

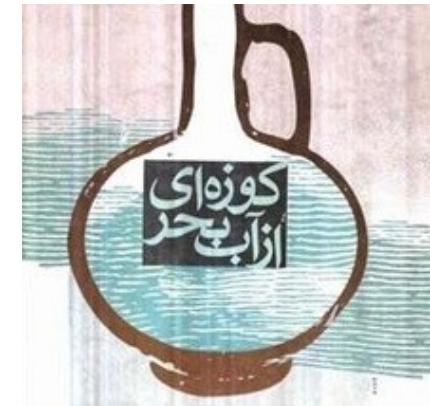
An Introduction to Algorithms

By

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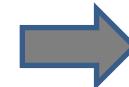
Intro



Complexity



Data Structure



Trees

Dynamic Programming



Sorting



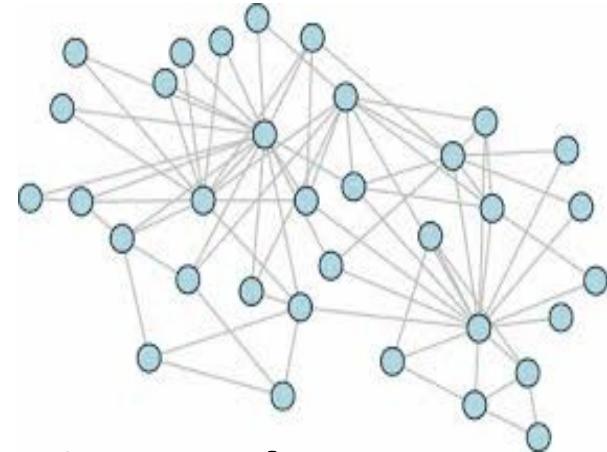
Hash Functions

Greedy Algorithm



Misc Graph/Tree
Algorithms

What is a Network?

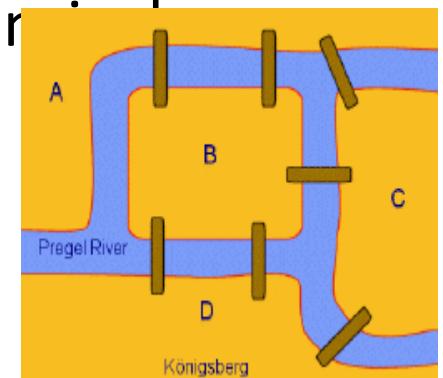


- A collection of **nodes (vertices)**
- And a collection of **edges (links) connecting nodes**
- A network model treats all nodes and links the same
 - But there are heterogeneous networks. Name a few?
- The spatial location of nodes is arbitrary (in visualization)
- Networks are abstractions of connection and relation
- A vast array of phenomena have been modeled by networks

Graphs

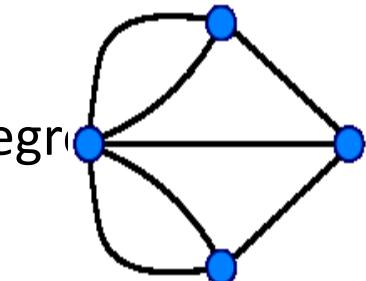
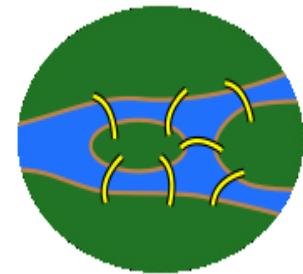
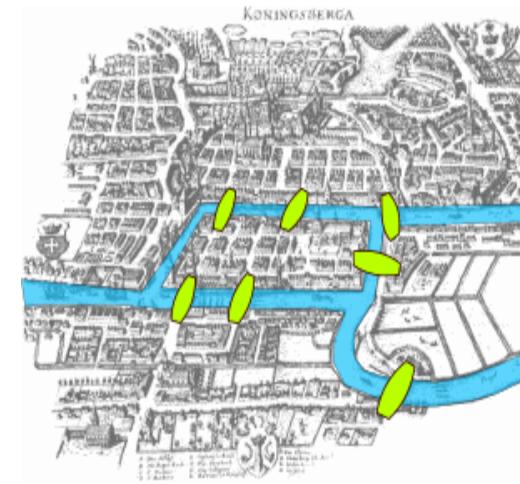


- In mathematics, networks are called **graphs**
- The entities are **nodes**, and the links are **edges**
- Graph theory starts in 18th century with **Leonhard Euler**
 - Euler wrote a paper about the Königsberg bridges problem
 - Since then graphs have been studied extensively



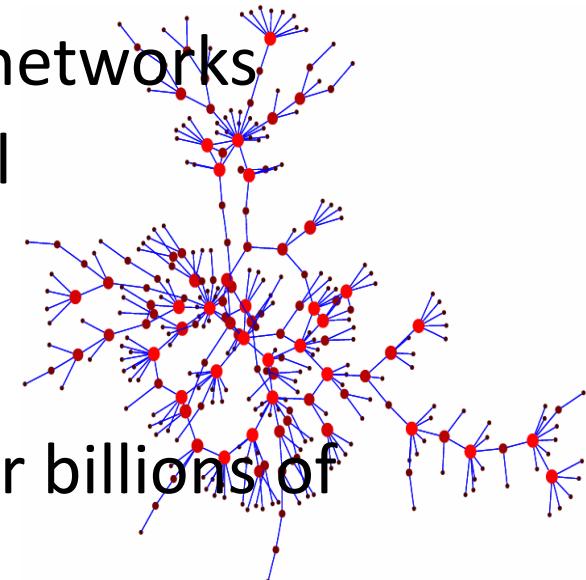
Königsberg Bridges Problem

- Königsberg (now Kaliningrad, Russia)
 - A river divided the city into 4 regions
 - Seven bridges connected the regions
- Problem: is there a path in which:
 - Cross each bridge once (and only once)
 - the trip ends in the same place it began
- Euler proved: It is not possible
 - Such a cycle exists if: 1-connected graph 2-all node-degrees even



Networks in the Past and Now

- Graphs have been used in the past to model existing networks
 - e.g., networks of highways, social networks
 - Usually, these networks were small
- Networks Now:
 - More and larger networks appear.
 - Networks of thousands, millions, or billions of nodes
 - impossible to visualize



Why Networks? Why Now?

- Products of **technological advancement**
 - e.g., Internet, Web
- Result of our **ability to collect** more, better, and more complex data
 - e.g., gene regulatory networks
- **Data availability**
 - Rise of the Web 2.0 and Social media

Why Networks? Why Now? (cont'd)

- **Universality**
 - Networks from various domains of science, nature, and technology are more similar than one would expect
- **Shared vocabulary between fields**
 - Computer Science, Social Sciences, Physics, Economics, Statistics, Biology, Political Science...
- **Advances in computational power**
 - Better hardware, cloud, clusters, distributed computing, ...

Many examples of networks

- Technological Networks
- Social Networks
- Networks of Information
- Biological Networks
- And ...

