Interdisciplinarity: What Works, What Doesn't

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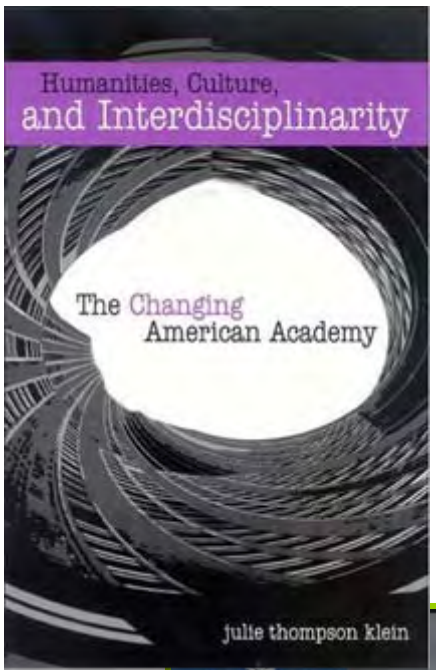


dis·ci·pline –*n.*
(Webster) **9.** a branch of instruction or learning: *the disciplines of history and economics.*

Director of

Revised
11/06/2007

Interdisciplinarity: Some Definitions

(guiding not prescriptive)

in·ter·dis·ci·pli·nar·y, ***adj.*** (Webster)

1. **combining or involving two or more academic disciplines or fields of study:** *The economics and history departments are offering an interdisciplinary seminar on Asia.*
2. **combining or involving two or more professions, technologies, departments, or the like, as in business or industry.**

[1935–40; INTER- + DISCIPLINARY]

Often tightly coupled with collaboration but not of necessity. How many disciplines sit in this Faculty? How many spill over?

col·lab·o·rate, ***v.i.*** (Webster)

1. **to work, one with another; cooperate, as on a literary work:** *They collaborated on a novel.*

INTERDISCIPLINARY STUDIES

	ROOM
CHEMISTRY FOR GEOLOGISTS	127
MATH FOR ARCHEOLOGISTS	214
PHYSICS FOR PSYCHOLOGISTS	206
BIOLOGY FOR MATHEMATICIANS	319
GEOLOGY FOR ENTOMOLOGISTS	114
BOTANY FOR ASTRONOMERS	
ANATOMY FOR PHYSICISTS	
PSYCHOLOGY FOR LABORATORIANS	
ANTHROPOLOGY FOR CHEMISTS	
TOPOLOGY FOR PALEONTOLOGISTS	
NUCLEAR PHYSICS	

Interdisciplinarity: what works, what doesn't

Some General Observations

- **Modern Research is Global and increasingly demands Interdisciplinary Collaboration**
  - **building knowledge networks & social networks is crucial**
- **Proposals, Papers, Presentations must simultaneously reach diverse groups**
  - **experts are rare; knowledge is not; information is over abundant**
- **Success rates are low (20%?)**
  - **so ideas must be repurposable**
- **Interdisciplinary collaboration can be great fun or very painful: Dal has both many collegial assets and serious institutional impediments**

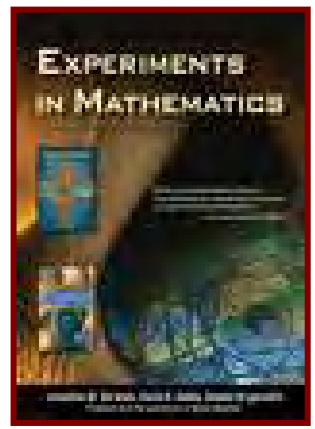
Drive

Further General Observations

- **distinct mediocre competences do not often make a good interdisciplinary marriage; but**
  - **Faraday** *``A centre of excellence is, by definition, a place where second class people may perform first class work."*
  - **Robin Wilson** *``At Oxford they thought me a second rate research mathematician and a first-rate teacher. At the OU just the opposite..."*
- **You are your own best proponent (sales-person)**
  - **but bullshit is obvious**
- **E.g., I advocate Experimental (Inductive) Mathematics**

  ≠ sloppy experiment + missing proofs

  (though many try to publish such)



Experimental Mathematics in Action

David H. Bailey
Jonathan M. Borwein
Neil J. Calkin
Roland Girgensohn
D. Russell Luke
Victor H. Moll

The last twenty years have been witness to a fundamental shift in the way mathematics is practiced. With the continued advance of computing power and accessibility, the view that "real mathematicians don't compute" no longer has any traction for a newer generation of mathematicians that can really take advantage of computer-aided research, especially given the scope and availability of modern computational packages such as Maple, Mathematica, and MATLAB. The authors provide a coherent variety of accessible examples of modern mathematics subjects in which intelligent computing plays a significant role.

