

# **Coordinating across the Enterprise:**

## **Finding a Balance Between Brokerage and Closure**



# Returning to Where We Began . . .

Lines indicate frequent and substantive work discussion; heavy lines especially close relationships.

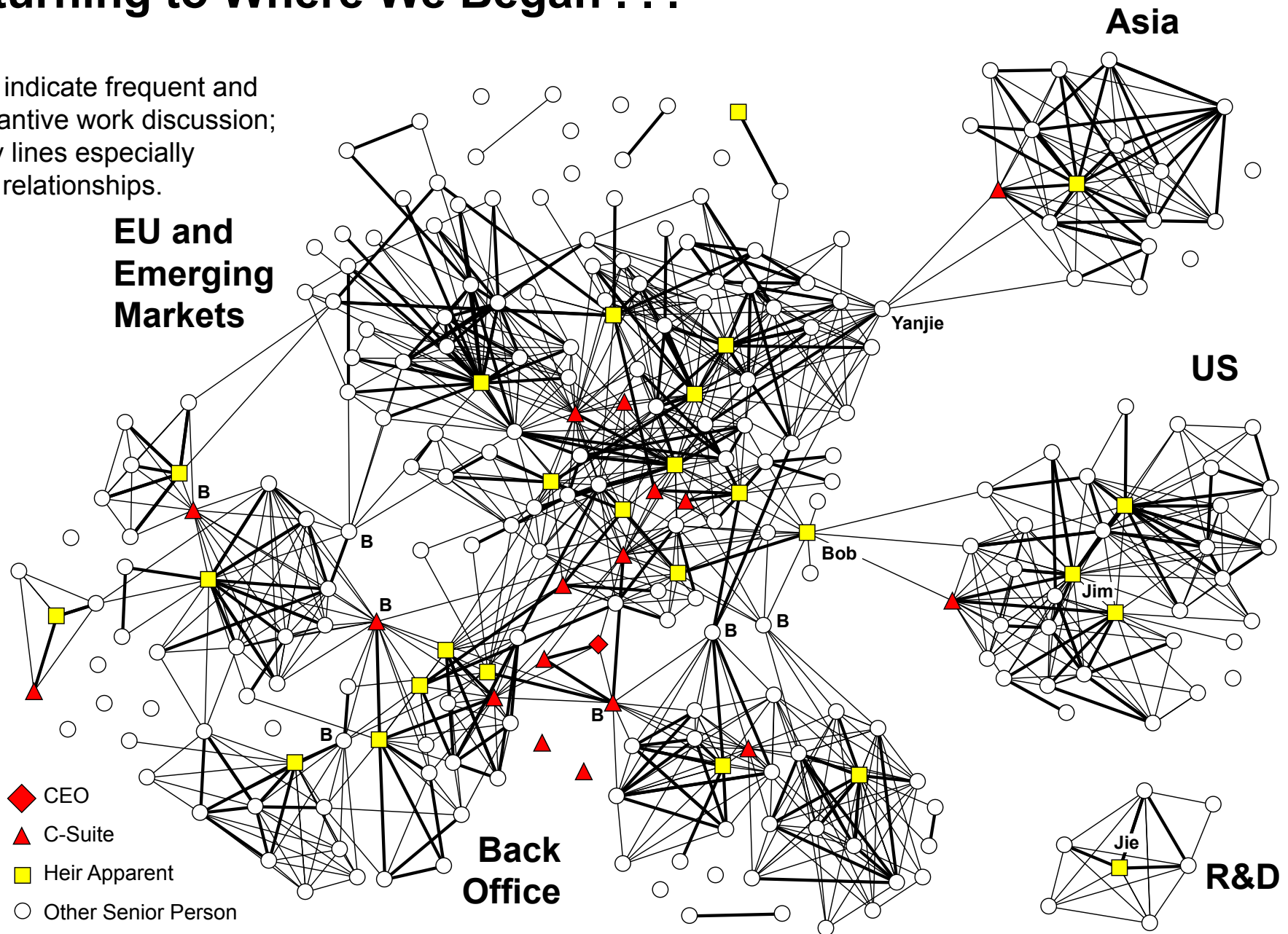


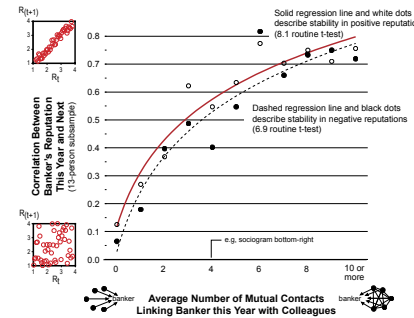
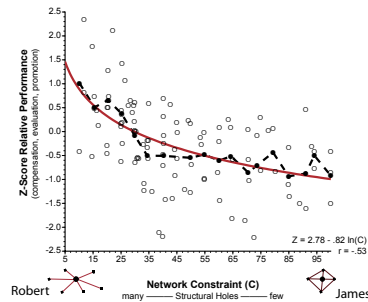
Figure 1 in Burt and Soda, "The social origins of great strategies" (*Strategy Science*, 2017)

# Strategic Leadership in the Management Network

**TOP-LINE GROWTH**  
New Services, New  
Processes, New Business

## MECHANISM

Information breadth,  
timing, and arbitrage  
advantages in detecting  
and developing good  
ideas



**BOTTOM-LINE GROWTH**  
Efficient Use of Resources  
(labor, supervision, speed)

## MECHANISM

Alignment from  
reputation cost for  
deviant opinion/  
behavior enforced  
by echoed stories in  
colleague gossip

**Brokerage**

Bridging  
Structural Holes  
between Clusters

**Closure**

Closing  
Structural Holes  
within the Cluster

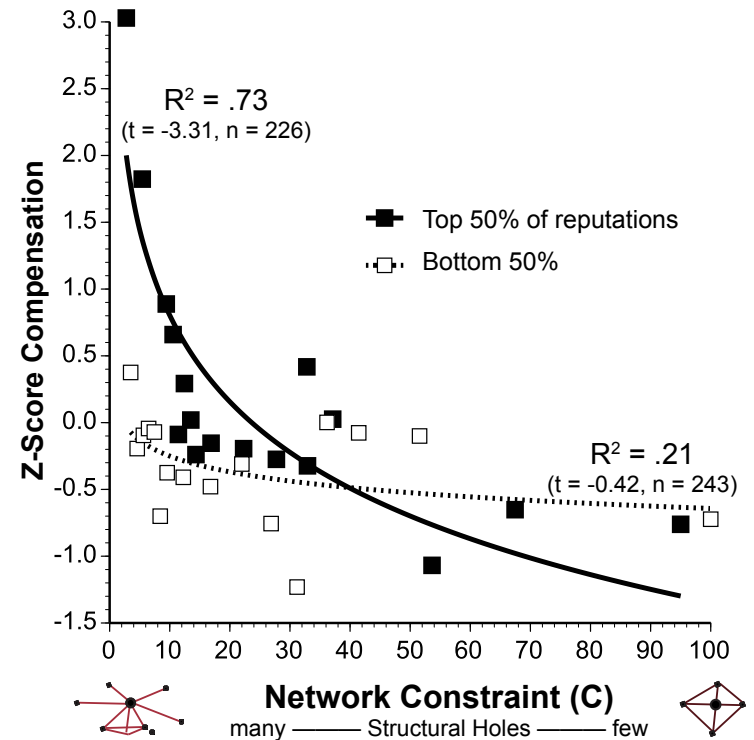
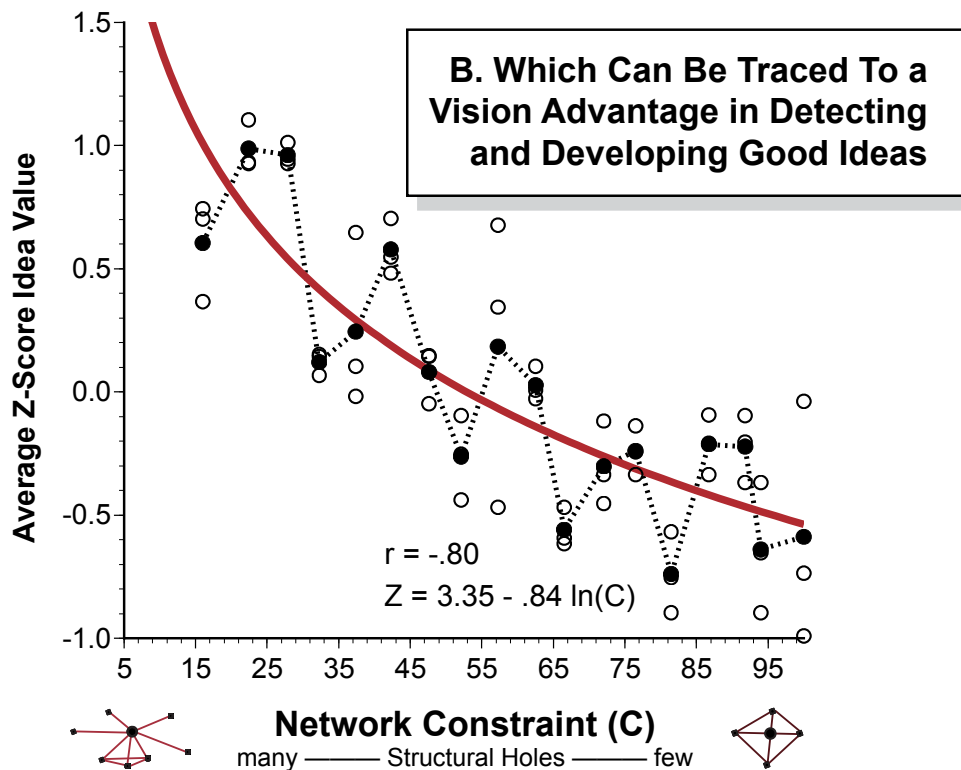
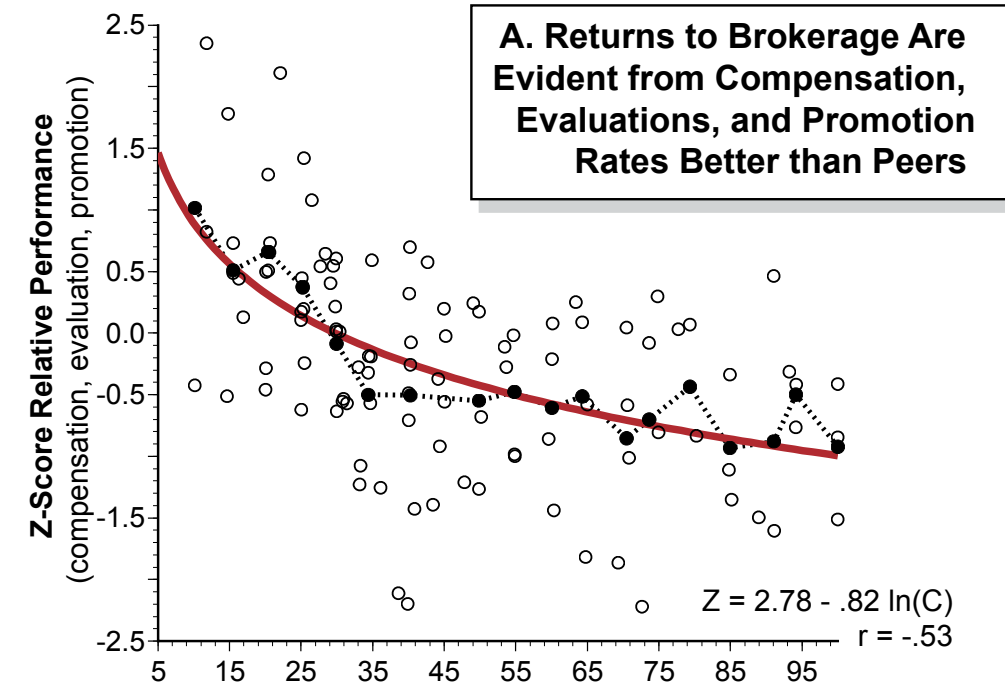
**PATHOLOGY**

Inefficiency,  
Agency Costs,  
Chaos

**PATHOLOGY**

Ignorant Certainty,  
Agentic State, Groupthink,  
Insider vs. Outsider

Graphs are from Figures 1.8 and 4.6  
in *Brokerage and Closure*.

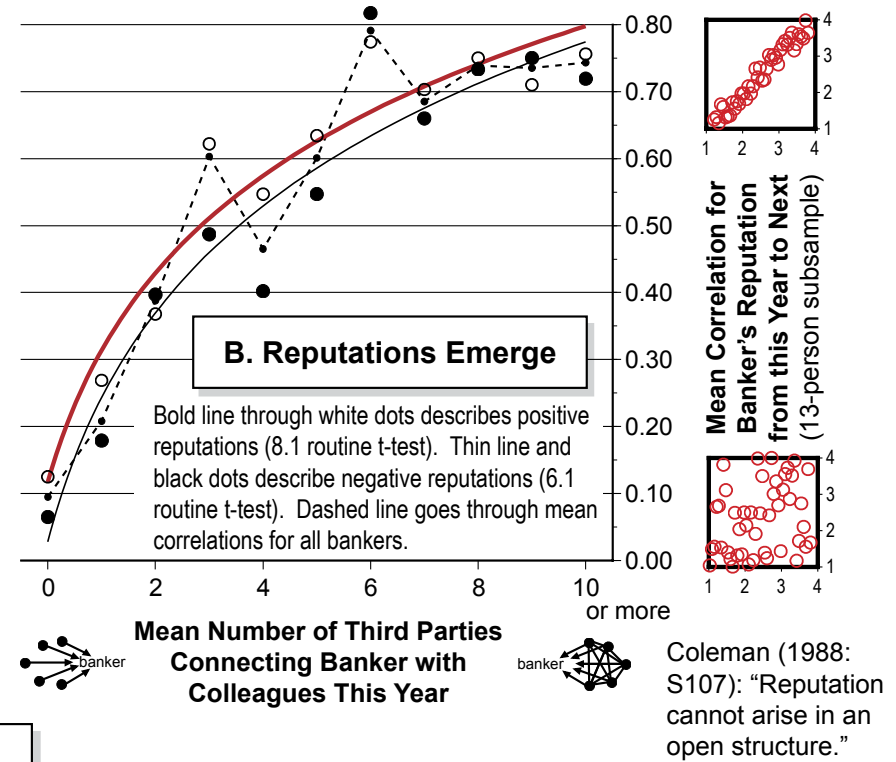
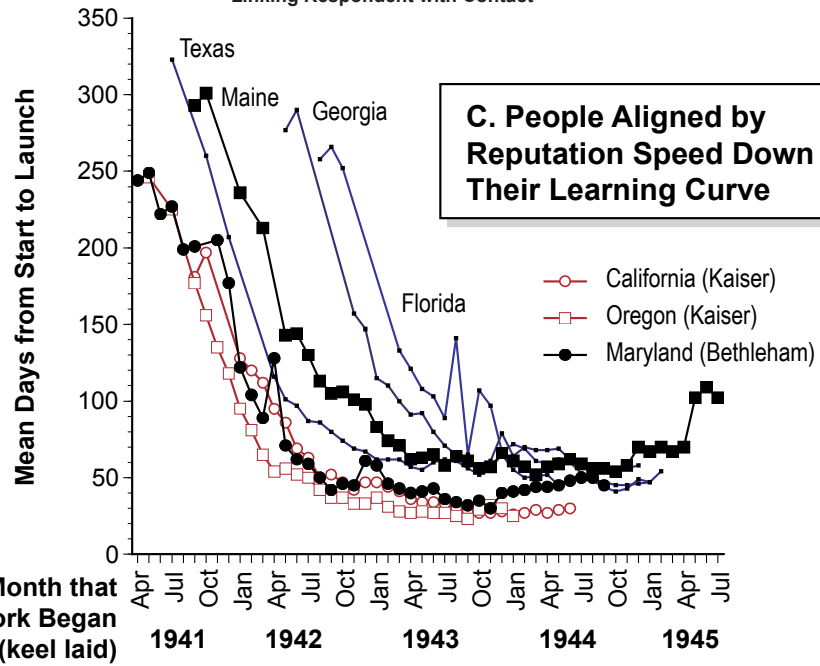
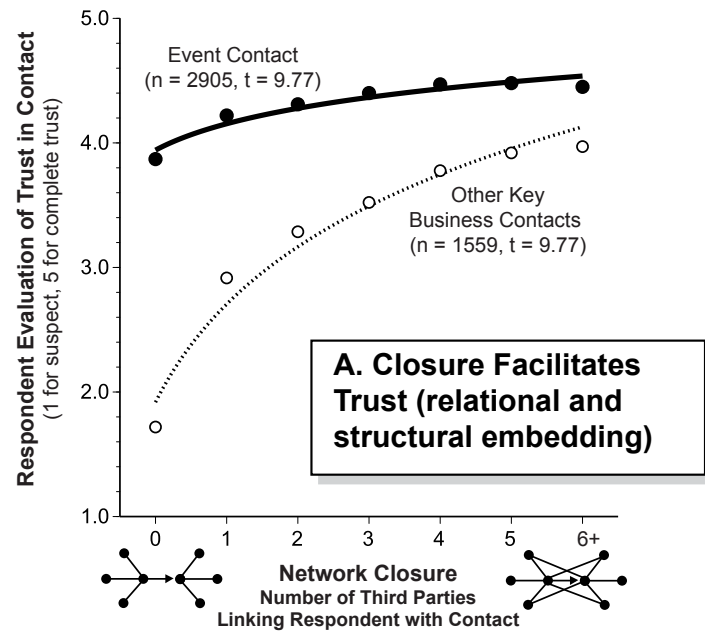


**C. But Returns to Brokerage Are Contingent on a Would-Be Broker's Social Standing in the Group to Which He or She Makes a Proposal.**

## Brokerage for Top-Line Growth

Circles are average scores on the vertical axis (Z) for a five-point interval of network constraint (C) within each study population. Dashed line goes through mean values of Z for intervals of C. Bold line is performance predicted by the natural logarithm of C. The study populations include bankers and managers in Asia, Europe, and the US (see Figures 1.8 and 2.3 in *Brokerage and Closure*).





## Closure for Bottom-Line Growth

Graph A describes 46,231 colleague relations with analysts and investment bankers. Graph B describes 262 subsample correlations between reputation this year and next for the bankers. Graph C describes "liberty" ship production times.

Graph C is from Figure 3.7 and graph B is from Figure 4.6 in *Brokerage and Closure*. Graph A is from Figure 5.6 in "Closure and Stability," (cf. Figure 4.8 in *Brokerage and Closure*).

# Balance on a Case-by-Case Basis

## Problems in Our Steam Turbine Production

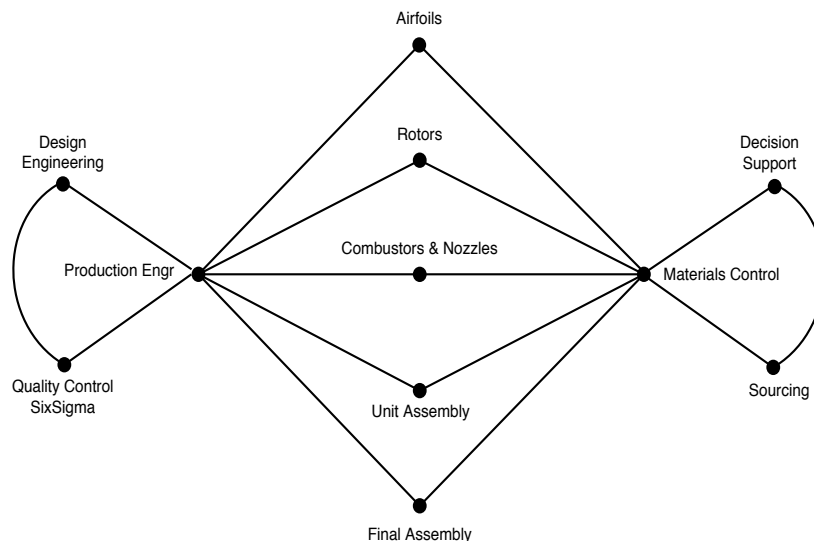
Joe: Please put everything aside and get down to our Oklahoma manufacturing plant. I don't know what is wrong down there, but that operation is killing us. The plant is hemorrhaging cash and losing us future orders. Almost every order involves substantial re-work, late-delivery penalties, and costly service calls after delivery. We've had a SixSigma team down there for ten months and the problem has only gotten worse with finger-pointing and mounting tension.

See if you can figure out what is going on. If we can't fix it, we have to rethink our decision about keeping the plant.

I'll have John draw up a quick sketch of the production process to guide you. I've had John call Jerry LeFleur, the plant manager, to let him know that you will be coming down. Get back to me quickly on this one. / Mike

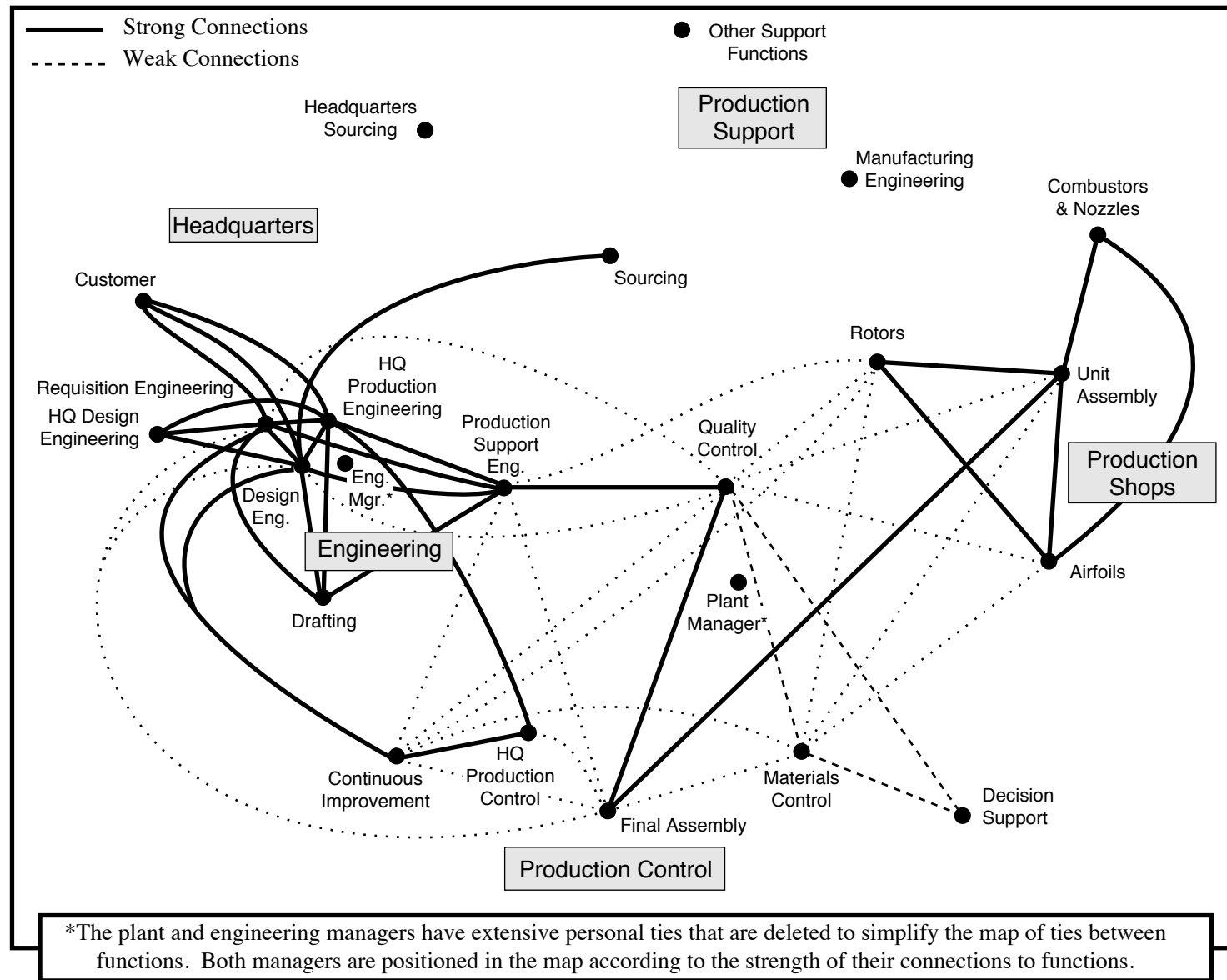
Joe: The Oklahoma plant is organized like our others (below). HQ works with the customer to figure out what turbine they want (requisition engr), we design it (design engr), then oversee its production (production engr & quality control). Working from our designs, production plan, and quality specs, people in the Oklahoma plant manufacture the airfoils, rotors, combustors and injectors, assemble the rotor unit, and assemble the casing around the rotor unit. Those five tasks define the five

work groups in the plant. The flow of product through the five groups is managed by the plant manager and the materials control people, who manage the flow of supplies from outside vendors and between work groups in the plant.



I had my assistant talk with people here and with Greg Anderson, Director of Final Assembly at the Oklahoma plant, to run a Network Diagnostic so you can get a quick sense of the plant's social organization. The Diagnostic is run from Greg Anderson's perspective, summary output follows this page, and my assistant sent a disk containing the raw data to your secretary. Let me know if I can be of any further help (use the mobile number; I'm away this weekend). Good luck. / John

# The Actual Organization Is Not so Simple



The situation and network are described in Burt and Ronchi, "Measuring a large network quickly" (*Social Networks*, 1994)

# Senior Management Network

Lines indicate frequent and substantive work discussion; heavy lines especially close relationships.