TECHNOLOGICAL NETWORKS

QUIZ



QUIZ



The Airline Networks



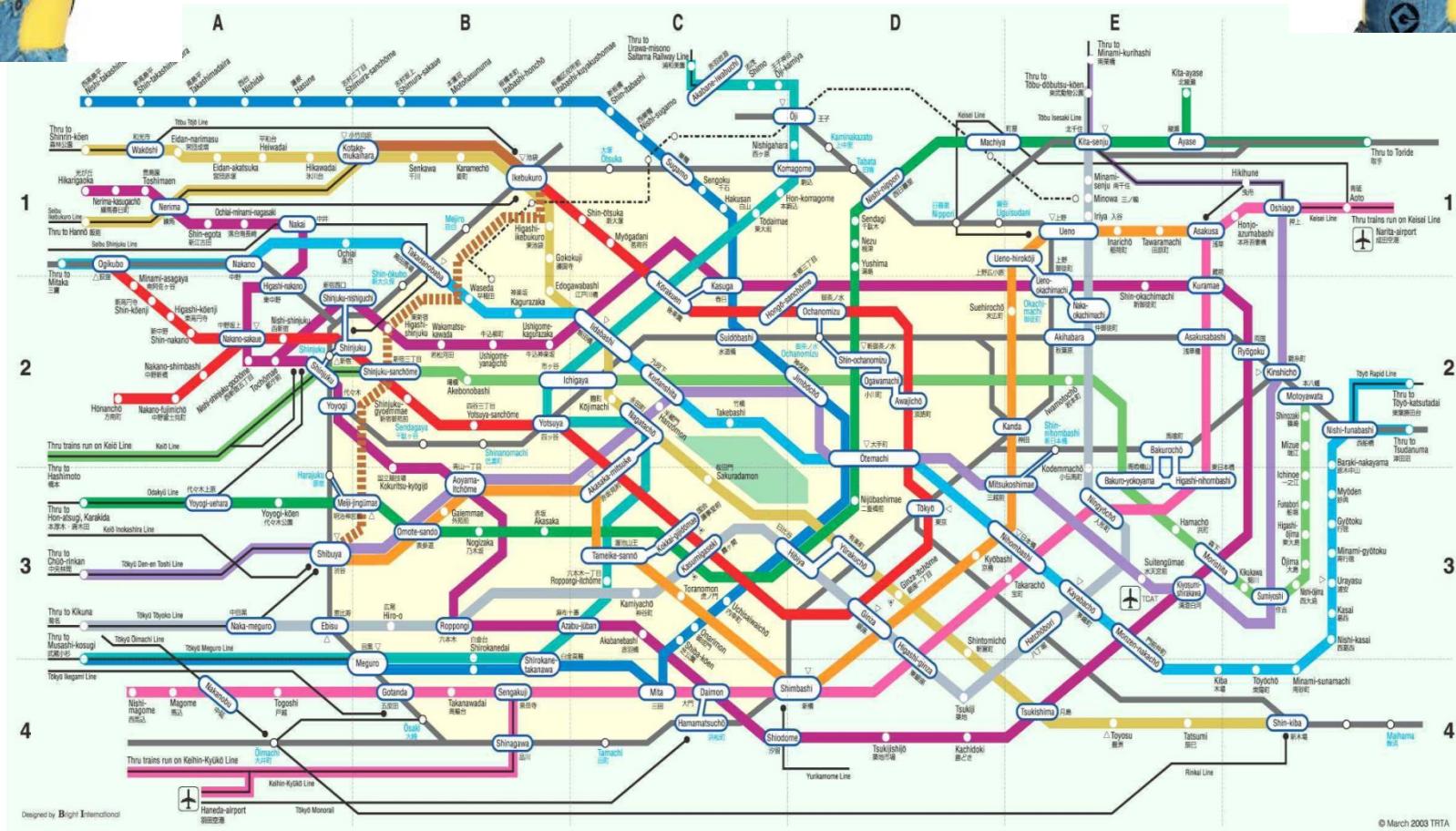
QUIZ



QUIZ



Railway Networks



Source: TRTA, March 2003 - Tokyo rail map

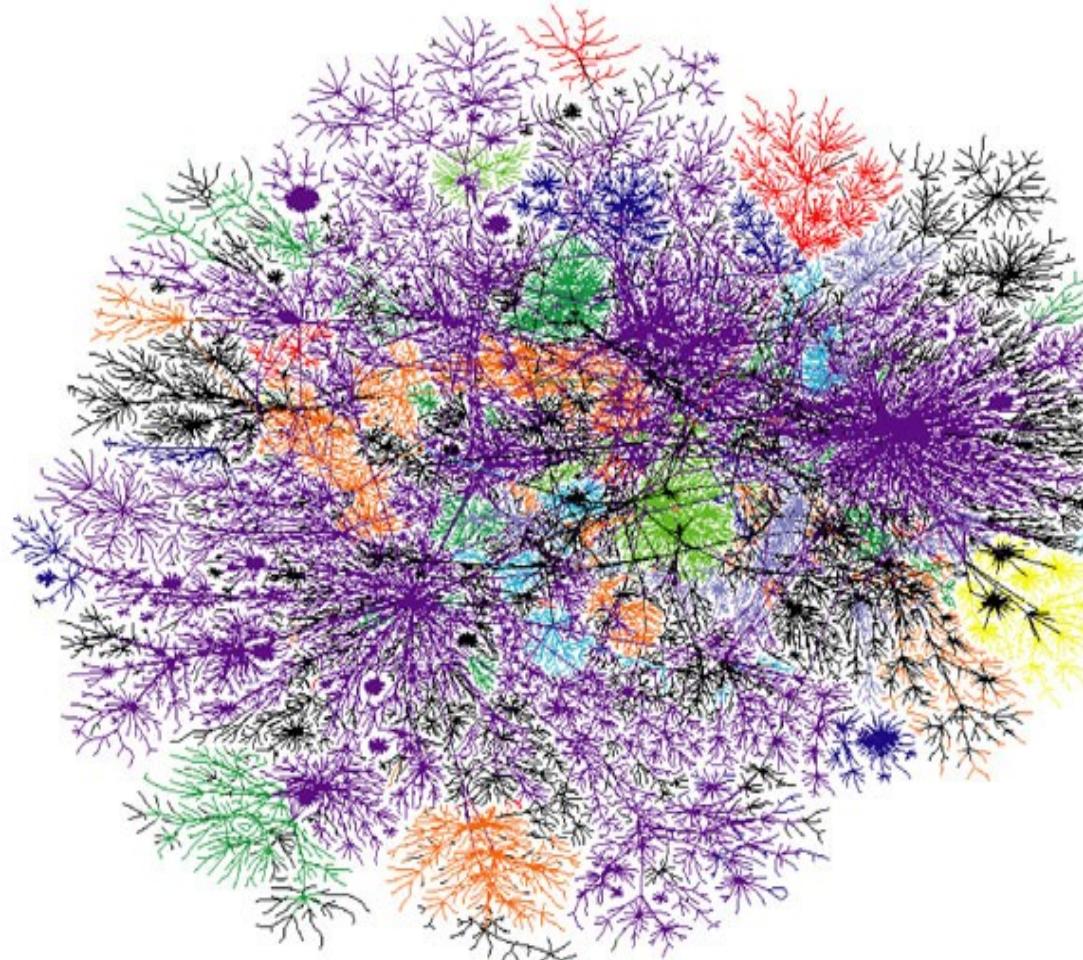
QUIZ



QUIZ



The Internet Map



■ Switzerland

■ Spain

■ Japan

■ Russian Federation

■ UK

■ Unknown

■ Germany

■ Italy

■ Netherlands

■ Sweden

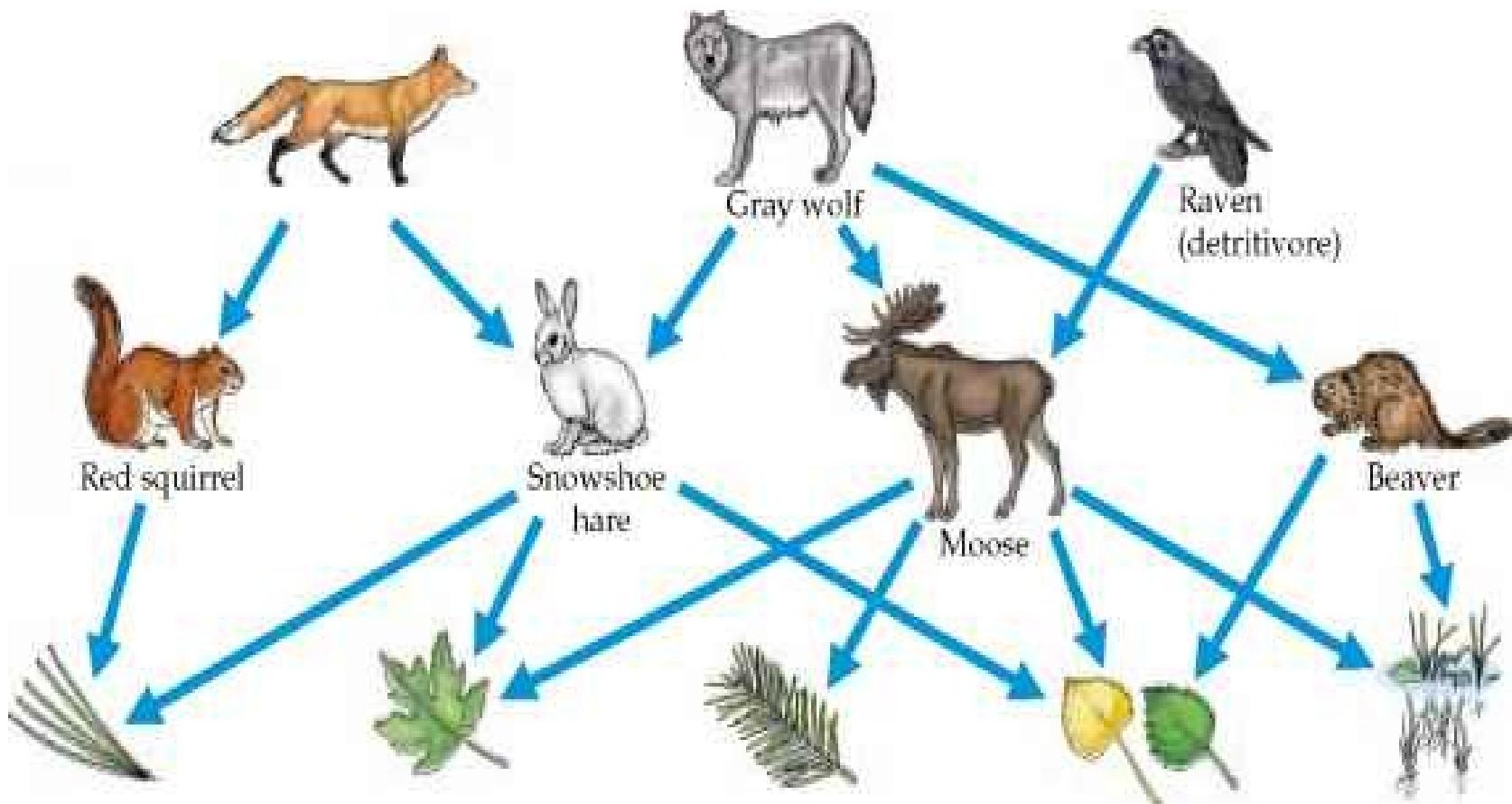
■ USA

Other Technological Networks?

- Internet
- Telecommunication Networks, e.g., telephone network
- Power Grid
 - The network of high-voltage transmission lines
 - that provide long-distance transport of electric power
- Transportation networks
 - Airlines, Railway, ...
- Delivery and distribution networks
 - Gas, oil, water, Post, ...

BIOLOGICAL NETWORKS

Food Webs (Ecology)