Advance Praise for *Experimental Mathematics in Action*

"Experimental mathematics has not only come of age but is quickly maturing, as this book shows so clearly. The authors display a vast range of mathematical understanding and connection while at the same time delineating various ways in which experimental mathematics is and can be undertaken, with startling effect."

—**Prof. John Mason**, Open University and University of Oxford

"Computing is to mathematics as telescope is to astronomy: it might not explain things, but it certainly shows 'what's out there.' The authors are expert in the discovery of new mathematical 'planets,' and this book is a beautifully written exposé of their values, their methods, their subject, and their enthusiasm about it. A must read."

—**Prof. Herbert S. Wilf**, author of *generatingfunctionology*

"From within the ideological blizzard of the young field of Experimental Mathematics comes this tremendous, clarifying book. The authors—all experts—convey this complex new subject in the best way possible; namely, by fine example. Let me put it this way: Discovering this book is akin to finding an emerald in a snowdrift."

—**Richard E. Crandall**, Apple Distinguished Scientist, Apple, Inc.

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LUKE
MOLL

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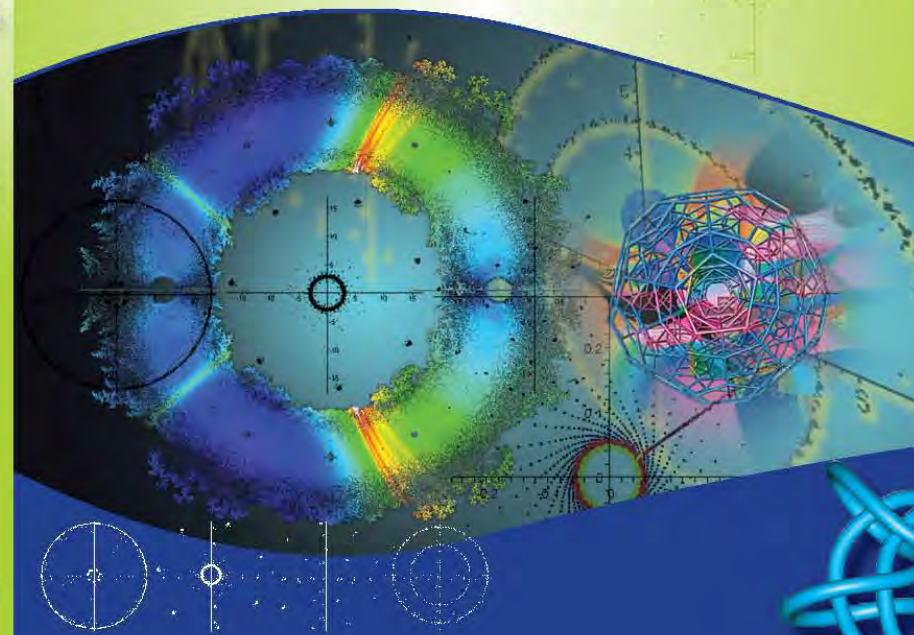
More use of visualization

Experimental Mathematics in Action

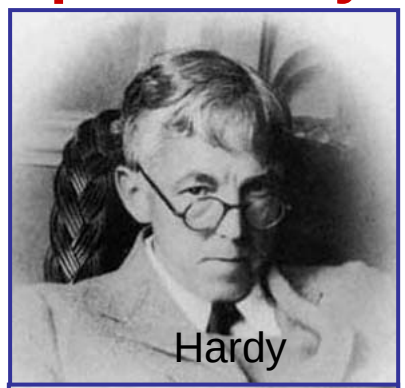


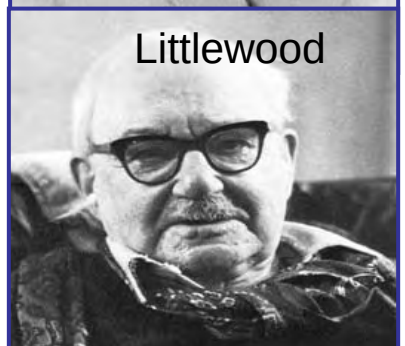

THEORIES
PROOFS

Hardy and Littlewood's Four Axioms for Collaboration (Harald Bohr, 1887-1951)

``**The first [axiom]** said that when one wrote to the other (they often preferred to exchange thoughts in writing instead of orally), it was completely indifferent whether what they said was right or wrong. As Hardy put it, otherwise they could not write completely as they pleased, but would have to feel a certain responsibility thereby.

