



# NETWORK SCIENCE

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# After 9/11



## THE HIJACKERS ...

### American Airlines 11

Crashed into WTC (north)



**Mohamed Atta**  
(Egyptian)  
Received pilot training



**Waleed M. Alshehri**  
(Saudi)  
Commercial pilot



**Wail Alshahri**  
(Saudi)  
Possible pilot training



**Satam al-Suqami**  
(Nationality unknown)



**Abdulaziz Alomari\***  
(Saudi)  
Possible pilot training

### American Airlines 77

Crashed into Pentagon



**Khalid al-Midhar**  
(Nationality unknown)  
Received pilot training



**Majed Moqed**  
(Nationality unknown)



**Salem Alhamzi\***  
(Saudi)  
Possible pilot training



**Nawaf Alhamzi\***  
(Saudi)



**Hani Hanjour**  
(Saudi)

### United Airlines 175

Crashed into WTC (south)



**Marwan al-Shehhi**  
(United Arab Emirates)  
Received pilot training



**Fayez Ahmed**  
(Believed to be Saudi)



**Ahmed Alghamdi**  
(Possibly Saudi)



**Hamza Alghamdi**  
(Believed to be Saudi)  
Possible pilot training



**Mohaid Alshehri**  
(Nationality unknown)  
Possible pilot training

### United Airlines 93

Crashed in Pennsylvania



**Ziad Jarrah**  
(Lebanese)  
Received pilot training



**Ahmed Alhaznawi**  
(Saudi)



**Ahmed Alnami**  
(Nationality unknown)



**Saeed Alghamdi\***  
(Seems to be Saudi)

\*Disputed identity

## AND HOW THEY WERE CONNECTED

### Attended same technical college

Hamburg, Germany

Mohamed Atta  
Marwan al-Shehhi  
Ziad Jarrah

### Took flight classes together

Pilot schools in Florida

Mohamed Atta  
Marwan al-Shehhi

Pilot schools in San Diego

Khalid al-Midhar  
Nawaf Alhamzi

### Bought flight tickets using same address

• Mohamed Atta\*  
Marwan al-Shehhi  
Abdulaziz Alomari\*  
\* Also used same credit card

• Waleed M. Alshehri  
Wail Alshahri

• Fayez Ahmed  
Mohaid Alshehri

• Ahmed Alghamdi  
Hamza Alghamdi

### Known to be together in week before attacks

Stayed together in a Florida motel

Mohamed Atta  
Marwan al-Shehhi

Attended a gym in Maryland (Sept 2-6), also seen dining together

Khalid al-Midhar  
Majed Moqed  
Salem Alhamzi  
Nawaf Alhamzi  
Hani Hanjour

### Bought flight tickets together

Mohamed Atta  
Ziad Jarrah  
Ahmed Alhaznawi

Picked up tickets bought earlier in Baltimore

Khalid al-Midhar  
Majed Moqed

Bought from the same travel agent in Florida

Ahmed Alnami  
Saeed Alghamdi

### Last known address

Hollywood, Florida

Marwan al-Shehhi  
Waleed M. Alshehri  
Wail Alshahri  
Ziad Jarrah  
Hani Hanjour

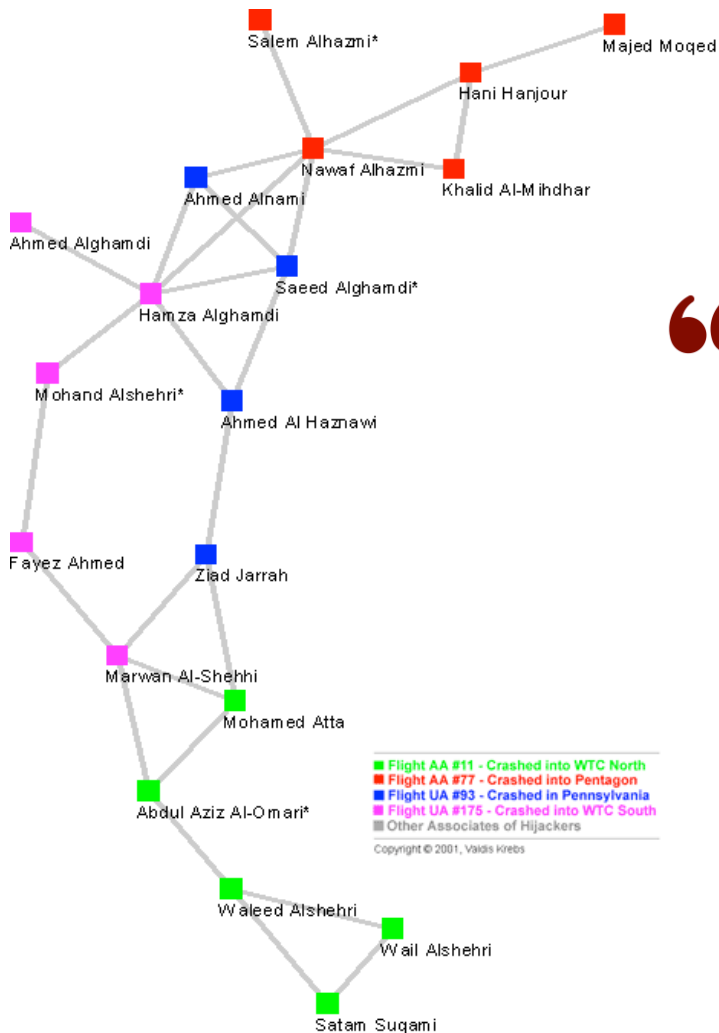
Other cities in Florida

Mohamed Atta  
Fayez Ahmed  
Ahmed Alghamdi  
Mohaid Alshehri  
Khalid al-Midhar  
Ahmed Alhaznawi  
Ahmed Alnami  
Saeed Alghamdi

Outside Florida

Satam al-Suqami  
Hamza Alghamdi  
Abdulaziz Alomari  
Majed Moqed  
Salem Alhamzi  
Nawaf Alhamzi

