

Title: Epidemics, Erdos numbers, and the Internet: The structure and function of networks

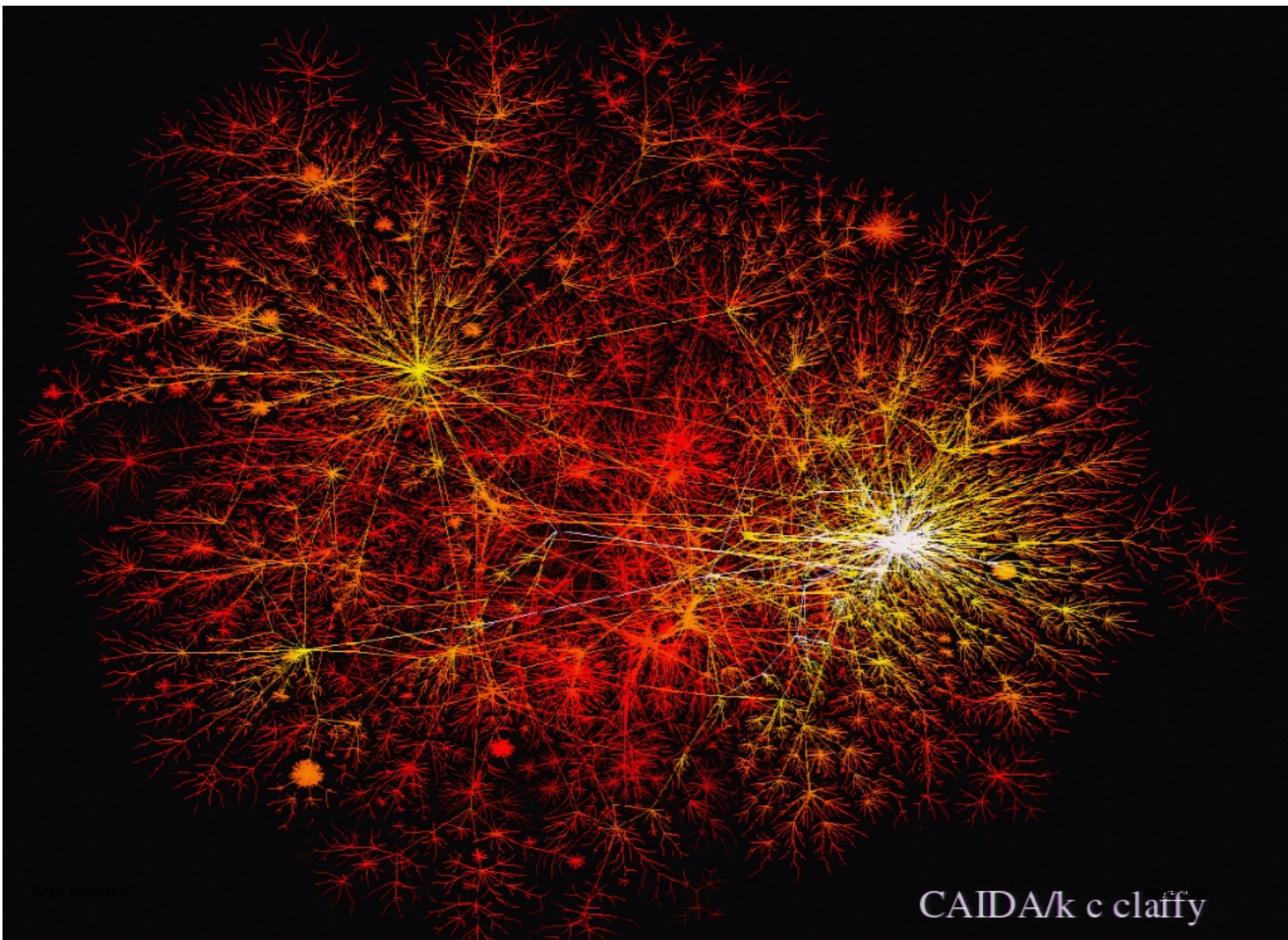
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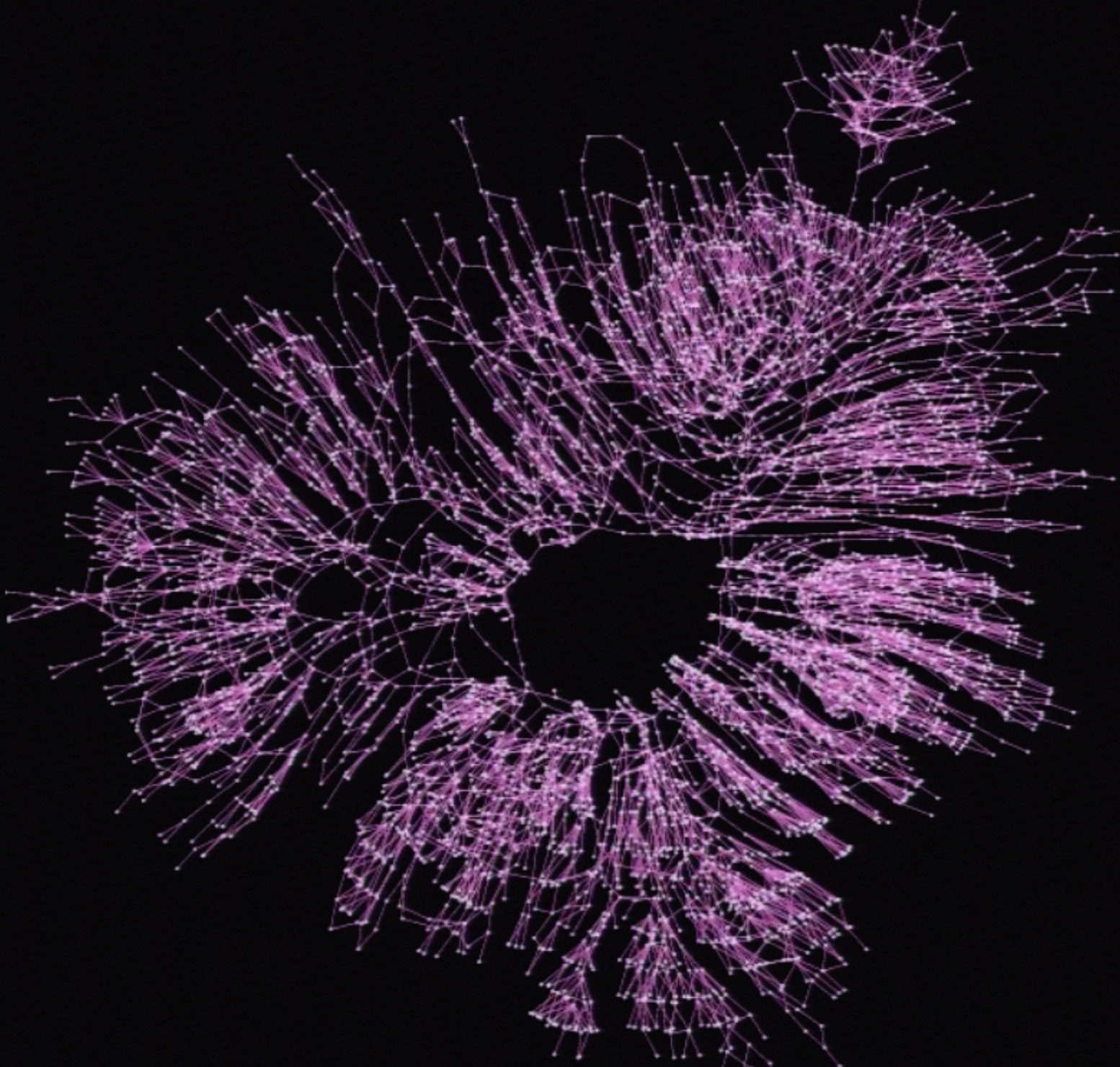
Abstract: Many systems take the form of networks: the Internet, the World Wide Web, social networks, distribution networks, citation networks, food webs, and neural networks are just a few examples. I will show some recent empirical results on the structure of these and other networks, particularly emphasizing degree sequences, clustering, and vertex-vertex correlations. I will also discuss some graph theoretical models of networks that incorporate these features, and give examples of how both empirical measurements and models can lead to interesting and useful predictions about the real world.

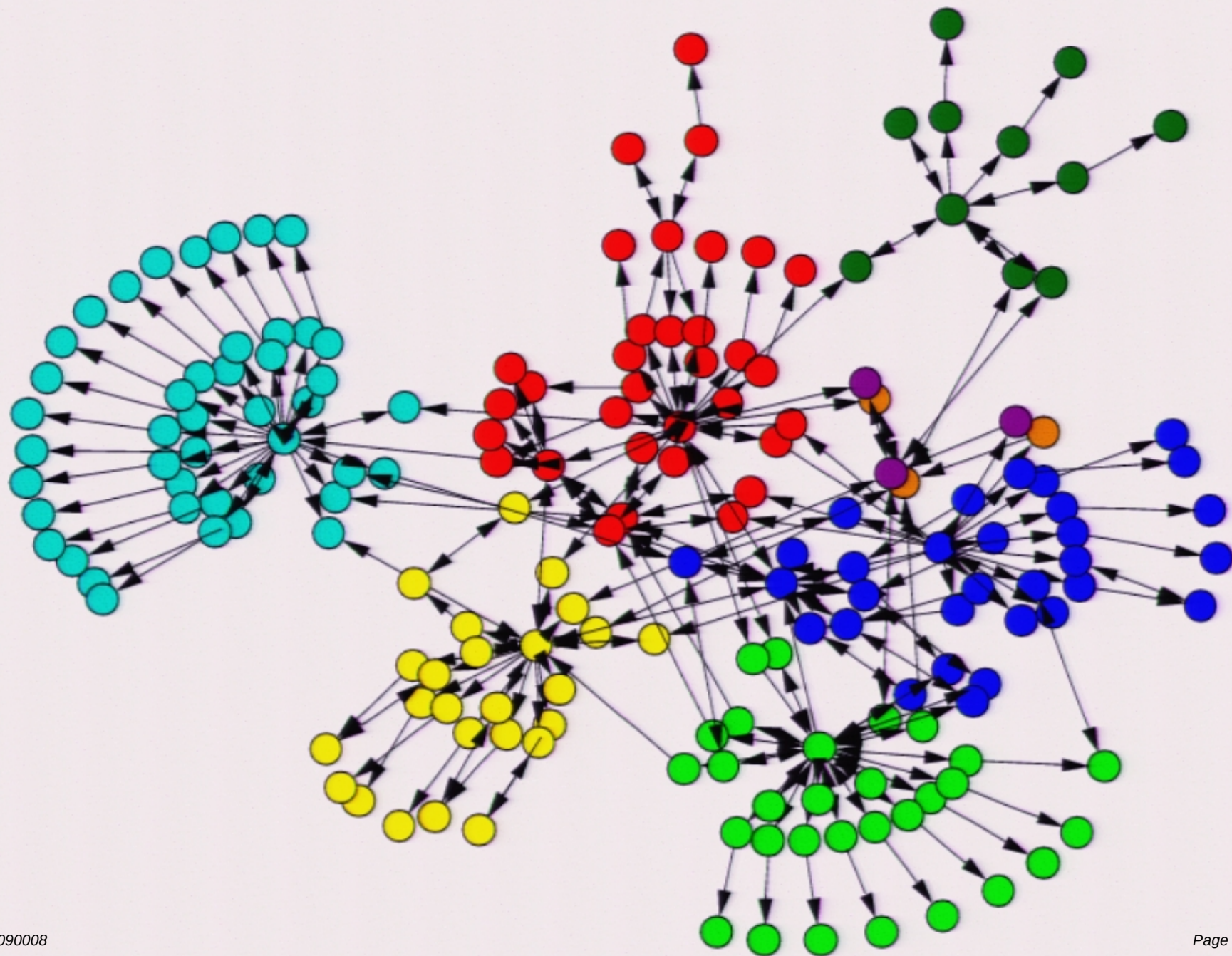
Erdos numbers, Epidemics, and the Internet: The Structure and Function of Networks