The second axiom was to the effect that, when one received a letter from the other, he was under no obligation whatsoever to read it, let alone answer it, --- because, as they said, it might be that the recipient of the letter would prefer not to work at that particular time, or perhaps that he was just then interested in other problems....


Hardy


Littlewood

G.H. Hardy (1877-1947) and J.E. Littlewood (1885-1977) Four Axioms for Collaboration

The third axiom was to the effect that, although it did not really matter if they both thought about the same detail, still, it was preferable that they should not do so.

And, finally, the fourth, and perhaps most important axiom, stated that it was quite indifferent if one of them had not contributed the least bit to the contents of a paper under their common name; otherwise there would constantly arise quarrels and difficulties in that now one, and now the other, would oppose being named co-author."

- **Pretty good rules for collaboration a century later**
- **Shared (even expressed) expectations are crucial!**
- **IP issues & treatment of students often need addressing**

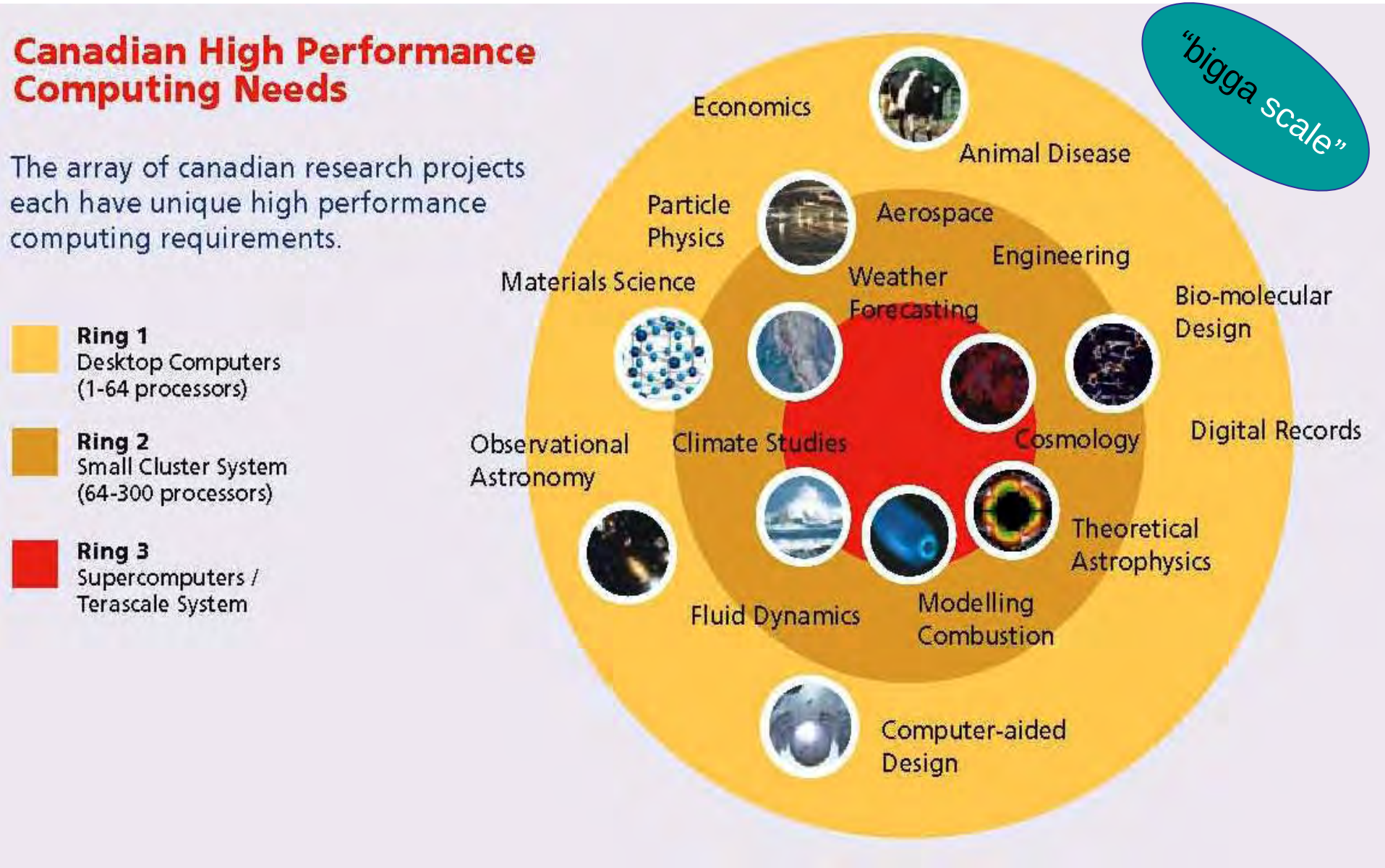
The most celebrated collaboration in math; the post worked then!