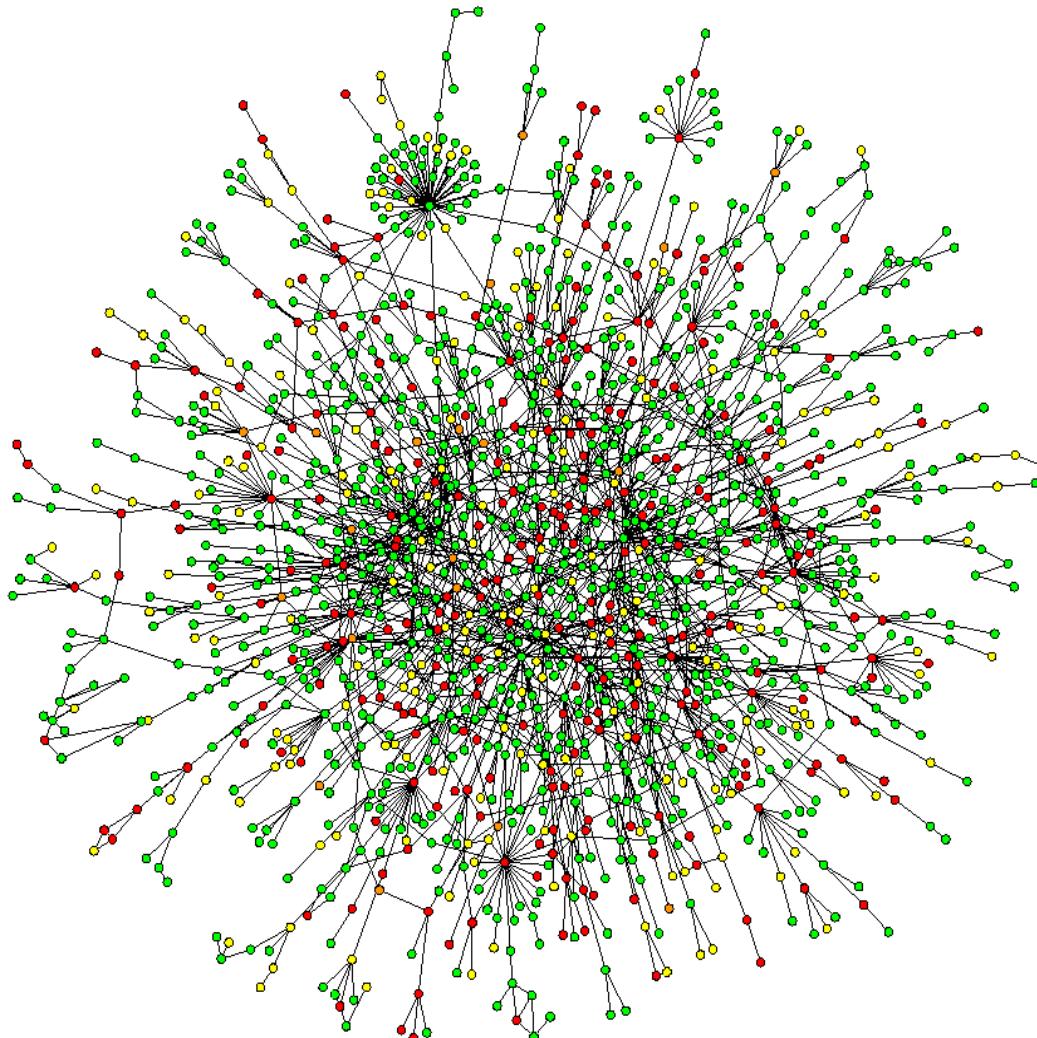
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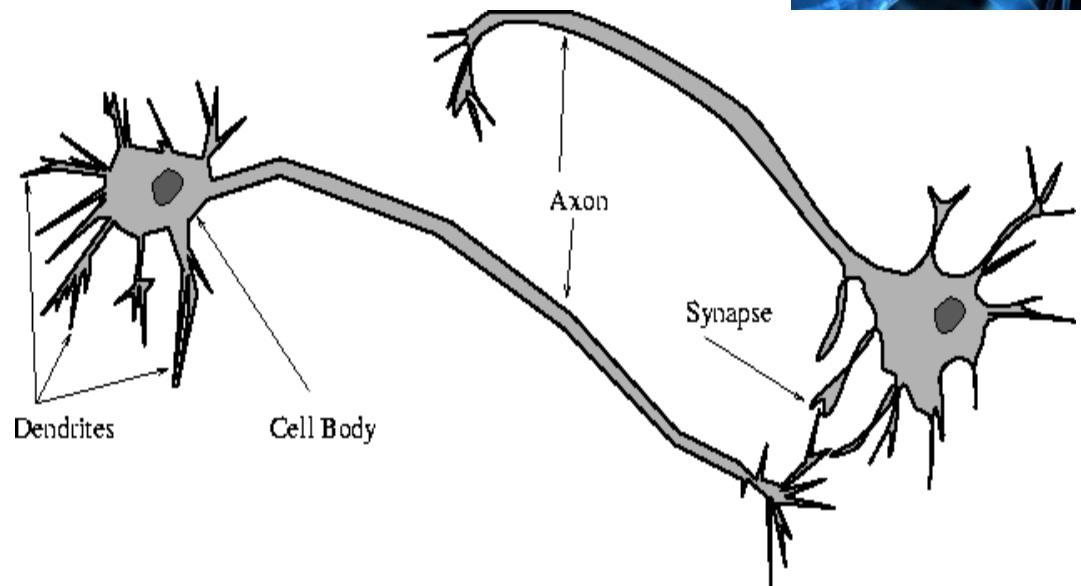
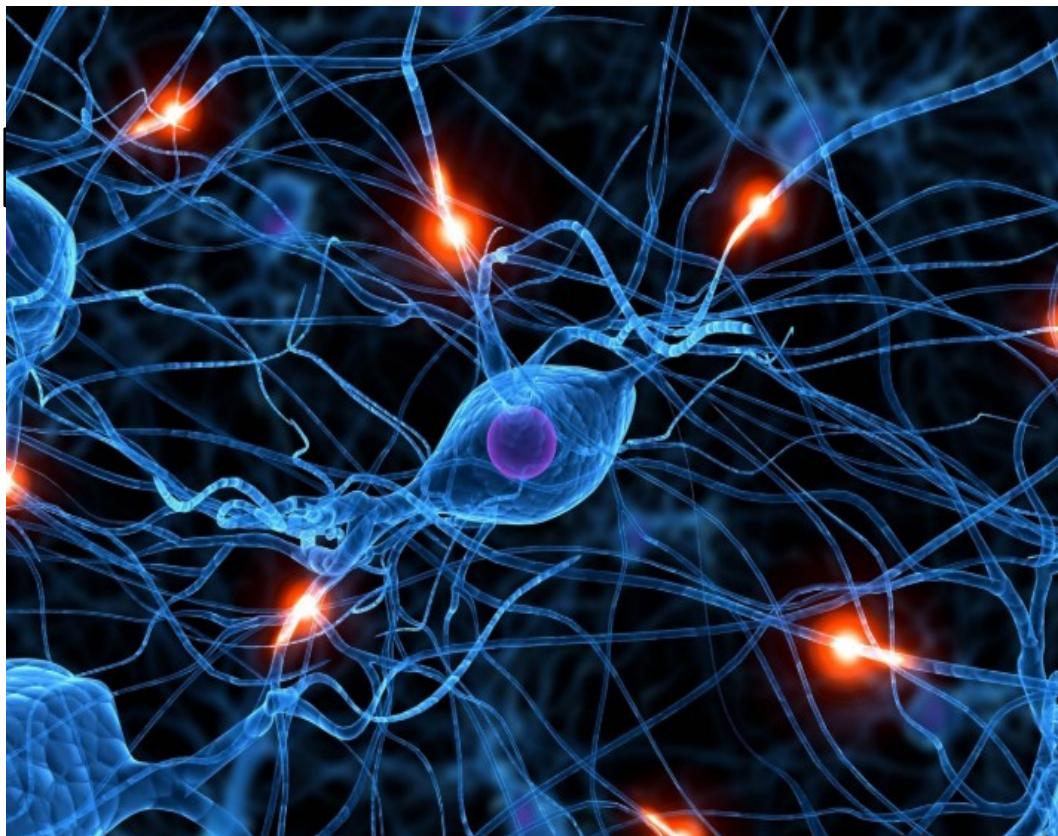
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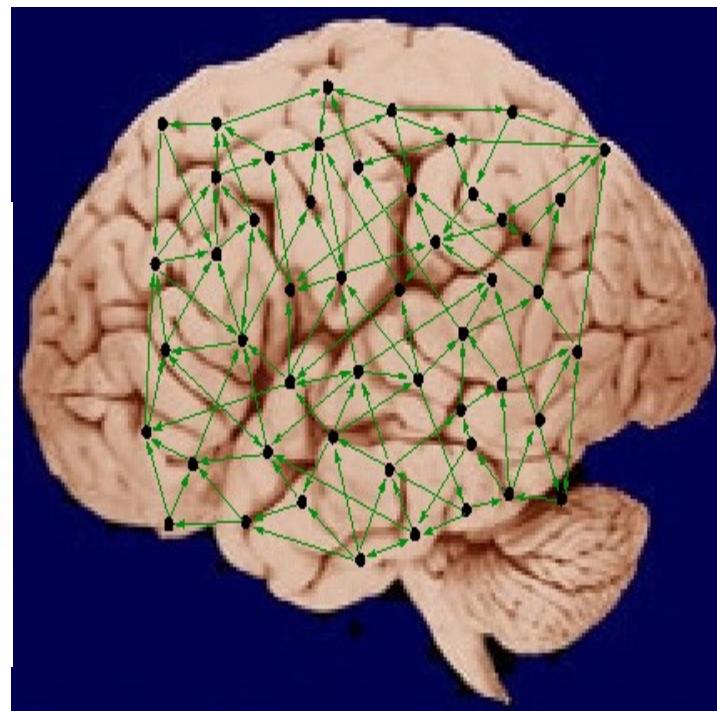
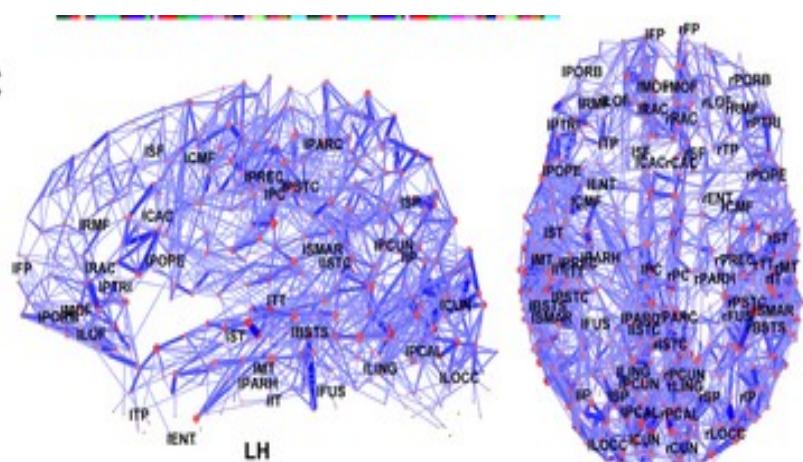
Protein-Protein Interaction



Neura



Brain Networks



Other Biological Networks

- Metabolic Networks
- Gene Regulatory Network
- Phylogenetic Trees
- Metabolic Pathways