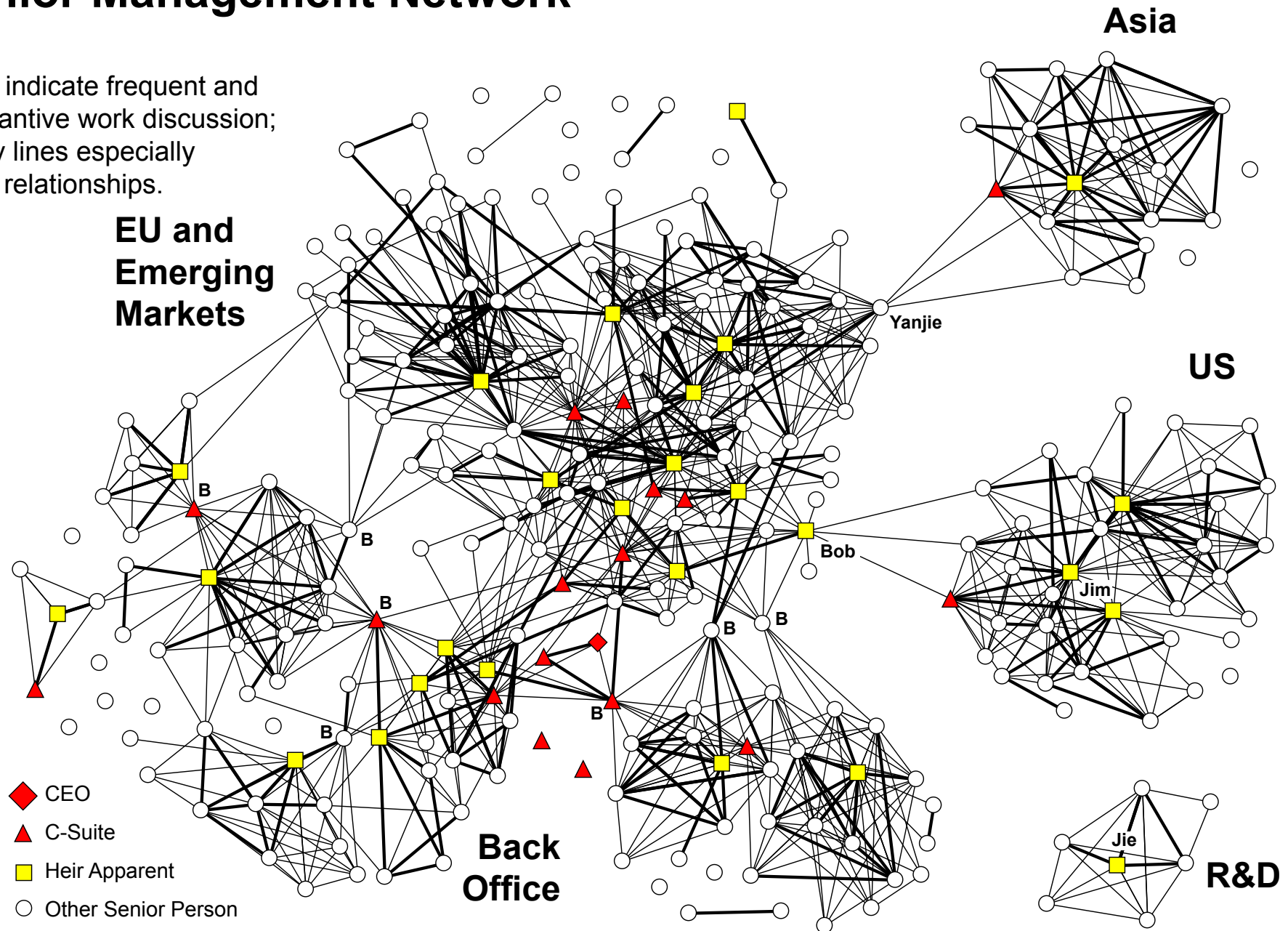
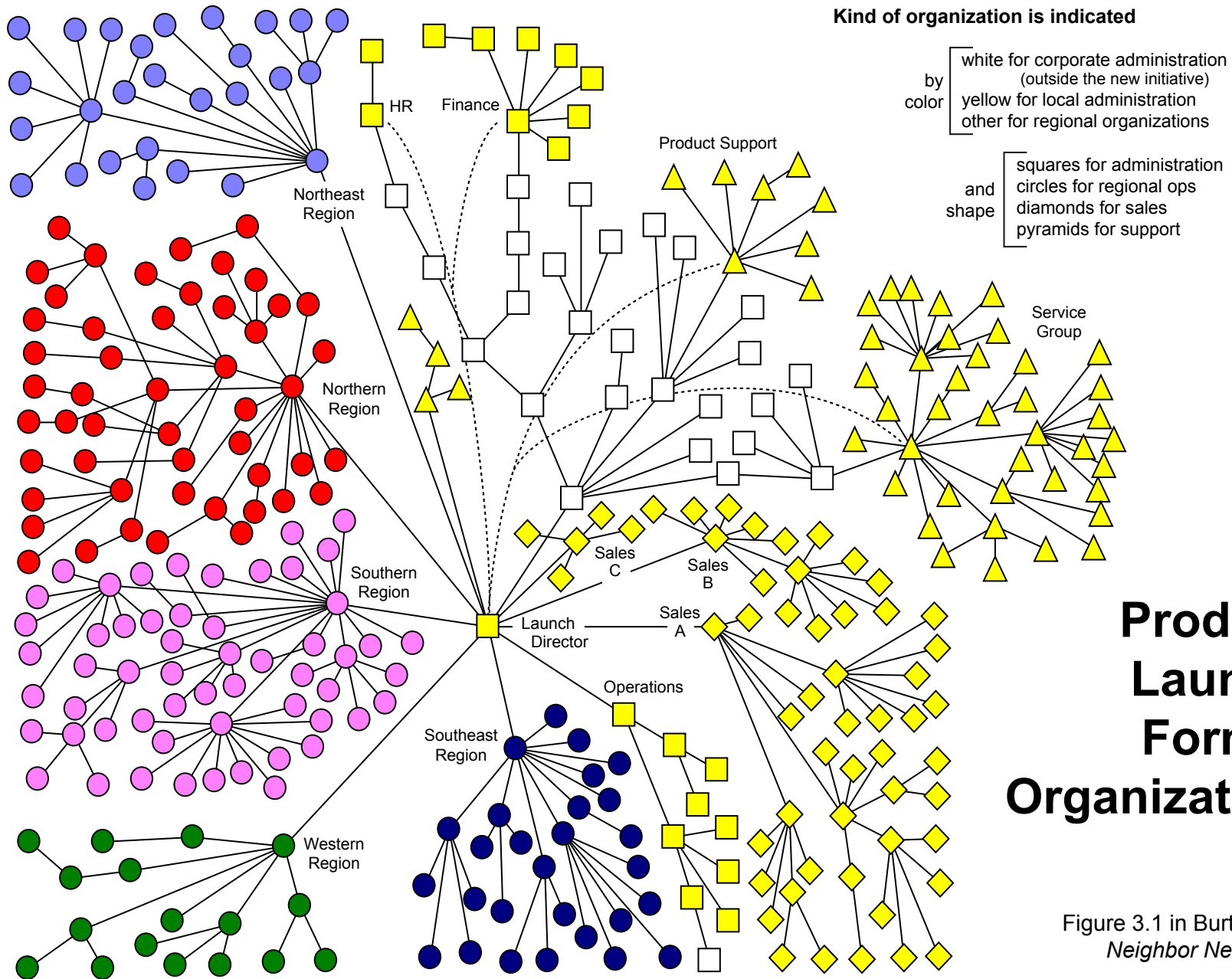


Figure 1 in Burt and Soda, "The social origins of great strategies" (*Strategy Science*, 2017)



## Product Launch Formal Organization

Figure 3.1 in Burt (2010, *Neighbor Networks*)



# Social Network Behind the Product Launch

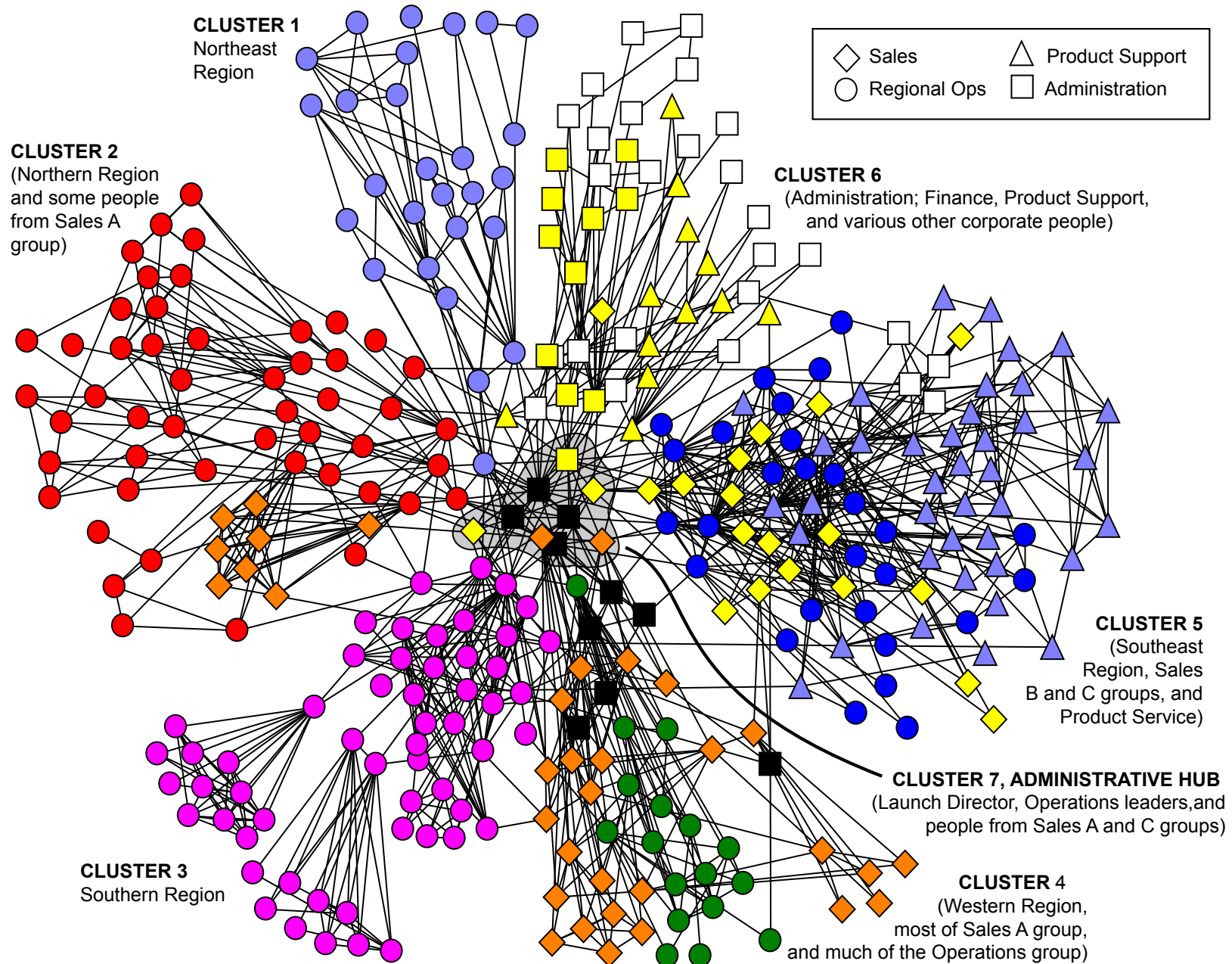
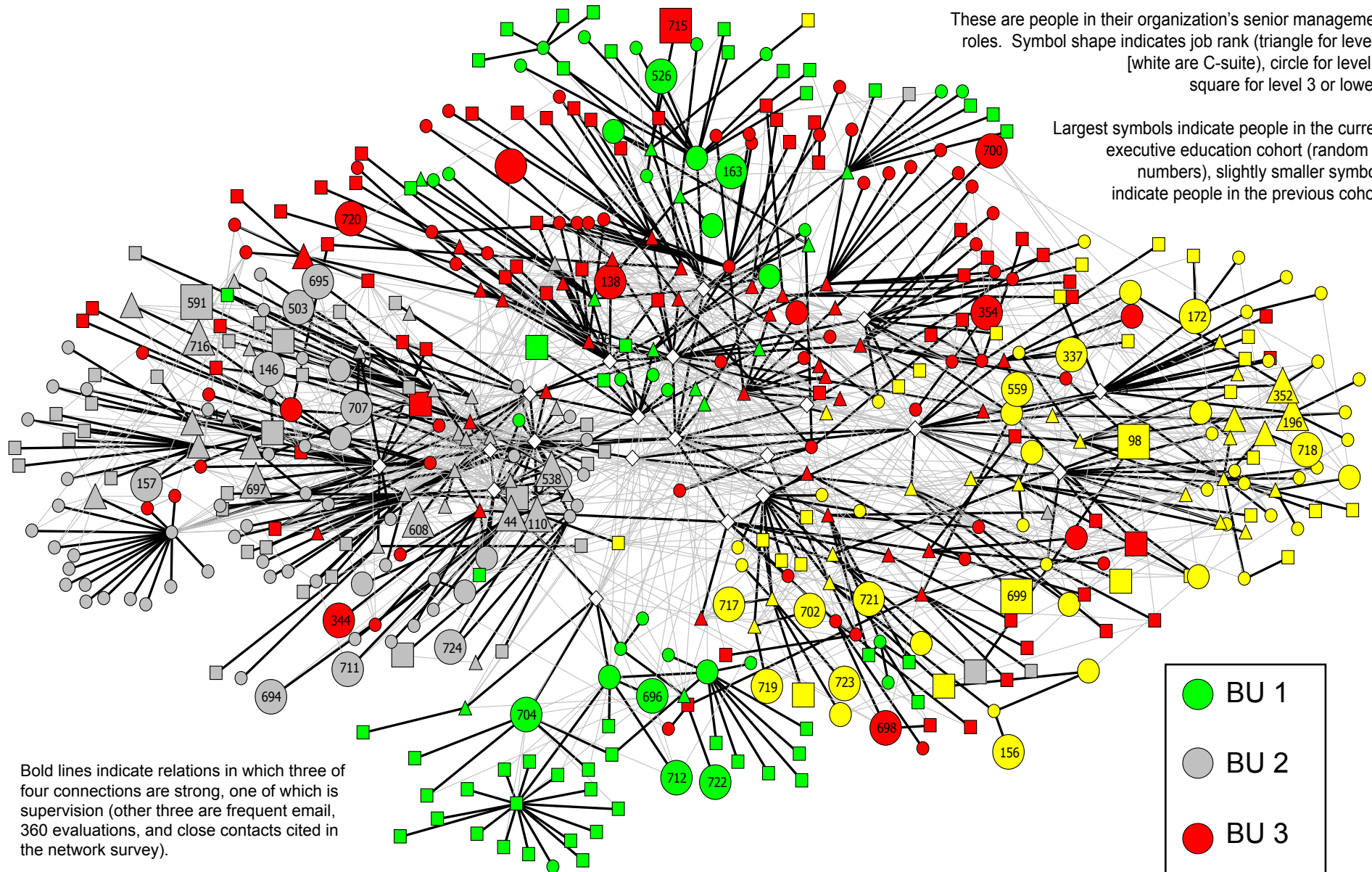


Figure 3.2 in Burt (2010, *Neighbor Networks*)

# Network Map of Senior Management in a Large Financial Organization

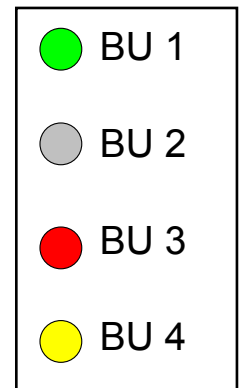
These are people in their organization's senior management roles. Symbol shape indicates job rank (triangle for level 1 [white are C-suite], circle for level 2, square for level 3 or lower).

Largest symbols indicate people in the current executive education cohort (random ID numbers), slightly smaller symbols indicate people in the previous cohort.



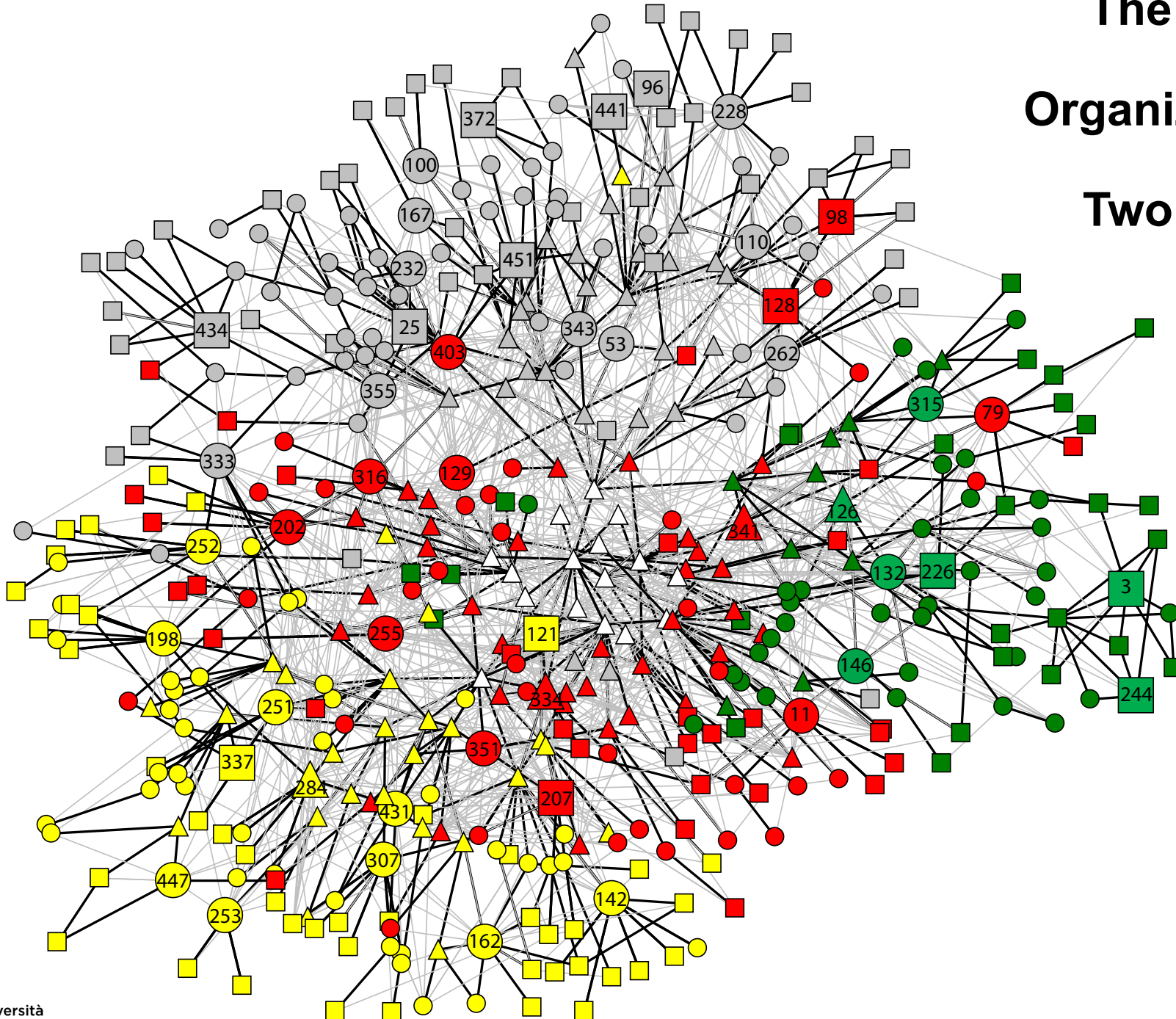
Bold lines indicate relations in which three of four connections are strong, one of which is supervision (other three are frequent email, 360 evaluations, and close contacts cited in the network survey).

Light lines indicate relations in which at least one of the three non-authority connections are strong.

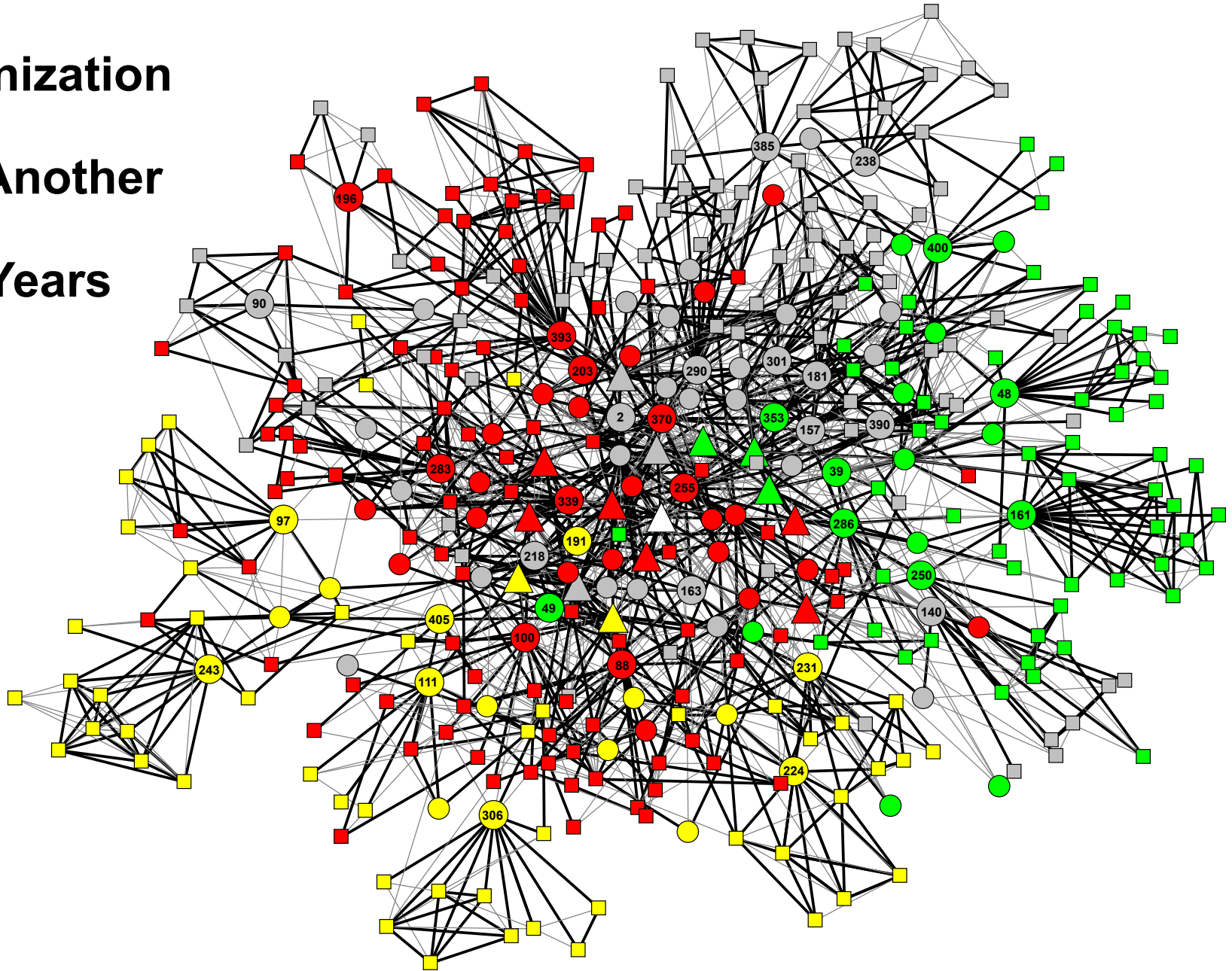




The Same  
Organization  
Two Years  
Later



**The Same  
Organization  
Still Another  
Two Years  
Later**

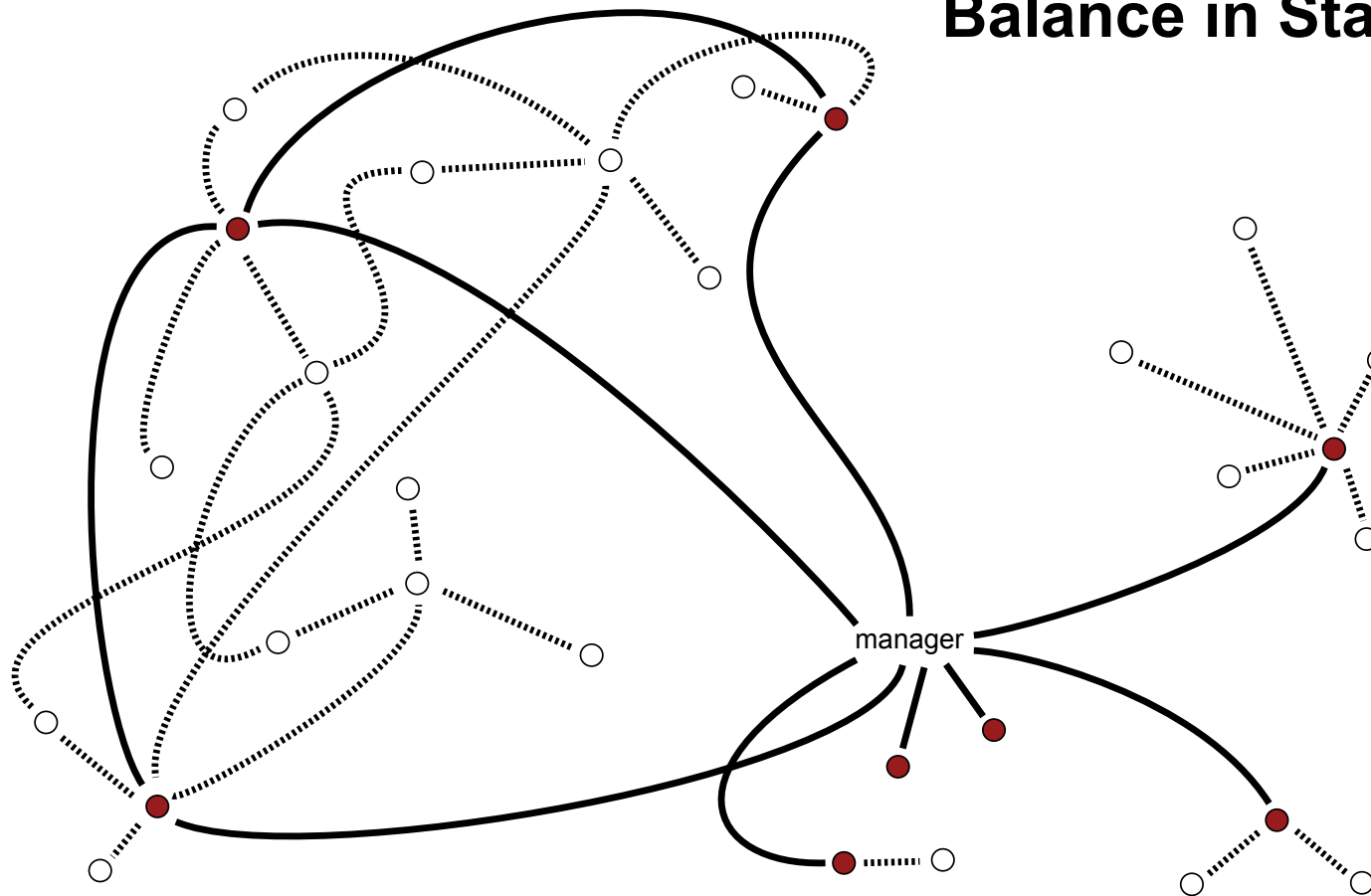


# Balance in Principle for the General Case

Brokerage for top-line growth (vision, dissipation)

Closure for bottom-line growth (alignment, myopia)

## Balance in Stable Networks, "Where"



## Balance in Dynamic Networks, "When"

For variations on the theme of balancing brokerage versus closure, see Klapp (1978) on opening vs. closing, Zaleznik (1977) and Kotter (1990) on leaders vs. managers, March (1991) on exploration vs. exploitation.