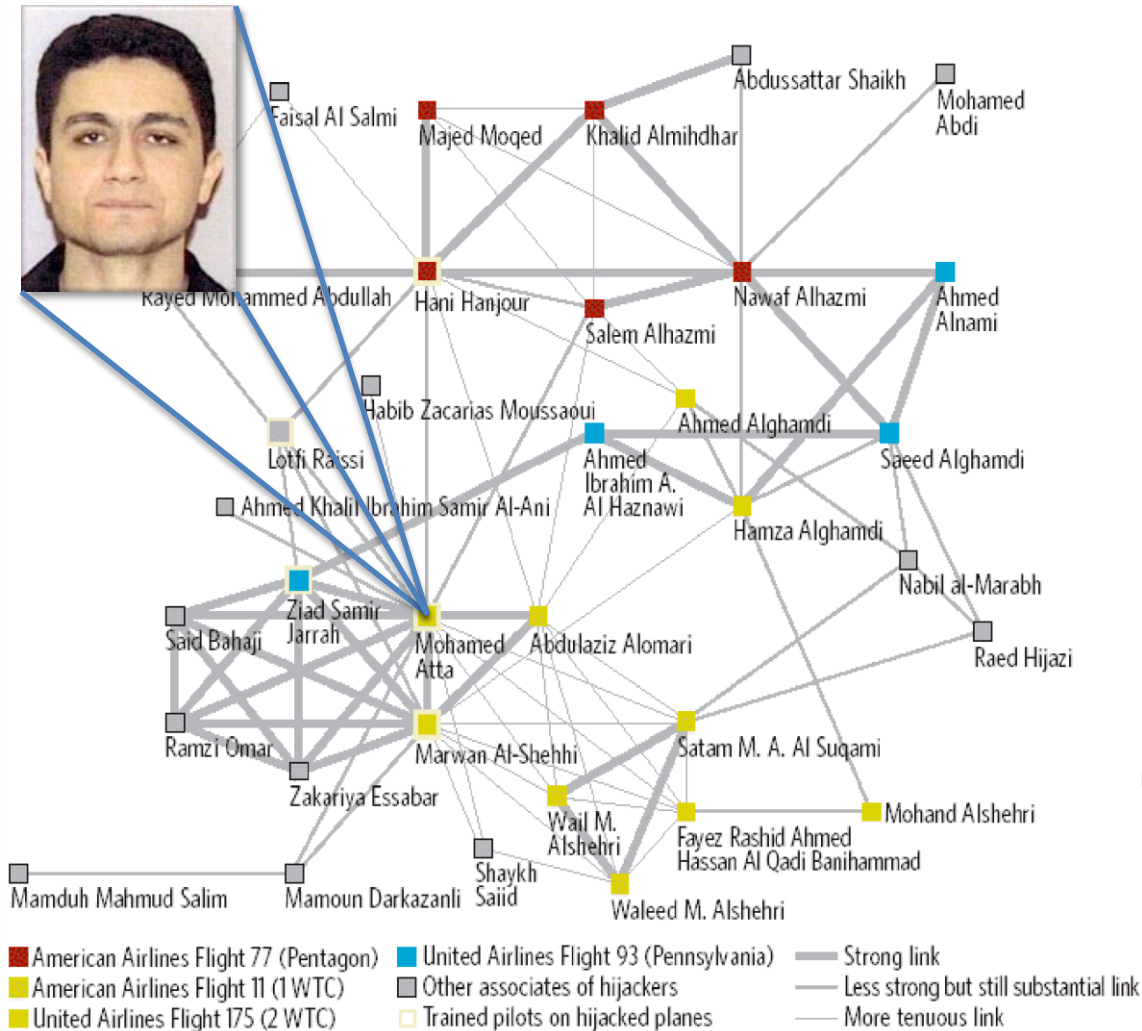
# The terrorist network / 1



“Those who were trained to fly didn't know the others.  
One group of people did not know the other group.”