SOCIAL NETWORKS

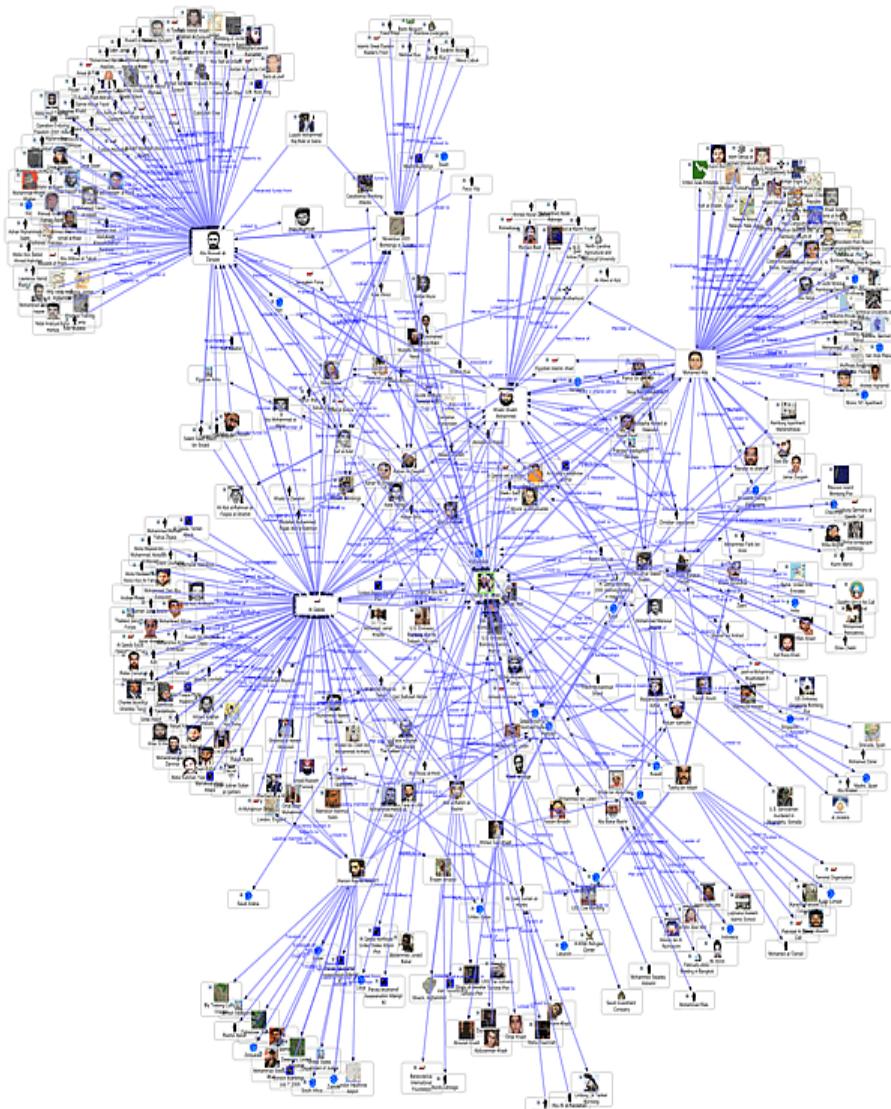
QUIZ



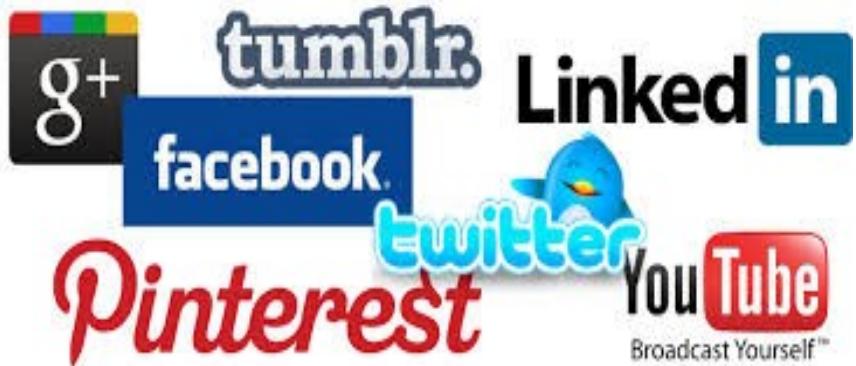
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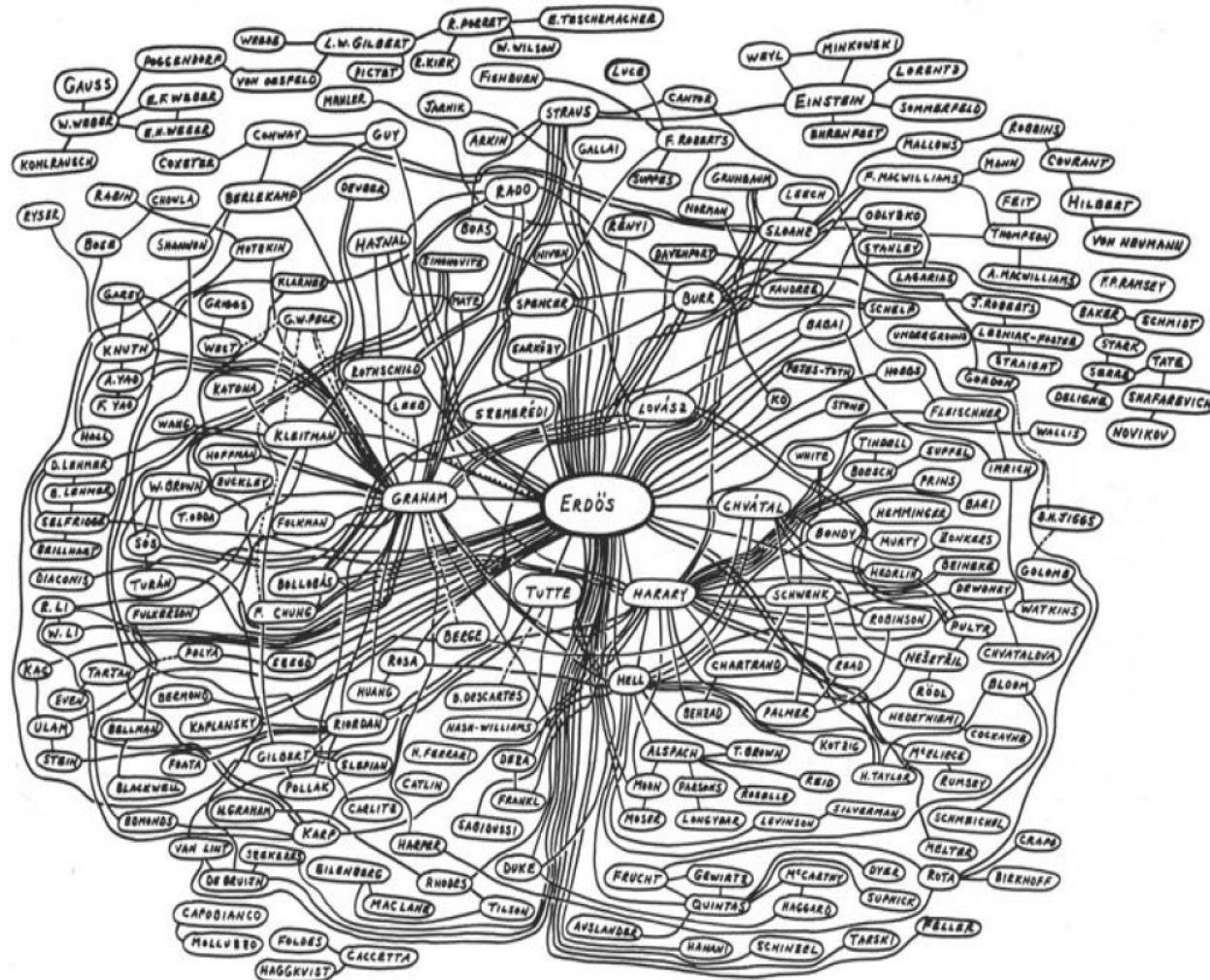
Friendship Networks



Online Social Networks

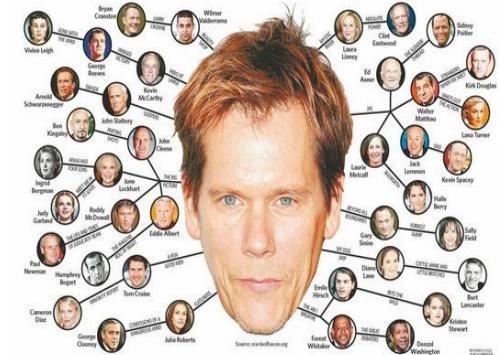


Co-authorship Network



Co-stardom Networks

- the collaboration graph of film actors
- Who is the co-star hub of Iranian films?!



