Increasing Investigator Productivity through Organizational Practices and Group Processes

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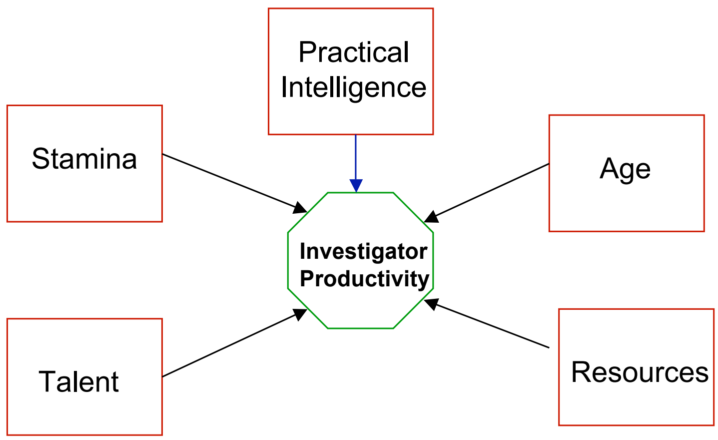
Agenda

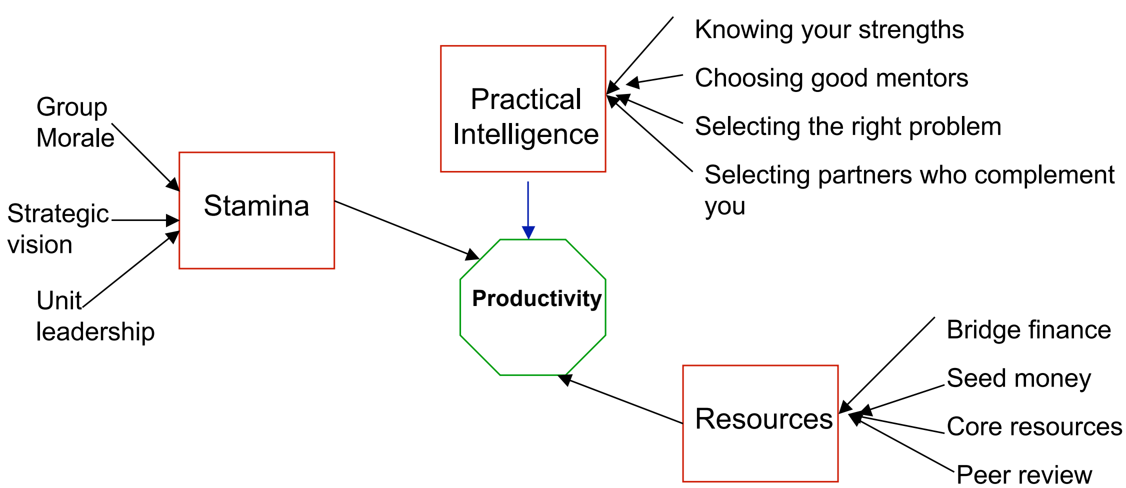
- Organization matters
- Collaboration has grown
- Collaboration increases investigator productivity
- What kind of group process is good for investigator productivity?
- The five categories of practice for improving investigator productivity
- What organization designs facilitate investigator productivity

Consider the following "five factor model" of productivity



Studies suggest that neither IQ, creativity, nor other measures of cognitive functioning varies much among scientists. Of course, everyone ages at the same rate.

This leads us to focus on three factors that can be influenced by the characteristics of social settings



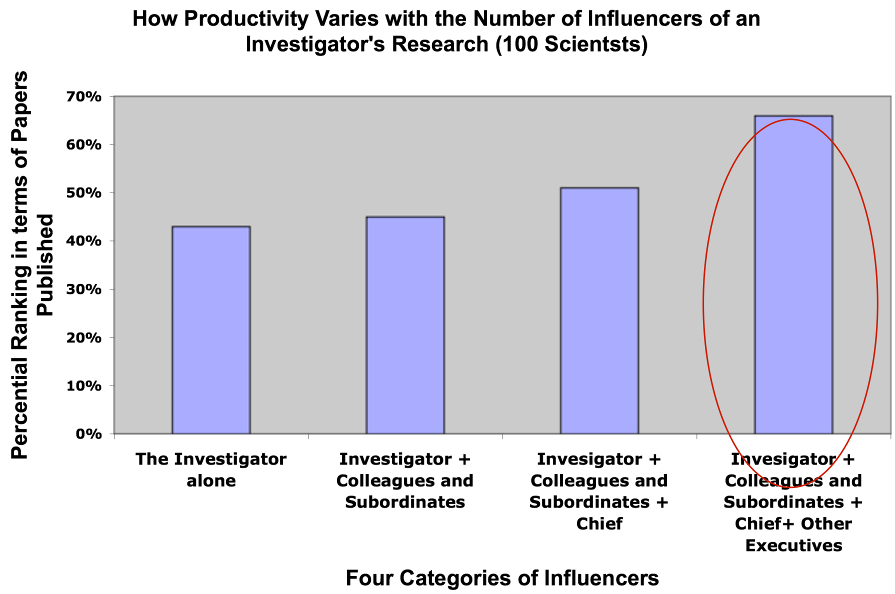
There are also some statistical studies that demonstrate a link between organizational factors and individual productivity

