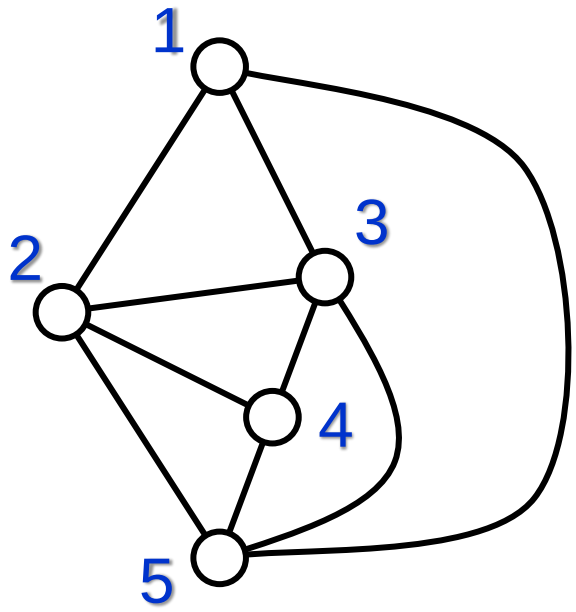
Network Thinking: Some Examples

NetSci High 2014 Boston University



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What Is Network Science?

- **A data-driven science** that focuses on *"how things are related"*, rather than what things are in isolation

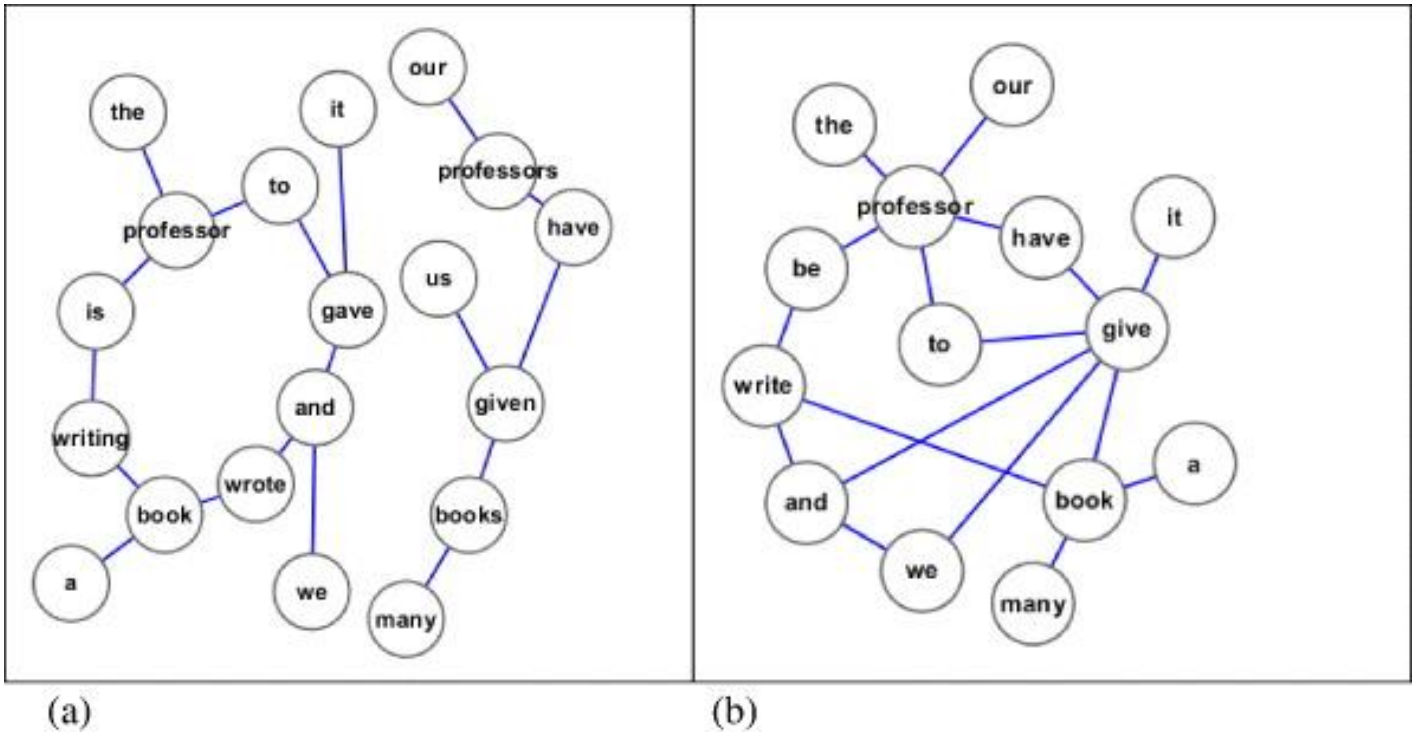
- **An interdisciplinary science** that draws upon concepts and methods taken from *mathematics, computer science, physics, social sciences, humanities, etc.*

Astonishing Facts

- Various complex networks share a number of common features, despite their completely different origins
- Most real-world networks are huge, complex and heterogeneous, yet very "small" and "efficient"

Networks in English

Network of Words (Syntactic)



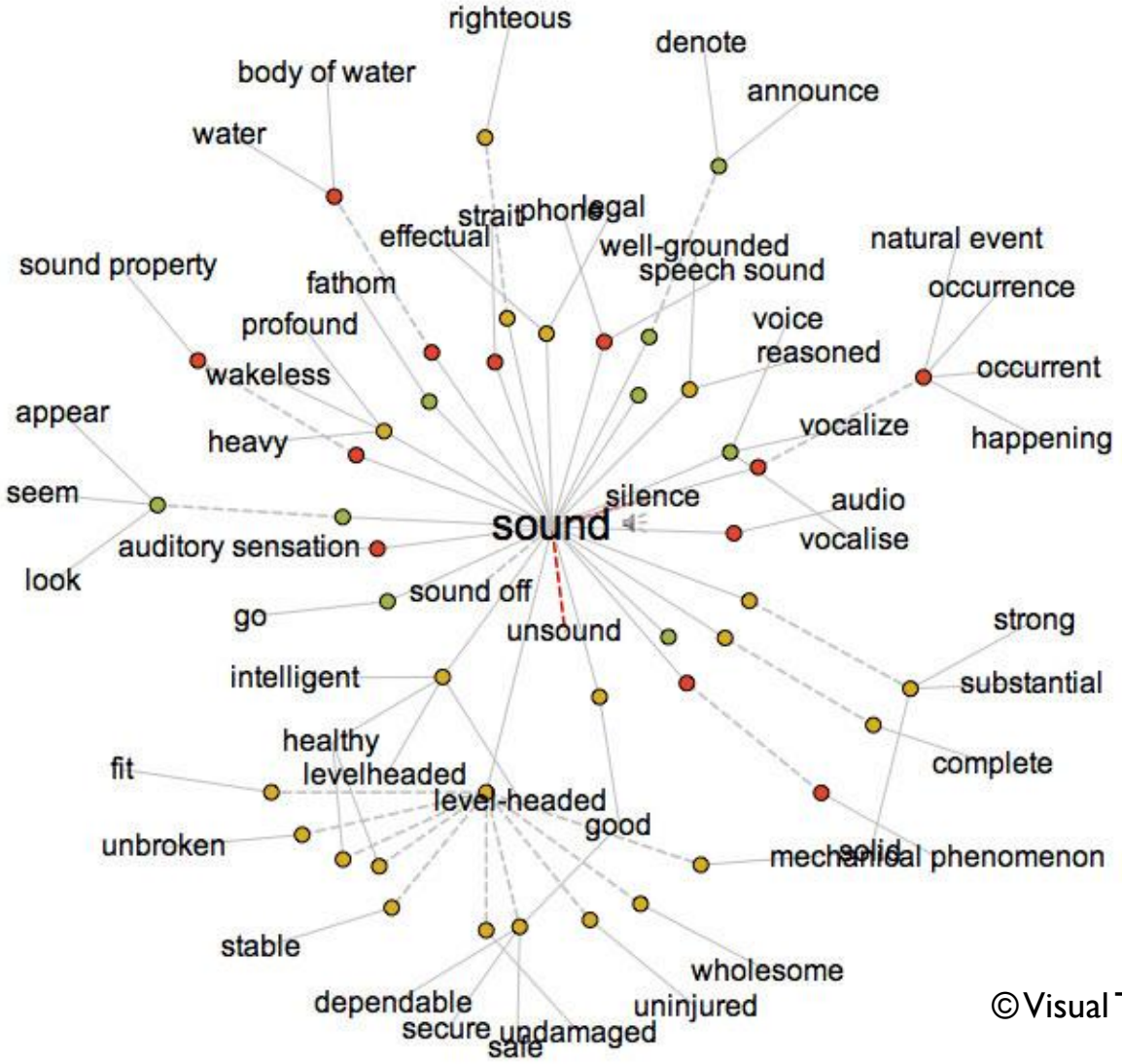
From Liu & Xu 2011; networks were generated from the following three sentences:

This professor is writing a book.

Our professors have given us many books.

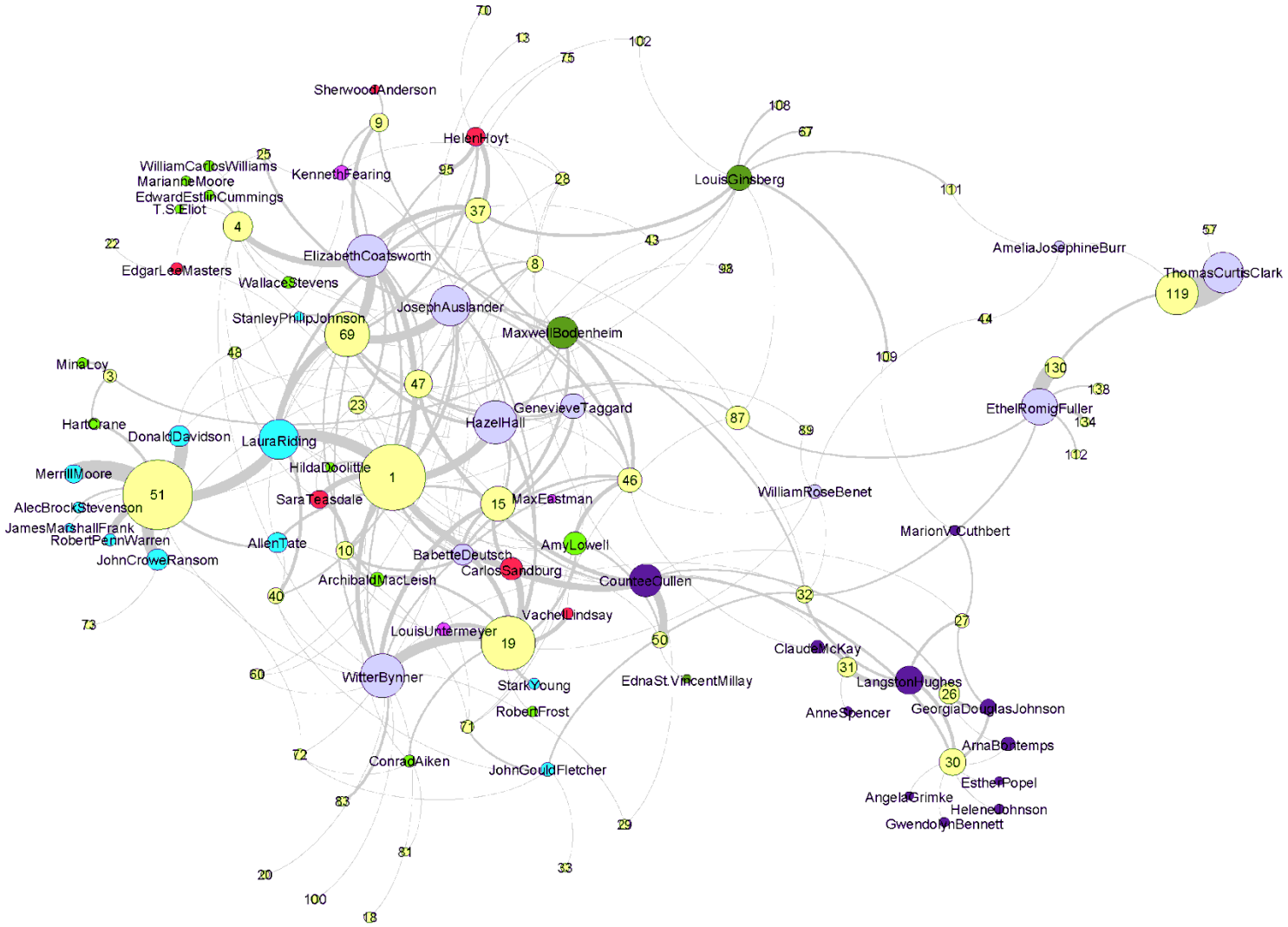
We wrote a book and gave it to the professor.