Osama Bin Laden

# The terrorist network / 2

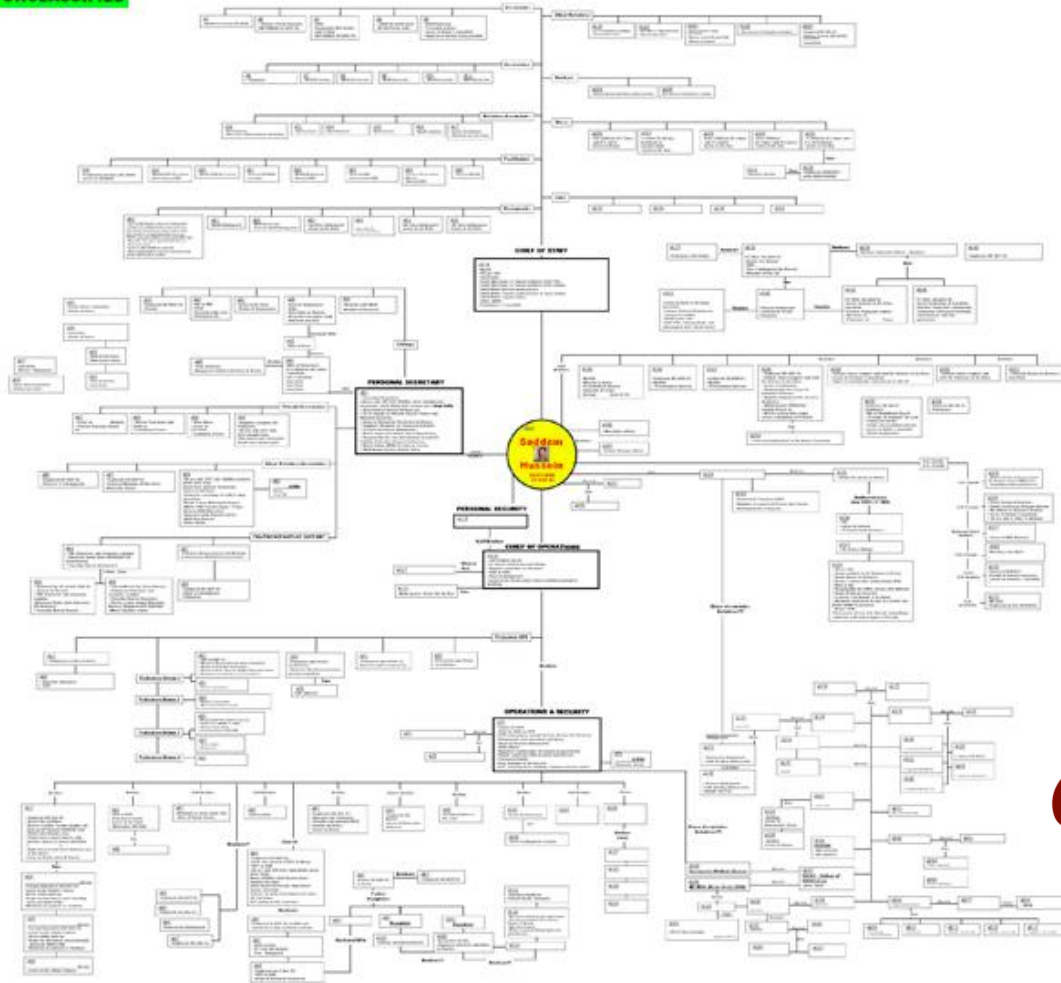


“ Muhammad (Atta) from the Egyptian family, was in charge of the group.

Osama Bin Laden

# Saddam Hussein's capture

UNCLASSIFIED

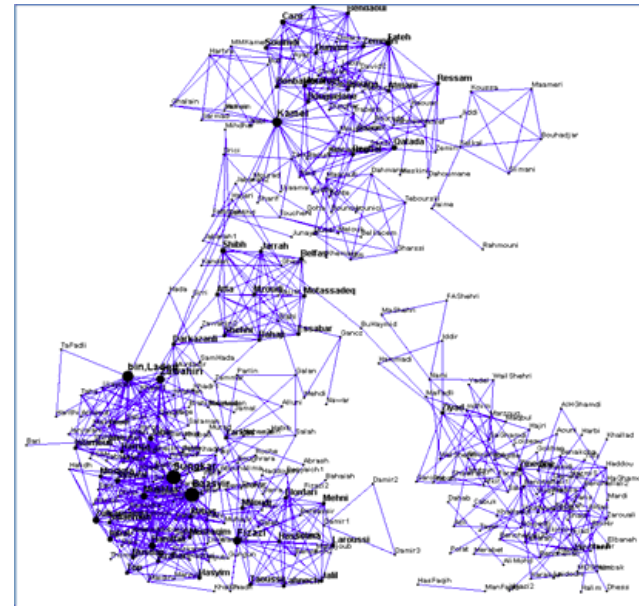
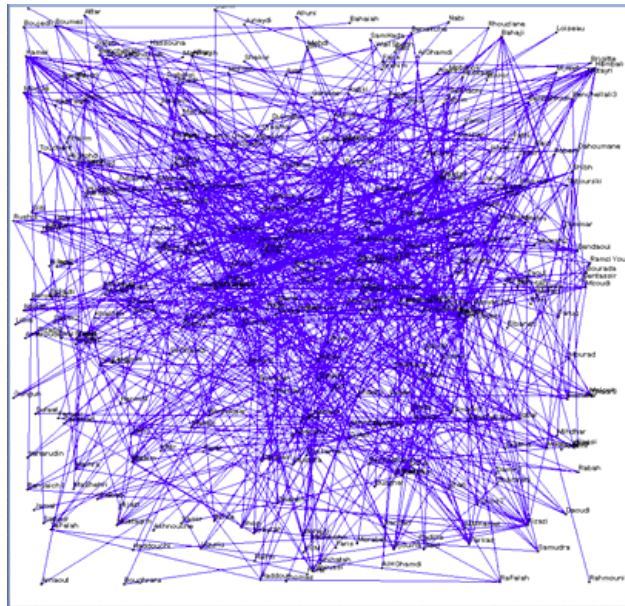


“ of the 214 actors in the total network, there are only 23 actors with direct ties to Saddam Hussein

Brian J. Reed (2006)

UNCLASSIFIED

# Emergence of structure



The “Global Salafi Jihad” social network (Yang, Liu & Sageman, 2006)

The clusters correspond to four known terroristic groups:

- The Central Staff (Al Qaeda command & control)
- Core Arabs (activists from the central Arab region)
- Maghreb Arabs (those from North Africa and the North African Diaspora)
- Southeast Asians (mostly Indonesians)

# Can we predict terrorist attacks?



## A Computer Program That Predicts Terrorist Attacks

A data-mining project that adapts analytics used by Amazon and big box retailers to predict customer behavior is now being used to stop terrorism before it starts.

**CORRIERE DELLA SERA**

L'ANALISI

## Si può prevedere un attentato? Gli studi che ci hanno provato

Dal gigantesco sistema di analisi computerizzata GTD (*Global Terrorism Database*) alle ricerche antropologiche comparse sulle riviste medico-scientifiche negli ultimi anni

di Cesare Peccarisi

A screenshot of the Global Terrorism Database (GTD) website. The header includes the GTD logo and navigation links: ABOUT GTD, USING GTD, FAQ, TERMS OF USE, CONTACT, and a START HOME PAGE button. The main content area features a search interface with a red background. It includes a search bar with the text "Search the Database", a "SEARCH" button, a checkbox for "I'm a New User", an "ADVANCED SEARCH" button, and a "Browse by:" dropdown menu with a "Go" button. To the right of the search interface, there is a section titled "Information on more than 140,000 Terrorist Attacks" with a brief description of the database and a "Learn more" link.