Interdisciplinarity: My own Evolution

- **Pure Math (1971) → Optimization (Multicriteria Choice, DPhil 1974) → OR and Computational Science (1984)→ High Performance Computation, Imaging (1994) → Collaborative Technology (2004)**
- **I would not have felt comfortable writing my recent books without having also studied some Logic, and some Philosophy & History (of Science)**
- **One of my most challenging experiences was coauthoring and then advocating for the 2005 Long Range Plan for Advanced Computation in Canada (2003-2005) for all disciplines**
  - **E.g., to CFI, Grant Councils, CSA, IC, Manning and Dion, etc**
  - **Led to recent $180 million infusion for Compute Canada**

The Seven Consortia (55 Universities) on the CANARIE Backbone

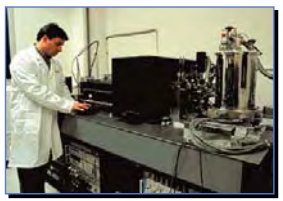
Three Rings: Canadian HPC Needs

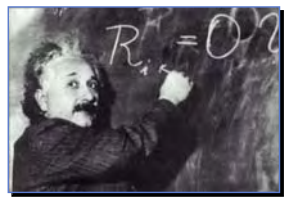


Changing Research Landscape: a new Triad

Computational

(dry science)





Experimental

(wet science)