Network of Words (Semantic)



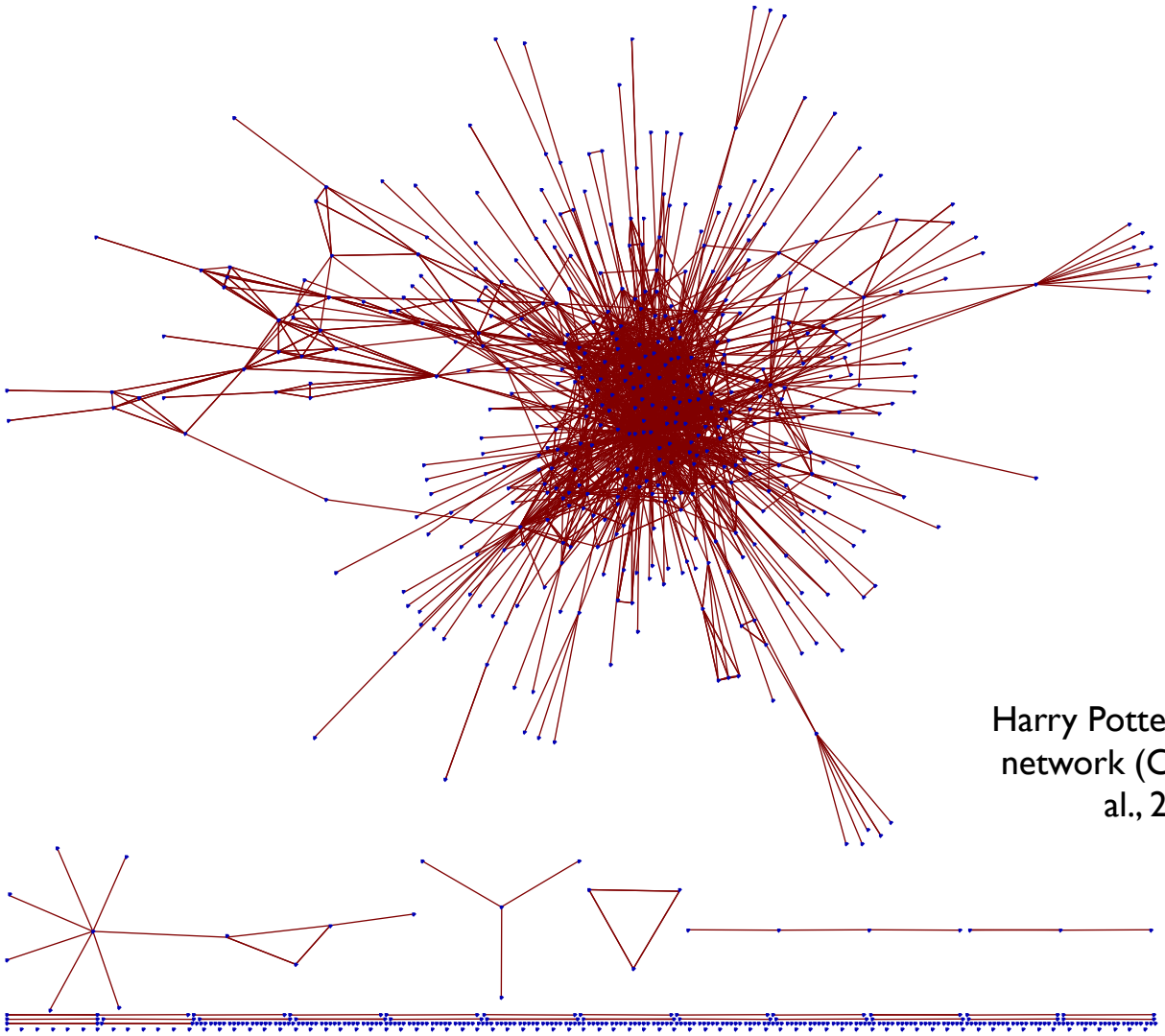
©Visual Thesaurus

Network of U.S. Poets (1924-25)



Hoyt Long: Literary Networks. http://lucian.uchicago.edu/blogs/literarynetworks/

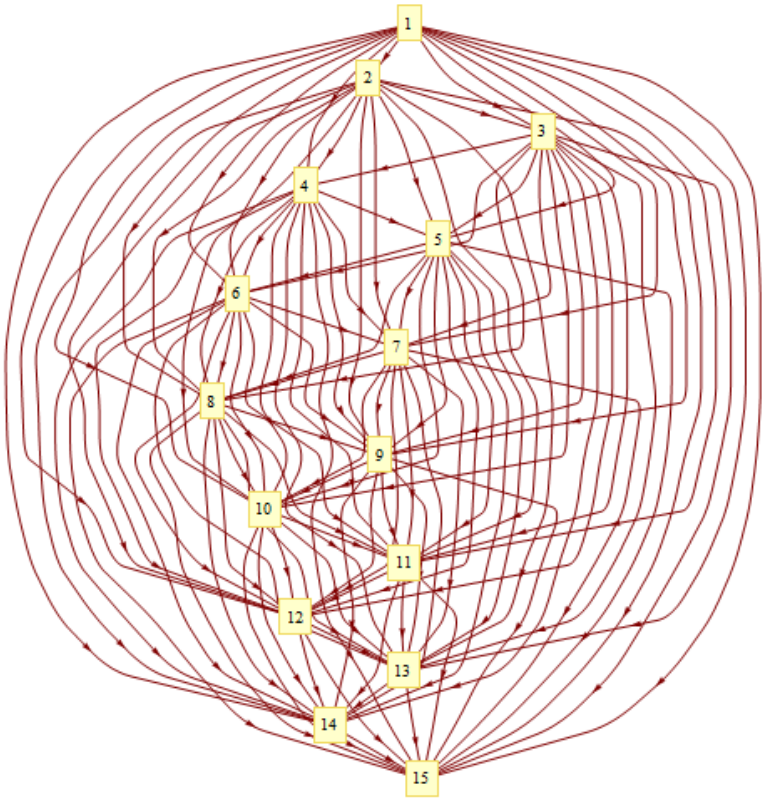
Network of Fictional Characters



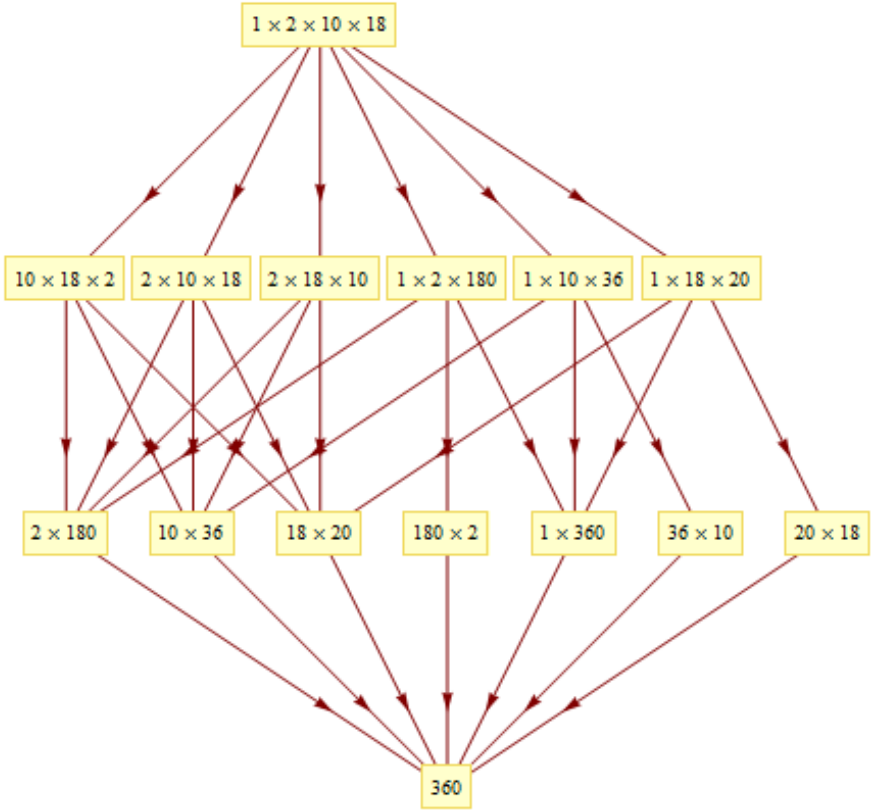
Harry Potter's character network (Calderone et al., 2011)

Networks in Math

Networks of Numbers (1)

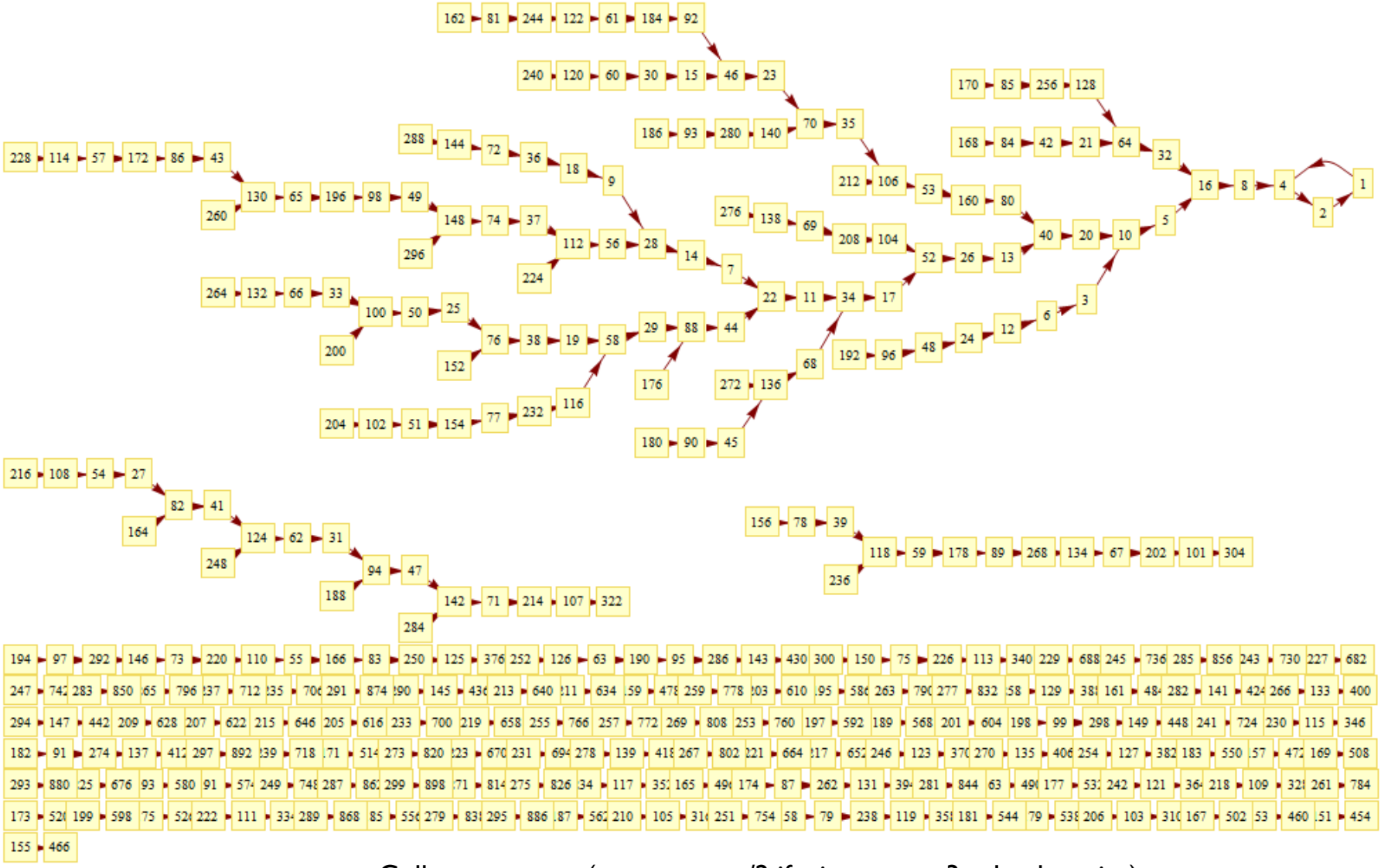


Transitivity network ($i \rightarrow j$ if and only if $i < j$)



