02: **Gathering information**

January 20, 2012

Announcements

- Please say your name when you make a comment
- If you didn't submit the research summary, please do so
- Our demo account: phdprocessme@gmail.com, phd%2012
  - Google
  - Mendeley
  - Web of Science / Endnote Web / ResearcherID

Our research words (final on ctools)

The practice of doing good research

methodical	a stepwise approach to answering the overarching research question; sequential
goal-oriented	having the end objective in mind
critical	rigorous in one's analysis; questioning
flexible	being able to take a new approach upon failure; adaptable
well-documented	organized and proper aggregation and explanation of information
ethical	

Evaluating good research

thorough	comprehensive presentation of your approach and solution/result
elegant	simple and concise
relevant	there must be a question to match the answer
repeatable	consistency
novel	creative, new solution

Attributes of a good researcher

zealous	curious and passionate; likes questioning everything
communicative	shares and receives information well
perseverent	able to overcome obstacles without losing motivation; not afraid of failure
versatile	able to apply knowledge from other fields; critical open-mindedness
balanced	self-aware of one's own limits; applied personal self-awareness
genius	creative, original, intellectual

This year vs. last year

methodical
goal-oriented
critical
flexible
well-documented
ethical

The practice of doing good research

thorough	presenting a complete solution to the questions you pose
rewarding	gives you a sense of purpose and accomplishment; and a source of
communicative	must be well-documented to be reproducible; clear to the relevant
creative	coming up with a novel approach to the problem
questioning	seeking new knowledge that doesn't necessarily accept established

thorough
elegant
relevant
repeatable
novel

Evaluating good research

repeatable	results can be achieved again by the same process, a different process if
communicated	should convey purpose, approach, results; clear, concise
novel	include new, innovative, creative ways of looking at an old problem
thorough	studied inside and out; and clearly state open questions
high-impact	provides insight or tools useful to the evaluator

zealous
communicative
perseverent
versatile
balanced
genius

Attributes of a good researcher

creative	something that hasn't been yet and is valuable, in an unexpected way
efficient	input of time and money translates to lots of output
communicative	experts and non-experts can understand what you do and why it's important
enthusiastic	natural drive, motivation, even during rough times
diligent	continuously hard-working

Learning styles

Visual

Auditory

Kinaesthetic

Research is defined in a context

The frugal way

George Whitesides CAMBRIDGE, MASSACHUSETTS

The promise of cost-conscious science

George Whitesides: professor of chemistry and principal investigator, Whitesides Research Group, Harvard University

Western science, particularly academic science, is culturally obsessed with superlatives, and often separated from technology: the most accurate measure of time, the most detailed accounting of a genome, the most distant star, the highest-energy particle. Why? Superlatives are necessary in some areas, and easy to keep score with in others. And there are technologies (such as GPS) that absolutely require extreme precision.

But superlatives tend to be expensive. Should cost be an issue in science? If knowledge is a treasure beyond price, perhaps obtaining it should be similarly cost-unconstrained—an idea enthusiastically supported by expensive fields such as high-energy physics. And even the most expensive science is cheap relative to, say, a war or a tsunami. Yet science in 2012 and beyond will be evolving a new variant of itself: frugal science, designed to generate knowledge (and technology based on that knowledge) with cost as an integral part of the subject.

The idea of including "cost" in science is perhaps déclassé in Western research universities, but it is based on an important change in the world. The 80% of the global population that is poor (and has long been excluded from science, technology and the benefits of both) would like to join the party. China, India and Brazil have already muscled their way into technology, and other less-developed countries will follow.

Behind the argument between "superlative" and "cost-effective" lie differences of opinion about the purpose of science. Is it the job of science to generate knowledge as an abstract good, with the benefits to the society that pays for it unpredictable, or should science at least think of serving society?

In the West, the answer is often two words: "quantum mechanics". Its development revolutionised both science and technology, and was indeed a product of pure curiosity. But there have been only one or two such events in fundamental science in the past century (genomics may eventually be as important); and the birth of quantum mechanics was not expensive, although its applications in technology were.

In the rich world, maintaining a distinction between curiosity-driven science and applications-driven technology may or may not be an affordable luxury. In the developing world, there are pressing problems whose solutions require relevant science and technology now.

2012 IN BRIEF

Computer geeks and universities salute and mourn **Alan Turing**, born a century ago

Quick, pass me the screwdriver!

Health care is one example. Western medicine does many things well, but it is not affordable in, or very useful to, most poor populations. What then should be the technology base for affordable health care? Answering that question requires the development of science that is conscious of cost from the beginning—a frugal health care that might, perhaps, be more related to Western public health than to end-of-life, high-tech medicine. What about other problems: the management of megacities, development of radically effective ways of delivering education, or providing water and energy? All of these problems can be phrased as technologies, which will require an appropriate foundation in science—and that must include cost. The race may not be to the swift, but rather to the cheap.

> The race may not be to the swift, but rather to the cheap

There is another reason to be encouraging frugal science: jobs. Frugal science has a chance of yielding cheap products, and thus jobs and other understandable benefits. The developing world is pioneering telecoms systems with structures quite different from those used in the rich world. The Shenzhen gene factories, using American technology, are among the lowest-cost producers of genomic information. The Tata Nano car represents a creative step towards low-cost personal transport. And the science that leads to affordable health care for Africa may provide some of the best approaches to reducing the no-longer-affordable cost of health care in America.