Theoretical

Tri-council boundaries are a huge impediment

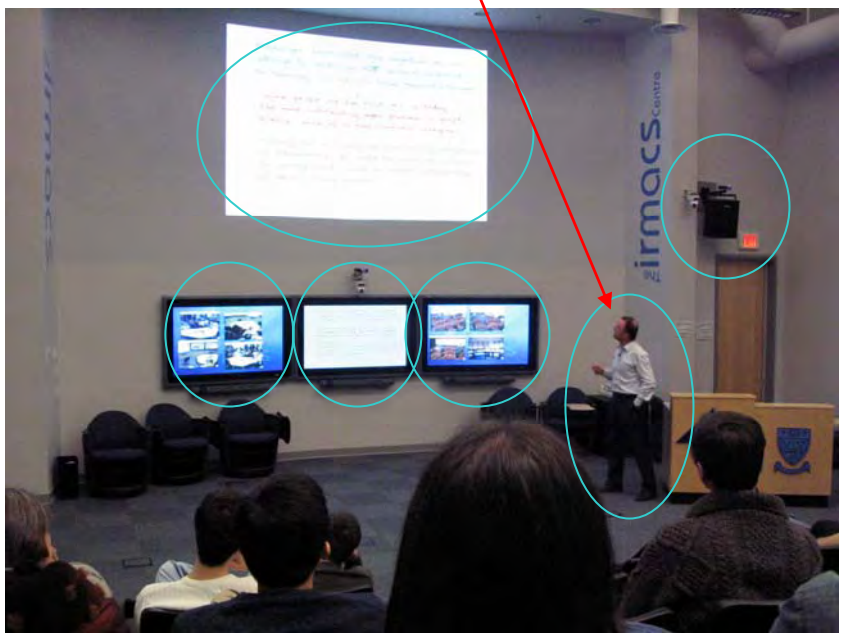
My Lab in FCS

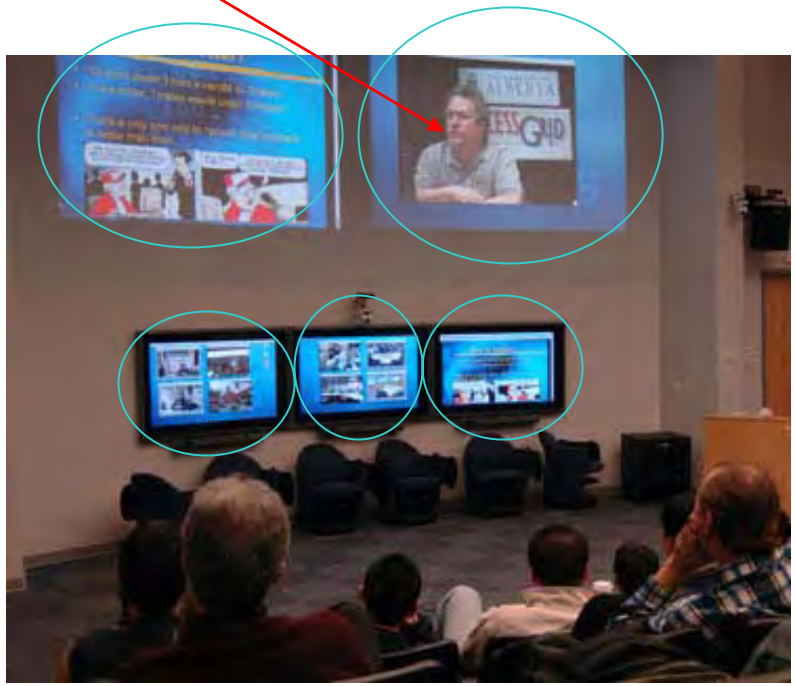
240 cpu Glooscap at Dal

Dalhousie Distributed Research Institute and Virtual Environment

D-Drive's Nova Scotia location lends us unusual freedom when interacting globally. Many cities around the world are close enough in a chronological sense to comfortably accommodate real-time collaboration.

C2C Sample Presentations: From SFU and Edmonton





Local Presentation Speaker

Presentation Slides

Remote Presentation Remote Audience

Local Camera Placement

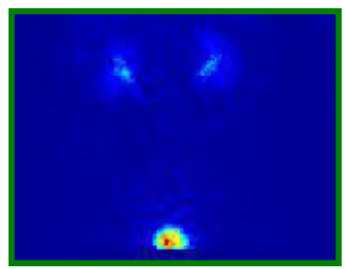
Interdisciplinarity: Success Relies On

- **Willingness to take reasonable risks**
  - **but should be viewed like portfolio diversification**
- **Lack of fear & mutual respect for the other's discipline:**

"Hardy asked `What's your father doing these days. How about that esthetic measure of his?' I replied that my father's book was out. He said, 'Good, now he can get back to real mathematics'." (Garret Birkhoff on his father's book Aesthetic Measures, 1933).

  - many physicists fear mathematicians; who are often uncomfortable or dismissive of informal reasoning and 'physical or economic intuition'

- **Sufficient common language**
  - a slow process as I found working with Vancouver Hospital's Medical Imaging Group (especially the clinicians)
- **Above all, a real project which interests all**
  - not grant foraging or publication snaring
  - much facilitated by shared students/PDFS

