Network Science

Class 1: Introduction (Ch1 in Textbook)

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With

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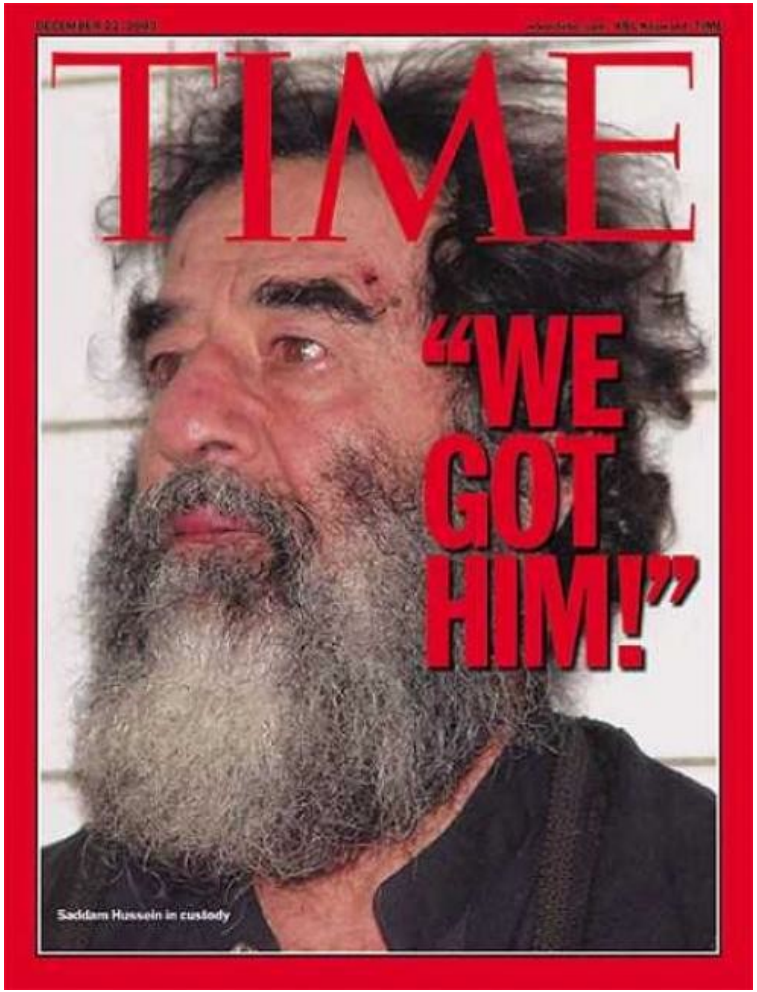
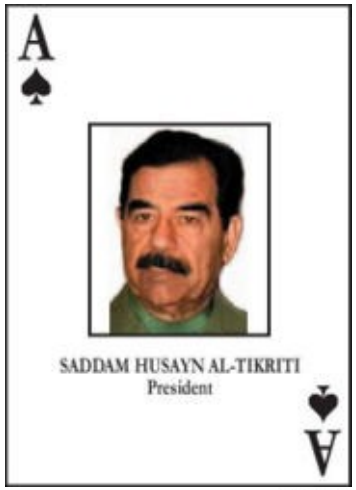
www.BarabasiLab.com/course

FROM SADDAM HUSSEIN TO NETWORK THEORY

A SIMPLE STORY (1) The fate of Saddam and network science





A SIMPLE STORY (1) The fate of Saddam and network science

The capture of Saddam Hussein:

→shows the strong predictive power of networks.

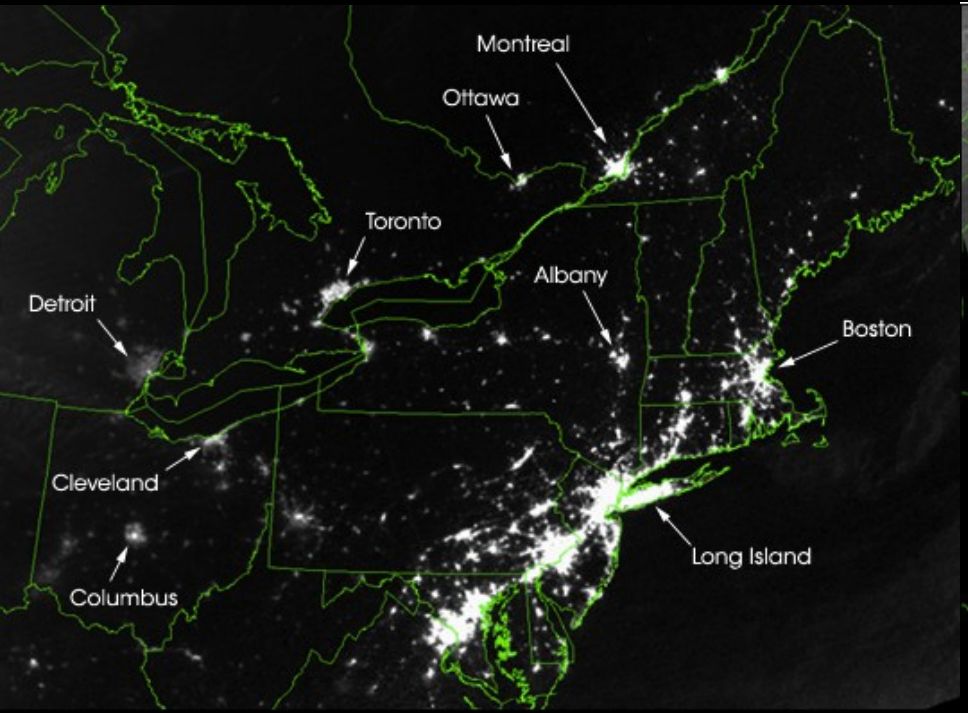
→ underlies the need to obtain accurate maps of the networks we aim to study; and the often heroic difficulties we encounter during the mapping process.

→ demonstrates the remarkable stability of these networks: The capture of Hussein was not based on fresh intelligence, but rather on his pre-invasion social links, unearthed from old photos stacked in his family album.

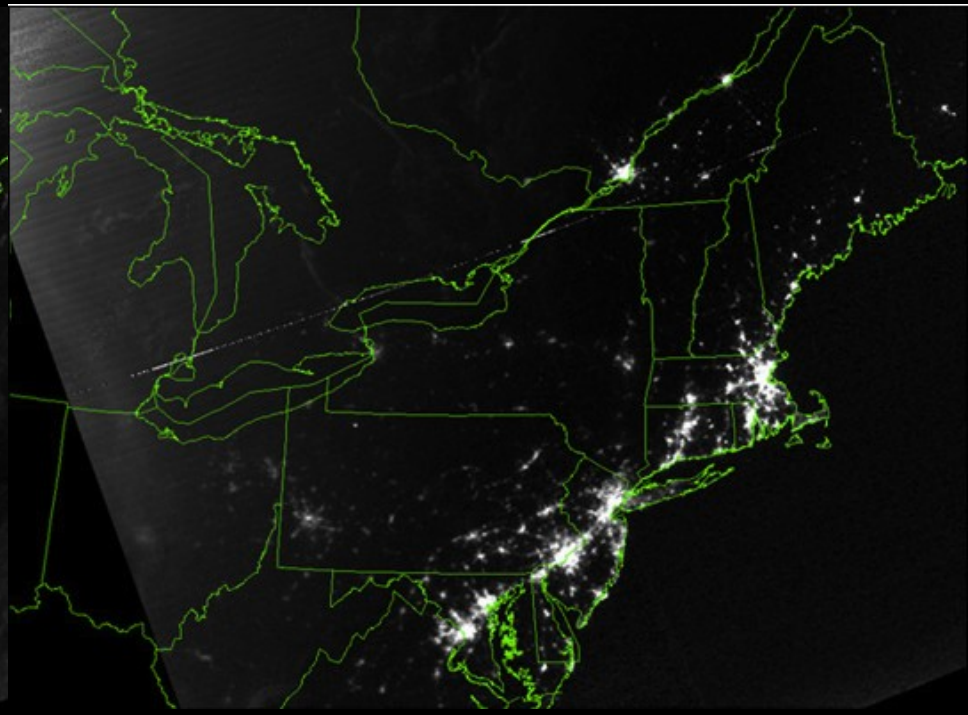
→ shows that the choice of network we focus on makes a huge difference: the hierarchical tree, that captured the official organization of the Iraqi government, was of no use when it came to Saddam Hussein's whereabouts.

VULNERABILITY DUE TO INTERCONNECTIVITY

A SIMPLE STORY (2): August 15, 2003 blackout.



August 14, 2003: 9:29pm EDT
20 hours before



August 15, 2003: 9:14pm EDT
7 hours after

A SIMPLE STORY (2): August 15, 2003 blackout.

An important theme of this class:

→ we must understand how network structure affects the robustness of a complex system.

→ develop quantitative tools to assess the interplay between network structure and the dynamical processes on the networks, and their impact on failures.

→We will learn that reality failures follow reproducible laws, that can be quantified and even predicted using the tools of network science.

NETWORKS AT THE HEART OF COMPLEX SYSTEMS


"I think the next century
will be the century
of complexity."
Stephen Hawking
January 23, 2000`

Complex

[adj., v. kuh m-pleks, kom-pleks; n. kom-pleks]

–adjective

1. composed of many interconnected parts; compound; composite: a complex highway system.
2. characterized by a very complicated or involved arrangement of parts, units, etc.: complex machinery.
3. so complicated or intricate as to be hard to understand or deal with: a complex problem.

Source: Dictionary.com

Complexity

Complexity, a **scientific theory** which asserts that some systems display behavioral phenomena that are completely inexplicable by any conventional analysis of the systems' constituent parts. These phenomena, commonly referred to as emergent behaviour, seem to occur in many complex systems involving living organisms, such as a stock market or the human brain.