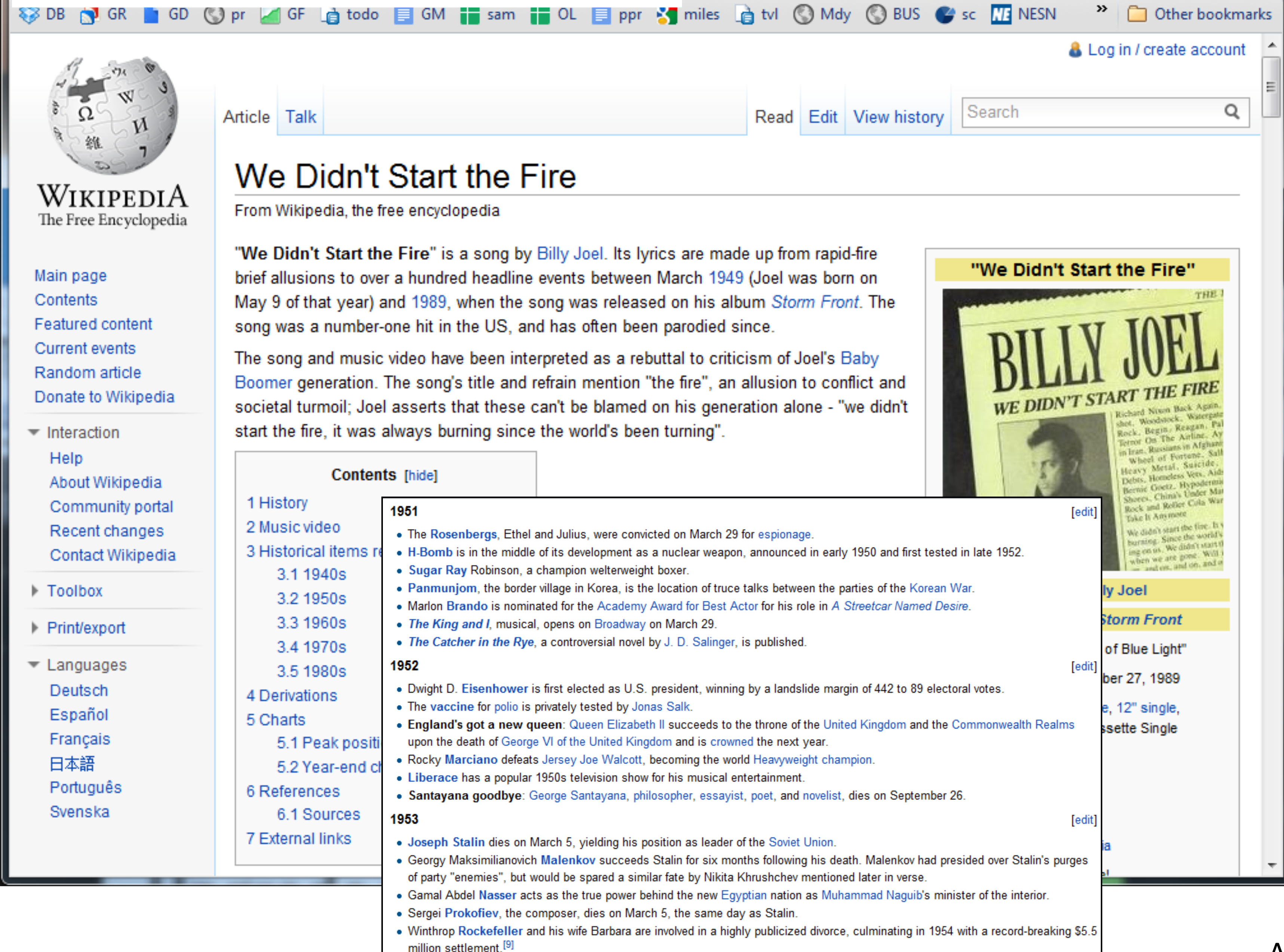
Foundations (Gates, Wellcome and others) are already developing frugal medicine, and much of the health-care spending in developing countries is on technology that is, of necessity, frugal. The science base for this—low-cost diagnostics, epidemiology and nutrition informed by mobile-phone reporting—is developing rapidly. Tata, GM, Toyota and their kin are all thinking about radically different concepts for the car: smaller, lighter, cheaper. To sell in world markets, affordability may in future be the first requirement, not an afterthought.

"But is it science?" ask the sceptics. Perhaps "No", under the old definitions of chemistry, physics and biology. But "Yes", as a new discipline, with an intellectual skeleton based on understanding complexity and simplicity, and on developing strategies for integrating information, including economic information, originating in entirely different fields. It will probably get a reluctant welcome at first in the mandarin research universities of America and Europe, but it may flourish in Beijing, Mumbai and Cairo. And where it flourishes best may determine whose grandchildren have jobs. ■

Our topics

- Elastofluidic actuators
- ABS braking control
- Nanocomposite materials
- Microofluidics
- Energy harvesting
- Vehicle dynamics
- Modeling piezoelectric actuators
- Molecular modeling of combustion
- High energy density plasmas
- Attitude estimation of mobile robots
- Combustion engines
- Moving magnet actuators
- etc…

The library has changed



I want to gather all the information (i.e., read all the literature) that might interest me (utopia), but when I can't do that (reality) I want to make sure that it is easy for me to find the most important/relevant literature, and that I use electronic tools to help me do so as efficiently as possible.