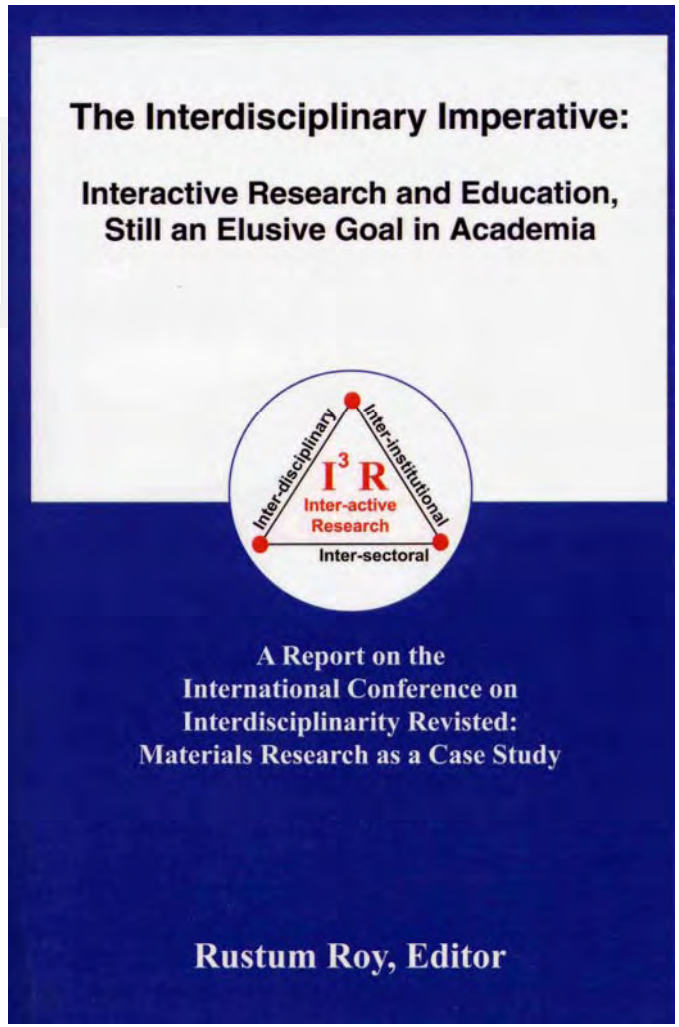


My collaborator's renal system

Interdisciplinarity: Success Relies On

- The view of one of the enthusiasts
  - Roy (2000): there is no successful single institution example of "I3R"

The key findings include the following: The entire research enterprise demands and is moving toward "interactive research" (Interactive includes inter-disciplinary, inter-institutional, and inter-sectoral research); The university world has, by and large, failed to organize itself to respond to this new reality; Specific hindrances to I3R are the traditional peer review process and academic intellectual property practices; New directions proposed include: funding largely on past performance and matching fund strategies.

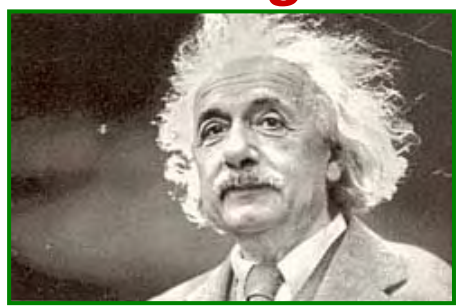


"I'M ON THE VERGE OF A MAJOR BREAKTHROUGH, BUT I'M ALSO AT THAT POINT WHERE CHEMISTRY LEAVES OFF AND PHYSICS BEGINS, SO I'LL HAVE TO DROP THE WHOLE THING."

Interdisciplinarity: what works, what doesn't

"Keynes distrusted intellectual rigour of the Ricardian type as likely to get in the way of original thinking and saw that it was not uncommon to hit on a valid conclusion before finding a logical path to it.

`I don't really start', he said, `until I get my proofs back from the printer. Then I can begin serious writing.' "
(Alec Cairncross, 1996)



- **Keynes the Man written 50 years after Keynes' death**

``Far better an approximate answer to the right question, which is often vague, than the exact answer to the wrong question, which can always be made precise." **(J. W. Tuckey, 1962)**

Ability to exchange intuition is fundamental to interdisciplinary success

Interdisciplinarity: Some Assessment Experience

- NSERC Collaborative Research Initiatives (1992-96)
  - Big Science from SNO to NASA and Global Warming
  - the more interdisciplinary the panel, the more protective members become of their disciplines
  - few good metrics for success; *'algorithms will be developed'*
- NATO Collaborative Research Grants, Physical Science, Engineering and Technology (1997-2000)
  - by 2000 a Georgian sat on the committee
  - Kosovo and Madeline Albright intervened
- Killam Selection Committee of Canada Council (2003-06)
  - great good will ---- but "Two solitudes" and "Two Cultures" (CP Snow) both rear their heads


7-5
"YOU CAN'T IMAGINE HOW TIGHT OUR BUDGET IS. WE CAN ONLY WORK WITH SINGLE-DIGIT NUMBERS."

Interdisciplinarity: Some Consequences

- **Many breakthroughs are made on boundaries of disciplines, often by brilliant interlopers**
  - **You have to speak enough of the new language to contribute; this should influence our graduate curriculum**
  - **Team Work is becoming the rule not the exception (biology, physics, engineering, finance, …, even math)**
- **This is still premised on having a core competence: in a discipline which has one**
  - **You have to know something substantial to contribute; this should influence our under-graduate curriculum**
  - **Is Computer Science such a discipline? Michigan decided Geography was not!**
  - **I question the value of our Interdisciplinary PhD (everyone's favourite niece?); what is wrong with a Management PhD which also contains a lot of IT or Sociology?**

See www.pkal.org/collections/Vol4InterdisciplinaryResearch.cfm (2006)