A study of physicists in France found that organizational context matters

- A study of 465 physicists employed at CNRS (Centre National de la Recherche Scientifiqe) looked at the impact of laboratory characteristics on individual productivity
  - *A productive group helps more individuals be more productive*
  - *Higher quality at the level of the laboratory results in fewer publications per individual:*
  - *Lab size decreases productivity*

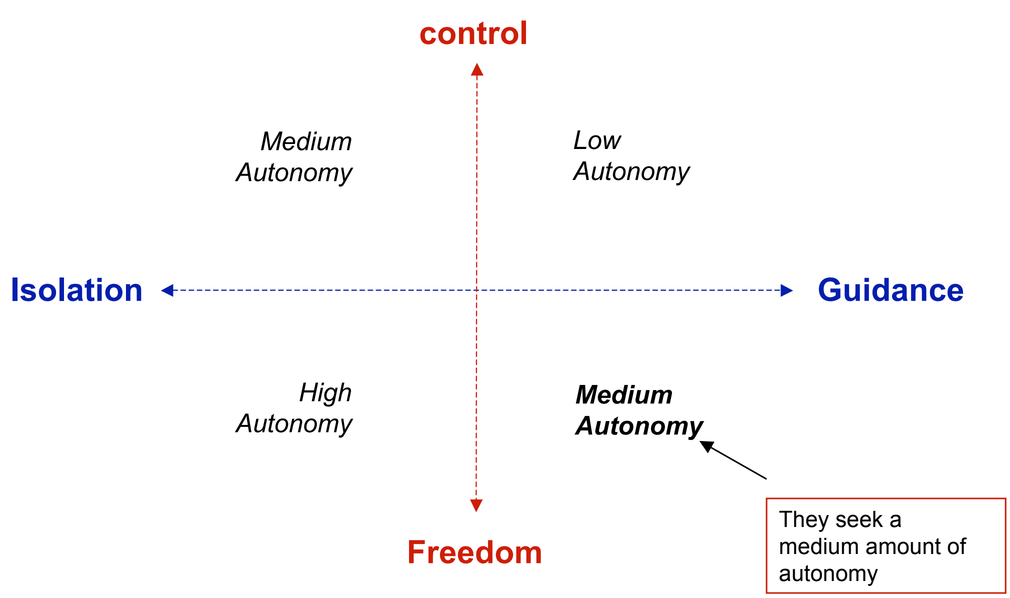
Source: Laure Turnera and Jacques Mairesse Individual Productivity Differences in Public Research :How important are non-individual determinants? An Econometric Study of French Physicists' publications (1986-1997)"

A research study demonstrated that scientists who reported being influenced by more of their peers and superiors were also more productive



The R&D Game, David Allison, ed., 1969.

Another research study suggests that scientists want freedom but want to avoid isolation



*Rose Trevelyan. "The Paradox of Autonomy: The Case of Research Scientists," **Human Relations**, Vol. 54, 2001.*

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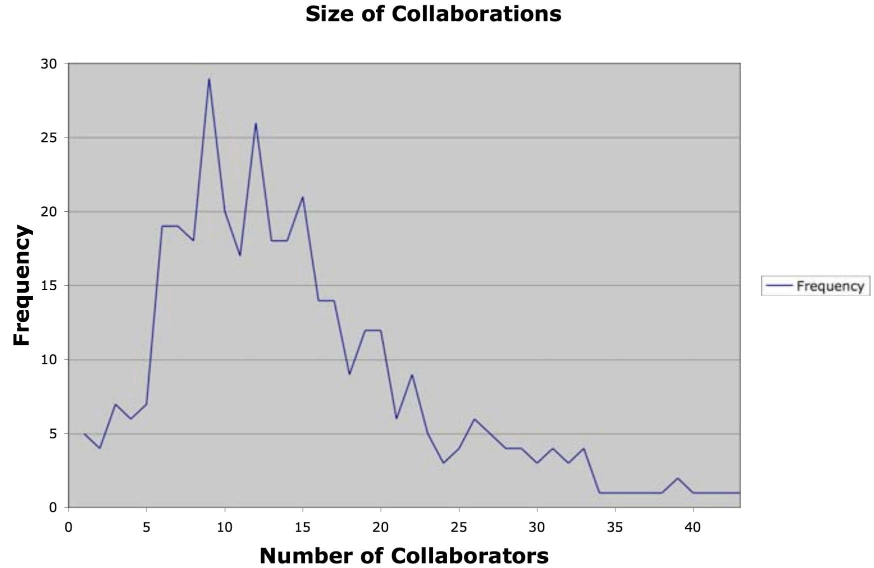
Interdisciplinary work has grown along with team size