# Social networks

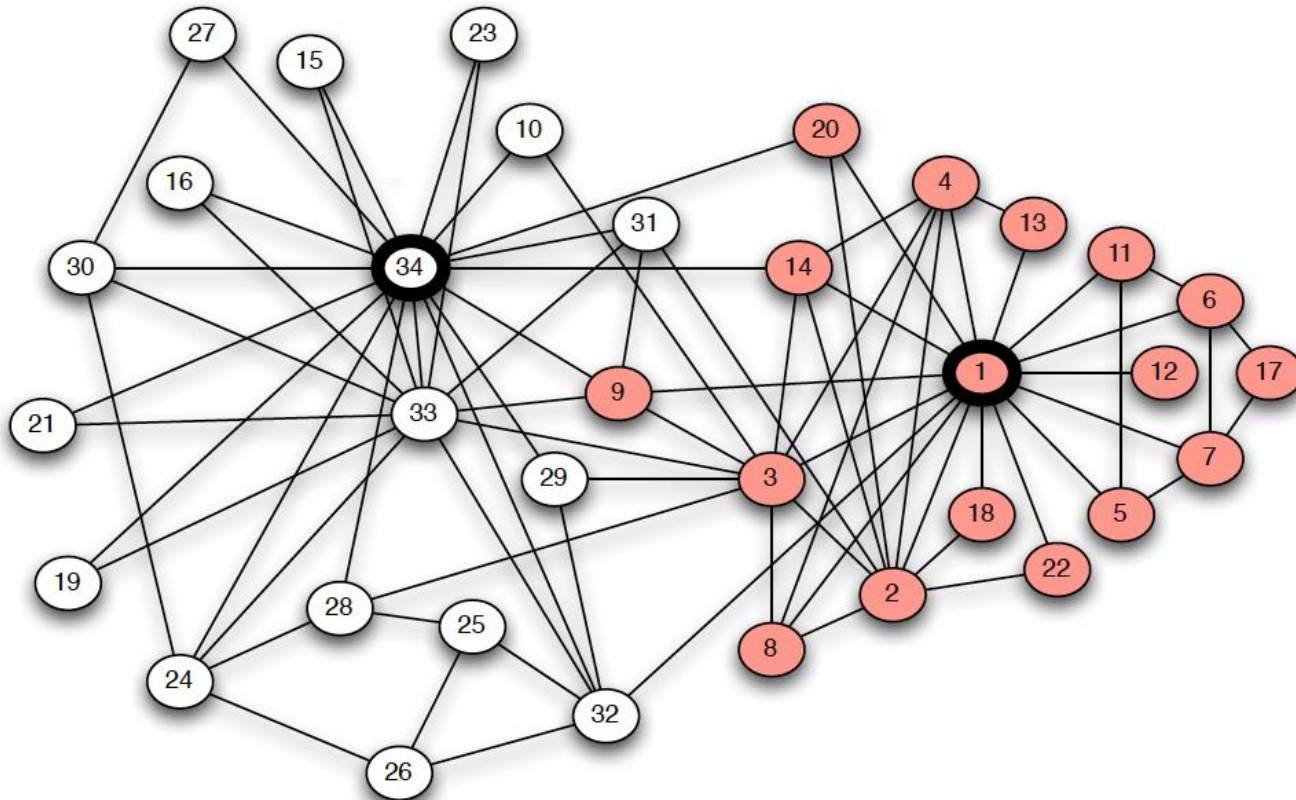
“ *Social Network Analysis is a mathematical methodology for connecting the dots — using science to fight terrorism. Connecting multiple pairs of dots soon reveals an emergent network of organization.*

Valdis Krebs





# Zachary's karate club



From the social network of friendships in the karate club, we can find clues to the latent schism that eventually split the group into two separate clubs (indicated by the two different shadings of individuals in the picture).

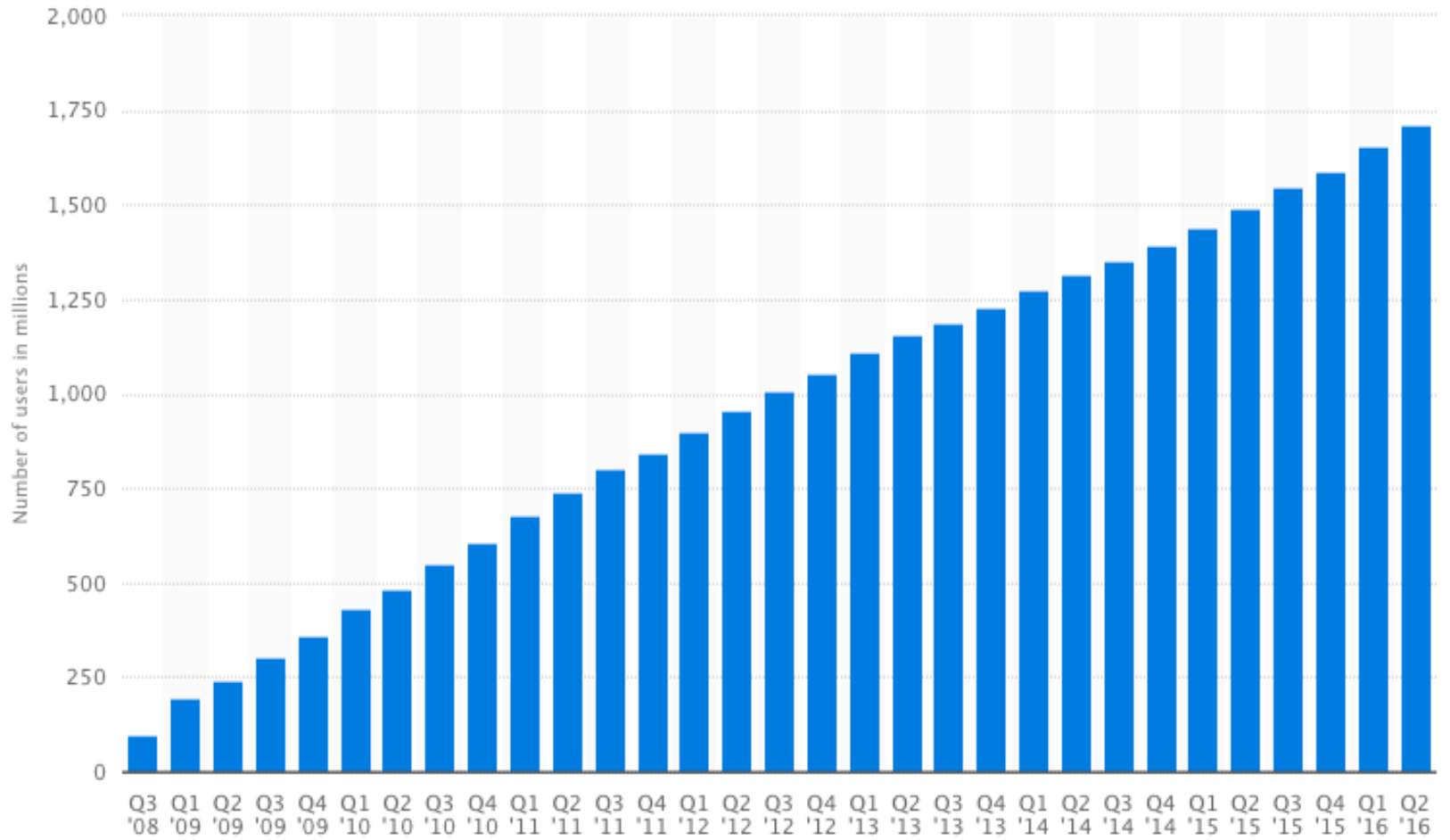
# Social networks can be large ...



