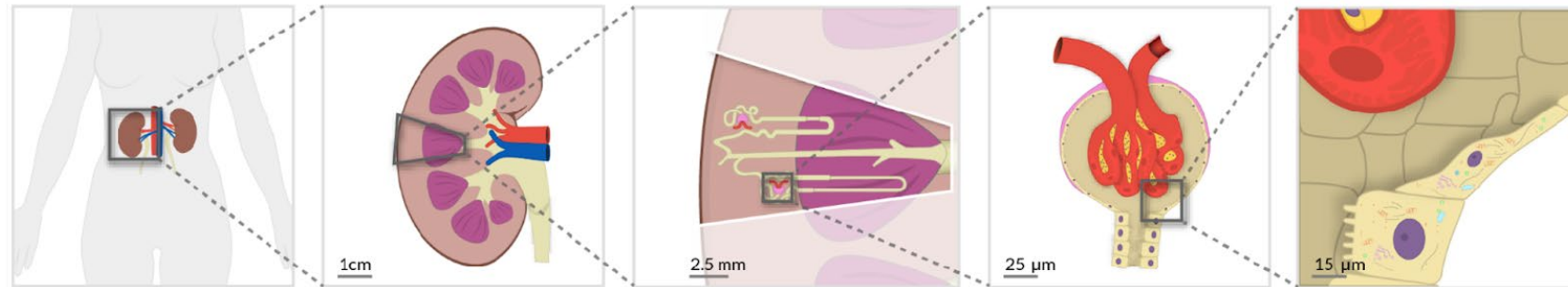
Fig. 3 | Map generation and assembly across cellular and spatial scales. HuBMAP aims to produce an atlas in which users can refer to a histological slide from a specific part of an organ and, in any given cell, understand its contents on multiple 'omic levels—genomic, epigenomic, transcriptomic, proteomic, and/or metabolomic. To achieve these ends, centres will apply a combination of imaging, 'omics and mass spectrometry

techniques to specimens collected in a reproducible manner from specific sites in the body. These data will be then be integrated to arrive at a high-resolution, high-content three-dimensional map for any given tissue. To ensure inter-individual differences will not be confounded with collection heterogeneity, a robust CCF will be developed.

CCF Requirements

The CCF must capture major **anatomical structures, cell types, and biomarkers** and their interrelations across **multiple levels of resolution**.

It should be **semantically explicit** (using existing ontologies, e.g., Uberon, CL) and **spatially explicit** (e.g., using 3D reference organs for registration and exploration).



Body

- Body
- Kidney (Left, Right)
- Aorta
- Renal artery
- Renal vein
- Ureter

Organ

- Renal capsule
- Renal pyramid
- Renal cortex
- Renal medulla
- Renal calyx
- Renal pelvis

Functional Tissue Unit

- Nephron
- Renal corpuscle
- Proximal convoluted tubule
- Loop of Henle
- Distal convoluted tubule
- Connecting tubule
- Collecting duct

FTU Sub-structure(s)

- Bowman's capsule
- Glomerulus
- Efferent arteriole
- Afferent arteriole

Cellular

- Parietal epithelial cell
- Capillary endothelial cell
- Mesangial cell
- Podocyte

ASCT+B Tables

Anatomical Structures (AS), Cell Types (CT), and Biomarkers (B) or ASCT+B tables aim to capture the partonomy of anatomical structures, cell types, and major biomarkers (e.g., gene, protein, lipid or metabolic markers).

ASCT Table

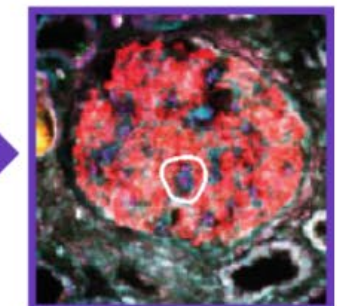
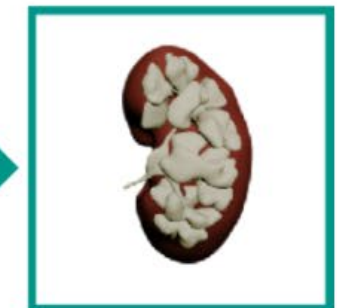
Structure/Region	Sub structure/Sub region	Cell Type
Renal Corpuscle	Bowman's (glomerular) Capsule/parietal layer	Parietal epithelial Cell
	Bowman's (glomerular) Capsule/visceral layer	Podocyte
	Glomerular Tuft	Capillary Endothelial Cell Mesangial Cell
Tubules	Proximal Tubule	Proximal Tubule Epithelial Cell (general)
		Proximal Convoluted Tubule Epithelial Cell Segment 1
		Proximal Tubule Epithelial Cell Segment 2
		Proximal Tubule Epithelial Cell Segment 2
		Proximal Tubule Epithelial Cell Segment 2
	Loop of Henle, Thin Limb	Descending Thin Limb Cell (general)
		Ascending Thin Limb Cell (general)
	Loop of Henle, Thick Limb	Thick Ascending Limb Cell (general)
	Distal Convolution	Cortex-TAL Cell
		Medulla-TAL Cell
		TAL-Macula Densa Cell
Distal Convoluted Tubule Cell (general)		
Connecting Tubule	DCT Type 1 Cell	
	DCT Type 2 Cell	
	Connecting Tubule Cell (general)	
		CNT-Principal Cell

Ontology

Anatomical Structures Partonomy
 kidney
 kidney capsule
 cortex of kidney
 outer cortex of kidney
 renal medulla

Cell Types Ontology
 connective tissue cell
 pericyte cell
 mesangial cell
 extraglomerular mesangial cell
 glomerular mesangial cell

3D Reference Object Library



ASCT+B Tables

Anatomical Structures, Cell Types, and Biomarkers (ASCT+B) tables aim to capture the partonomy of anatomical structures, cell types, and major biomarkers (e.g., gene, protein, lipid or metabolic markers).

Structure/Region	Substructure/Sub region	Cell Type	Subset of Marker Genes
Renal Corpuscle	Bowman's Capsule	Parietal epithelial cell	<i>CRB2*</i> , <i>CLDN1*</i>
	Glomerulus	Podocyte	<i>NPHS2*</i> , <i>PODXL*</i> , <i>NPHS1*</i>
		Capillary Endothelial Cell	<i>EHD3*</i> , <i>EMCN*</i> , <i>HECW2*</i> , <i>FLT1*</i> , <i>AQP1*</i>
	Mesangial Cell	<i>POSTN*</i> , <i>PIEZO2*</i> , <i>ROBO1*</i> , <i>ITGA8*</i>	

Partial ASCT+B Table from

- El-Achkar et al. A Multimodal and Integrated Approach to Interrogate Human Kidney Biopsies with Rigor and Reproducibility: The Kidney Precision Medicine Project. bioRxiv. 2019, Updated Aug 2020. doi:10.1101/828665

Table 3: Cell types and associated markers from KPMP Pilot 1 transcriptomic studies. Asterisk denotes genes detected by more than one technology. *Italics*, genes detected by a single technology.

Structure/Region	Sub structure/Sub region	Cell Type	Abbreviation	Subset of Marker Genes	Pertinent negatives/comments
Renal Corpuscle	Bowman's Capsule	Parietal epithelial cell	PEC	<i>CRB2*</i> , <i>CLDN1*</i>	
	Glomerulus	Podocyte	POD	<i>NPHS2*</i> , <i>PODXL*</i> , <i>NPHS1*</i>	
		Capillary Endothelial Cell	GC-EC	<i>EHD3*</i> , <i>EMCN*</i> , <i>HECW2*</i> , <i>FLT1*</i> , <i>AQP1*</i>	
		Mesangial Cell	MC	<i>POSTN*</i> , <i>PIEZO2*</i> , <i>ROBO1*</i> , <i>ITGA8*</i>	
Tubules	Proximal Tubule	Proximal Tubule Epithelial Cell (general)	PT	<i>CUBN*</i> , <i>LRP2*</i> , <i>SLC13A1*</i> , <i>ALDOB*</i> , <i>GATM*</i>	There is overlap among the segments
		Proximal Convoluted Tubule Epithelial Cell Segment 1	PT-S1	<i>SLC5A2*</i> , <i>SLC5A12*</i>	
		Proximal Tubule Epithelial Cell Segment 2	PT-S2	<i>SLC22A6*</i>	
		Proximal Tubule Cell Epithelial Segment 3	PT-S3	<i>PDZK1IP1*</i> , <i>MT1G*</i>	
	Loop of Henle, Thin Limb	Descending Thin Limb Cell (general)	DTL	<i>CRYAB*</i> , <i>VCAM1*</i> , <i>AQP1*</i> , <i>SPP1*</i>	<i>CLDN10</i> low
		Ascending Thin Limb Cell (general)	ATL	<i>CRYAB*</i> , <i>TACSTD2*</i> , <i>CLDN3*</i>	<i>AQP1</i> low to none
	Loop of Henle, Thick Limb	Thick Ascending Limb Cell (general)	TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	<i>SLC12A3</i> low to none
		Cortex-TAL cell	C-TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	
		Medulla-TAL cell	M-TAL	<i>SLC12A1*</i> , <i>UMOD*</i>	
		TAL-Macula Densa cell	TAL-MD	<i>NOS1*</i> , <i>SLC12A1*</i>	
	Distal Convolution	Distal Convoluted Tubule Cell (general)	DCT	<i>SLC12A3*</i> , <i>TRPM6*</i>	
		DCT type 1 cell	DCT-1	<i>SLC12A3*</i> , <i>TRPM6</i>	<i>SLC8A1</i> , <i>HSD11B2</i> (low to none)
		DCT type 2 cell	DCT-2	<i>SLC12A3*</i> , <i>SLC8A1*</i> , <i>HSD11B2</i>	Has CNT and DCT signature
	Connecting Tubule	Connecting Tubule Cell (general)	CNT	<i>SLC8A1*</i> , <i>CALB1</i> , <i>TRPV5</i>	<i>SLC12A3</i> low to none. IC or PC without <i>SLC8A1</i> could be in the CNT structure
CNT-Principal Cell		CNT-PC	<i>SLC8A1*</i> , <i>AQP2*</i> , <i>SCNN1G*</i>		
CNT-Intercalated Cell		CNT-IC	<i>SLC8A1*</i> , <i>CA2</i> , <i>ATP6VOD2*</i>		
CNT-IC-A cell		CNT-IC-A	<i>SLC8A1*</i> , <i>SLC4A1*</i> , <i>SLC26A7*</i>		
CNT-IC-B cell		CNT-IC-B	<i>SLC8A1*</i> , <i>SLC26A4*</i> , <i>SLC4A9*</i>		
Collecting Duct	Collecting duct (general) cell	CD	<i>GATA3*</i>	<i>GATA3</i> may be in subpopulation of DCT, CNT and vSMC/P. <i>SLC8A1</i> , <i>CALB1</i> , <i>TRPV5</i>	
	CD-PC (general)	CD-PC			
	C-CD-PC	C-CD-PC	<i>AQP2*</i> , <i>AQP3*</i> , <i>FXYD4*</i>		
	M-CD-PC	M-CD-PC	<i>SCNN1G*</i> , <i>GATA3*</i>		
	Outer medulla-CD-PC	OM-CD-PC			
	Inner Medulla-CD cell	IM-CD	<i>AQP2*</i> , <i>SLC14A2</i>		

Structure/Region	Sub structure/Sub region	Cell Type	Abbreviation	Subset of Marker Genes	Pertinent negatives/comments			
Vessels	Endothelial Cells (non-glomerular)	Transitional PC-IC cell	TRC-IC	<i>FXYD4*</i> , <i>SLC4A9*/SLC26A7*</i>	(low to none); Low to No <i>CALCA</i> and <i>KIT</i> in C-CD-IC-A. It may not be possible to assign IC or PC to CNT or CD structures without regional information of their source.			
		CD-IC (general) cell	CD-IC	<i>CA2</i> , <i>ATP6VOD2*</i>				
		CD-IC-A (general) cell	CD-IC-A	<i>SLC4A1</i> , <i>SLC26A7*</i> , <i>TMEM213*</i>				
		C-CD-IC-A cell	C-CD-IC-A	<i>SLC26A7*</i> , <i>SLC4A1*</i>				
		M-CD-IC-A cell	M-CD-IC-A	<i>SLC26A7*</i> , <i>SLC4A1</i> , <i>KIT*</i> , <i>CALCA</i>				
		CD-IC-B (general) cell	CD-IC-B	<i>SLC4A9*</i> , <i>SLC26A4*</i>				
		C-CD-IC-B cell	C-CD-IC-B					
		M-CD-IC-B cell	M-CD-IC-B					
		Vessels	Endothelial Cells (non-glomerular)	Endothelial Cell (general)		EC	<i>EMCN*</i> , <i>PECAM1*</i> , <i>FLT1*</i>	
				EC-Afferent/Efferent Arteriole		EC-AEA	<i>SERPINE2*</i> , <i>TM4SF1*</i>	likely <i>PALMD</i>
EC-Peritubular capillaries	EC-PTC			<i>PLVAP*</i>				
EC-Descending Vasa Recta	EC-DVR			<i>TM4SF1*</i> , <i>PALMD</i>				
EC-Ascending Vasa Recta	EC-AVR			<i>DNASEIL3*</i>	low to none			
EC-Lymphatics	EC-LYM			<i>MMRN1*</i> , <i>PROX1</i>				
Interstitium	Stroma (non-glomerular)	Vascular Smooth Muscle/Pericyte (general)	vSMC/P	<i>TAGLN*</i> , <i>ACTA2*</i> , <i>MYH11*</i> , <i>NTRK3</i> , <i>MCAM</i>				
		vSMC/P-Renin	vSMC/P-REN	<i>REN</i>				
		Fibroblast	FIB	<i>DCN*</i> , <i>ZEB2</i> , <i>C7</i> , <i>LUM</i>				
	Immune	Macrophages-Resident	MAC-R	<i>CD163*</i> , <i>IL7R*</i>				
		Macrophage	MAC	<i>S100A9</i>				
		Natural Killer Cell	NKC	<i>NKG7</i>				
		Dendritic Cell	DC	<i>APOE</i>				
		Monocyte	MON	<i>C1QA</i> , <i>HLA-DRA</i>				
		T lymphocyte (general)	T	<i>CD3</i>				
		T Cytotoxic	T-CYT	<i>GZMA</i>				
		B lymphocyte	B	<i>IGJ</i>				