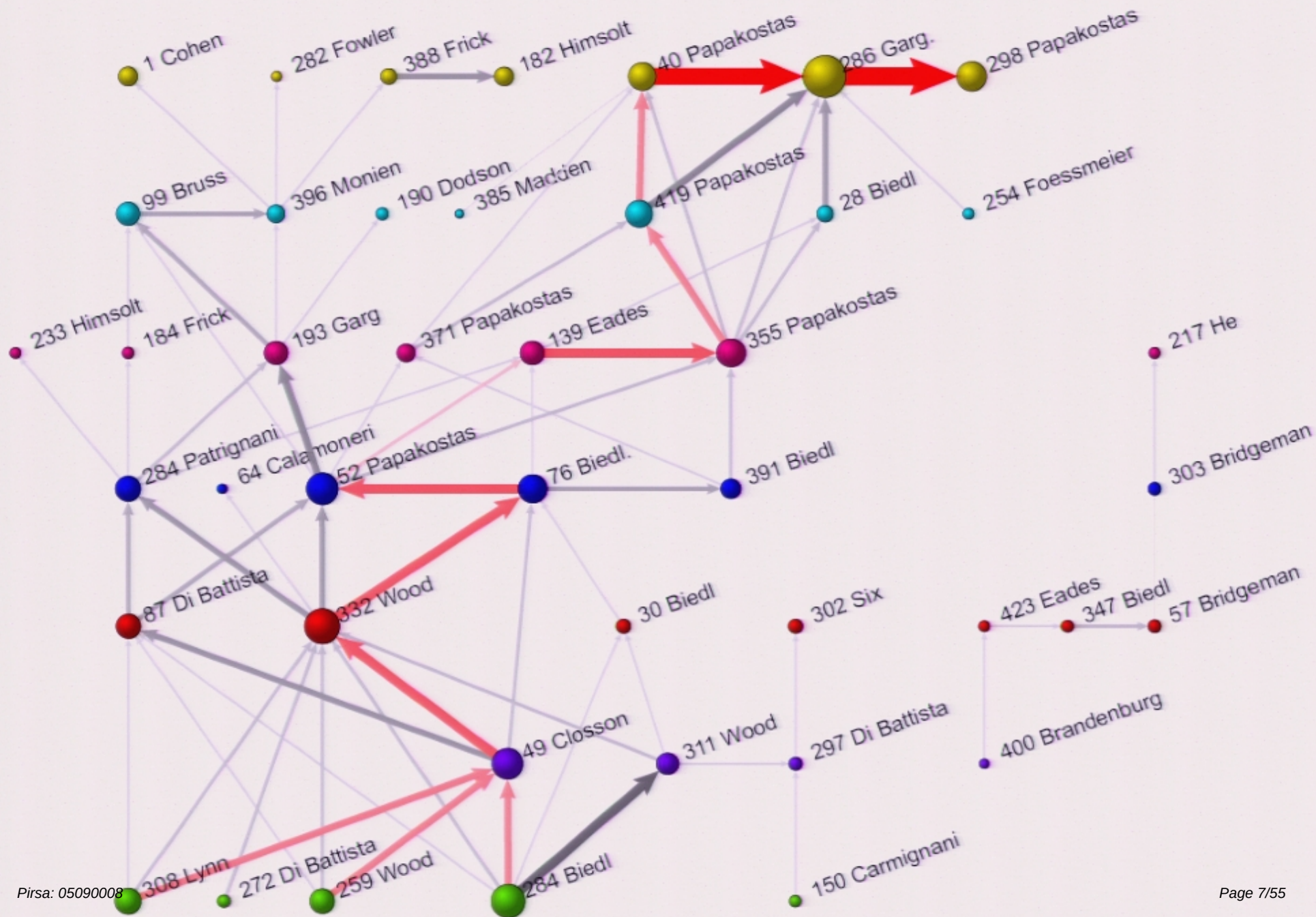
Mark Newman
University of Michigan



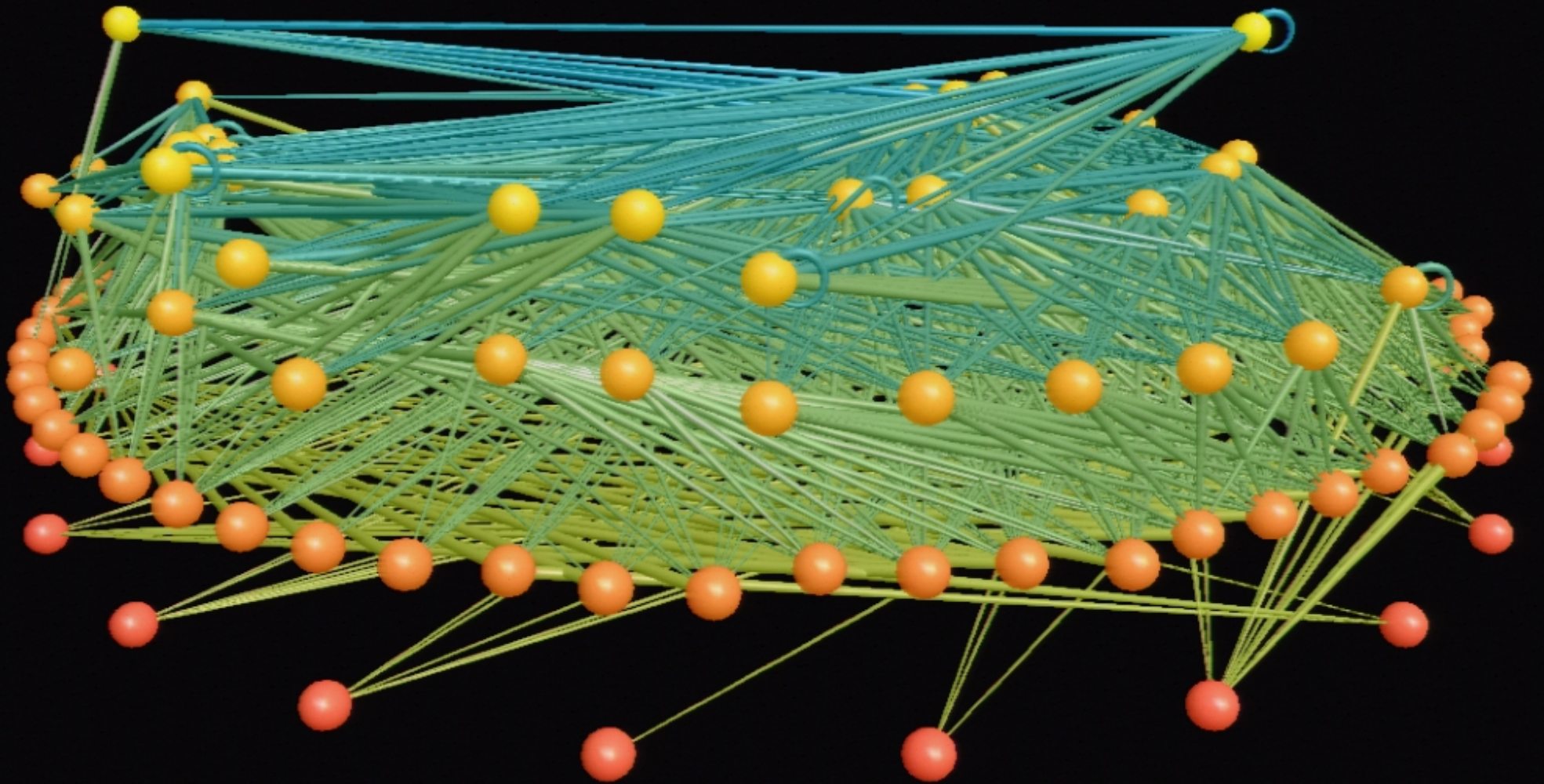






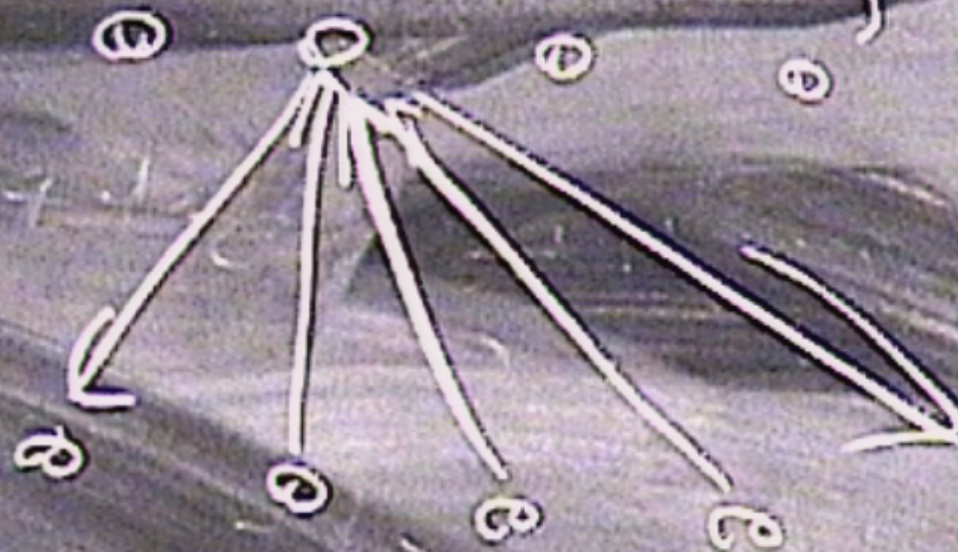




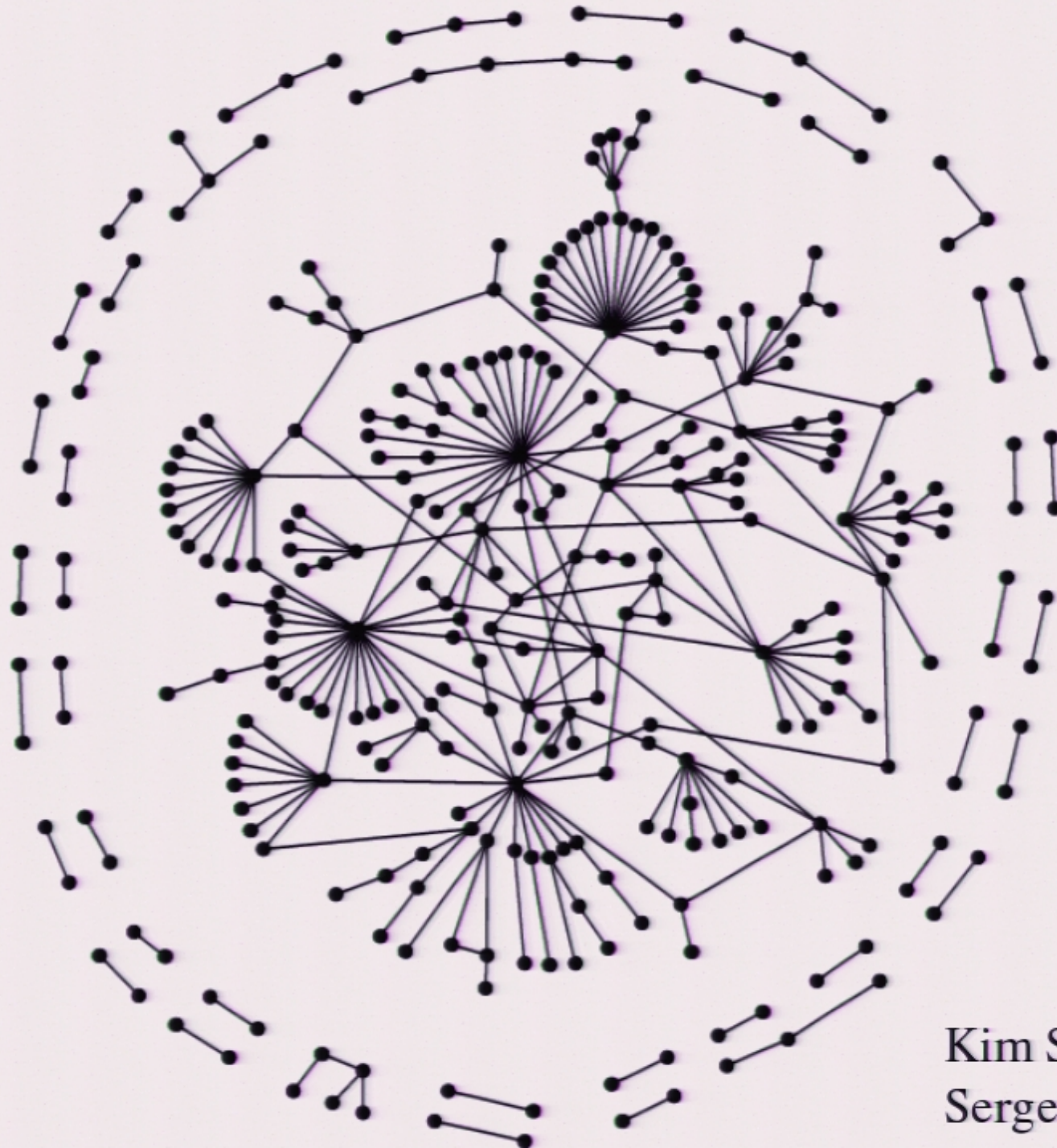


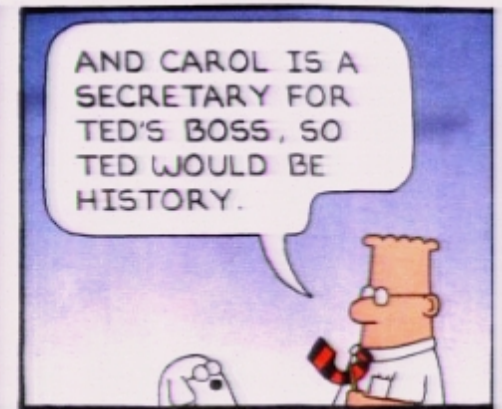