Today’s mission

→ How do I…

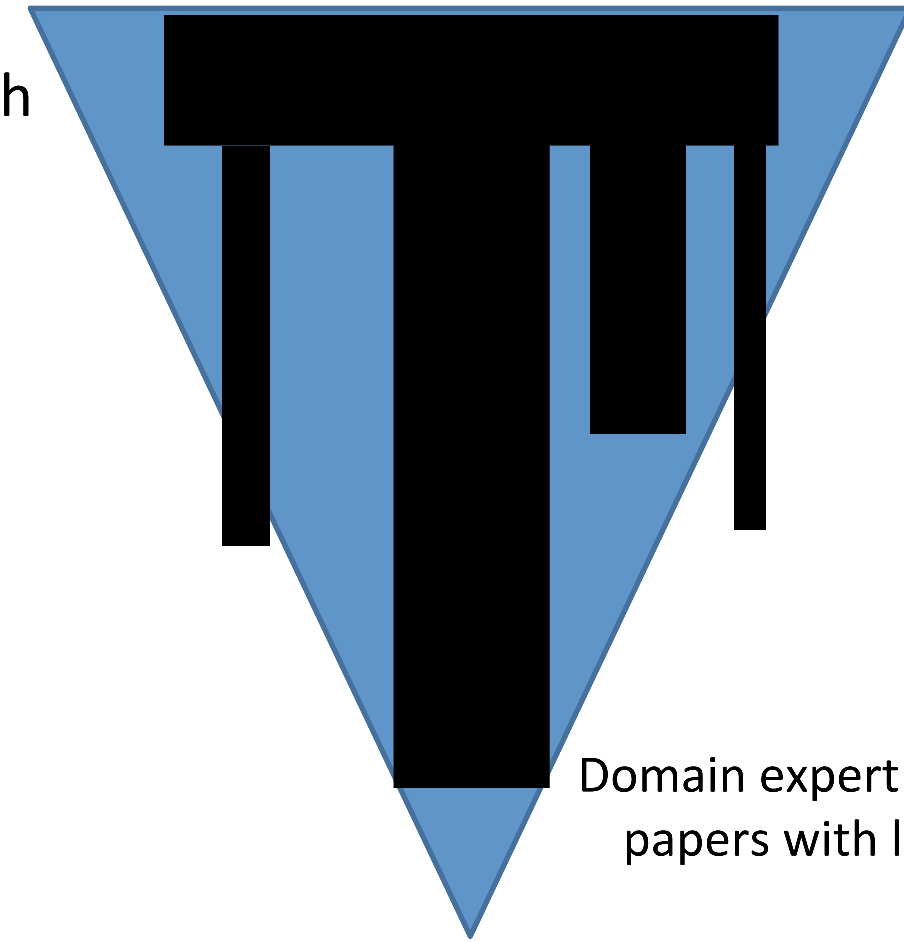
- ..know what and where to search?
- ..do the search?
- ..know if what I’m reading is important to my field/topic?
- ..keep track of what I read?
- ..keep up to date on the latest “news” after my big search is complete?

What sources should I read? (ex. battery research)

- Journals
  - Inside your field (e.g.. Journal of the Electrochemical Society)
  - Interdisciplinary (e.g., Advanced Materials, Nature)
  - Outside your field but encompassing complementary topics (e.g., Journal of the Mechanics and Physics of Solids)
- Conference proceedings (abstracts or papers)
  - These should come up in your searches, and you should know which conferences are most relevant, and get the proceedings if you can't attend the conference
- Theses
  - Theses often have much more detail than journal papers. You might need to search the library website of the university where the research was done.
- Patents and industry reports
  - If your work has commercial applications, patents can give important design/process details and practical hints.

Depth

Breadth



Interdisciplinary journals,
review papers

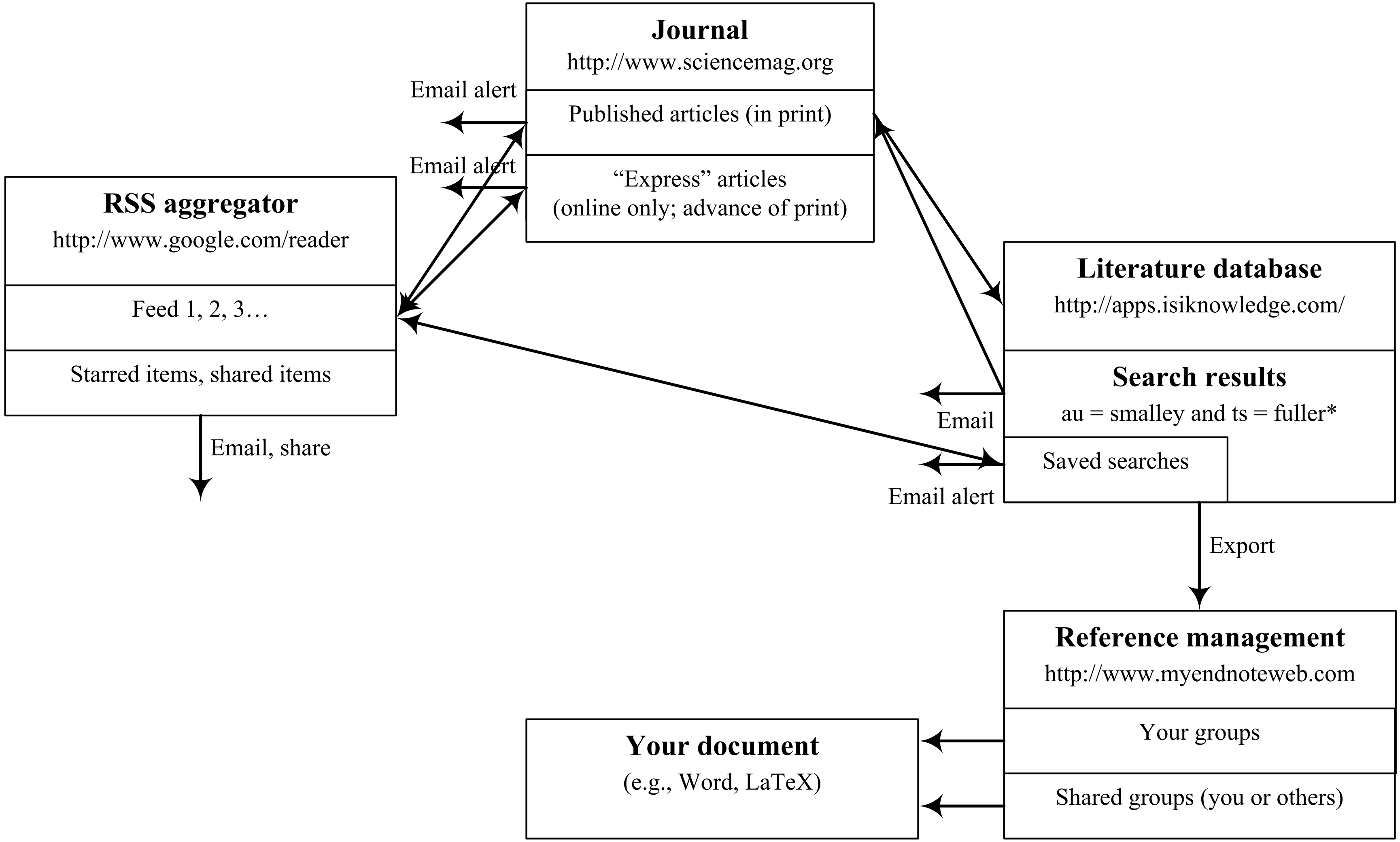
Domain expert journals, long
papers with lots of equations

How do I search about a new topic?