BIOCHEMISTRY: JOHNS HOPKINS UNIVERSITY	1969-1973	1979-1983	1989-1993	1999-2003
Total Publications	18	113	132	191
Total Sample Size	18	22	26	38
% Sample	100%	19%	20%	20%
Total Authors	52	62	78	157
Average Authors/Paper	**2.89**	**2.82**	**3.00**	**4.13**
Authors from other departments/disciplines	5	14	15	37
"Other disciplines-departments/paper publish	**0.28**	**0.64**	**0.58**	**0.97**

From Science Citation Index

This table was constructed by counting the number of authors for a 20% sample of papers written by scientists who gave as their address, “Biochemistry at Johns Hopkins University” over a four year period. Authors per paper rises steadily over the decade. By 1999, the Department of Biochemistry had itself been renamed the “Department of Biochemistry and Microbiology.”

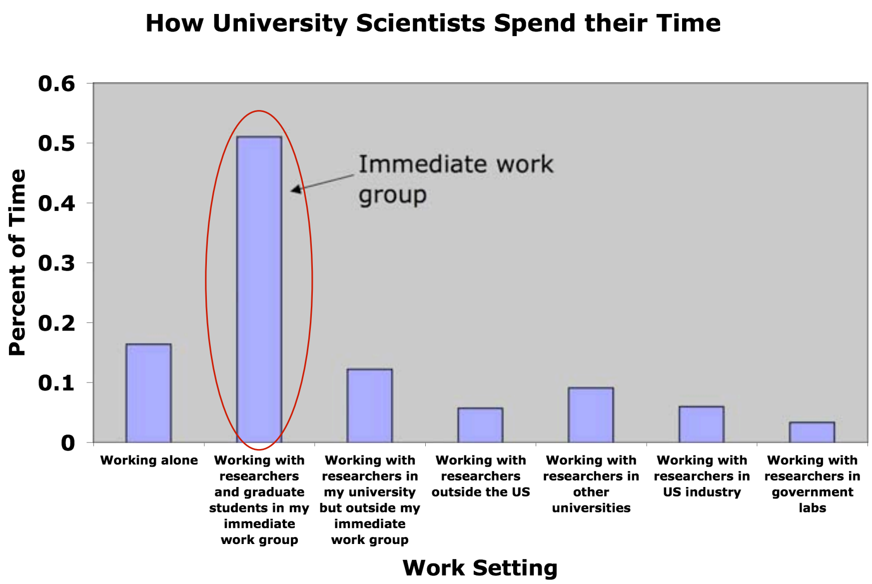
The most frequent number of collaborators a scientist worked with in 2000 was nine



The mode for life-science scientists was 9.74

Source: Barry Bozeman and Sooho Lee, "The Impact of Research Collaboration on Scientific Productivity," Georgia Institute of Technology, February, 2003.

Despite the internet, the immediate work group is still the most important source of collaborators



The sample of 443 researchers were asked how they spent their research time. Note how significant the immediate work group is to collaboration

Source: Barry Bozeman and Sooho Lee, "The Impact of Research Collaboration on Scientific Productivity," Georgia Institute of Technology, February, 2003.

Proximity promotes collaboration

- Most collaborations begin informally
- Co-authorship decreases exponentially with the distance separating pairs of partners

Source:**J. Sylvan Katz and Ben R. Martin, "What is Research Collaboration," University of Sussex, 1995**

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Six studies show that collaboration pays-off: Studies 1-3

- In a study of leading astronomy journal papers, multiple authored papers were more likely to be accepted
- In a study of cancer research, as the number of authors per paper increase the impact of the paper (in terms of citations) increases.
- Research by larger groups tends to be more influential

Source J. Sylvan Katz and Ben R Martin, “What is Research Collaboration” Research Policy, 26, pp.1-18, 1997:

Six studies show that collaboration pays-off: Studies 4-6

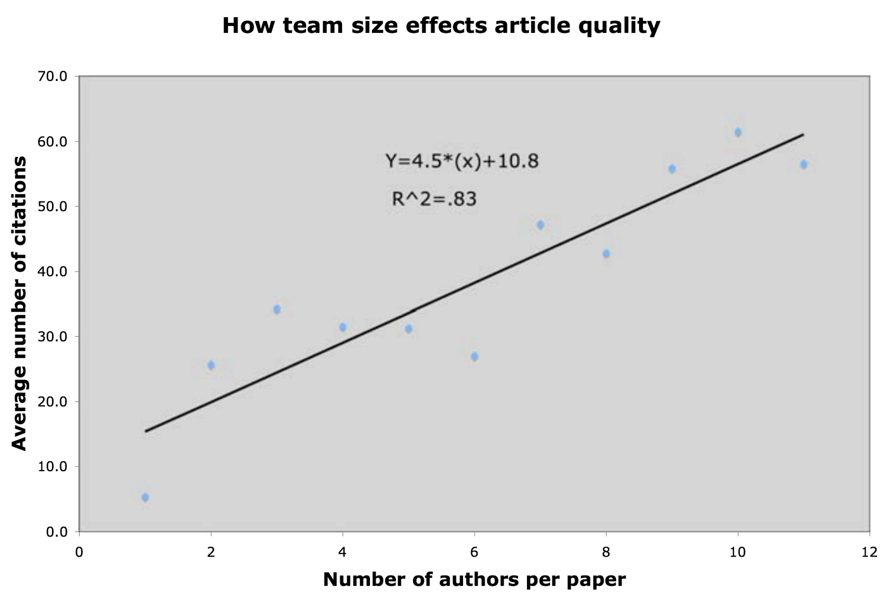
- Citations to multiple authorship papers are worth more in terms of salary and earning ability to an author than citations to single authorship papers (Study of Berkeley Mathematicians)[1]
- In a 1967 study of Nobel laureates, laureates published more and were more apt to collaborate than a matched sample[2]
- A 1966 study of 592 scientists found that the most productive scientists were also the most collaborative [2]

1. Arthur M. Diamond Jr., “What is a Citation Worth,” *The Journal of Human Resources, Volume 21, No. 2, 1986*
2. Barry Bozeman and Sooho Lee, “The Impact of Research Collaboration on Scientific Activity,”Georgia Institute of Technology, February, 2003

I did a study a citation study to see if teams are in fact more research productive than individuals

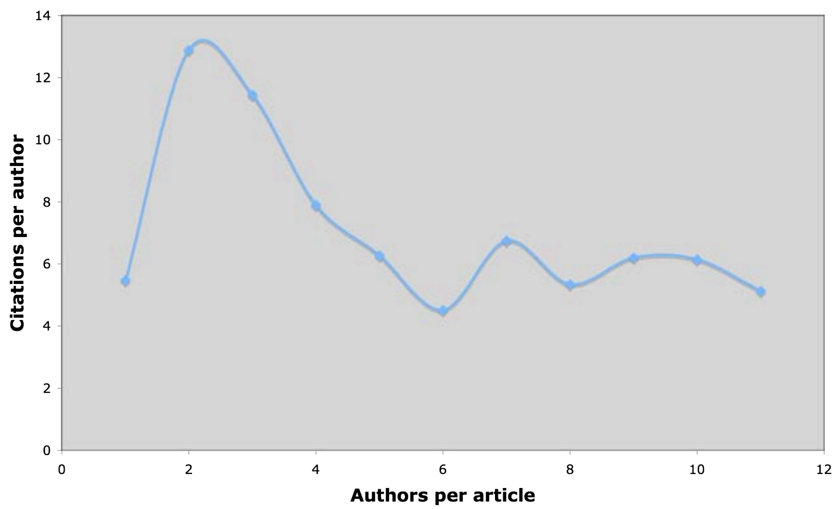
- Looked at the journals "Science," "Nature" and eight other journals from the fields of neuroscience and psychiatry
- Took an average a 9% sample of all articles (about 10,000) published in the year 2000 and listed in the index.
- Calculated how many citations on average, articles of a particular authorship size,has received.
- Regressed average citations against authorship size

The following is the scatter plot and regression equation

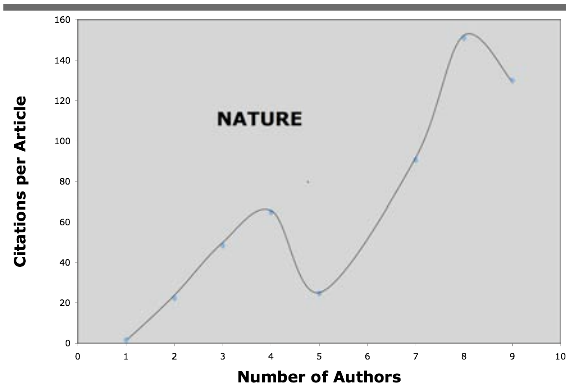


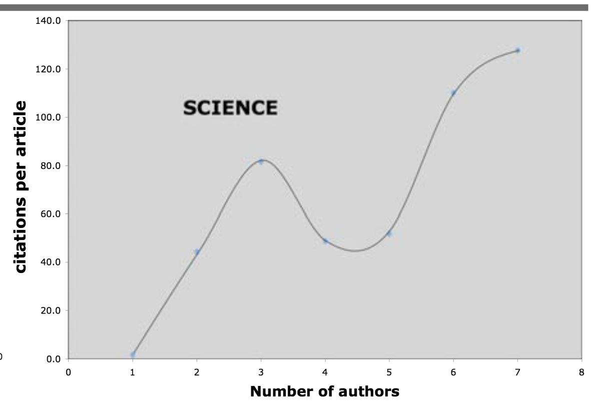
One confounding factor is that authors cite themselves. But if this were the case we would expect the average number of citations per author to remain unchanged as authorship size increased