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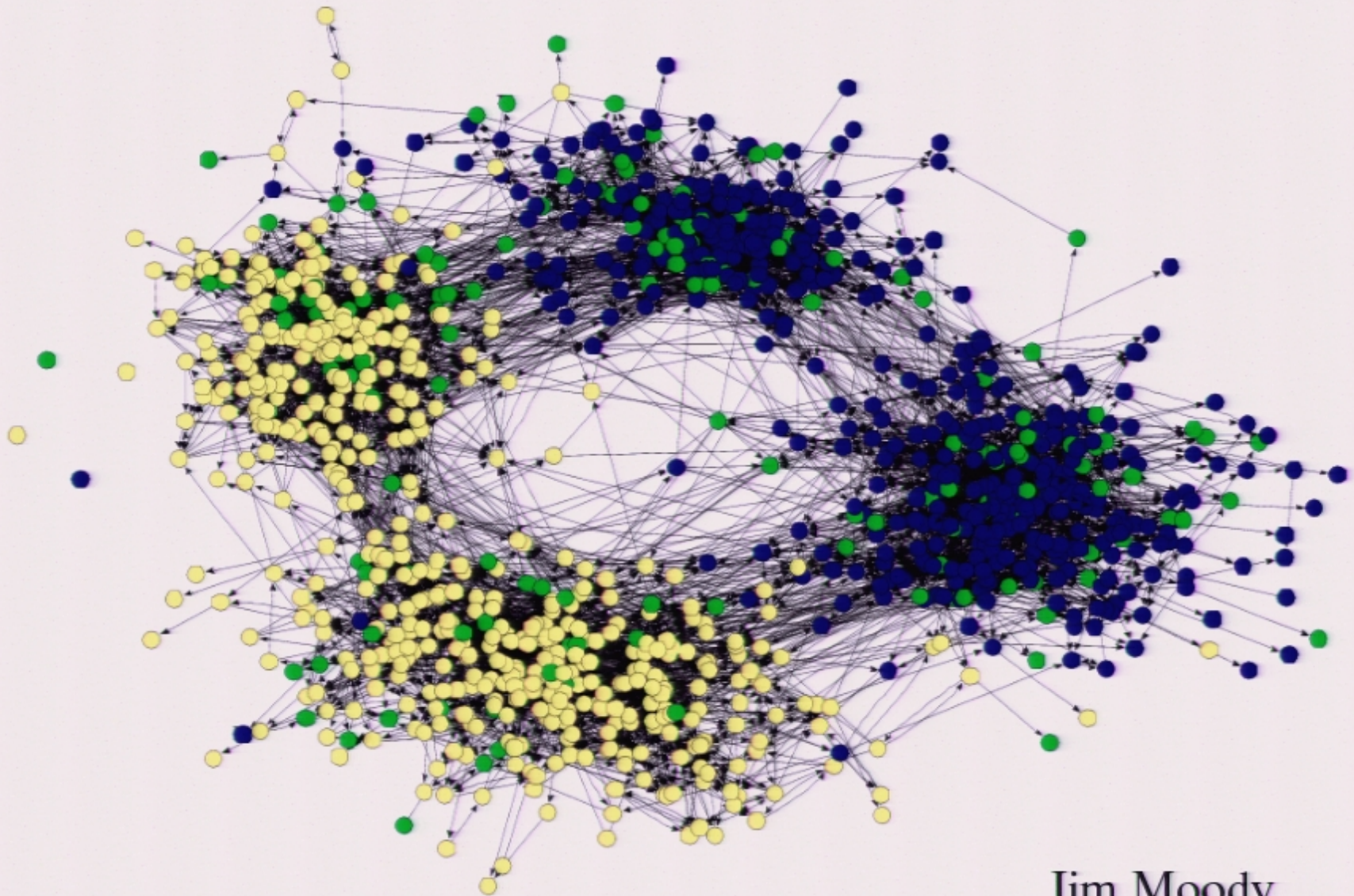
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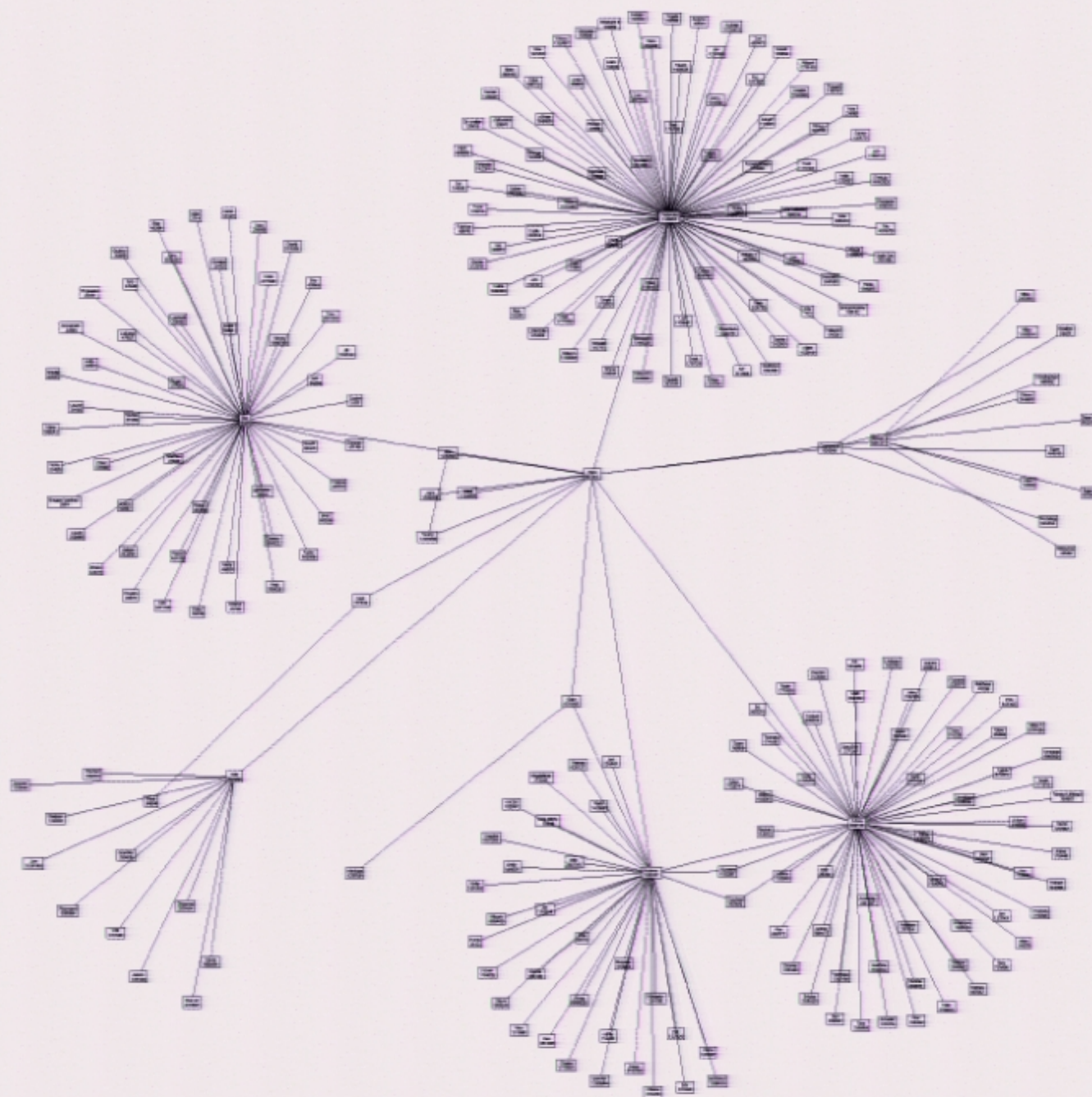
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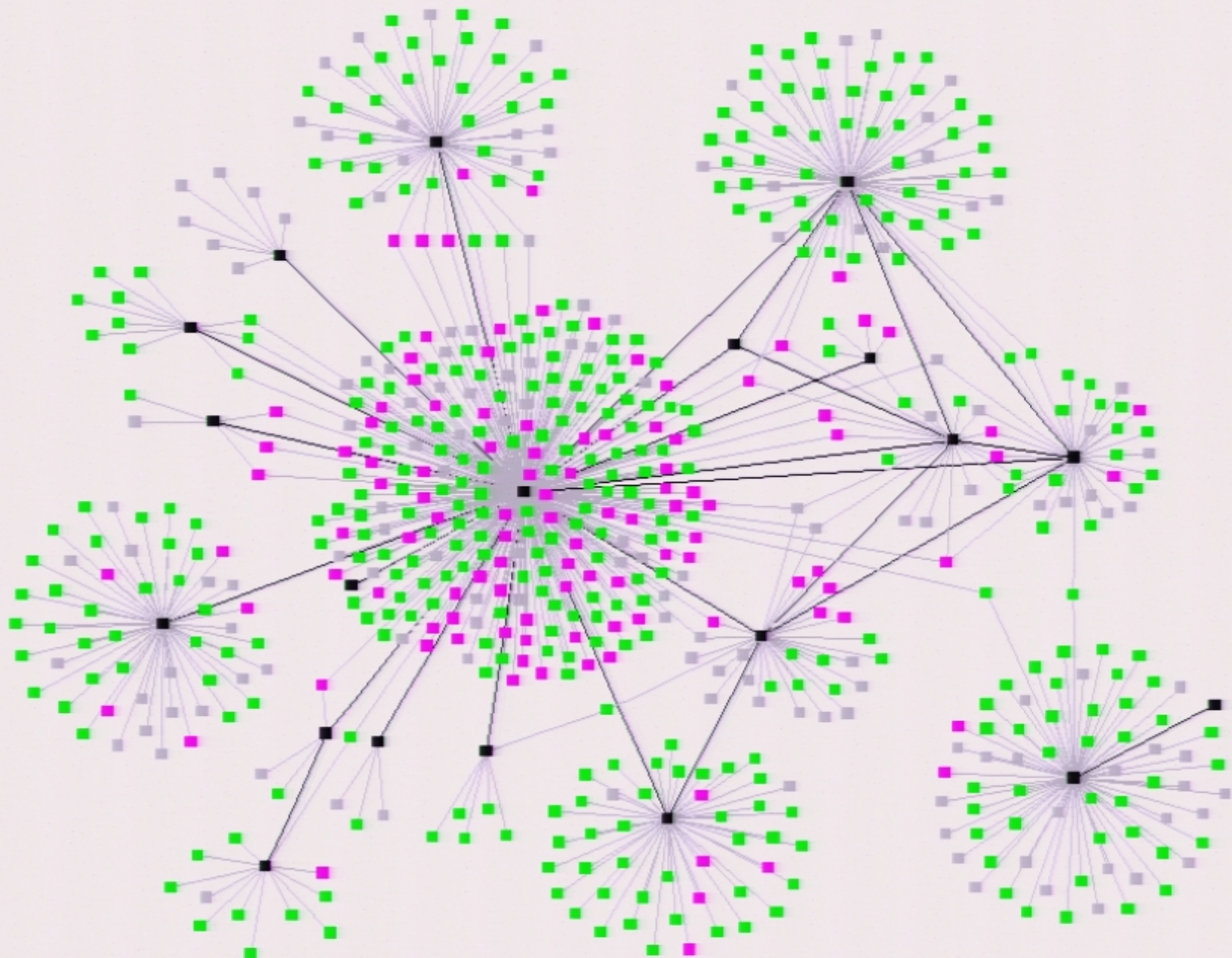