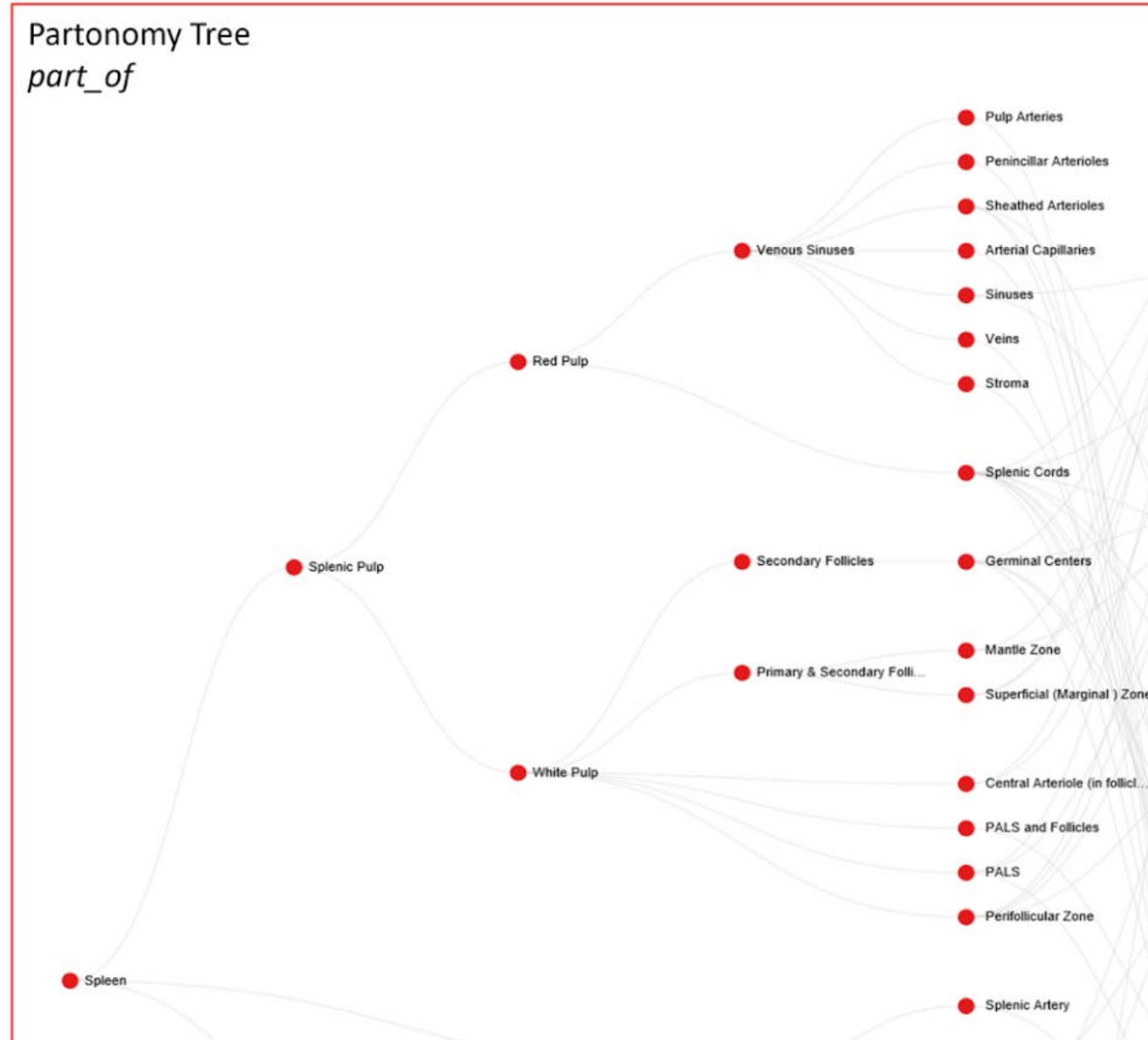
El-Achkar et al. A Multimodal and Integrated Approach to Interrogate Human Kidney Biopsies with Rigor and Reproducibility: The Kidney Precision Medicine Project. bioRxiv. 2019, Updated Aug 2020. doi:10.1101/828665

Anatomical Structures (AS)

Cell Types (CT)

Biomarkers (B)

Partonomy Tree
part_of



Bimodal network describing which CT are located_in what AS

Typology Tree
is_a

- adventitial stromal cell
- B cell
- Dendritic cell
- Endothelial
- Endothelial cell
- Erythrocytes
- fibroblast
- Fibroblastic reticular cell
- Follicular Dendritic cell
- Granulocytes
- Littoral cell
- Lymphatic endothelium
- macrophage
- Monocytes
- Myofibroblast
- neurons
- NK cell
- Plasma cell
- Plasmablasts
- Platelets

Bimodal network describing which B characterize what CT

BG - Genes
BP - Proteins

- CD10
- CD11b
- CD11c
- CD138
- CD14
- CD141
- CD15
- CD163
- CD19
- CD20
- CD21
- CD22
- CD23+
- CD235a
- CD27
- CD27-
- CD271
- CD271-
- CD3
- CD3-
- CD31
- CD34
- CD4
- CD4 (helper)
- CD41

ASCT+B Table Working Group

Lead by Katy Börner and Jim Gee; Ellen M Quardokus serves as Knowledge Manager

Meetings take place monthly to review and approve tables, formalize and unify table design language, discuss and expand table usage, see [WG Charter](#).

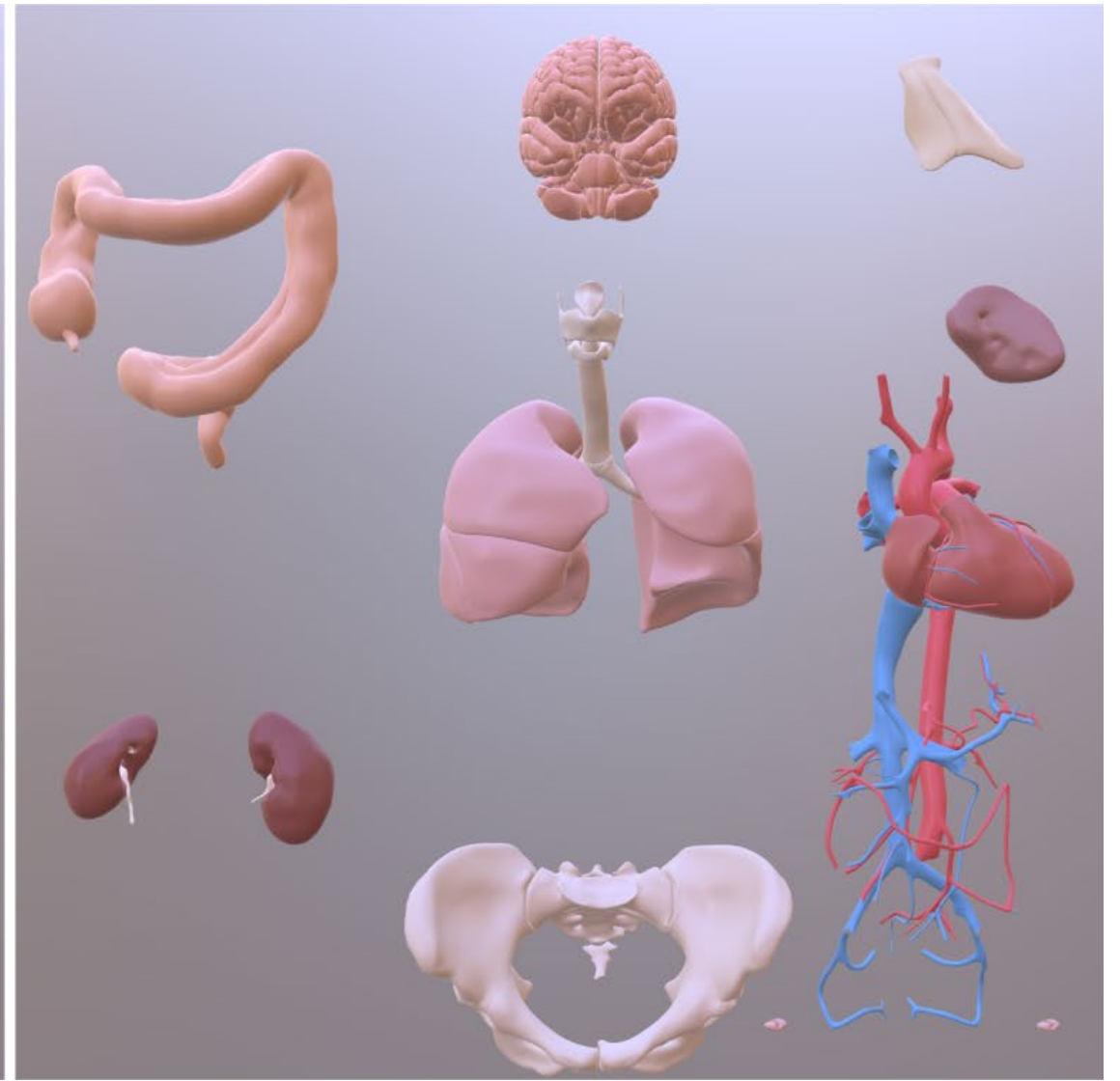
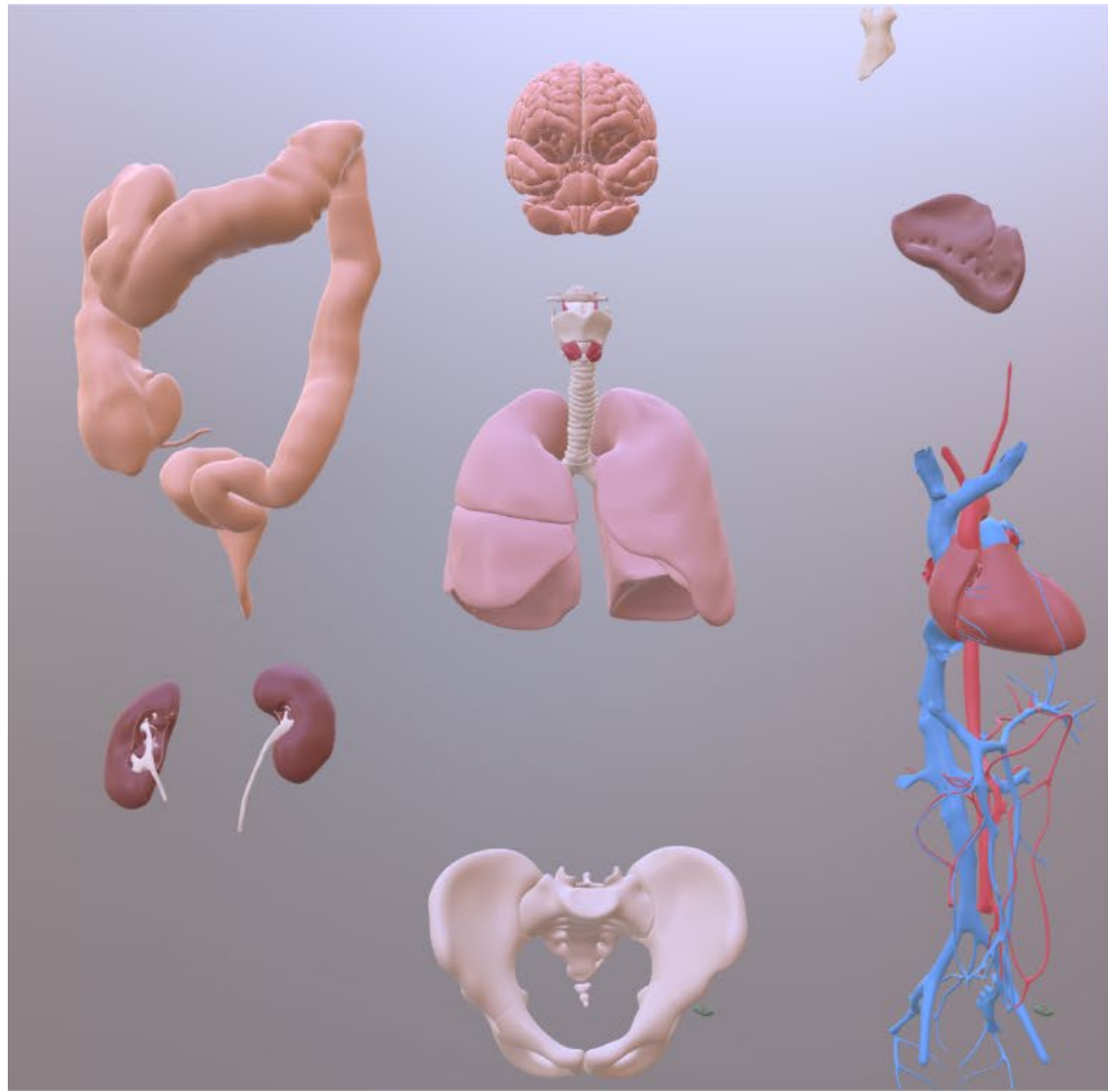
Next meetings in **2021**: April 7, May 5, 11a-noon ET.

Please [register](#) to receive invites and updates.



	HuBMAP	RBK	KPMP	SPARC	LungMAP	HTAN	HCA	GUDMAP	Gut Cell Atlas	BICCN	Allen Brain	TCGA	Wellcome	MRC	H2020	GTEx	Total
Kidney	1	1	1	0	0	0	1	1	0	0	0	1	1	1	0	1	9
Liver	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	3
Spleen	1	0	0	0	0	0	1	0	0	0	0	0	1	0	0	1	4
Heart	1	0	0	1	0	0	1	0	0	0	0	0	0	0	0	1	4
Lung	1	0	0	1	1	1	1	0	0	0	0	1	1	1	1	1	10
L intestine/Colon	1	0	0	1	0	1	1	0	1	0	0	1	0	0	0	1	7
S intestine	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1	2
Bladder	1	0	0	1	0	0	0	1	0	0	0	1	0	0	0	1	5
Ureters	1	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	2
Thymus	1	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	2
Lymph nodes	1	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	2
mediastinal lymph node	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Eye	1	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	3
Brain	0	0	0	0	0	0	1	0	0	1	1	1	0	0	1	1	6
Brain stem	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	1
Cerebellum	0	0	0	0	0	0	1	0	0	0	1	0	0	0	0	1	3
Spinal cord	0	0	0	1	0	0	0	0	0	1	0	0	0	0	0	0	2
Pancreas	0	0	0	0	0	1	1	0	0	0	0	1	0	0	1	1	5
Breast	0	0	0	0	0	1	1	0	0	0	0	1	1	0	0	1	5
Skin	0	0	0	0	0	1	0	0	0	0	0	1	0	0	0	1	3
Pediatric systems	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	0	2
Ovaries	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Testes	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Cervix	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	0	1
Uterus	0	0	0	0	0	0	0	0	0	0	0	1	1	1	1	1	5
Blood	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	0	2
Bone	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Placenta	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Decidua	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Embryo	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
esophagus	0	0	0	0	0	0	1	0	0	0	0	1	0	0	0	1	3
hematopoietic system	0	0	0	0	0	0	1	0	0	0	0	0	0	1	0	0	2
immune system bulk	0	0	0	0	0	0	1	0	0	0	0	0	0	0	0	0	1
Stomach	0	0	0	1	0	0	0	0	0	0	0	1	0	0	0	1	3
Thyroid	0	0	0	0	0	0	0	0	0	0	0	1	0	0	0	1	2
Prostate	0	0	0	0	0	0	0	1	0	0	0	1	0	0	0	1	3
Adrenal gland	0	0	0	0	0	0	0	0	0	0	0	1	1	0	0	1	3
Totals	11	1	1	7	1	6	21	4	1	2	2	20	7	5	4	21	114

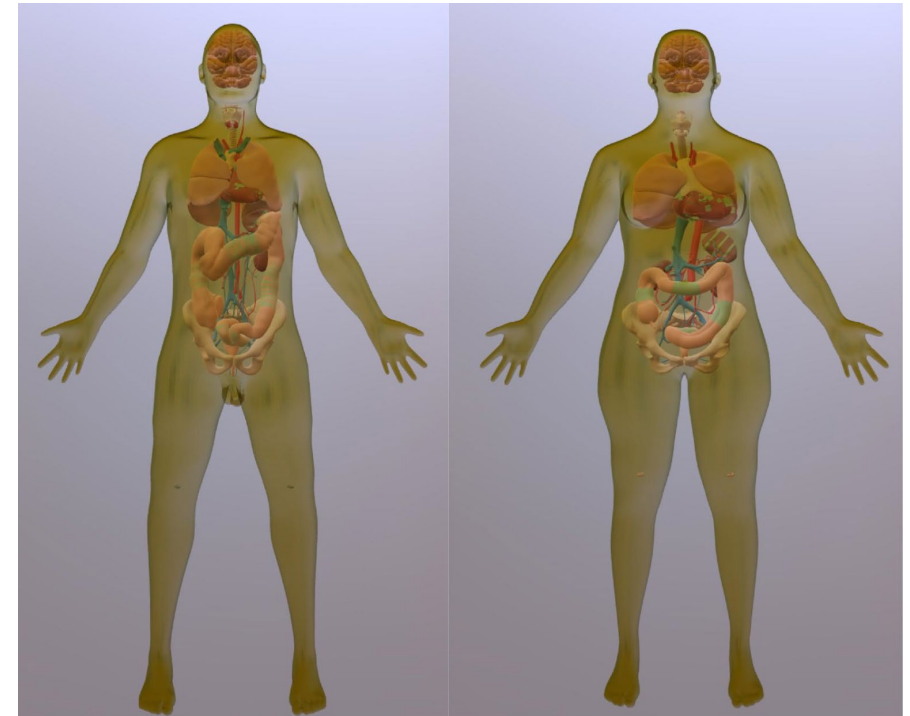
Table compiled for, during, and after the NIH-HCA Joint Meeting in March 2020, <https://hubmapconsortium.org/nihhca2020>