# B-C Balance in Stable Networks, "Where"

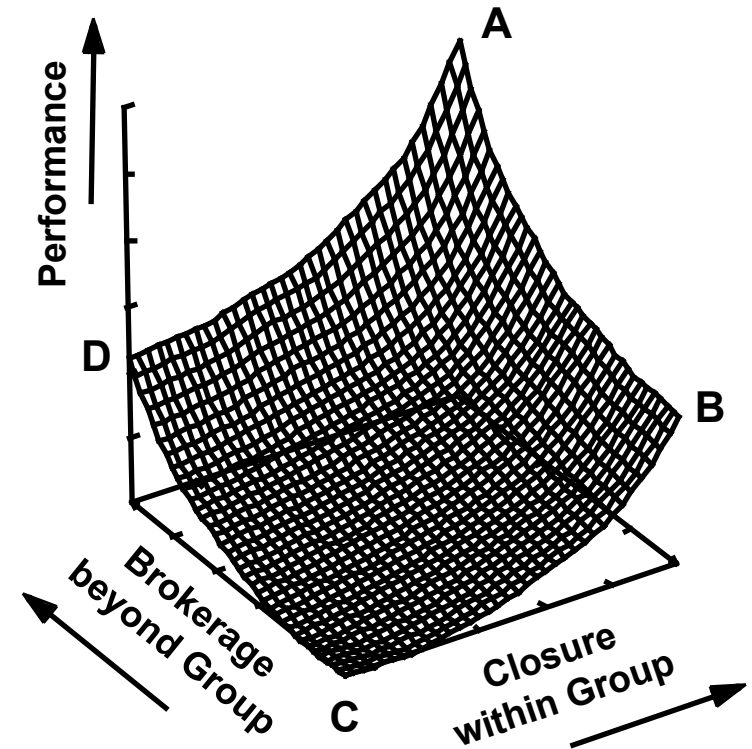
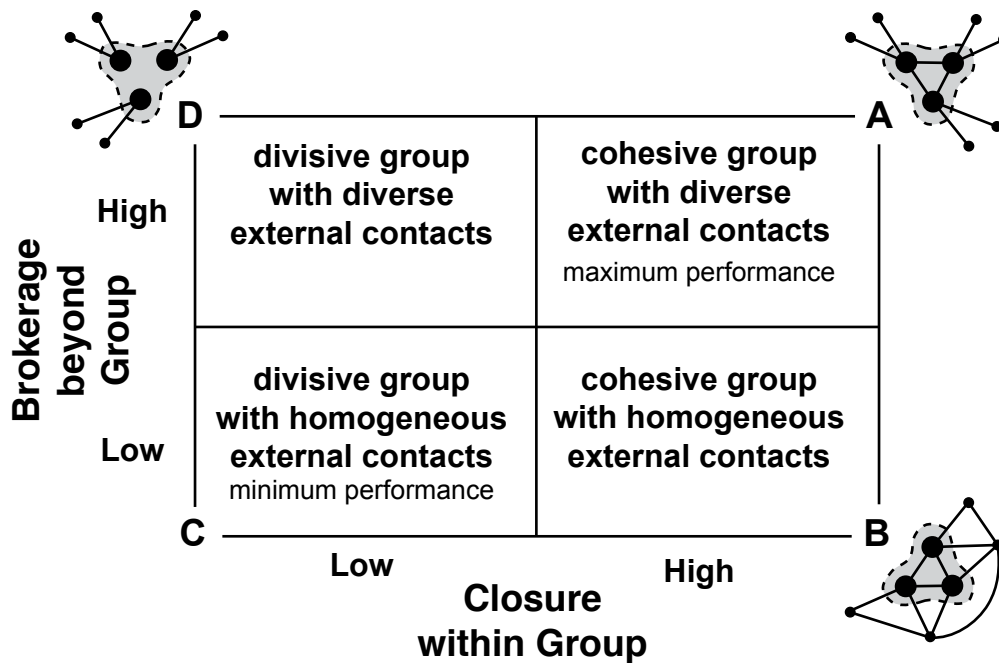
Performance Is Highest

for

## Closure Within a Group

combined with

## Brokerage Beyond the Group



Structural Autonomy =

$E(\text{Performance}) =$

$$\alpha \text{ Closure\_in}^\beta \text{ Brokerage\_out}^\gamma$$

Steve Jobs, 1995



From Figure 3.5 in *Brokerage & Closure*



# Which Can Make a "Business Network" Valuable

A business network brings together otherwise disconnected people to share valuable and otherwise difficult-to-obtain information (i.e., the network creates bridge relations embedded in a reputation-inducing, trust-facilitating, closed network; e.g., Les Cunningham's Business Network of home contractors\*, Chicago's Commercial Club, Ian McDaniels' China-US Business Council, Mark Twain Bancshares\*, Dennis and Donna Joannides' National Business Associates)

Pro: early access to experience and leads, broad access to benchmarking experience

Con: early disclosure of future plans, broad disclosure of past mistakes (rep critical)

**Consider Michael McCarthy's experience, quoted in *Inc Magazine* (November, 1995):** Many entrepreneurs worry that they'll outgrow their early relationships with banks. But not Michael McCarthy, CEO of McCarthy Co., a St. Louis construction company. Although McCarthy has grown his business to \$1 billion in sales, he remains close to the local community bank that backed him more than 20 years ago, Mark Twain Bancshares.

"The bigger the bank, the more you're at the whim of a very capricious management situation. You never know when the senior executives of a big bank will suddenly decide that your kind of company doesn't fit in with its new business plan and you'll be out of luck."

"I've continued to do business with Mark Twain Bancshares even when I also needed to borrow larger sums from bigger banks," he says. "And that saved us during one year, seven or eight years ago, when we had unexpectedly large, multiple losses. Our big banks suddenly came up with all kinds of new criteria and required us to pay off our loans, because of our financial problems. Mark Twain stood by us and continued to support us, even creating a new \$7-million line of credit for us."

His conclusion: "Big banks often respond to an entrepreneur and his or her special needs with edicts. If you've built a good relationship with a smaller bank, maintain it. You never know when you'll need that extra level of support."

\*See Sgourev and Zuckerman, "Improving capabilities through industry peer networks" (2006, *Sloan Management Review*) and the HBS case, "Mark Twain Bancshares," for details on using the bank-branch board of directors as a business network to identify attractive loans with mid-size companies and high-wealth individuals.

## NEWS

## A look inside the richest club in China

by Neil Koenig, Producer, China's Billionaires' Club, 23 October 2014

In the north-west corner of Beijing, in an area renowned as a base for huge technology companies, stands a non-descript building a few stories high. Inside, in a small set of modest offices, is the hub of something quite extraordinary - a club that counts billionaires amongst its members. "There's little else like it anywhere else in the world," says leadership expert Steve Tappin, who is the presenter of the BBC TV documentary China's Billionaires' Club. "It's very hard to imagine the top 50 CEOs in America or Europe happily getting together or going on foreign trips as a group," he adds.

The China Entrepreneur Club consists of 46 of China's top business leaders. They are joined by politicians, academics and other advisers. Several of the members are billionaires. They include Guo Guangchang, who's been described as China's answer to Warren Buffett, property tycoon Wang Jianlin, and Jack Ma of e-commerce giant Alibaba, who's believed to have recently overtaken Mr Wang as China's richest man.

The club offers a forum where company founders can meet and share ideas, and offer advice to each other. Since it was formed in 2006, the organisation has held regular events, some on a large scale. CEC members have also travelled the world together, meeting presidents and prime ministers keen to learn more about China's business elite. The club is extremely difficult to join, and new members are rarely admitted. Amongst other attributes, candidates need to have an exemplary track record of business success, and must share the club's values.

Given that entrepreneurs are often extremely competitive people, how could a club like this possibly work? The answer, according to Charles Chao, chief executive of giant internet firm Sina, is that the members come from different industries, so they are not competing with one another. "It's an honour just to belong to this organisation," adds Mr Chao. Members also rally round each other when one of them encounters difficulties. Mr Chao says the level of support available "is beyond my expectation." He sees it as a key benefit of membership.

So how did it all come about? The answer partly lies in the uncertain status of the business community in China. "Society sometimes mistreats entrepreneurs, and has a lot of misconceptions about them," says the club's founder, Liu Donghua, who used to publish a magazine aimed at people who have launched businesses. Mr Liu says that one of the main reasons he started the club was to promote greater acceptance and understanding of the private sector.





CAREERS | NOVEMBER 26, 2009

THE WALL STREET JOURNAL. CAREERS

# What Facebook Can't Give You

*Over 52 Years, These Men Have Evolved Into Movers and Shakers—Together*

By KATHERINE ROSMAN (photos by Bryan Derballa for The Wall Street Journal)

Before there was Facebook, there was the Wednesday 10.

In 1957, as men in their late 20s, they began meeting—initially over breakfast, then over dinners held at the Sherry-Netherland Hotel or at the Harvard Club in midtown Manhattan. Few were born to means. Many were sons of immigrants. Most went on to become luminaries in their fields—presidents of television networks, partners at banks, editors of magazines.

On occasion, they shared their influence with one another. When member Mort Janklow made a career switch from corporate attorney to literary agent, a fellow member, columnist William Safire, offered himself as a famous first client. When Robert Menschel, a senior director at Goldman Sachs Group Inc., was considering deals involving large consumer companies such as Procter & Gamble, he would pick the brain of fellow club member Ed Meyer, the former chief executive of Grey Advertising.

In a day when “social network” is a buzz term from colleges to board rooms, the members of Wednesday 10 show the benefits of old-fashioned networking. “We were all young kids starting out, and it is easy when you are so involved in building your career to lose touch with other people who are outside your field,” says Mr. Menschel, who has been at Goldman Sachs for 55 years. “It helped me to understand why other people do what they do—which is important in life and in business. You don’t learn anything from talking to sameness.”

The Wednesday 10 comprised, at various points, more than 20 men; the goal was a number small enough to maintain intimacy yet large enough to ensure that at least 10 members would show up for each of the monthly Wednesday-night meetings. No



**The Wednesday 10, shown at a 1960s banquet with their dates, began meeting 52 years ago.**



# Elite Intellectuals Positioned for Innovation and Integration across Interest Clusters or Silos in Academic Disciplines

(from van der Leij and Goyal, 2011,  
Review of Network Economics)

Remember  
the *guanxi ties*  
in networks  
around Chinese  
entrepreneurs  
(high trust  
without structural  
embedding).

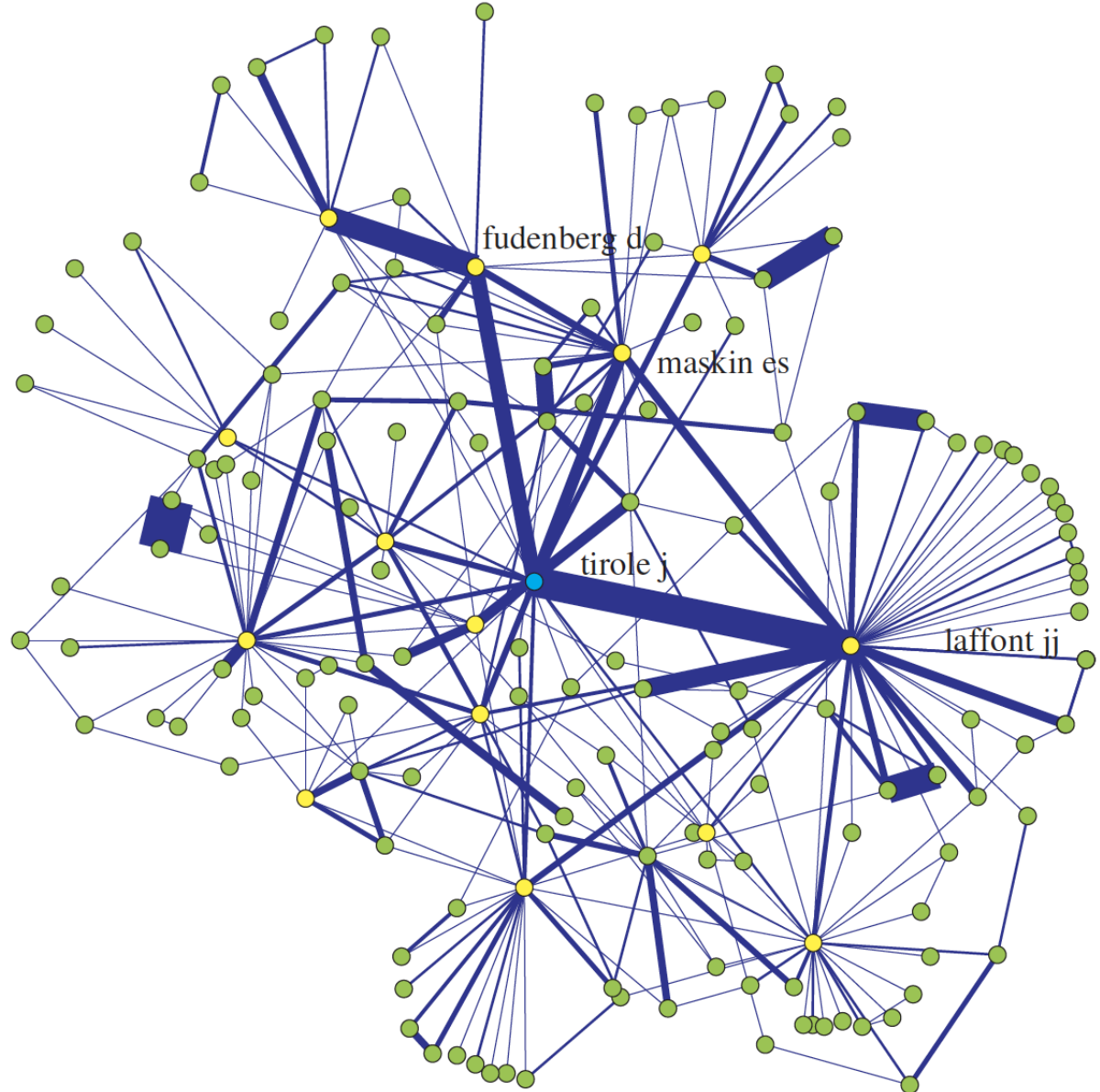


Figure 1: The local network of Jean Tirole.

# Balance Can Vary Over the Three Worlds: Periphery, Outer Circle, Inner Circle

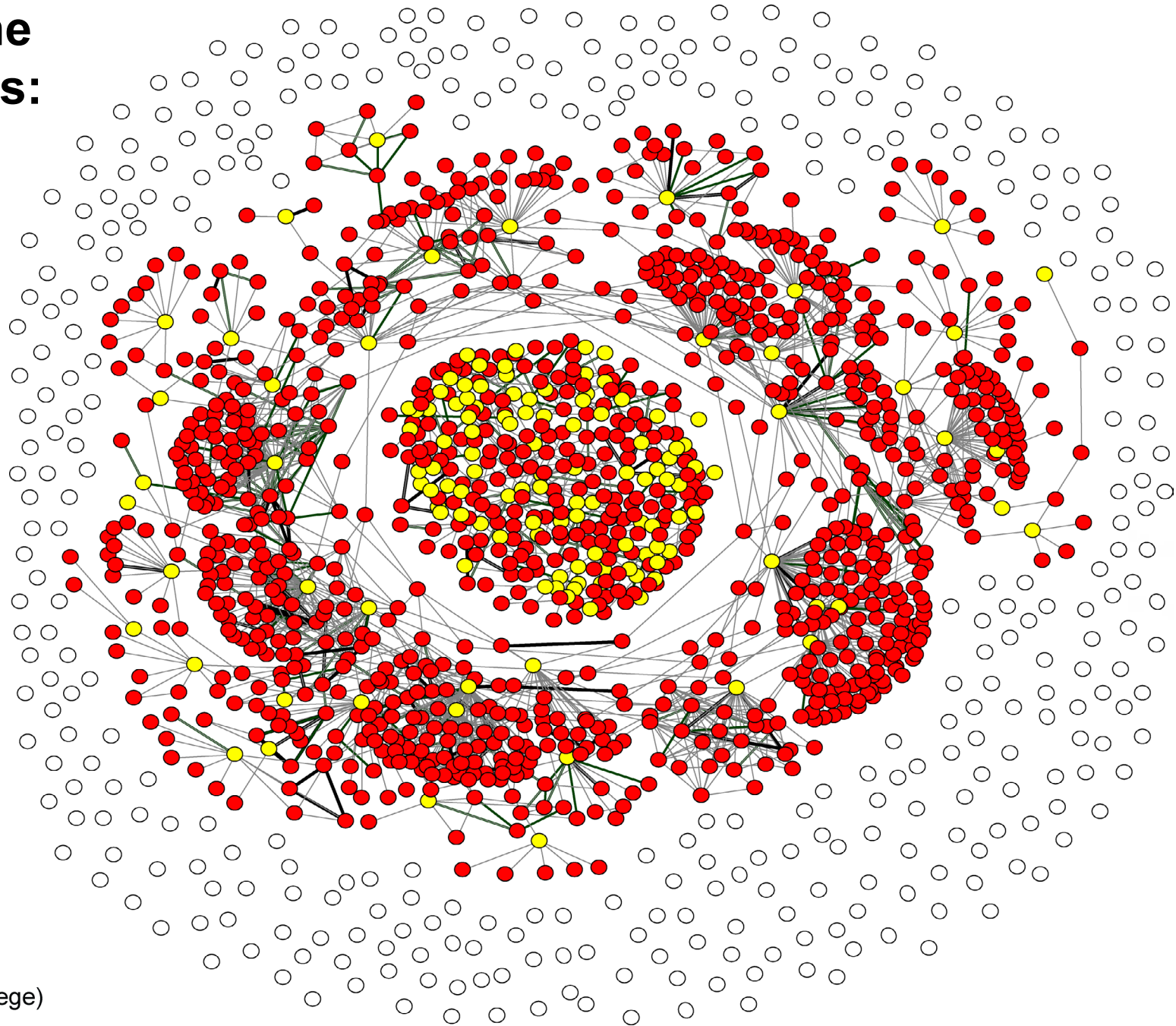
A random sample of 500 people was drawn in the virtual world Second Life,

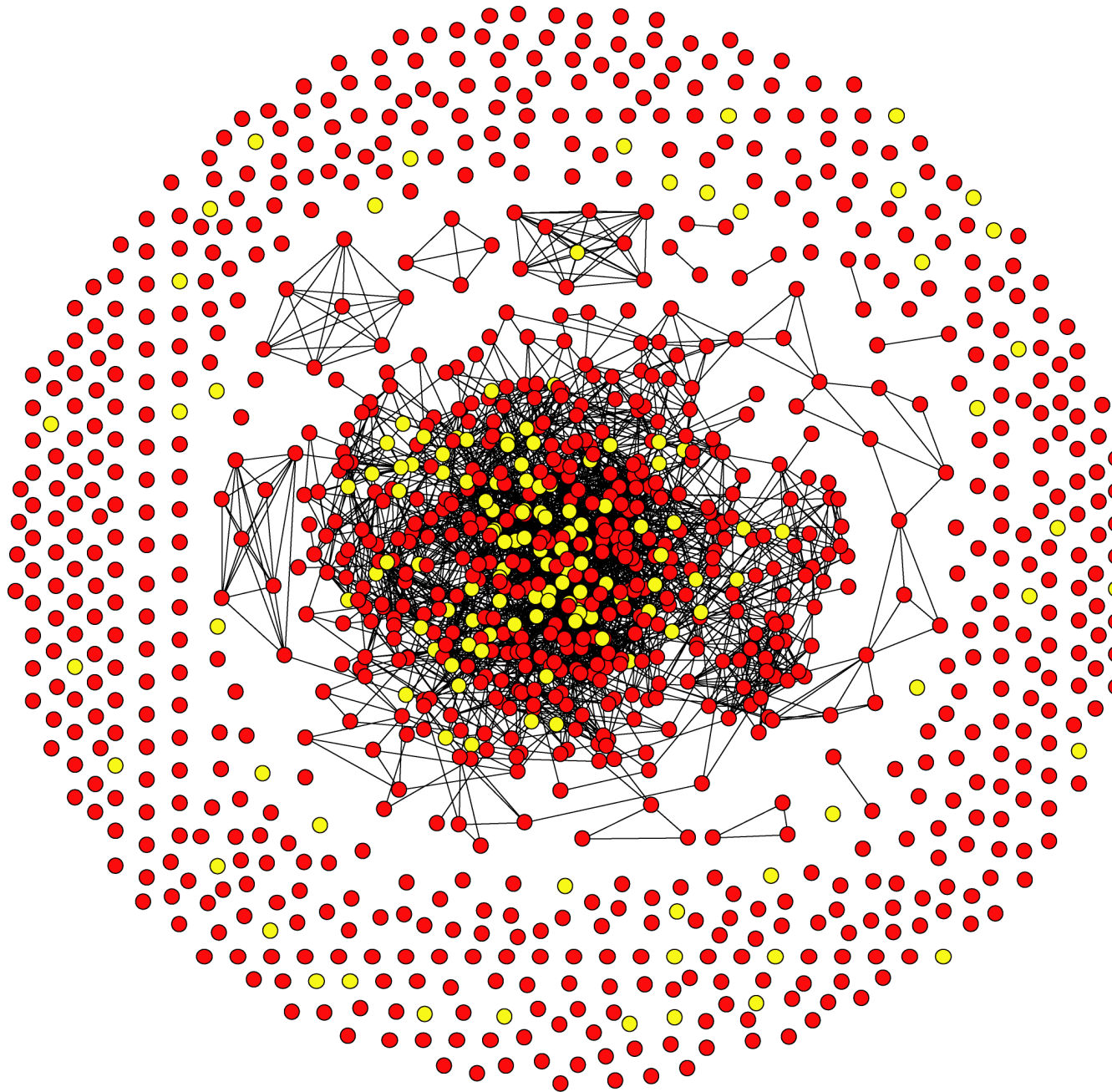
then snowballed out to include friends of the sampled people,

resulting in a network of 1,533 people.

- Sample Isolate
- Sample Person Who Has Friends
- Friend to a Sample Person

- Strong Tie (modify objects)
- Tie (locate)
- Weak Tie (online, no-privilege)





## Sociogram of Directors in Chicago Index Companies

1,380 Chicago directors.

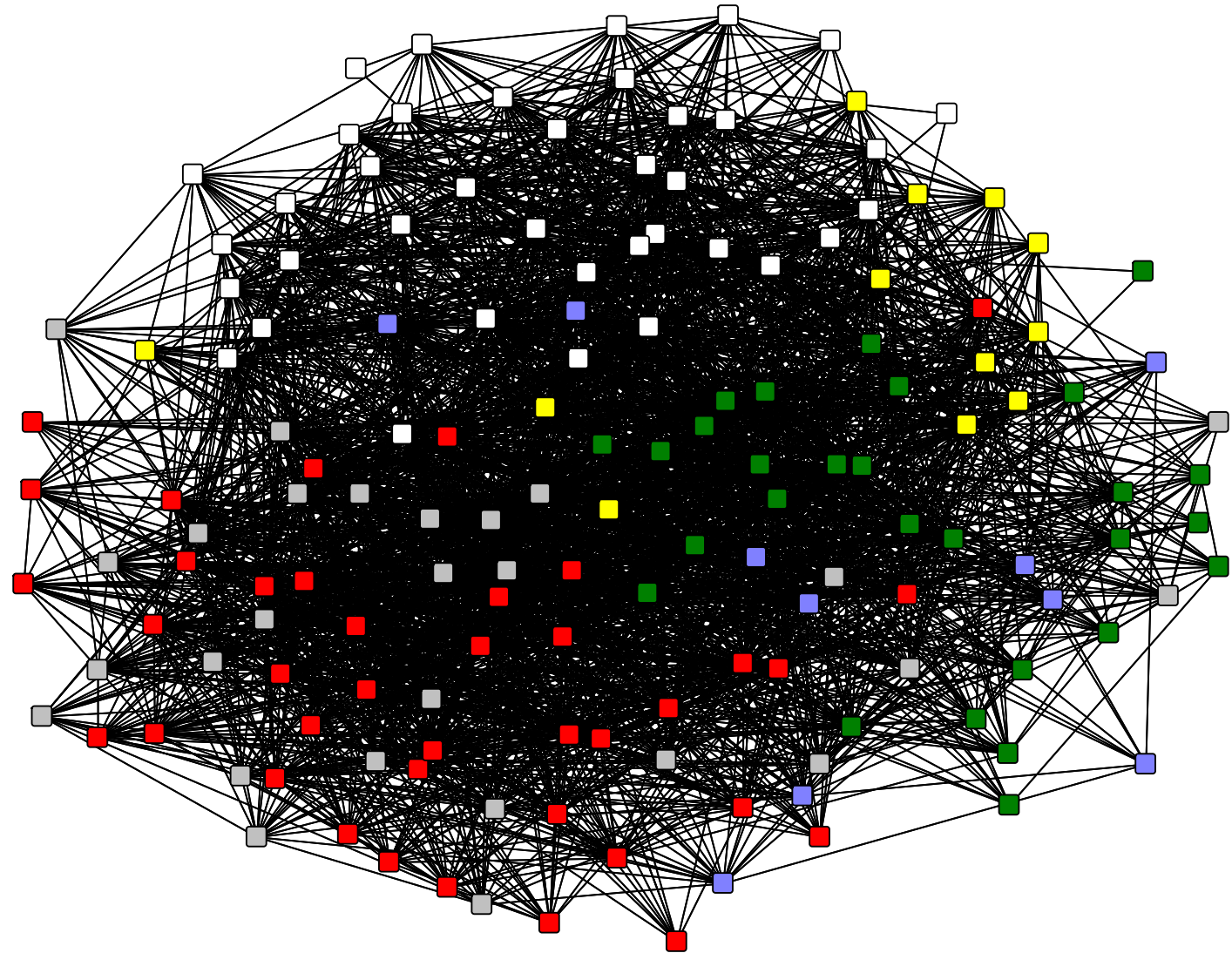
Gold indicates  
Commercial Club  
member, concentrated in  
center (13.2 t-test).