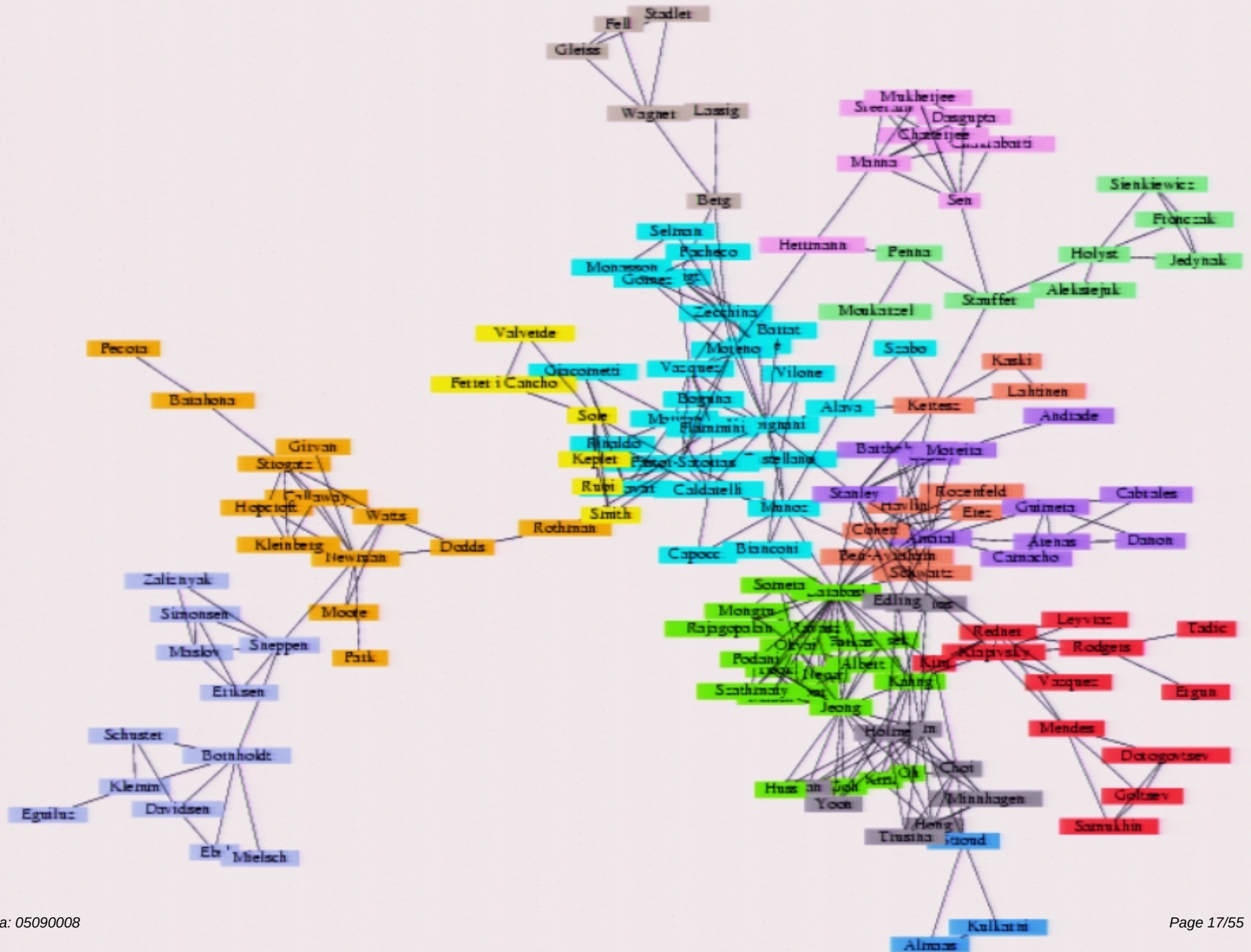


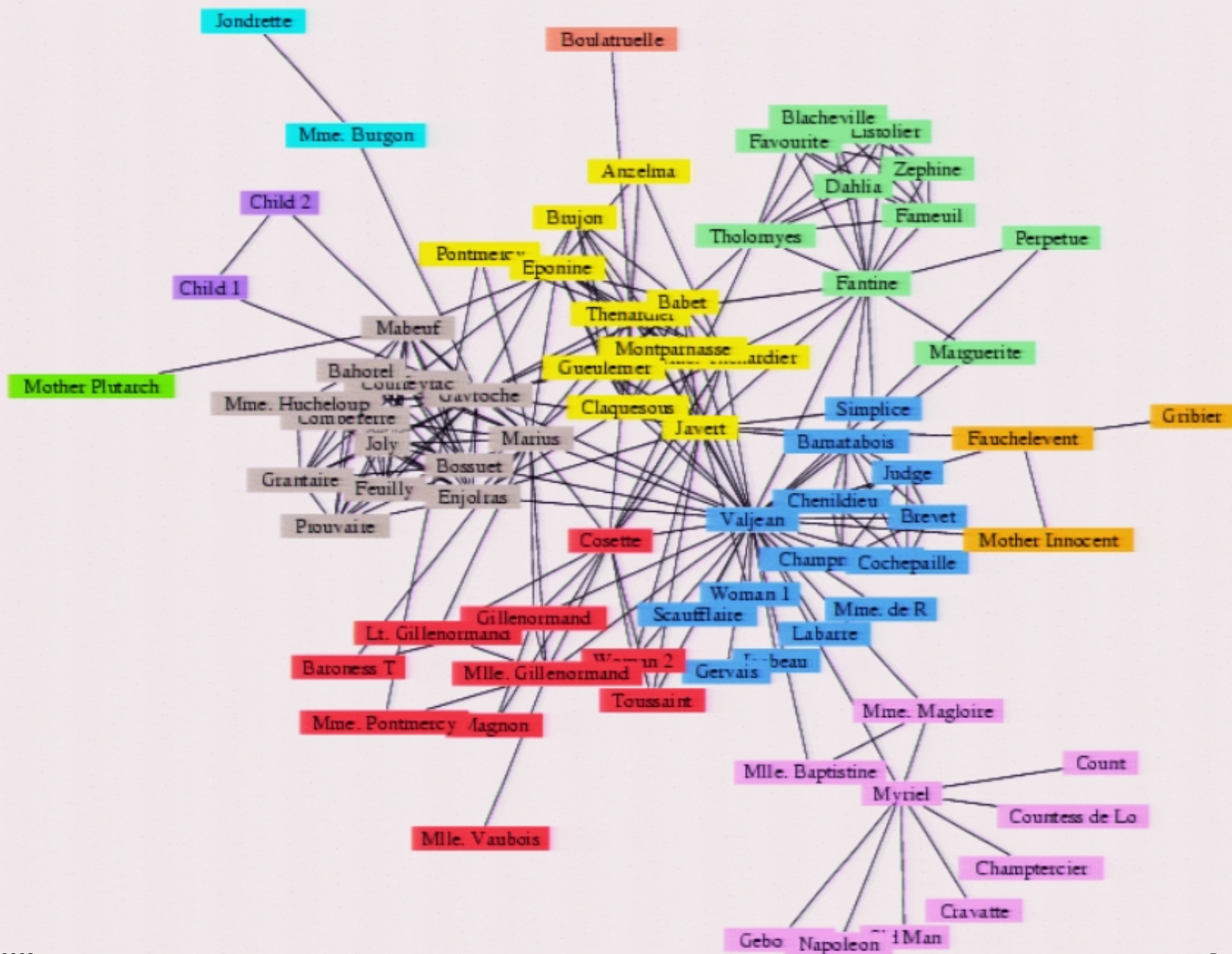


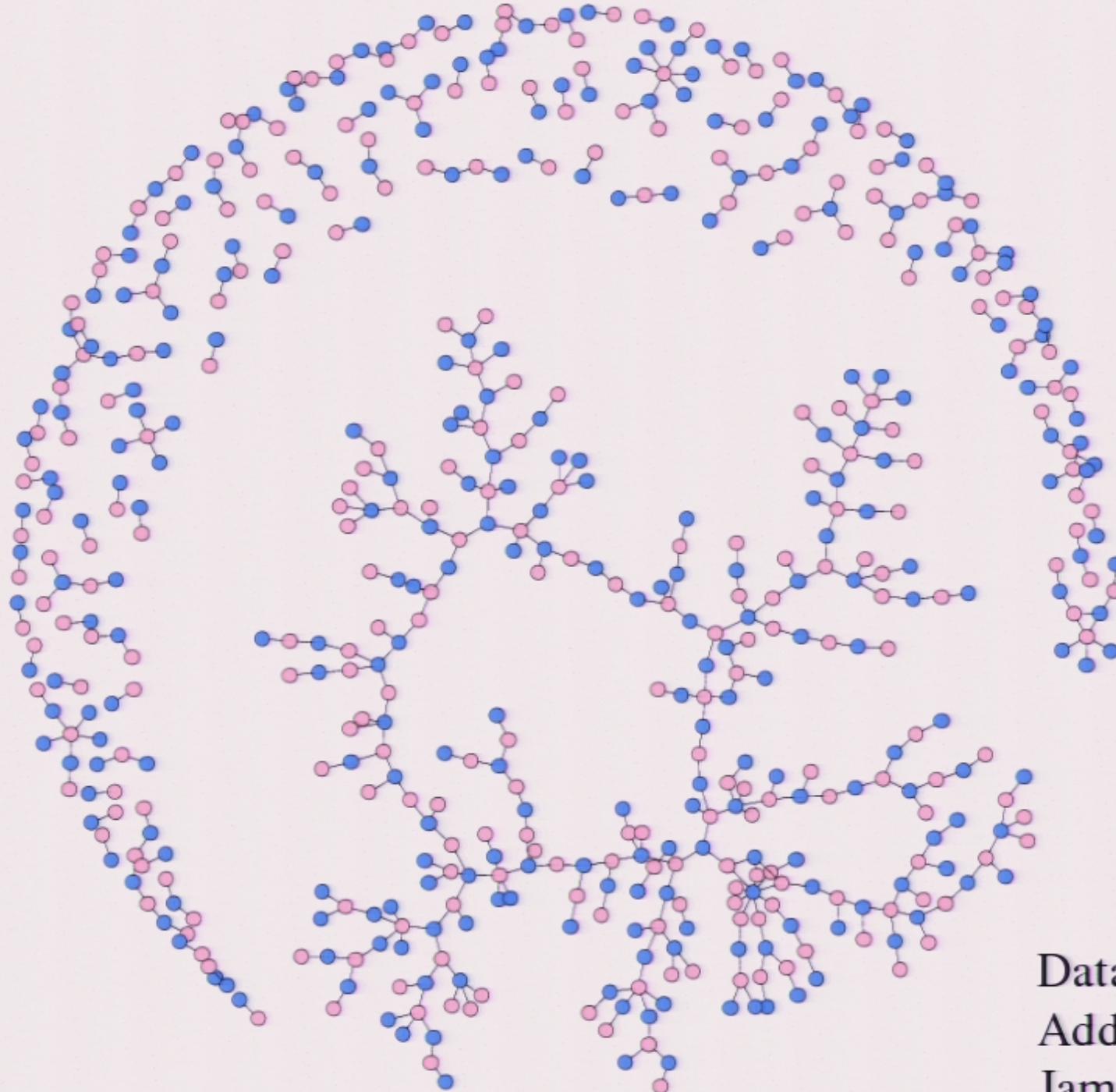
Jim Moody



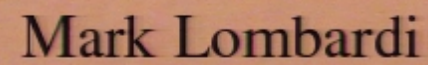


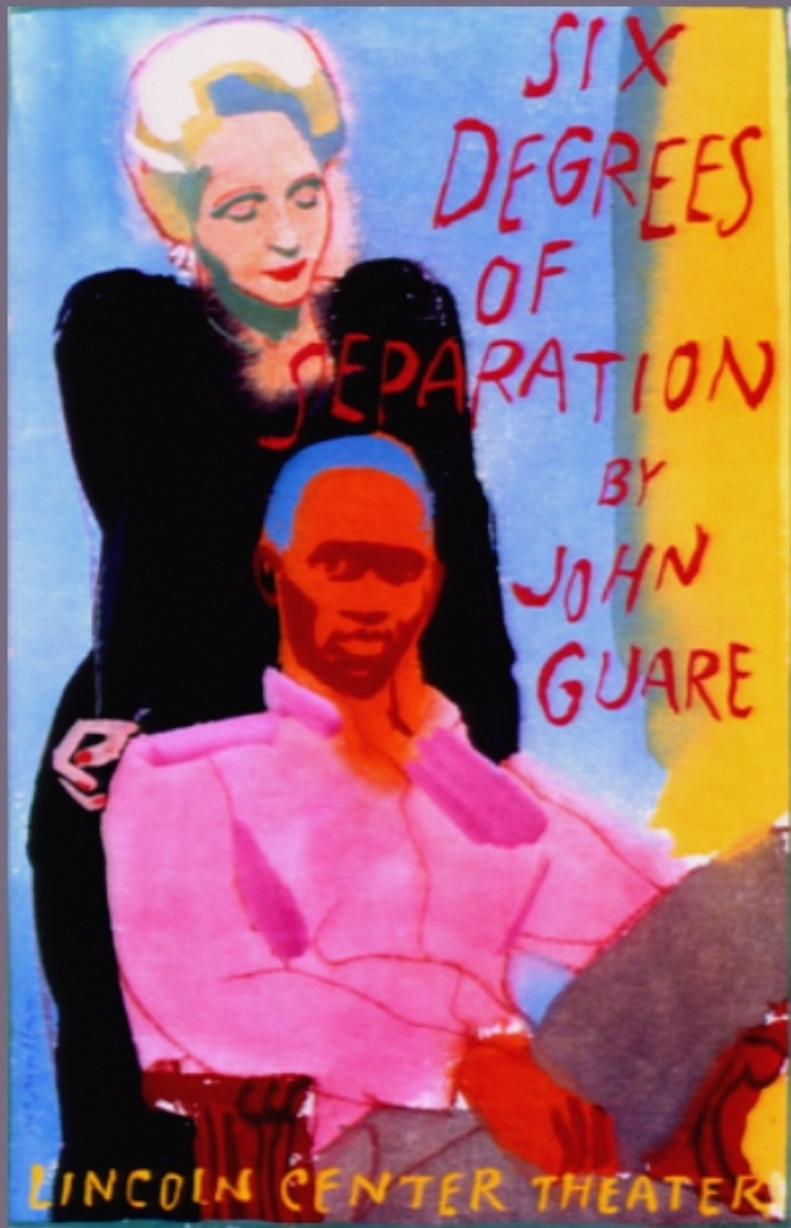






Data from
AddHealth via
James Moody





Are Actors All Related? Or Is It Just Kevin Bacon?

By MEL GUSSOW

Three years ago, three students at Albright College in Reading, Pa., were watching "Footloose" on television, and began naming dozens of other movies featuring the actor Kevin Bacon. On the spot, they decided that he was the center of the entertainment universe — and the game was afoot.

It is called "Six Degrees of Kevin Bacon." No, that is not a misprint for "Six Degrees of Separation," although the John Guare play is one of the inspirations. In the play, Mr. Guare suggested that everyone is related to everyone else in the world by no more than six degrees of relativity. In the game, the supposition is that Mr. Bacon can be traced to all (well, almost all) other actors by moving through the movies each has made.

For example: only four degrees separate Greta Garbo from Mr. Bacon. She was in "Ninotchka" with Bela Lugosi, who was in "The Body Snatcher" with Boris Karloff, who was in "The Terror" with Jack Nicholson, who was in "A Few Good Men" with Mr. Bacon.

Marilyn Monroe is also four degrees away. She was in "The Misfits" with Montgomery Clift, who was in "A Place in the Sun" with Elizabeth Taylor, who was in "Lassie Come Home" with Roddy McDowall, who was in "The Big Picture" with Mr. Bacon.

Spreading the word from college campuses to the public at large, the creators of the game (Craig Fass, Mike Ginelli and Brian Turtle) have appeared on television and radio talk shows, daring listeners to stump them. And now it has become so popular that the team has written a book titled "Six Degrees of Kevin Bacon," to be published next month by Plume. At first, Mr. Bacon kept his distance. Later, swept up in the enthusiasm, he wrote the introduction to the book. While he admits that other actors have beaten him out for roles, he says, "Hey, I'm the only one with a game."

The reasoning behind "Six Degrees" is that Mr. Bacon is perhaps the busiest actor in Hollywood. Since 1978, he has made more than 30 movies, appearing with major stars but not yet achieving his own stardom. Often he has been in an ensemble, as in

Continued on Page C14

Kevin Bacon Linked To Al-Qaeda



The Onion

How many actors does it take to get to Kevin Bacon from Miss Piggy, Elvis and John Wayne?

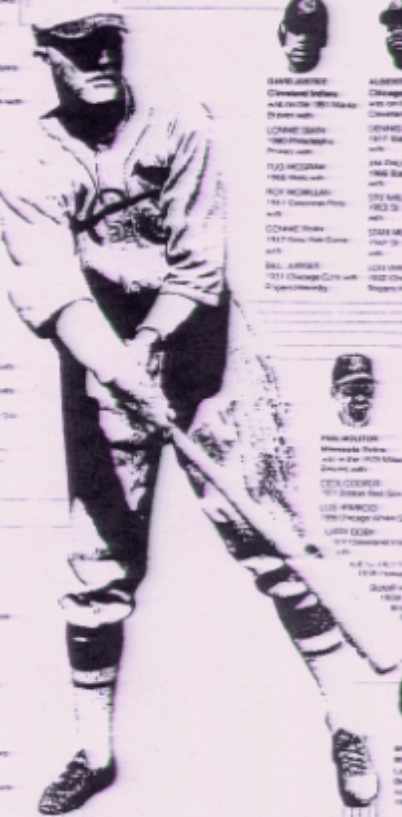
Answers Page C15



Answers (Bacon): Tim Star Pictures (Miss Piggy): CBS (Presley): PBS (Wayne)

Six Degrees of Rogers Hornsby

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[illegible]

JOHN SANDERS
Chicago Cubs
1st Base
1987 Philadelphia
Pitcher
1988-1990
1991 Boston Red Sox
1992
JOHN ADAM
1988 Baltimore Orioles
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JOHN WOODWARD
1987 Philadelphia
Pitching
1988
JOHN LARSEN
1987 Baltimore Orioles
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JOHN L. HENRY
1987 Chicago - Packer
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STUDY ABSTRACT
Background: Atrial fibrillation (AF) is the most common cardiac arrhythmia, with a prevalence of 1% to 2% in the general population. AF is associated with an increased risk of stroke, heart failure, and mortality. The aim of this study was to evaluate the effectiveness of a new treatment for AF, the ablation catheter, compared with the standard treatment, antiarrhythmic drugs.

Methods: A randomized controlled trial was conducted in 100 patients with AF. The patients were randomly assigned to receive either the ablation catheter or antiarrhythmic drugs. The primary endpoint was the proportion of patients who were free of AF at 12 months. Secondary endpoints included the proportion of patients who were free of AF and had no side effects, the proportion of patients who were free of AF and had no need for hospitalization, and the proportion of patients who were free of AF and had no need for surgery.