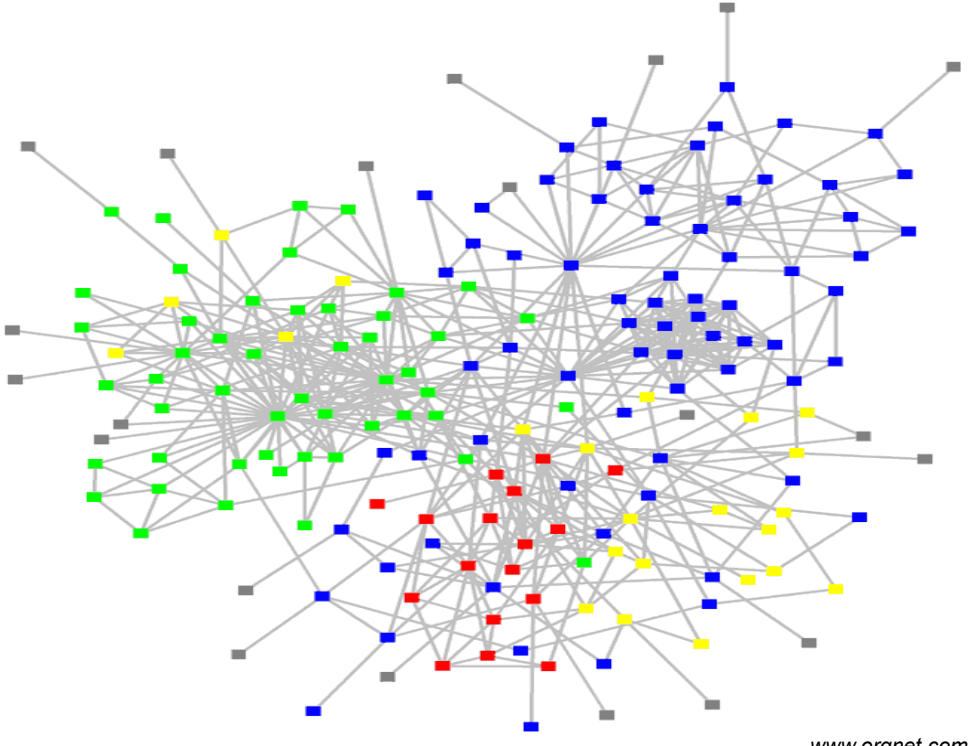
Source: John L. Casti, Encyclopædia Britannica

Behind each complex system there is a **network**, that defines the interactions between the components.

The “Social Graph” behind Facebook

Keith Shepherd's "Sunday Best”. http://baseballart.com/2010/07/shades-of-greatness-a-story-that-needed-to-be-told/

STRUCTURE OF AN ORGANIZATION

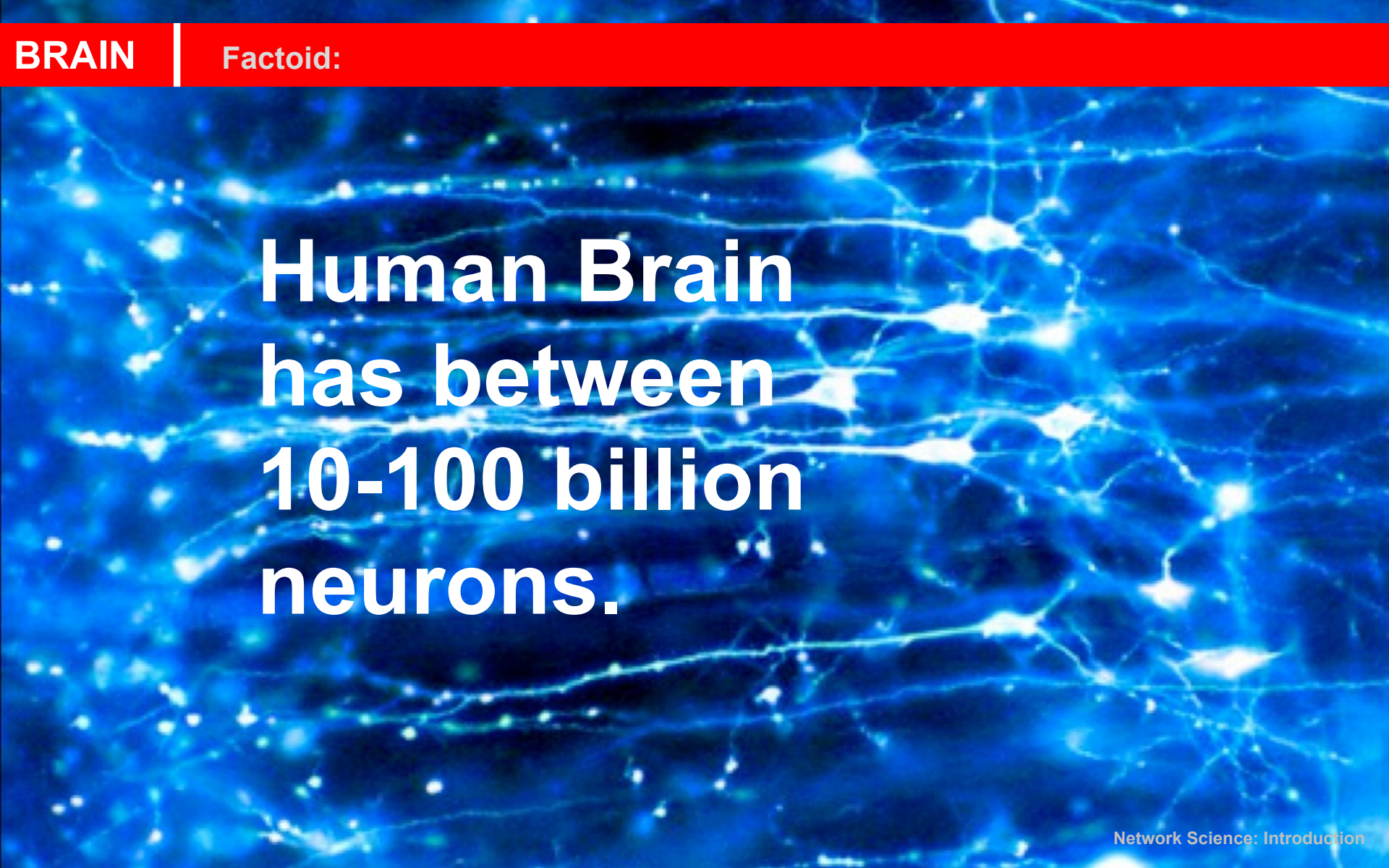


www.orgnet.com

: departments

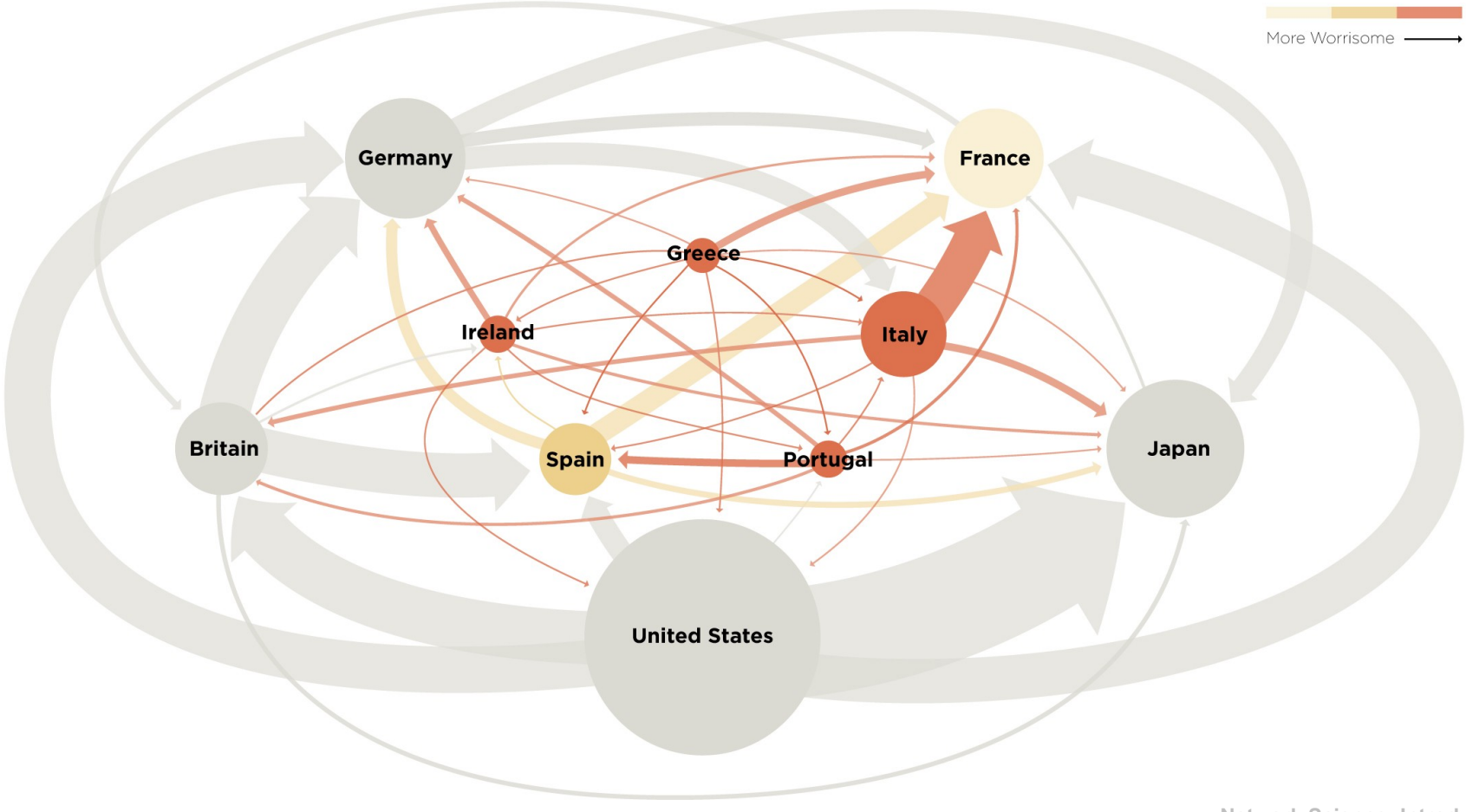
: consultants

: external experts


Human Brain
has between
10-100 billion
neurons.