Overview of CCF 3D Reference Models

Male

Female



Organ	3D Ref. Organ				ASCT+B Table			#AS-AS (part_of)	#CT-AS (located_in)	#B-CT (characterizes)
	#AS M-L	#AS F-L	#AS M-R	#AS F-R	#AS	#CT	#B			
BM & Blood / Pelvis	23	23			14	46	202	24	97	296
Brain	141	141			187	127	29	187	127	36
Heart	39	46			50	25	48	57	164	78
Intestine, Large	10	10			66	69	89	409	1410	192
Kidney	38	44	39	41	64	64	129	63	58	215
Lung	74	74			91	85	174	108	123	296
Lymph Nodes	7	7	7	7	40	49	161	60	117	342
Skin	1	1			16	42	70	17	19	105
Spleen	8	8			46	66	0	68	172	0
Thymus	2	2			18	46	55	20	103	64
Vasculature	84	85			869	2	1	868	606	2
Totals	427	441	46	48	1461	621	958	1881	2996	1626



<https://hubmapconsortium.github.io/ccf/pages/ccf-anatomical-structures.html>

Table counts on 2/28/2021

<https://hubmapconsortium.github.io/ccf/pages/ccf-3d-reference-library.html> (NLM VH organs)

<https://community.brain-map.org/t/allen-human-reference-atlas-3d-2020-new/> (brain)

<https://www3.cs.stonybrook.edu/~ari/> (male colon)

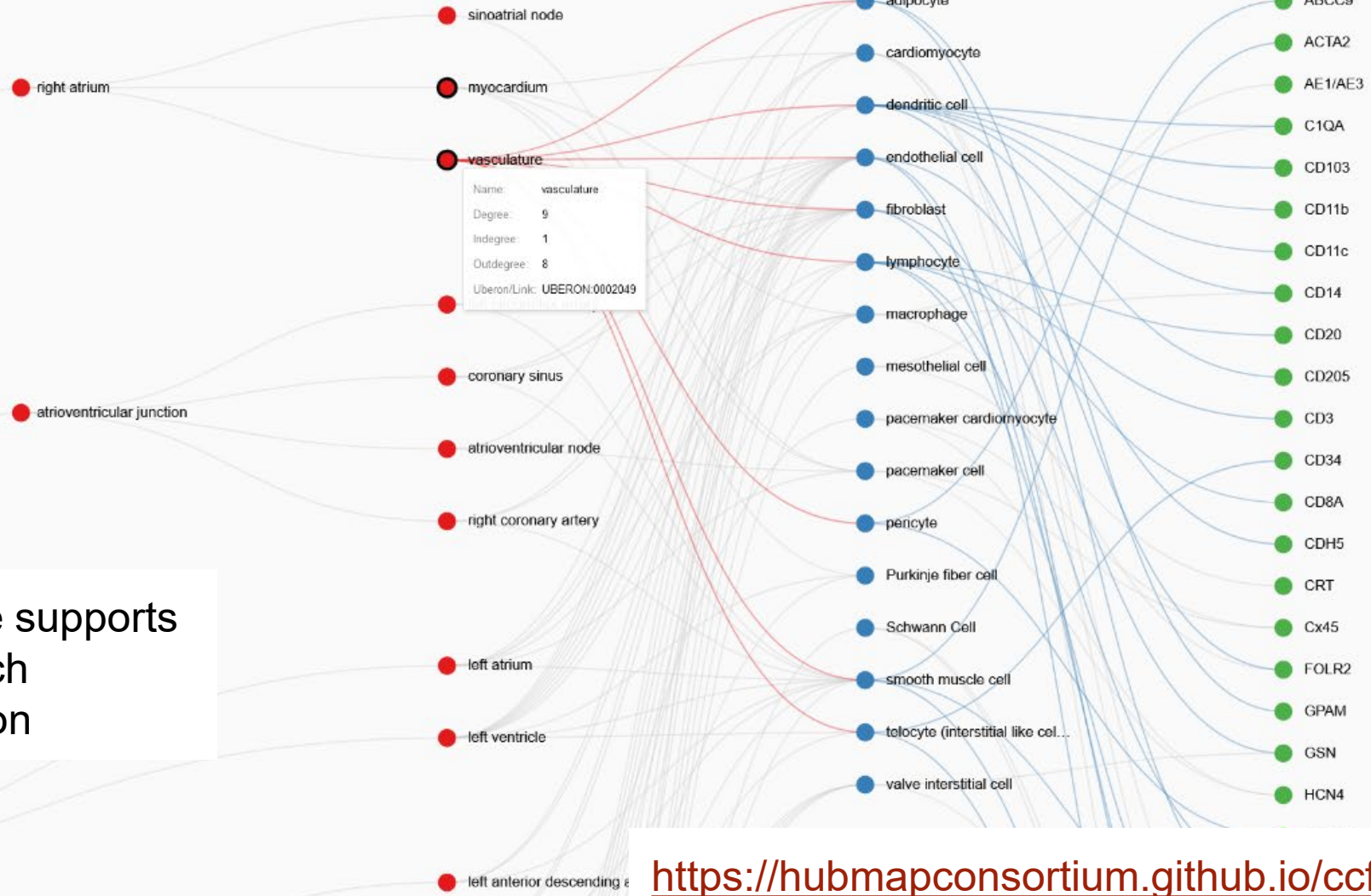
Anatomical Structures

Cell Types

Biomarkers

Legend

- Anatomical Structures
- Cell Types
- Biomarkers
- See Debug Log



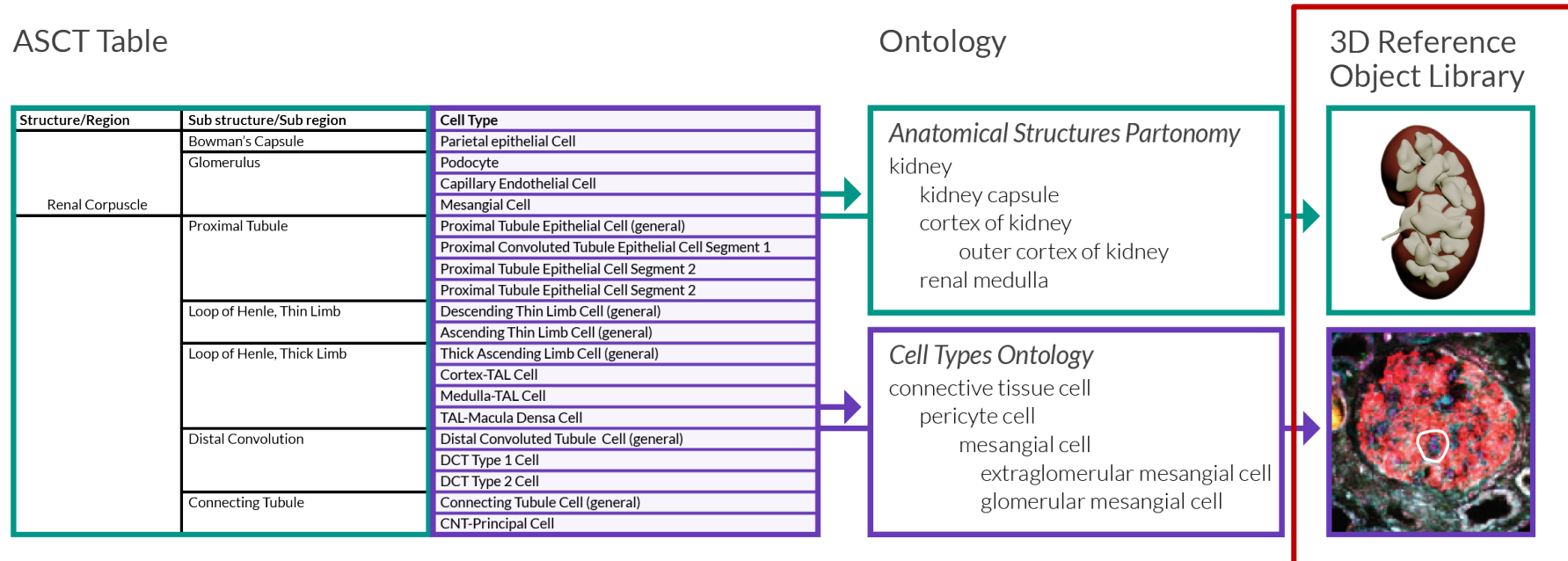
XMAS 2020 release supports

- AS, CT, B Search
- Table comparison

<https://hubmapconsortium.github.io/ccf-asct-reporter>

ASCT+B Table Usage

ASCT+B tables guide **CCF Ontology** and **3D Reference Object Library** design that semantically name and spatially place tissue data from different donors into one CCF (i.e., mapping).



Tissue blocks are registered into the CCF using the Registration User Interface (RUI), and they can be explored via the Exploration User Interface (EUI).

Document the tissue extraction site by registering tissue blocks within a 3D reference organ.

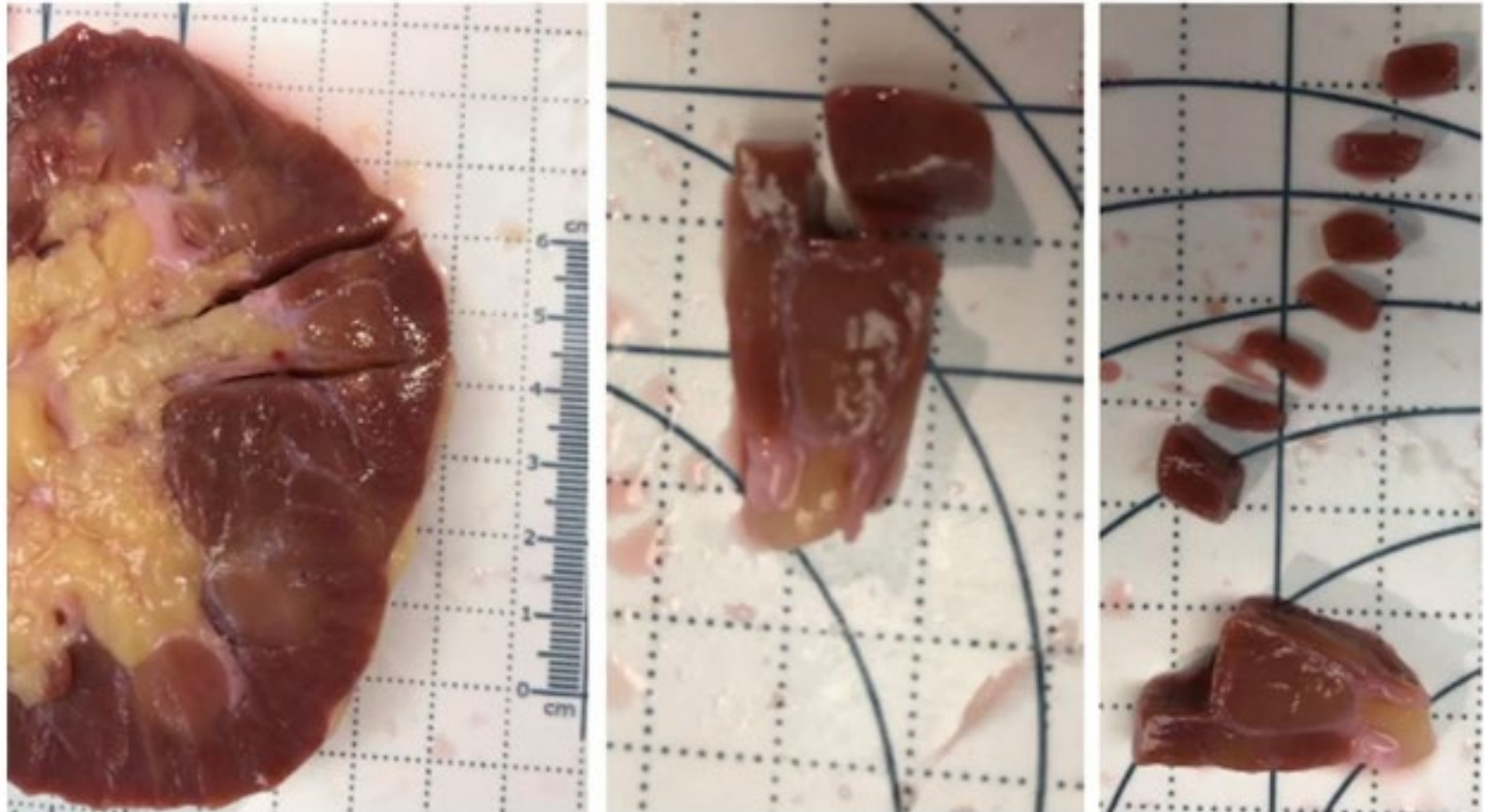
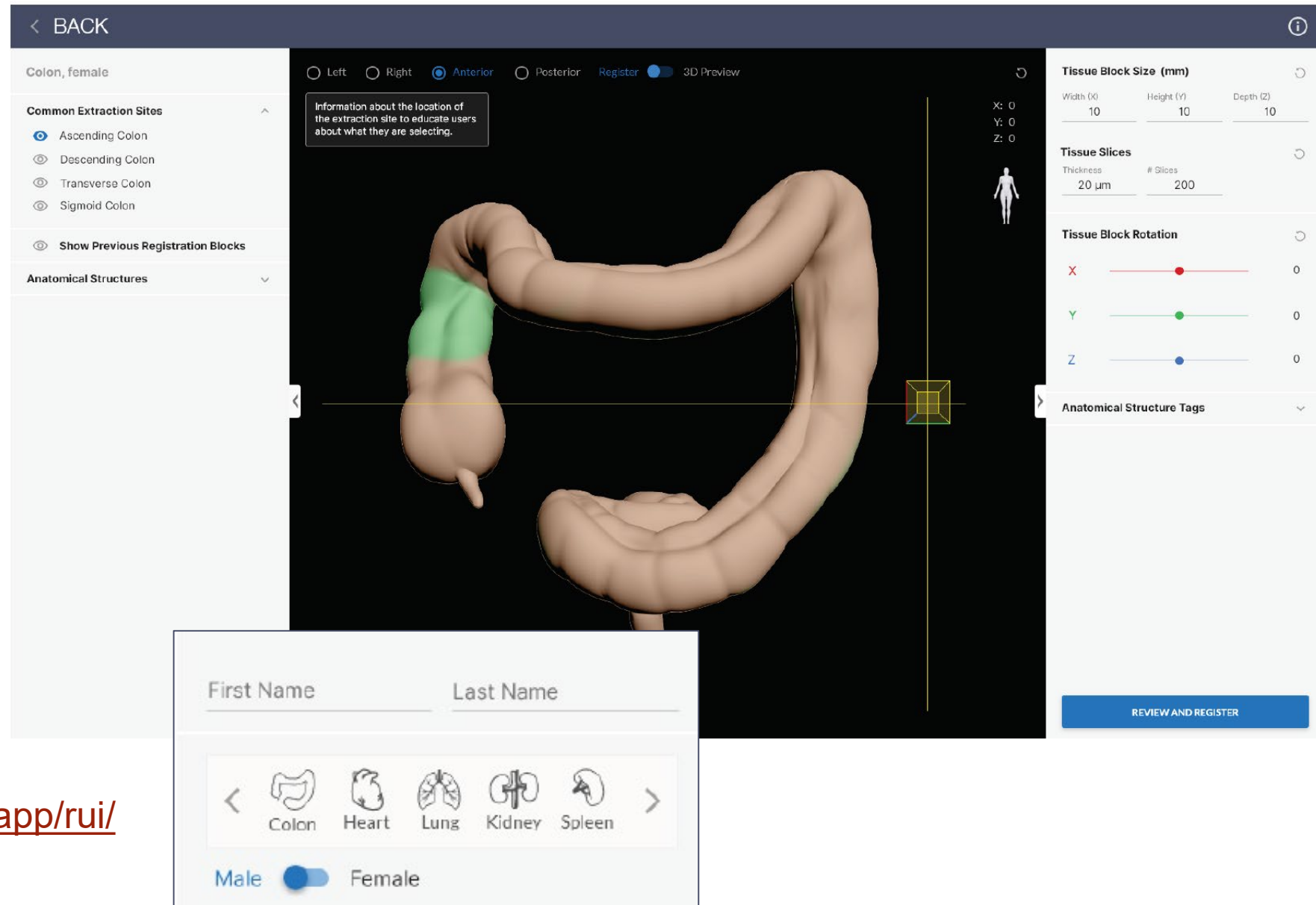