- Identify keywords for your topic and browse ALL the articles you find.
  - "It is advisable to make a thorough study of all the relevant literature early in the investigation, for much effort may be wasted even if only one significant article is missed." [Beveridge]
- Identify key sources (journals, books, conference proceedings) related to your topic, and browse these sources.
- Identify leaders (heroes!) and look up their publications. Follow the references.
- Find review papers, and follow the references back and forth.

- ALWAYS: revise the keywords, follow references back and forth, stay on top of the alerts.

John's approach to Digital Literature Management (DLM)



Things to do to setup basic DLM

- ISI web of science account (sign up from campus network)
  - This is also your endnote web (ENW) account, www.myendnoteweb.com
- Google account
  - Lets you into Google Reader, www.google.com/reader/
- Install ENW "Cite While You Write" plugin
  - ENW homepage → at bottom "Download Installers"
  - You only need this one to import references into Word
- Proxy server for off-campus access
  - http://www.lib.umich.edu/mlibrary-labs/proxy-server-bookmarklet
  - or VPN (use Cisco client software)

Other things?

- h-index
- The DOI (dx.doi.org)
- The UM proxy server and VPN

- How much time should I spend per week (in steady-state mode)?
- How do I archive what I read?

Literature search assignment

Due on ctools at 2p Friday, February 3

a. Identify at least 5 journals that publish articles in your area of interest. Sign up for RSS feeds from these journals, e.g., using Google Reader.

b. Identify 5-10 keywords that represent the research theme that you will explore in this class.

c. Identify at least 3 combinations of these keywords that return a reasonable number of distinct articles in ISI Web of Science (or other suitable database). Sign up for search alerts (email or RSS feed) on these combinations. It will be helpful to look through the results of each search to see if the contents are highly relevant, and iterate on the keywords/syntax chosen.

d. Start a library using Endnote Web, Mendeley, or another platform. Based on the results from (c) or other searches that you find to be more effective, add the following to your library:
   1. 3 seminal (= relatively old, highly cited) papers.
   2. 2 recent (within 5 years) review papers.
   3. 5 very recent (0-2 years) papers which are highly relevant to your research topic.

e. **Submit a Word document including**
   1. A summary (<0.5 page) of the anticipated theme of your Ph.D. research (or other topic discussed with John). This may be identical to your "research summary" assignment, or it may be revised as you wish. The theme should align well what you are searching for this assignment.
   2. A screenshot of your RSS reader listing the journal feeds. It's ok if some of the feeds don't have new items yet, as long as the journal name is
   3. The list of 5 journals from (a), along with the impact factor of each journal (as found in the ISI citation index), and a 1-2 sentence summary of why you chose each journal.
   4. Your list of keywords.
   5. Your search terms (combinations of keywords), in the advanced search syntax of Web of Science. State the number of articles that each search returned.
   6. Citations for the papers from (d), separated by category as listed in (d), and formatted using the "Nature" reference format. If you are having trouble (or prefer not to) install the Endnote plugin, enter the references using you preferred method (e.g., the Word footnote or endnote feature), in a consistent and complete format of your choice.

<u>Note:</u> if you have a different preferred way to search (e.g., database) and cite literature (e.g., way to import references into document software), you are welcome to use this process as long as you mention it in your submission, and fulfill all the requirements listed above.

Gathering information might be thorny

Serengeti National Park, Tanzania, August 2008

The search for information is endless

> “The lame in the path outstrip the swift
> who wander from it.”—FRANCIS BACON

Study

THE research worker remains a student all his life. Preparation for his work is never finished for he has to keep abreast with the growth of knowledge. This he does mainly by reading current scientific periodicals. Like reading the newspapers, this study becomes a habit and forms a regular part of the scientist’s life.

Beveridge, The Art of Scientific Investigation

Read critically

One of the most common mistakes of the young scientist starting research is that he believes all he reads and does not distinguish between the results of the experiments reported and the author's interpretation of them. Francis Bacon said :

> " Read not to contradict and confute, nor to believe and take for granted . . . but to weigh and consider." [7]

The man with the right outlook for research develops a habit of correlating what is read with his knowledge and experience, looking for significant analogies and generalisations. This method of study is one way in which hypotheses are developed, for instance it is how the idea of survival of the fittest in evolution came to Darwin and to Wallace.

Beveridge, The Art of Scientific Investigation

Read beyond your topic

Successful scientists have often been people with wide interests. Their originality may have derived from their diverse knowledge. As we shall see in a later chapter on Imagination, originality often consists in linking up ideas whose connection was not previously suspected. Furthermore, variety stimulates freshness of outlook whereas too constant study of a narrow field predisposes to dullness. Therefore reading ought not to be confined to the problem under investigation nor even to one's own field of science, nor, indeed, to science alone. However, outside one's immediate interests, in order to minimise time spent in reading, one can read for the most part superficially, relying on summaries and reviews to keep abreast of major developments. Unless the research worker cultivates wide interests his knowledge may get narrower and narrower and restricted to his own speciality. One of the advantages of teaching is that it obliges the scientist to keep abreast of developments in a wider field than he otherwise would.