818 isolates sit on one  
Chicago board or one  
Chicago board plus  
outside boards  
containing no other  
Chicago elites.



# These are the senior leaders at the top of a large bank.

Lines indicate people who have frequent and substantial face-to-face contact. Average such connection is embedded in 28 mutual friends (0 minimum, 63 maximum).



- Executive Function
- Corporate Operations
- Insurance
- Retail
- Other Divisions
- Wholesale

## (Q137) How does an informal alumni group like the “Wednesday 10” provide competitive advantage?

- A. Advantage comes from dense trust relations among the alumni, who know one another from time together in school.
- B. Advantage comes from the diverse occupations of the alumni, providing bridge relations into diverse markets.
- C. Advantage comes from the similar backgrounds of people invited into the group which improves communication.
- D. The alumni graduated together from an elite college. Any group they form will be associated with success.
- E. Advantage comes from dense trust relations within the group and diverse bridge relations beyond the group.



The Wednesday 10, shown at a 1960s banquet with their dates, began meeting 52 years ago.

(Q145) A general rule for managing your team's network is to build closure within the team, and brokerage beyond the team. True or false?

A. True

B. False

(Q22) For senior leadership to operate as "one company," each leader should be strongly connected with every other senior leader in the senior management network. **True or false?**

A. True

B. False

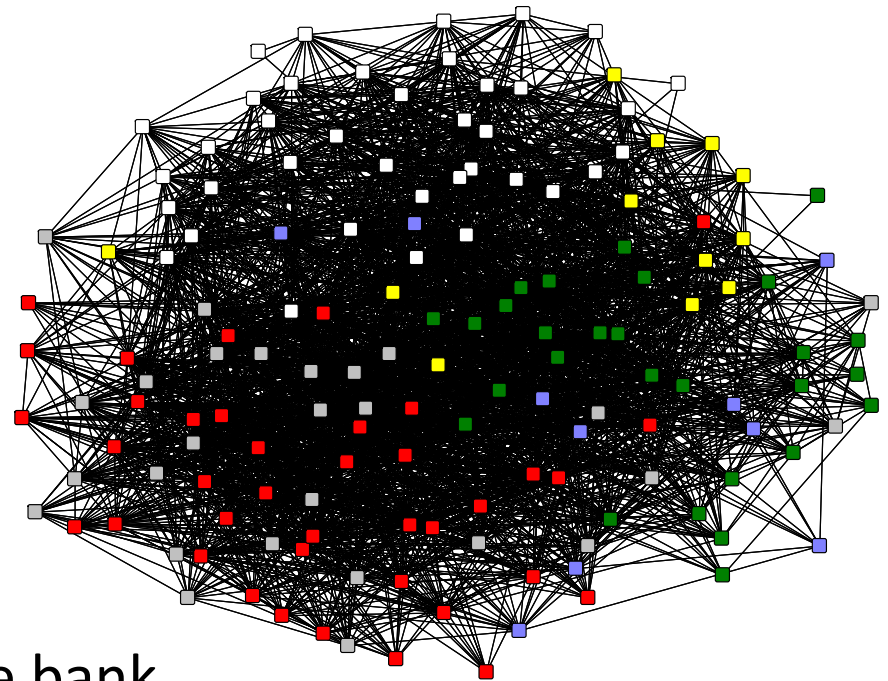
(Q80) Structural holes are a problem for coordination. An able manager should work to eliminate the structural holes in his or her organization. **True or False?**

- A. True, because structural holes are disconnections in the flow of information between employees.
- B. False, because structural holes often result from an efficient division of labor.
- C. True, because structural holes are places where the manager can broker ideas to create value for the organization.
- D. False, because structural holes can contribute to job security.
- E. True, because employees are less engaged when they are segregated in groups separated by structural holes.



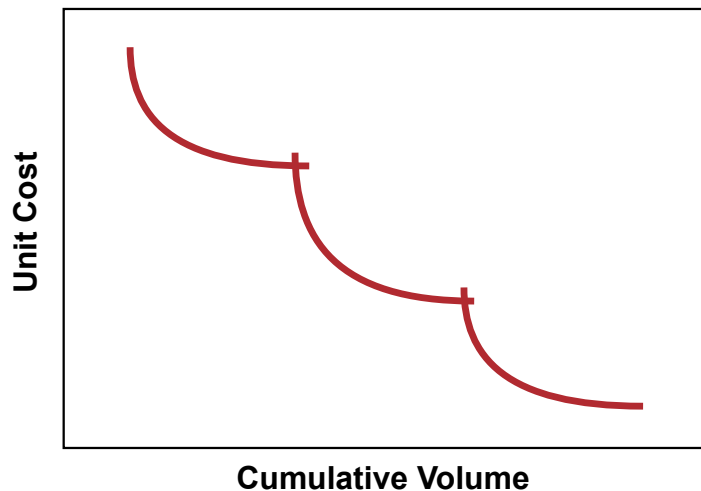
(Q10) The sociogram below describes the social network among the 150 most senior people in a large commercial bank. **Reasoning from our discussion of balancing brokerage against closure, you could expect all except which of the following characteristics from the bank?**

- A. Stable banker reputations.
- B. Efficient bank operations.
- C. Innovative bank operations.
- D. Suspicion of people outside the bank.
- E. Frequent expressions from senior people of loyalty to the bank.

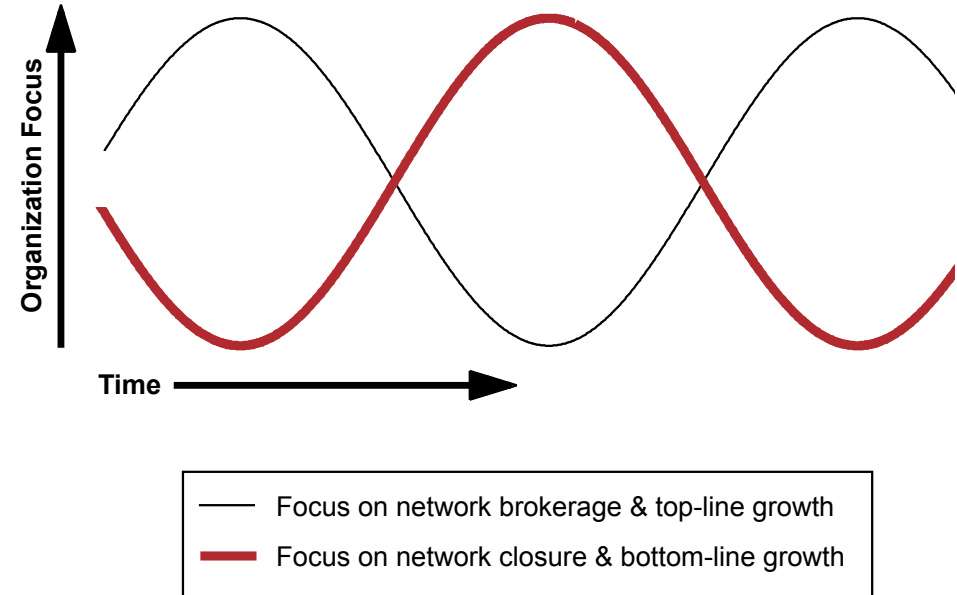


# Contingent Optimum Raises a Question of "When" to Push Brokerage or Closure

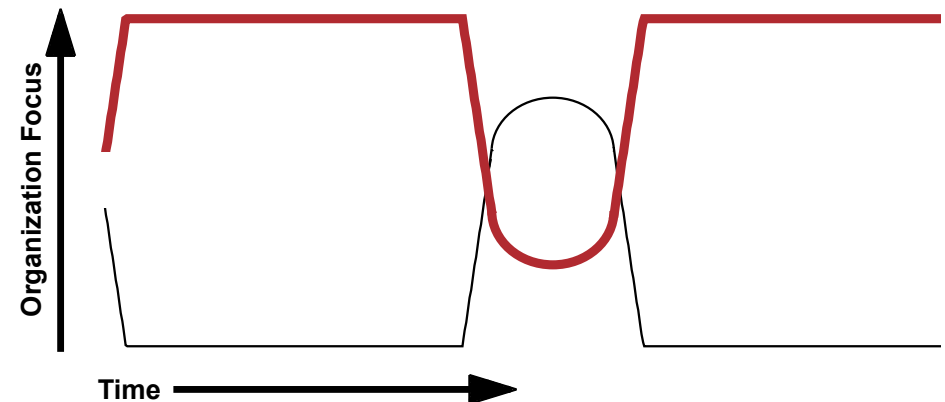
For example, Oscillation and Learning-Curve Cascades



A. Business Cycles



B. Learning-Curve Cascade



# Building Your Network: A Broker Network Can Result from Always Being a Broker or from Network Oscillation

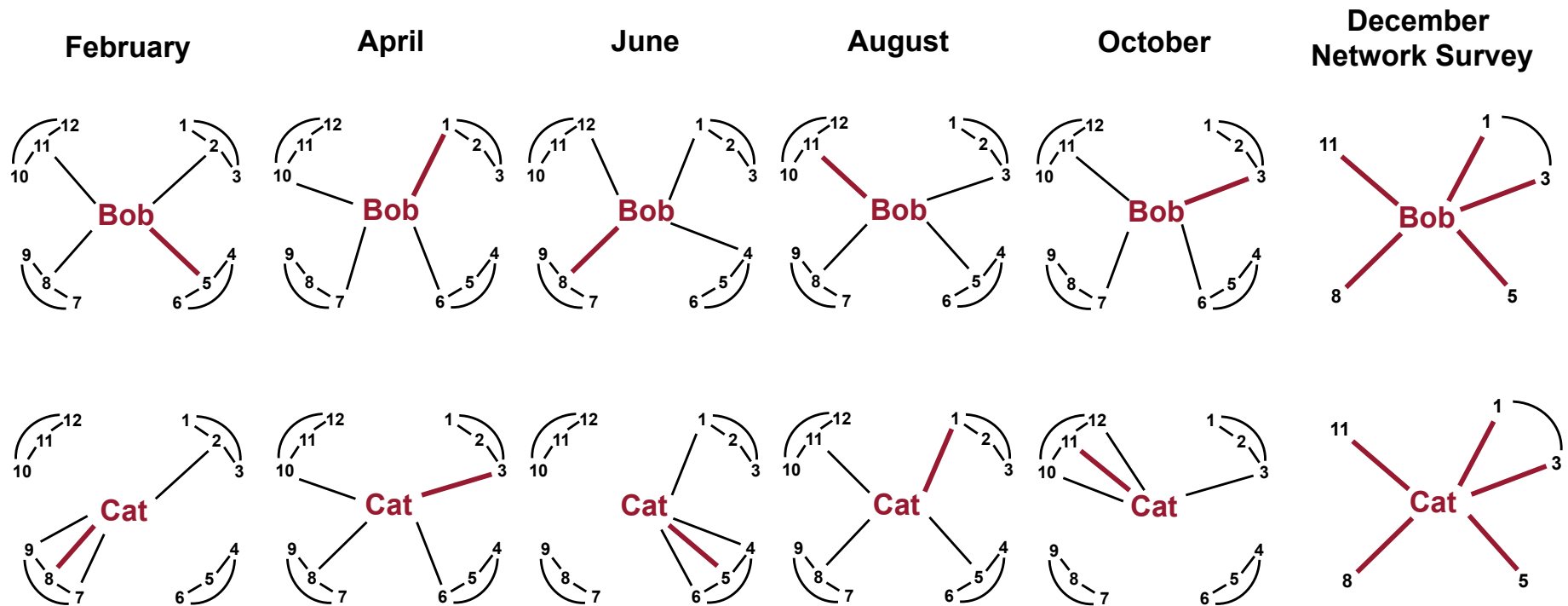
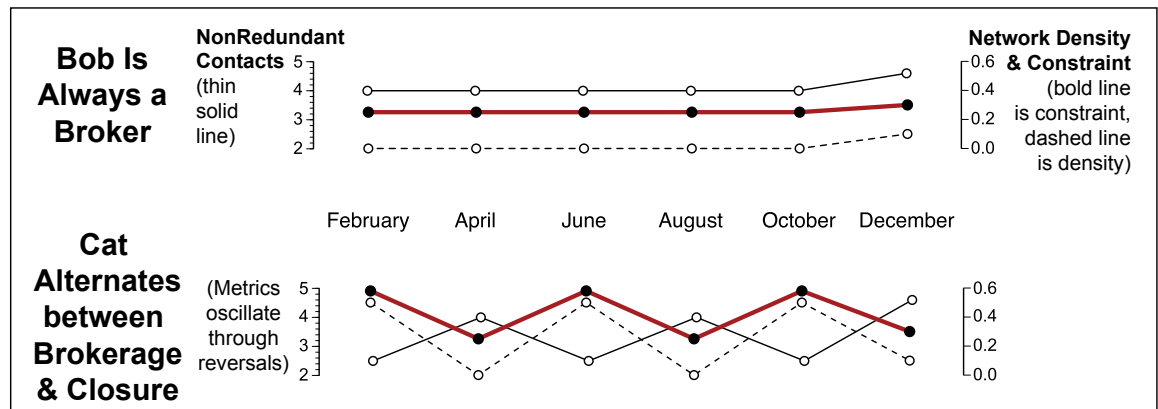


Figure 1 in Burt & Merluzzi, "Network Oscillation" (2016, *Academy of Management Discoveries*)



## Substantial Differences in Individual Returns to Brokerage

Graph A below is from *Brokerage & Closure* and the previous handout showing achievement increasing with more access to structural holes. Circles are z-score residual achievement for 1,986 observations averaged within five-point intervals of network constraint in each of six management populations (analysts, bankers, and managers in Asia, Europe, and North America, see discussion of Figure 2.3 in Chapter 2; heteroscedasticity is negligible,  $X^2 = 2.97$ , 1 d.f.,  $P \sim .08$ ). Bold line is the vertical axis predicted by network constraint.

Graph B to the right shows the raw data that were averaged to create Graph A. Vertical axis is wider to accommodate more variable achievement. Heteroscedasticity is high due to achievement differences between advantaged individuals ( $X^2 = 269.5$ , 1 d.f.,  $P < .001$ ), but the association between achievement and network advantage remains statistically significant when adjusted for heteroscedasticity (Huber-White,  $t = -8.49$ ).

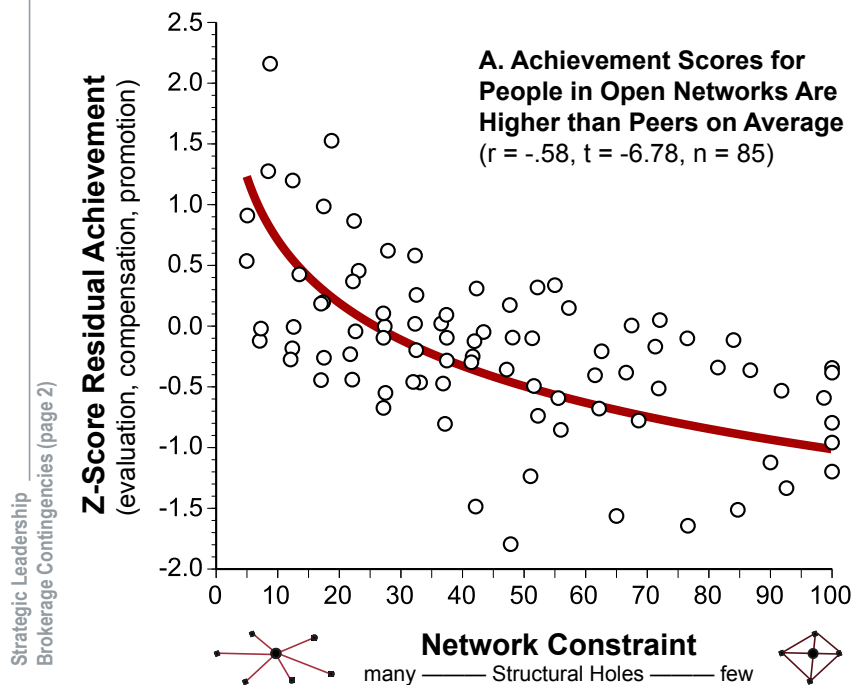
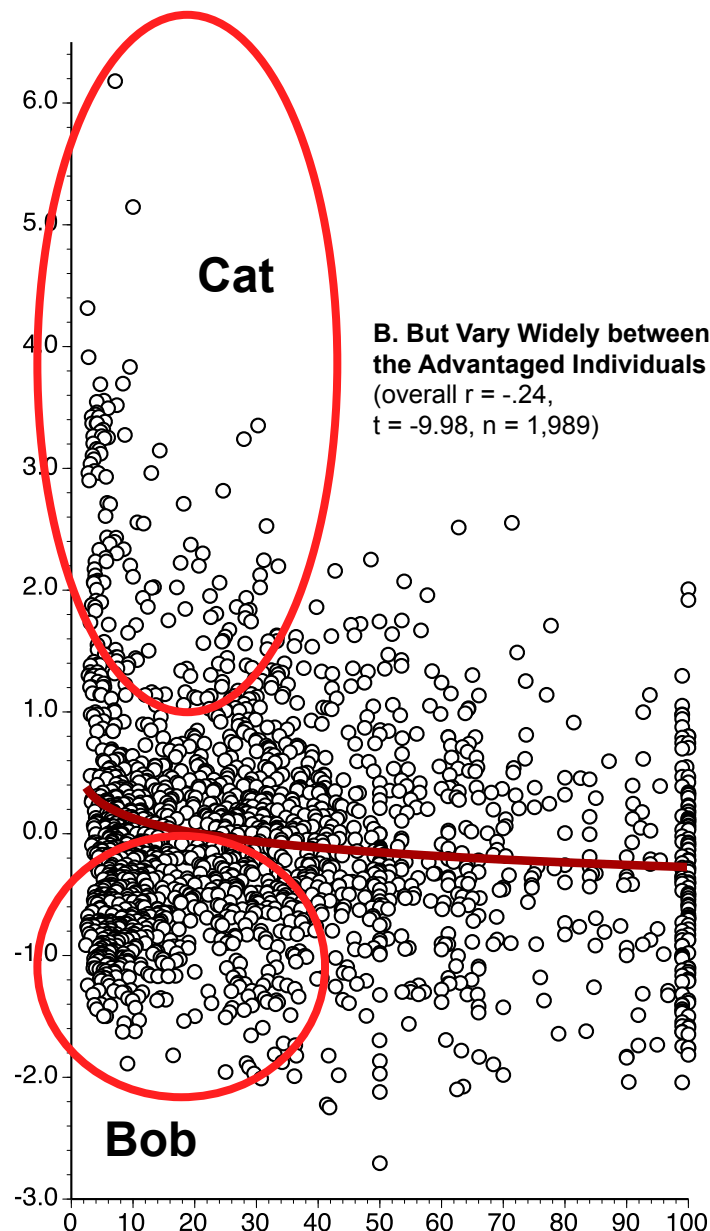
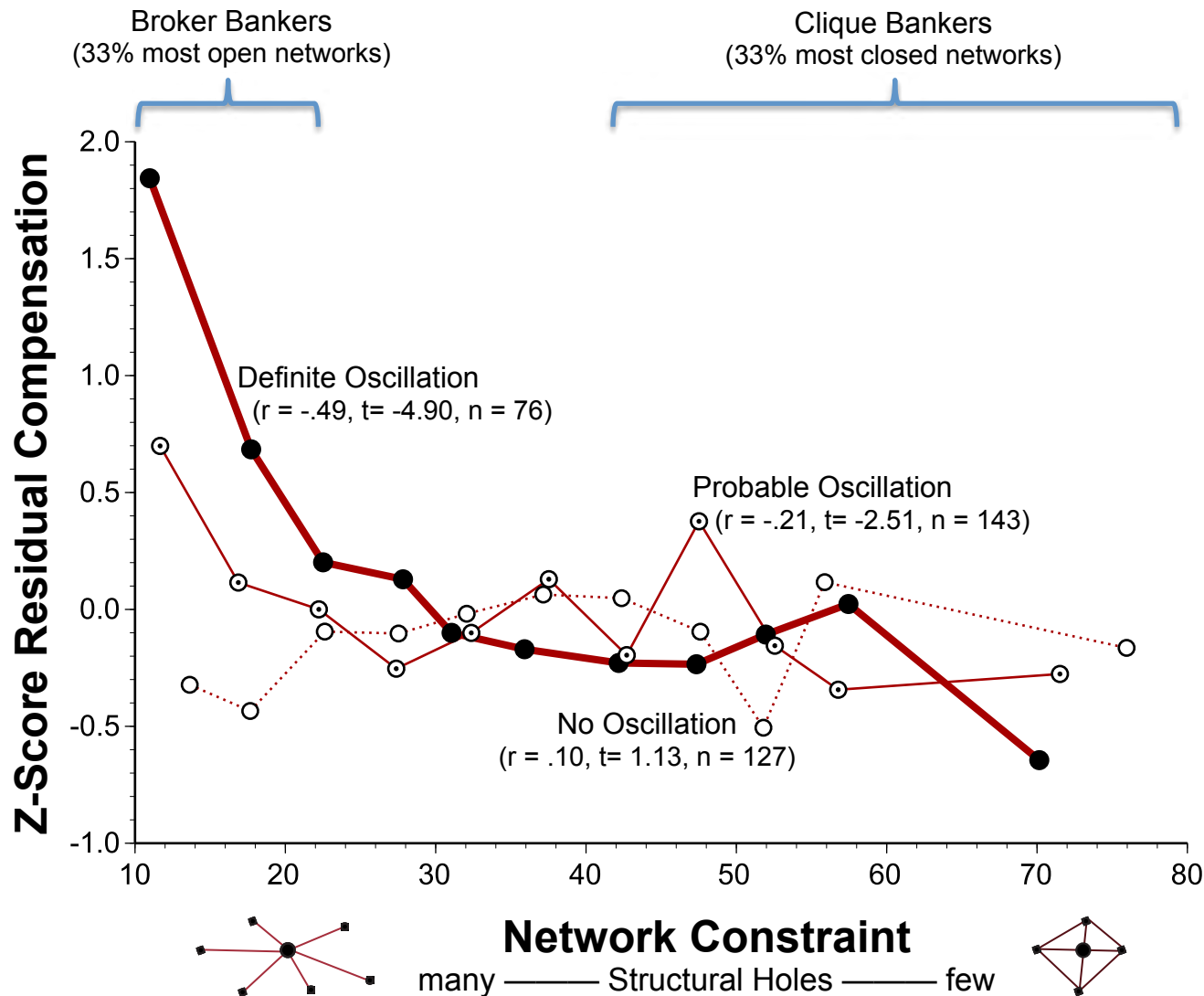


Figure adapted from Figure 1 in Burt (2012, "Network Related Personality," *American Journal of Sociology*).



from the first handout, "Brokerage"



## How Much Does Oscillation Matter for Each Category of Bankers?

	N	t-test	P
Broker Bankers	111	4.38	<.001
Middling Bankers	116	0.08	.94
Clique Bankers	119	-0.84	.84

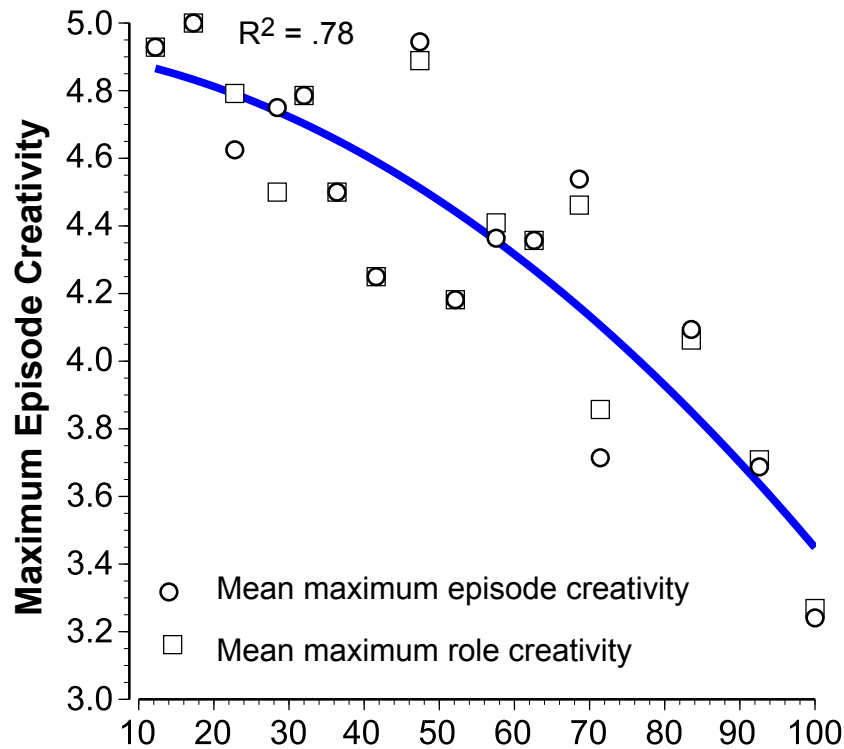
NOTE - Test for oscillation association with relative compensation for each row of bankers using a contrast of 1 for definite oscillation, 0 for probable oscillation, and -1 for no oscillation. Average z-score compensation across four years is predicted from average network constraint, holding constant job rank, seniority, peer evaluations, gender, race, and geography (Model IV, Table 1, Burt and Merluzzi, 2015).