Results: At 12 months, the proportion of patients who were free of AF was significantly higher in the ablation catheter group (85%) than in the antiarrhythmic drugs group (65%). The proportion of patients who were free of AF and had no side effects was also significantly higher in the ablation catheter group (75%) than in the antiarrhythmic drugs group (55%). The proportion of patients who were free of AF and had no need for hospitalization was significantly higher in the ablation catheter group (80%) than in the antiarrhythmic drugs group (60%). The proportion of patients who were free of AF and had no need for surgery was significantly higher in the ablation catheter group (85%) than in the antiarrhythmic drugs group (65%).

Conclusion: The ablation catheter is a more effective treatment for AF than antiarrhythmic drugs. It is also safer, as it is associated with a lower risk of side effects, hospitalization, and surgery.

Keywords: Atrial fibrillation, ablation catheter, antiarrhythmic drugs, stroke, heart failure, mortality.

Abbreviations: AF, atrial fibrillation; RCT, randomized controlled trial; AF-free, free of atrial fibrillation; AF-free and no side effects, free of atrial fibrillation and no side effects; AF-free and no need for hospitalization, free of atrial fibrillation and no need for hospitalization; AF-free and no need for surgery, free of atrial fibrillation and no need for surgery.

Introduction: Atrial fibrillation (AF) is the most common cardiac arrhythmia, with a prevalence of 1% to 2% in the general population. AF is associated with an increased risk of stroke, heart failure, and mortality. The aim of this study was to evaluate the effectiveness of a new treatment for AF, the ablation catheter, compared with the standard treatment, antiarrhythmic drugs.

Methods: A randomized controlled trial was conducted in 100 patients with AF. The patients were randomly assigned to receive either the ablation catheter or antiarrhythmic drugs. The primary endpoint was the proportion of patients who were free of AF at 12 months. Secondary endpoints included the proportion of patients who were free of AF and had no side effects, the proportion of patients who were free of AF and had no need for hospitalization, and the proportion of patients who were free of AF and had no need for surgery.

Results: At 12 months, the proportion of patients who were free of AF was significantly higher in the ablation catheter group (85%) than in the antiarrhythmic drugs group (65%). The proportion of patients who were free of AF and had no side effects was also significantly higher in the ablation catheter group (75%) than in the antiarrhythmic drugs group (55%). The proportion of patients who were free of AF and had no need for hospitalization was significantly higher in the ablation catheter group (80%) than in the antiarrhythmic drugs group (60%). The proportion of patients who were free of AF and had no need for surgery was significantly higher in the ablation catheter group (85%) than in the antiarrhythmic drugs group (65%).

Conclusion: The ablation catheter is a more effective treatment for AF than antiarrhythmic drugs. It is also safer, as it is associated with a lower risk of side effects, hospitalization, and surgery.

Keywords: Atrial fibrillation, ablation catheter, antiarrhythmic drugs, stroke, heart failure, mortality.

Abbreviations: AF, atrial fibrillation; RCT, randomized controlled trial; AF-free, free of atrial fibrillation; AF-free and no side effects, free of atrial fibrillation and no side effects; AF-free and no need for hospitalization, free of atrial fibrillation and no need for hospitalization; AF-free and no need for surgery, free of atrial fibrillation and no need for surgery.



PHILIP H. HARRIS
 Department of
 Psychiatry
 Columbia University
 College of Physicians
 and Surgeons
 630 West 168th St.
 New York, NY 10032
 212/305-5800
 FAX 212/305-5801
 e-mail: philip.harris@columbia.edu



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JOHN W. BROWN
 President and CEO
 10000 E. 1st Ave.
 Suite 100
 Denver, CO 80231
 303.733.1111
 jbrown@brownco.com

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Artist	Album	Label	Release Date
Black Sabbath	Black Sabbath	Mercury	1970
Black Sabbath	Master of Reality	Mercury	1971
Black Sabbath	Iron Man	Mercury	1973
Black Sabbath	Sabbath Bloody Sabbath	Mercury	1975
Black Sabbath	Vol. 4	Mercury	1976
Black Sabbath	Technical Ecstasy	Mercury	1978
Black Sabbath	Seven Stars	Mercury	1980
Black Sabbath	Black Sabbath	Mercury	1982
Black Sabbath	Black Sabbath	Mercury	1984
Black Sabbath	Black Sabbath	Mercury	1986
Black Sabbath	Black Sabbath	Mercury	1988
Black Sabbath	Black Sabbath	Mercury	1990
Black Sabbath	Black Sabbath	Mercury	1992
Black Sabbath	Black Sabbath	Mercury	1994
Black Sabbath	Black Sabbath	Mercury	1996
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Black Sabbath	Black Sabbath	Mercury	2022

2

2000

W Y

SIX Degrees of Monica

First came John Guare's play "SIX DEGREES OF SEPARATION," with its theory that everyone is connected to everyone else through a chain of no more than six people. Then some college students with too much free time inexplicably began connecting the dots to the actor Kevin Bacon, and a small industry on the theme of "Six Degrees of Kevin Bacon" was born. Can "that woman," the world's most famous former White House intern, be far behind?



for years had a manager named whose daughter **NEYSA DEMANN CRILAND** recently resided to the Whitewater grand jury about conversations she had with her childhood friend.

created a Broadway catastrophe starring **RUBEN BLADES**, who is friends with the former New York City Mayor, who sits on the board of the Cosmetics Center, which is run by a subsidiary of the Revlon Corporation, which got both and then withdrew a job offer to.

(short route) lives in Greenwood, which is also home to the father of

(long route) was investigated by **MARK FURMAN**, who wrote a book that was handled by **LUCIANNE GOLDBERG**, who persuaded **LINDA TRIPP** to record conversations with

will remain in New York thanks to who is a big fan of **PLACIDO DOMINGO**, whose son he was the subject of a book by the self-described "gleefully Beverly Hills writer" **MARISA LEWIS**, who gave birth to

JASON ALEXANDER plays a neurotic, self-obsessed New Yorker on a show starring who appears in commercials for American Express, on whose board sits who arranged job interviews at the company's New York office for

(short route) tried to cover up a break-in at Democratic headquarters in the Watergate complex, which is home to

(long route), in the 1972 election, trounced **GEORGE MCGOVERN**, who flew around with Nixon spy-masquerading-as-a-reporter who (you know the rest)

(alternate long route) was almost impeached by a Congressional committee that included Senator **HOWARD BAKER**, who is now part of the tobacco lobby, which is represented by a law firm that includes **KENNETH STARR**, who is making life very difficult for

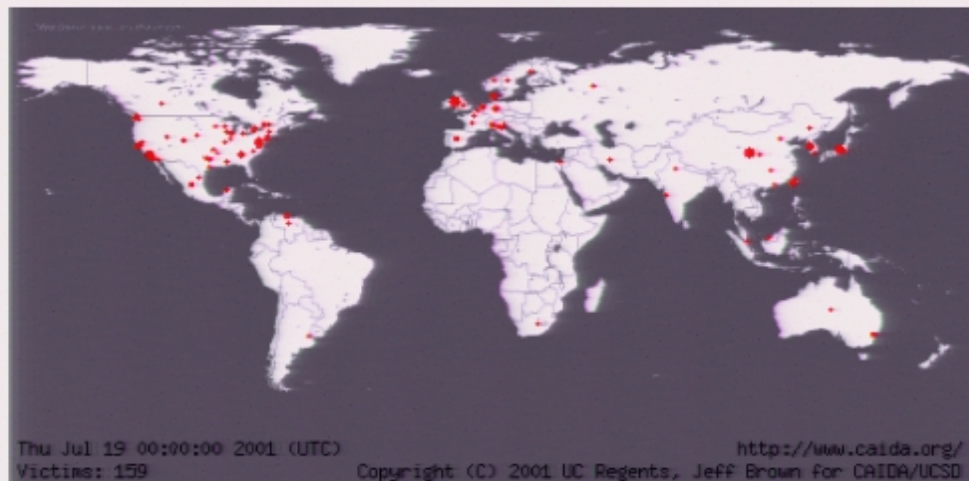
may be about to be bombed by American warplanes in an attack directed by Secretary of Defense whose top military spokesman is **KENNETH BACON**, who is in no way related to but who once hired a White House aide named

whose play introduced this whole concept, once stayed overnight at the White House, which may or may not remain on the resume of

My mother, **BARBARA KIRBY**, once ate lunch in a Los Angeles restaurant that is said to be a favorite of **NANCY REAGAN**, who lives in Bel Air and down the way from **ELIZABETH TAYLOR**, who was dear friends with **MICHAEL WOOD**, whose daughter graduated from Beverly Hills High School, which also matriculated