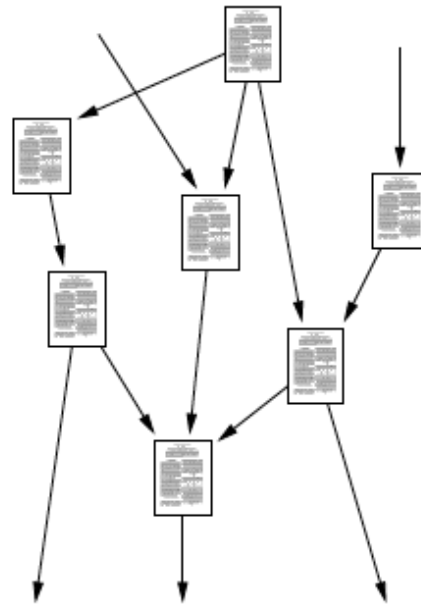
As of the second quarter of 2016, Facebook had **1.71 billion** monthly active users

<https://www.statista.com/statistics/264810/number-of-monthly-active-facebook-users-worldwide/>

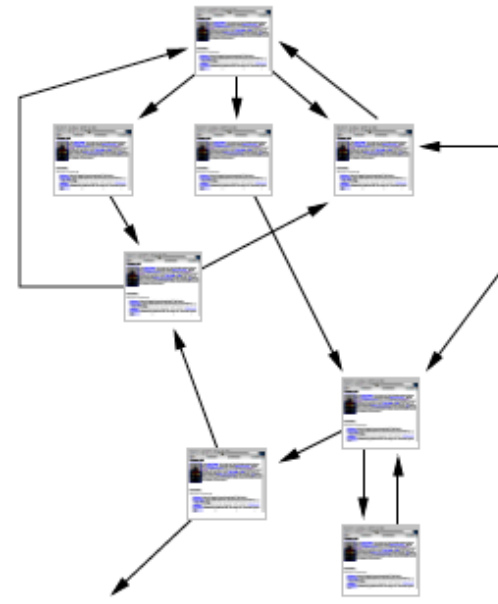
# ... and might grow fast



# Information networks



citation network

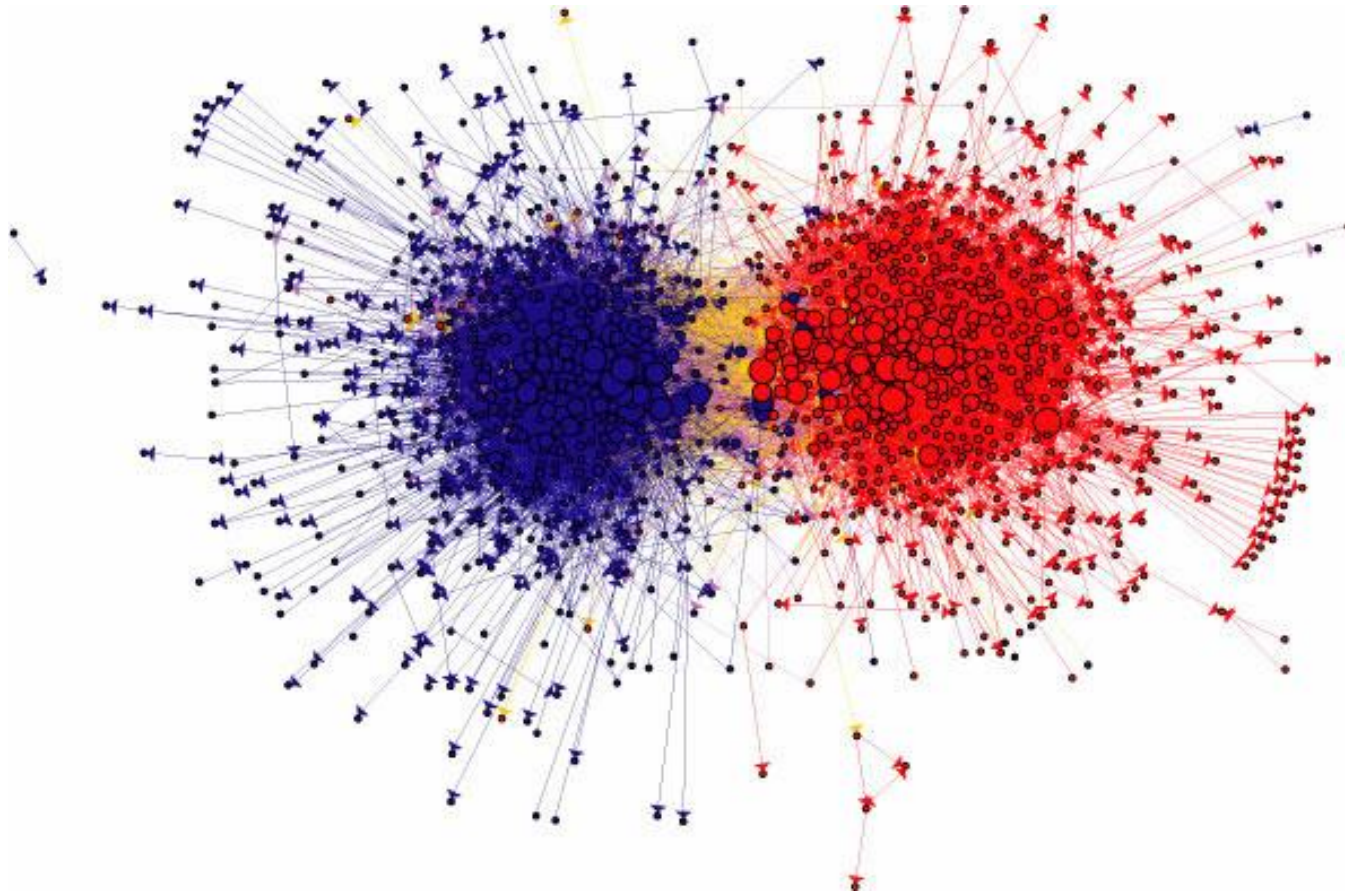


World-Wide Web

**Left:** the citation network of academic papers in which the vertices are papers and the directed edges are citations of one paper by another. Since papers can only cite those that came before them (lower down in the figure) the graph is acyclic -- it has no closed loops.