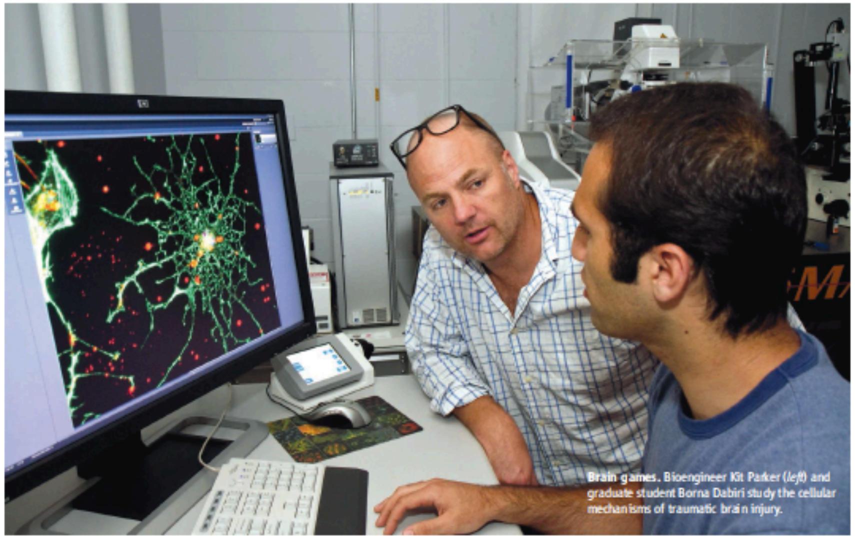
Beveridge, The Art of Scientific Investigation

"A successful person [researcher] isn't necessarily better than her less successful peers at solving problems, her pattern-recognition facilities have just learned what problems are worth solving."

-Ray Kurzweil

Inspiration and information go hand-in-hand

NEWSFOCUS



Brain games. Bioengineer Kit Parker (*left*) and graduate student Borna Dabiri study the cellular mechanisms of traumatic brain injury.

PROFILE: KIT PARKER

Engineering a New Line of Attack On a Signature War Injury

By jolting neurons in the lab, an Army officer and bioengineer hopes to gain ground on traumatic brain injury

When hijacked planes slammed into the World Trade Center towers in 2001, Kevin Kit Parker knew he had to do something. He'd always had a patriotic streak, and years earlier, while a graduate student in applied physics at Vanderbilt University in Nashville, Tennessee, Parker had enrolled in the Army Reserve Officers' Training Corps (ROTC). By the time of the attacks, he was a postdoctoral fellow, working on cardiac electrophysiology at Johns Hopkins University in Baltimore, Maryland, and in the middle of hunting for his first faculty position. He felt certain the country would soon be going to war, and despite having several job interviews on his calendar, he transferred to a unit he knew would be deployed. "I wanted to get in the game," he says.

While waiting to deploy, Parker accepted a job at Harvard University. With considerable trepidation, he asked the dean who'd just hired him for an immediate leave of absence to go to Afghanistan. It was a very unusual request, says then-dean Venkatesh Narayanamurti. Few, if any, Harvard professors have taken combat leave since World War II. But Narayanamurti admired Parker's dedication to national service. "I knew right away I would support him," he says.

By fall 2002, Parker was leading a team that patrolled a 900-square-kilometer swath between Kandahar and the Pakistan border, providing aid to villagers and searching for Taliban and Al Qaeda fighters. He finally started his job at Harvard in the summer of 2003, then deployed again in 2008, putting postdocs in charge of running the lab in his absence. His deployments caused Parker to reconsider the focus of his research and to establish a project on a signature injury of the wars in Iraq and Afghanistan: traumatic brain injury (TBI). He has been back to Afghanistan twice more as part of a panel of experts convened to assess how the military handles TBI and combat stress.

The Pentagon estimates that more than 200,000 U.S. troops have experienced TBIs in the recent conflicts, mostly from roadside bombs and other improvised explosive devices (IEDs). The long-term effects of these brain injuries won't be known for decades, but there are already worrisome hints that TBI may compound the effects of combat stress and predispose veterans to the type of early-onset dementia seen in football players with a history of head injuries (*Science*, 29 July 2011, pp. 514 and 517). Despite the urgency of the problem, frustratingly little is known about the mechanisms by which an explosive blast injures the brain, Parker says. "I kept seeing guys get hit, and I thought, all right, I'll take a look at this and see if I can get a better angle on the problem."

Mission shift

On a recent morning, Parker's students and postdocs mill about a conference room before their weekly lab meeting. They pour coffee and set out a plate of jalapeño bagels for Parker, who likes to goad others into eating spicy food. He arrives a few minutes late, wearing torn jeans and a red Harvard baseball cap with the bill folded into a sharp crease. A commanding presence at just under 6′6″ (2 meters), Parker has a booming voice that bears more than a trace of his upbringing in west Tennessee. He launches into a list of lab business he's scribbled on a whiteboard. Some Italian researchers have asked about collaborating; so has a team from Merck, the pharmaceutical giant. And Parker has just returned from a molecular medicine conference in Korea. "Y'all make some damn fine fried chicken over there," he says to one of his Korean-born postdocs. "Hyungsuk, do you make that stuff at home?" When he shakes his head no, Parker pretends to be heartbroken. A second later, he's back to his list.

When Parker first arrived at Harvard, his main academic interest was the physical forces that determine how cells and tissues build themselves. His lab did cardiac tissue engineering, and that's still the focus for about two-thirds of his group. At the lab meeting, postdoc Anna Grosberg presents a computational tool she's developed for quantifying the alignment of sarcomeres, the protein fibers that make up muscle cells. How the fibers line up affects how a muscle contracts, and Parker thinks the tool could be useful for clinical pathologists or companies interested in engineering cardiac tissue for drug screens or therapies. In quick asides, he quizzes David Coon, who handles industry relations and intellectual property issues for the lab, about the commercialization prospects, and asks Sean Sheehy, a grad student with a computer science background, how hard it would be to incorporate Grosberg's metric into a graphical software package. When Sheehy says it's doable, Parker jokingly tells him: "This is your project now, baby!"

Ideas and projects spring up freely in the lab. A cotton-candy machine inspired a new way for making nanofiber scaffolds on which to grow cells (and a 2010 paper in *Nano Letters*). Back in his office, Parker shows off a movie on his computer of a more recent project: an artificial jellyfish. Cut from a polymer sheet coated with rat heart muscle cells, its form lacks the organic curves of the real thing, but the ghostly flap of tissue pulses across the screen with surprisingly lifelike motion.