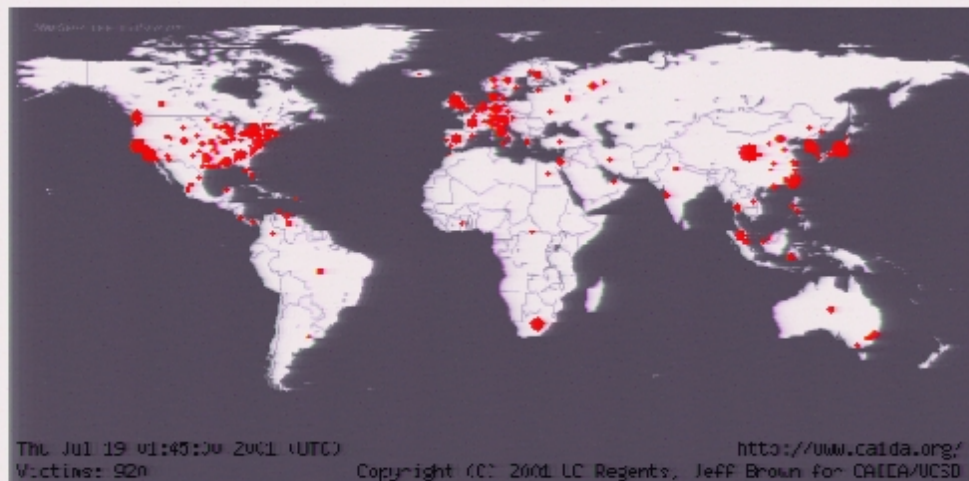
New York Times

Example: A computer virus

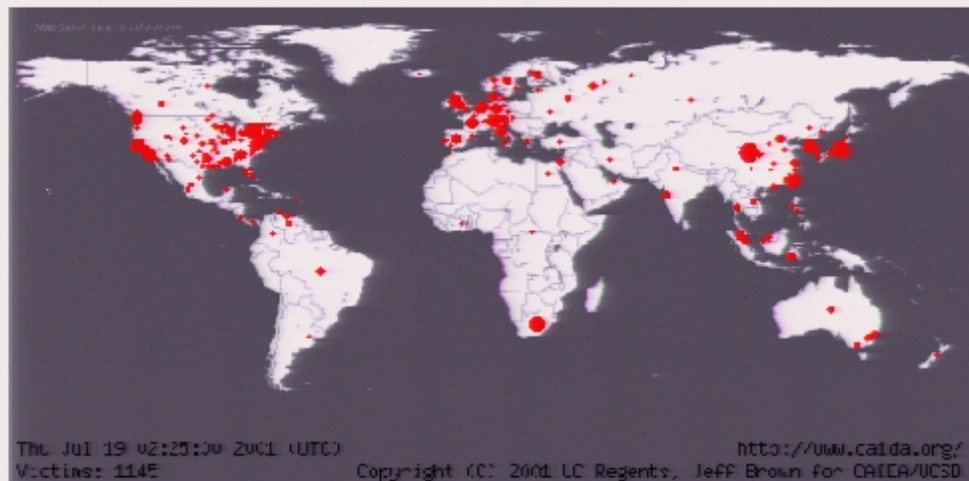


k c claffy/CAIDA

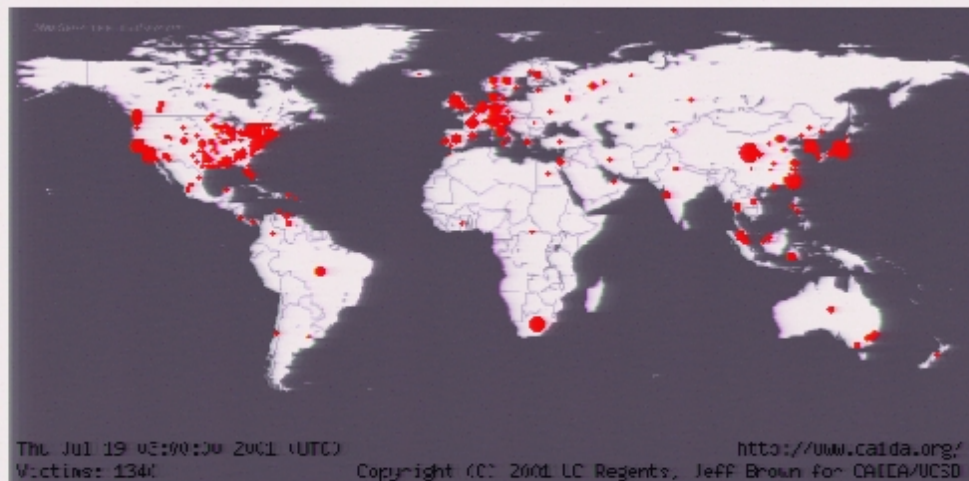
Example: A computer virus



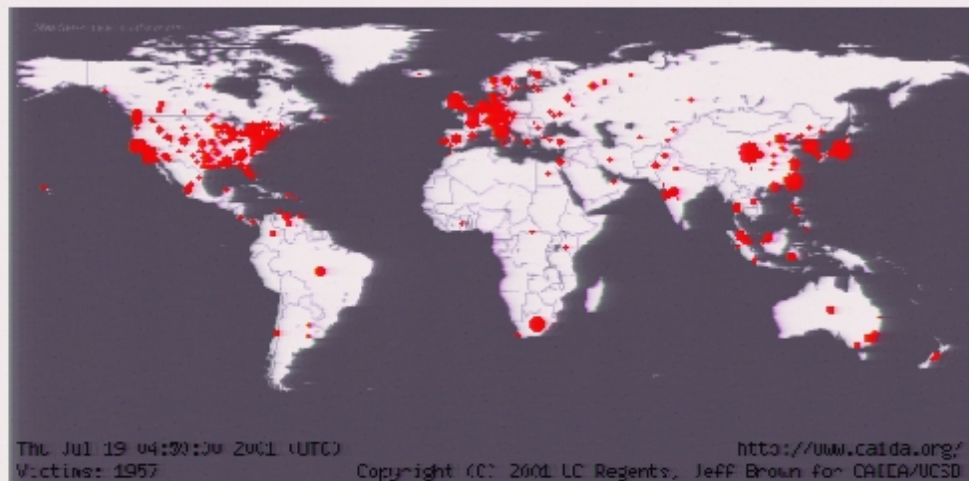
Example: A computer virus



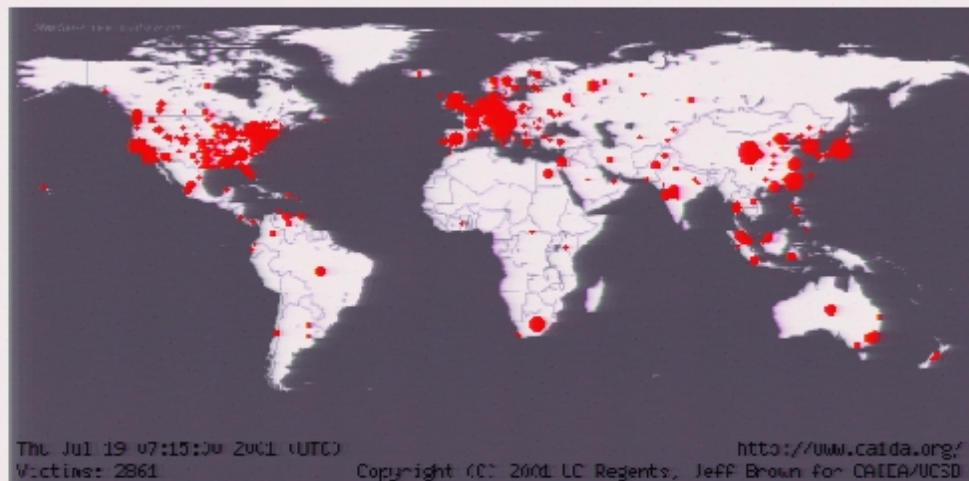
Example: A computer virus



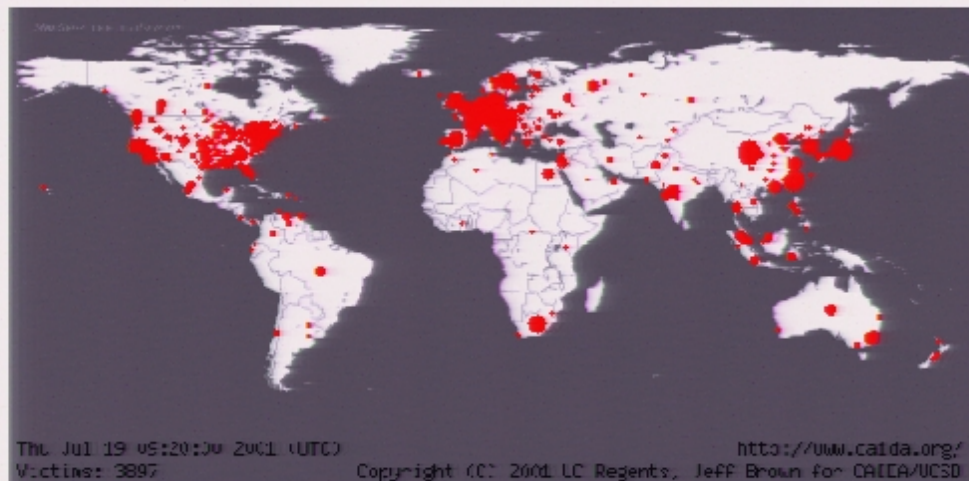
Example: A computer virus



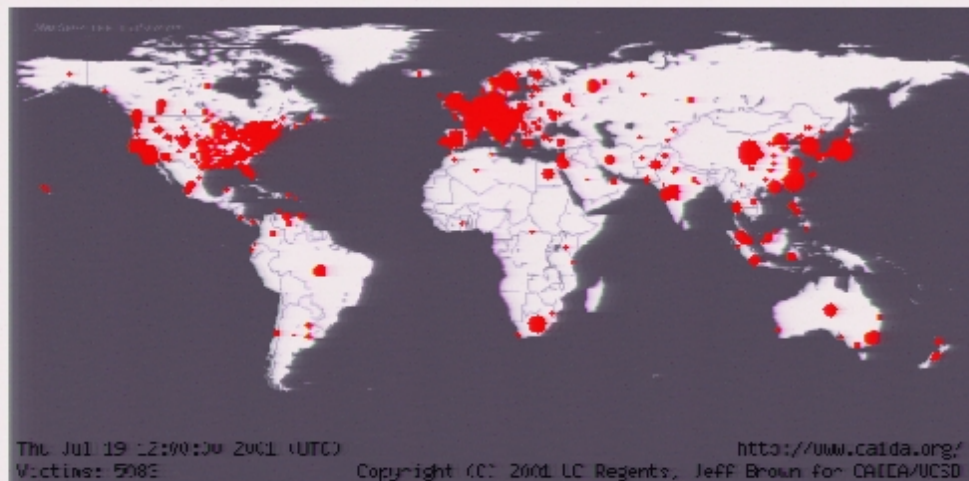
Example: A computer virus



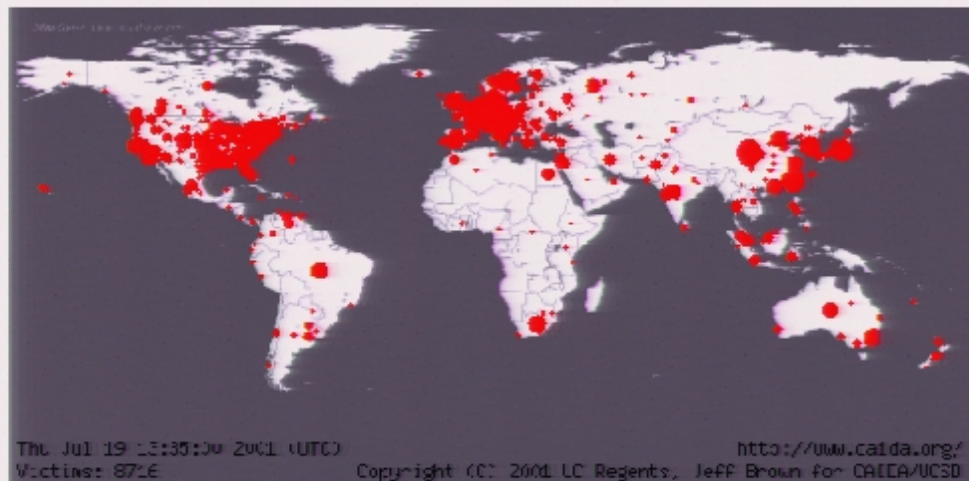
Example: A computer virus



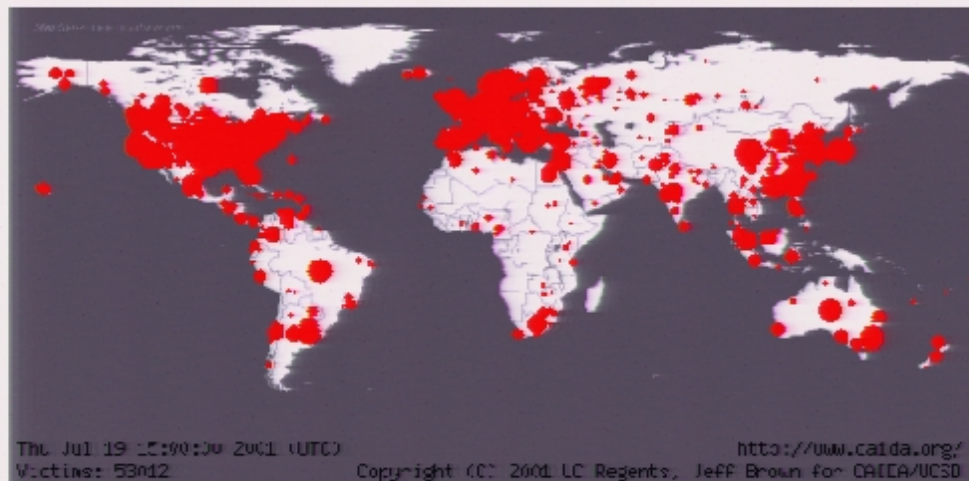
Example: A computer virus



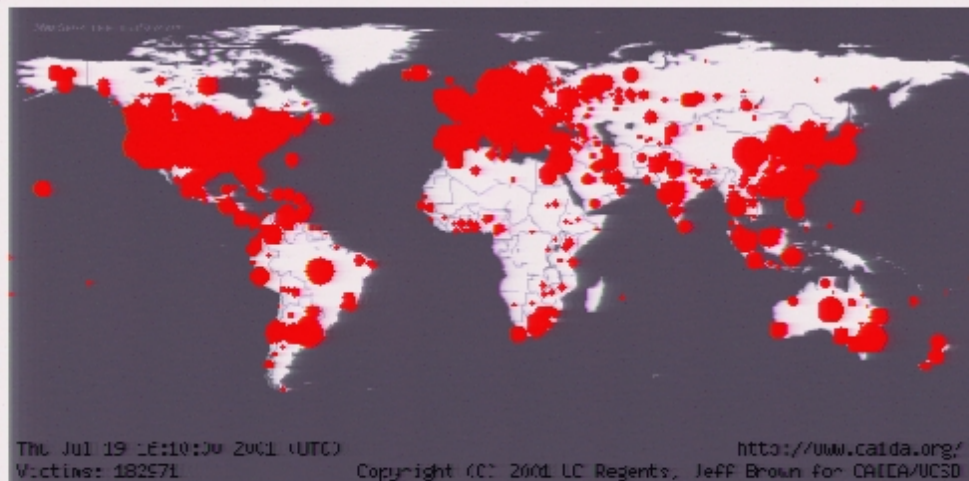
Example: A computer virus



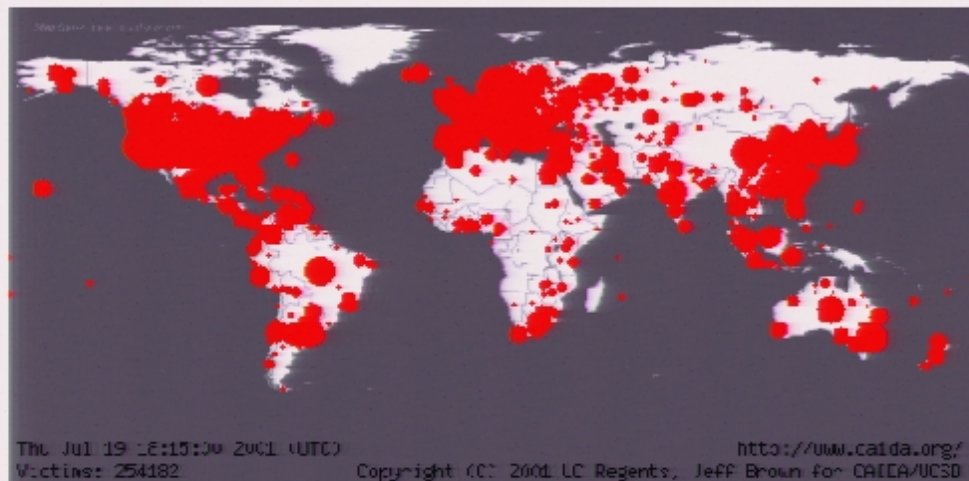