The subtle financial networks

The not so subtle financial networks: 2011



ECONOMY | Factoid:

The world economy produced goods and services worth almost $55 trillion in 2005.
(http://siteresources.worldbank.org/ICPINT/Resources/ICPreportprelim.pdf)

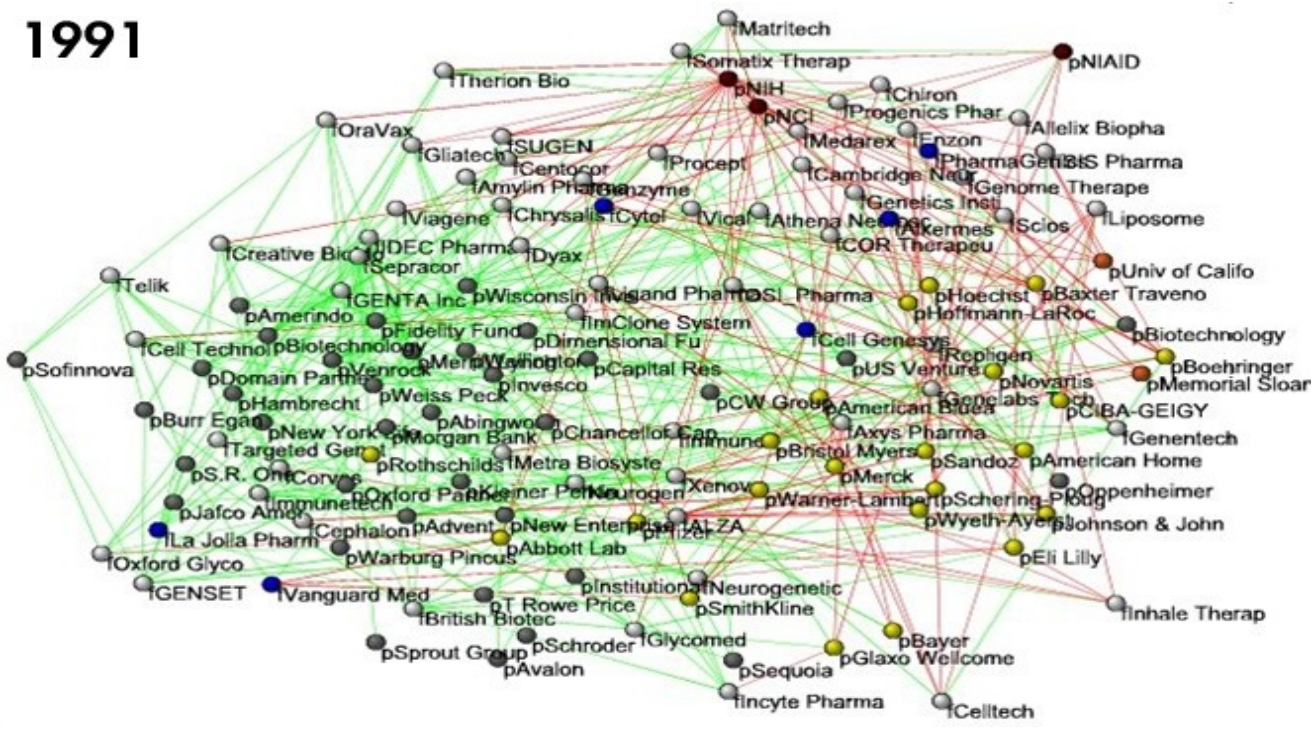
BUSINESS TIES IN US BIOTECH-INDUSTRY

Nodes:

- Companies
- Investment
- Pharma
- Research Labs
- Public
- Biotechnology

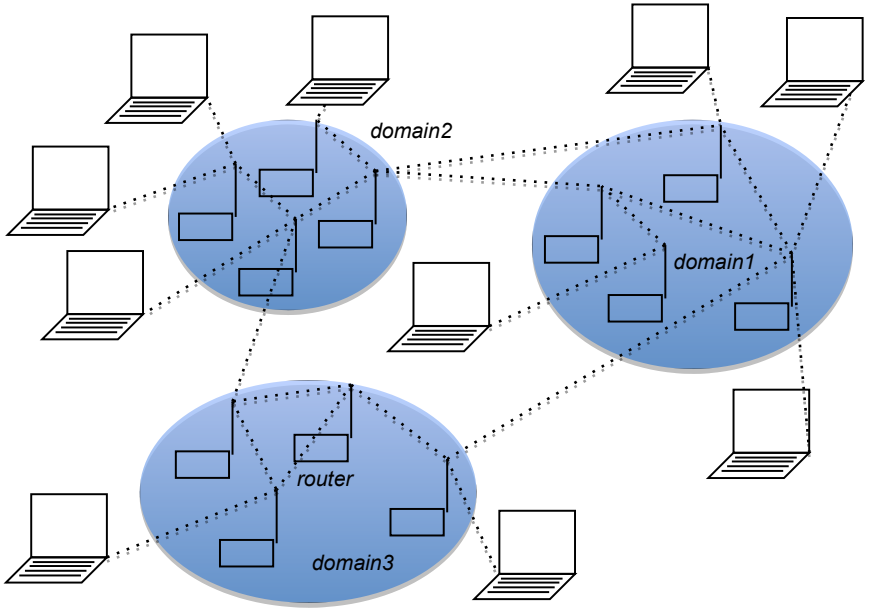
Links:

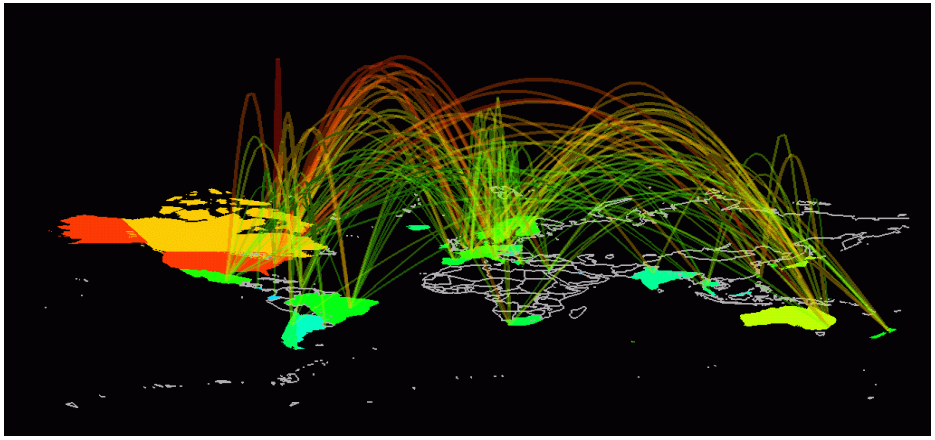
- Collaborations
- Financial
- R&D

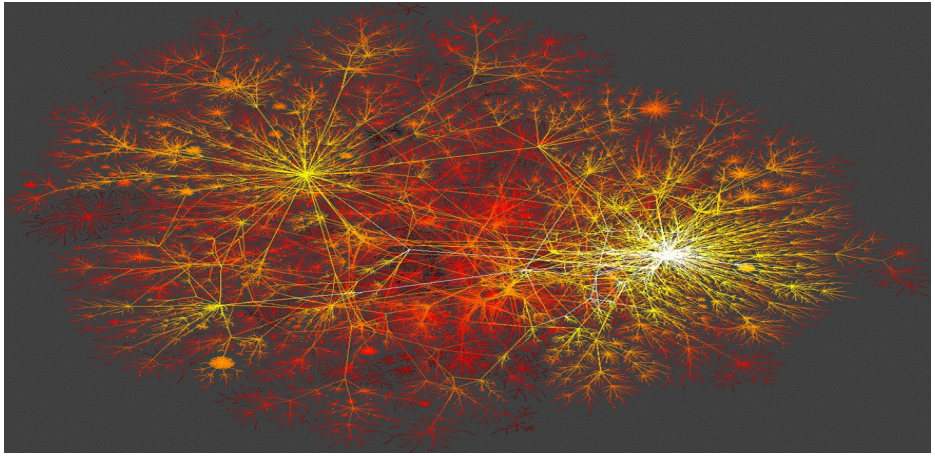


http://ecclectic.ss.uci.edu/~drwhite/Movie

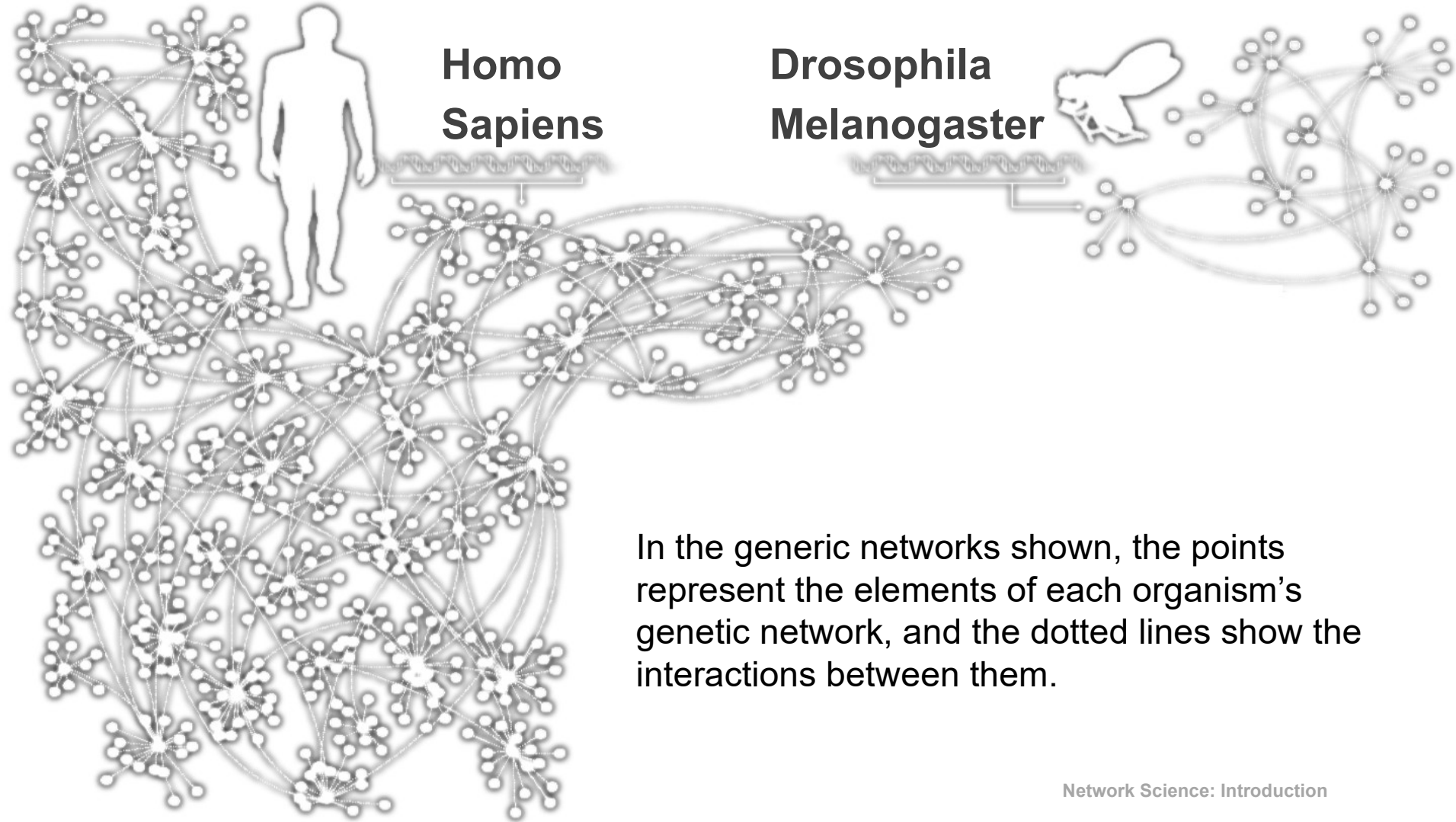
INTERNET





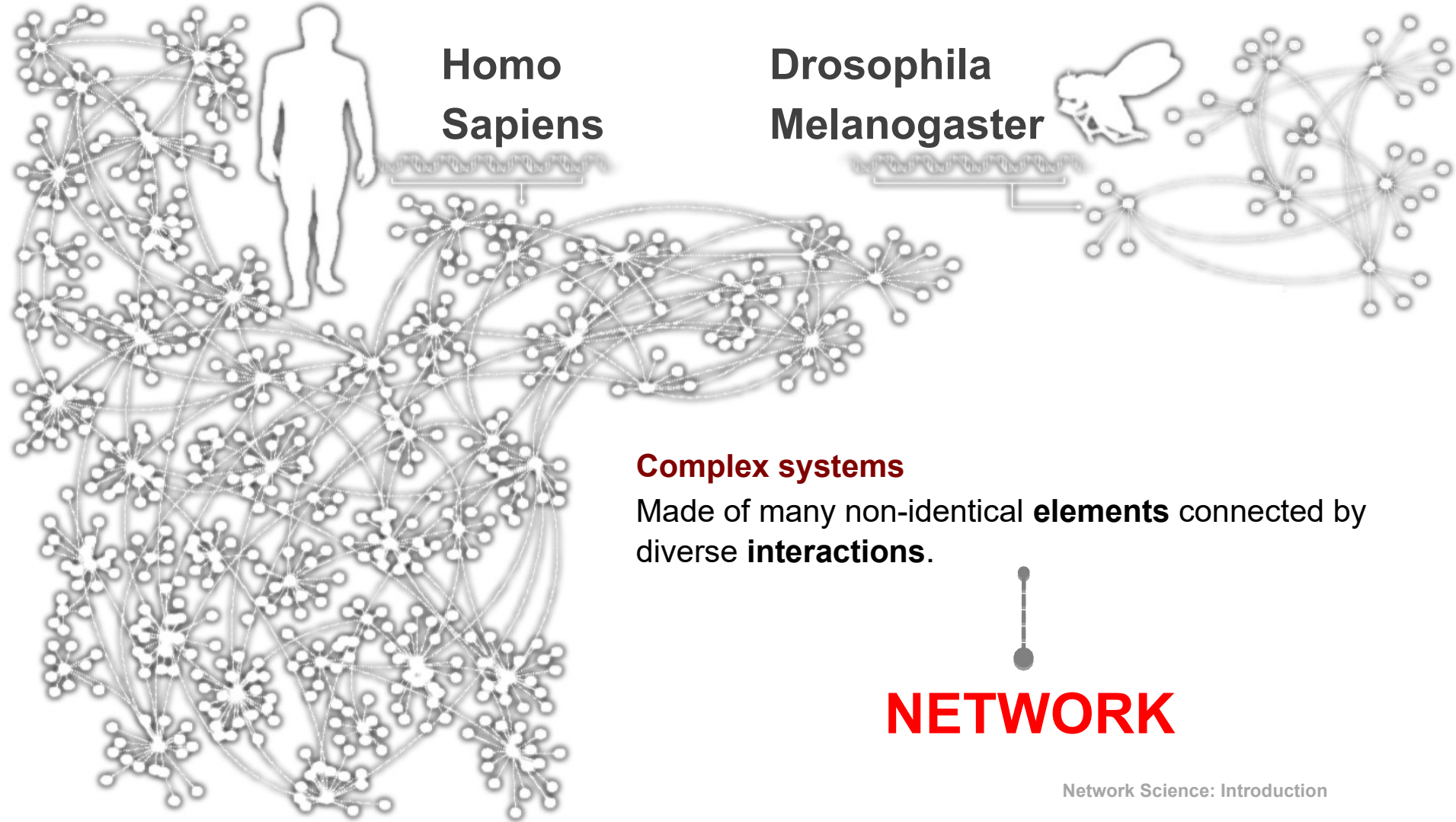


HUMANS GENES



In the generic networks shown, the points represent the elements of each organism's genetic network, and the dotted lines show the interactions between them.

HUMANS GENES



Complex systems

Made of many non-identical **elements** connected by diverse **interactions**.

NETWORK

THE ROLE OF NETWORKS

Behind each system studied in complexity there is an intricate wiring diagram, or a **network**, that defines the interactions between the component.

We will never understand complex system unless we map out and understand the networks behind them.

TWO FORCES HELPED THE EMERGENCE OF NETWORK SCIENCE

THE HISTORY OF NETWORK ANALYSIS

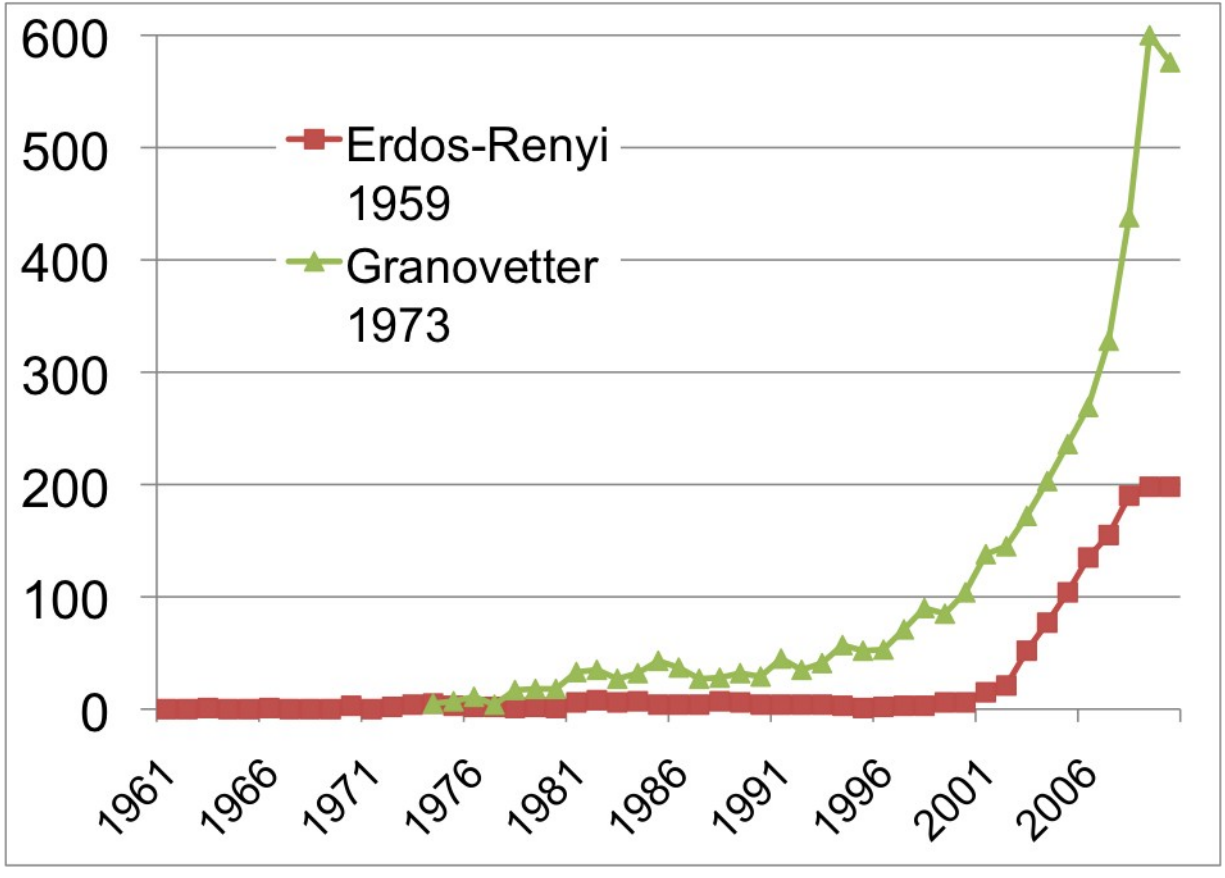
Graph theory: 1735, Euler

Social Network Research: 1930s, Moreno

Communication networks/internet: 1960s

Ecological Networks: May, 1979.

THE HISTORY OF NETWORK ANALYSIS



The emergence of network maps:

Movie Actor Network, 1998;
World Wide Web, 1999.
C elegans neural wiring diagram 1990
Citation Network, 1998
Metabolic Network, 2000;
PPI network, 2001

The universality of network characteristics:

The architecture of networks emerging in various domains of science, nature, and technology are more similar to each other than one would have expected.

THE CHARACTERISTICS OF NETWORK SCIENCE

THE CHARACTERISTICS OF NETWORK SCIENCE

Interdisciplinary

Empirical

Quantitative and Mathematical

Computational

THE CHARACTERISTICS OF NETWORK SCIENCE

Interdisciplinary

Empirical, data driven

Quantitative and Mathematical

Computational

THE CHARACTERISTICS OF NETWORK SCIENCE

Interdisciplinary

Empirical

Quantitative and Mathematical

Computational

THE CHARACTERISTICS OF NETWORK SCIENCE

Interdisciplinary

Empirical

Quantitative and Mathematical

Computational

THE IMPACT OF NETWORK SCIENCE

ECONOMIC IMPACT

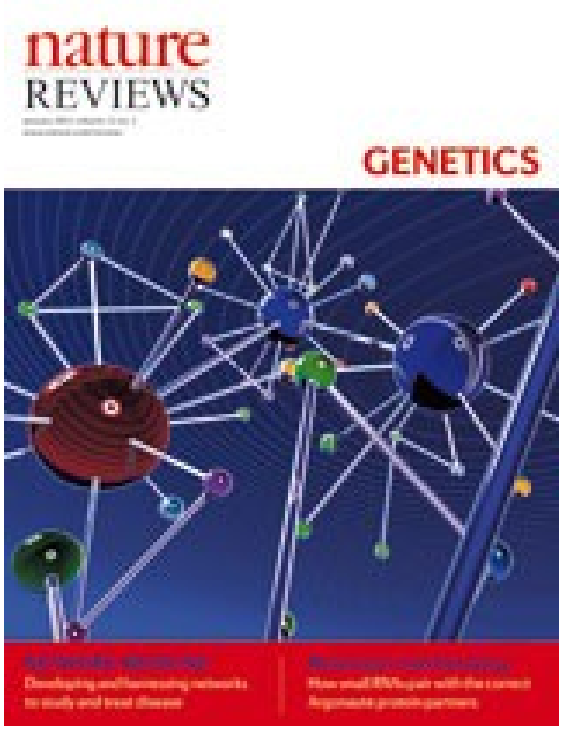
Google
Market Cap(Jan 1, 2010):
$189 billion