Interdisciplinarity: Further Consequences

- You need to know enough about the culture of the other discipline or country
  - publishing practices & styles: books vs papers vs proceedings
  - citation rates differ wildly: "*Multidisciplinary journals tend to have low self-citation rates*." (ISI)
  - Finance, Economics (social science) rank a lot like Mathematics

Table 1. Comparison of the numbers of citations in different fields of science. Based on the data from *Science and Engineering Indicators 2004. National Science Foundation, May 04, 2004.*

Field	Average ratio of citation number to the number of citations in mathematics	1992		1994		1996		1997		1999		2001	
		number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths	number of citations	ratio to maths
Clinical medicine	78	475793	69	516665	78	554332	80	574859	90	584330	78	589762	76
Biomedical research	78	460148	67	518304	78	562361	81	572122	89	594596	79	568328	73
Biology	8	52535	8	57825	9	58649	8	58130	9	56981	8	57899	7
Chemistry	15	88010	13	96827	15	105960	15	105762	16	110927	15	109703	14
Physics	19	137922	20	141653	21	138417	20	131958	21	125968	17	120593	15
Earth/space sciences	9	55086	5	58818	9	71230	10	73507	11	83053	11	82614	11
Engineering/technology	5	32680	5	35189	5	33664	5	32958	5	34001	5	36809	5
Mathematics	1	6858	1	6631	1	6961	1	6418	1	7520	1	7794	1

- In some countries (UK, Oz) University funding is being driven by such "impact factor" metrics (MPUs)
- Europe and the English World are diverging?

Interdisciplinarity: Further Consequences

- **The Jury is still out, somewhat**
  - **good research however performed will usually rise to the top**
  - **"collaboration is associated with higher article citation rates, … research has suggested that this is, in part, related to the access to a larger social network and the increased visibility of research …" (2003, NZ study)**

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Scientometrics, Vol. 39, No. 2 (1997) 173–184

SCIENTIFIC COLLABORATION IN FINANCE DOES NOT LEAD TO BETTER QUALITY RESEARCH

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(Received January 27, 1997)

The study reports an empirical comparison of quality of collaborative research with the quality of individual research. Quality of a paper is measured by the citation rate over the four years following the year of publication. Papers published in fourteen Finance journals between 1987–1991 are sampled. There is no significant difference between the quality of collaborative and individual research. Decision-makers should hesitate in interpreting collaborative research as a definitive sign of ability to produce better research.

Interdisciplinarity: Final Conclusion

- **A pretty compelling recent study**

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Science 18 May 2007:
Vol. 316. no. 5827, pp. 1036 - 1039
DOI: 10.1126/science.1136099

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Reports

The Increasing Dominance of Teams in Production of Knowledge

Stefan Wuchty,[1*] Benjamin F. Jones,[2*] Brian Uzzi[1,2*†]

We have used 19.9 million papers over 5 decades and 2.1 million patents to demonstrate that teams increasingly dominate solo authors in the production of knowledge. Research is increasingly done in teams across nearly all fields. Teams typically produce more frequently cited research than individuals do, and this advantage has been increasing over time. Teams now also produce the exceptionally high-impact research, even where that distinction was once the domain of solo authors. These results are detailed for sciences and engineering, social sciences, arts and humanities, and patents, suggesting that the process of knowledge creation has fundamentally changed.