## Returns to Brokerage Are Contingent on Oscillation

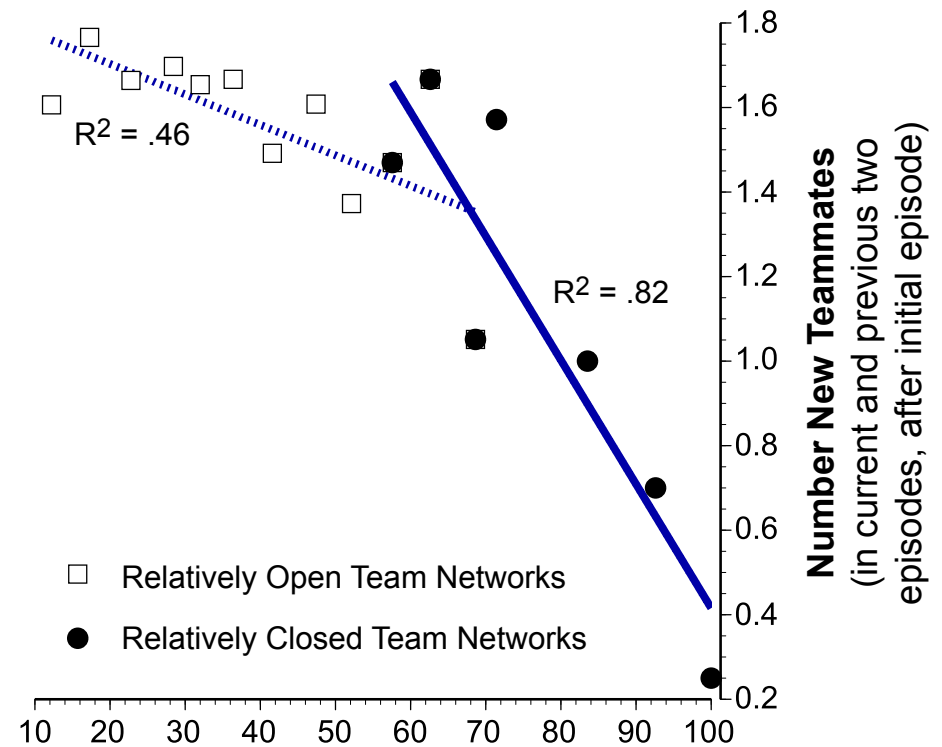
Vertical axis is a banker's z-score annual compensation — adjusted for the banker's job rank, evaluation by colleagues, years with the bank, gender, race, and geographic location — averaged across the four-year observation period. Horizontal axis is annual network constraint averaged across the four years. Symbols indicate averages of individual scores on the horizontal and vertical axes, within five-point intervals of network constraint. The three lines distinguish bankers by the extent to which oscillation across the four years is visible in their annual networks: Definite oscillation refers to bankers who experienced reversals in network status and constraint. Probable oscillation refers to bankers who experienced a reversal in status or constraint, but not both. No oscillation refers to bankers who experienced no reversals. As a summary test for oscillation, compensation was regressed for all 346 bankers across the control variables plus a dummy variable for probable oscillation and a dummy variable for definite oscillation, plus two interactions between the oscillation dummies and log network constraint. Negligible association between constraint and compensation for "no oscillation" bankers (-.86 t-test,  $P \sim .39$ ), increases to significantly higher associations for probable and definite oscillation ( $15.28 F_{2,333}$ ,  $P < .001$ ), yielding significantly higher levels of compensation for broker bankers ( $17.20 F_{2,333}$ ,  $P < .001$ ).

Figure 5 in Burt and Merluzzi, "Network Oscillation" (2016 AMD)

## A. Broker teams are more creative.



## B. Broker teams are more likely to refresh with new teammates.



Network Closure  
(100 x team network constraint)



Teams are composed of a producer, 1 or 2 directors, and 1 to 3 writers:

64 teams of three  
176 teams of four  
33 teams of 5+

# Broker team networks, and refreshing with new teammates, both predict team creativity.

Graphs plot averages for 200 people in any of all episodes. A third of the people only worked on an initial episode.  $R^2$  is .75 in graph B for continuous function in graph A.



# **Cocoon Hypothesis — Success is more likely, and greater, for network brokers who begin their project within a closed network, which dissolves in subsequent brokerage.**

An initial closed network provides safe haven for engaging and surviving the exploratory trial and error of getting a project launched.

Network brokers enjoy the information breadth, timing, and arbitrage advantages associated with project success.



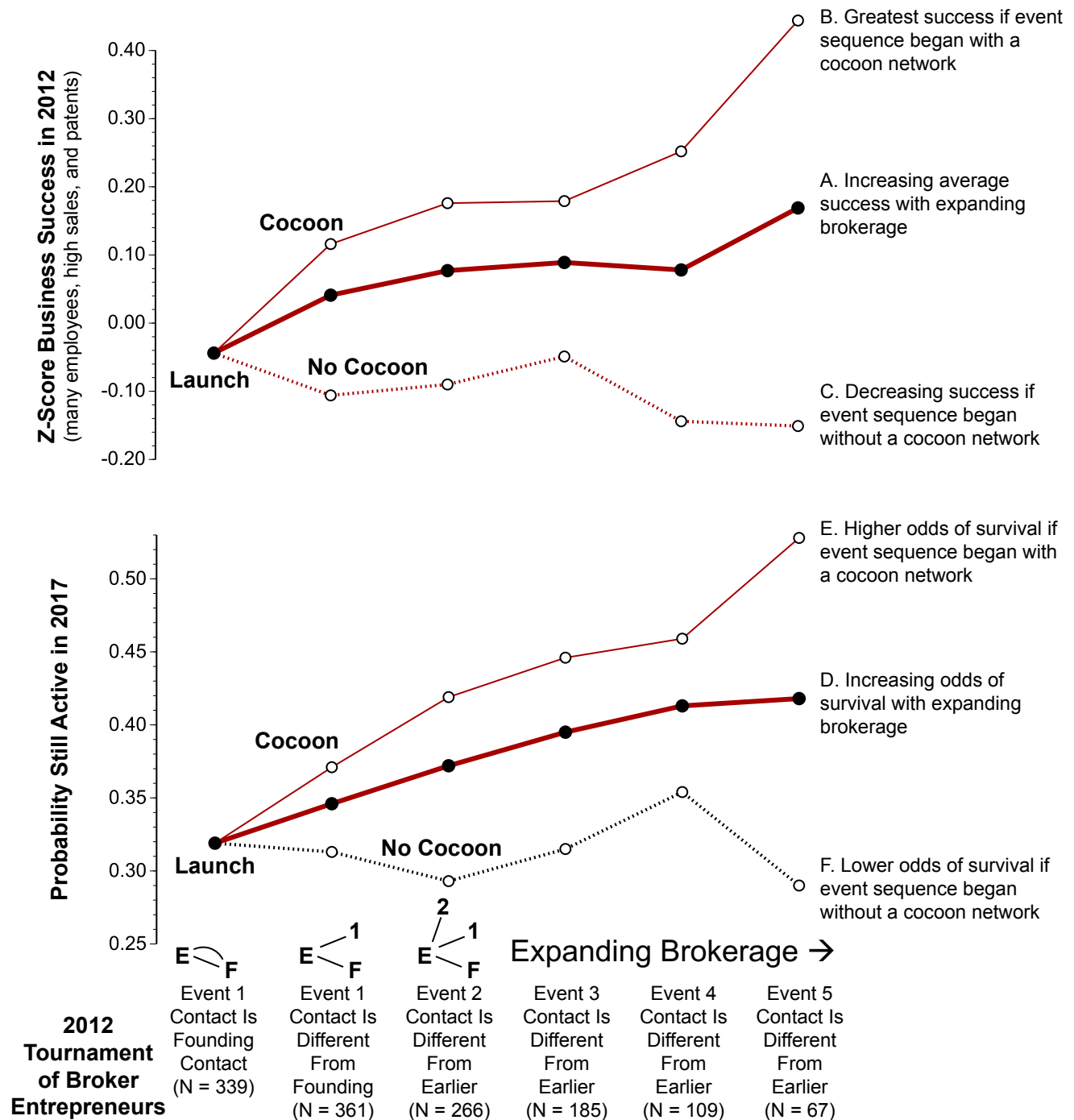


# Initial Cocoon Network Improves Later Success,

The graph shows benefit to entrepreneurs of having an early multi-person, closed network subsequently expanded into a large, open network characteristic of a broker.

A tournament is defined across the horizontal axis. Entrepreneurs are removed when they use a contact for help on more than one significant event in building the business.

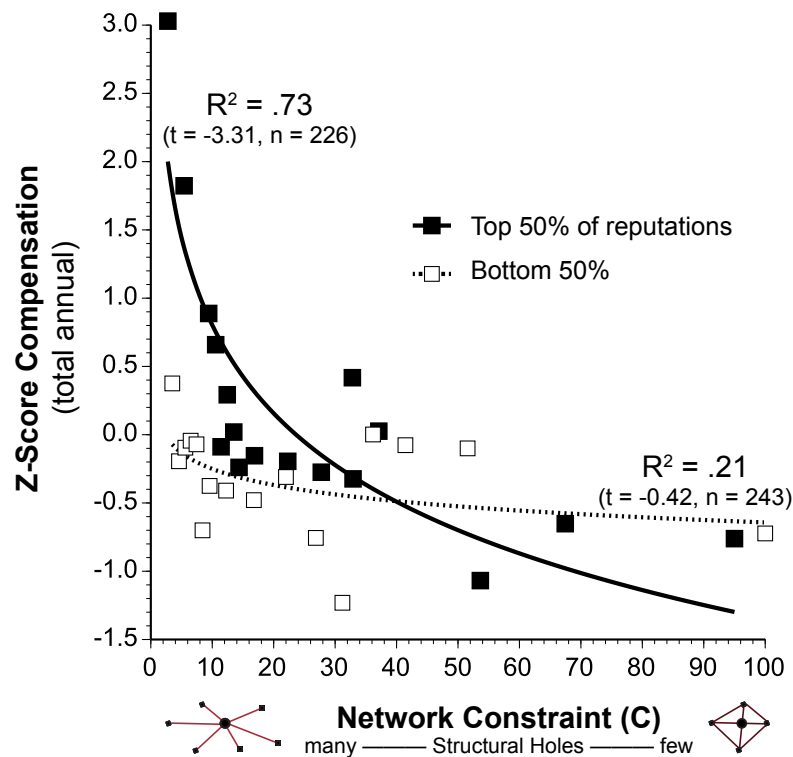
This is from Figure 11 in Burt and Oppen (2017, *MOR*), Figure 3 in Zhao and Burt (2018, *MOR*), Figure 4 in Burt (2019, *ETP*).



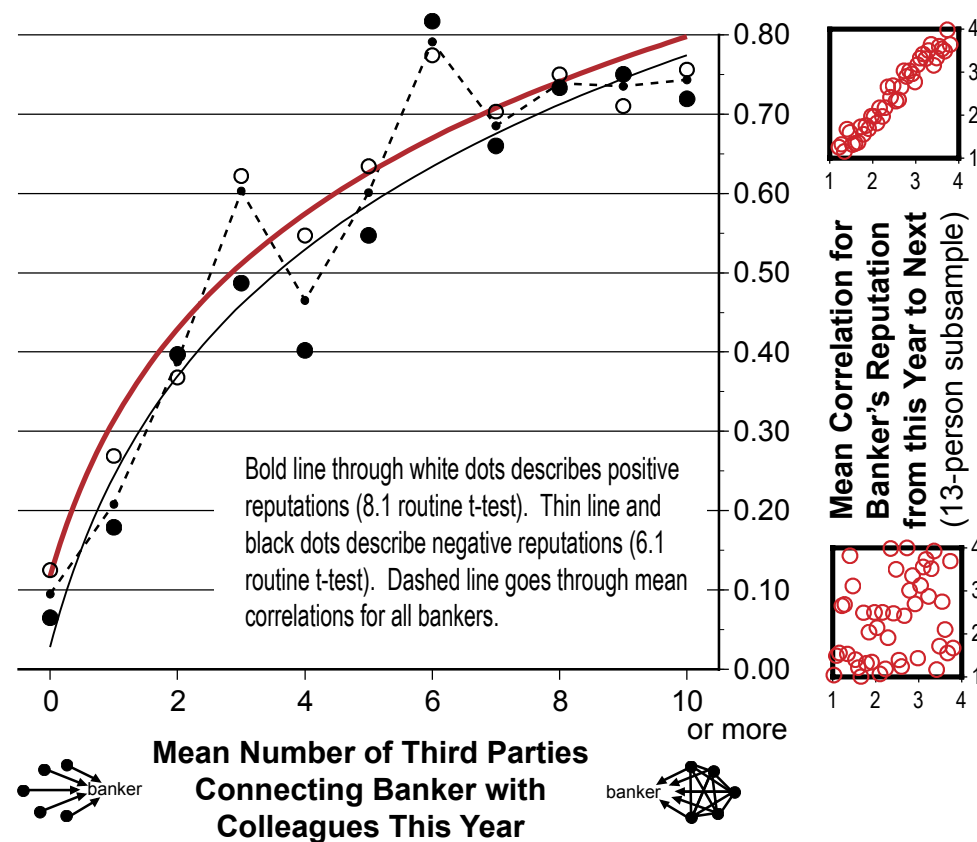
# (1) Reputation Is Essential to Broker Achievement, and Reputation Is Maintained in Closed Networks

(Graphs are from "Closure" handout.)

**A. Broker Achievement Depends on Reputation**



**B. And Reputation Depends on Closed Networks**



## (2) A Second Oscillation Advantage: Large Networks.

"Dunbar's number" — an extrapolation from correlation between primate brain size and average group size — says 150 relations is the average upper limit to a human group.

Below graph is based on numbers in Table 1 of Dunbar's initial report (1992, *J Human Evolution*), "Neocortex size as a constraint on group size in primates." Black dots are primates. White dot is humans. Graph to the right is from Dunbar (1998, *Evolutionary Anthropology*), "The social brain hypothesis."

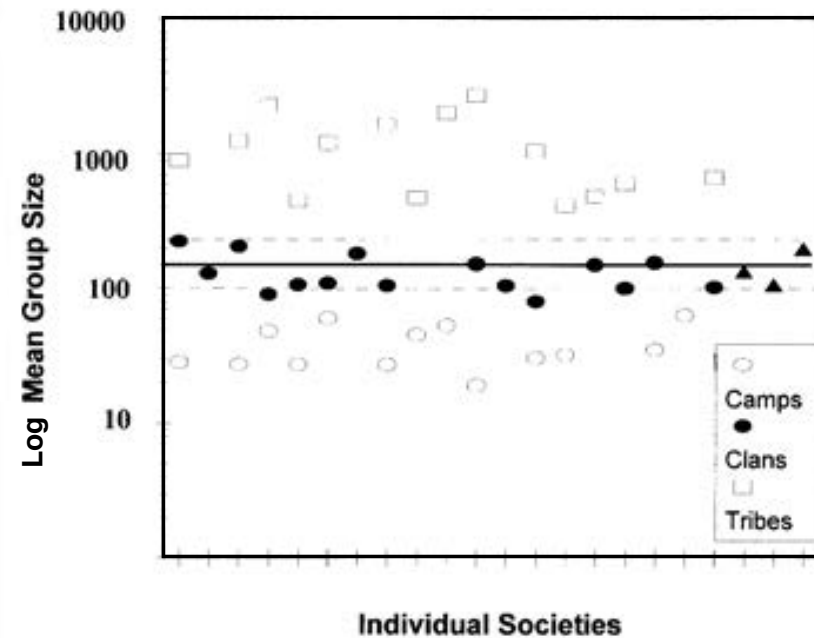
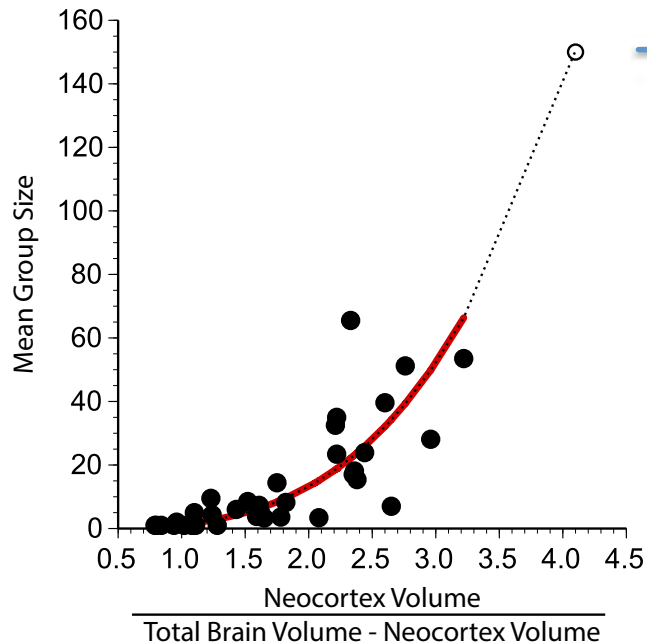
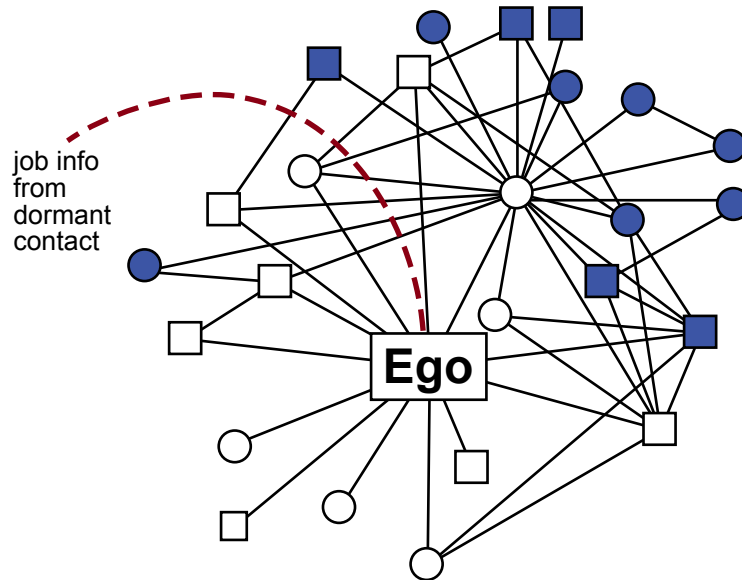


Figure 7. Mean sizes for different types of groups in traditional human societies. Individual societies are ordered along the bottom, with data for three main types of social groups (overnight camps, clans or villages, and tribes). Societies include hunter-gatherer and settled horticulturalists from Australia, Africa, Asia, and North and South America. The triangles give mean group sizes for three contemporary United States samples: mean network size from small-worlds experiments ( $N = 2$ ),<sup>67</sup> mean Hutterite community size,<sup>68</sup> and the size of an East Tennessee mountain community.<sup>69</sup> The value of 150 predicted by the primate neocortex size relationship (from Fig. 1d) is indicated by the horizontal line, with 95% confidence intervals shown as dashed lines.

Note Wide Variation in Mean Group Size

## (2 cont.) Second Oscillation Advantage: Large Networks.

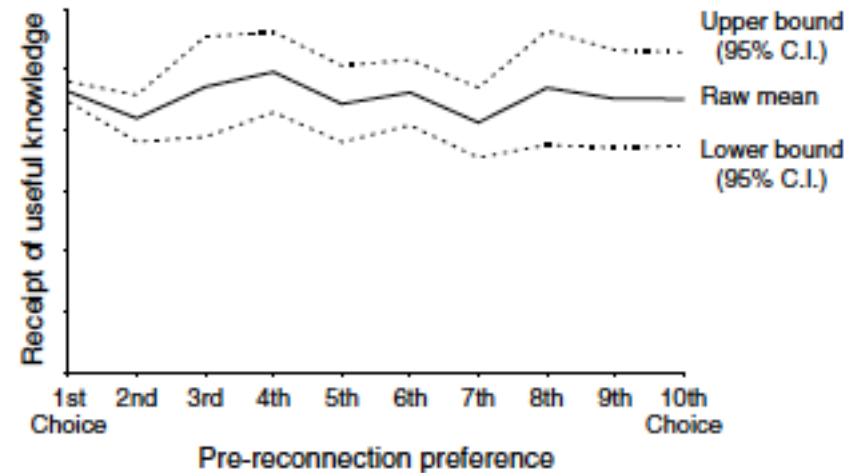
Dunbar calculations ignore dormant relations. In addition to sharpening skills in shifting between projects, and building reputation, oscillation creates an inventory of dormant contacts to be re-animated as needed.



Granovetter (1973, AJS) "The strength of weak ties." Information that leads to a new job tends not to come from close friends or colleagues. It is more likely to come from a dormant contact — a person with whom you were close in school, or where you used to live, or where you used to work, et cetera. The point in this classic article: Dormant ties, when re-animated, are often valuable bridges.

Relatedly, Small (2017, *Someone To Talk To*) describes people using casual ties for significant support. This veers into agility, the third and next explanation for oscillation and success.

Figure 1 The Pool of Useful Dormant Ties Is Deep



Levin, Walter, Murnighan (2011, *Org Science*) "Dormant ties: the value of reconnecting." Some EMBA students were asked to think of an important current project, then name 10 contacts dormant for at least three years who would be likely to have information useful on the project, then sort the 10 contacts from most to least likely to have useful information. People were asked to re-connect with the first-ranked dormant contact and one other randomly selected from the other nine contacts. The above graph shows a high perceived value to information received, on average, from the first through the tenth contact. If there is a decline in value, it happens beyond the first 10 dormant contacts.



## (2 cont.) The volume of structural holes to which you have access is likely much higher than you might believe . . .

This worksheet is completed in four steps:

(1) In the oval, write your name.

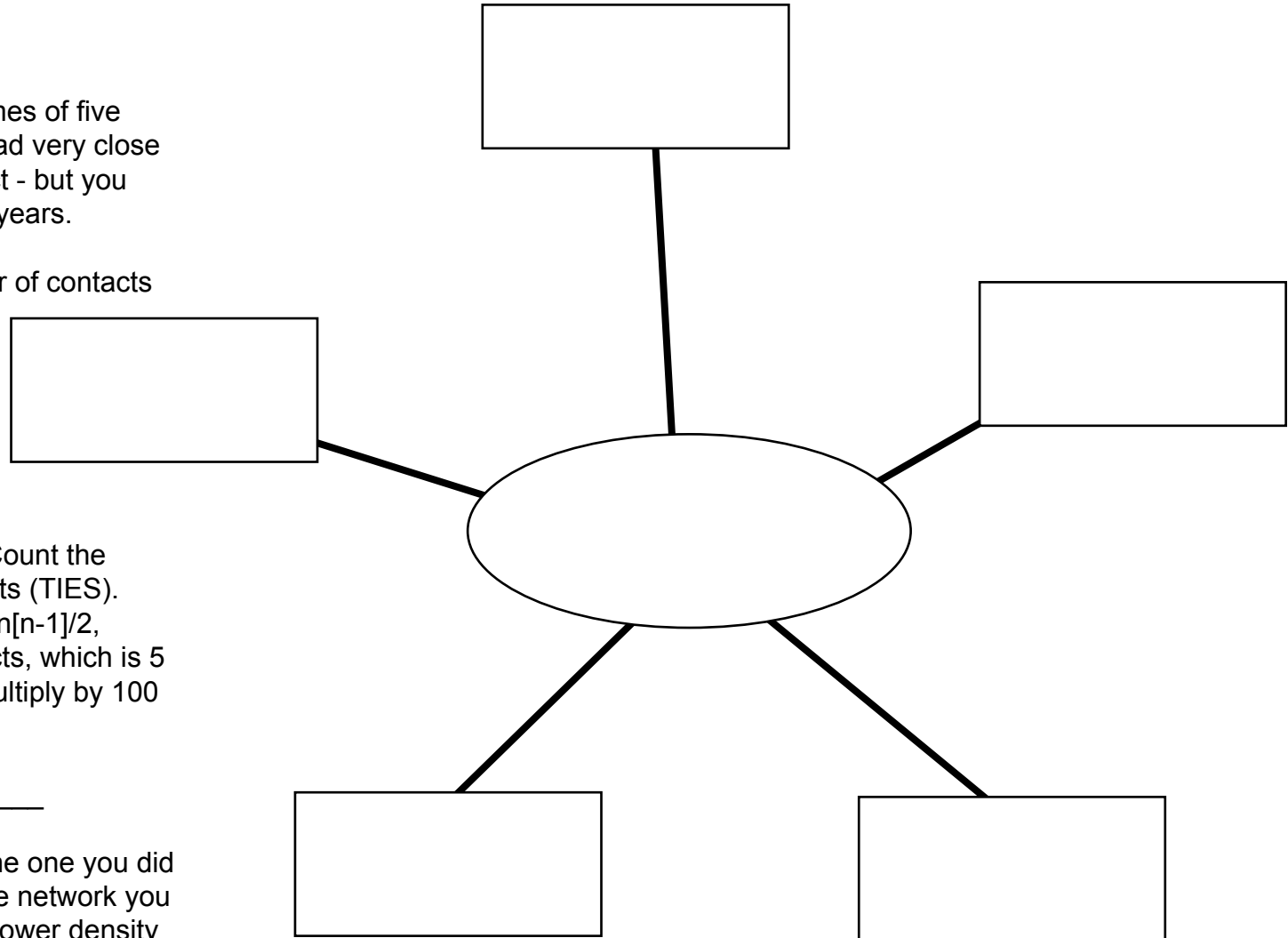
(2) In the squares, write the names of five contacts with whom you once had very close and substantial business contact - but you haven't seen for more than two years.