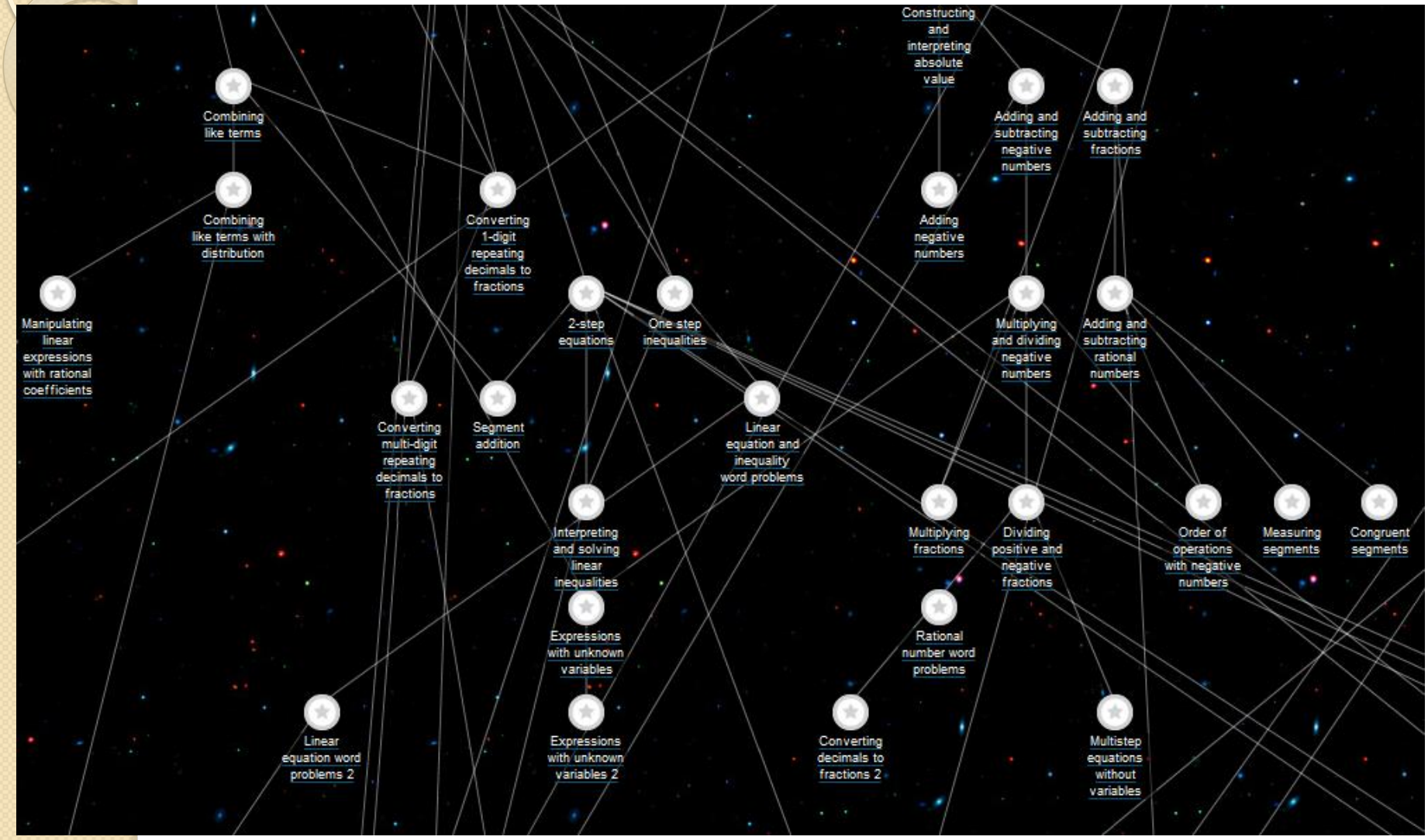
Associativity network (about multiplication)

Networks of Numbers (2)



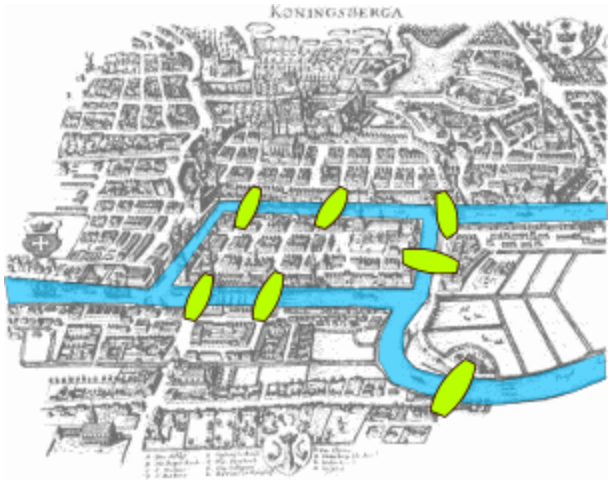
Collatz sequence ($x \rightarrow y$; $y = x/2$ if x is even, or $3x+1$ otherwise)

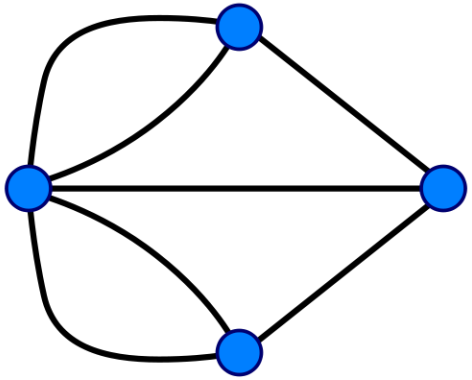
Network of Concepts



Knowledge Map (from Khan Academy)

Networks in Math Puzzles



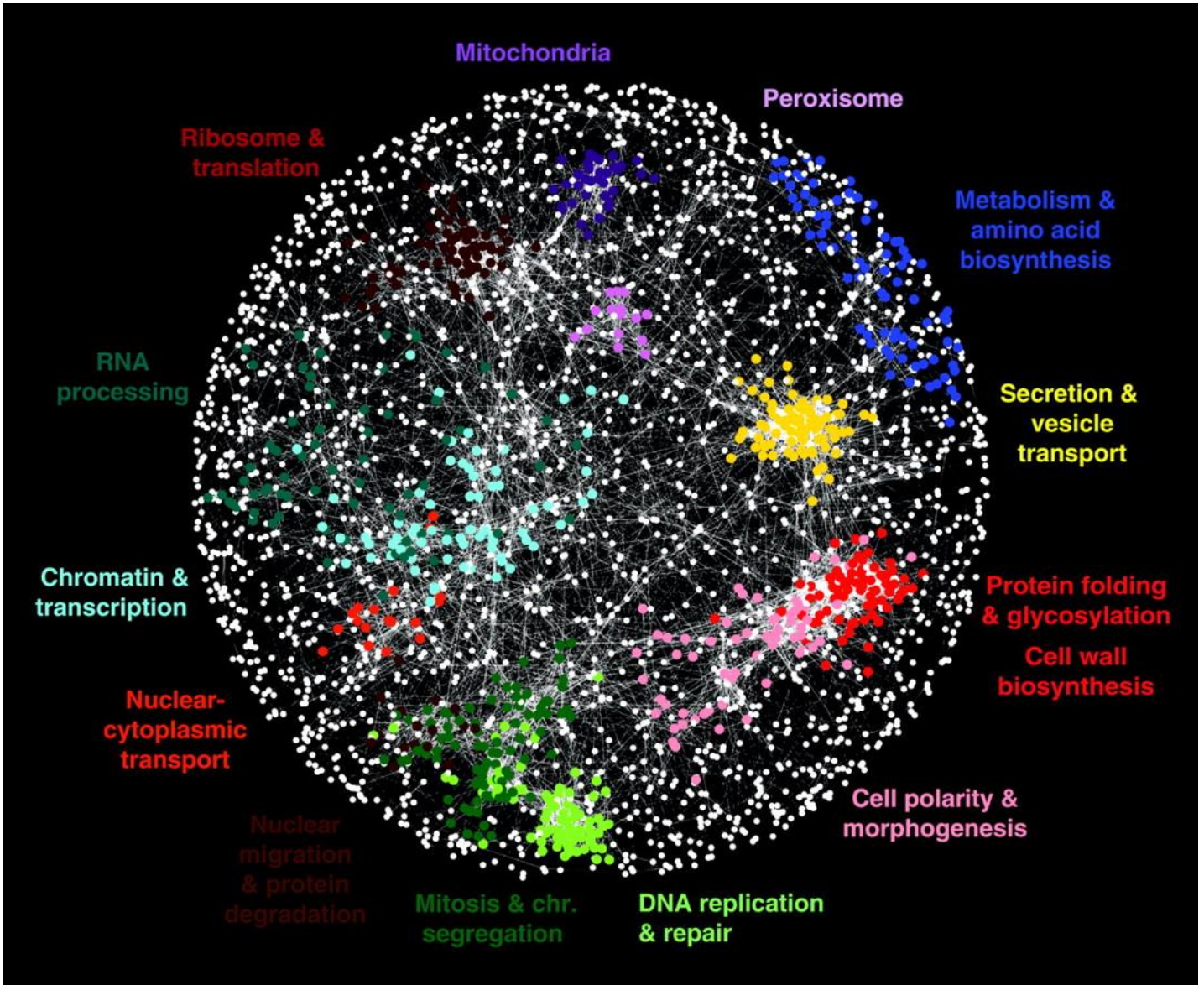


Seven bridges of Konigsberg
(images from Wikipedia)

42 bridges in Bristol, UK
(images from Bristol Post / Dr. Thilo Gross)