Image provided by Sanjay Jain, TMC-UCSD

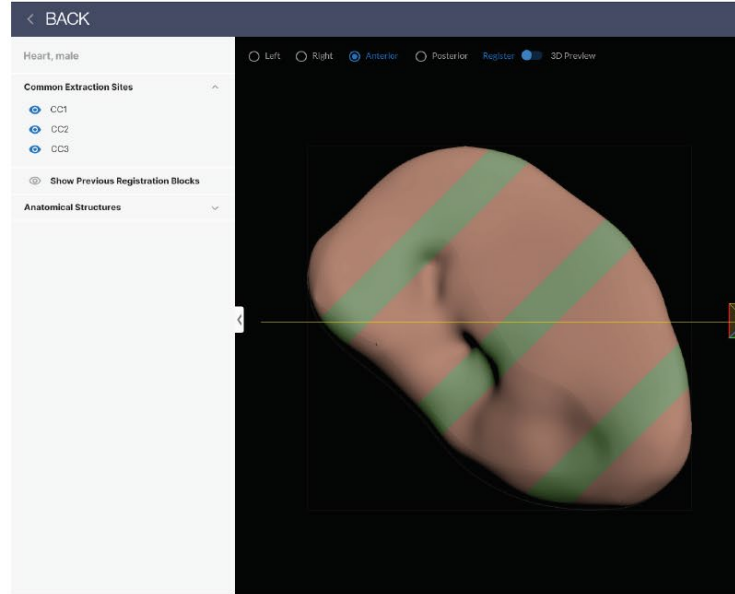
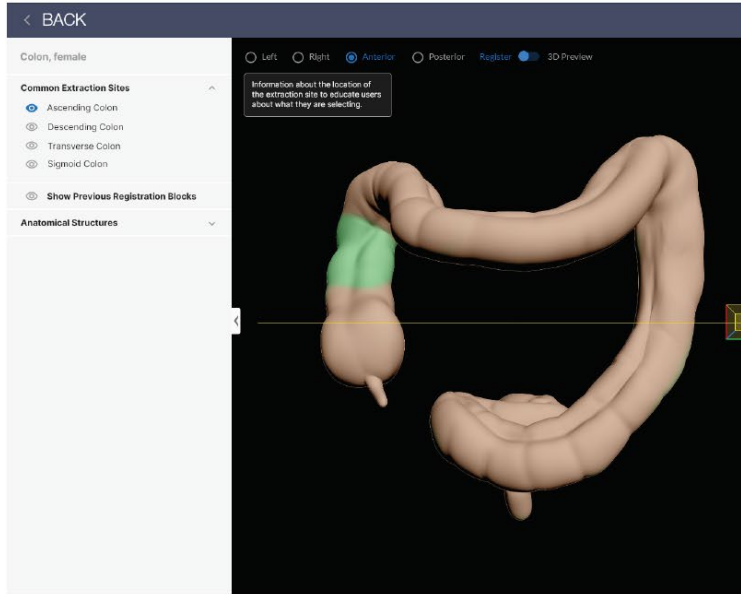
CCF Registration User Interface (RUI) v1.0.0

New Features:

- Organ carousel with 4 reference organs
- Support for tissue extraction sites
- Expanded ontology
- Semantic annotation via collision detection & manual annotation
- Support for non-HuBMAP usage



<https://hubmap-ccf-ui.netlify.app/rui/>



Kidney

- Bisection Line

Spleen

- CC1
- CC2
- CC3

Colon

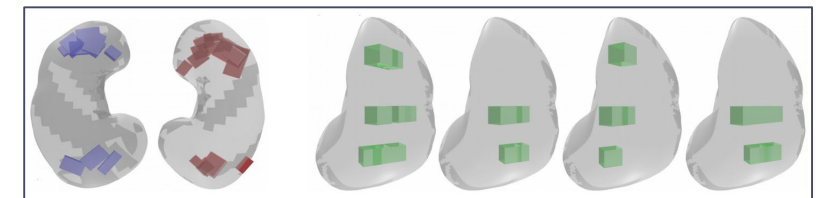
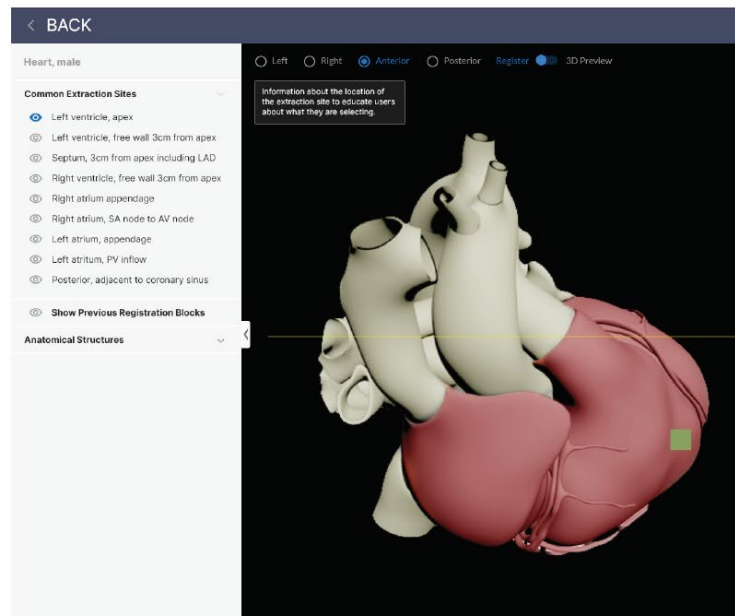
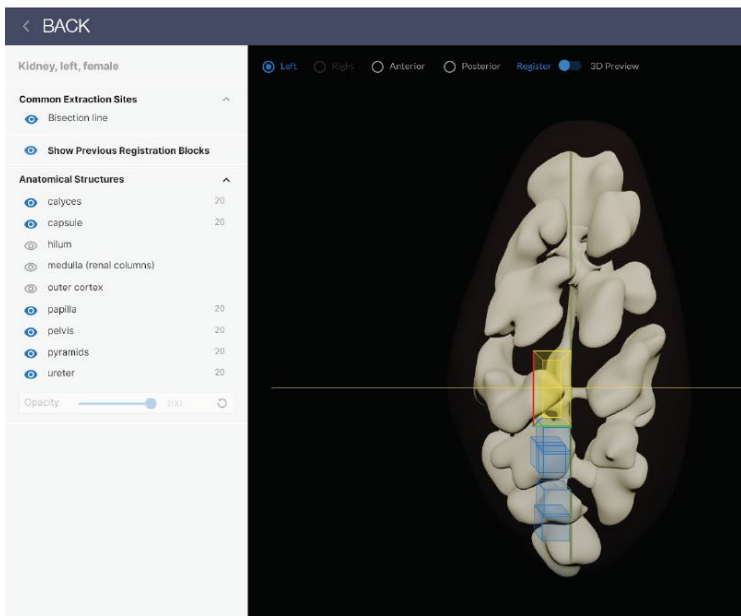
- Ascending Colon
- Descending Colon
- Transverse Colon
- Sigmoid Colon

Heart

- Left atrium, appendage
- Left atrium, PV inflow
- Left ventricle, apex
- Left ventricle, free wall 3cm from apex
- Septum, 3cm from apex including LAD
- Posterior, adjacent to coronary sinus
- Right atrium appendage
- Right atrium, AV (atrioventricular) node
- Right atrium, SA (sinoatrial) node
- Right ventricle, free wall 3cm from apex

Extraction Site Mapping

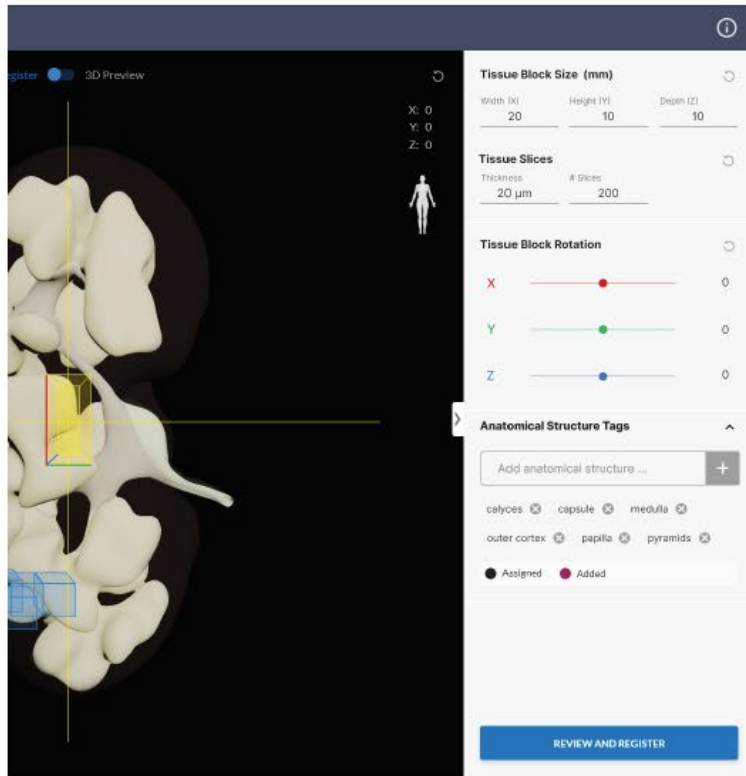
• Left atrium, appendage	7
• Left atrium, PV inflow	8
• Left ventricle, apex	1
• Left ventricle, free wall 3cm from apex	2
• Septum, 3cm from apex including LAD	3
• Posterior, adjacent to coronary sinus	9
• Right atrium appendage	5
• Right atrium, AV (atrioventricular) node	6a
• Right atrium, SA (sinoatrial) node	6b
• Right ventricle, free wall 3cm from apex	4



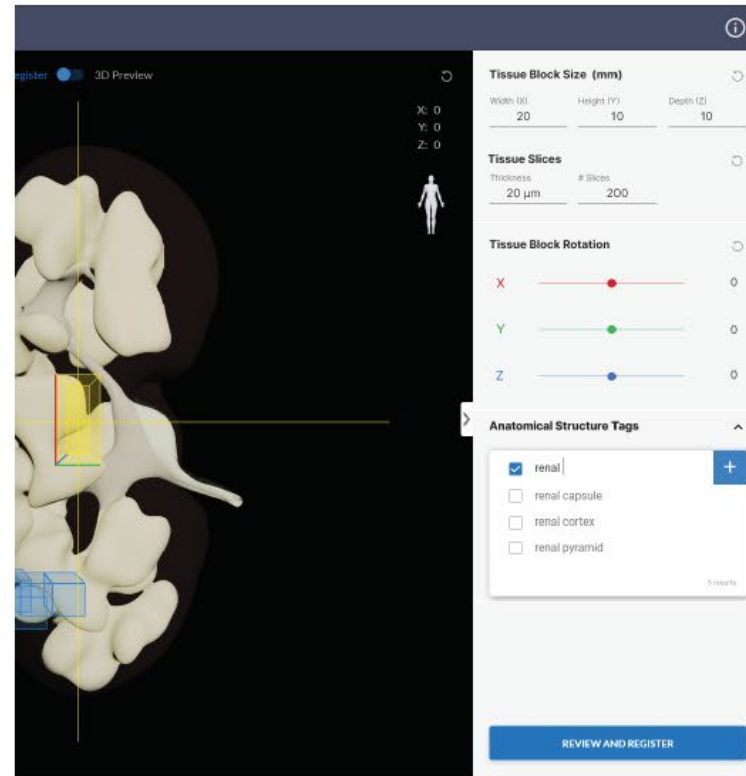
For the first HuBMAP portal release, 48 tissue blocks were registered.

CCF Registration User Interface (RUI) v1.0.0 cont.

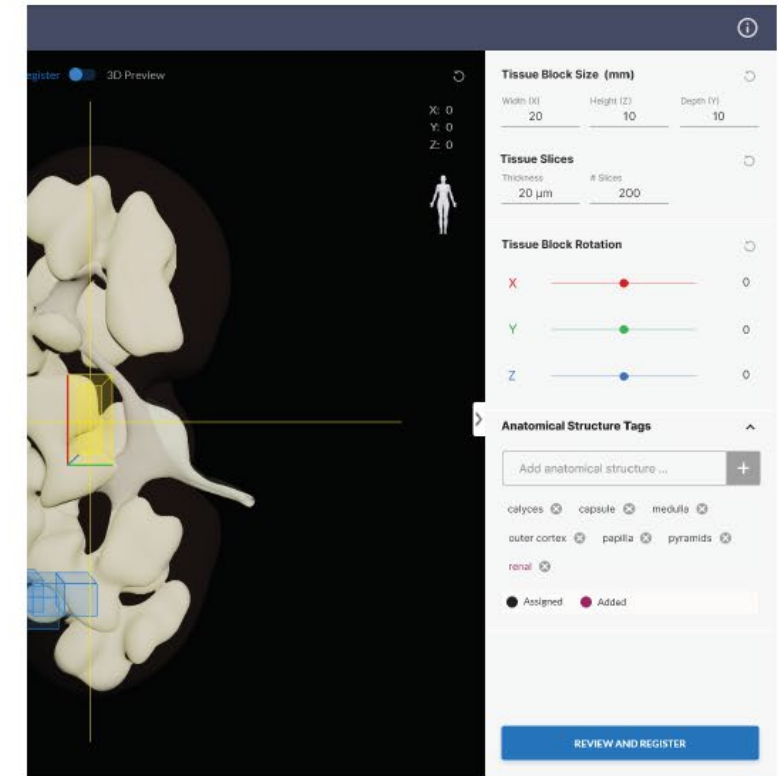
Collision when Tissue Block hits Reference Organ



Tag Search behavior



Custom tag added to list



CCF Exploration User Interface (EUI)

HuBMAP Sex: Both Age: 1-110 BMI: 13-83 [Login](#)

Search ontology terms ...