(3) Draw a line between any pair of contacts that are connected, to the best of your knowledge, in the sense that the two people speak often enough that they have some familiarity with current issues in one another's work.

(4) Compute network density. Count the number of lines between contacts (TIES). Divide by the number possible ( $n[n-1]/2$ , where  $n$  is the number of contacts, which is 5 if you entered five contacts). Multiply by 100 and round to nearest percent.

DENSITY = \_\_\_\_\_

This exercise is a variation on the one you did in the "Brokerage" handout. The network you describe here is typically much lower density than a current network.



### **(3) Agility is another oscillation advantage**

#### **The Wisdom of the Naskapi Indians (Weick, The Social Psychology of Organizing, 1979:262-263)\***

The Naskapi Indians of Labrador survive primarily by hunting. Each morning the adult males gather to ask: “Where should we hunt today?”

An unusual procedure is used to answer the question: The men take the shoulder bone of a caribou, hold it over a fire until the bone cracks, then hunt in which ever direction the crack points.

The procedure works. The Naskapi almost always find game, which is rare among hunting bands.

### **Why is their procedure successful?**

\*Also Appendix VII in the "Closure" handout, William Starbuck, “Unlearning ineffective or obsolete technologies” Journal of Technology Management 1996 (<http://www.stern.nyu.edu/~wstarbuc/unlearn.html>); page 10 in Levy, "The Nut Island Effect" (2001, HBR) on how to stop the Nut Island effect before it starts; and Adam Grant's (2021) *Think Again*.

### (3 cont.) Agility as Third Oscillation Advantage

During a discussion at a conference on learning, one of the attendees, a U.S. Army Colonel who runs a course for field commanders at the Army's Command and General Staff College (a graduate school for American and foreign military leaders founded in 1881), told a story about a misguided search for knowledge. For many years this course has been based on nine war games played by intact battalion teams. In the long history of the course, only one commander has ever won all nine war games. That was in 1985.

The success of this commander is the stuff of folklore at the college. It has led many subsequent commanders on a hunt for how the celebrated commander was able to achieve perfection. Typically, operations commanders who are scheduled to attend the course try to get a copy of the 1985 "battle book" written by the victorious commander. It doesn't seem to matter that battle scenarios and technology have changed considerably since 1985. Nor does it seem to matter that it is well-known that the underlying reason for the unique 1985 success is not in the codified knowledge in the battle book, but in the commander's style of preparation for the course. Every week for six months prior to the course, the commander assembled his staff for an informal lunch. The commander began by sketching a hypothetical battle scenario, then inviting his team to discuss how they would engage the enemy. In the ensuing debate, the team explored alternatives with the commander — serving less as final authority, and more as a Socratic instructor helping his team reason through the risks and advantages of alternative tactics. By the time this team entered the course, they had explored hundreds of hypothetical scenarios and learned a great deal not only about how each of his colleagues reasons, but how to reason together.

Dwight Eisenhower 1957  
on national defense:  
"Plans mean nothing, but  
planning is everything."

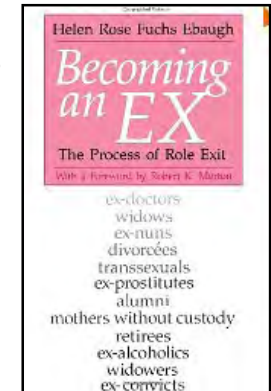
This example illustrates the somewhat depressing fact that often times it's not a lack of knowledge that causes performance failures but an inability to take in, metabolize, and learn from knowledge that is readily available. If we try to solve every puzzle only through the paradigm of the learning curve, we shall discover that all learning curves reach an asymptote. Eventually we exhaust the stock of knowledge available to us in our immediate community.

Time and again I see in my own company examples of people who become quite content — indeed even take great pride — with the fact that they have formed highly cohesive, close-knit teams. Surely cohesiveness is valuable ... to a point. But at some point, cohesiveness starts to take on the characteristics of a cult. Cults abhor questioning, criticism, and, debate. They are petrie dishes for group think. Great leaders intuitively understand this. They are like conductors who ensure that while their teams may be playing from the same overall score, there is always the sound of alternative voices. Positions are framed and argued on the basis of available knowledge and data but always in juxtaposition to one or more alternatives.

Text is from Dr. Mike Prevou (Lt. Col., US Army Retired), relayed by Dr. Don Ronchi (Exec. VP, Raytheon). On tactics in adaptive organization, see Bechky & Okhuysen (2011, *Org Science*), "Expecting the unexpected? How swat officers and film crews handle surprises."



Herminia Ibarra's (2003) book, *Working Identity*, is a helpful and accessible discussion for network brokers transitioning to new identities (also see her HBR note "How leaders create and use networks"). Herminia elaborates nine points of advice (below). Note the similarities to our discussion of tactical issues in establishing brokerage in an organization (second session). If you feel trapped in a closed network, then you might find it useful to read Helen Ebaugh's (1988) book, *Becoming an Ex*, on her transition from being a nun (and the similarity to other transitions).



**1: Act your way into a new way of thinking and being.** You cannot discover yourself by introspection. Start by changing what you do. Try different paths. Take action, and then use the feedback from your actions to figure out what you think, feel, and want. Don't try to analyze or plan your way into a new career. Conventional strategies advocated by self-assessment manuals and traditional career counselors would have you start by looking inside. Start instead by stepping out.

**2: Stop trying to find your one true self.** Focus your attention on which of your many possible selves you want to test and learn more about. Reflection is important. But we can use it as a defense against testing reality; reflecting on who we are is less important than probing whether we really want what we think we want. Acting in the world gives us the opportunity to see our selves through our behaviors and allows us to adjust our expectations as we learn. In failing to act, we hide from ourselves.

**3: Allow yourself a transition period in which it is okay to oscillate between holding on and letting go.** Better to live the contradictions than come to premature resolution. The years preceding a career change necessarily involve difficulty, turmoil, confusion, and uncertainty. One of the hardest tasks of reinvention is staying the course when it feels like you are coming undone. Those who try to short-circuit the process often just end up taking longer.

**4: Resist the temptation to start by making a big decision that will change everything in one fell swoop.** Focus on small wins, in which incremental gains lead you to more profound changes in the basic assumptions that define your work and life. Accept the crooked path. Small steps lead to big changes, so don't waste time, energy, and money on finding the "answer" or the "lever" that, when pushed, will have dramatic effects. Almost no one gets change right on the first try.

**5: Identify projects that can help you get a feel for a new line of work or style of working.** Try to do these as side projects, temporary assignments, or parallel paths so that you can experiment seriously without binding decisions. Pursue these activities seriously, but delay commitment. Just make sure that you vary your experiments, so that you can compare and contrast experiences before you narrow your options.

**6: Don't just focus on the work.** Find people who are what you want to be and who can provide support for the transition. But don't expect to find them in your same old social circles. Break out of your established network. Branch out. Look for role models—people who give you glimpses of what you might become and who are living examples of different ways of working and living.

**7: Don't wait for a cataclysmic moment when the truth is revealed.** Use everyday occurrences to find meaning in the changes you are going through. Practice telling and retelling your story. Over time, it will clarify. Major career transitions take three to five years. The big "turning point," if there is one, tends to come late in the story. In the interim, make use of anything as a trigger. Don't wait for a catalyst.

**8: Step back, but not for too long.** When you get stuck and are short on insight, take time to step back from the fray to reflect on how and why you are changing. Only through interaction and active engagement in the real world do we discover ourselves.

**9: Change happens in bursts and starts.** There are times when you are open to big change and times when you are not. Take advantage of any natural windows (e.g., the period just after an educational program or assuming a new position; a milestone birthday) to start off on the right foot. Communicate to others that you have changed (and will be making more changes). Don't let unanswered questions bog you down; move on, even if to an interim commitment.

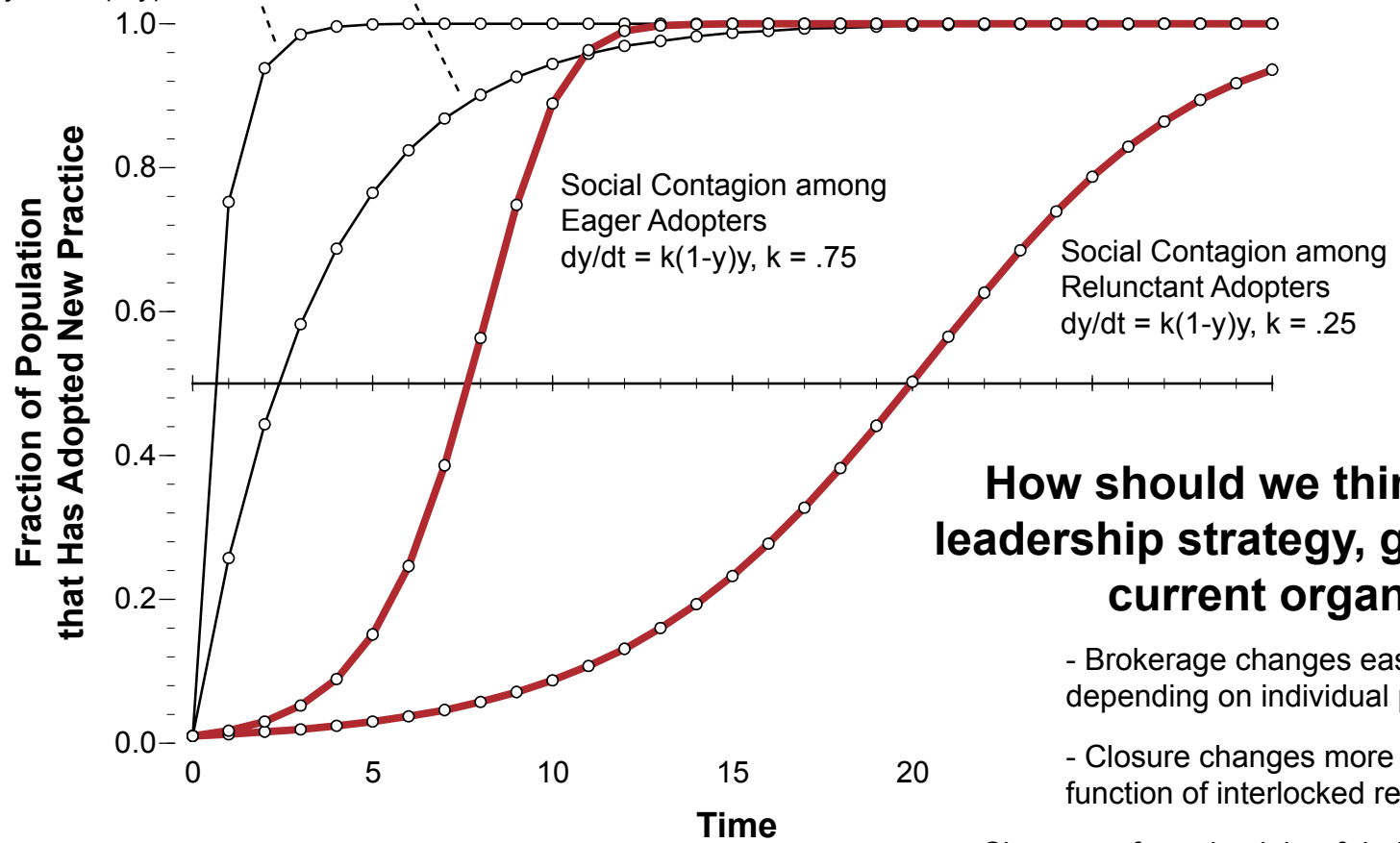


# More So for an Organization: Adopting a New Practice

$y$  = proportion of target population that has adopted

$k$  = probability of adoption by average individual

Individual Adoptions among Eager versus Reluctant  
 $dy/dt = k(1-y)$ ,  $k = .75$  versus  $.25$



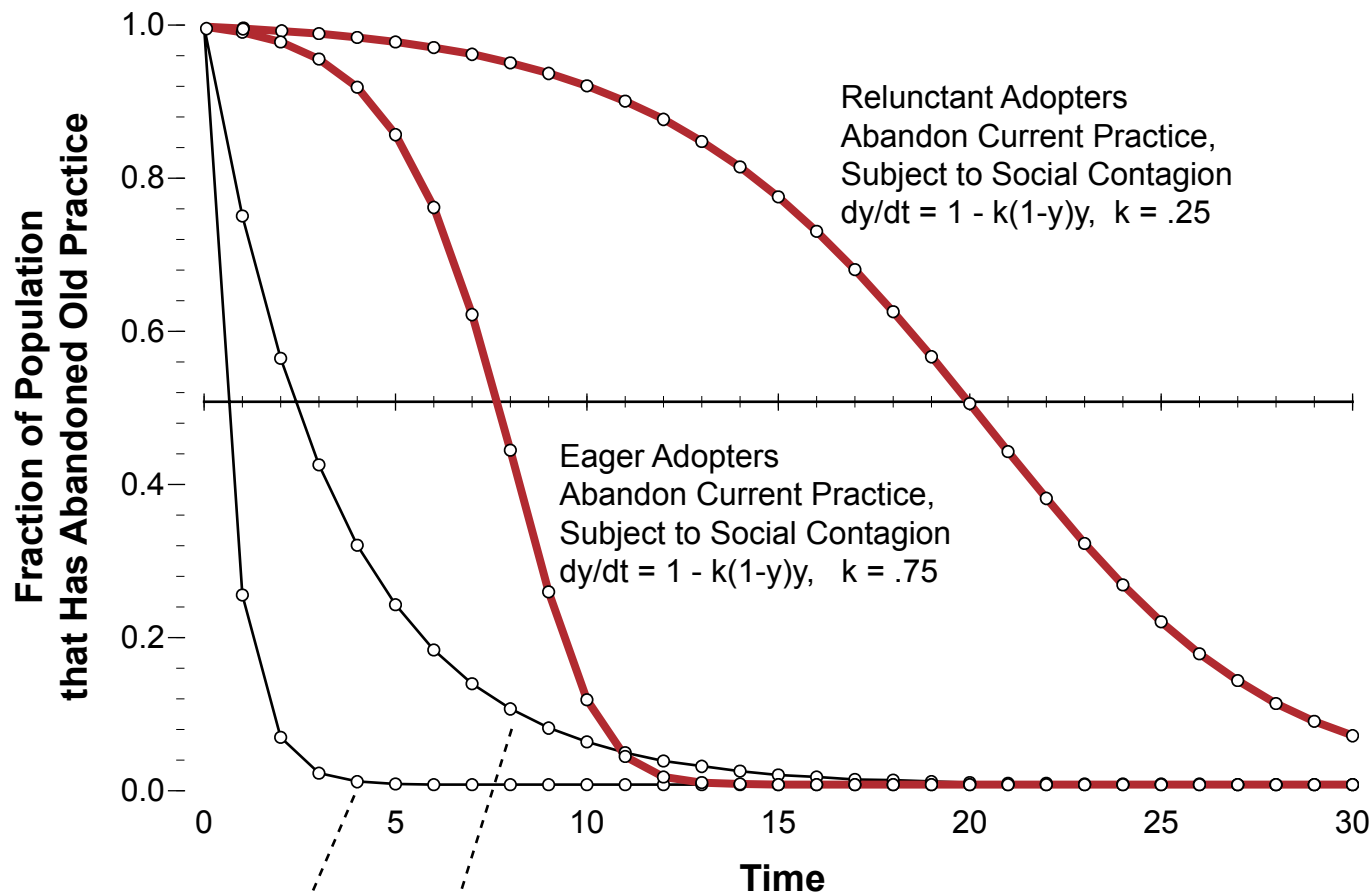
**How should we think about leadership strategy, given the current organization?**

- Brokerage changes easily, depending on individual preferences.
- Closure changes more slowly as a function of interlocked relationships.
- Closure-enforced opinion & behavior norms can arise from minor initial social behavior (Salganik, Dodds & Watts, 2006 *Science*).

# Abandoning a Current Practice

$y$  = proportion of target population that has abandoned the practice

$k$  = probability that average individual will abandon the practice



Individuals Abandon, Eager versus Reluctant  
 $dy/dt = 1 - k(1-y)$ ,  $k = .75$  versus  $.25$

Even when people want to change and have complete control over change, they tend not to change. Ingram and Morris (2007, ASQ, "Do people mix at mixers?") show that EMBA students intending to meet new people at a program mixer provided in response to student requests for a networking mixer tend to spend their time with people they already know.

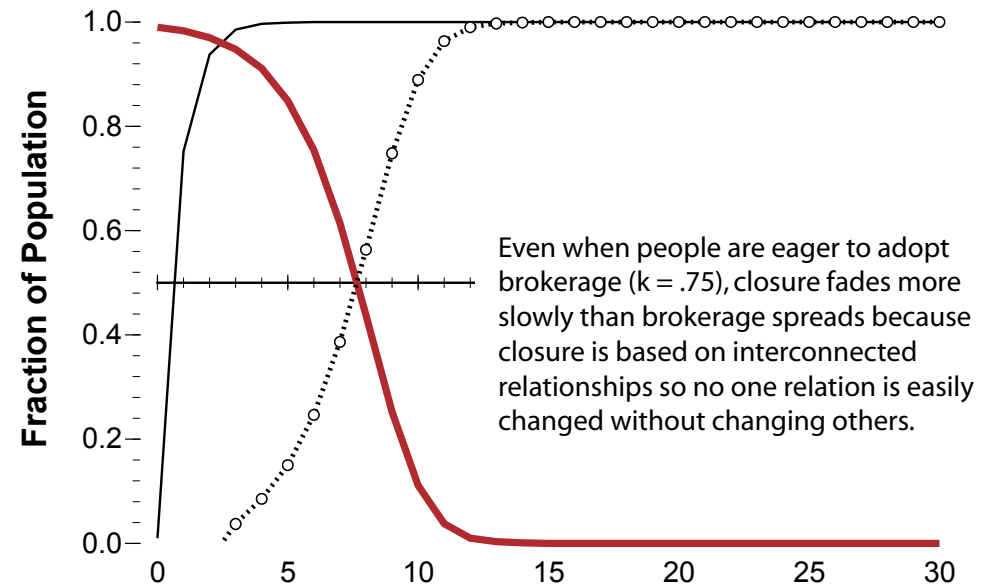
In the early days of WWII, when armaments of all kinds were in short supply, the British made use of a venerable field piece that came down to them from previous generations. These guns, hitched to trucks, served as useful mobile units in the coast defense. But it was felt that the rapidity of fire could be increased. A time-motion expert was called in to suggest ways to simplify the firing procedures. He watched one of the gun crews of five men at practice in the field for some time. Puzzled by certain aspects of the procedures, he took some slow-motion pictures of the soldiers performing the loading, aiming, and firing routines. When he ran these pictures over once or twice, he noticed something odd. A moment before the firing, two members of the gun crew ceased all activity and came to attention for a three-second interval extending throughout the discharge of the gun. He summoned an old colonel of artillery, showed him the pictures, and pointed out this strange behavior. What, he asked the colonel, did it mean. The colonel, too, was puzzled. He asked to see the pictures again. "Ah," he said when the performance was over, "I have it. They are holding the horses." (from Elting Morison, pp. 17-18, 1966, *Men, Machines, and Modern Times*)

# Timing Transition to a New Practice

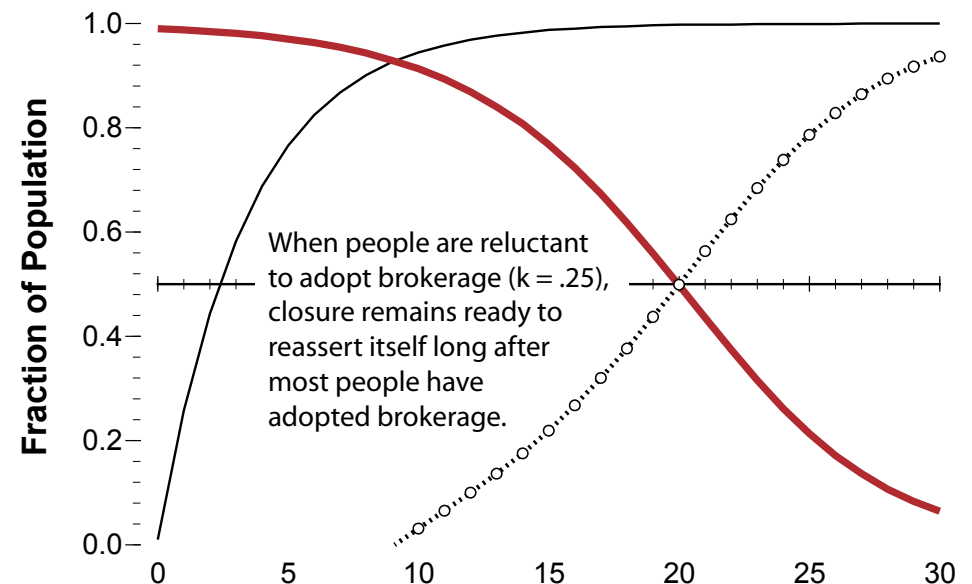
## The Shadow of History as a New Focus on Brokerage Spreads through the Organization

- Brokerage spreads as a process of individuals adopting.
- Closure is abandoned as a social contagion process triggered by friends abandoning it.
- So brokerage is understood more quickly than it is used because closure preserves the legacy organization (fraction adopting brokerage minus fraction stuck in closure).

### A. Shift to Brokerage among Eager Adopters



### B. Shift to Brokerage among Reluctant Adopters



# Random Shocks Can Help (if they are central, so they are difficult to ignore)

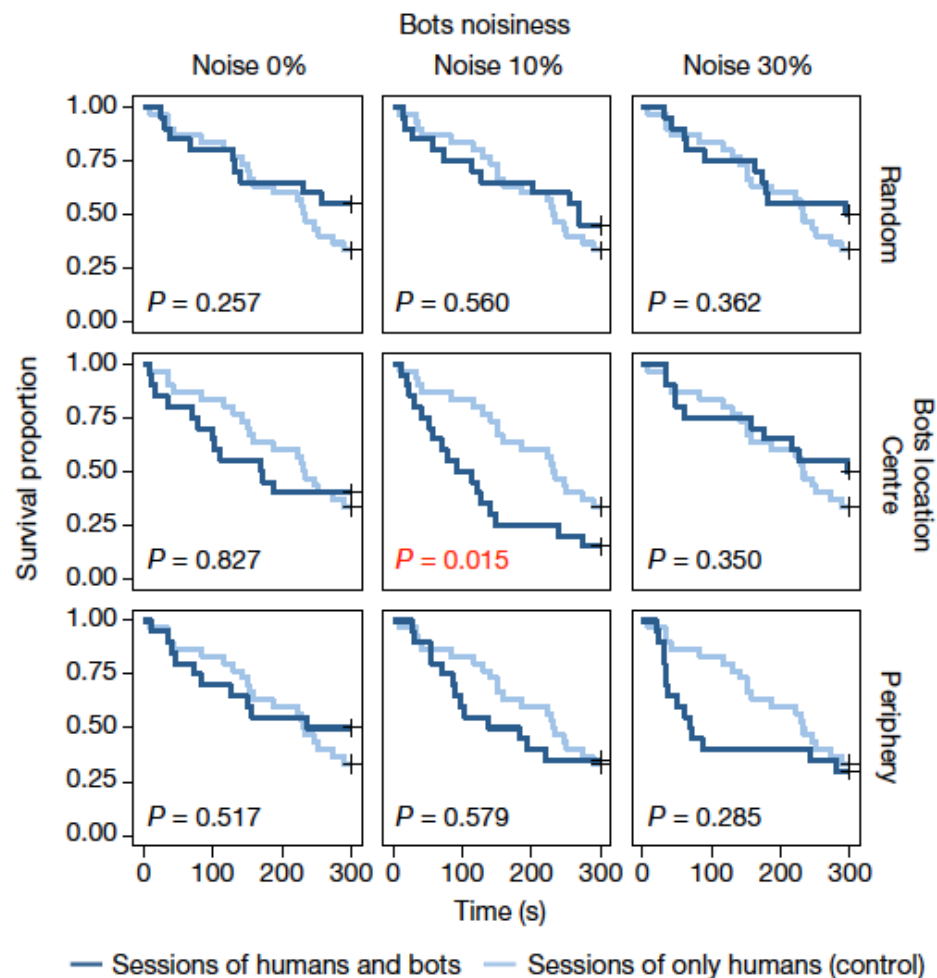
(Shirado & Christakis, "Locally noisy autonomous agents improve global human coordination in network experiments" *Nature* 2017, 454:370-374): "We show that bots acting with small levels of random noise and placed in central locations meaningfully improve the collective performance of human groups, accelerating the median solution time by 55.6%. This is especially the case when the coordination problem is hard."

The task is color coordination within a 20 person network (details on last page of this handout). You have 3 contacts and a choice of 3 colors. Conflict is when you and one of your contacts is the same color. Solution is when there are no conflicts. In some trials, three bots replace people, and chose their colors at one of three levels of random. Quicker solution is indicated in the graphs by faster and further drop in "survival proportion" (which is % of sessions that remain unsolved at the x-axis time).

Figure 2 | Survival curves of sessions, by noisiness and location of bots. The curves show the percentage of sessions unsolved at a given time.

Dark blue lines show results for the sessions including bots ( $n = 20$ ), by their noise level (horizontal dimension) and geodesic location (vertical dimension). Light blue curves show results for the control sessions involving solely human players ( $n = 30$ ). Total  $n = 210$ . Sessions are censored at 300 s; P values given by the log-rank test.

Bots having 10% behavioural noise and located at the centre of the network cause a significant improvement in the solvability of the game ( $P = 0.015$ ), and induce 55.6% acceleration in the median time to solution, from 232.4 s to 103.1 s.