Cisco Systems
networking gear Market cap (Jan 1, 2010):
$112 billion

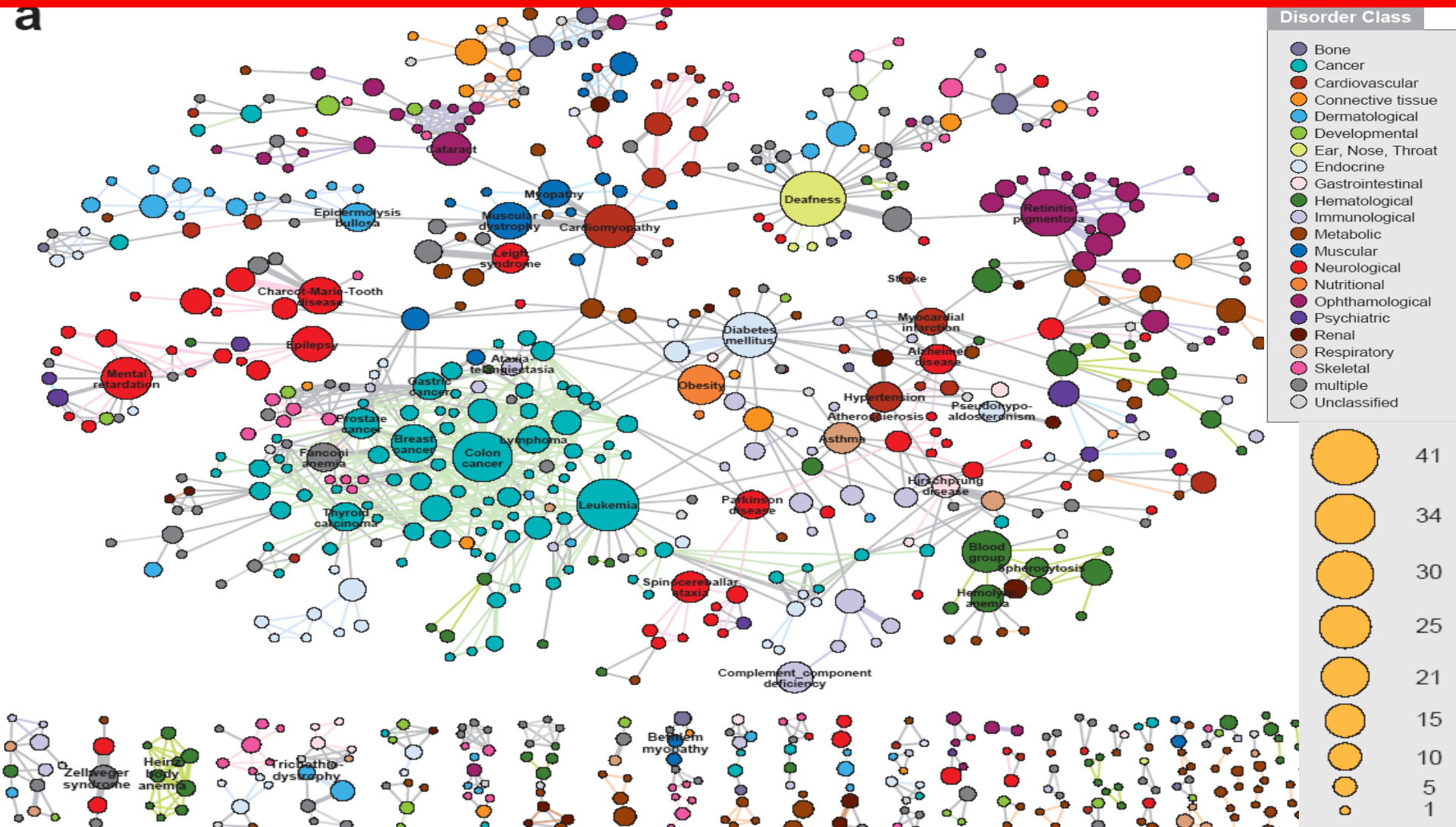
Facebook
market cap:
$50 billion

www.bizjournals.com/austin/news/2010/11/15/facebooks... - Cached

Network Biology/Network Medicine



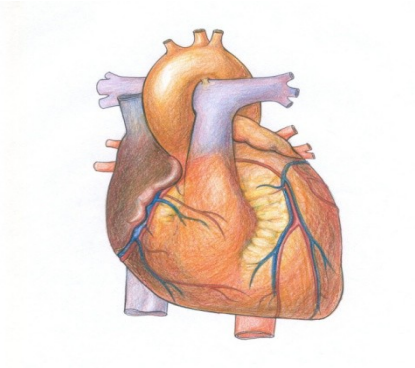
HUMAN DISEASE NETWORK

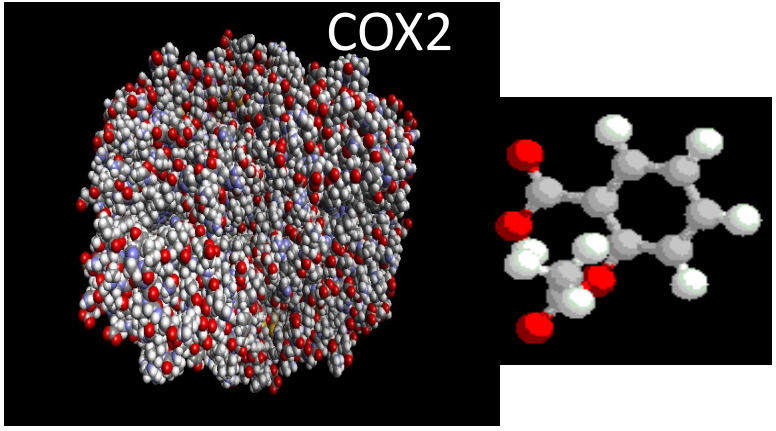


DRUG DESIGN, METABOLIC ENGINEERING:

Reduces
Inflammation
Fever
Pain

Prevents
Heart attack
Stroke



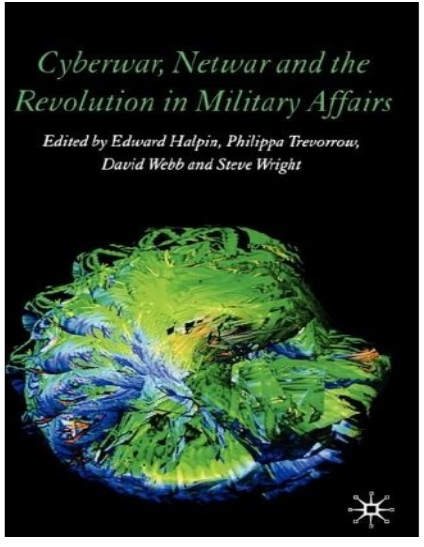


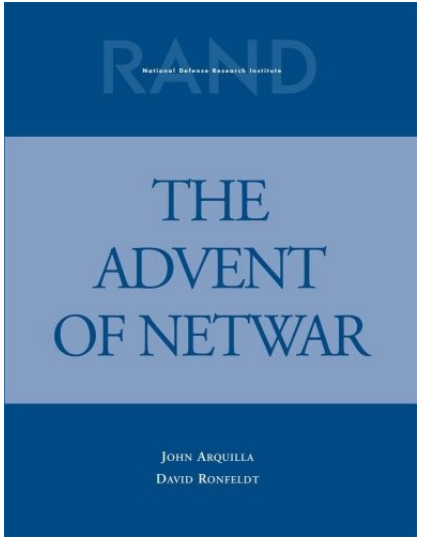
Reduces the risk of
Alzheimer's Disease

Reduces the risk of
breast cancer
ovarian cancers
colorectal cancer

Causes
Bleeding
Ulcer

FIGHTING TERRORISM AND MILITARY

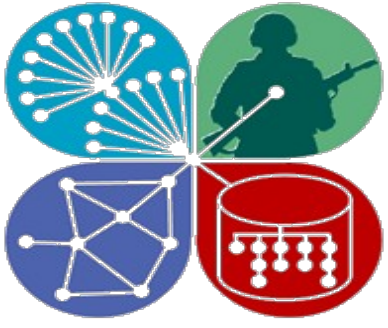




http://www.slate.com/id/2245232

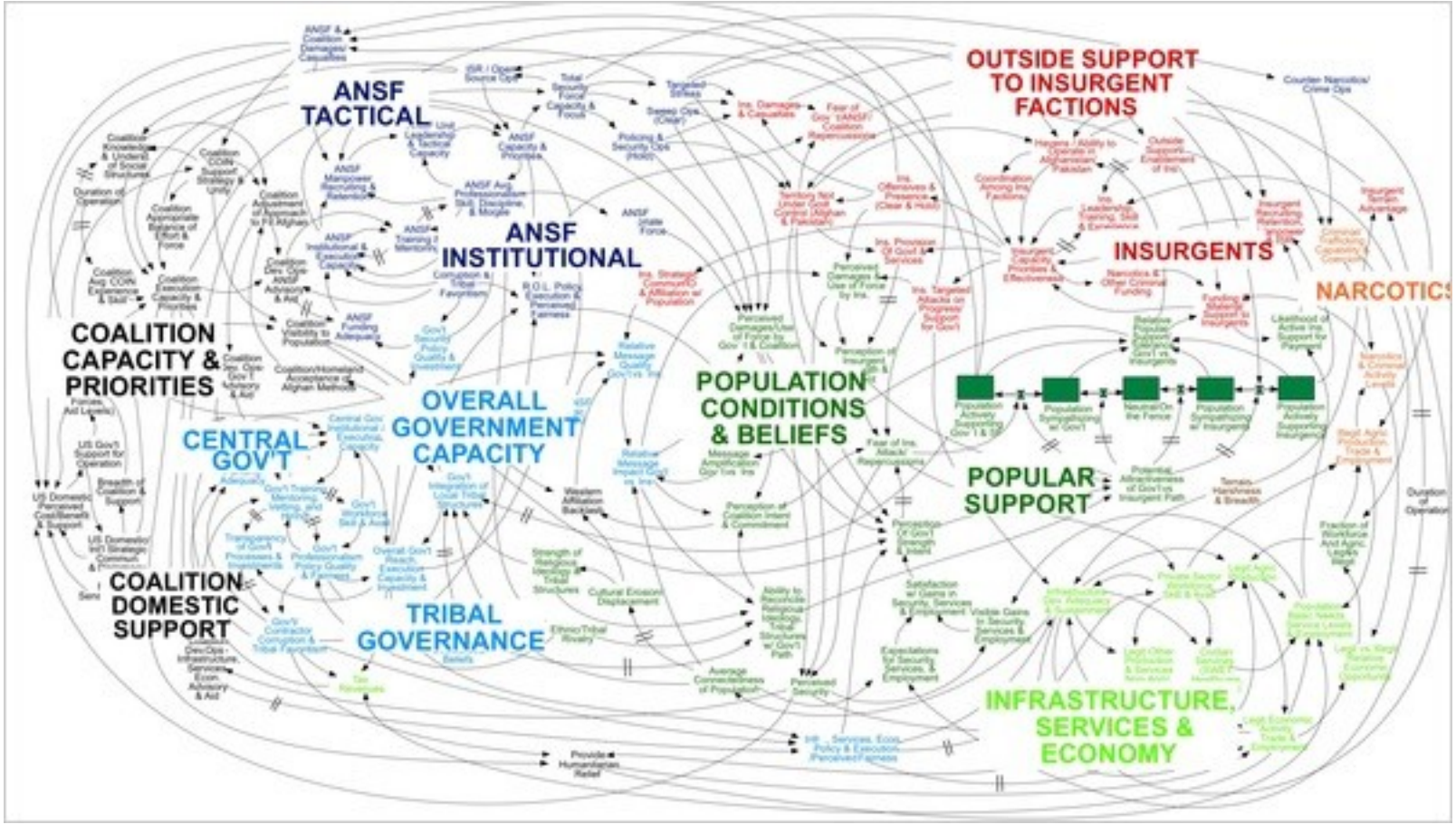
FIGHTING TERRORISM AND MILITARY

Network Science Center
West Point



http://www.ns-cta.org/ns-cta-blog/

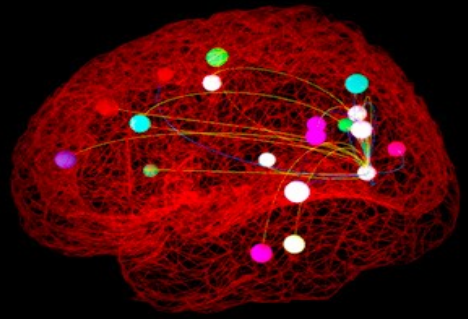
The network behind a military engagement