Parker sees his fledgling TBI research project as a moral obligation. He saw IED explosions firsthand in Afghanistan, and he has buddies who've suffered the consequences. When Colonel Geoffrey Ling, the program manager who oversees TBI research at the Defense Advanced Research Projects Agency (DARPA), asked Parker in 2006 if he'd ever thought about studying TBI, he demurred at first. "I said, 'There have to be better people than me; I'm not a brain guy,'" Parker says. But as he started reading the scientific literature, he was struck by how little was known about what happens at the cellular level in a TBI.

In the thick of it. Parker, here searching for IEDs in Afghanistan, has changed the course of his research after two tours of duty.

Concussion on a chip

One prevalent idea has been that a blast wave or physical blow to the head tears the membranes of neurons, allowing positive ions to rush in and overexcite neurons to the point of killing them. Based on his experience with tissue engineering, Parker suspected something else might be going on instead, or in addition. He was surprised to see nothing in the research literature about integrins, proteins in the membrane of all cells that connect a cell's internal protein skeleton to the scaffold of proteins outside the cell, the so-called extracellular matrix. Parker reasoned that the force of a blast could propagate through this network of proteins, interfering with integrins and the many cell-signaling pathways they interact with.

The first challenge was figuring out how to go about studying TBI in the lab. Researchers have studied TBI by issuing blows to the heads of rats, pigs, and other animals, but it's not clear how well those experiments replicate what the human brain experiences in a car crash or explosive blast. Moreover, Parker says, "if I start blowing up goats at Harvard, I'm not going to last long." As an alternative, his lab has devised an arsenal of devices that can subject cultured neurons or slices of brain tissue to carefully calibrated forces. "We need to think of ways to replicate this on the bench top so you can mainstream the science," Parker says.

Their early work supports the idea that integrins may play a role in TBI. In one study, graduate student Matthew Hemphill and others put cultured rat neurons on a stretchy, square sheet of silicone that could be given a short tug by a high-precision motor. These tugs subjected the neurons to forces that the researchers estimated would be similar to those generated inside the head of a soldier exposed to an IED blast. Within a few minutes, microscopic swellings appeared on the spindly axons and dendrites that send and receive messages from neighboring neurons. Axonal injury is a hallmark of TBI, and a diffusion tensor imaging study by a different group published 2 June 2011 in *The New England Journal of Medicine* found evidence of axon damage in U.S. soldiers who suffered TBIs in Iraq. Additional experiments with the cultured rat neurons implicated a particular integrin signaling pathway in this damage. Treating the neurons with a drug that inhibits a component of this pathway called Rho-kinase reduced damage to neurons after a simulated blast, the researchers reported in *PLoS ONE* in July 2011.

In another study, published 2 August 2011 in the *Proceedings of the National Academy of Sciences*, a team led by then-postdoc Patrick Alford used the same setup to investigate the effects of a simulated blast on blood vessels. In this case, the researchers used rat muscle cells from the lining of blood vessels. When subjected to a sudden stretch, these cells flipped a genetic switch that made them more likely to contract and promoted their proliferation. Both effects would tend to clamp down on blood vessels,

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CREDIT: KIT PARKER

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Cracking Open the Scientific Process

Timothy Fadek for The New York Times

A GLOBAL FORUM Ijad Madisch, 31, a virologist and computer scientist, founded ResearchGate, a Berlin-based social networking platform for scientists that has more than 1.3 million members.

By THOMAS LIN

Published: January 16, 2012

The New England Journal of Medicine marks its 200th anniversary this year with a timeline celebrating the scientific advances first described in its pages: the stethoscope (1816), the use of ether for anesthesia (1846), and disinfecting hands and instruments before surgery (1867), among others.

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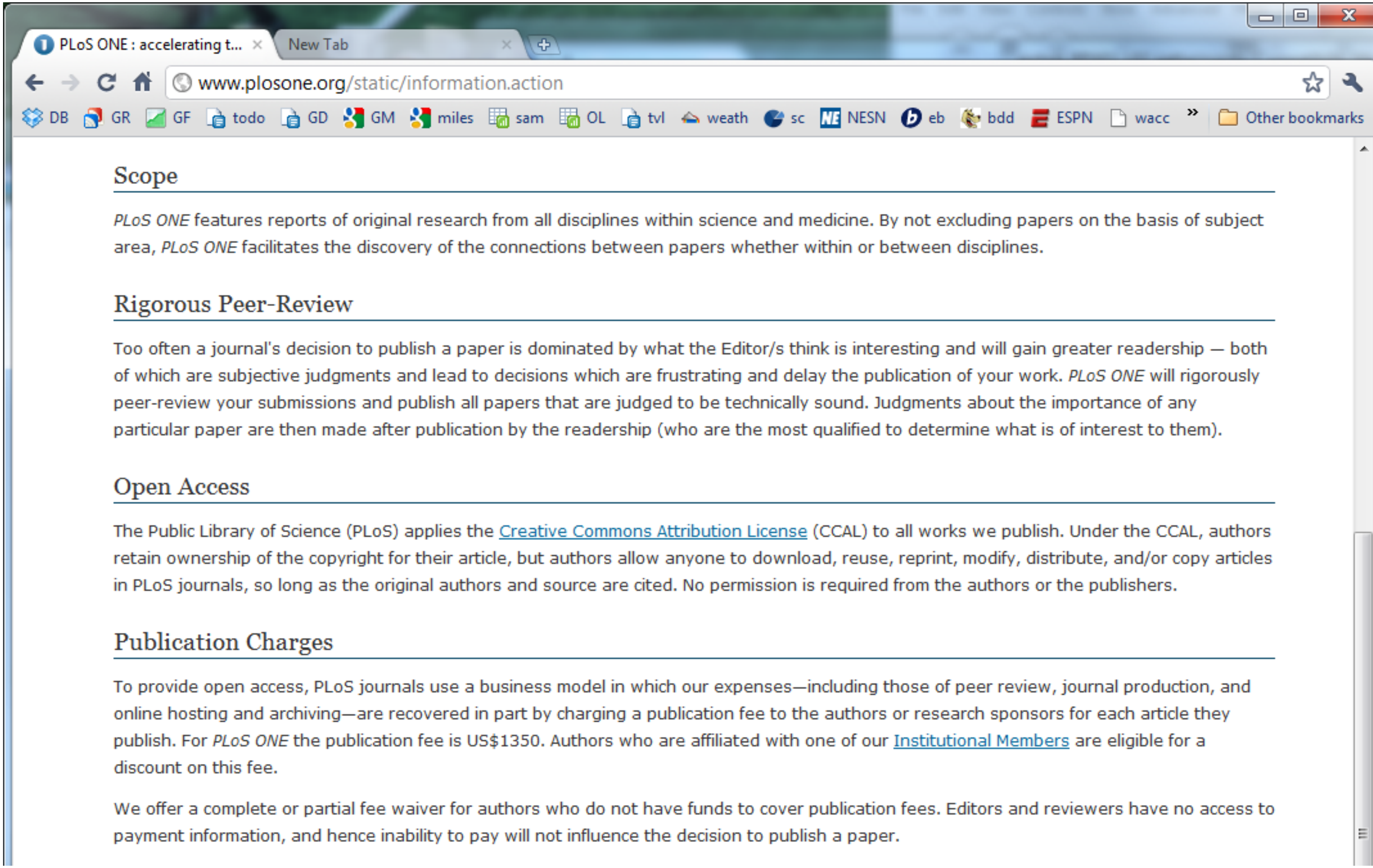
What does the future hold?