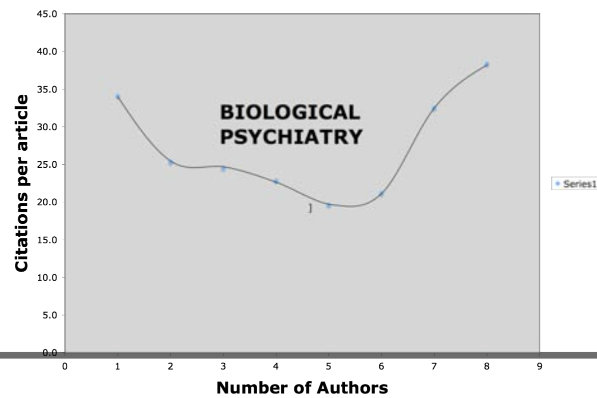
Citations per author as a function of the number of authors



When we look at individual journals there are also significant nonlinearities

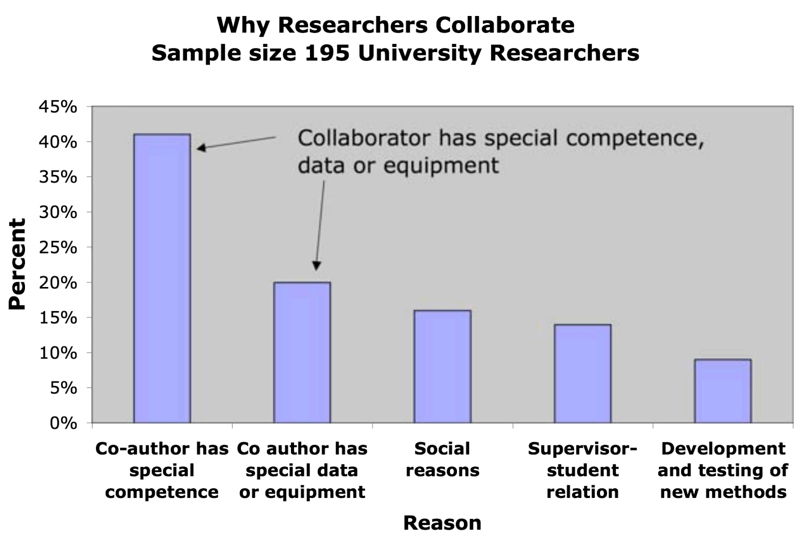






One study suggests that collaboration works because the skills and resources of the partners are complementary

60% gave as their primary reason for collaborating, the *complementarity* between themselves and their partners.



G. Melin and O.Persson. "Studying Research Collaborations Using Co-authorships." *Scientometrics, 36(3), 1996*

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Hypothesis I: Supportive research groups facilitate both flexibility and discipline of thought

		Flexibility: Low	Flexibility: High
Discipline	High	Few discoveries	Productive
	Low	Unproductive	Too many false starts

Discipline

- Groups help individuals overcome confirmation bias- e.g. rejecting disconfirming data rather than rejecting the hypothesis
- Groups help individuals who are too eager to see results, stick with an experiment, rather than stopping it too early.
- Experienced scientists help inexperienced scientists focus on the discrepancy between an hypothesis and a result. The inexperienced scientists are more likely to change the experiment in the hopes of proving the hypotheses.

"

Source: Kevin Dunbar. "Scientific Creativity," *Encyclopedia of Creativity*, Vol. 1, 1999.

Flexibility

- Kevin Dunbar taped laboratory meetings. Some findings:
  - Individuals "have great difficulties in generating alternative inductions from data and also have great difficulties in either limiting or expanding deductions."
  - The pattern of challenging inductions the presenter made was ubiquitous across the four labs Dunbar studied.
  - In the HIV lab 30% of inductions and deductions are shared by more than on individual.
  - 12% of all deductions and inductions have more than two participants.