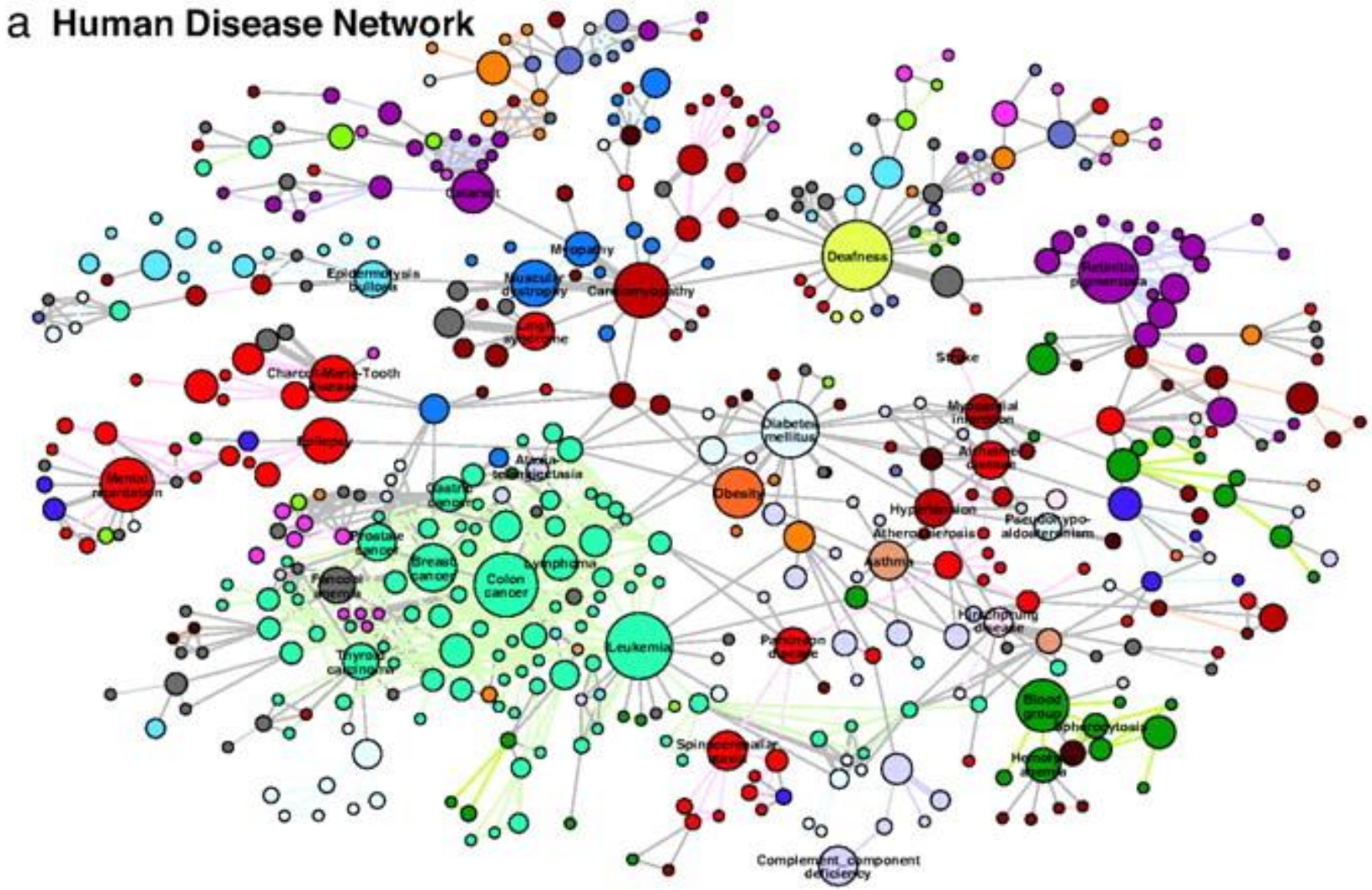
Networks in Science

Network of Genes



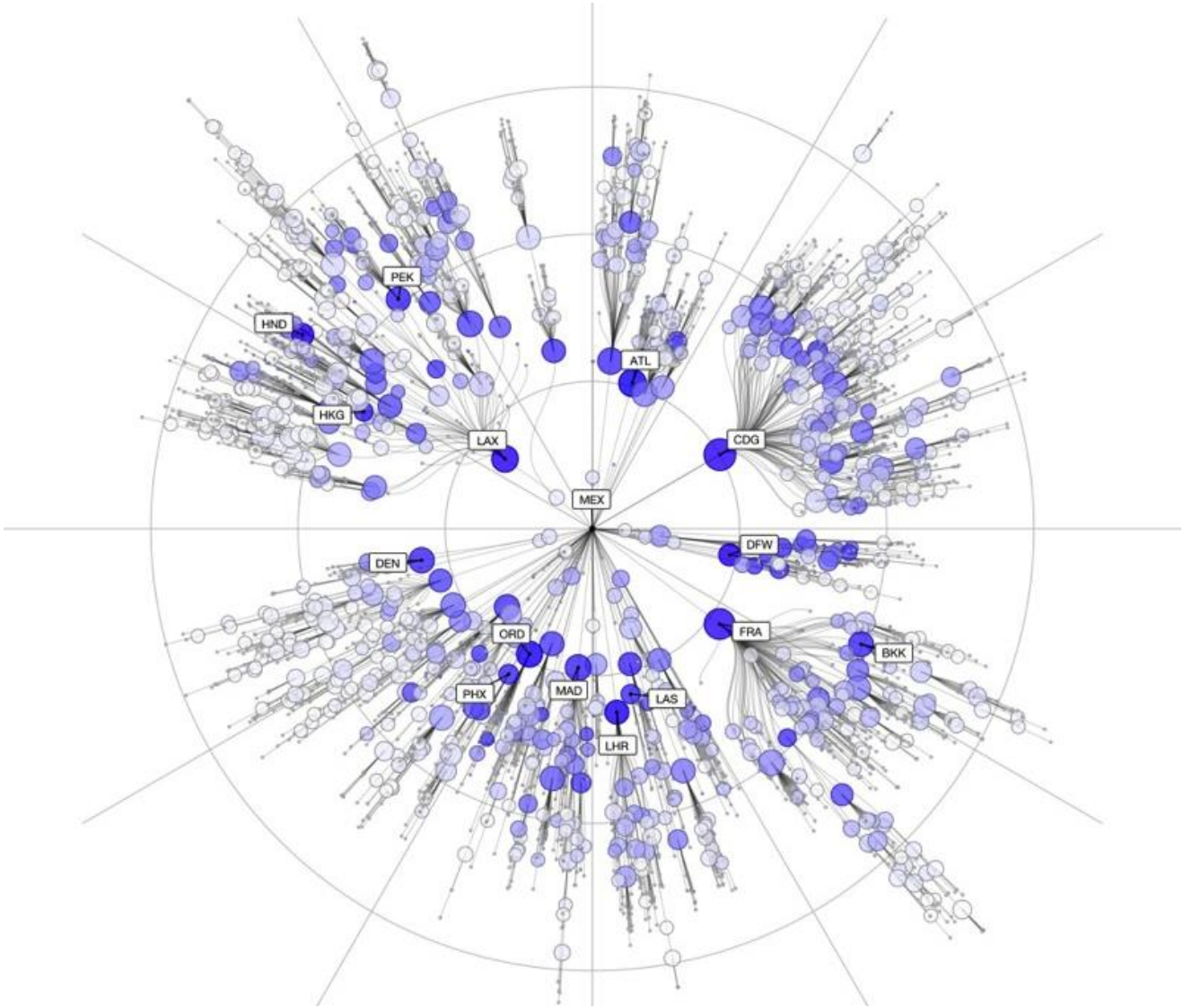
Costanzo et al. ,2010

Network of Diseases



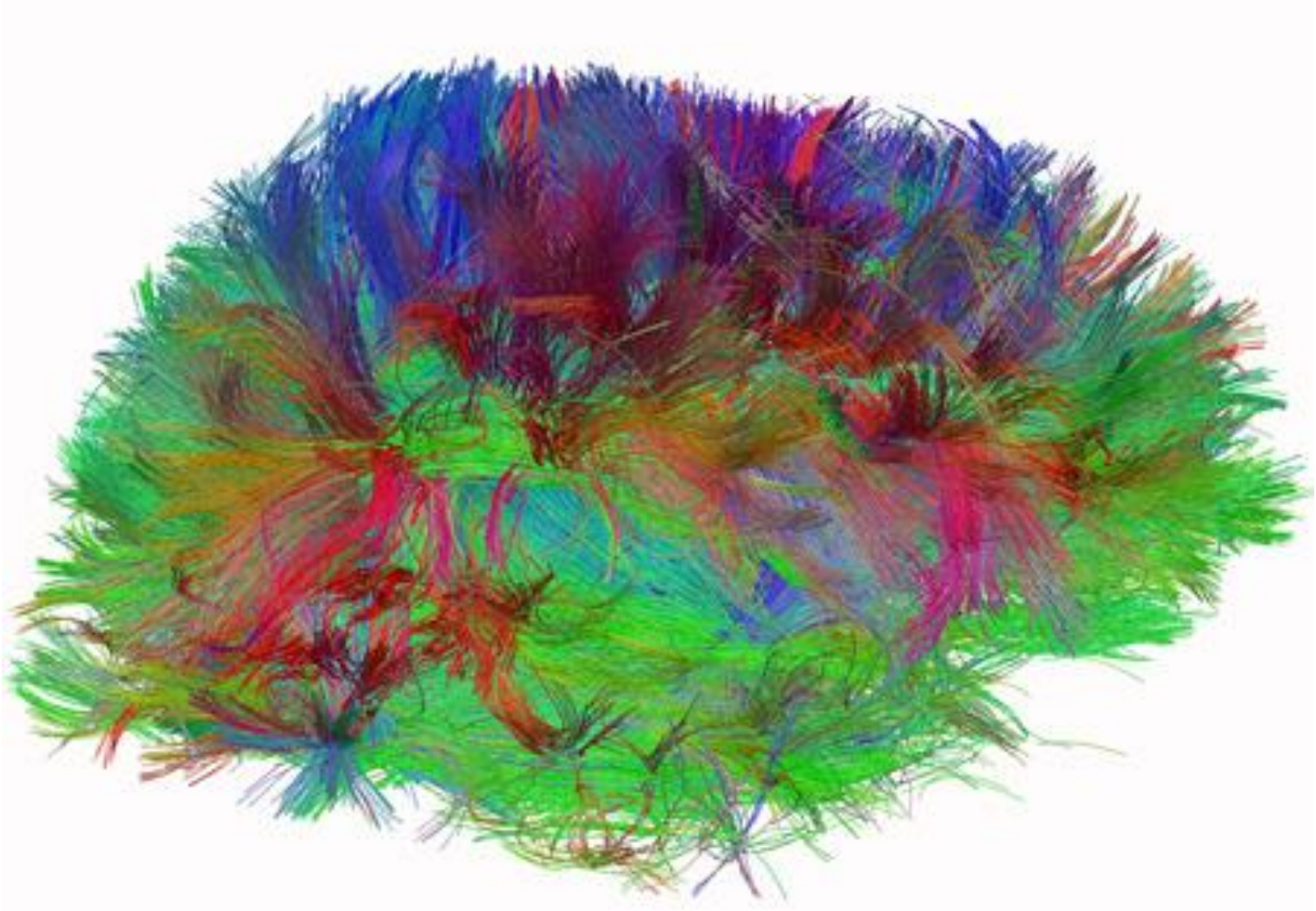
Goh et al., 2007

Network of Disease Propagation



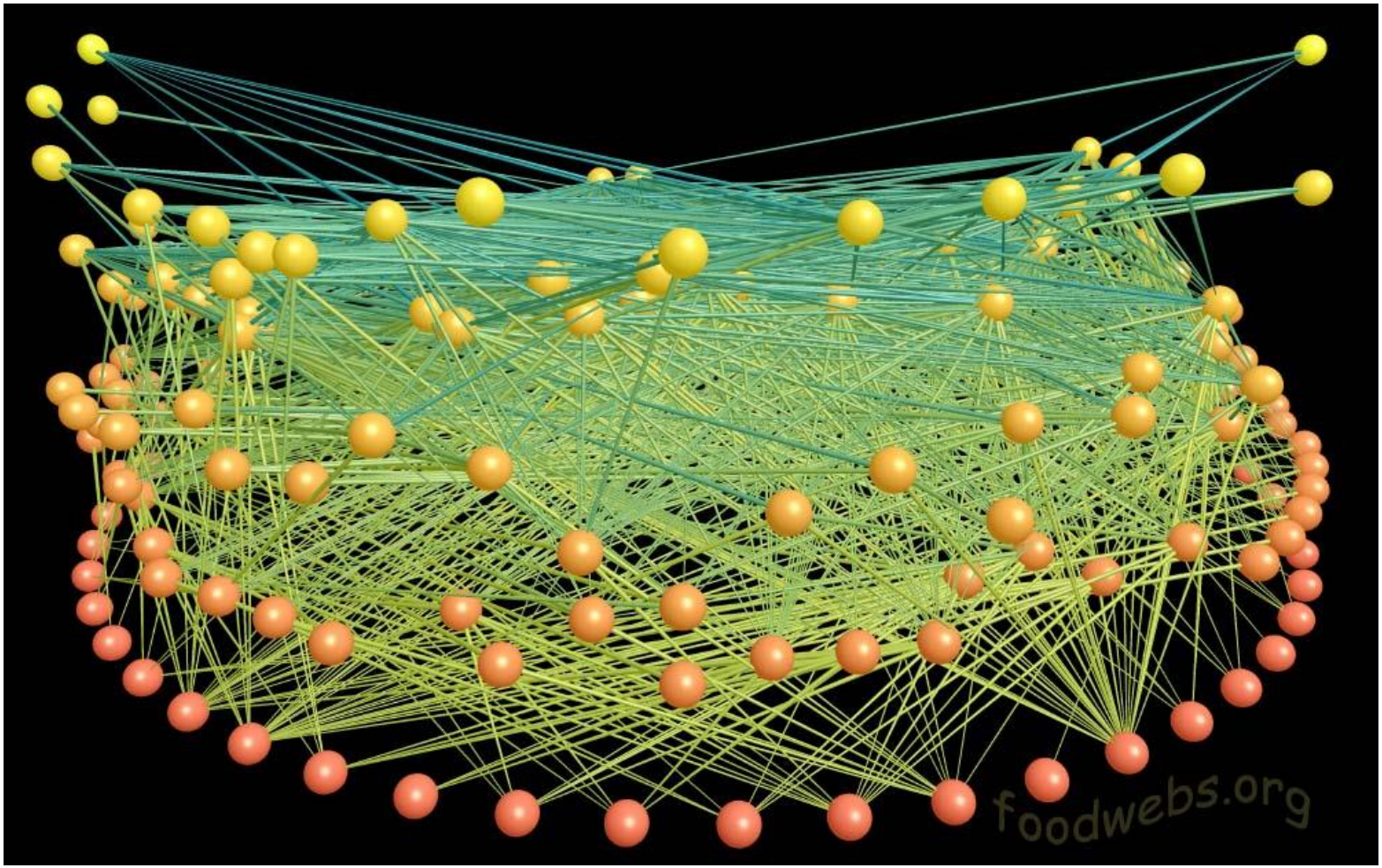
H1N1 activities illustrated according to distance from MEX airport (Brockmann, 2013)