- Open-access journals
- Multimedia journals
- New publication formats?
- Social reviewing?
- Natural language processing
- Cloud computing (parallelism …shipping HDs is the bottleneck)
- …?

PLoS (plosone.org)



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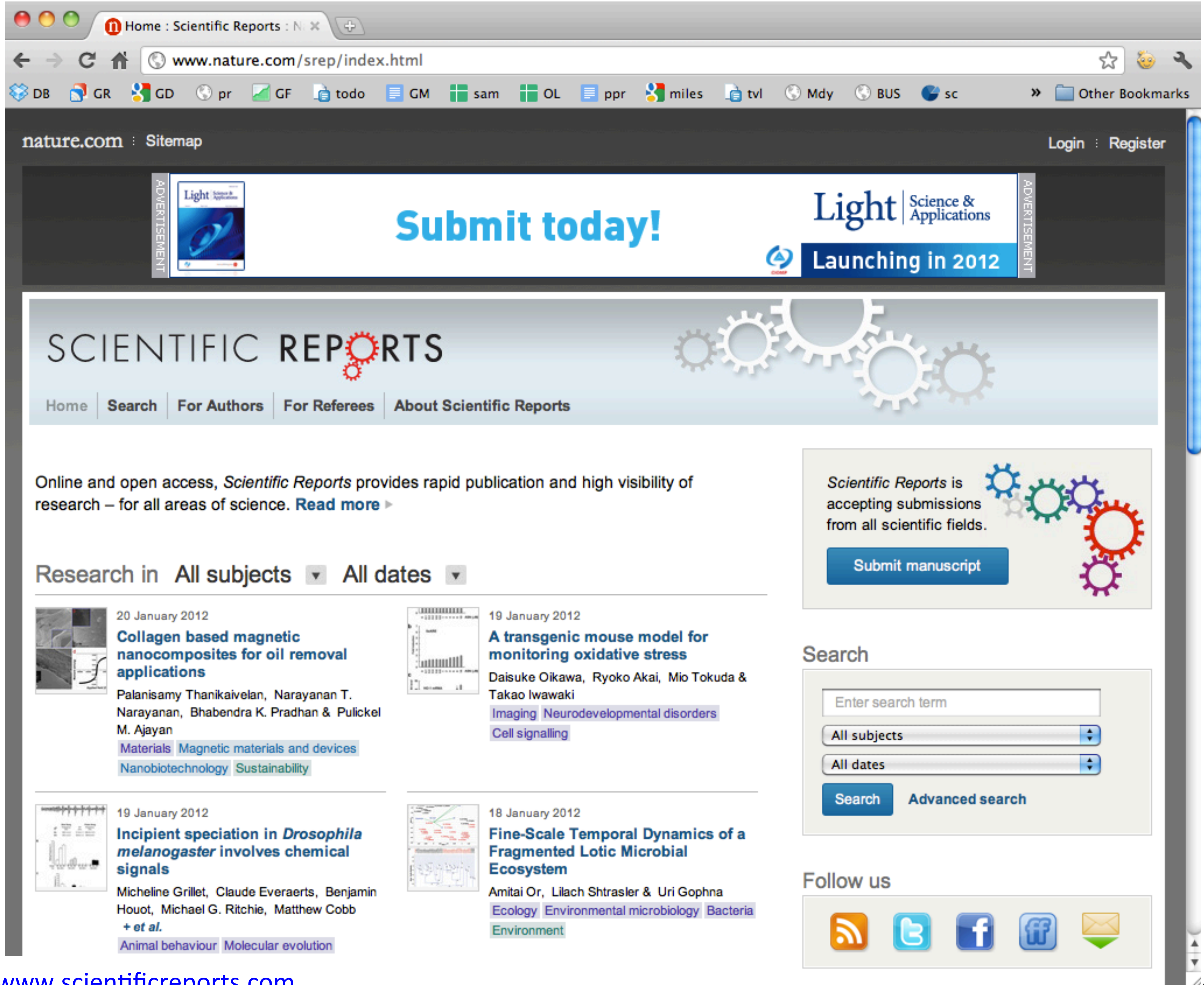

www.scientificreports.com

Quantifying interdisciplinarity: what fields does nanotechnology span?