In discussing an HIV Experiment, the group helped the presenter limit, expand, replace or discard inductions

Limit the scope of the induction	3 times
Expand the scope of the induction	1
Replace the induction	2
Discard the induction	1

Source: Kevin Dunbar, “How Scientists Think: On line Creativity and Conceptual Change in Science,” in *Conceptual Structures and Processes,* Washington, APA Press, 1997

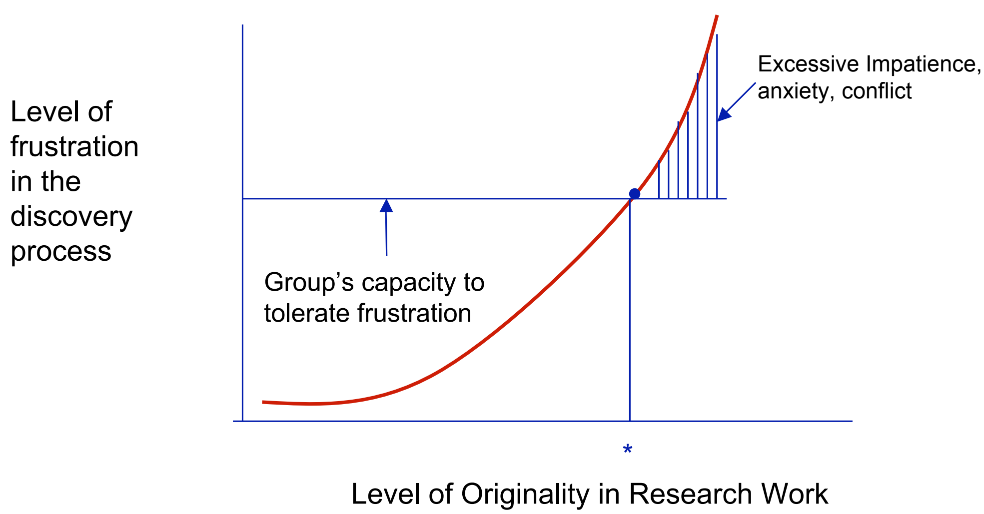
Hypothesis II: Productive work groups help its members tolerate dissatisfaction and frustration, both of which are essential to discovery

Gaps and inconsistencies stimulate discovery, by promoting dissatisfaction

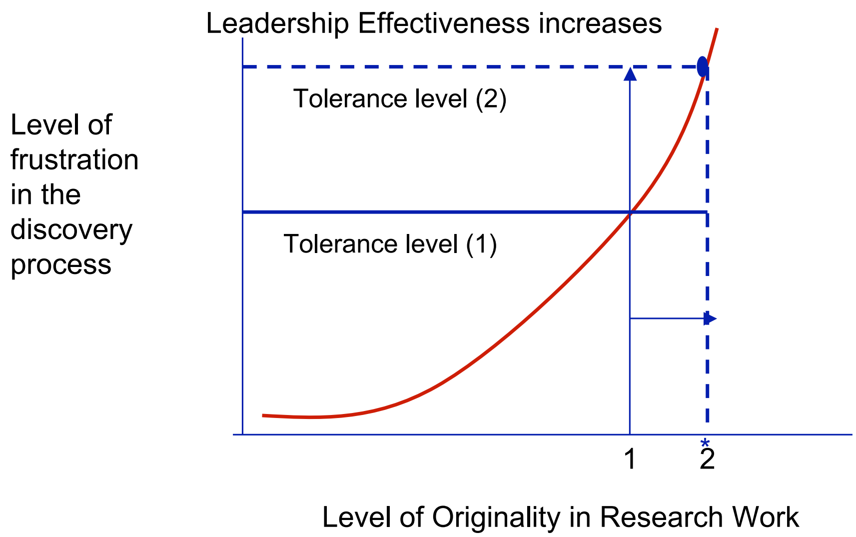
- "Who would have been so bold as to say that the RNA we saw there was not the messenger but that the messenger was another kind of RNA, as yet undetected, turning over rapidly and thus probably there in small amounts. Only the gradual accumulation of experimental facts that appeared to contradict our basic idea could jolt us out of preconception"
- "Yet we were acutely aware that something was wrong and were continually trying to find out what it was. It was this *dissatisfaction* with our ideas that made it possible for us to spot where the mistake was. If we had not been conscientious in dwelling on these contradictions we should never have seen the answer. "
- This *dissatisfaction is* itself a source of irritability and frustration

Francis Crick, *What Mad Pursuit: A Personal View of Scientific Discovery,* p.140

We can conceptualize the link between the level of originality a research team can sustain and how much frustration it can tolerate in the following way