Example: A computer virus



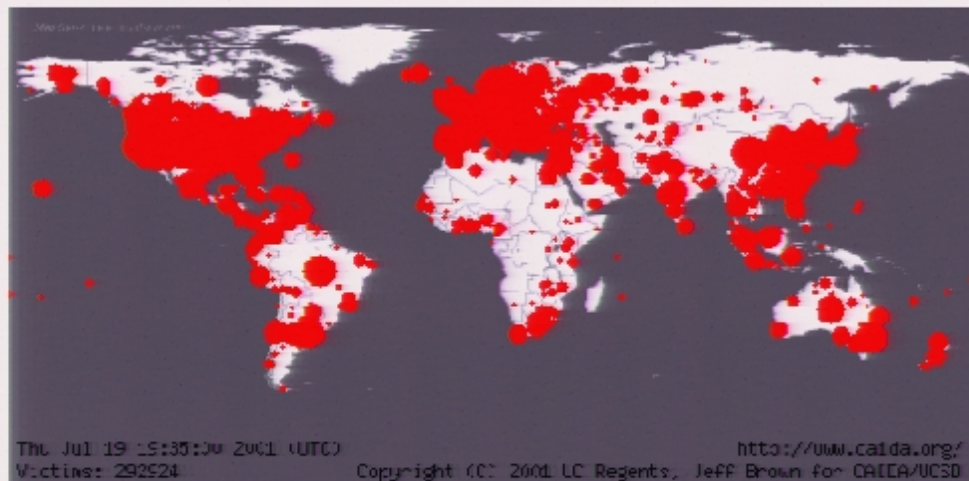
Example: A computer virus



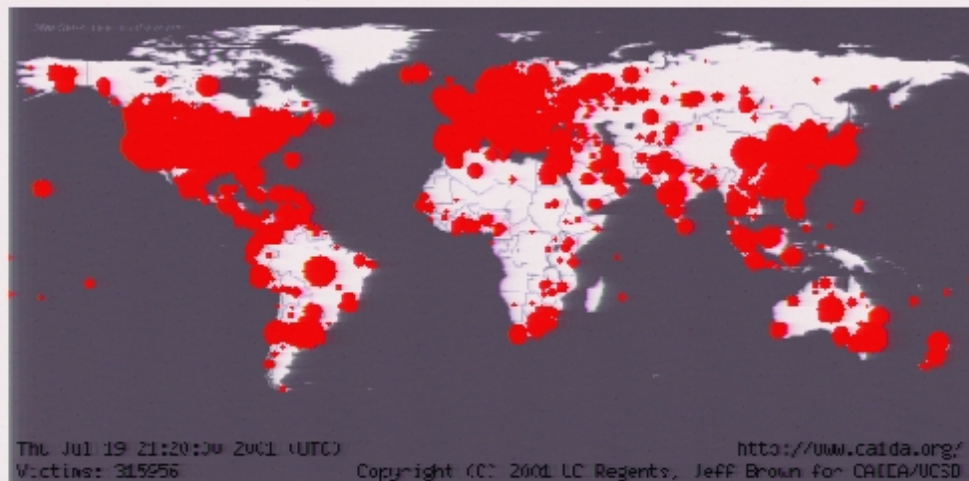
Example: A computer virus



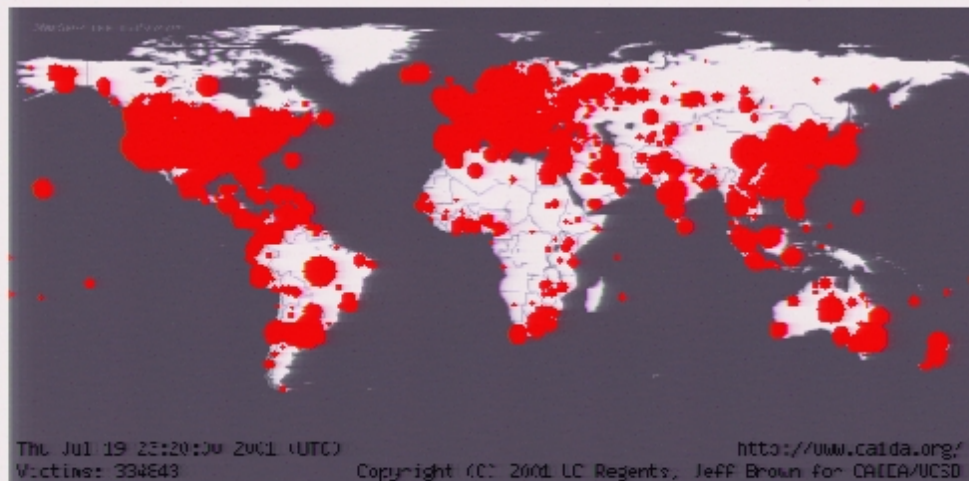
Example: A computer virus



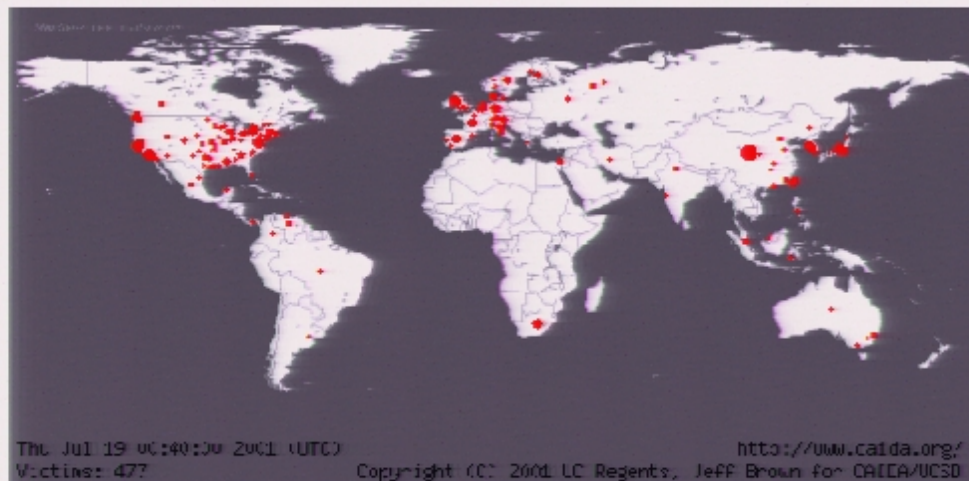
Example: A computer virus

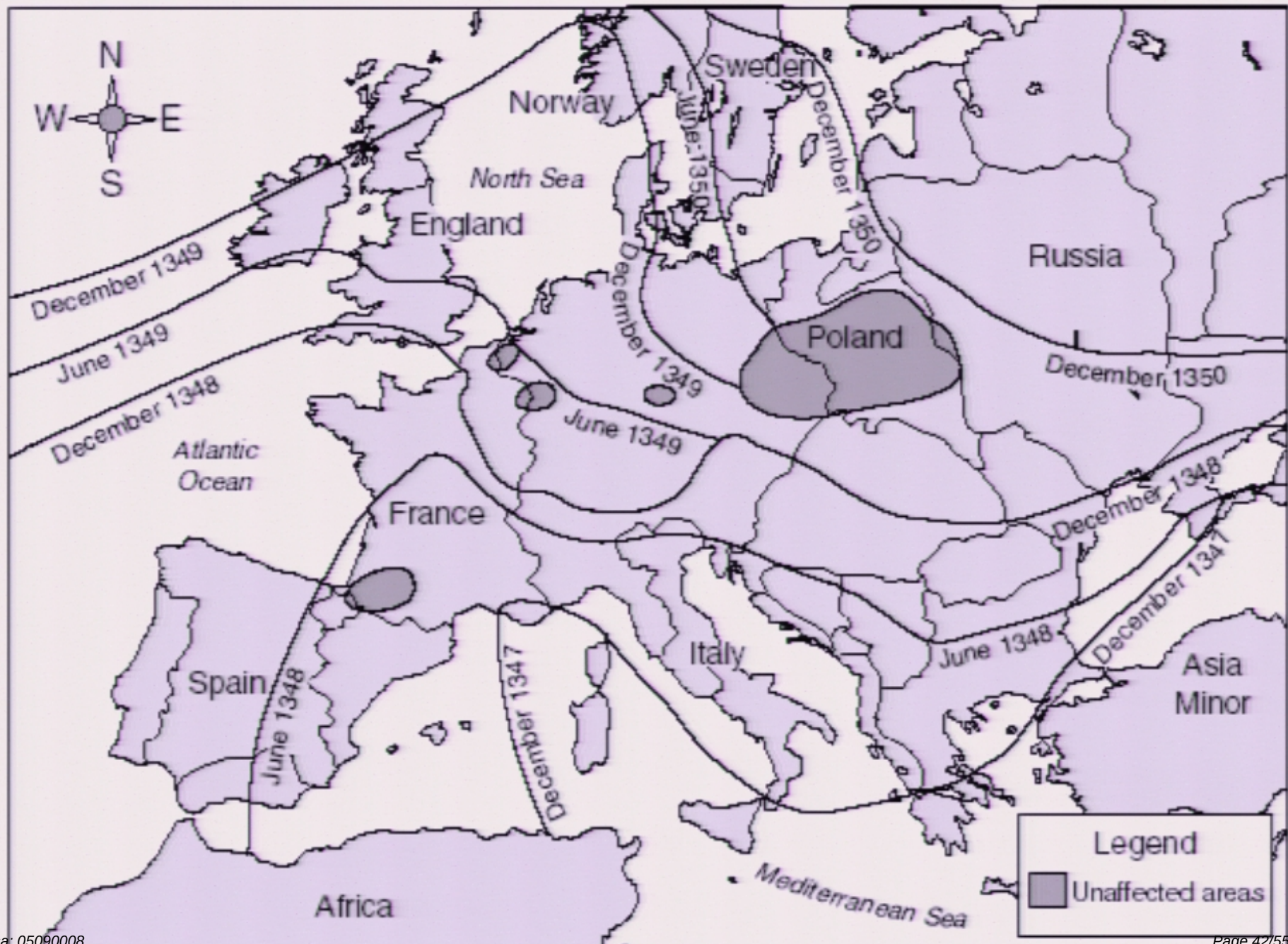


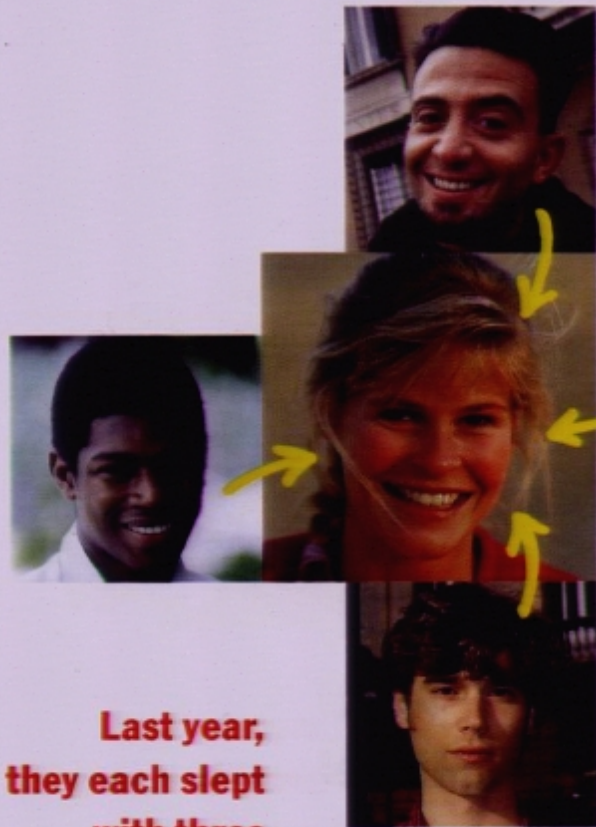
Example: A computer virus



Example: A computer virus

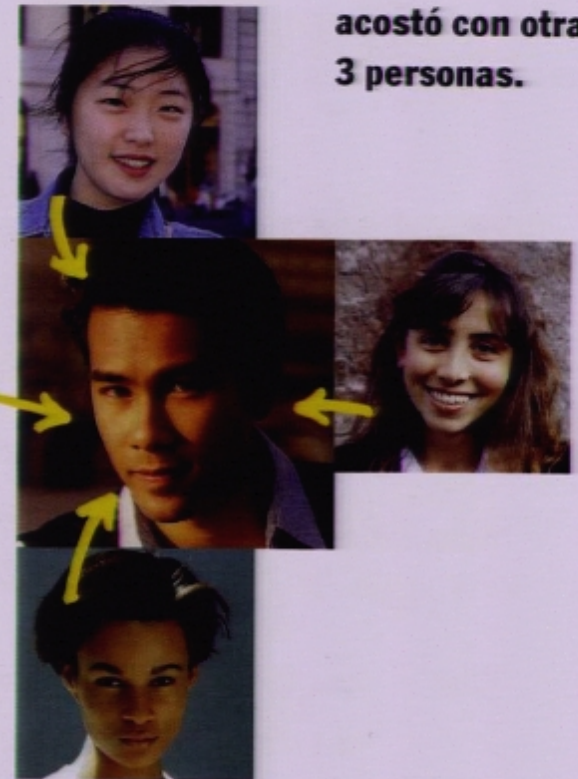




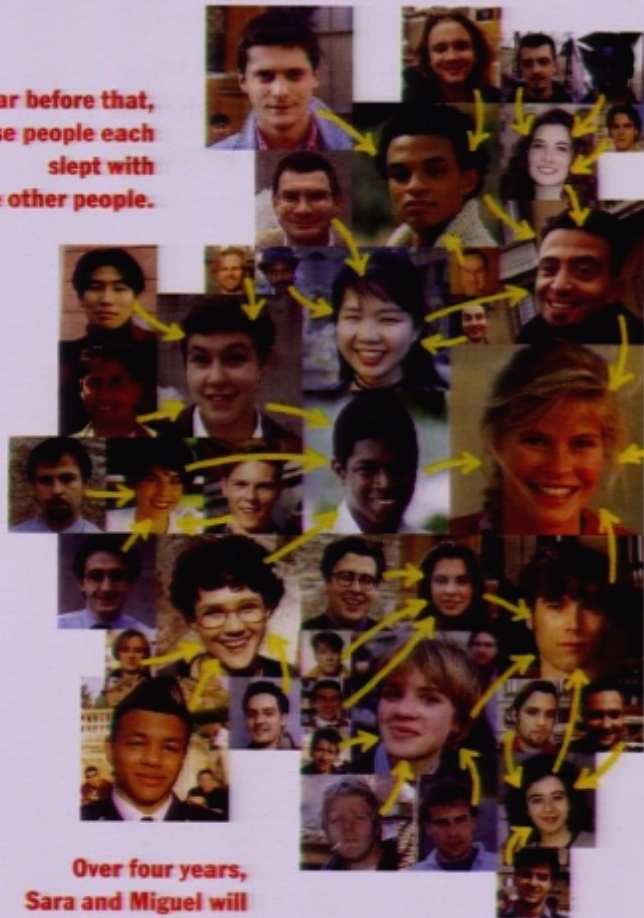


**Last year,
they each slept
with three
other people.**

**El año pasado,
cada uno se
acostó con otras
3 personas.**

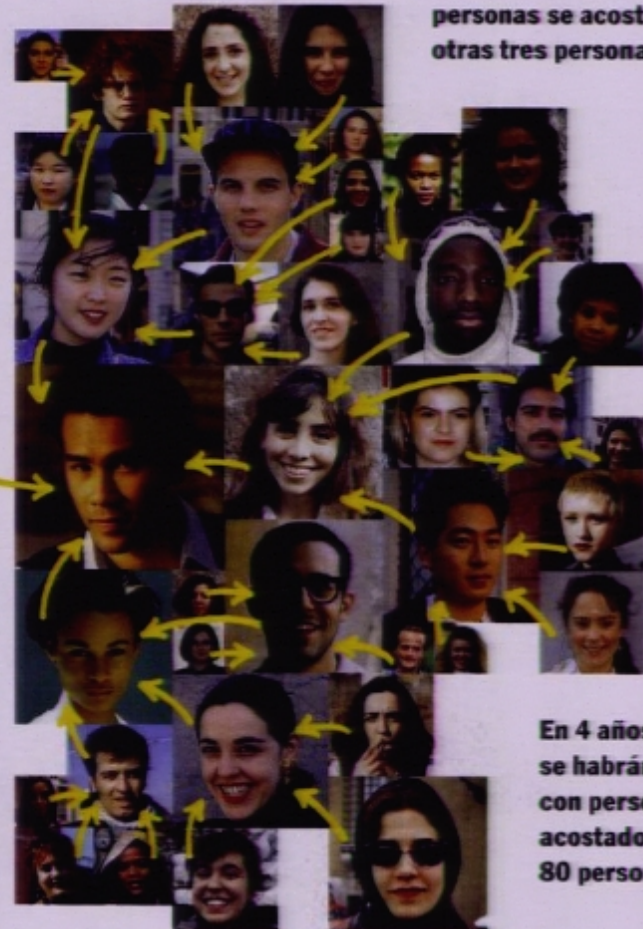


Each year before that,
those people each
slept with
three other people.