- body
 - heart
 - lung
 - kidney
 - right kidney
 - left kidney
 - kidney capsule
 - cortex of kidney
 - renal medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - kidney calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron

body

- 2 Centers
- 27 Donors
- 41 Samples

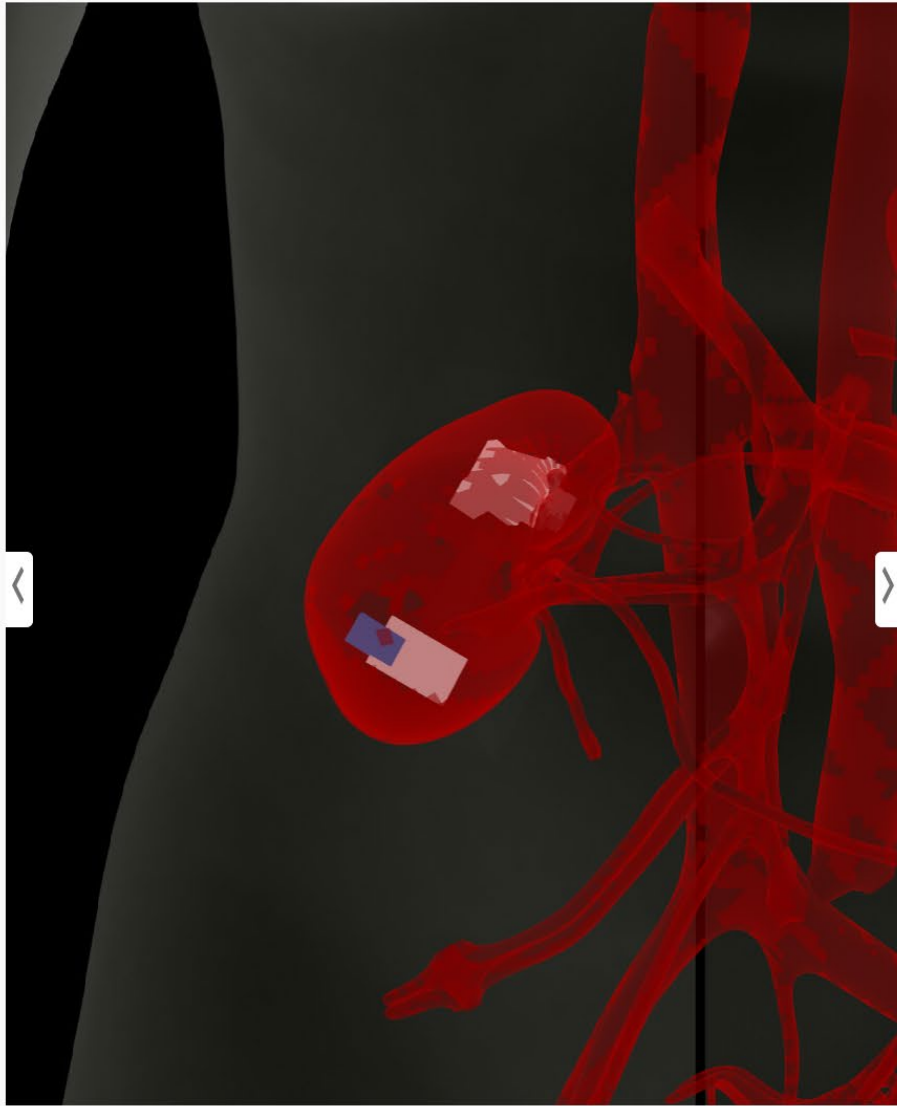
	Female, Age 14, BMI 14.7 HBM894.MPVN.828 TMC-Florida First case collected. Incomplete d...	
	Male, Age 18, BMI 27.1 HBM436.GHWX.449 TMC-Florida section is 190um from block surface	
	Male, Age 56, BMI 32.5 HBM696.XTVL.498 TMC-Vanderbilt Age 56, White Male	
	Male, Age 53, BMI 26.5 HBM652.VRLD.292 TMC-Vanderbilt Age 53, Black Male	
	Male, Age 58, BMI 22.0 HBM477.CJKM.888 TMC-Vanderbilt 107-111	
	Male, Age 18, BMI 25.5 HBM473.VKCM.878 TMC-Florida section is 255um from block surface	
	Male, Age 55, BMI 25.4 HBM824.BLXF.883 TMC-Vanderbilt 13-16	



body

- 1 Centers
- 9 Donors
- 40 Samples

	Male, Age 55, BMI 25.4 HBM695.RTLJ.484 TMC-Vanderbilt 13-16	
	Male, Age 21, BMI 21.8 HBM634.MMGK.572 TMC-Vanderbilt Age 21 , White Male, Trauma Patient	
	Female, Age 44, BMI 28.0 HBM457.NNQN.252 TMC-Vanderbilt Age 44, white female.	
	Female, Age 44, BMI 28.0 HBM465.VKHL.532 TMC-Vanderbilt Age 44, white female.	
	Male, Age 21, BMI 21.8 HBM693.HFFJ.752 TMC-Vanderbilt Age 21 , White Male, Trauma Patient	
	Female, Age 58, BMI 23.0 HBM536.LDTZ.757 TMC-Vanderbilt Age 58, White Female	
	Male, Age 48, BMI 35.3 HBM334.GCCX.874 TMC-Vanderbilt Age 48, White Male	
	Male, Age 31, BMI 32.6 HBM776.PKJF.786 TMC-Vanderbilt Age 21, White Male	
	Female, Age 66, BMI 31.3 HBM284.TRCV.726	

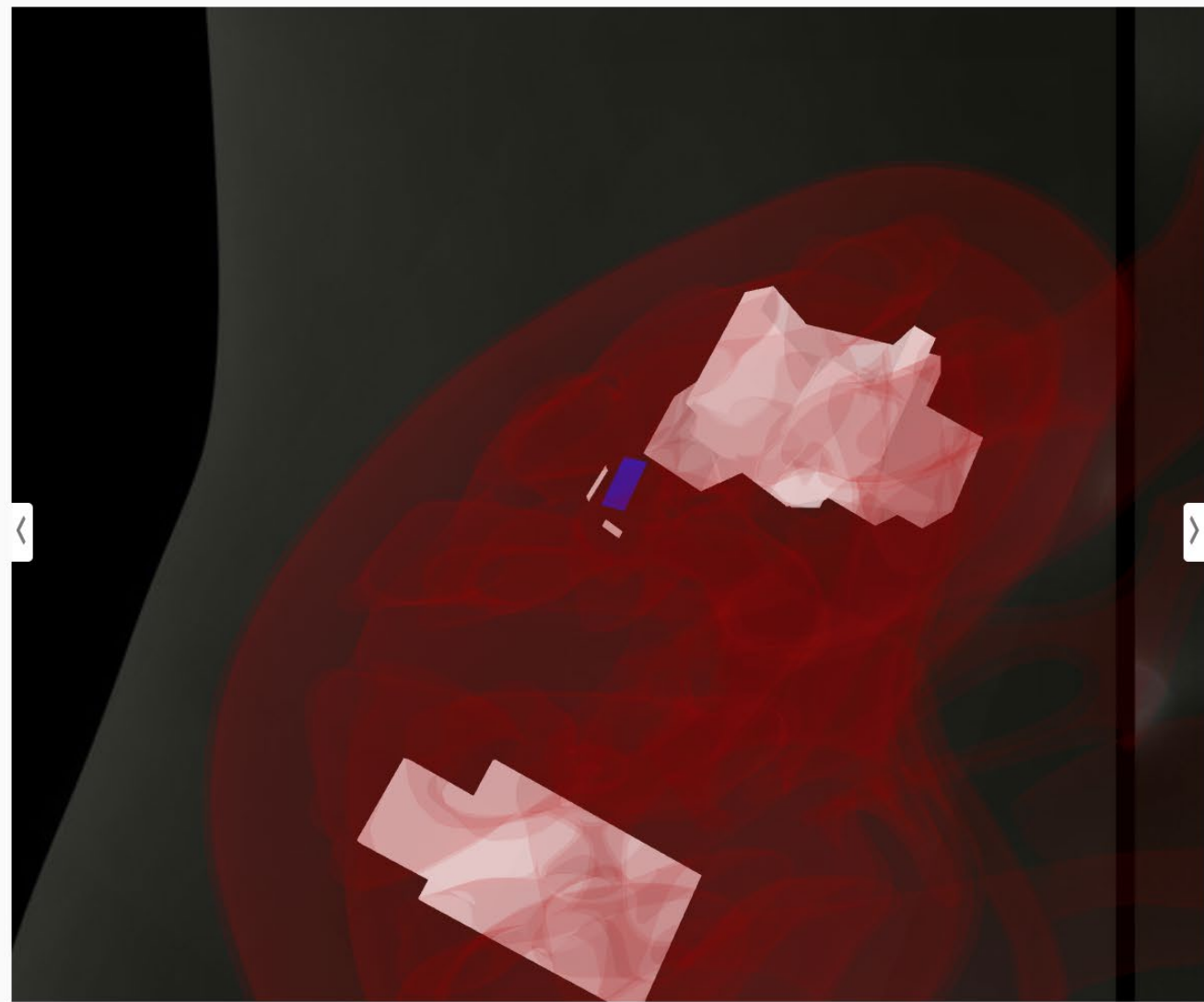


Search ontology terms ...

- body
 - heart
 - lung
 - kidney
 - right kidney
 - left kidney
 - kidney capsule
 - cortex of kidney
 - renal medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - kidney calyx
 - major calyx
 - minor calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron
 - spleen
 - colon

Search ontology terms ... 🔍

- ▼ body
 - heart
 - lung
 - ▼ kidney
 - right kidney
 - left kidney
 - kidney capsule
 - ▼ cortex of kidney
 - outer cortex of kidney
 - ▼ renal medulla
 - outer medulla
 - inner medulla
 - renal column
 - renal pyramid
 - hilum of kidney
 - kidney interstitium
 - ▼ kidney calyx
 - major calyx
 - minor calyx
 - renal pelvis
 - ureter
 - renal papilla
 - renal fat pad
 - nephron
 - spleen
 - colon
 - small intestine

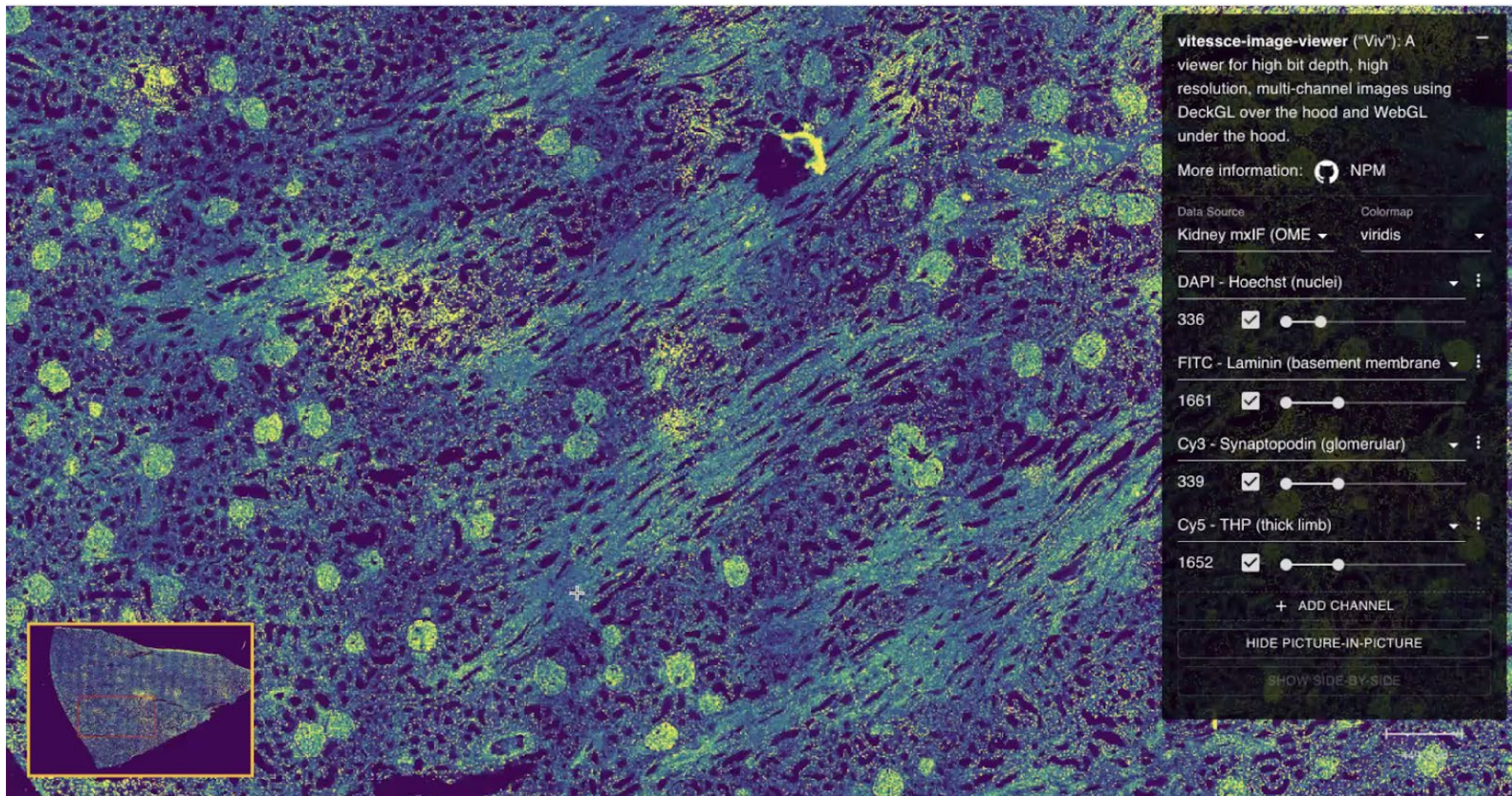


body

- 2 Centers
- 9 Donors
- 14 Samples

	CoverNephrectomy 10.1016/j.trsl.2017.07.006 KPMP-IU/OSU Isolated as a part of a kidney st...	☁
	Patient B Cortical biopsy 10.1681/ASN.2016091027 KPMP-IU/OSU Biopsy from Nephrology bioban...	☁
	Patient A Cortical biopsy 10.1681/ASN.2016091027 KPMP-IU/OSU Biopsy from Nephrology bioban...	☁
	Male, Age 55, BMI 25.4 HBM824.BLXF.883 TMC-Vanderbilt 13-16	☁
	Female, Age 66, BMI 31.3 HBM554.ZRCG.496 TMC-Vanderbilt 21-24	☁
	Female, Age 58, BMI 23.0 HBM926.VBJV.597 TMC-Vanderbilt Age 58, White Female	☁
	Male, Age 62, BMI 34.9 HBM947.VLDP.894 TMC-Vanderbilt Kidneys 153-156	☁
	Female, Age 44, BMI 28.0 HBM457.NNQN.252 TMC-Vanderbilt Age 44, white female.	☁
	Male, Age 21, BMI 21.8 HBM693.HFFJ.752 TMC-Vanderbilt Age 21, White Male, Trauma Pat...	☁
	Female, Age 58, BMI 23.0 HBM536.LDTZ.757 TMC-Vanderbilt Age 58, White Female	☁
	Male, Age 48, BMI 35.3	☁

Register your data via <https://hubmap-ccf-ui.netlify.app/rui/> so it can be spatially/semantically explored in EUI.



<http://gehlenborglab.org/research/projects/vitessce/>


VH Massive Open Online Course (VHMOOC)

Goals

- Communicate tissue data acquisition and analysis,
- Demonstrate single-cell analysis and CCF mapping techniques, and
- Introduce major features of the HuBMAP portal.

Learning modules come with

- Videos (incl. interviews, tool demos)
- Hands-on exercises
- Self-quizzes



HuBMAP Visible Human MOOC (VHMOOC)
Started Aug 4, 2020
[GO TO CANVAS COURSE](#)
You are enrolled.



Course Introduction

This 10h course introduces the HuBMAP project which aims to create an open, global reference atlas of the human body at the cellular level. Among others, the course describes the compilation and coverage of HuBMAP data, demonstrates new single-cell analysis and mapping techniques, and introduces major features of the HuBMAP portal.

Delivered entirely online, all coursework can be completed asynchronously to fit busy schedules. If you have questions or experience issues during registration, please email cnsctr@indiana.edu.