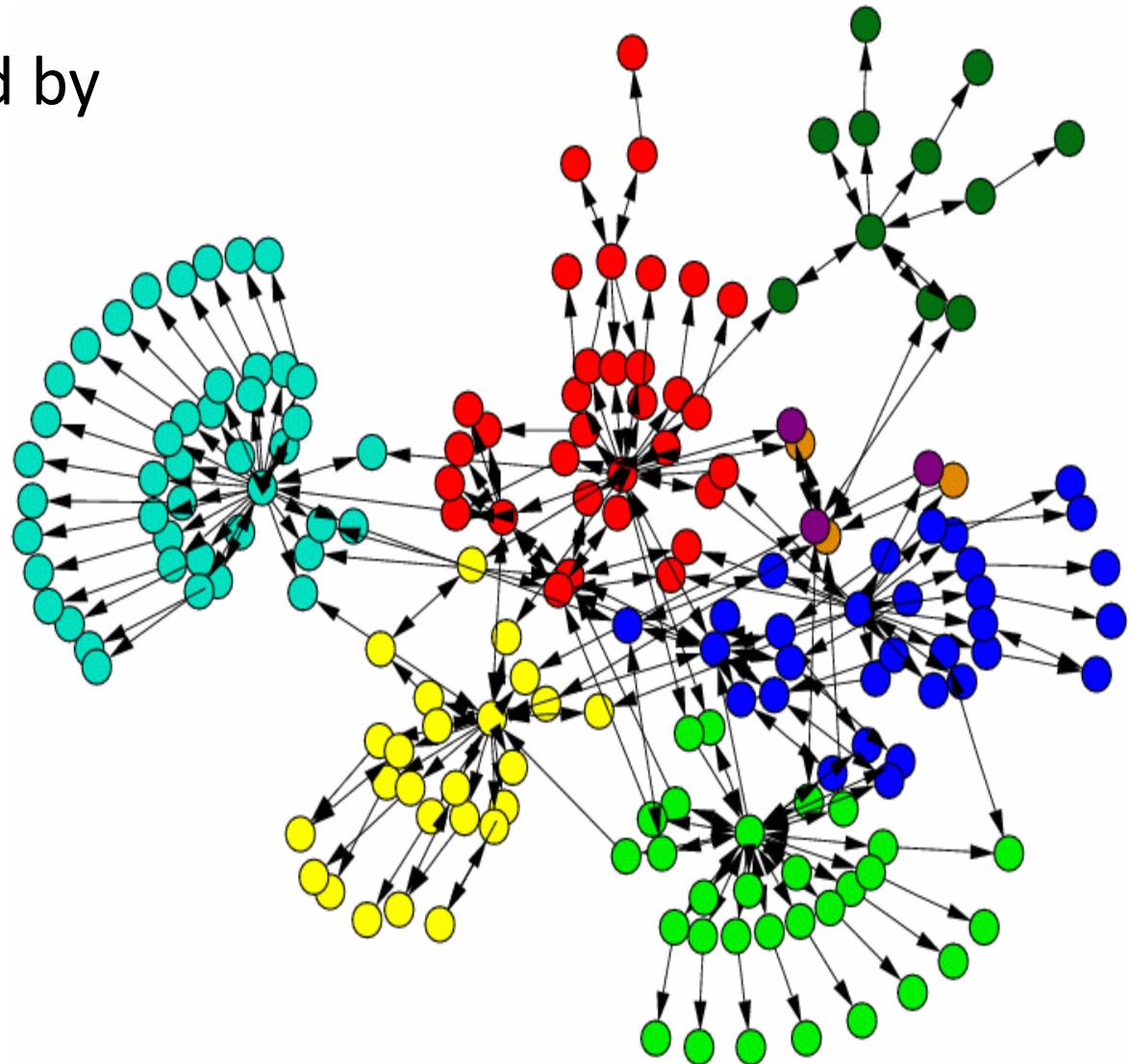
Other Social Networks?

- Affiliation Networks
- Messaging Networks
 - Emails, phone calls, instant messaging, ...
- Trust Network
- Non-human relations
 - Dolphins, ...

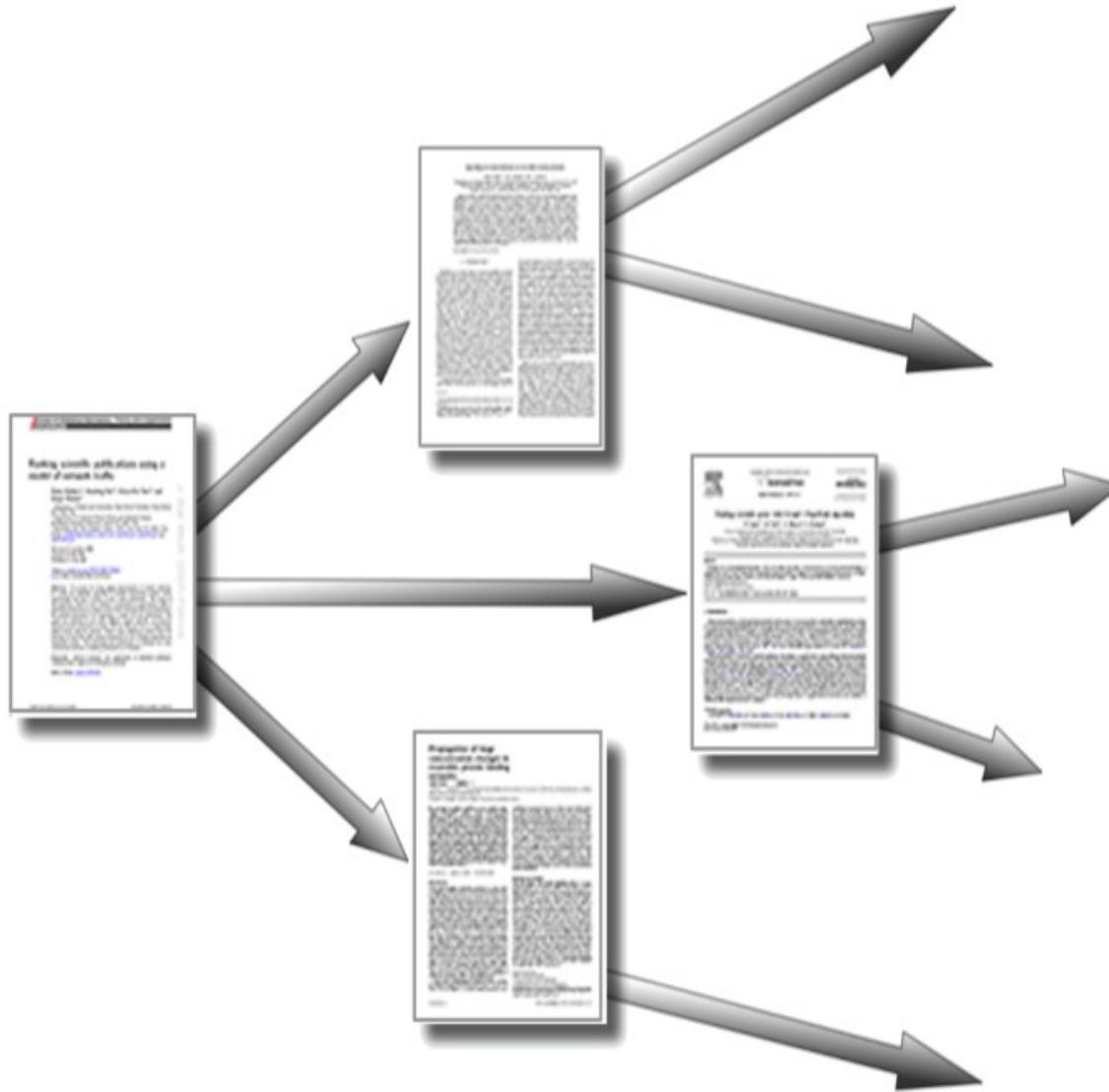
NETWORKS OF INFORMATION

Webgages

Webpages connected by
hyperlinks



Citation Networks



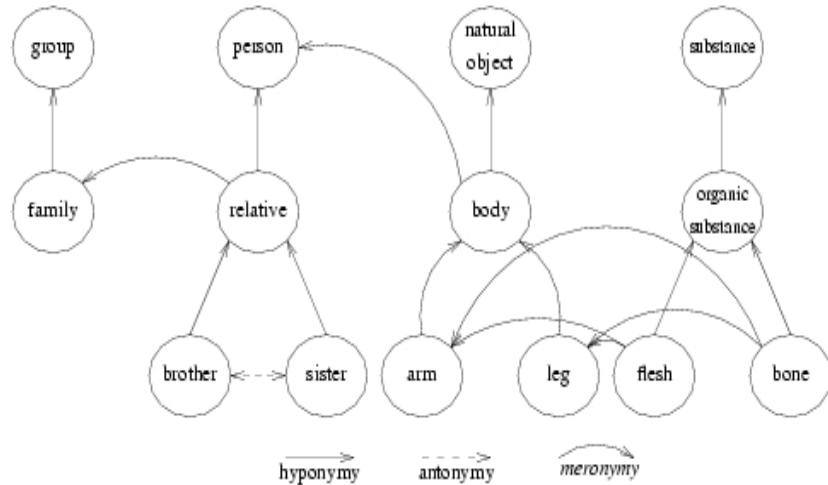
Information Networks

- WWW
- Citation Networks
 - Papers, patents, ...
 - Usually acyclic
 - Authors Citations: a social network extracted from papers
- P2P
- ...