Network of the Brain



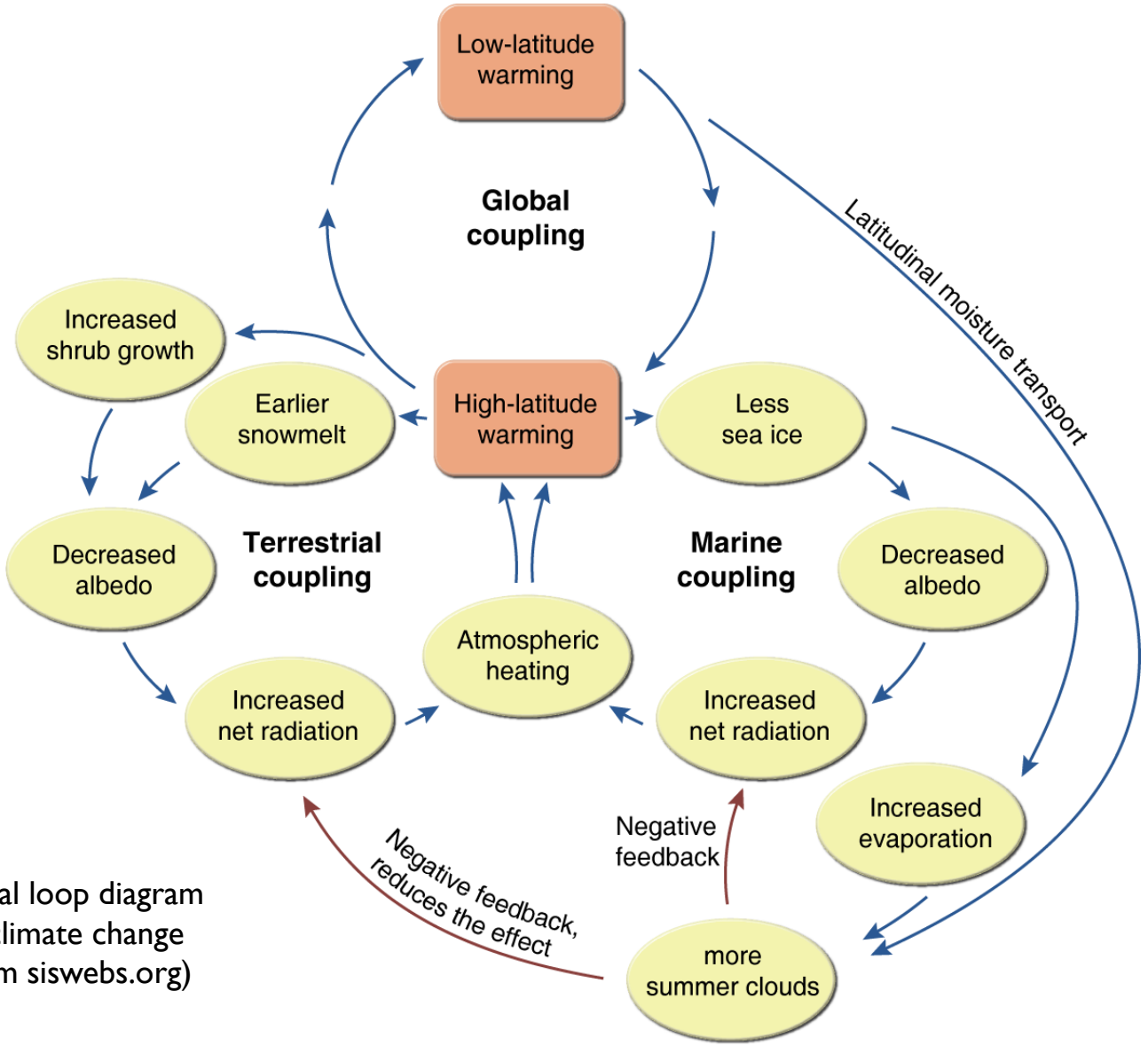
Van J. Wedeen, M.D., MGH/Harvard U.

Food Webs



Food web in El Verde Rainforest, Puerto Rico by J. Dunne (from foodwebs.org)

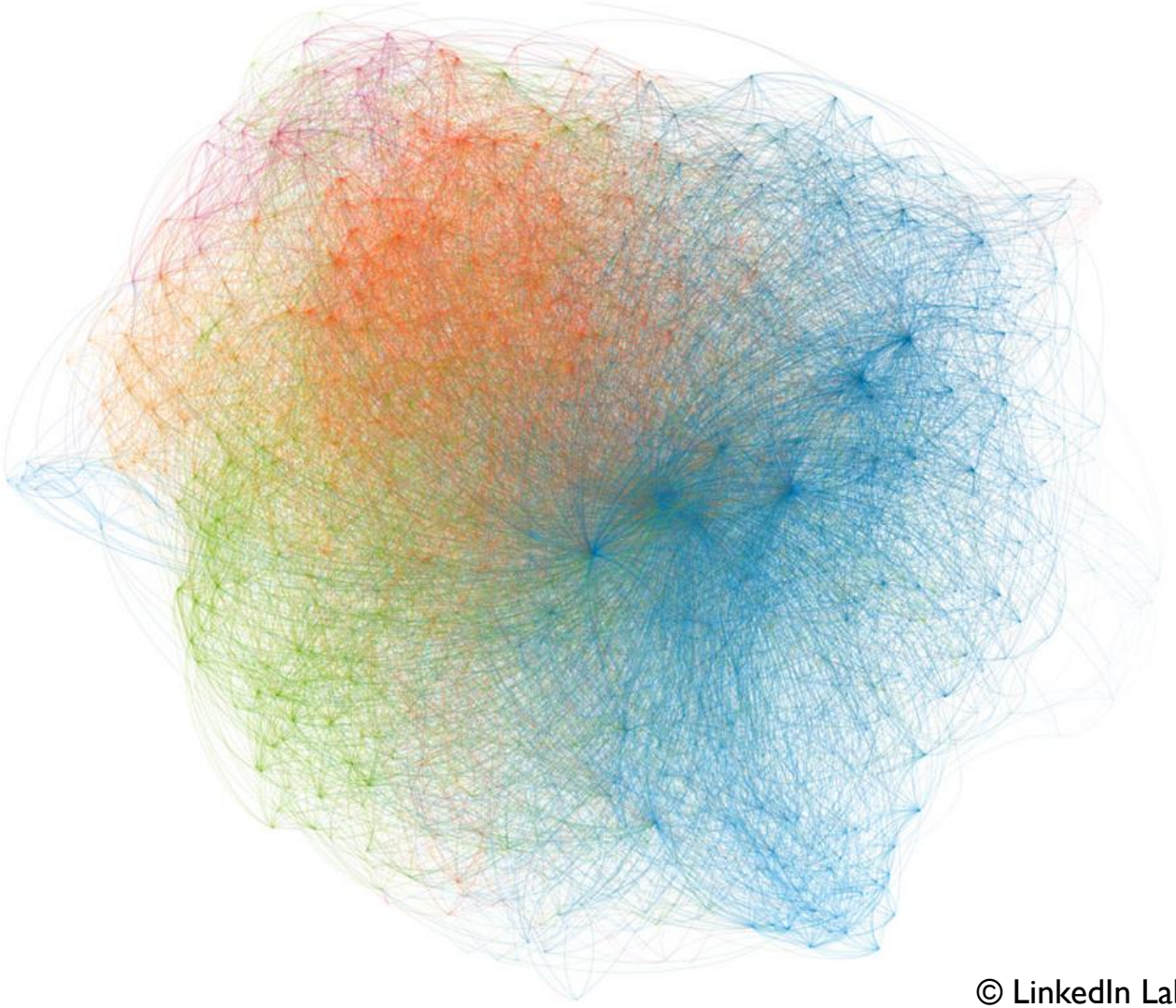
Causal Loop Diagram



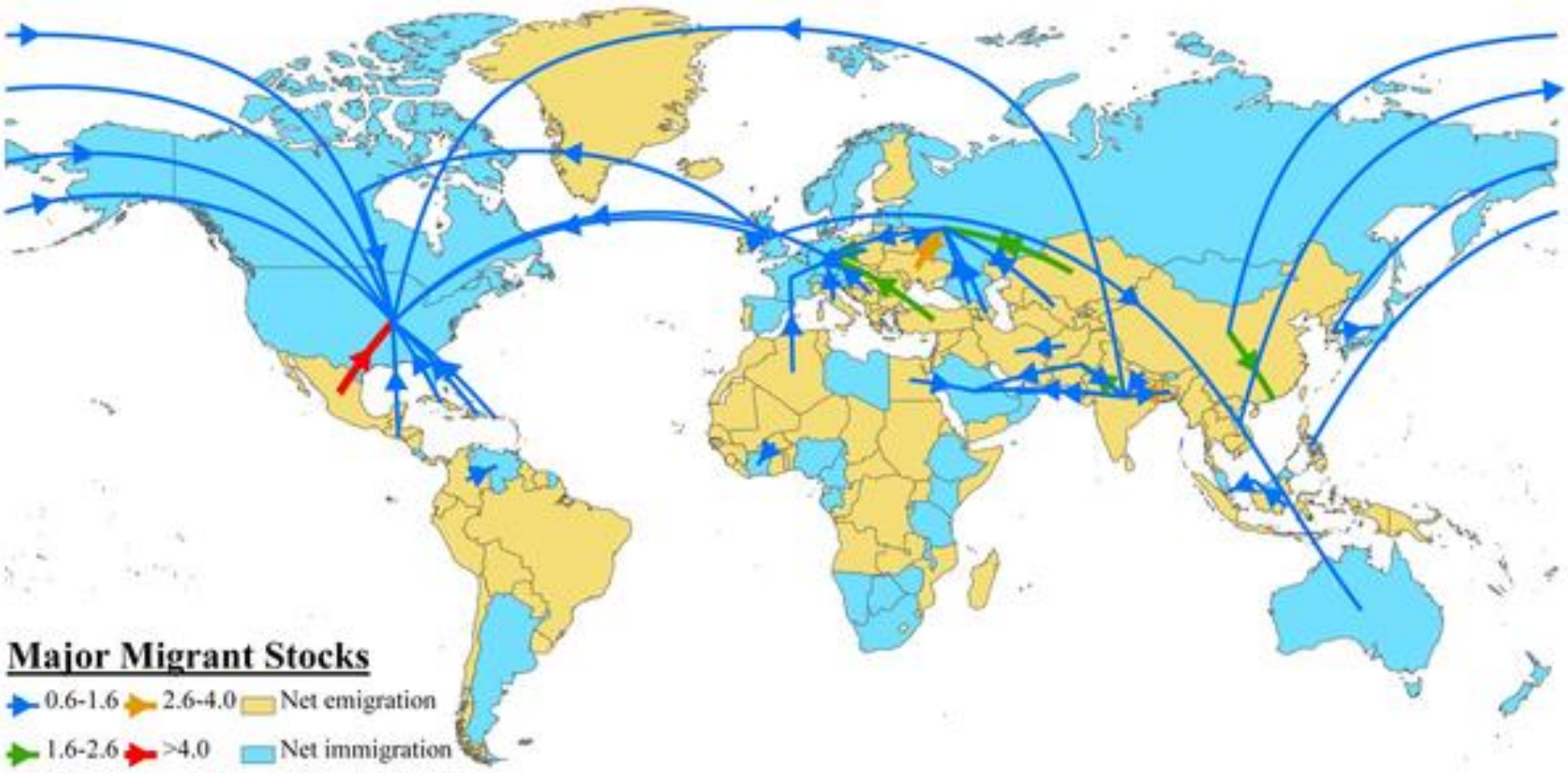
Causal loop diagram of climate change (from siswebs.org)