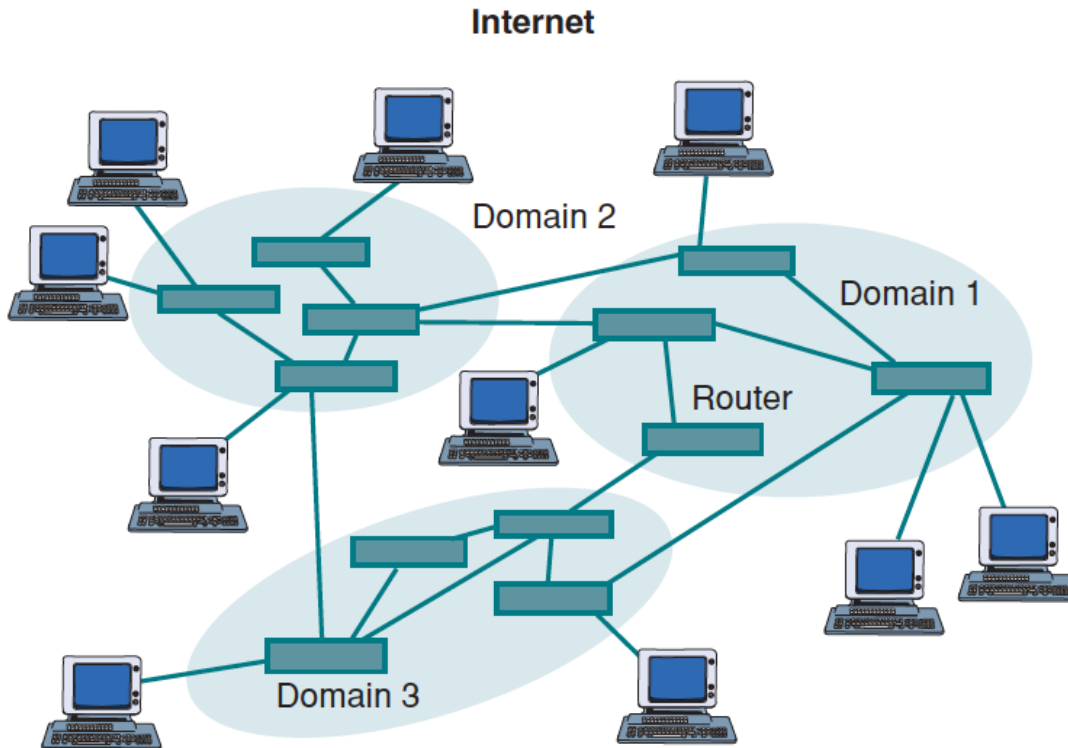
**Right:** the World Wide Web, a network of text pages accessible over the Internet, in which the vertices are pages and the directed edges are hyperlinks. There are no constraints on the Web that forbid cycles and hence it is in general cyclic.

# Communities



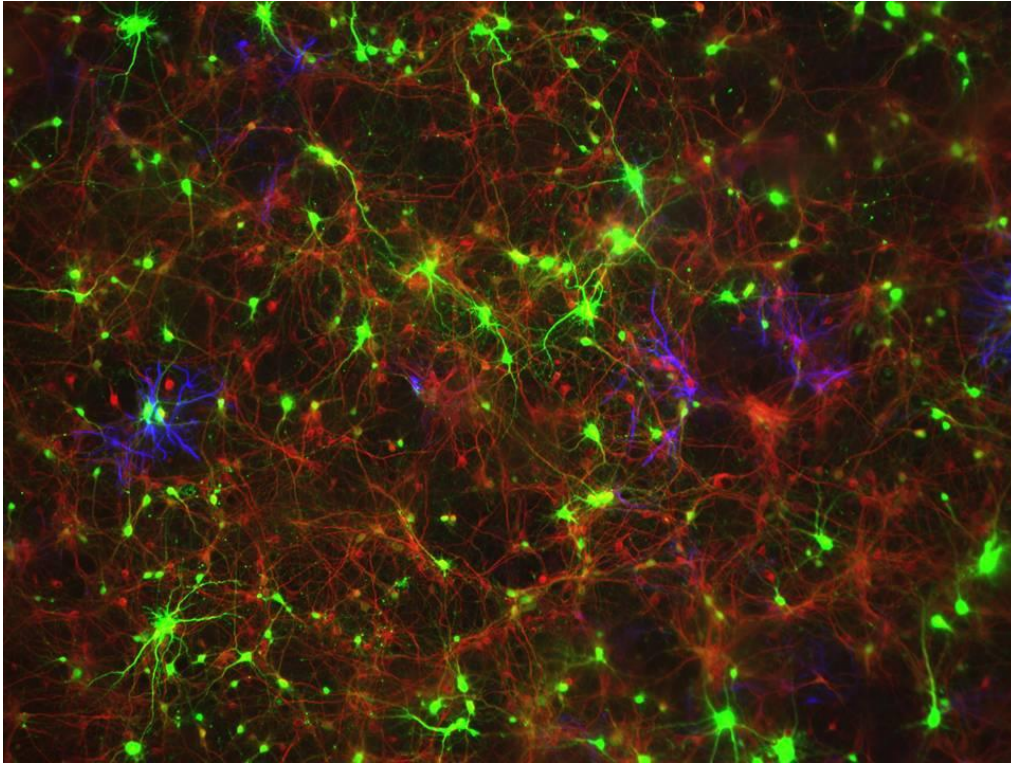
The links among Web pages can reveal densely-knit communities and prominent sites. In this case, the network structure of political blogs prior to the 2004 U.S. Presidential election reveals two natural and well-separated clusters. (Image from <http://wwwpersonal.umich.edu/~ladamic/img/politicalblogs.jpg>)

# Technological networks



- Internet
- Electric power grid
- Network of airline routes
- Networks of roads
- Railways
- Telephone networks
- ...