# Company Processes Can Help People Pay Attention To, Rather than Ignore, Exogenous Shocks to the Status Quo

## WINNERS FOR 2003...

Here are many of the winners of the Industrial Design Excellence Awards:

DESIGN FIRMS	AWARDS				CORPORATIONS	AWARDS			
	GOLD	SILVER	BRONZE	TOTAL		GOLD	SILVER	BRONZE	TOTAL
IDEO	3	3	2	8	LOGITECH	2	2	2	6
ZIBA DESIGN	3	2	1	6	BMW	2		2	4
RKS DESIGN	1	1	3	5	HEWLETT-PACKARD		1	2	3
@RADICAL.MEDIA	2		1	3	IBM	1		2	3
DESIGN CONTINUUM		1	2	3	SAMSUNG ELECTRONICS	1	2		3
FUSEPROJECT	2		1	3	WHIRLPOOL	1		2	3
HERBST LAZAR BELL	2	1		3	APPLE COMPUTER	1	1		2
LUNAR DESIGN		2	1	3	BOMBARDIER RECREATIONAL	1		1	2
DESIGN EDGE	1	1		2	MOTOROLA	1		1	2
DESIGNWORKS/USA	1	1		2	NIKE		1	1	2
NEWDEALDESIGN	1	1		2	TARGET		2		2
PENTAGRAM		1	1	2	WARN INDUSTRIES	2			2
RALPH APPELBAUM			2	2					

## ...AND OVER FIVE YEARS

Year after year, some design firms and corporations win:

DESIGN FIRMS	AWARDS			CORPORATIONS	AWARDS		
	1999-2002	2003	TOTAL		1999-2002	2003	TOTAL
IDEO	42	8	50	APPLE COMPUTER	17	2	19
ZIBA DESIGN	17	6	23	SAMSUNG ELECTRONICS	15	3	18
LUNAR DESIGN	12	3	15	IBM	12	3	15
SMART DESIGN	14	1	15	HEWLETT-PACKARD	9	3	12
DESIGN CONTINUUM	11	3	14	MICROSOFT	10	1	11
PENTAGRAM	11	2	13	NIKE	8	2	10
HERBST LAZAR BELL	9	3	12	OXO INTERNATIONAL	9	1	10
FROG DESIGN	10		10	STEELCASE	10		10
HAUSER	8		8	FISHER-PRICE	9		9
RALPH APPELBAUM	6	2	8	BMW	4	4	8
				LOGITECH	2	6	8
				MOTOROLA	6	2	8
				PHILIPS DESIGN	7	1	8
				TARGET	6	2	8

Data: Industrial Designers Society of America

## IDEO: Leading Design Firm\*

Using what you have learned so far, how would you explain how they do it?

Tom Kelley & Jonathan Littman (2005), The Ten Faces of Innovation; for elaboration of the IDEO saying, "fail often to succeed sooner," see Firestein (2016) Failure: Why Science is So Successful.



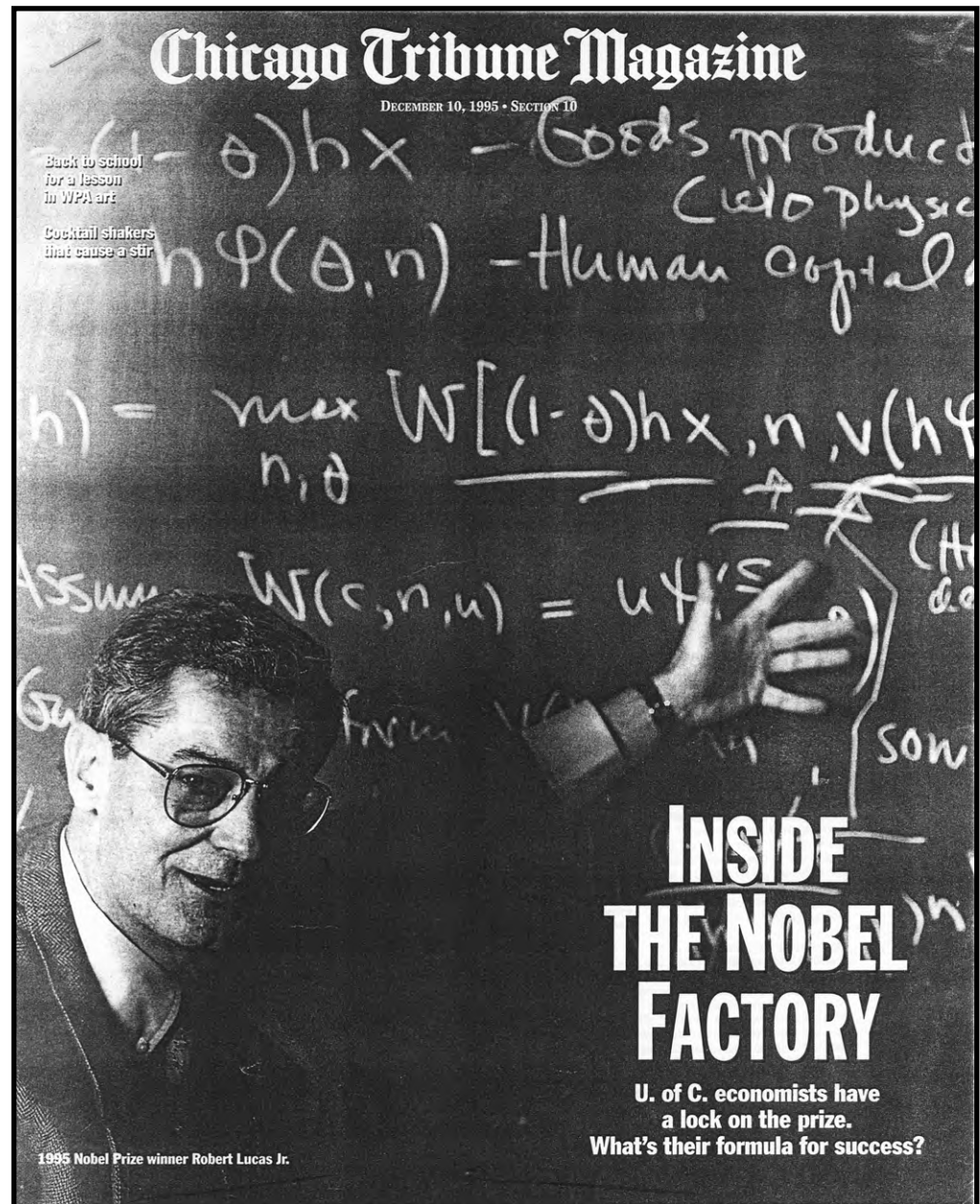
\*Photos are from the 1999 Nightline video on IDEO's "shopping cart" project.



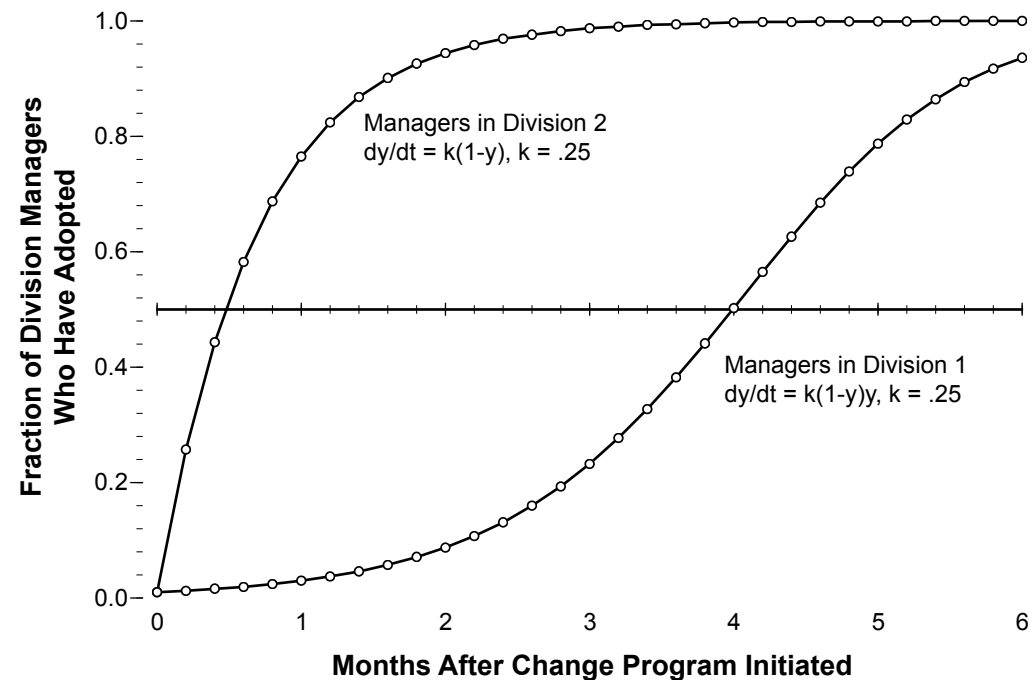
# The IDEO process looks like the oral, workshop culture of certain educational institutions.

"Inside the Nobel Factory: U. of C. economists have a lock on the prize. What's their formula for success?"

(Chicago Tribune Magazine, December, 1995)



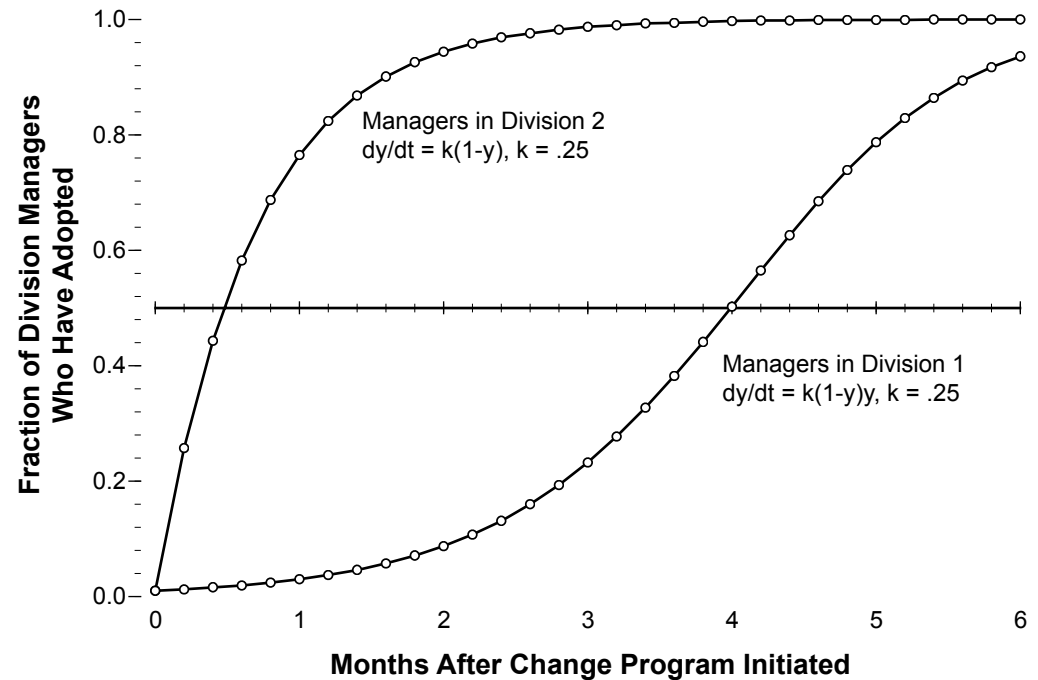
(Q114) You accepted the job of turning around a troubled organization. After a quick study of the organization and its markets, you have a sense that the organization needs to adopt Six Sigma practices to be a serious competitor. After six months in office, you have email traffic monitored to get a sense of which employees are adopting Six Sigma practices. You are given the results in the graph to the right describing the spread of Six Sigma in your organization's two divisions.



**What network mechanisms are driving Six Sigma adoption in the two divisions?**

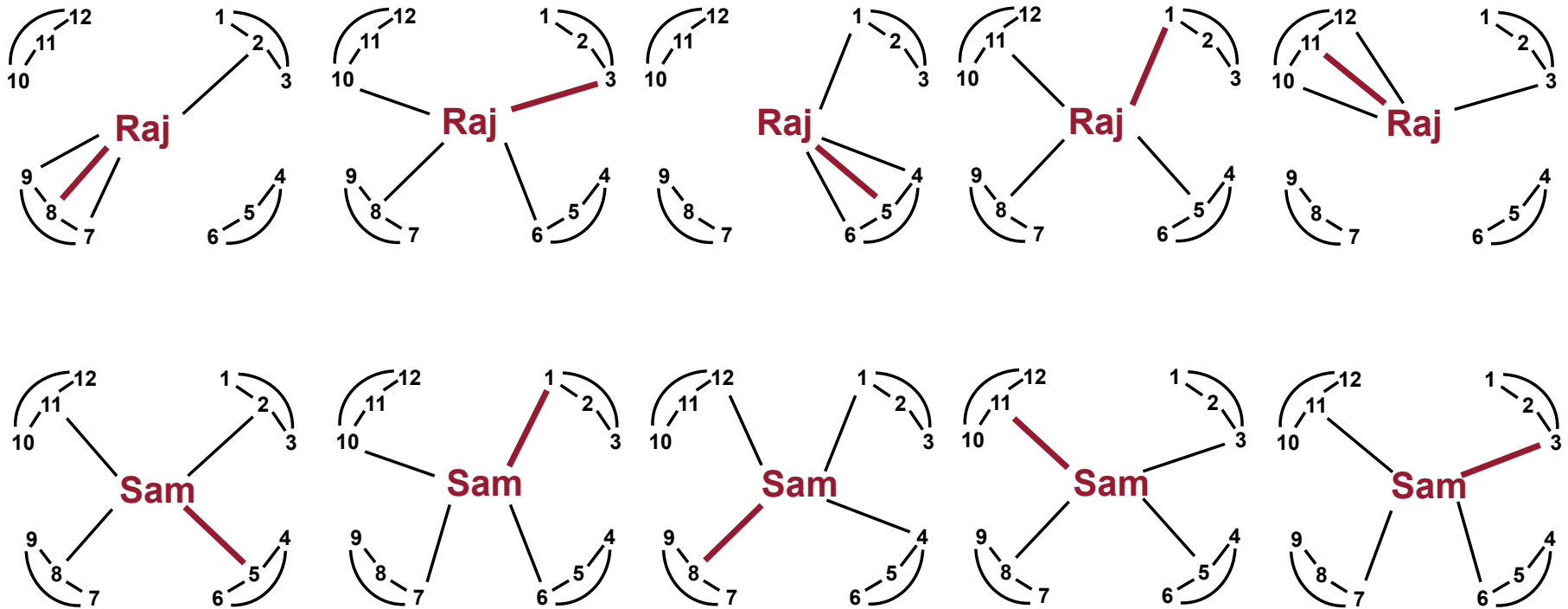
- A. Social contagion in Division 1 and independent adoption in Division 2
- B. Social contagion in Division 2 and independent adoption in Division 1
- C. Social contagion in both divisions
- D. Independent adoption in both divisions

(Q115) You accepted the job of turning around a troubled organization. After a quick study of the organization and its markets, you have a sense that the organization needs to adopt Six Sigma practices to be a serious competitor. After six months in office, you have email traffic monitored to get a sense of which employees are adopting Six Sigma practices. You are given the results in the graph to the right describing the spread of Six Sigma in your organization's two divisions.



**Which division, 1 or 2, is more likely to show benefits from Six Sigma practices?**

- A. Division 1
- B. Division 2
- C. Neither division is likely to show benefits in this case.



(Q199) The above network sequences both cumulate to the same broker network, but differ substantially in their development.

**What performance level would you expect from Jim and Bob?**

A. Raj & Sam similar

B. Raj higher

C. Sam higher



(Q265) We discussed research demonstrating that random shocks can be beneficial in moving a work group away from a local solution to a more beneficial global solution. **Which of the below sentences best describes our conclusion that this research, while accurate, requires cautious application in practice?** (Hint: Recall the Naskapi Indians.)

- A. Random shocks prevent the group from over-hunting the same territory again and again.
- B. Random shocks can be confusing.
- C. Random shocks can be ignored.
- D. Random shocks can lead a group to inferior alternative solutions.

## Three Summary Points

**Balance is most often discussed on case-by-case basis of correcting for too much closure, or too much brokerage.**

Examples: Gas turbine plant, pharma firm, computer tech firm, financial advisory firm.

**As a general principle about where to focus on closure versus brokerage, look for "closure within, brokerage beyond."**

Combines the breadth, timing, and arbitrage advantages of brokerage with the cooperation and social comparison advantages of closure. This encourages guanxi-like ties among cohesive elites at the center of the network. Examples: China Entrepreneur's Club, Wednesday 10, Economics, Second Life, City of Chicago, commercial bank.

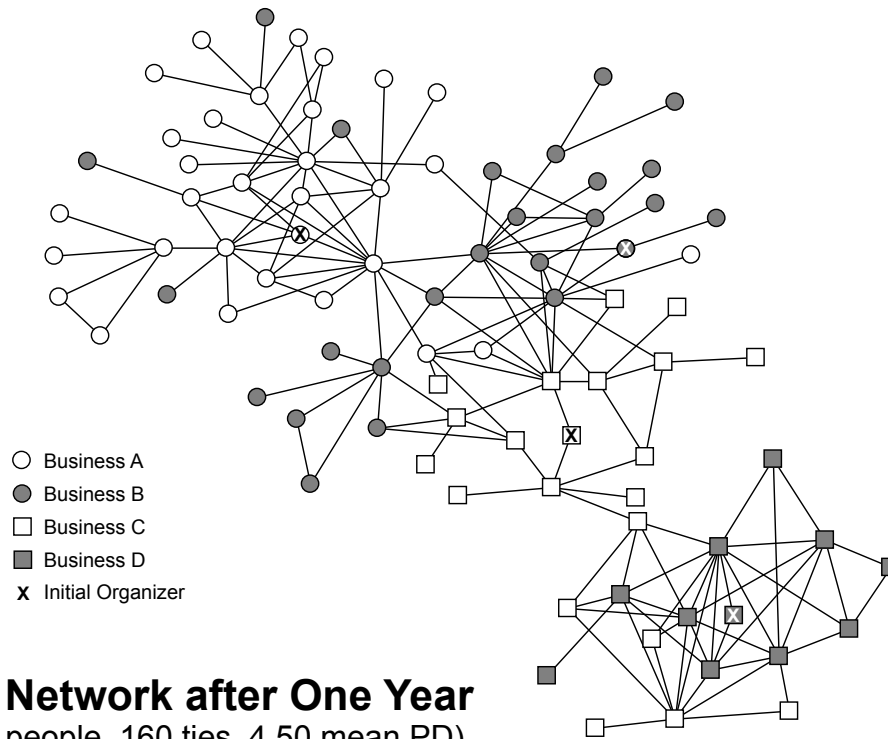
**As a general principle about when to focus on closure versus brokerage, look for oscillation.**

Combines the breadth, timing, and arbitrage advantages of brokerage with the information access and reputation-building of closure. Different forms: continuous (bankers), episodic (entrepreneurs). Three explanations for effect: Reputation stability, network breadth, agility.

Can be difficult for individuals (Ibarra vs. Ebaugh), but dramatically more difficult for whole organizations, especially larger organizations. Organizations resist change, often reverting to old form (Atlanta, virtual organization for Homeland Security). Forecasting transition with diffusion curves. Random shocks break through suboptimal solutions. Institutional rituals facilitate organizational oscillation (IDEO)



# Appendix Materials



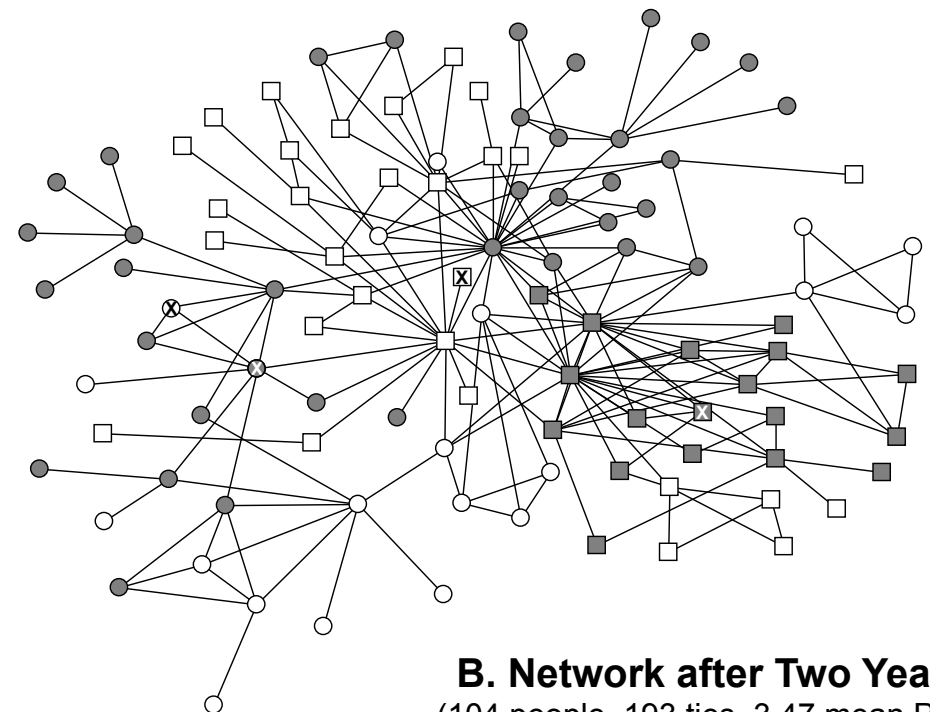
**A. Network after One Year**  
(88 people, 160 ties, 4.50 mean PD)

Figure 4 in Burt and Soda (2021, "Network capabilities: brokerage as a bridge between network theory and the resource-based view of the firm," *Journal of Management*) and Figure 5 in Burt "Network duality of social capital," in *Social Capital*, edited by Viva Bartkus and James H. Davis (2009). Also remember two examples discussed in class: corruption in Atlanta and Coca-Cola distributors.

# At the Organization Level, B-C Shifting Is Especially Difficult

This is a Virtual Organization across a Four-Division Manufacturing Company

Discussion Network  
Before and After an Intervention



**B. Network after Two Years**  
(104 people, 193 ties, 3.47 mean PD)

## Turnover

88 after one year (58% exit)



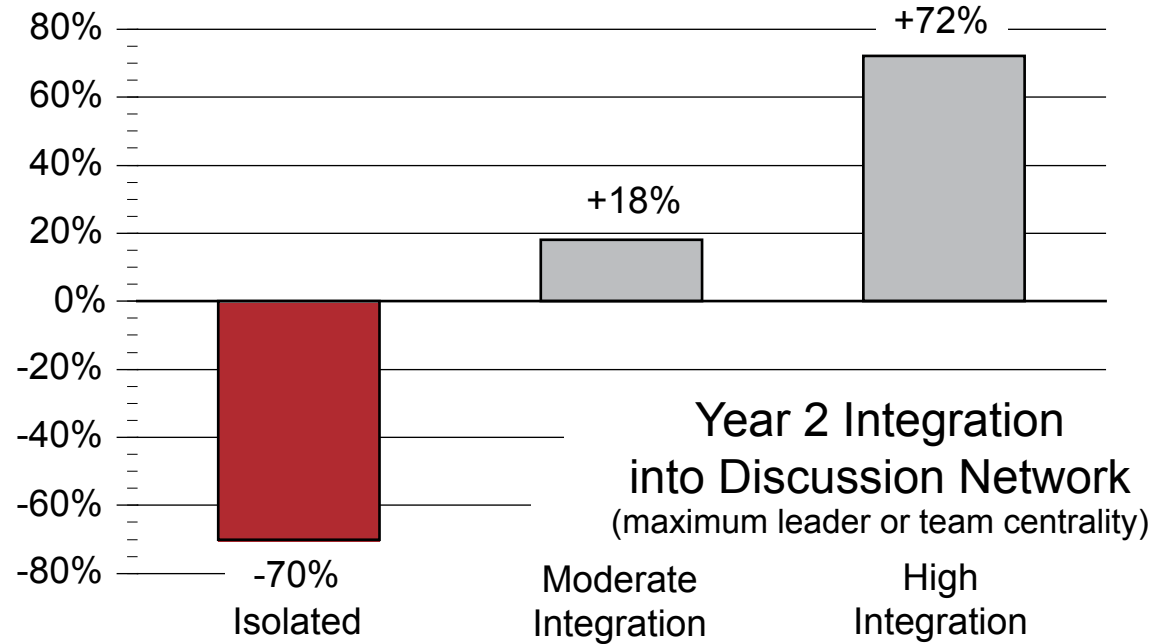
37 continue



104 after two years (64% new)

## Myopia

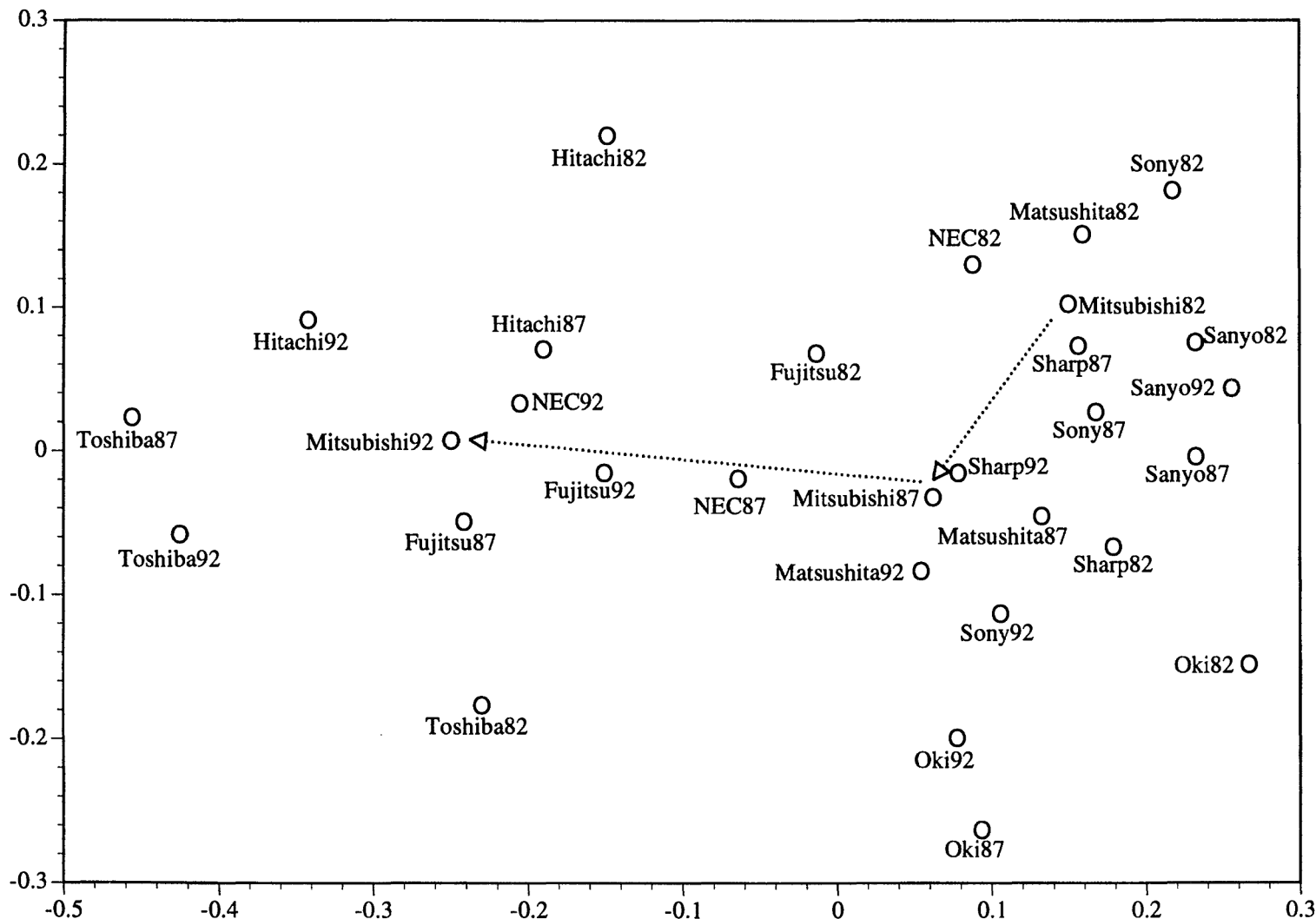
Budget for Specific New Products,  
Year 3 versus 2 (FY3 - FY2) / FY2





# Network Map of Japanese Micro-Chip Production

Map lists firms at three points in time: 1982, 1987, and 1992. Firms are close together (e.g., Sharp and Sony in 1987) to the extent that they filed US patents citing the same antecedent patents (i.e., are structurally equivalent with respect to past technology). Firms that continue in the same location over time (e.g., Sanyo in 1982, 1987 and 1992) worked the same technology niche over time. The arrow shows Mitsubishi's evolution from a specialty producer in the upper right (producing for their own consumer electronics businesses) to an industry-leader at the far left (producing complex devices such as logic circuits and MOS memory for computer and industrial applications, e.g., as a second source for Intel microprocessors).



from Figure 3 in Stuart and Podolny (1996), "Local search and the evolution of technological capabilities," *Strategic Management Journal*.