Effective leaders help a group tolerate frustration



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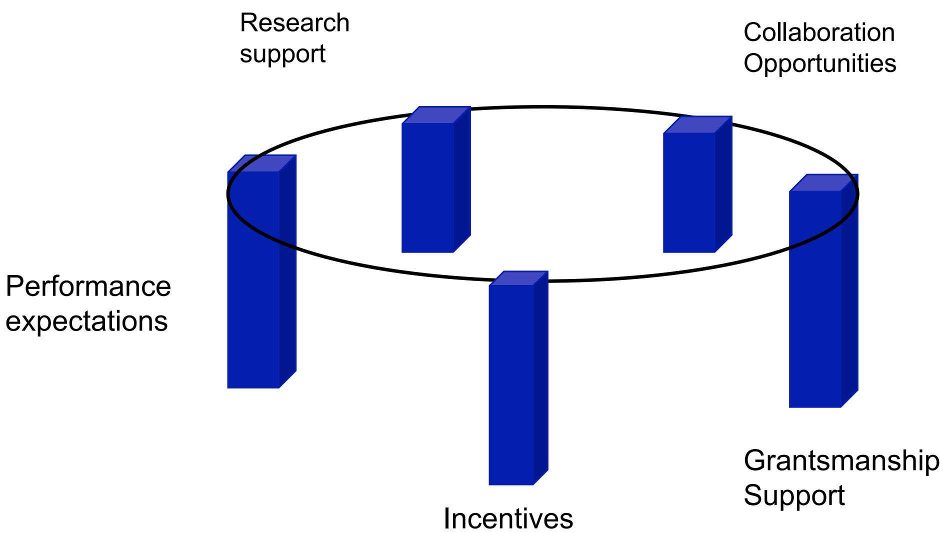
Interviewed nine people who have wrestled with the problem of facilitating and increasing investigator productivity

- 2 institute directors
- 1 medical school director
- 1 department chair
- 1 director of an NIH institute
- 1 Center directors
- 1 scientist/research administrator
- 1 internal consultant within a medical school
- 1 researcher on faculty productivity

I also drew on research conducted with my colleague Elizabeth Blaylock which appears in an unpublished paper, "The Economics of Publicly Funded Biomedical Research,"

You need five legs for the research table



Examples of research support

- A "safety-net" in the form of bridge financing when a scientist who has taken risks fails to get funded
- A culture of appreciation for good work done.
  - "There is so much failure in science, peers should recognize when one of their own succeeds in some endeavor."
- Streamlined bureaucratic processes
- Project Managers to help manage complex projects
- Specialized managers of core resources
- Internal sabbaticals for the stalled researcher
- Strategic planning,retreats, and other methods for looking at the big picture, for identifying the bottlenecks
  - "I proposed three important questions that we could solve that we aren't solving And then we talked about what they were working on. Some of it was really fascinating – and we talked about the future. – And it became clear that no one had ever talked to them in this way"

Examples of incentives

- Recognition awards (one time bonuses)
- Research program incentives such as returning overhead to investigators, allowing researchers to bank overhead, giving researchers total discretion on how to spend the overhead,
  - But to create a system for financing investigators' discretion you often need to make the funding system transparent.
  - This means as one dean suggested eliminating the "special deals" investigators accrue over time. Everyone needs to play by the same rules, and there should be no mystery about who gets money and why.
- Seed money to fund preliminary investigations
- Incentives for departments to recruit together.

Examples of incentives (con't)

- Providing scarce resources, such as a lab space to the better performers
- Asking underperformers to leave (which is in fact an incentive for the above average performers)

Returning overhead is an investment with a rate of return

- Investigators always use current grant support to develop the preliminary data required for the next grant application.It is a form of "skunk-works"
- This means there is a multiplier linking dollars spent on skunk works and dollars of grants awarded.
- For example imagine the following scenario:
  - Dean returns $25,000 in overhead
  - This leads to an extra 240,000 in grants awarded and if grants are awarded for four years, $60,000 in extra spending per year
  - Overhead rate is 50%
  - Then the overhead returned is $20,000
  - Net overhead invested is $25,000-$20,000 = $5,000

directs +.5 x directs=60, 3/2 x (directs)=60, directs=40, indirects=60-40=20

Policies should be designed with incentives in mind

- A dean of a medical school instituted the following changes vis a vis post-docs.
  - Increased the stipend for post -docs to market range
  - Removed limits on the number of post-docs that could be hired.
  - Committed to funding the first three semesters of the post-doc's tenure, thereafter the investigator had to provide the funds
  - Allowed investigators to bank funds if post-docs moved through the system faster than expected.
- The results:
  - More post doc's hired
  - Better post-doc's hired
  - More training grants obtained.

The primary purpose of incentives is to increase investigator discretion

Performance expectations

- Salary support (usually above 60%)
- Other direct expenses (usually 100% except for explicit agreements around startup and interim funding)
- Indirects (often based on $/square foot metric)
- Using performance benchmarks to stimulate effort

Benchmarks were developed from public sources for a research institute client

Institute	Total Research Revenue ($ millions)	Investigators	Grant Revenue Per Investigator
Burnham	50,988	66	$772,545
TIGR	46,805 (excludes one $17,000 contract)	36	$961,467
Jackson Labs	61,800	86	$718,605
Salk	59,148	78	$758,308
Scripps	222,580	297	$893,168
Torrey Pines	6,990	19	$367,872
Wistar	30,442	115	$264,713

Examples of collaboration opportunities

- Opportunities for co-teaching so that investigators can get to know each other before joining together as research team.
- Appointing a vice-chair to make matches between potential collaborators
  - "It is amazing how often people even in a tight-knit institution do not know that there are people who are next door who are doing things they should be interested in."
- Encouraging 2-3 investigators to apply for seed funding together
- Co-location with physicists, computer scientists, mathematicians