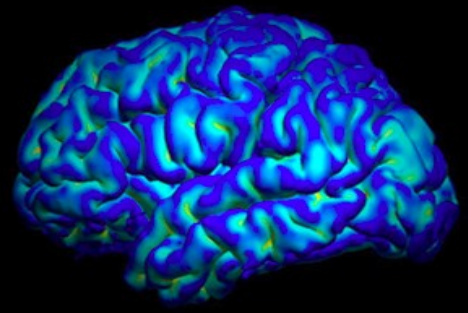
Predicting the H1N1 pandemic

BRAIN RESEARCH

In September 2010 the National Institutes of Health awarded $40 million to researchers at Harvard, Washington University in St. Louis, the University of Minnesota and UCLA, to develop the technologies that could systematically map out brain circuits.



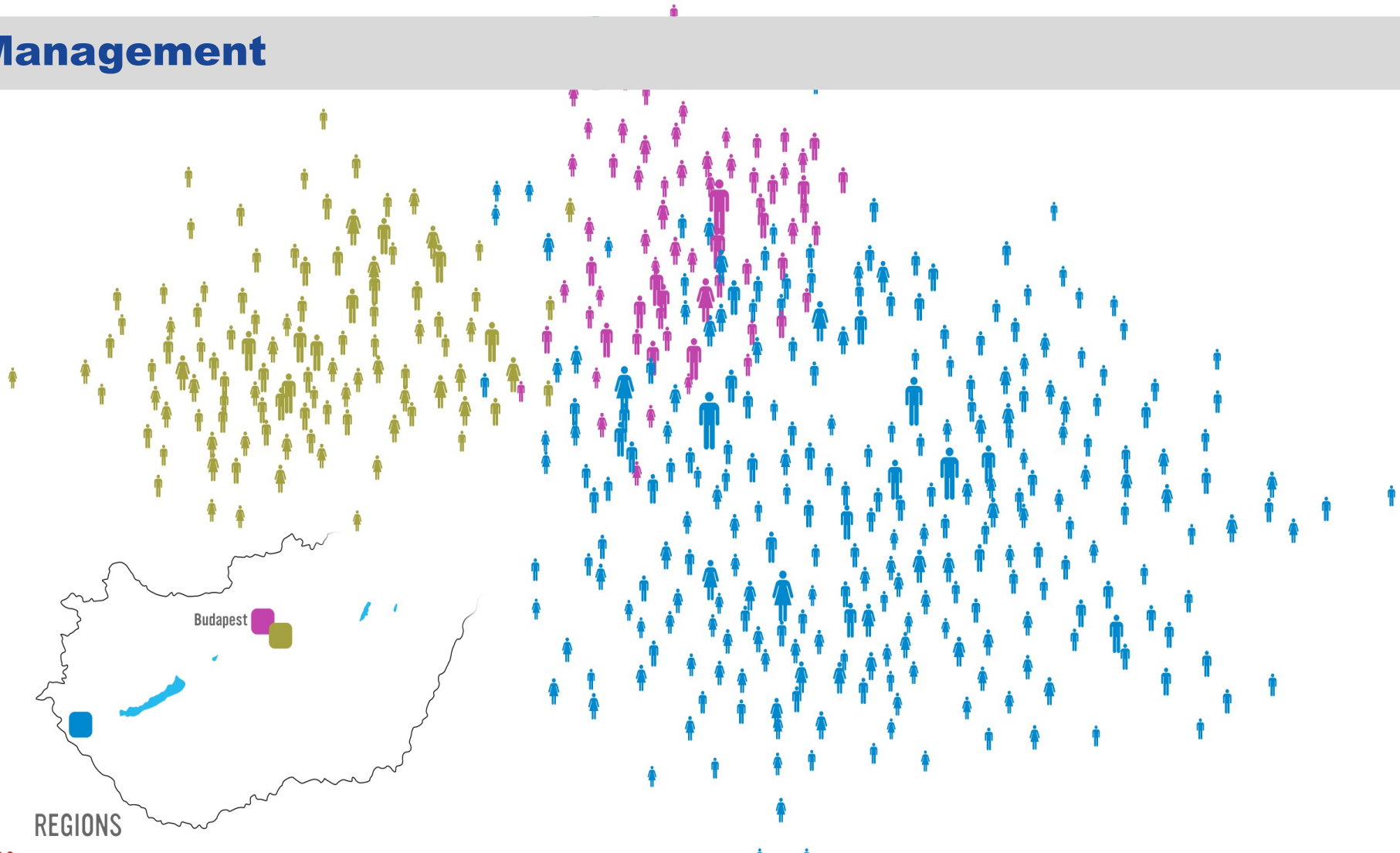
The Human Connectome Project (HCP) with the ambitious goal to construct a map of the complete structural and functional neural connections in vivo within and across individuals.

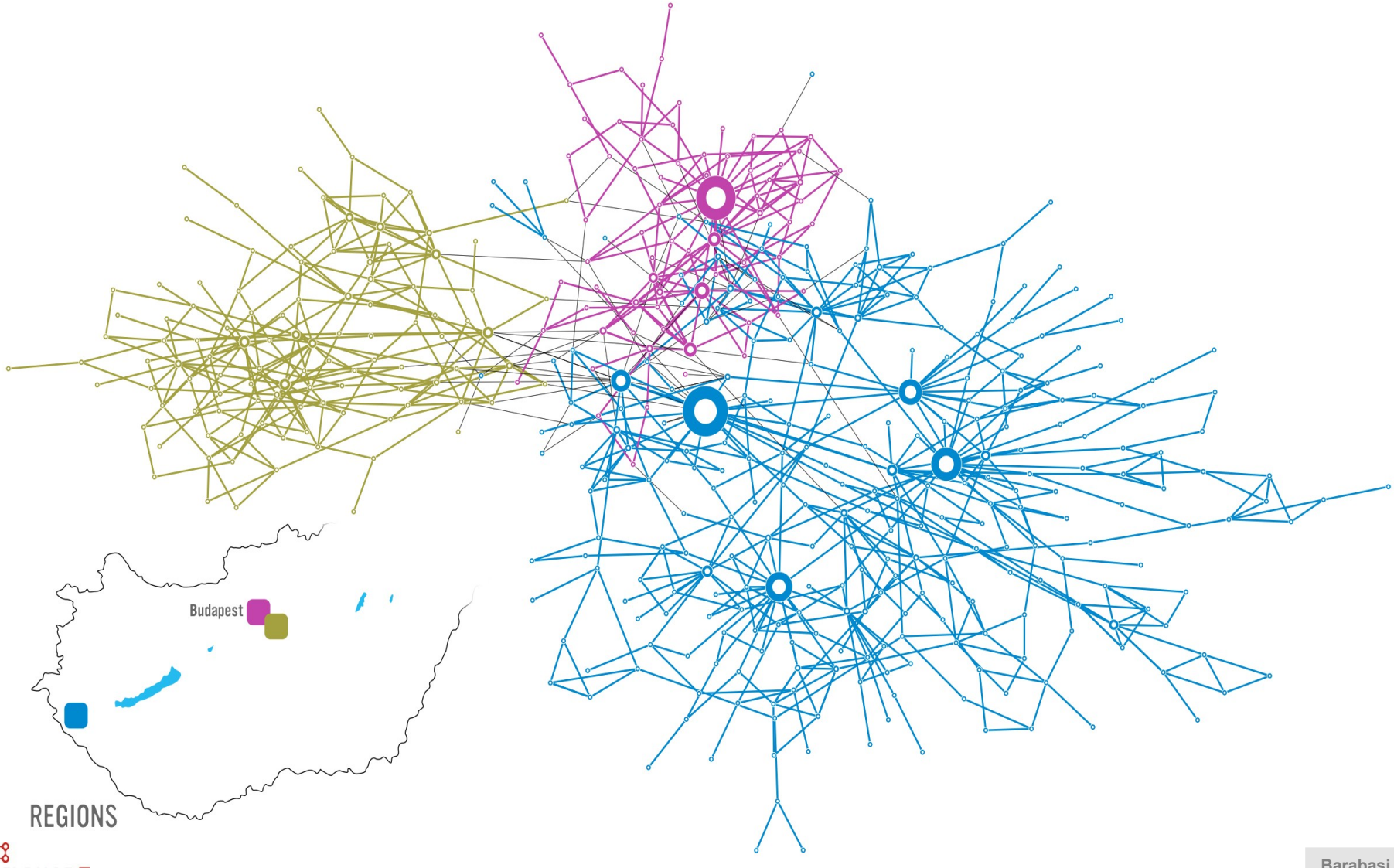


http://www.humanconnectomeproject.org/overview/

In April 2013 the Obama administration announced the BRAIN initiative, with a proposed initial expenditure for 2014 of $110 million, from DARPA, the NIH, and the NSF.