Learning Outcomes

- Theoretical and practical understanding of different single-cell tissue analysis techniques.
- Expertise in single-cell data harmonization used to federate data from different individuals analyzed using different technologies in diverse labs.
- Hands-on skills in the design and usage of semantic ontologies that describe human anatomy, cell types, and biomarkers (e.g., marker genes or proteins).
- Knowledge on the design and usage of a semantically annotated three-dimensional reference system for the healthy human body.
- An understanding of how the HuBMAP reference atlas might be used to understand human health but also to diagnose and treat disease.

Module Topics Include

- HuBMAP Overview: Project Goals, Setup, and Ambitions
- Tissue Data Acquisition and Analysis
- Biomolecular Data Harmonization
- Ontology, 3D Reference Objects, and User Interfaces
- HuBMAP Portal Design and Usage

Meet the Instructors



Katy Börner, Victor H. Yingve Distinguished Professor of Engineering and Information Science. Founding Director of the [Cyberinfrastructure for Network Science Center](#) at Indiana University.



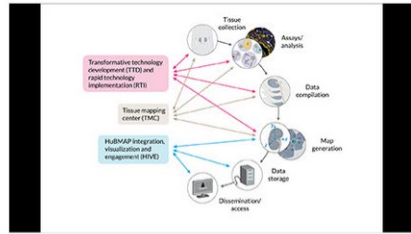
Ellen M. Quardokus, staff in the Chemistry Department and research scientist, [Cyberinfrastructure for Network Science Center](#), SICE with expertise in molecular biology, microscopy, anatomy, and interdisciplinary communication.



Andreas Bueckle, PhD Candidate in Information Science, performing research on information visualization, specifically virtual and augmented reality.

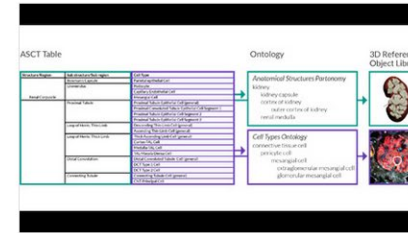
- Length:** 10 hours
- Department:** Cyberinfrastructure Network Science
- Credit:** None
- Audience:** Biomedical students and professionals interested in single-cell tissue analysis and visualization

<https://expand.iu.edu/browse/sice/cns/courses/hubmap-visible-human-mooc>



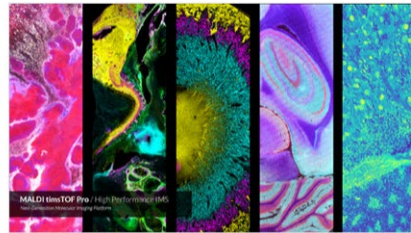
HuBMAP Overview

- Project Goals, Setup, and Ambitions



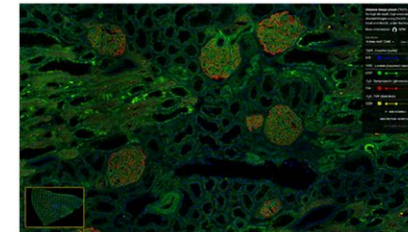
CCF Ontology, 3D Reference Objects, and User Interfaces

- Creating an Atlas of the Human Body



Tissue Data Acquisition and Analysis

- Behind the Scenes at Vanderbilt University



Portal Design and Usage

- Datasets and Software in the 1st HuBMAP Portal Release



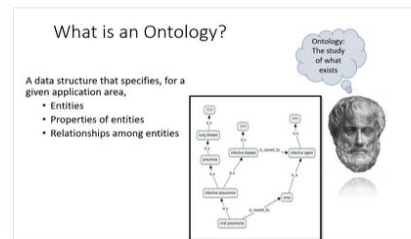
Biomolecular Data Harmonization

- An Introduction to Seurat



Open Consent Your Data

- In Support of Research



Ontologies 101

- A gentle introduction on how to use ontologies the world.



Anatomical Structures, Cell Types, and Biomarkers (ASCT+B) Tables

- What are ASCT+B tables and how they are used.

Acknowledgements

HuBMAP Consortium (<https://hubmapconsortium.org>)



Thanks go to all the **patients** that agreed to volunteer healthy tissue and open use of their data.



TMCs



Jeffrey Spraggins
TMC-Vanderbilt
Vanderbilt University



Sanjay Jain
TMC-UCSD
Washington University,
St. Louis



Clive Wasserfall
TMC-UFL
University of Florida



Marda Jorgensen
TMC-UFL
University of Florida



Kristen Browne
Medical Imaging and
3D Modeling Specialist
NIAID

3D Models

MC-IU HIVE Team



Katy Börner
MC-IU PI
CNS Director



Griffin Weber
Assoc. Professor of Medicine
Harvard Medical School



Lisel Record
MC-IU PM
CNS Associate Director



Bruce Herr II
Sr. Systems Architect/PM



Ellen Quardokus
Sr. Research Analyst



Yingnan Ju
PhD Candidate



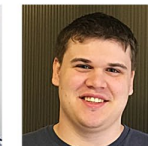
Andreas Bueckle
PhD Candidate



Leonard Cross
Sr. UX/UI Designer



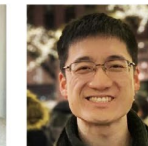
Matthew Martindale
Center Assistant



Daniel Bolin
Software Developer



Adam Phillips
Software Developer



Edward Lu
Software Developer



Paul Hrishikesh
Research Assistant



Leah Scherschel
Research Assistant



Avinash Boppana
Research Consultant

Data Visualization Literacy Framework

Börner, Katy, Andreas Bueckle, and Michael Ginda. 2019. Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *PNAS*, 116 (6) 1857-1864.

Data Visualization Literacy (DVL)

Data visualization literacy (ability to read, make, and explain data visualizations) requires:

- literacy (ability to read and write text in titles, axis labels, legends, etc.),
- visual literacy (ability to find, interpret, evaluate, use, and create images and visual media), and
- mathematical literacy (ability to formulate, employ, and interpret math in a variety of contexts).

Being able to “read and write” data visualizations is becoming as important as being able to read and write text. Understanding, measuring, and improving data and visualization literacy is important to strategically approach local and global issues.

DVL Framework: Desirable Properties

- Most existing frameworks focus on **READING**. We believe that much expertise is gained from also **CONSTRUCTING** data visualizations.
- Reading and constructing data visualizations needs to take human perception and cognition into account.
- Frameworks should build on and consolidate prior work in cartography, psychology, cognitive science, statistics, scientific visualization, data visualization, learning sciences, etc. in support of a de facto standard.
- Theoretically grounded + practically useful + easy to learn/use.
- Highly modular and extendable.

DVL Framework: Development Process

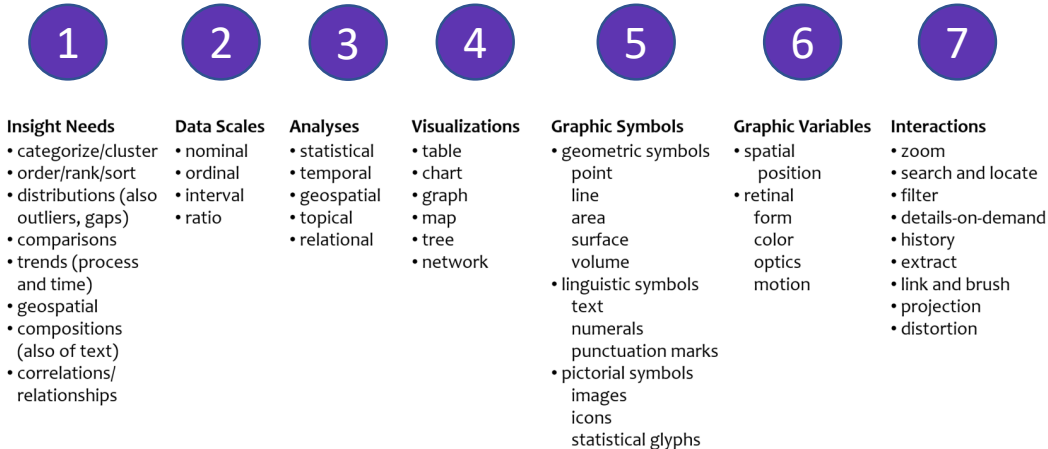
- The initial DVL-FW was developed via an extensive literature review.
- The resulting DVL-FW typology, process model, exercises, and assessments were then tested in the *Information Visualization* course taught for more than 17 years at Indiana University. More than 8,500 students enrolled in the IVMOOC version (<http://ivmooc.cns.iu.edu>) over the last six years.
- The FW was further refined using feedback gained from constructing and interpreting data visualizations for 100+ real-world client projects.
- Data on student engagement, performance, and feedback guided the continuous improvement of the DVL-FW typology, process model, and exercises for defining, teaching, and assessing DVL.
- The DVL-FW used in this course supports the systematic construction and interpretation of data visualizations.

Data Visualization Literacy Framework (DVL-FW)

Consists of two parts:

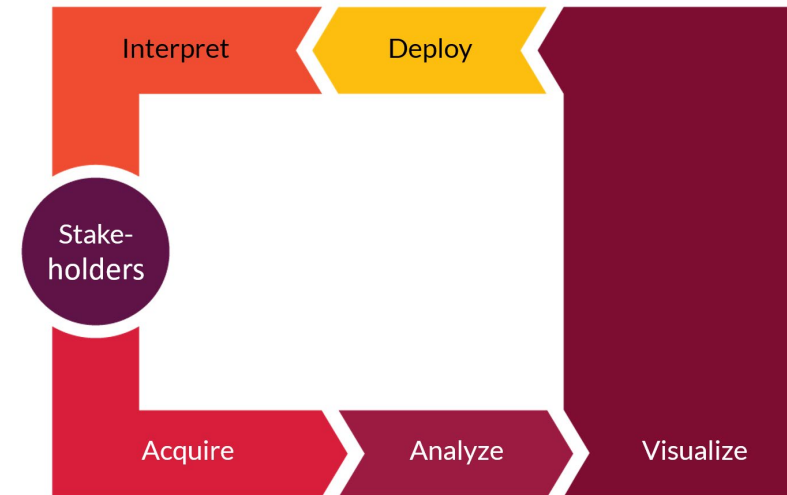
DVL Typology

Defines 7 types with 4-17 members each.



DVL Workflow Process

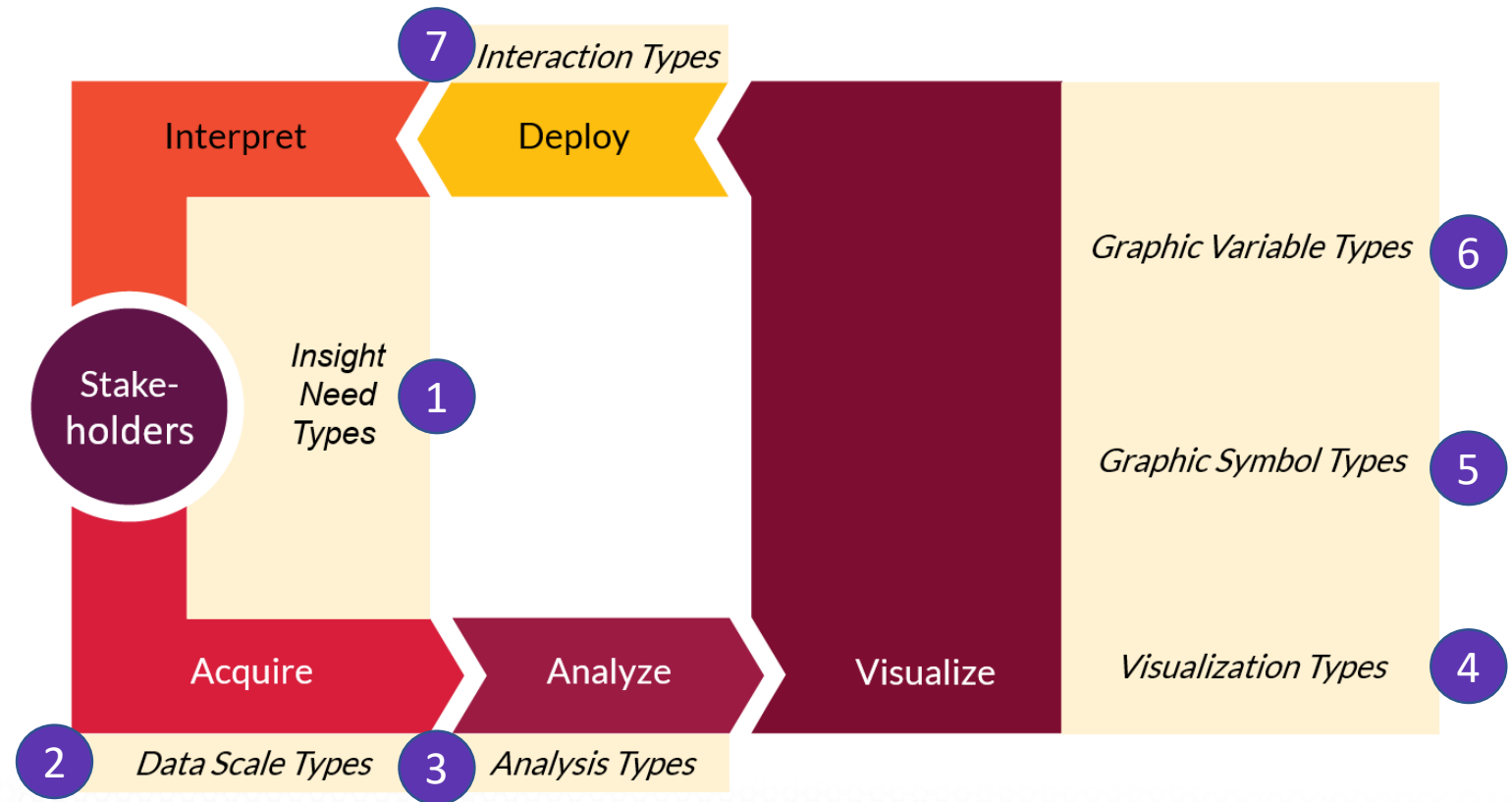
Defines 5 steps required to render data into insights.