# Biological networks



- Neural networks
- Food web
- Metabolic pathways
- Genetic regulatory networks
- ...

# Basic statistics of some publicly available networks

	network	type	$n$	$m$	$z$	$\ell$	$\alpha$	$C^{(1)}$	$C^{(2)}$	$r$	Ref(s).
social	film actors	undirected	449 913	25 516 482	113.43	3.48	2.3	0.20	0.78	0.208	20, 416
	company directors	undirected	7 673	55 392	14.44	4.60	–	0.59	0.88	0.276	105, 323
	math coauthorship	undirected	253 339	496 489	3.92	7.57	–	0.15	0.34	0.120	107, 182
	physics coauthorship	undirected	52 909	245 300	9.27	6.19	–	0.45	0.56	0.363	311, 313
	biology coauthorship	undirected	1 520 251	11 803 064	15.53	4.92	–	0.088	0.60	0.127	311, 313
	telephone call graph	undirected	47 000 000	80 000 000	3.16		2.1				8, 9
	email messages	directed	59 912	86 300	1.44	4.95	1.5/2.0		0.16		136
	email address books	directed	16 881	57 029	3.38	5.22	–	0.17	0.13	0.092	321
	student relationships	undirected	573	477	1.66	16.01	–	0.005	0.001	–0.029	45
	sexual contacts	undirected	2 810				3.2				265, 266
information	WWW <a href="http://nd.edu">nd.edu</a>	directed	269 504	1 497 135	5.55	11.27	2.1/2.4	0.11	0.29	–0.067	14, 34
	WWW Altavista	directed	203 549 046	2 130 000 000	10.46	16.18	2.1/2.7				74
	citation network	directed	783 339	6 716 198	8.57		3.0/–				351
	Roget's Thesaurus	directed	1 022	5 103	4.99	4.87	–	0.13	0.15	0.157	244
	word co-occurrence	undirected	460 902	17 000 000	70.13		2.7		0.44		119, 157
technological	Internet	undirected	10 697	31 992	5.98	3.31	2.5	0.035	0.39	–0.189	86, 148
	power grid	undirected	4 941	6 594	2.67	18.99	–	0.10	0.080	–0.003	416
	train routes	undirected	587	19 603	66.79	2.16	–		0.69	–0.033	366
	software packages	directed	1 439	1 723	1.20	2.42	1.6/1.4	0.070	0.082	–0.016	318
	software classes	directed	1 377	2 213	1.61	1.51	–	0.033	0.012	–0.119	395
	electronic circuits	undirected	24 097	53 248	4.34	11.05	3.0	0.010	0.030	–0.154	155
	peer-to-peer network	undirected	880	1 296	1.47	4.28	2.1	0.012	0.011	–0.366	6, 354
biological	metabolic network	undirected	765	3 686	9.64	2.56	2.2	0.090	0.67	–0.240	214
	protein interactions	undirected	2 115	2 240	2.12	6.80	2.4	0.072	0.071	–0.156	212
	marine food web	directed	135	598	4.43	2.05	–	0.16	0.23	–0.263	204
	freshwater food web	directed	92	997	10.84	1.90	–	0.20	0.087	–0.326	272
	neural network	directed	307	2 359	7.68	3.97	–	0.18	0.28	–0.226	416, 421



# Complex Systems

# 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, 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**

# Complexity

# Complex Systems

## Complex systems

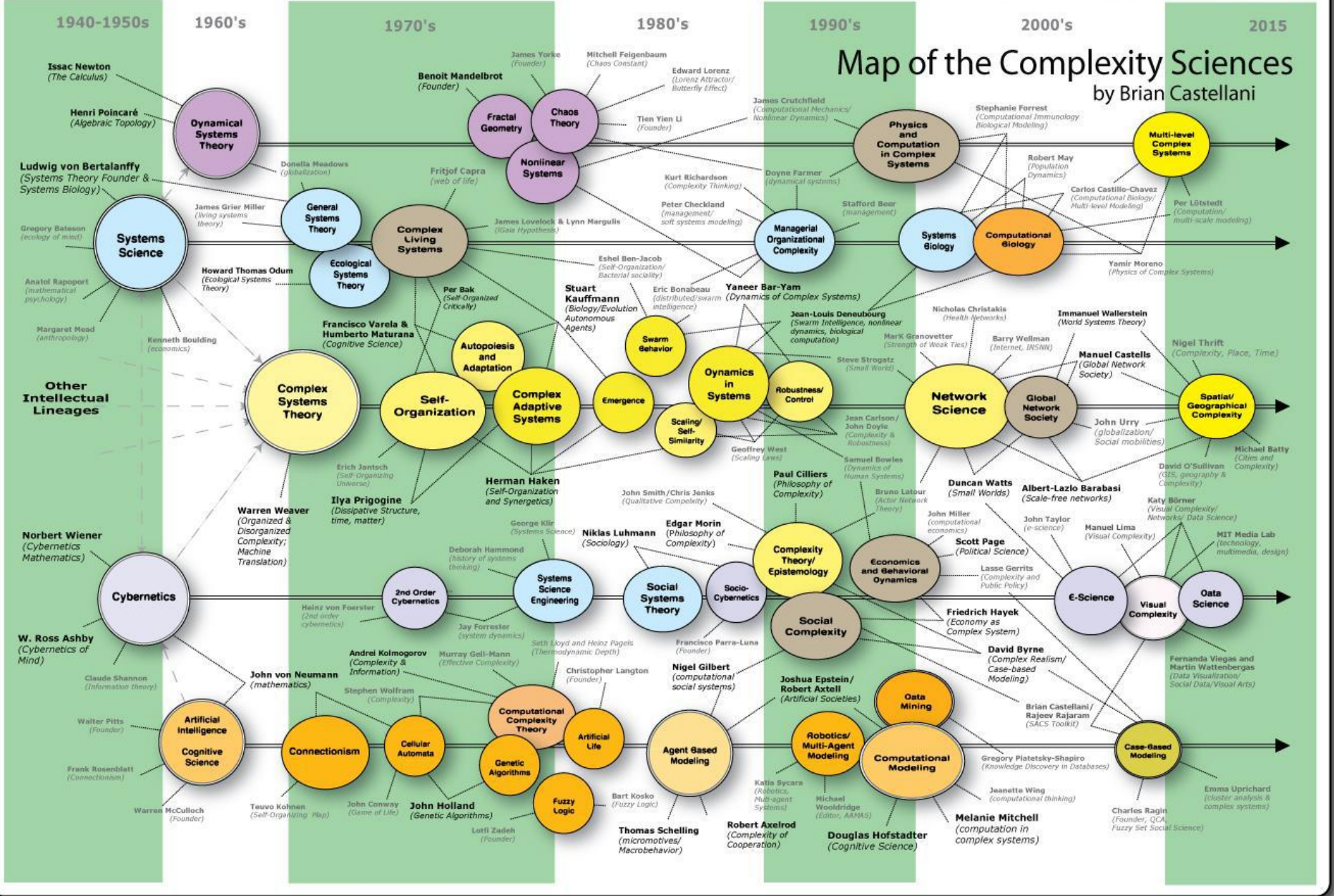
Made of many non-identical **elements** connected by diverse **interactions**.