Management

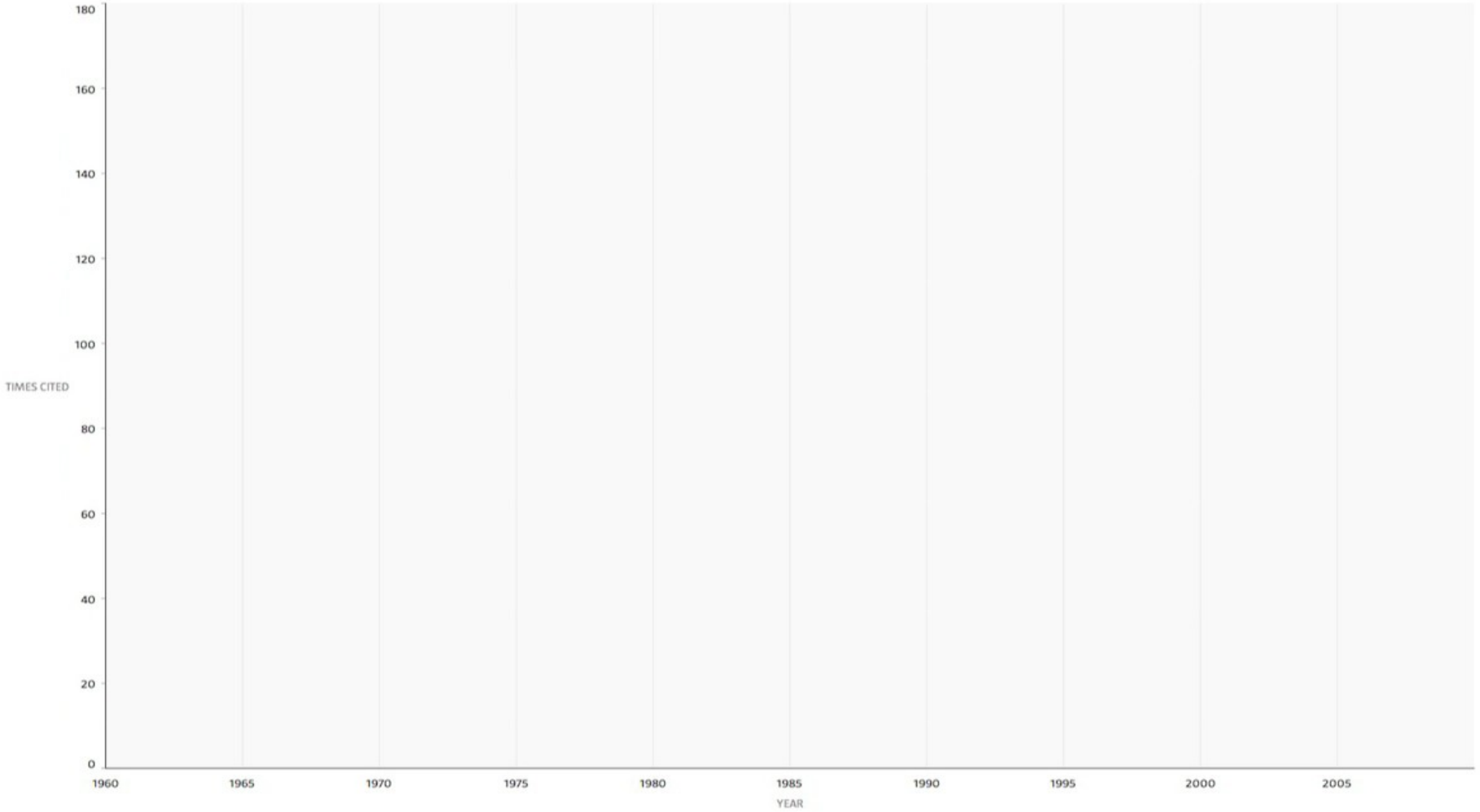




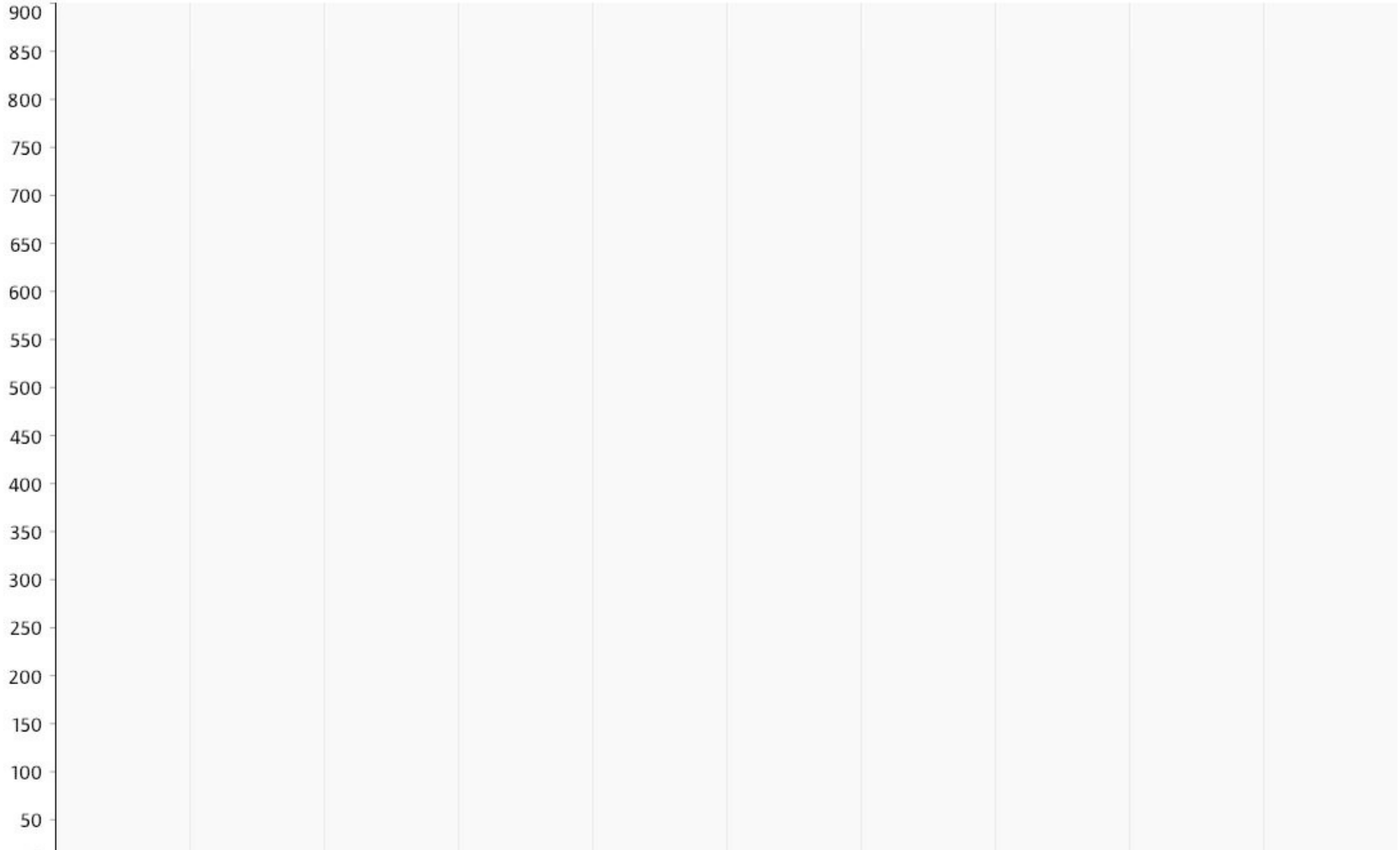

1
2
22 LINKS

SCIENTIFIC IMPACT

NETWORK SCIENCE | The science of the 21st century



NETWORK SCIENCE | The science of the 21st century



Complex systems and networks.

- **Science**:

Special Issue for the 10 year anniversary of Barabasi & Albert 1999 paper.

Original papers:

- 1998: Watts-Strogatz paper in the most cited **Nature** publication from 1998; highlighted by ISI as one of the ten most cited papers in physics in the decade after its publication.

- 1999: Barabasi and Albert paper is the most cited **Science** paper in 1999;highlighted by ISI as one of the ten most cited papers in physics in the decade after its publication.

- 2001: Pastor -Satorras and Vespignani is one of the two most cited papers among the papers published in 2001 by **Physical Review Letters**.

- 2002: Girvan-Newman is the most cited paper in 2002 **Proceedings of the National Academy of Sciences**.

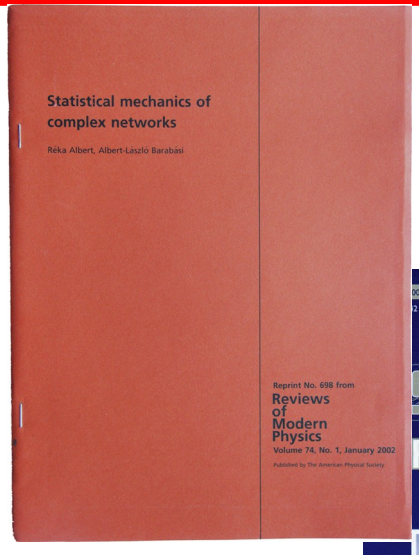
REVIEWS:

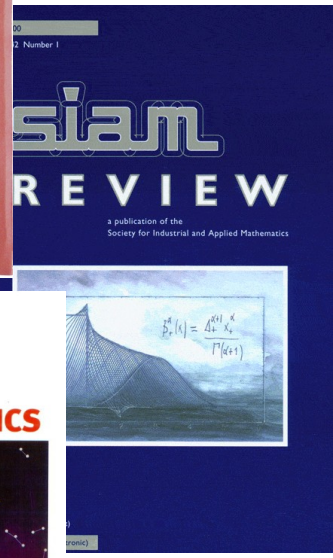
- The first review of network science by Albert and Barabasi, 2001) is the second most cited paper published in **Reviews of Modern Physics**, the highest impact factor physics journal, published since 1929. The most cited is *Chandrasekhar*'s 1944 review on solar processes, but it will be surpassed by the end of 2012 by Albert *et al.*

Update Sept. 2018: Now far surpassed, 20345 to 9502.

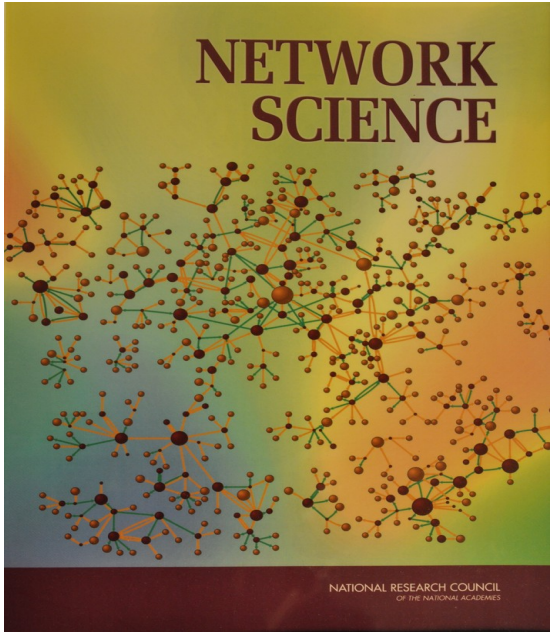
- The SIAM review of Newman on network science is the most cited paper of any **SIAM journal**.

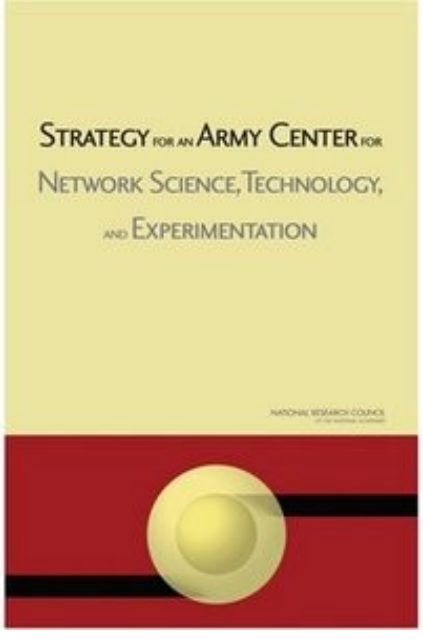
- BIOLOGY: "Network Biology", by Barabasi and Oltvai (2004) , is the second most cited paper in the history of **Nature Reviews Genetics**, the top review journal in genetics.