Networks in Social Studies

Network of People Around You

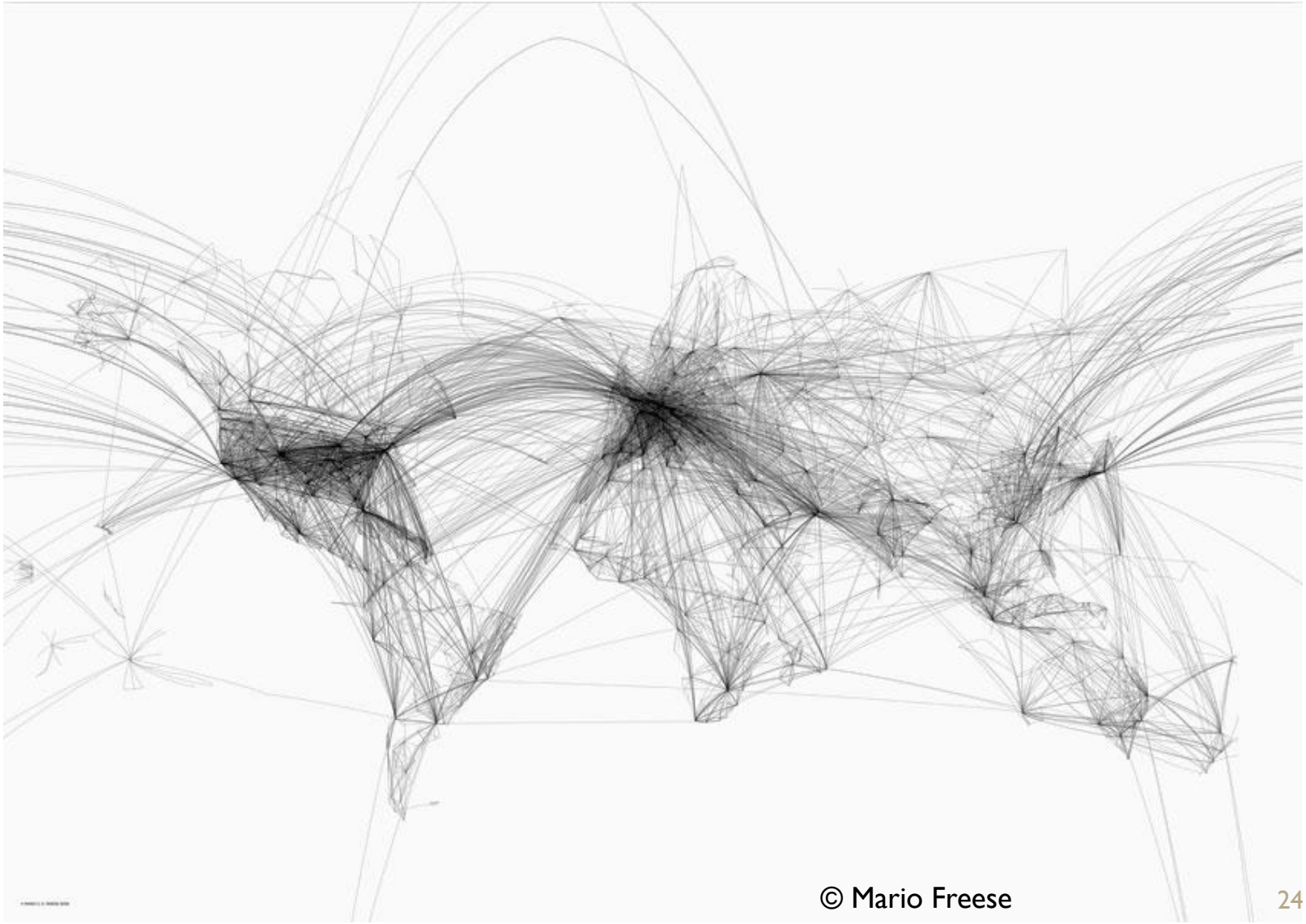


Network of Human Migration

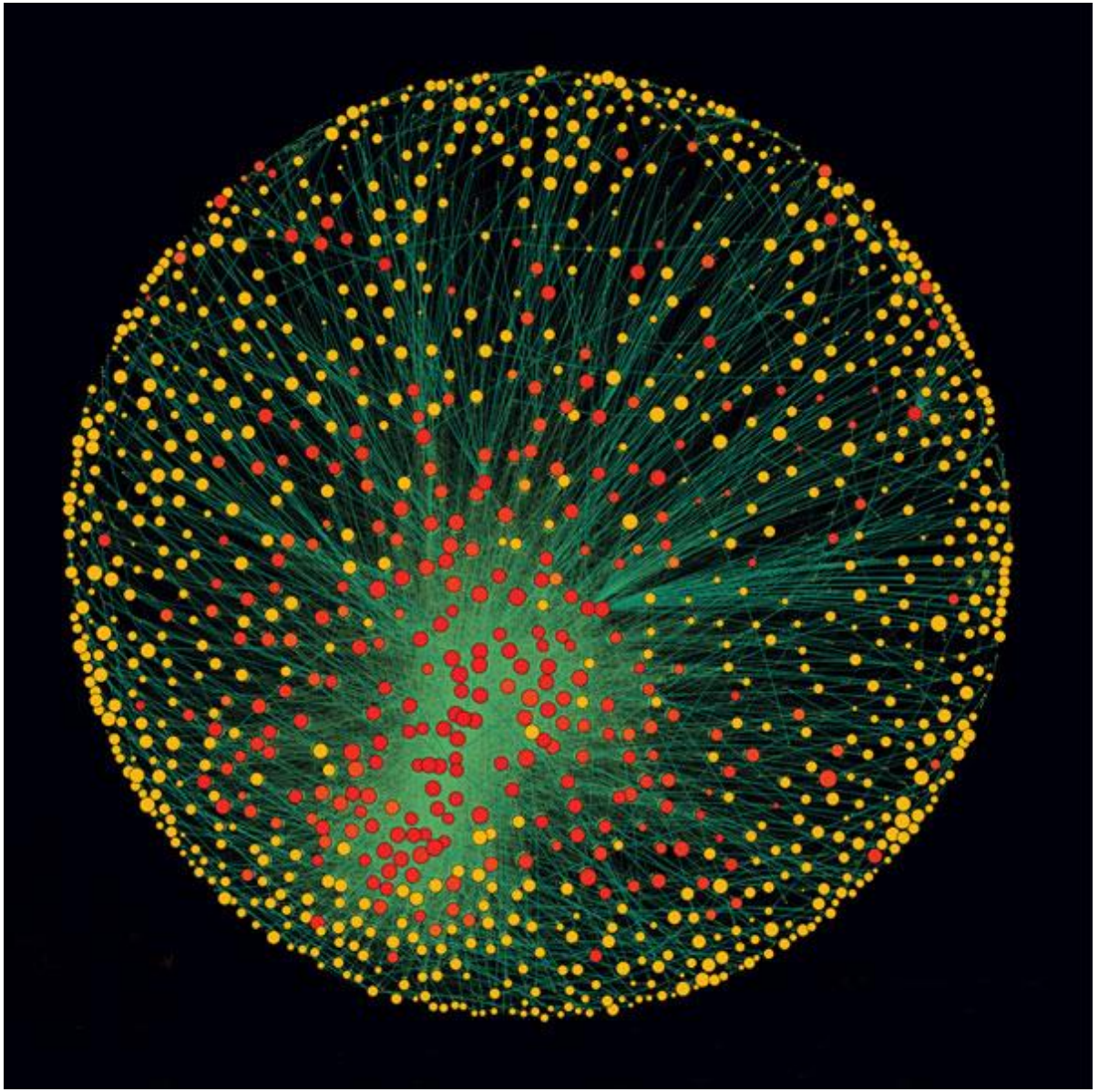


Davis et al., 2013

Network of Air Transportation

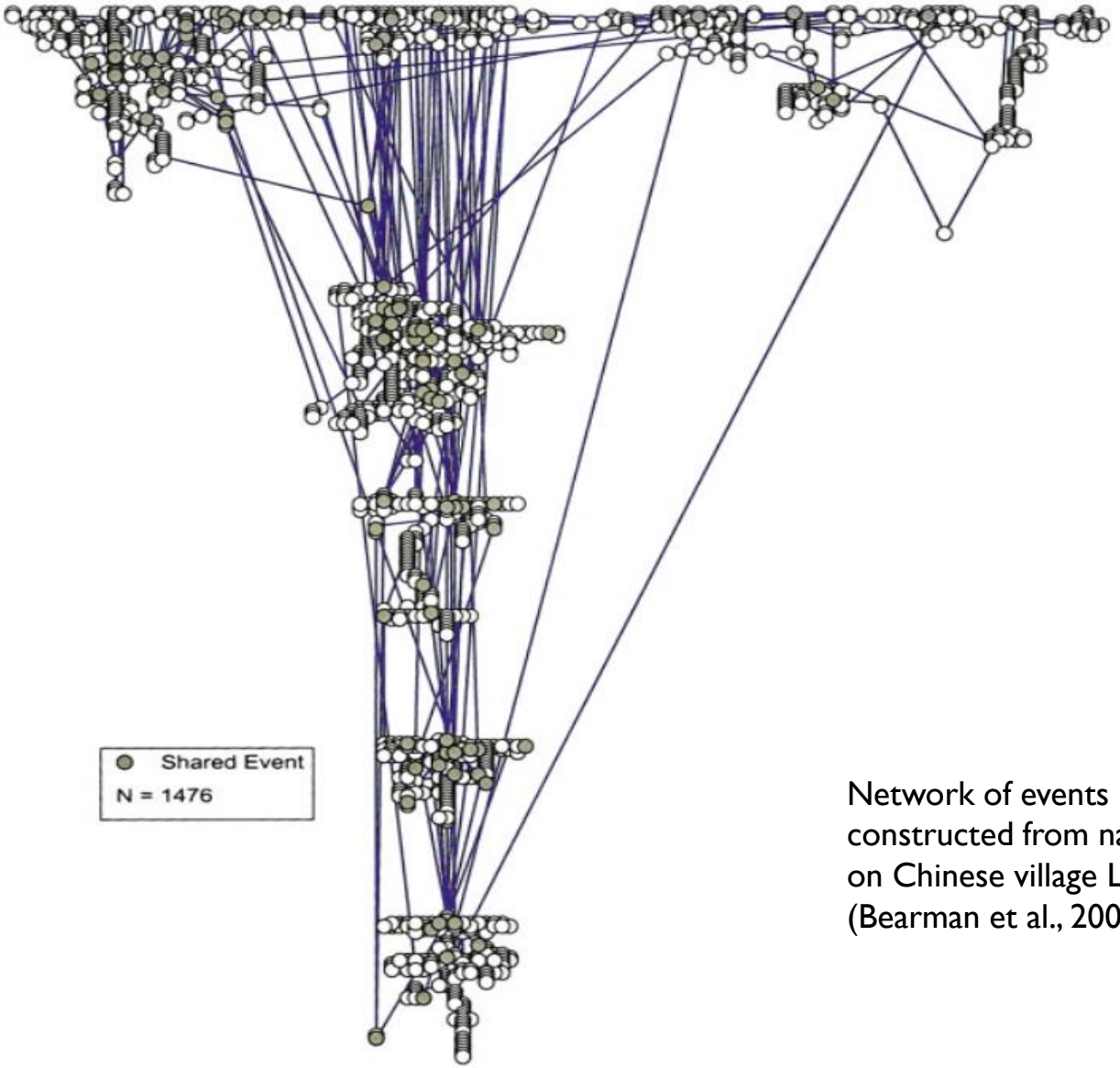


Network of Corporations



Vitali et al., 2011

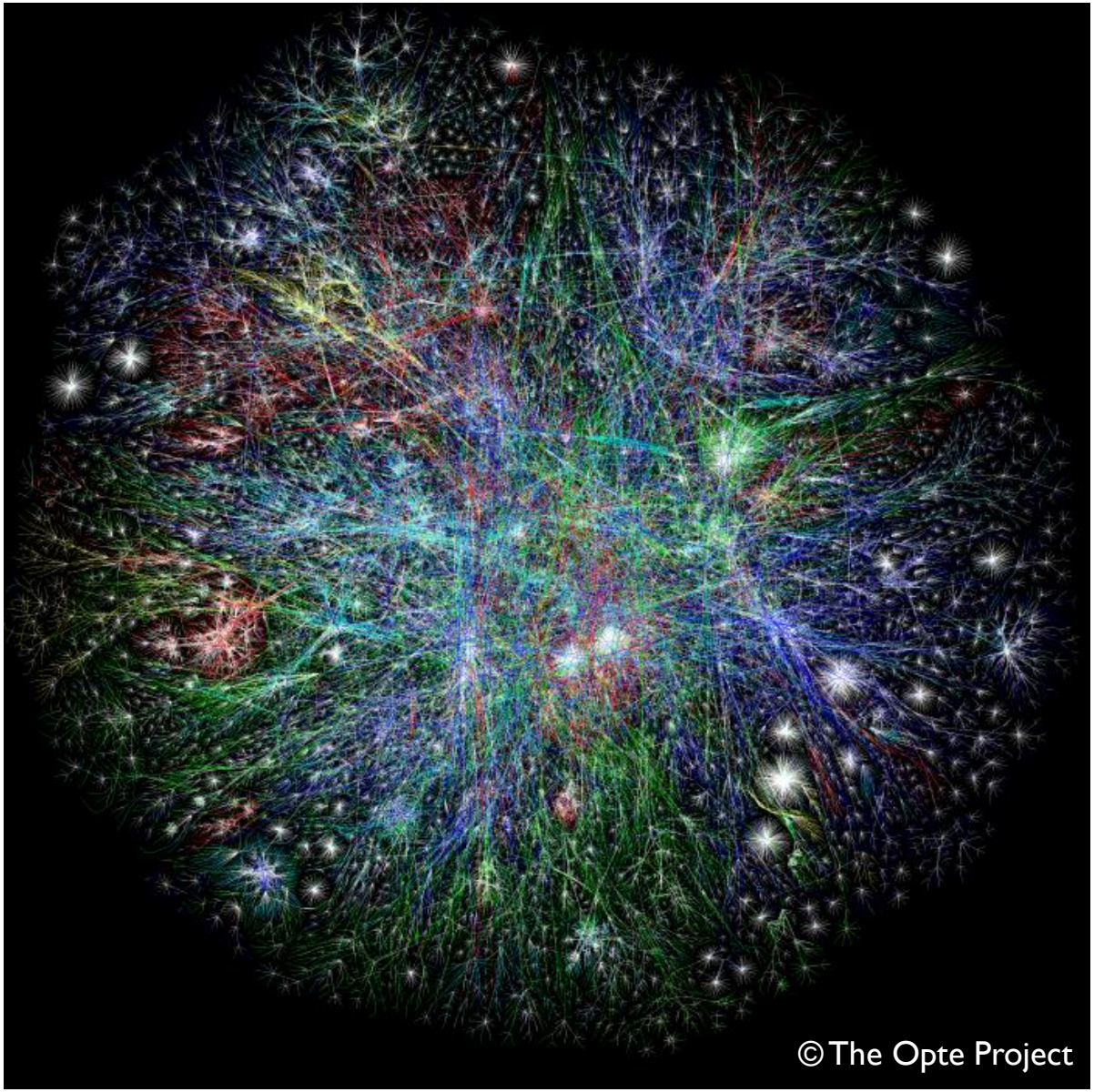