Over four years,
Sara and Miguel will
have slept with people
who slept with
a total of 80 people.

Cada año antes de esto,
cada una de esas
personas se acostó con
otras tres personas.



En 4 años, Sara y Miguel
se habrán acostado
con personas que se han
acostado con otras
80 personas en total.



Over 7 years, those people will have slept with 1,460 people.

And over 12 years, those people will have slept with 531,441 people. (It would take another 728 pages to show you all their pictures.)

By the way, in Paris, where Sara and Miguel live, one in 100 people is HIV positive.

You might want to use a condom.



En 7 años, esas personas se habrán acostado con 1.460 personas.

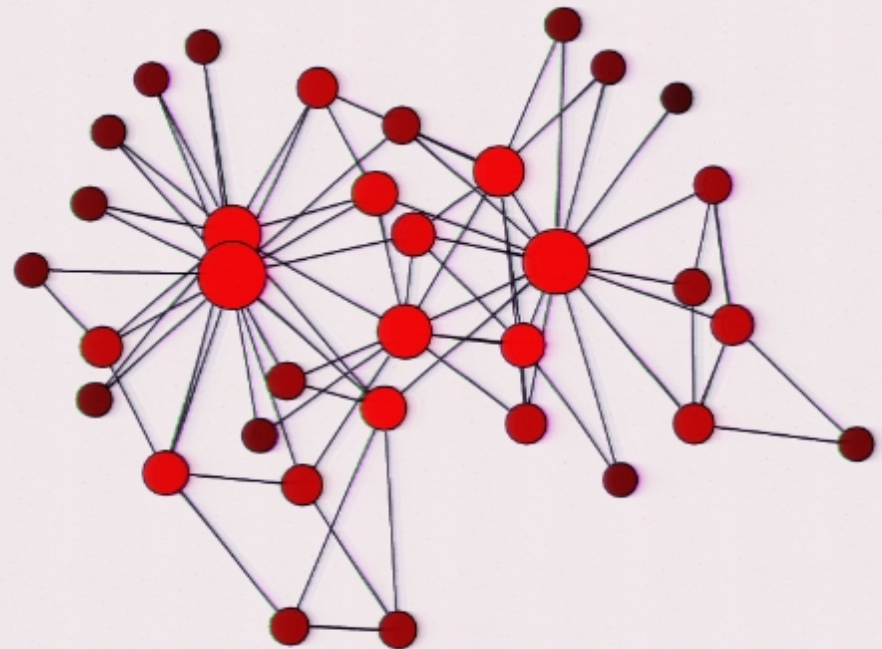
En 12 años, todo esto implica un total de 531.441 personas. (Necesitaríamos 728 páginas más para mostrar las fotos de todas esas personas).

A propósito, en París, donde viven Sara y Miguel, una persona sobre 100 es seropositiva.

Quizás conviene usar un preservativo.

Transitivity

- If A knows B and B knows C, then probably A knows C
 - “the friend of my friend is also my friend”
 - *or* two of my friends are likely also to be friends of each other



- The **clustering coefficient** is the probability that two of your friends are friends of each other
 - it typically has values of a few tens of per cent

network	size n	mean degree z	clustering coefficient C	
			measured	random graph
Internet (autonomous systems)	6 374	3.8	0.24	0.00060
World-Wide Web (sites)	153 127	35.2	0.11	0.00023
power grid	4 941	2.7	0.080	0.00054
biology collaborations	1 520 251	15.5	0.081	0.000010
physics collaborations	52 909	9.7	0.43	0.00018
mathematics collaborations	253 339	3.9	0.15	0.000015
film actor collaborations	449 913	113.4	0.20	0.00025
company directors	7 673	14.4	0.59	0.0019
word co-occurrence	460 902	70.1	0.44	0.00015
neural network	282	14.0	0.28	0.049
metabolic network	315	28.3	0.59	0.090
food web	134	8.7	0.22	0.065

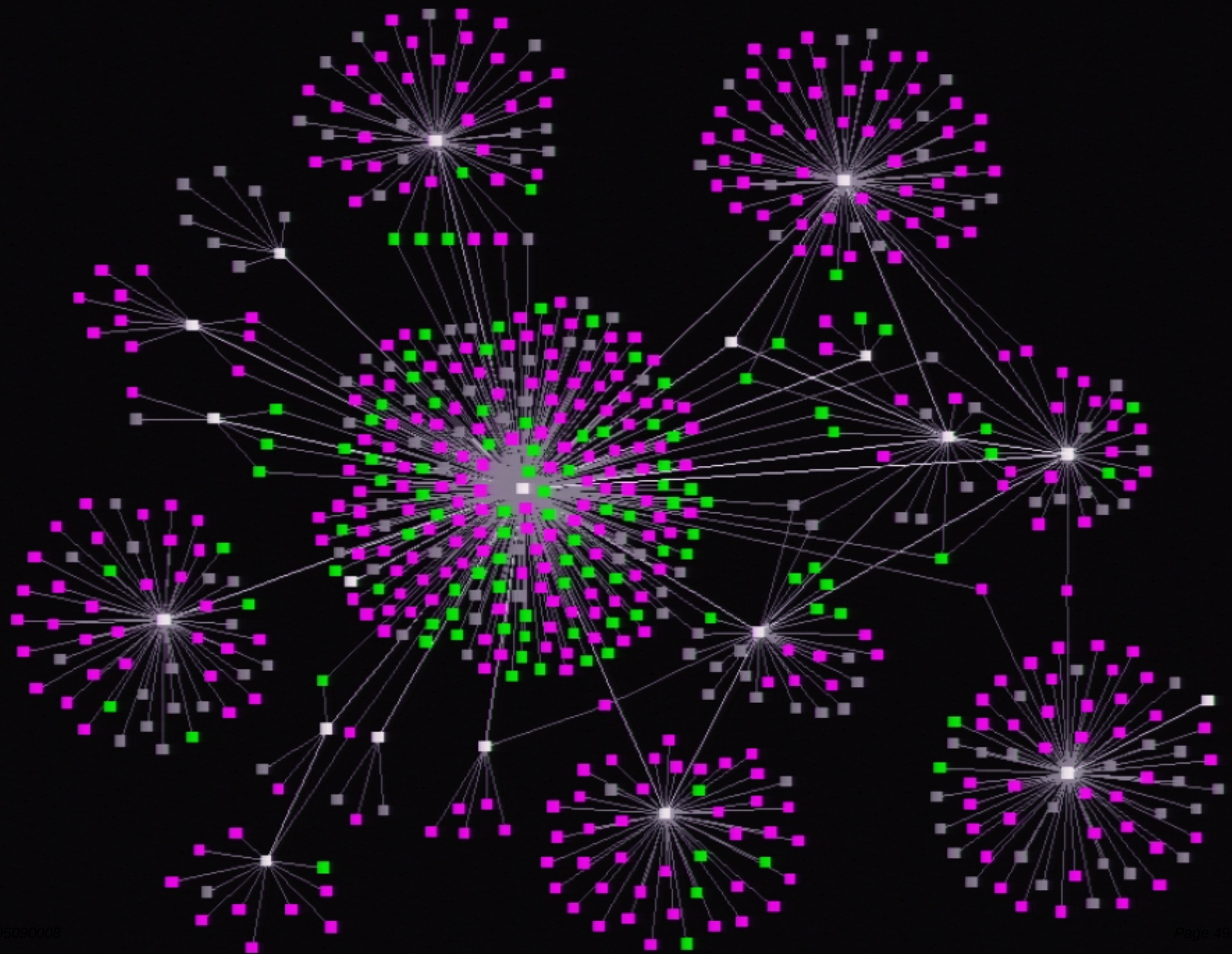
ANNALS OF SOCIETY

SIX DEGREES OF LOIS WEISBERG

She's a grandmother, she lives in a big house in Chicago, and you've never heard of her. Does she run the world?

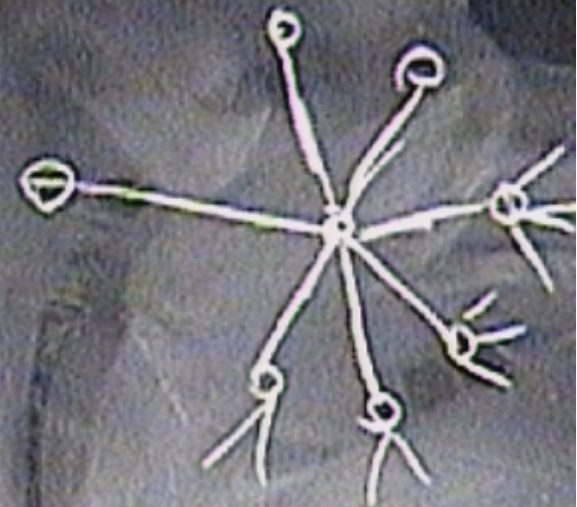
BY MALCOLM GLADWELL

*People like Lois Weisberg stand at the intersection of different worlds, connecting people, creating opportunities, and spreading ideas.*



$P_k = \#$ fraction of nodes deg = k

$$q_k = \frac{k p_k}{\sum_k k p_k}$$



level matching $(L_0 - \tilde{L}_0) / \phi_{hye}$

P_k = fraction of nodes deg k

$$q_k = \frac{k p_k}{\sum_k k p_k}, \quad \sum_{k=0}^{\infty} k q_k = \frac{\sum_k k^2 p_k}{\sum_k k p_k} = \frac{\langle k^2 \rangle}{\langle k \rangle}$$

$P_k = \frac{1}{N}$ fraction of nodes deg = k

$$q_k = \frac{k p_k}{\sum_k k p_k}, \quad \sum_{k=0}^{\infty} k q_k = \frac{\sum_k k^2 p_k}{\sum_k k p_k} = \frac{\langle k^2 \rangle}{\langle k \rangle}$$

$$\langle k^2 \rangle$$

$$- \langle k \rangle$$

$$= \frac{1}{\langle k \rangle} \left\{ \langle k^2 \rangle - \langle k \rangle^2 \right\}$$

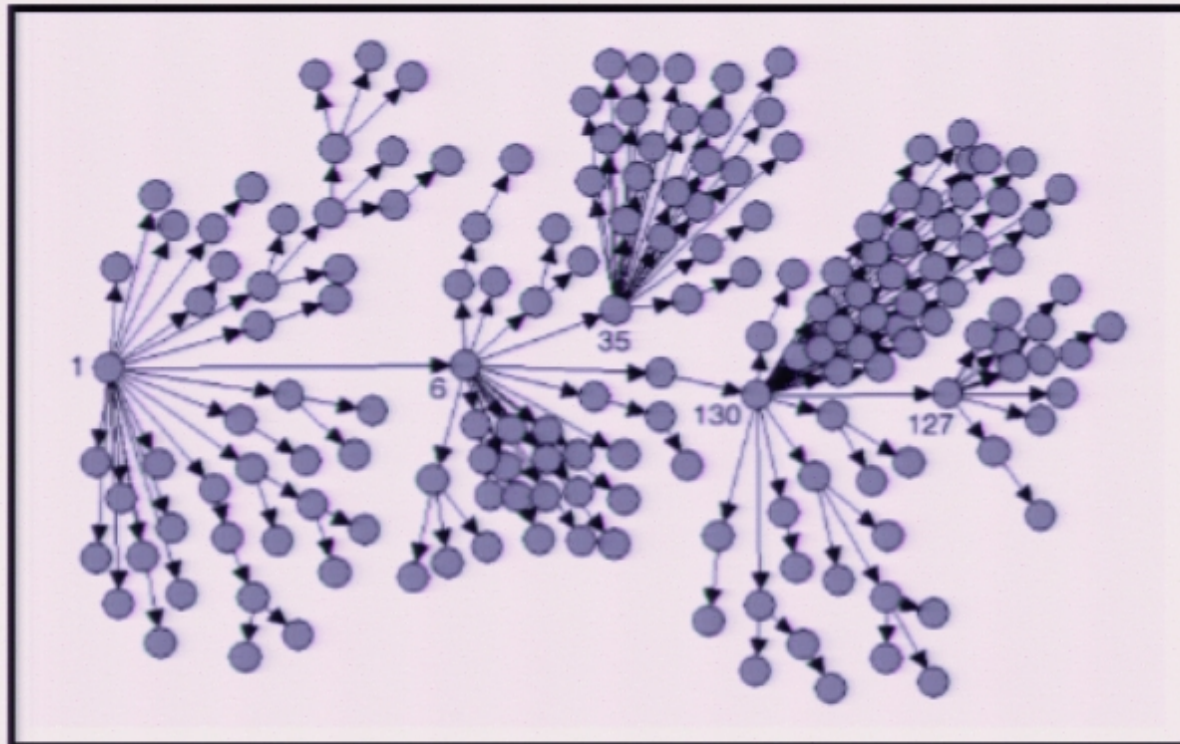
$$\left\{ \langle k^2 \rangle - \langle k \rangle^2 \right\}$$

$P_k = \#$ fraction of nodes deg. k

$$q_k = \frac{k p_k}{\sum_k k p_k}, \quad \sum_{k=0}^{\infty} k q_k = \frac{\sum_k k^2 p_k}{\sum_k k p_k} = \frac{\langle k^2 \rangle}{\langle k \rangle}$$

$$\frac{\langle k^2 \rangle}{\langle k \rangle} - \langle k \rangle = \frac{1}{\langle k \rangle} \left\{ \langle k^2 \rangle - \langle k \rangle^2 \right\} = \frac{\sigma_k^2}{\langle k \rangle} \geq 0$$

FIGURE 2. Probable cases of severe acute respiratory syndrome, by reported source of infection* — Singapore, February 25–April 30, 2003



* Patient 1 represents Case 1; Patient 6, Case 2; Patient 35, Case 3; Patient 130, Case 4; and Patient 127, Case 5. Excludes 22 cases with either no or poorly defined direct contacts or who were cases translocated to Singapore and the seven contacts of one of these cases.

Reference: Borgatti SP. Netdraw 1.0 Network Visualization Software. Harvard, Massachusetts: Analytic Technologies, 2002.

Degree distributions