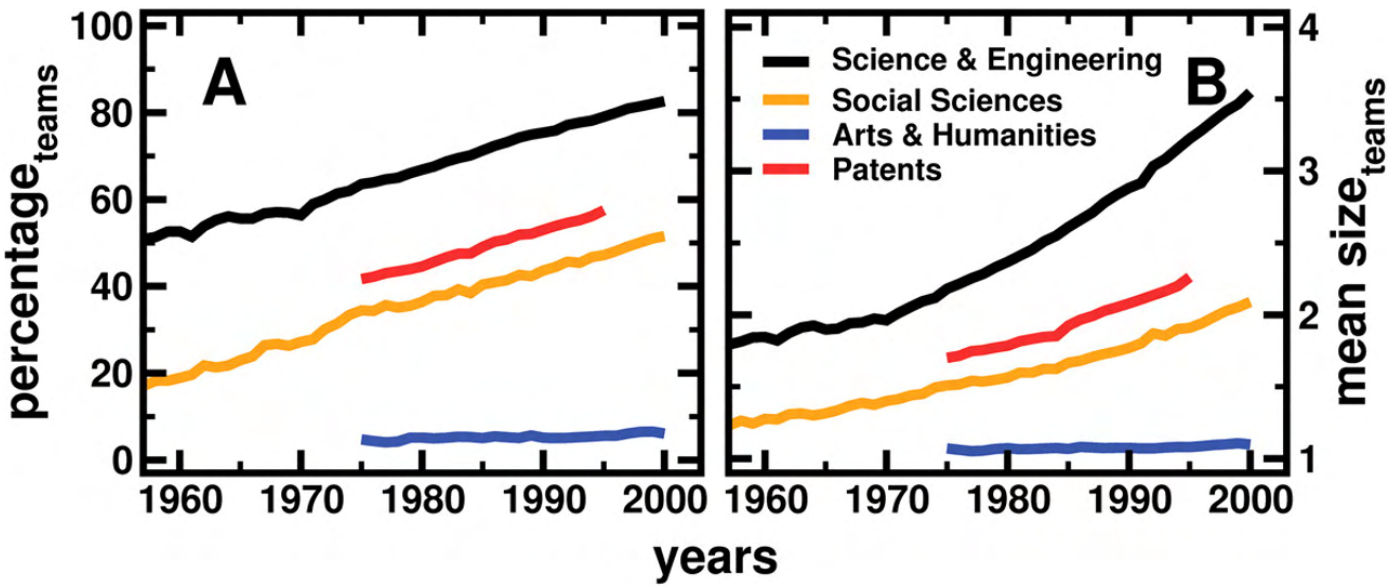
"An acclaimed tradition in the history and sociology of science emphasizes the role of the individual genius in scientific discovery (*1*, *2*). This tradition focuses on guiding contributions of solitary authors, such as Newton and Einstein, and can be seen broadly in the tendency to equate great ideas with particular names, such as the Heisenberg uncertainty principle, Euclidean geometry, Nash equilibrium, and Kantian ethics. The role of individual contributions is also celebrated through science's award-granting institutions, like the Nobel Prize Foundation (*3*)."

Interdisciplinarity: Final Conclusion

		Increasing team size		RTI > 1 (with self-citations)		RTI > 1 (no self-citations)	
	N_{fields}	N_{fields}	%	N_{fields}	%	N_{fields}	%
Science and engineering	171	170	99.4	167	97.7	159	92.4
Social sciences	54	54	100.0	54	100.0	51	94.4
Arts and humanities	27	24	88.9	23	85.2	18	66.7
Patents	36	36	100.0	32	88.9	-	-

Trends for individual fields are presented in table S1. In the sciences, areas like medicine, biology, and physics have seen at least a doubling in mean team size over the 45-year period. Surprisingly, even mathematics, long thought the domain of the loner scientist and least dependent of the hard sciences on lab scale and capital-intensive equipment, showed a marked increase in the fraction of work done in teams, from 19% to 57%, with mean team size rising from 1.22 to 1.84. In the social sciences, psychology, economics, and political science show enormous shifts toward teamwork, sometimes doubling or tripling the propensity for teamwork. With regard to average team size, psychology, the closest of the social sciences to a lab science, has the highest growth (75.1%), whereas political science has the lowest (16.6%). As reflected in Fig. 1A, the humanities show lower growth rates in the fraction of publications done in teams, yet a tendency toward increased teamwork is still observed. All areas of patents showed a positive change in both the fraction of papers done by teams and the team size, with only small variations across the areas of patenting, suggesting that the conditions favoring teamwork in patenting are largely similar across subfields.

Fig. 1. The growth of teams



S. Wuchty et al., Science 316, 1036 -1039 (2007)

"'BE CAREFUL'! ALL YOU CAN TELL ME IS 'BE CAREFUL'?"

FAMILIARIZE yourself with these URLS

Enigma

NSERC www.nserc.gc.ca/index.htm

• the core source for Science Grants

NSERC Related Sites www.nserc.gc.ca/relate.htm

• great one-stop shopping

AAAS-Science http://sciencenow.sciencemag.org

• keep up on trends and policy issues (also Nature)

"My morale has never been higher than since I stopped asking for grants to keep my lab going."

Robert Pollack, Columbia Professor of biology, speaking on "the crisis in scientific morale", Sept. 19, 1996 at GWU symposium *Science in Crisis at the Millennium*. (p. 1805 27/09/96 **Science**)