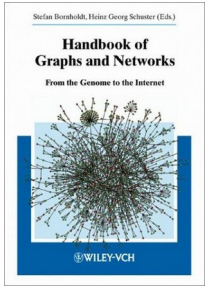


National Research Council

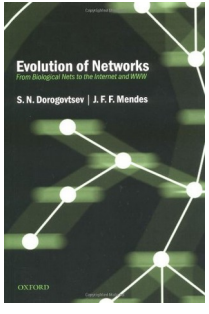




BOOKS



Handbook of Graphs and Networks: From the Genome to the Internet (Wiley-VCH, 2003).



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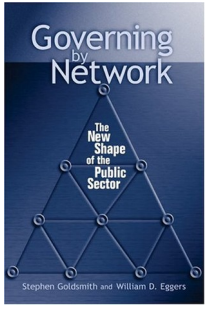

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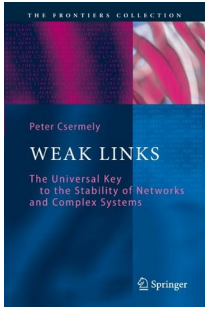

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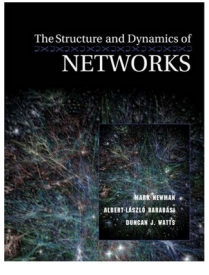

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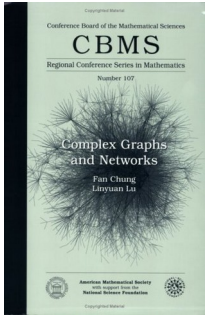

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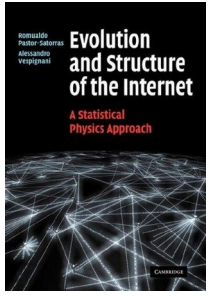
BOOKS



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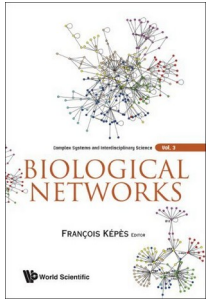

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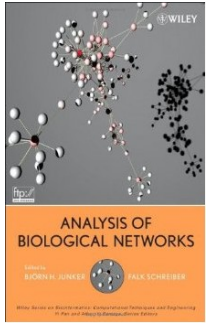

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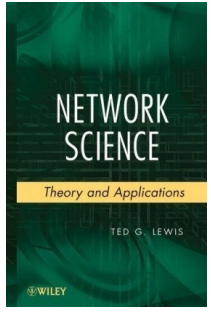

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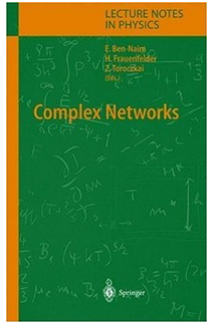

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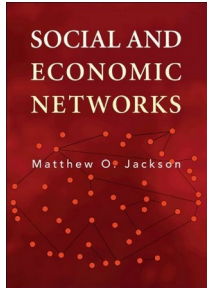
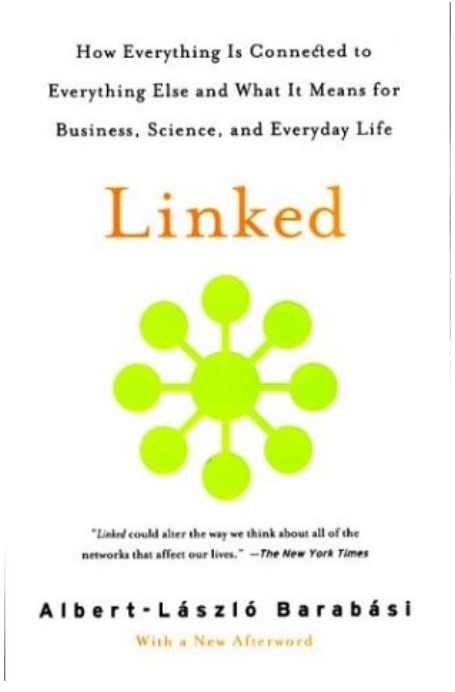
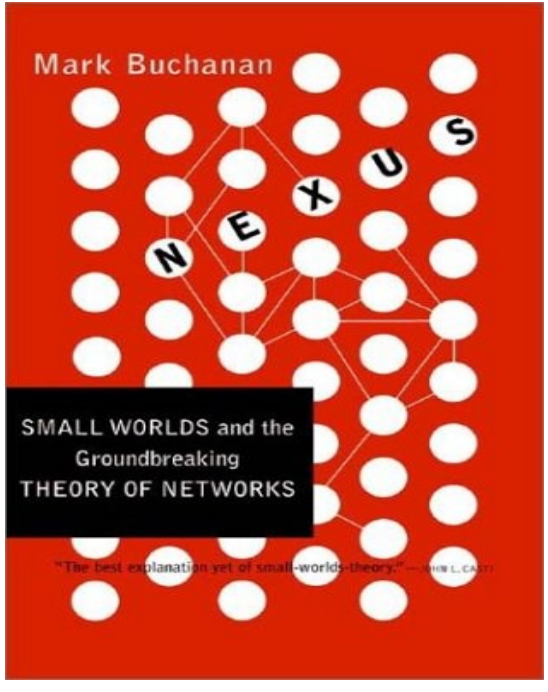
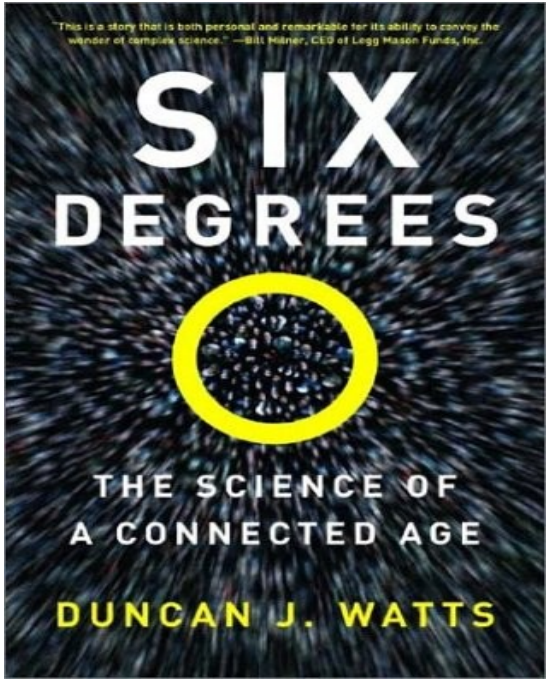


M. O. Jackson, Social and Economic Networks (Princeton University Press, 2010).

GENERAL AUDIENCE



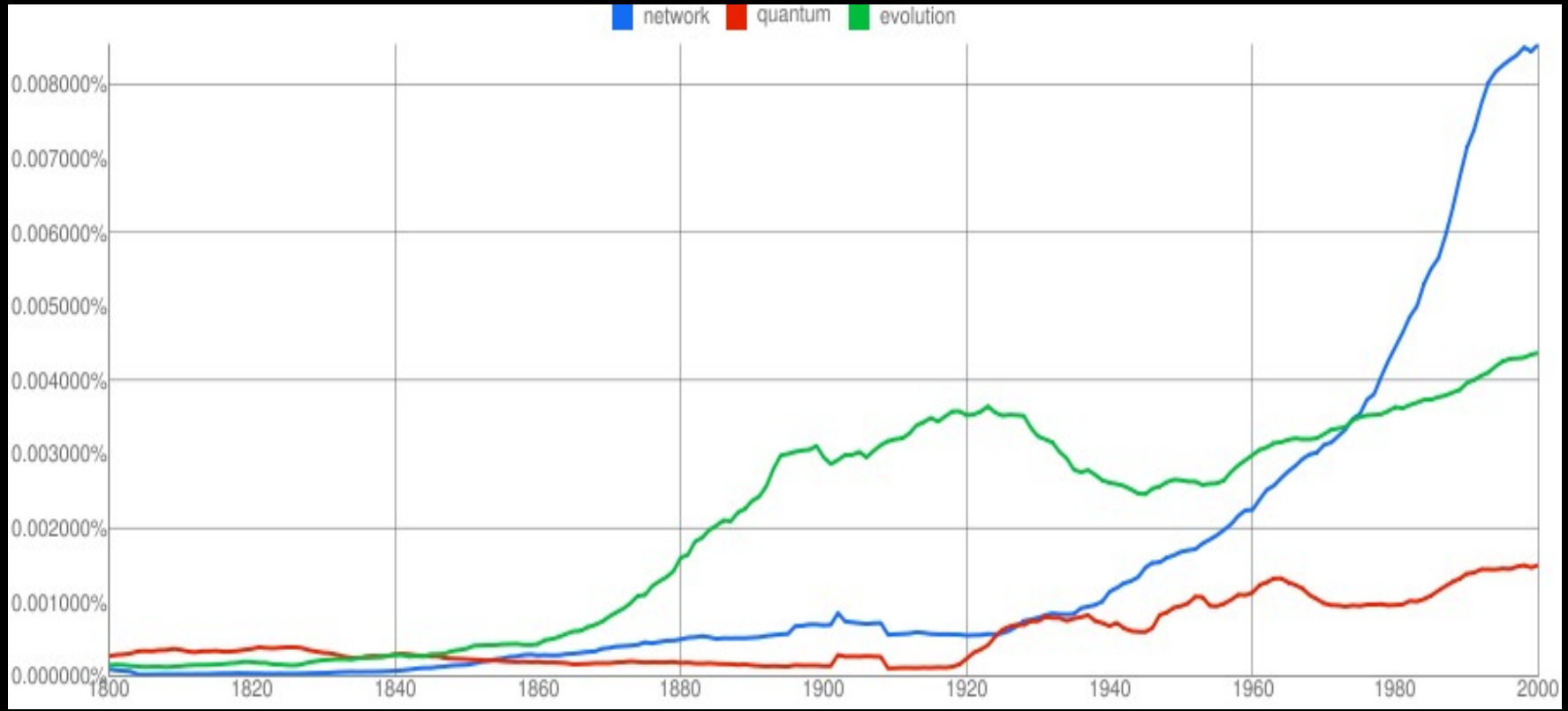




DOCUMENTARY

SUMMARY

NGRAMS | Networks Awareness



If you were to understand the spread of diseases, **can you do it without networks?**

If you were to understand the WWW structure, searchability, etc, **hopeless without invoking the Web's topology.**

If you want to understand human diseases, **it is hopeless without considering the wiring diagram of the cell**.