## MECHANICAL MACHINES



from Figure 3.2 in Burt (1992) *Structural Holes*; also see Figure 1 in Burt & Carlton (1989)

# Building a Strategy Map

Strategy maps can be constructed as spatial representations of structural equivalence distances between projects or the components and processes involved in projects. The raw data are illustrated below. Rows correspond to projects. Columns correspond to components or processes. Cell (3,b) measures the extent to which project 3 involves component/process b. Cell entries could be a binary measure of involved versus not, or a continuous measure of relative investment.

The (M,M) matrix of distances among the M projects in the rows defines a strategy map in terms of projects. Projects close together in the map use similar components or processes.

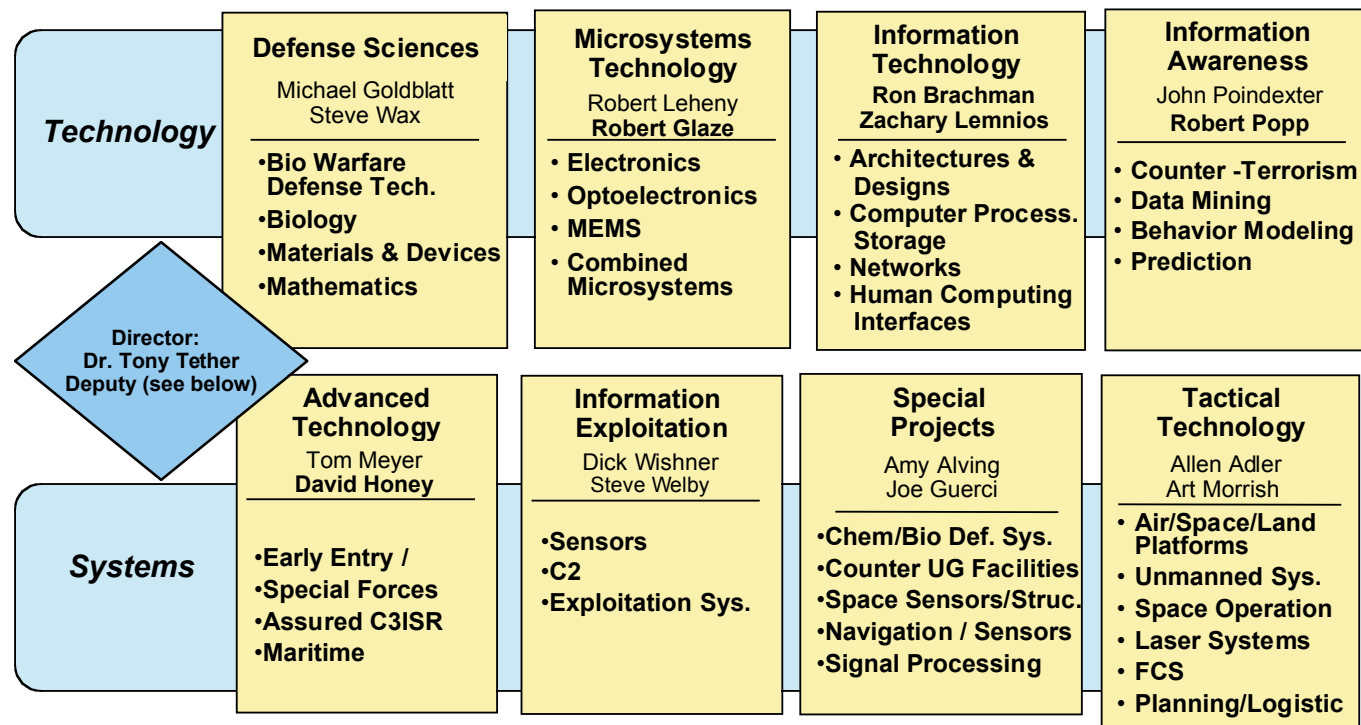
The (N,N) matrix of distances among the N columns defines a strategy map in terms of components and processes. Components/processes close together in the map are being used in the same projects.

Coordination across the structural holes between proximate projects, components, or processes is most likely successful and rewarding in terms of new products/services/revenue and resources liberated from investments in redundant work.

	a	b	c	...	N
R&D project 1					
R&D project 2					
R&D project 3					
.					
.					
.					
R&D project M					

# Targeting Structural Holes in the Client

Here is a company's September 2002 reach into the Defense Advanced Research Projects Agency (DARPA, founded in response to Sputnik launch in 1958 and father of the internet).

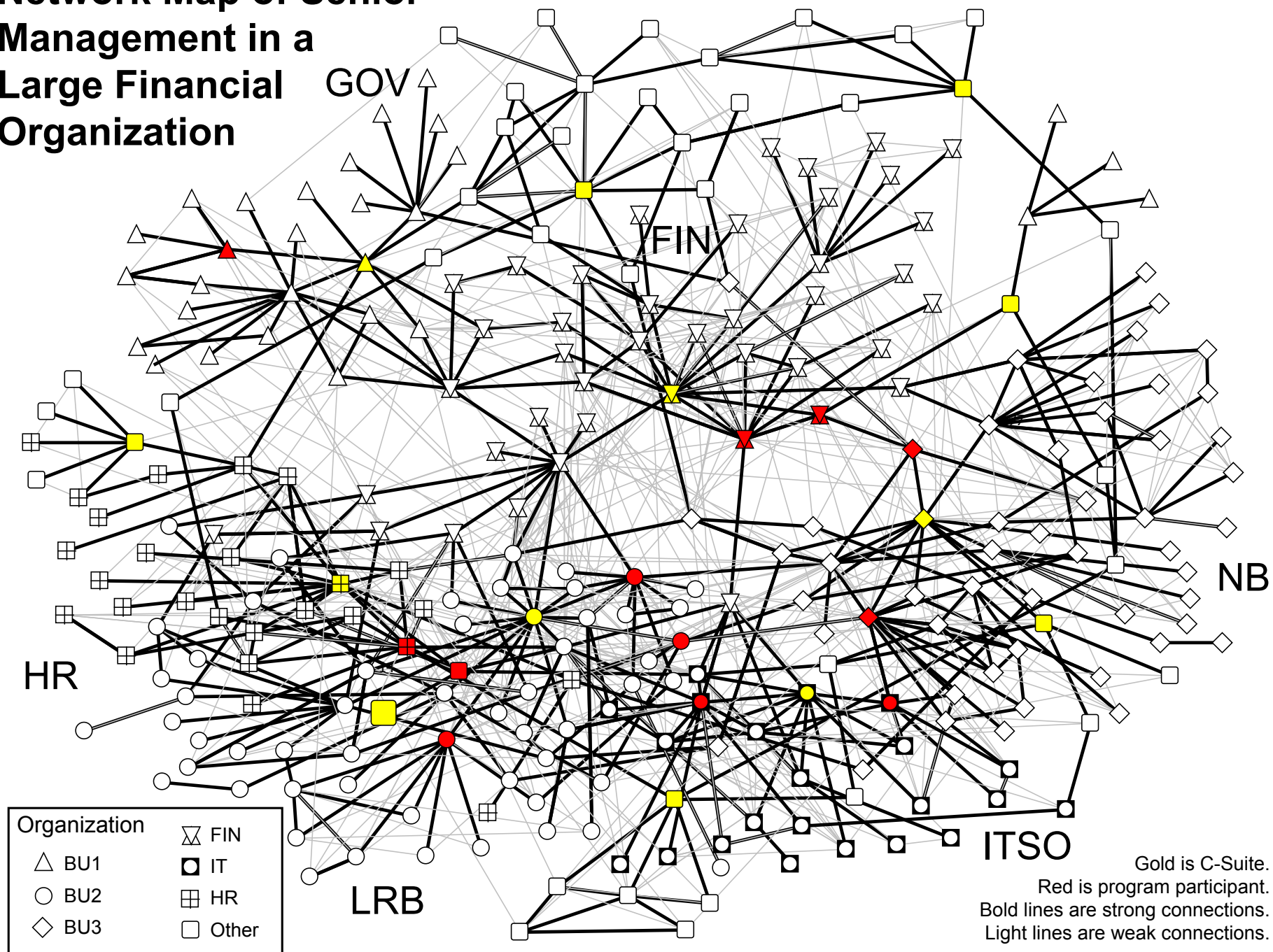


Defense Sciences	10	1							
Microsystems Tech	80	-	32						
Information Technology	8	-	-	5					
Information Awareness	7	-	-	-	5				
Advanced Technology	49	-	10	-	-				
Information Exploitation	62	-	-	1	2				
Special Projects	29	-	4	-	-				
Tactical Technology	24	-	4	-	-				
<b>TOTAL</b>	<b>952</b>	<b>15</b>	<b>141</b>	<b>17</b>	<b>21</b>				

(641 within our organization)

Density of Perceived Discussion Ties within & across DARPA offices


# Network Map of Senior Management in a Large Financial Organization



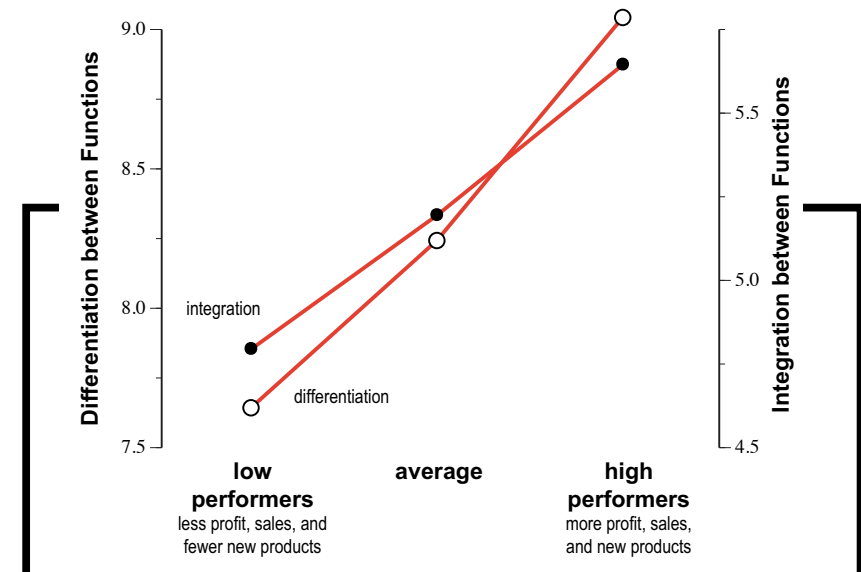


## Contingent Optimum

Optimum balance between integrating operations (closure) and preserving differentiation (brokerage) is contingent on the work being performed. In a classic study showing contingency, Lawrence and Lorsch distinguish kinds of work by the industry in which a firm operates.

Firm profitability in the plastics industry increases with both integration across the three functions (sales, production, and research), and differentiation (structural holes) between the three functions. This is an illustration of Jack Welch's "integrated diversity."

## Firms in the Plastics Industry



**managers behave and are organized differently in different functions**

functions compared on four dimensions:  
goals (e.g., quantity vs. quality)  
time frame (short-term vs. long-term)  
interpersonal (getting job done vs. building relations)  
hierarchy (many levels, reviews, supervisors/employee)

difference between two functions  
on each attribute divided into five categories:  
1 two functions least different on attribute  
(e.g., sales and research functions have similar hierarchy in low-A firm, relative to the other 9 firms)  
...  
5 two functions most different on attribute

then summed across the four attributes  
to describe differentiation between functions:

		S	P	R
e.g., here is differentiation in the low-A firm	Sales	—	—	—
	Production	5	—	—
	Research	13	9	—

and the firm's differentiation score is average differentiation between key functions  
(e.g., the 9 on p. 103 for low-A firm is  $[5+9+13]/3$ )

**managers are tightly coordinated across functions**

respondents think about cross-function ties:  
senior managers who span functions  
cross-function teams  
scheduling procedures  
individual managers working outside official channels

then are asked to characterize relations between each pair of functions:  
1 couldn't be worse; bad relations; serious problems  
2-3 somewhat breakdown in relations  
4 average — sound enough to get by  
5-6 better than average, almost full unity  
7 sound, full unity of effort is obtained

then their average response is used to describe integration between functions:

		S	P	R	
	Sales	—	—	—	e.g., here is integration in the low-A firm
Production	5.87	—	—		
Research	4.55	4.88	—		

and the firm's integration score is average integration between key functions  
(e.g., the 5.1 on p. 103 for low-A firm is  $[5.87+4.55+4.88]/3$ )

Data are from pp. 40 (performance), 36, 50 (differentiation), and 47, 50 (integration) of Lawrence and Lorsch (1967, 1986), *Organization and Environment*, (see pp. 258-260 of the book for methodological details).

**Optimum is contingent on work being performed,**

**here distinguished by the industry in which a firm operates.**

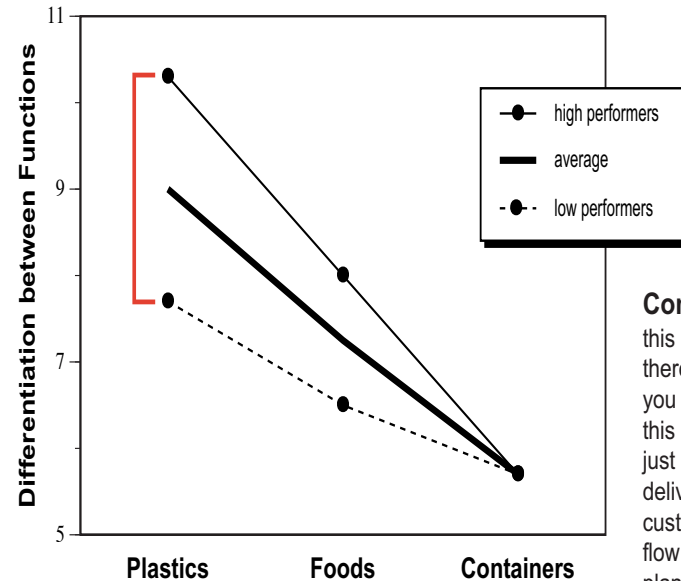
Where firms compete primarily on price, differentiation (structural holes) has no value. It is best to tightly integrate operations across functions. To the right, container firms compete primarily on price (e.g., tin can producers). Low- and high-performing container firms have low differentiation. High-performers are distinguished by their integration across functions.

The economic value of having a strong corporate culture shows a similar contingency (next page).

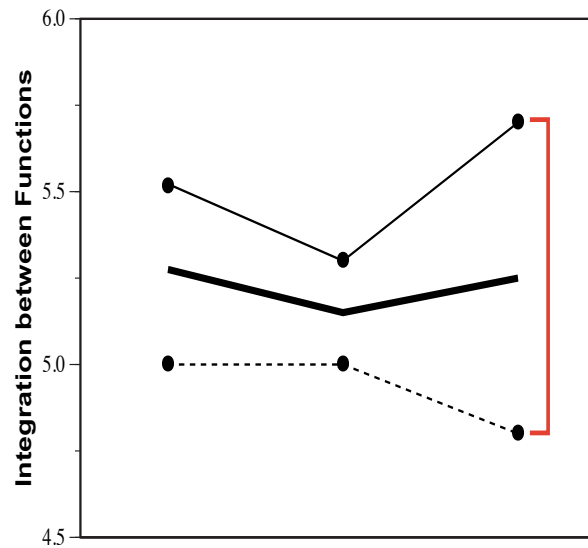
**Plastics:** "The development of plastics materials is more of an art than a science. ... However, we have developed the art to a high enough degree so we can hit a target area, even if we can't hit the target in every case."

"Because our customers typically use the products we sell in a chemical reaction, we have a relatively high level of control over the suitability of our product to the customer. ... Consequently, we have a hundred markets, each different in requirements because of the customers' processing needs."

**Foods:** "This is a profitable business, which is an intensely competitive market, but not a very price-sensitive one. Top competition takes the form of a very intense merchandising effort around new product innovations."



**Containers:** "As far as this business is concerned, there is no innovation. If you really want to grow in this business, you ... have just got to have good delivery service to the customer, optimizing the flow of your material into his plant."

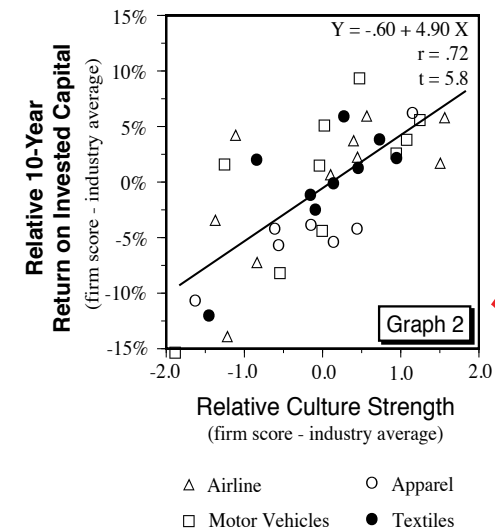
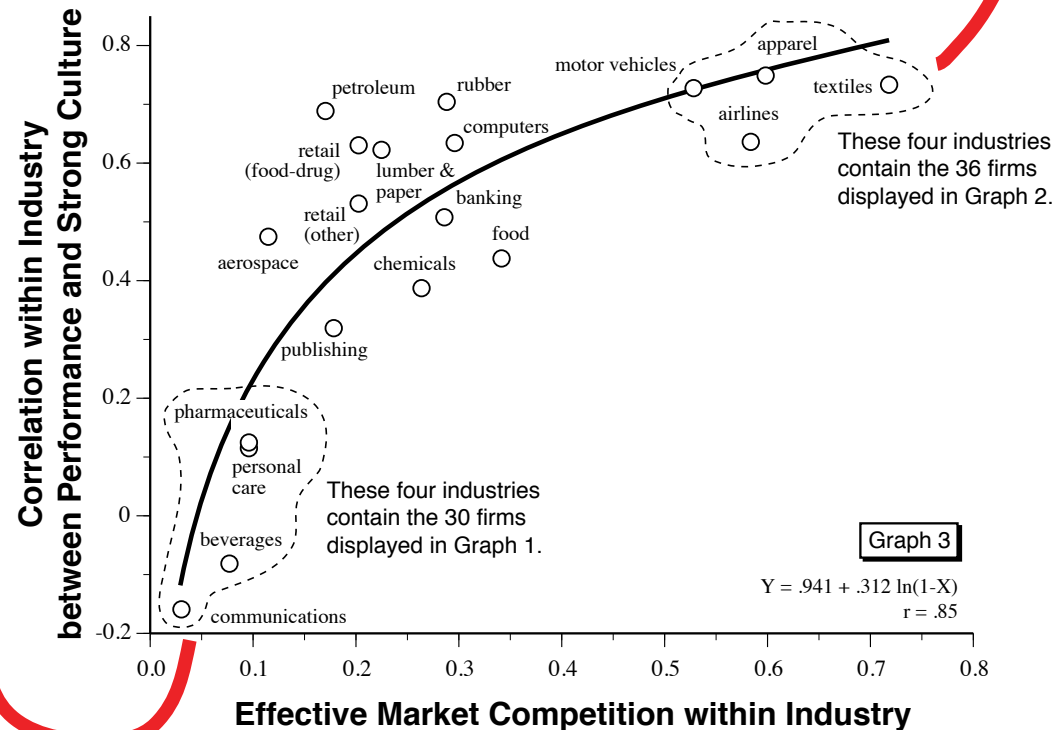
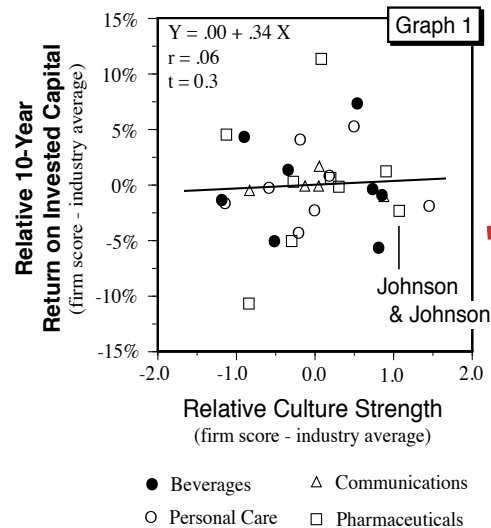


"Prices are important in this industry only in the sense that you must meet them. Also, product specifications are standardized, ... so we are producing a very undifferentiated product. Obviously, you have to sell something else. ... The customers, because of the speed at which they run their lines, are very concerned about imperfect containers. They keep detailed records of their losses and whose containers caused them."

Quotes are from pp. 25-26, 89-90, in Lawrence and Lorsch (1967, 1986), *Organization and Environment*. Graph is from page 103 of the book (plastics high-performer scores are averages of the two high-performing firms and low-performer scores are averages of the two low-performing firms).

## Contingent Optimum (cont.)

When competition is on price, the bottom-line growth associated with network closure (here in the form of strong corporate culture in the early 1980s) is a competitive advantage.



From Burt, "When is corporate culture a competitive asset?" (1999, *Financial Times*, text given in Appendix IV in the "Closure" handout)

**Detail on color coordination task** on page 40 of this handout (from Shirado & Christakis, "Locally noisy autonomous agents improve global human coordination in network experiments" *Nature* 2017, 454:370-374). Text below is from the article [brackets added], and here is a video of the coordination task in process: <https://media-nature-com.proxy.uchicago.edu/original/nature-assets/nature/journal/v545/n7654/extref/nature22332-sv1.mp4> (you will need to authenticate yourself via U of Chicago).

We recruited 4,000 unique subjects online and randomly assigned them to 1 of 11 conditions in a series of 230 sessions (see Supplementary Information). Subjects were assigned a location in a network of 20 nodes, generated by a preferential attachment model; the network structure was created de novo for each session by attaching new nodes (each with two links) to existing nodes; and subjects were placed into the resulting networks at random. [Each subject has three contacts.] The collective goal is for every node to have a colour different than all of its neighbour nodes. This colour coordination game successfully captures the problem of systematic failure by sub-optimization in coordination; that is, while each individual attempts to reach a solution that is optimal for that individual, this may not be optimal for the whole group.

In the sessions, each subject was allowed to choose a colour from three choices (green, orange and purple) at any time. The number of colours made available was the minimum necessary to colour the entire network without conflicts [conflict means your color matches one of your neighbors], which is known as the chromatic number; and all networks in our experiments are, by construction, globally solvable. However, while all the networks allowed the subjects to reach the collective goal, the networks could (by chance) vary in their number of solutions (that is, the networks ranged from 6 to 13,824 possible colourings that would work, known as the chromatic polynomial; see Supplementary Information).

Subjects could see only the colours of neighbours to whom they were directly connected, in addition to their own colour. Thus, although a subject might have solved the problem from his or her own point of view, the game might continue because the network still had conflicts in other regions of the graph. In terms of the optimization problem, the cost function of the game is expressed as the sum of the number of conflicts. As in past work, the subjects got paid according to how long it took for all conflicts in the network to be resolved, and they had to complete the task within 5 min (see Supplementary Information for details).