Examples of grantsmanship support

- Develop a timeline – Many organizations have a standard process and timeline for grant applications (typically several months long). These processes are particularly important for young PIs who have not been through the grant application process before.
- Know the funder – A key skill is knowing how to find out what the funder you are approaching is interested in at the moment. Institutions can ask specific people to remain current on major funders and/or, or they can develop ways to educate investigators to find out.
- Funder knows you – Investigators should be expected to engage in a range of service activities such as NIH study sections to increase their own visibility and the visibility of their institution in funding networks. They may need some coaching on how to identify and select appropriate opportunities

Examples of grantsmanship support (con't)

- Mentor young investigators – Getting young investigators funded and fundable requires a systematic approach. Having senior, NIH-funded PIs work with junior investigators is a key component of such a system.
- Internal peer review – Some organizations put all of their grant applications through an internal peer review process before they are submitted to the funding agency. While onerous, these internal reviews have the double benefit of improving the application being developed and helping the reviewers hone their own grant-application skills.
- Quality control – In addition to the internal peer review, some organizations also put a quality control mechanism in place. They do not permit an application to be submitted unless it meets some internal standard of quality. In this way, they feel that they can develop the reputation of the institute and make it easier for applicants down the road to be successful

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It is also useful to consider broader issues of organization design

We can learn something about organizing research by looking at specialized research organizations

- At the Rockefeller Institute, a premier research setting, the molar unit of organization was the lab not the department
- Work was organized around research questions pursued by a head scientists rather than around disciplines
- When a lab head left, the lab itself was often disbanded. This meant that the structure could be renewed without major organizational upheaval.

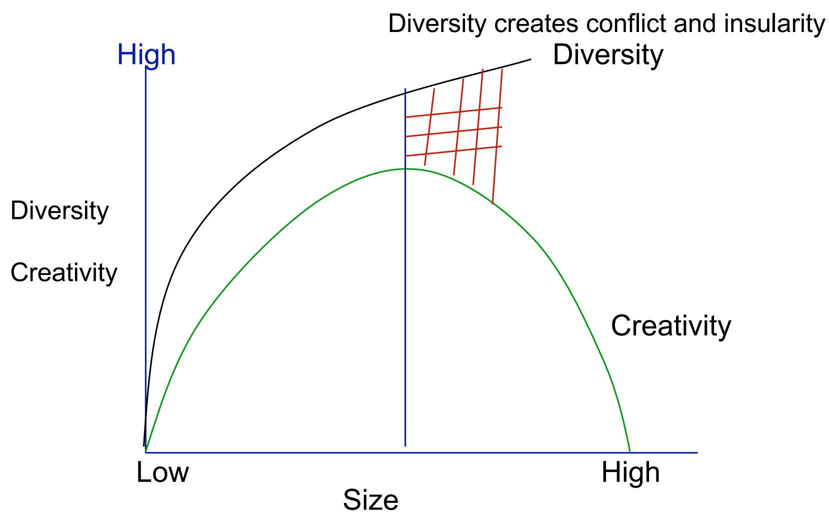
A study of research institutes, including Rockefeller, points to four factors that inhibit creativity

- Too much differentiation, e.g., funding and recruitment are carried out at the department or subunit level
- Too much centralization, e.g., research goals are determined centrally
- Too much diversity so that communication across specialties is difficult
- Too little flexibility, due to an organizational structure based in departments
- Too large, when size itself creates the prior four conditions.

Source: J. Roger Hollingsworth, "Research Organizations and Major discoveries in Twentieth Century Science: A Case Study of Excellence in Biomedical Research." Department of History, University of Wisconsin

There is an optimum scale or size, conditioned by the links between scale and diversity

You need size for diversity but if an institute is too large the diversity will not be integrated



We can summarize these lessons with the following heuristic "formula" for creative scientific institutions

$$\text{Creativity} = \frac{\text{Diversity} \times \text{Organizational Flexibility}}{\text{Size}}$$

Diversity: So that scientists can choose the best problems to work on

Flexibility: So that scientists can adapt to new discoveries

Size: So that scientists can integrate the diverse specialties and talents available to them

The Janelia Farms polemic against the current organization of research

Medical Centers	New Design Principle
Investigators work on a time scale of 3-5 years	Investigators work on a time scale of 7-10 years
Principal investigators spend little time hands on in the lab*	Investigators spend a lot of time hands on in the lab
Incoming post-docs are expected to have publications.	Incoming post docs have time and space to find a generative research questions
Outsiders appraise the investigators' talents	Senior investigators within the research institution appraise investigator talents

*A survey of 300 Howard Hughes Fellows--elite scientists work work in academic settings--revealed that only 1% spend more than 20 hours a week in hands-on work

Interview with Dr. Gerald Rubin, March 12, 2004

Influencing investigator productivity