OTHER KINDS OF NETWORKS

Words Network

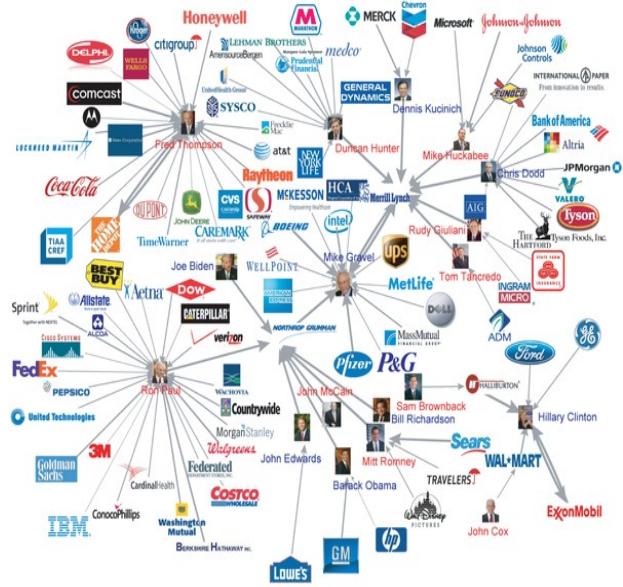
- E.g., wordnet



- Other words network?
 - Co-occurrences (in sentences, poems, ...)
 - ...

US presidential Candidates

- A bipartite network
US presidential candidates
and 100 corporations
- The corporations: as their logos
- Republican candidates colored red
- Democratic candidates colored blue



2012 Presidential Election



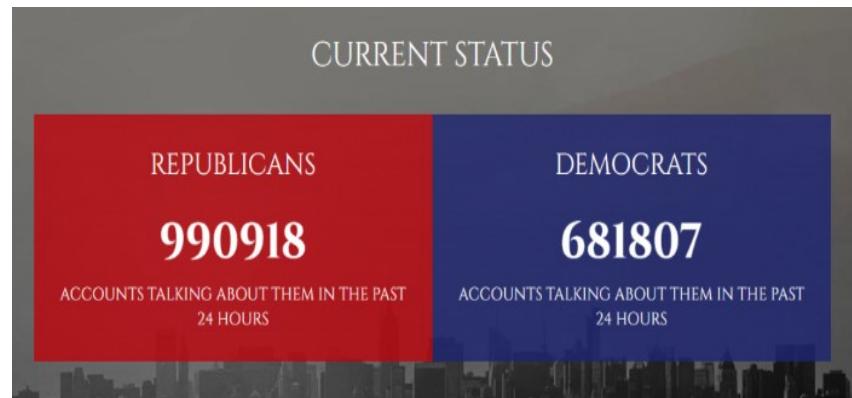
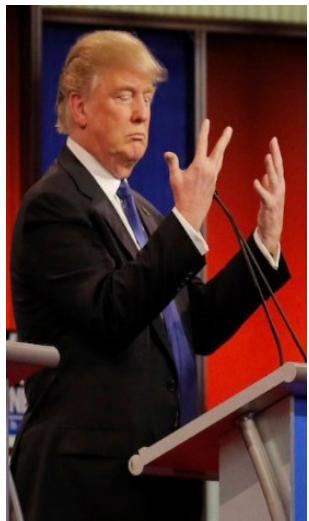
- *How Obama Won the Social Media Battle in the election*
- *How Obama's Team Used Big Data to Rally Voters*
- Obama ran one of the most **tech-savvy** political campaigns in the history of US politics.

Rayid Ghani



And, Now, in 2016

- WSO2 Report (September 13, 2016)



- AI Predicts Donald Trump Becomes President
 - Hopefully wrong!

Other Networks

- Economical Networks
 - Trade Networks
 - Industry
 - Financial Networks
- Tourism
- ...

NETWORK QUESTIONS

Network Questions

- Structural
- Communities
- Dynamics of
- Dynamics on
- Algorithms
- Outlook



Network Questions: Structure



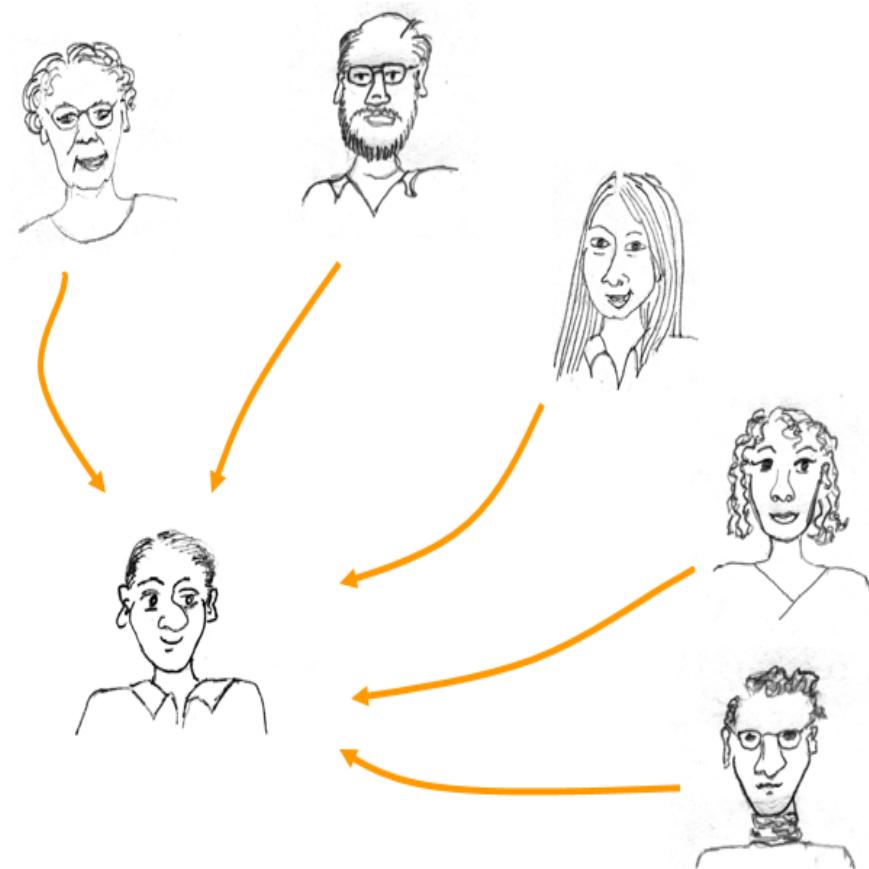
- How many connections does the average node have?
- Are some nodes more connected than others?
- Is the entire network connected?
- How many links are there between nodes?
 - Average distance, network diameter, ...
- Are there clusters or groupings within which the connections are particularly strong?

Network Questions: Structural (cont'd)