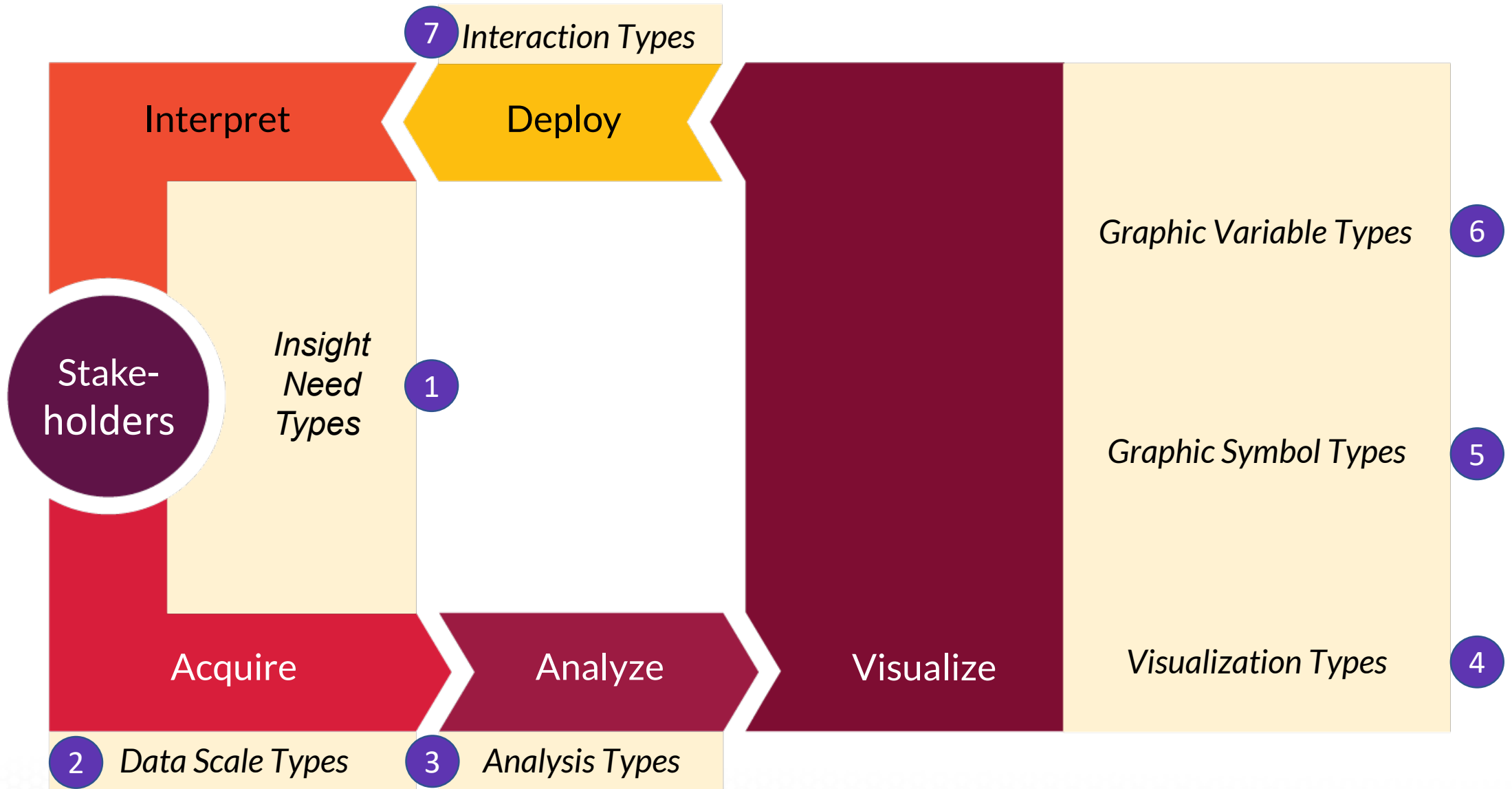


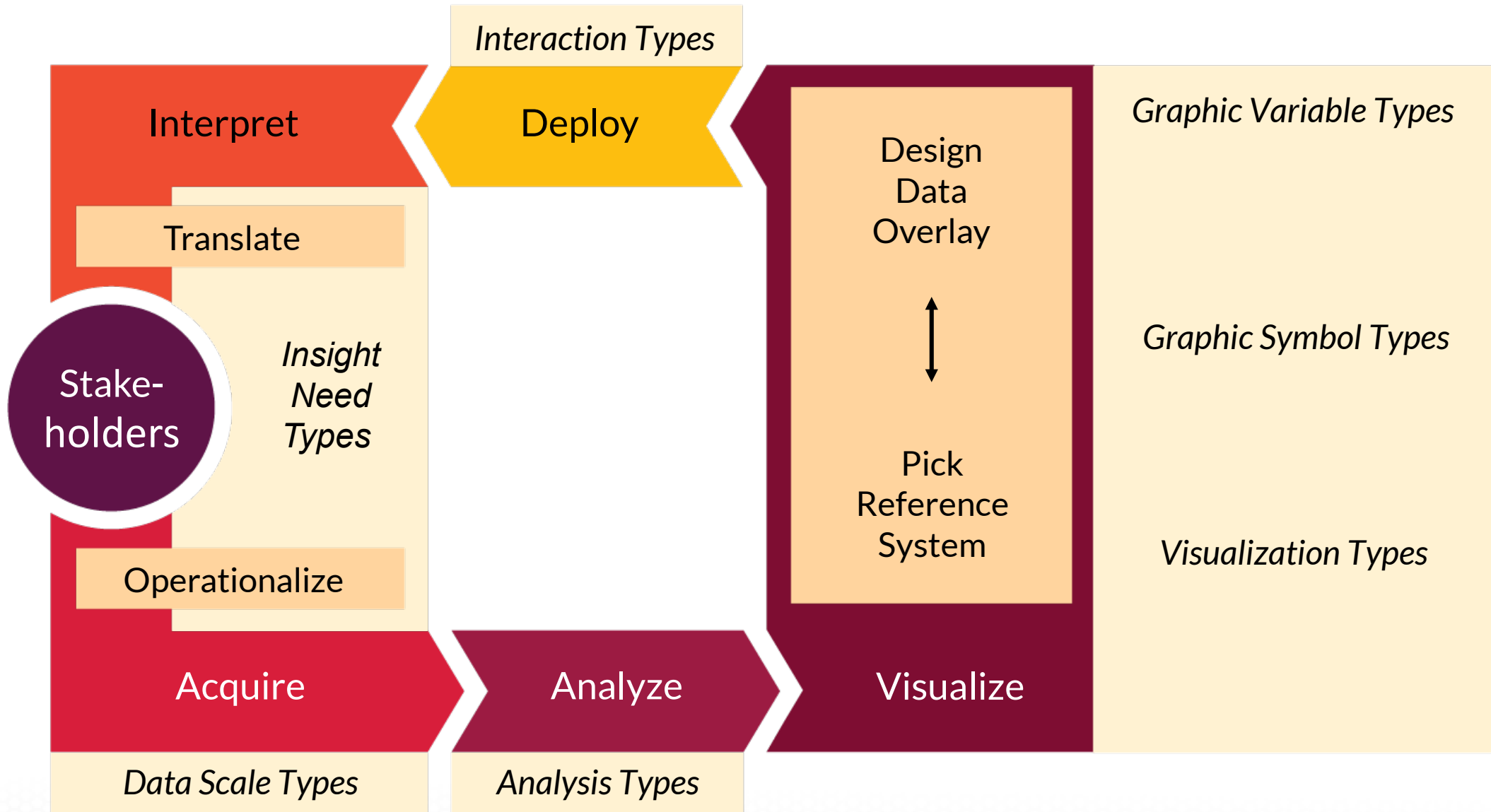
Data Visualization Literacy Framework (DVL-FW)

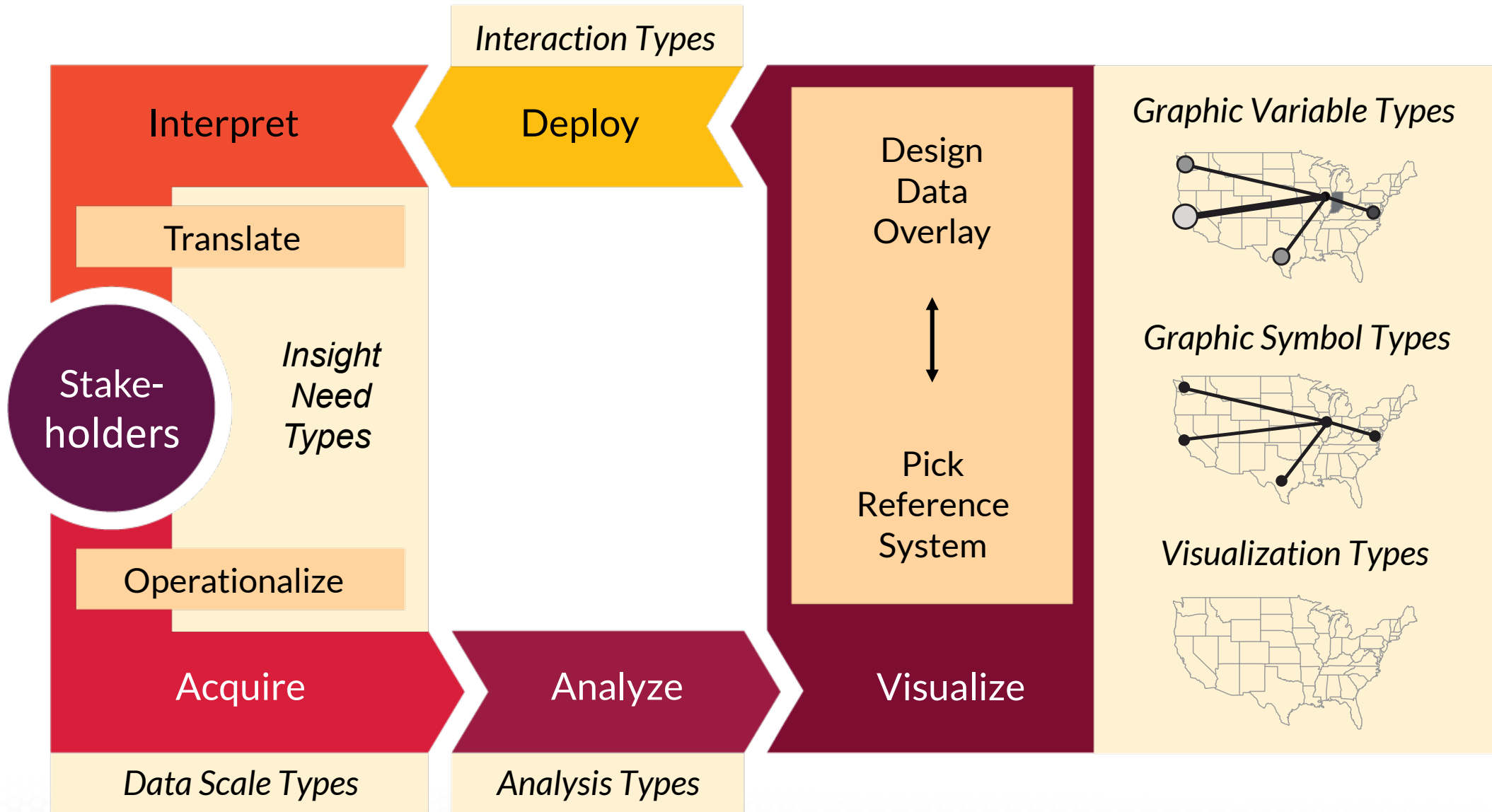
Consists of two parts *that are interlinked*:

**DVL Typology +
DVL Workflow Process**









Data Visualization Literacy Framework (DVL-FW)

Implemented in Make-A-Vis (MAV) to support learning via horizontal transfer, scaffolding, hands-on learning, etc.

Make-A-Vis

Data

ISI Publications: (CSV) Preprocessed-wos

Title	Authors	Journal	Year	#Cites
[Progress bar]				

Total Records: 562

Journals: (from ISI Publications)

Name	#Papers	#Cites	First Year	Last Year
BMC EVOL BIOL	1	7	2006	2006
FEBS J	2	0	2005	2005
NAT PHYS	3	18	2005	2006

Total Records: 562

Make Visualization

Select Visualization Type

- Scatter Graph
- Geomap
- Scimap
- Temporal Bar Graph**

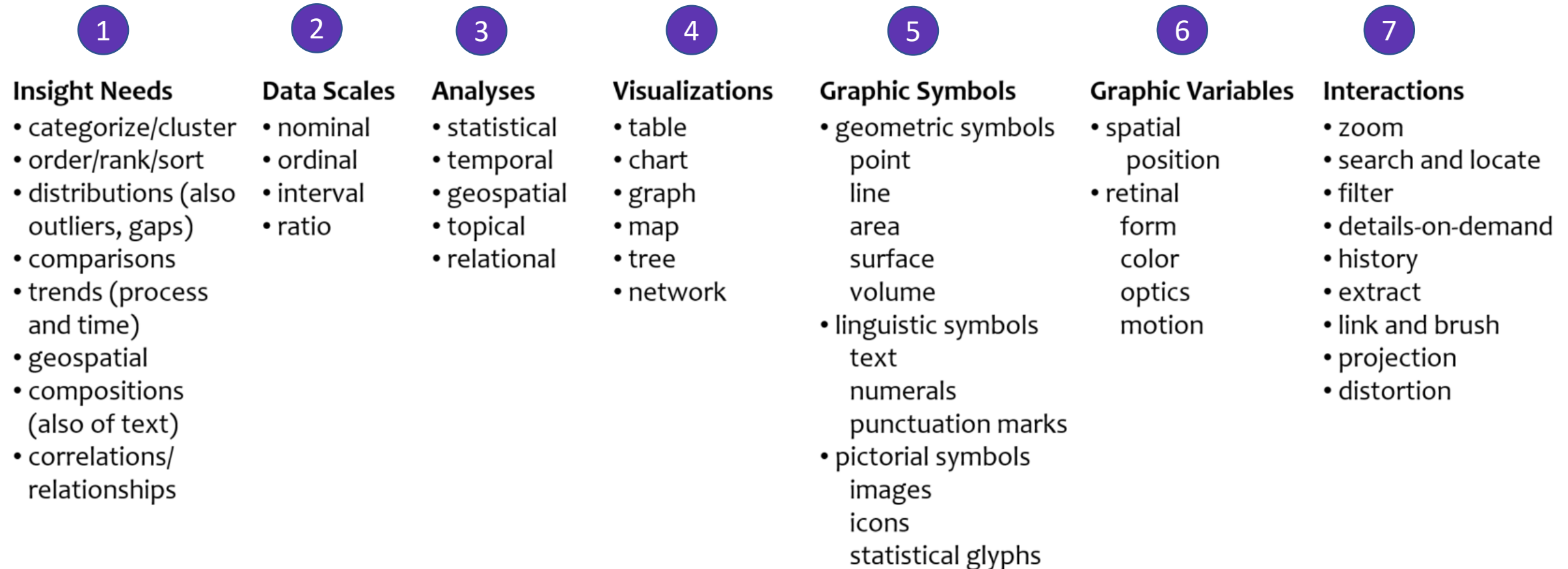
Done

Select Graphic Symbol Type(s)

Select Graphic Variable Types

Temporal Bar Graph

Typology of the Data Visualization Literacy Framework



Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 25.

Typology of the Data Visualization Literacy Framework

1

Insight Needs

- categorize/cluster
- order/rank/sort
- distributions (also outliers, gaps)
- comparisons
- trends (process and time)
- geospatial
- compositions (also of text)
- correlations/relationships

Data Scales

- nominal
- ordinal
- interval
- ratio

Analyses

- statistical
- temporal
- geospatial
- topical
- relational

Visualizations

- table
- chart
- graph
- map
- tree
- network

Graphic Symbols

- geometric symbols
 - point
 - line
 - area
 - surface
 - volume
- linguistic symbols
 - text
 - numerals
 - punctuation marks
- pictorial symbols
 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
- retinal
 - form
 - color
 - optics
 - motion

Interactions

- zoom
- search and locate
- filter
- details-on-demand
- history
- extract
- link and brush
- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 26-27.

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

Typology of the Data Visualization Literacy Framework

4

Insight Needs

- categorize/cluster
- order/rank/sort
- distributions (also outliers, gaps)
- comparisons
- trends (process and time)
- geospatial
- compositions (also of text)
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 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
- retinal
 - form
 - color
 - optics
 - motion

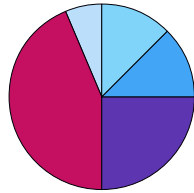
Interactions

- zoom
- search and locate
- filter
- details-on-demand
- history
- extract
- link and brush
- projection
- distortion

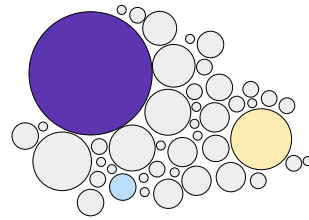
Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 30-31.