**NETWORK**

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.



# Connected: Six Degrees of Separation

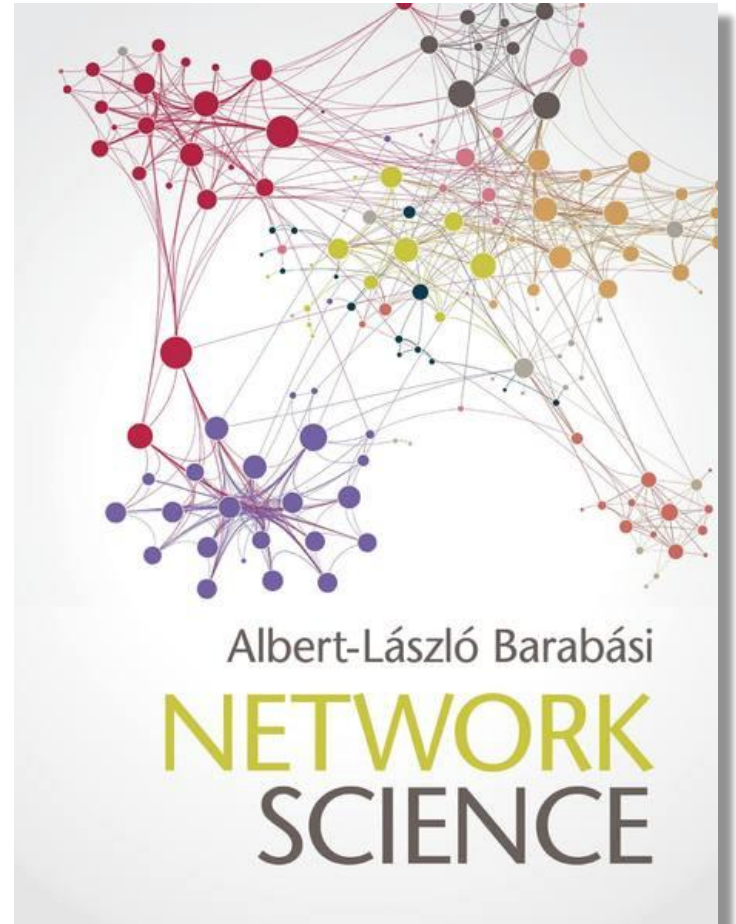
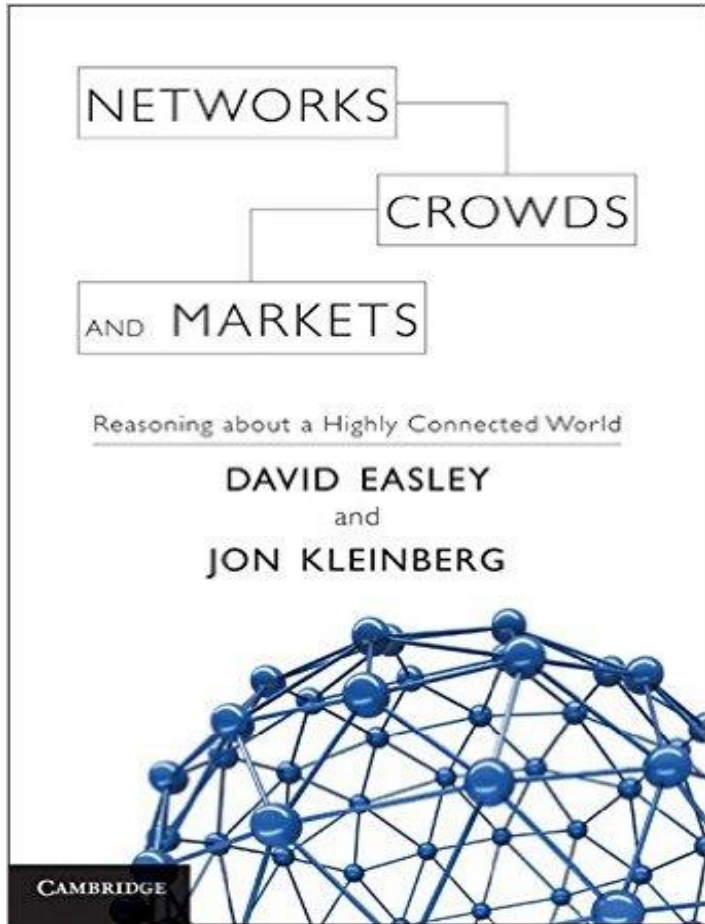


<http://topdocumentaryfilms.com/six-degrees-of-separation/>

# Course content

- Graphs and networks
- Game theory
- Networks and the WWW
- Networks dynamics

# Textbooks



# The exam

- Oral exam
- Hands-on activity:
  - Seminar **or**
  - Project development