Network of Historical Events



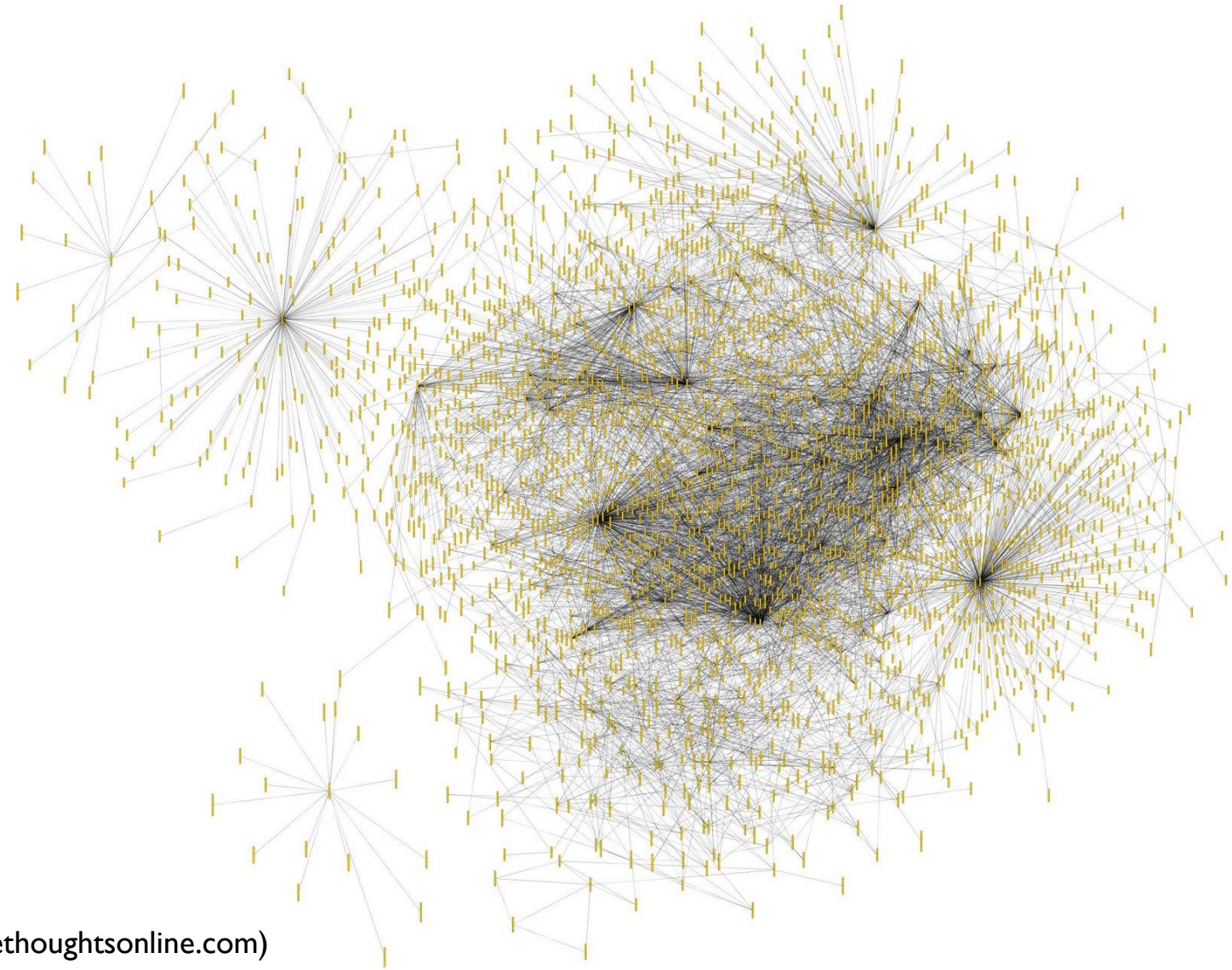
Network of events constructed from narratives on Chinese village Liu Ling (Bearman et al., 2003)

Networks in Technology

The Internet



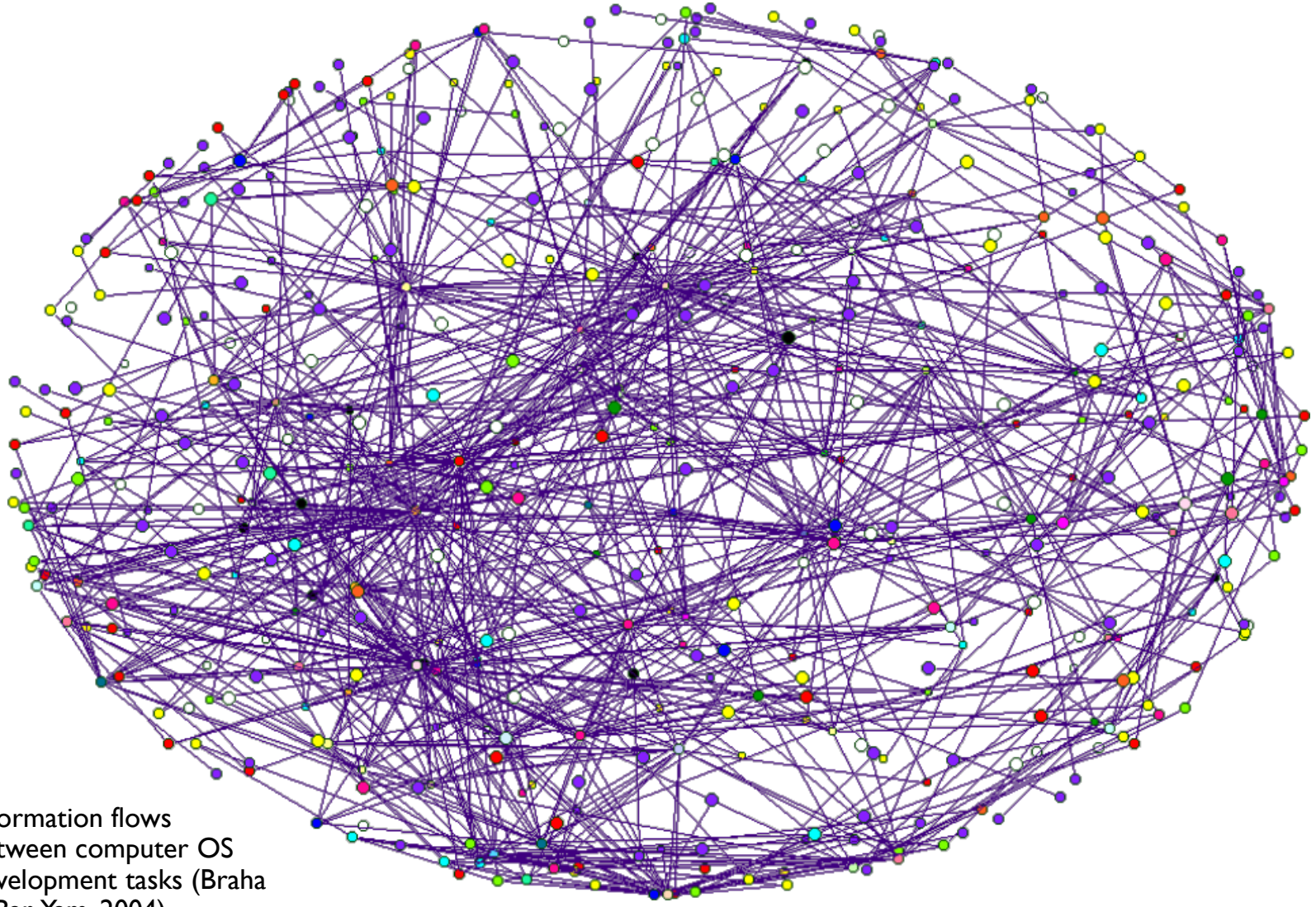
Network of Java Classes



Cavlin, 2012

(from simplethoughtsonline.com)