Visualization Types

Chart

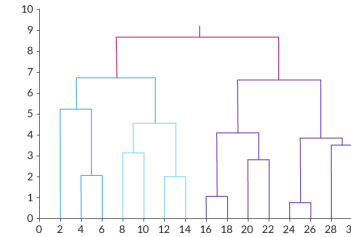


Pie Chart

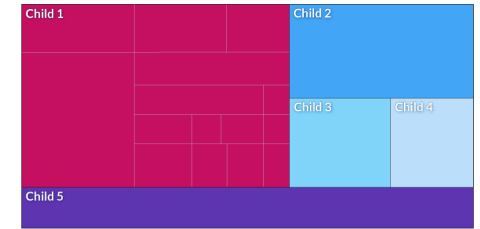


Bubble Chart

Tree

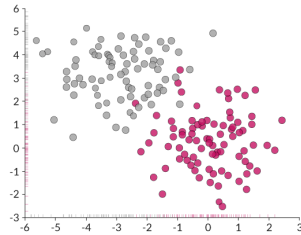


Dendrogram

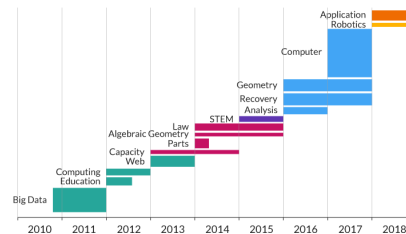


Tree Map

Graph

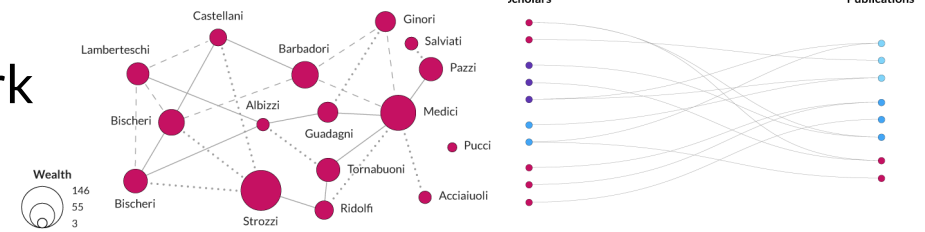


Scatter Graph



Temporal Bar Graph

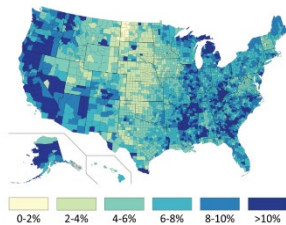
Network



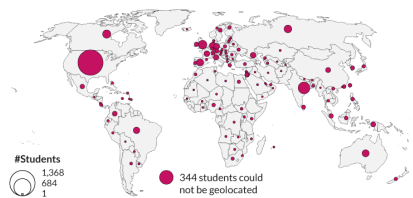
Force-Directed Network Layout

Bimodal Network Layout

Map



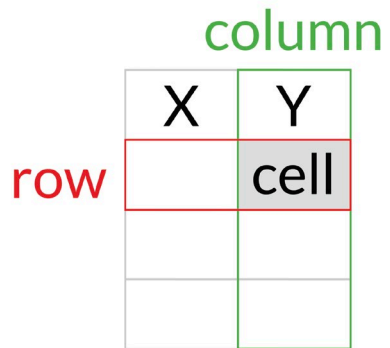
Choropleth Map



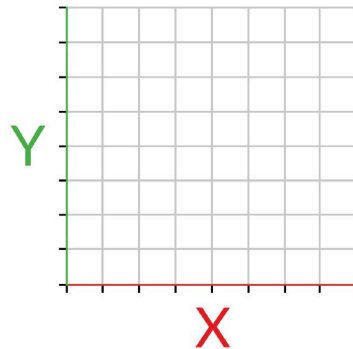
Proportional Symbol Map

Visualize: Reference Systems

Table
columns by rows



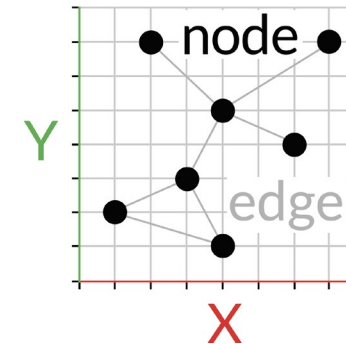
Graph
x-y coordinates



Map
latitude/
longitude



Network
local similarity

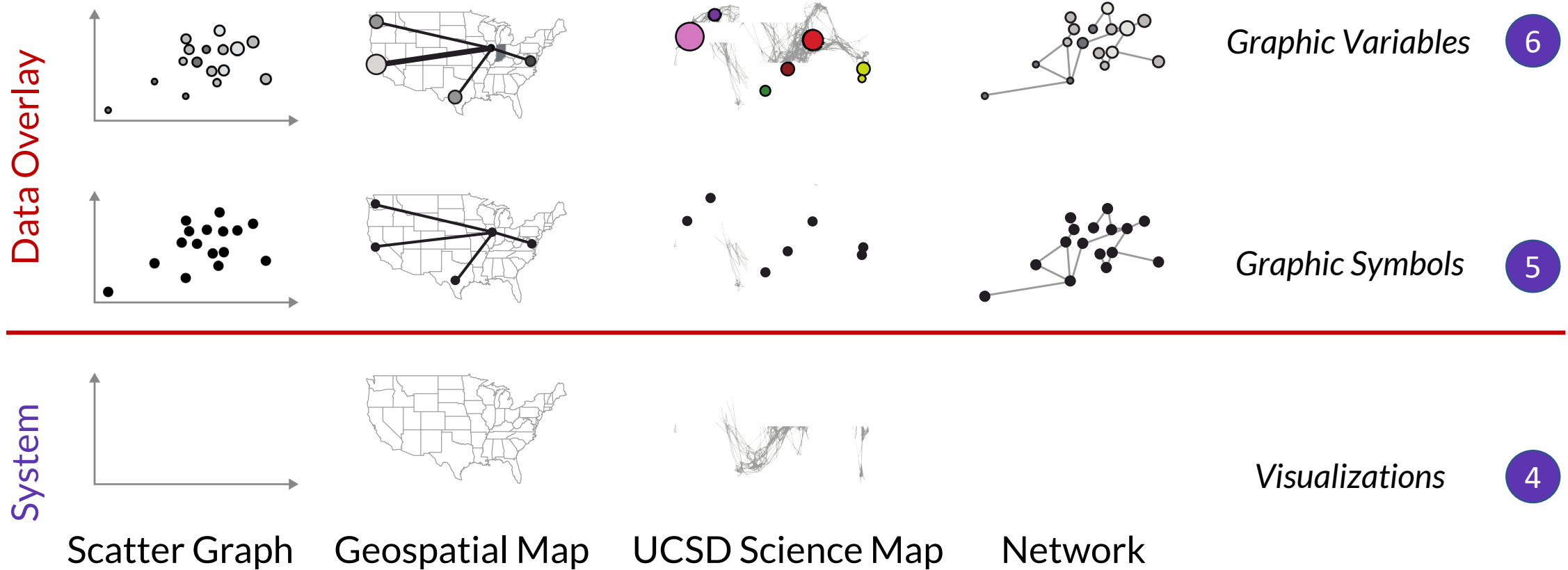


4

Visualization Types

- table
- chart
- graph
- map
- network layout

Visualize: Reference Systems, Graphic Symbols and Variables



Typology of the Data Visualization Literacy Framework

5

Insight Needs

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- geospatial
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- ratio

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- geometric symbols
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 - line
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 - volume
- linguistic symbols
 - text
 - numerals
 - punctuation marks
- pictorial symbols
 - images
 - icons
 - statistical glyphs

Graphic Variables

- spatial
 - position
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 - form
 - color
 - optics
 - motion

Interactions

- zoom
- search and locate
- filter
- details-on-demand
- history
- extract
- link and brush
- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 32-33.

Typology of the Data Visualization Literacy Framework

6

Insight Needs

- categorize/cluster
- order/rank/sort
- distributions (also outliers, gaps)
- comparisons
- trends (process and time)
- geospatial
- compositions (also of text)
- correlations/relationships

Data Scales

- nominal
- ordinal
- interval
- ratio

Analyses

- statistical
- temporal
- geospatial
- topical
- relational

Visualizations

- table
- chart
- graph
- map
- tree
- network

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- history
- extract
- link and brush
- projection
- distortion

Börner, Katy. 2015. [Atlas of Knowledge: Anyone Can Map](#). Cambridge, MA: The MIT Press. 34-35.

Graphic Variable Types

Position: x, y; possibly z

Form:

- Size
- Shape
- Rotation (Orientation)

Color:

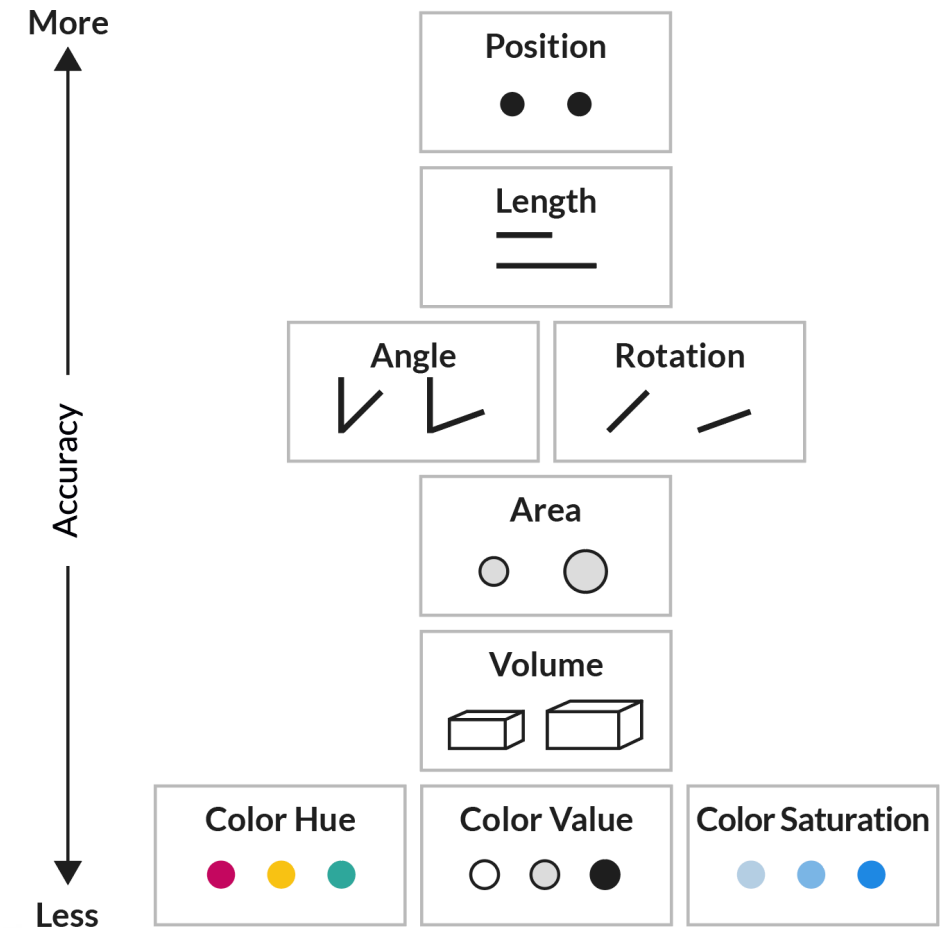
- Value (Lightness)
- Hue (Tint)
- Saturation (Intensity)



Optics: Blur, Transparency, Shading, Stereoscopic Depth

Texture: Spacing, Granularity, Pattern, Orientation, Gradient

Motion: Speed, Velocity, Rhythm



Graphic Symbol Types

			Geometric Symbols		Linguistic Symbols	Pictorial Symbols
			Point	Line		
Spatial	Position	X Y				
		Retinal	Form	Size		
Shape					Text Text Text	
Color	Value				Text Text Text	
	Hue				Text Text Text	
	Saturation				Text Text Text	
Texture	Granularity					
	Pattern					
Motion Optics	Blur				Text Text Text	
	Speed					

Graphic Variable Types

See *Atlas of Knowledge* pages 36-39 for complete table.

Qualitative

Also called:
Categorical Attributes
Identity Channels

Quantitative

Also called:
Ordered Attributes
Magnitude Channels

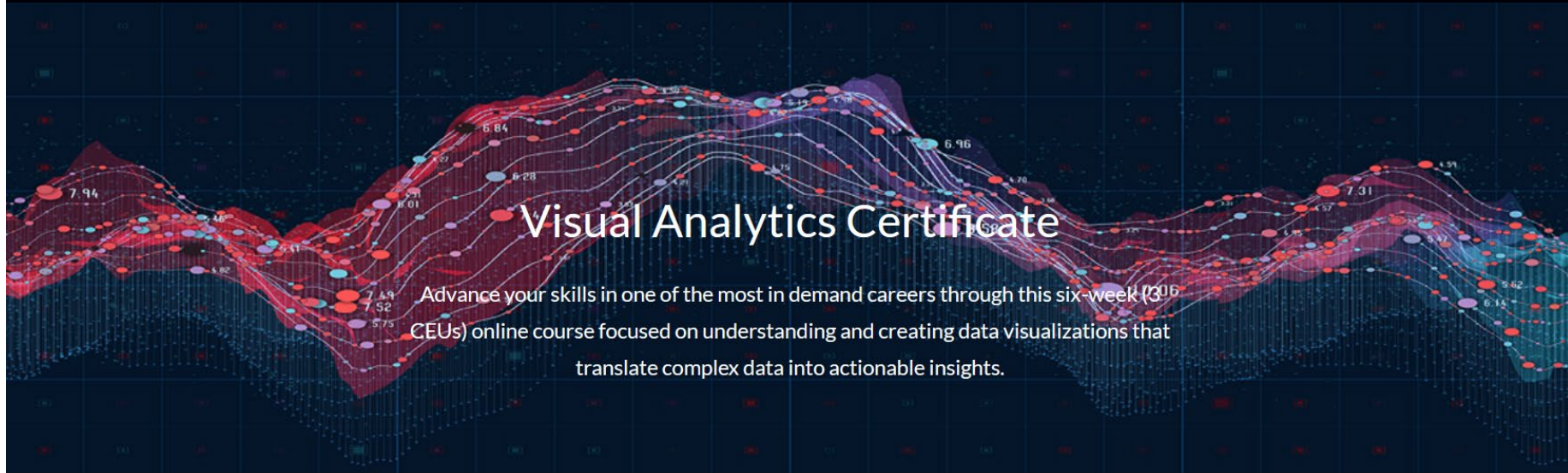
Graphic Variable Types Versus Graphic Symbol Types

			Geometric Symbols					Linguistic Symbols Text, Numerals, Punctuation Marks					Pictorial Symbols Images, Icons, Statistical Glyphs					
			Point	Line	Area	Surface	Volume											
Spatial	x	quantitative																
	y	quantitative																
	z	quantitative																
Retinal	Form	Size	quantitative	NA (Not Applicable)														
		Shape	qualitative	NA														
		Rotation	quantitative	NA														
		Curvature	quantitative	NA														
	Angle	quantitative	NA															
	Closure	quantitative	NA															
	Value	quantitative																
	Color	Hue	qualitative															
Saturation	quantitative																	
Retinal	Texture	Spacing	quantitative															
		Granularity	quantitative															
		Pattern	qualitative															
		Orientation	quantitative	NA														
		Gradient	quantitative															
	Optics	Blur	quantitative															
		Transparency	quantitative															
		Shading	quantitative															
	Motion	Stereoscopic Depth	quantitative	Point in foreground .. background	Line in foreground .. background	Area in foreground .. background	Surface in foreground .. background	Volume in foreground .. background	Text in foreground .. background					Icons in foreground .. background				
		Speed	quantitative															
Velocity		quantitative																
Rhythm	quantitative	Blinking point slow .. fast	Blinking line slow .. fast	Blinking area slow .. fast	Blinking surface slow .. fast	Blinking volume slow .. fast	Blinking text slow .. fast					Blinking icons slow .. fast						

See Atlas of Knowledge pages 36-39 for complete table.

Empower Yourself and Others! Data Visualization Literacy

Börner, Katy, Andreas Bueckle, and Michael Ginda. 2019. Data visualization literacy: Definitions, conceptual frameworks, exercises, and assessments. *PNAS*, 116 (6) 1857-1864.



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US Employers which have sent students include
The Boeing Company, Eli Lilly, DOE, CDC, NSWC Crane.

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.

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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>



Q&A