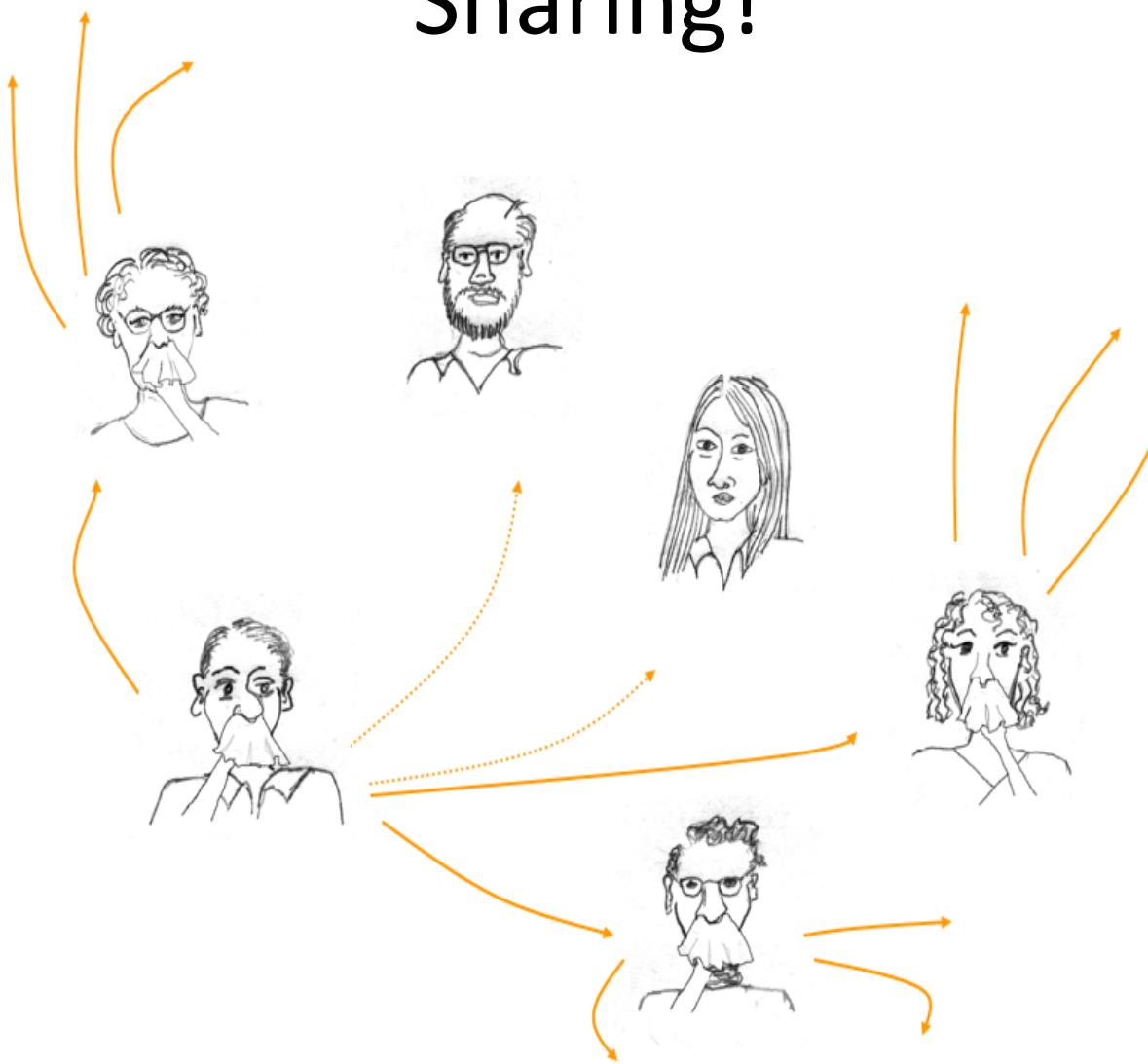
- Is there any hierachal structure?
- What is the best way to characterize a complex network?
- How can we tell if two networks are “different” or “similar”?
- Are there useful ways of classifying/categorizing nodes?
- Are there useful ways of classifying/categorizing networks?
- What are the important nodes and links?

Example

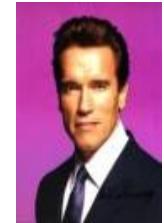
- In social networks,
it's nice to be a hub



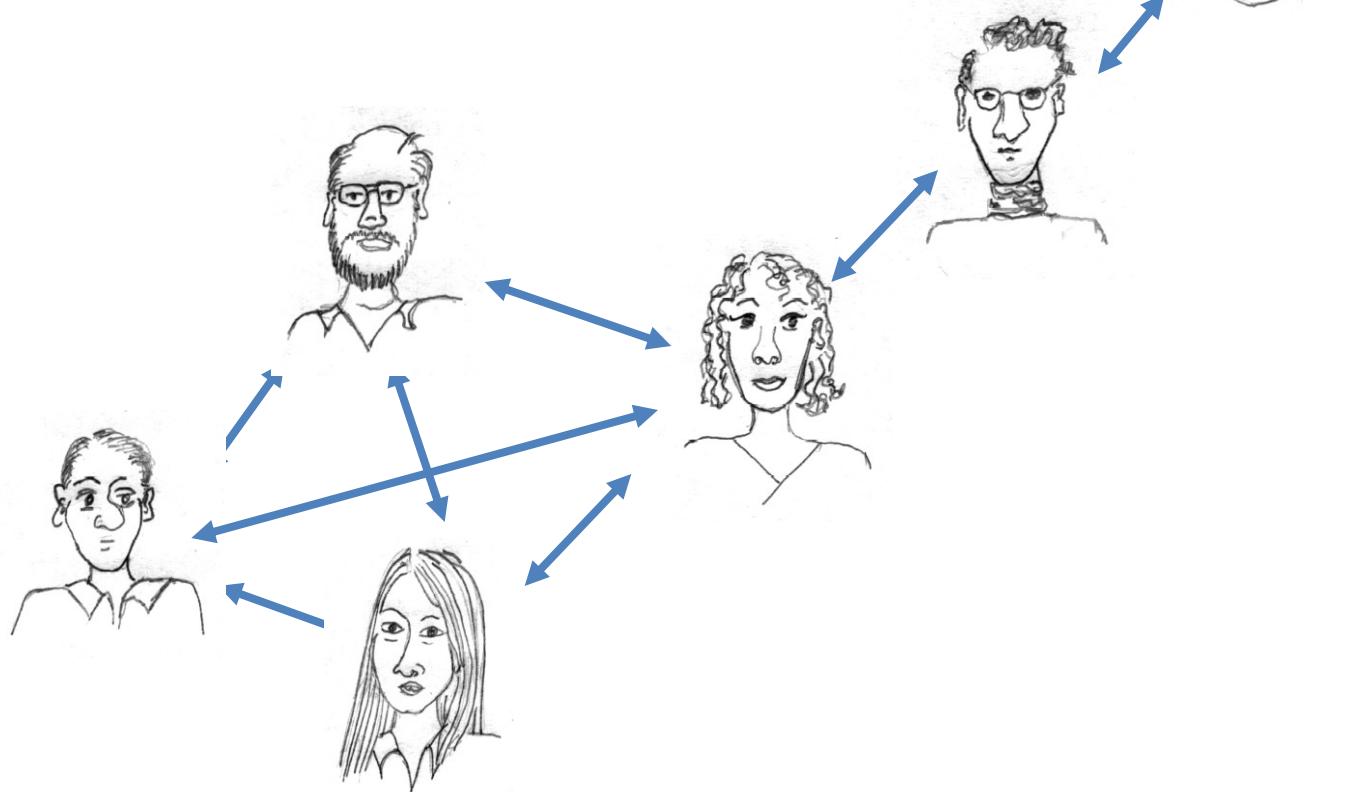
But it Depends on What You're Sharing!



Example: Small Worlds



- A friend of a friend is also frequently a friend
- Only six hops separate any two people in the



Network Questions: Communities

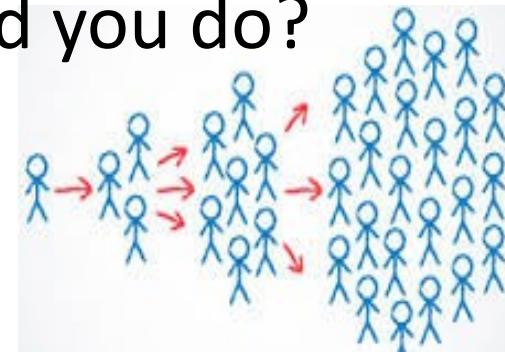
- Are there clusters in which the connections are particularly strong?
- How to discover communities, especially in large networks?
- How can we tell if these communities are statistically significant?
- What do these clusters tell us in specific applications?
- How we can optimize the number of communities?

Network Questions: Dynamics Of

- How can we model the growth of networks?
- What are the important features of networks that our models should capture?
- Are there “universal” models of network growth?
 - What details matter and what details don’t?
- How is the time-evolution of a network?
 - How about the reverse-time?! (e.g., sampling)
- How the network properties affected by its dynamical evolution?

Network Questions: Dynamics On

- How do diseases, computer viruses, innovations, rumors, revolutions, and opinions propagate on networks?
- What properties of networks are relevant to the answer of the above question?
- If you wanted to prevent (or encourage) spread of something on a network, what should you do?



Network Questions: Dynamics On

- What types of networks are **robust** to **random attack** or failure?
- What types of networks are robust to **intentional** and cascading attack?

Network Questions: Algorithms

- What types of networks are **searchable** or navigable?
- What are good ways to **visualize** complex networks?
- What are the optimal algorithms for **computing network metrics**?
- How does google **page rank** work?
- If the internet were to double in size, would it still work?