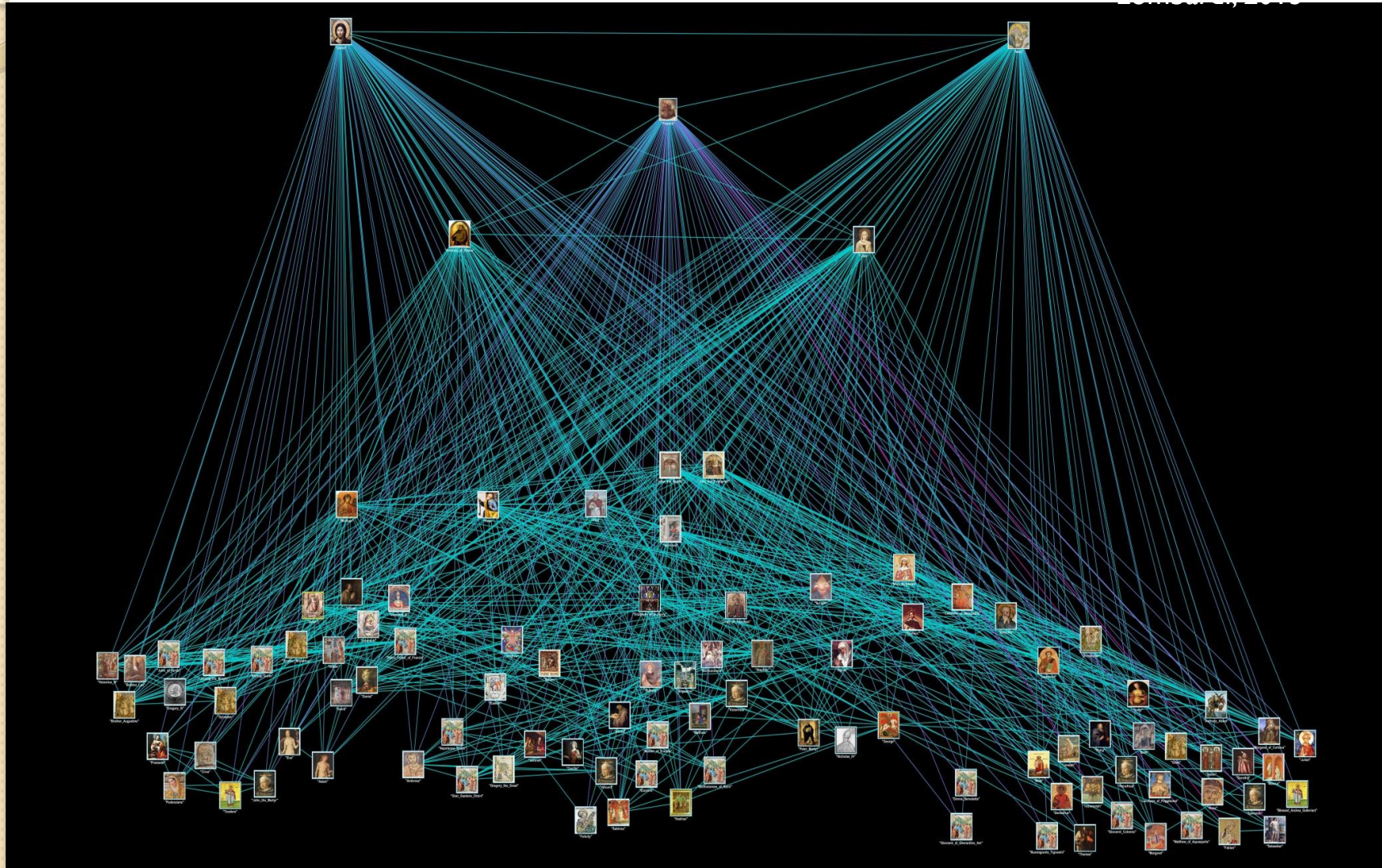
Network of Product Design



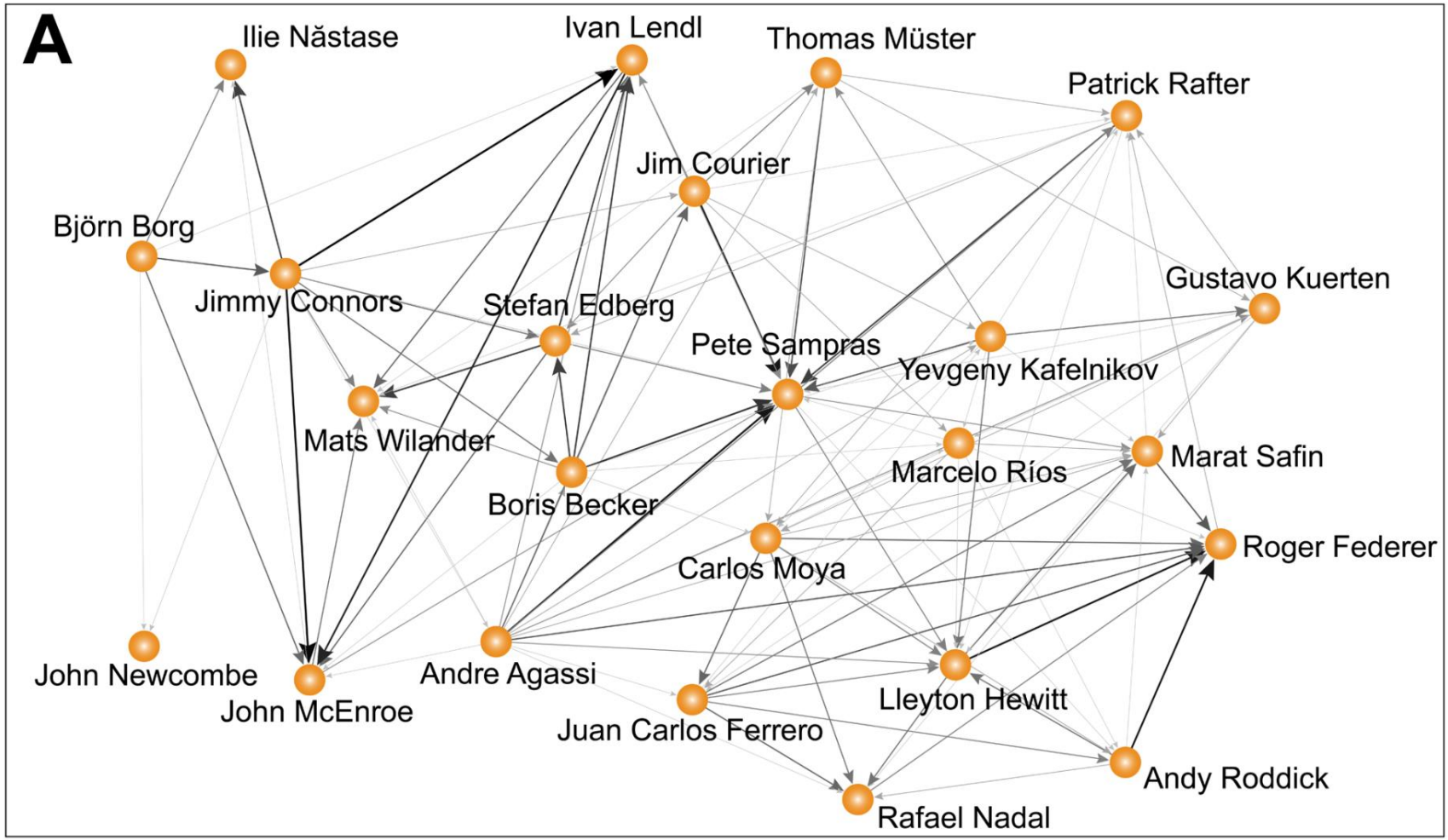
Information flows between computer OS development tasks (Braha & Bar-Yam, 2004)

Networks in Other Disciplines

Network of Saints in Iconography



Network of Top Tennis Players

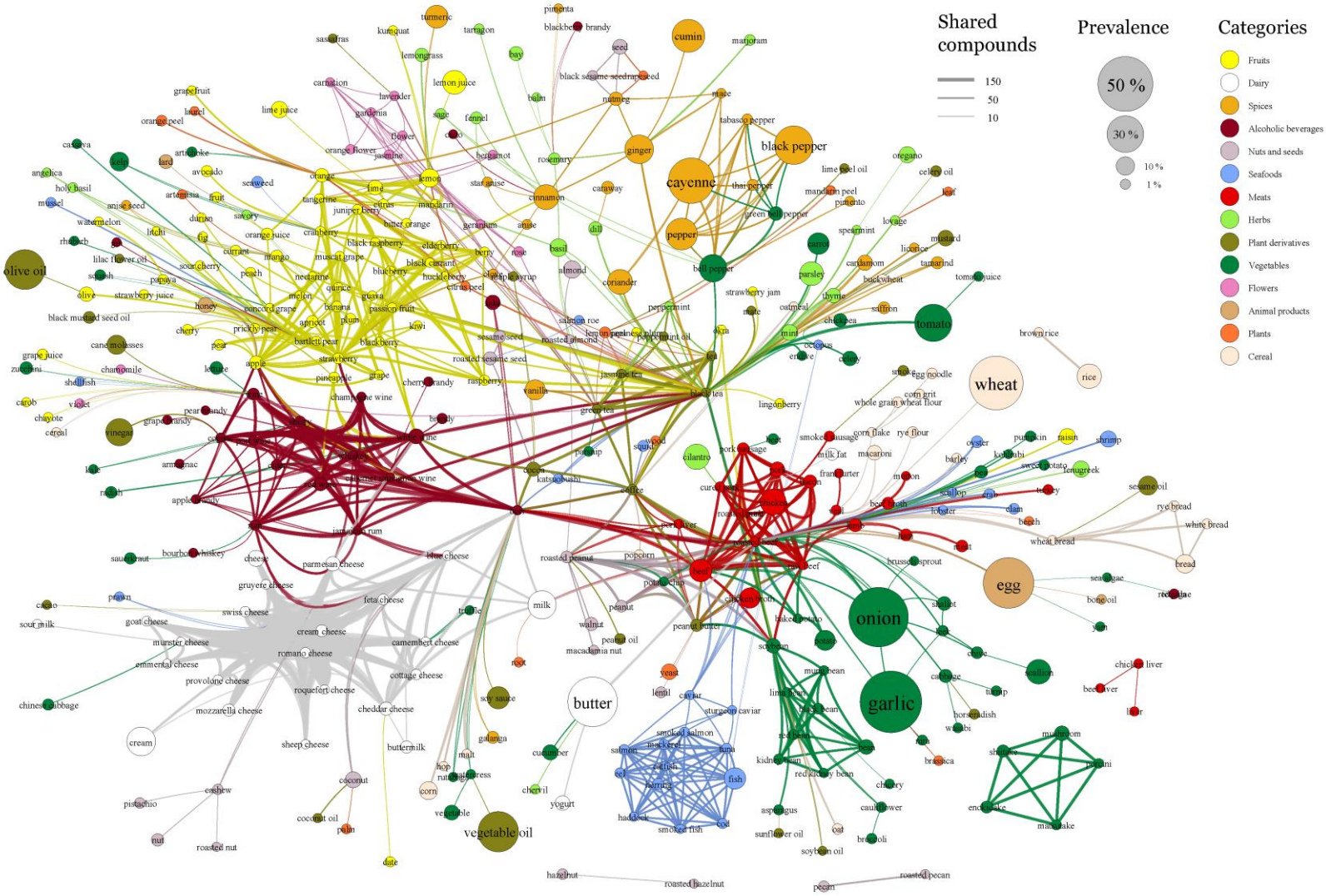


Radicchi, 2011

Flavor Network

Yong-Yeol Ahn, Sebastian Ahnert, James P. Bagrow, and A.-L. Barabási

"Flavor network and the principles of food pairing", *Scientific Reports* **1**, 196 (2011)



Flavor network. Culinary ingredients (circles) and their chemical relationship are illustrated. The color of each ingredient represents the food category that the ingredient belongs to, and the size of an ingredient is proportional to the usage frequency (collected from online recipe databases: epicurious.com, allrecipes.com, menupan.com). Two culinary ingredients are connected if they share many flavor compounds. We extracted the list of flavor compounds in each ingredient from the book "Fenaroli's handbook of flavor ingredients (5th ed.)" and then applied a backbone extraction method by Serrano et al. (*PNAS* **106**, 6483) to pick statistically significant links between ingredients. The thickness of an edge represents the number of shared flavor compounds. To reduce clutter, edges are bundled based on the algorithm by Danny Holten (http://www.win.tue.nl/~dholten/).

Take-Home Message

- Anything can be understood as a network if you pay attention to "**connections**" among things