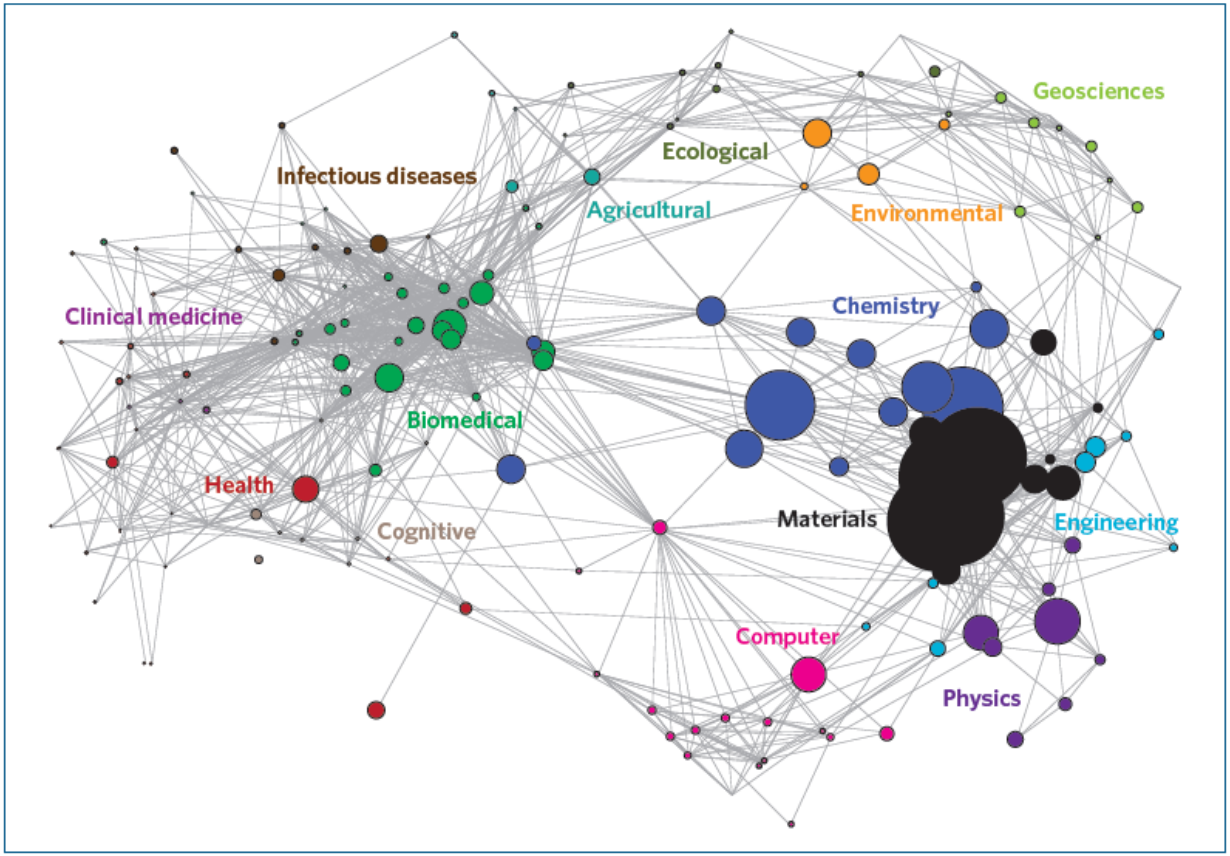

Figure 1 | The position of nanoscience and nanotechnology over a base map of science. Each node in this map[15] is one of the 175 subject categories in the SCI. The size of each node is proportional to the number of nanopapers published in journals in each subject category during the period January–July 2008. Location on the axes in this Kamada–Kawai algorithm representation has no inherent meaning: the connecting arcs and proximity reflect similarity based on cross-citation patterns, reinforced by colouring to reflect the clustering of subject categories into macrodisciplines (see Methods). See Table 1 for full macrodiscipline names.

Porter and Youtie, *Nature Nanotechnology*, 2009.

Mapping the emergence of new fields

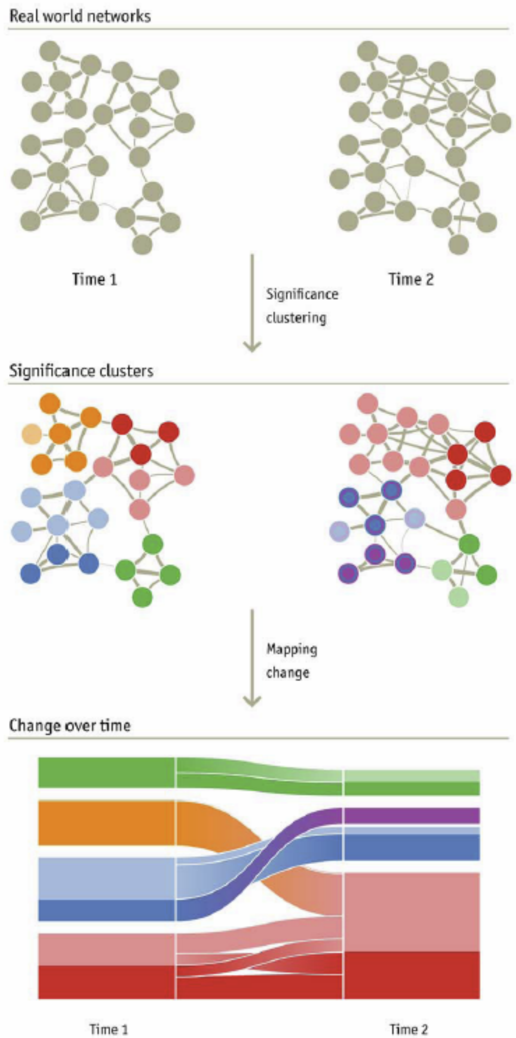

Figure 2. Mapping change in networks. An alluvial diagram (bottom), with clusters ordered by size, reveals changes in network structures over time. Here the height of each block represents the volume of flow through the cluster, with significant subsets in darker color. The orange module merges with the red module, but the nodes are not clustered together in 95% of the bootstrap networks. The blue module splits, but the significant nodes in the blue and purple modules are clustered together in more than 5% of the bootstrap networks. With a 5% significance threshold, neither change is significant.
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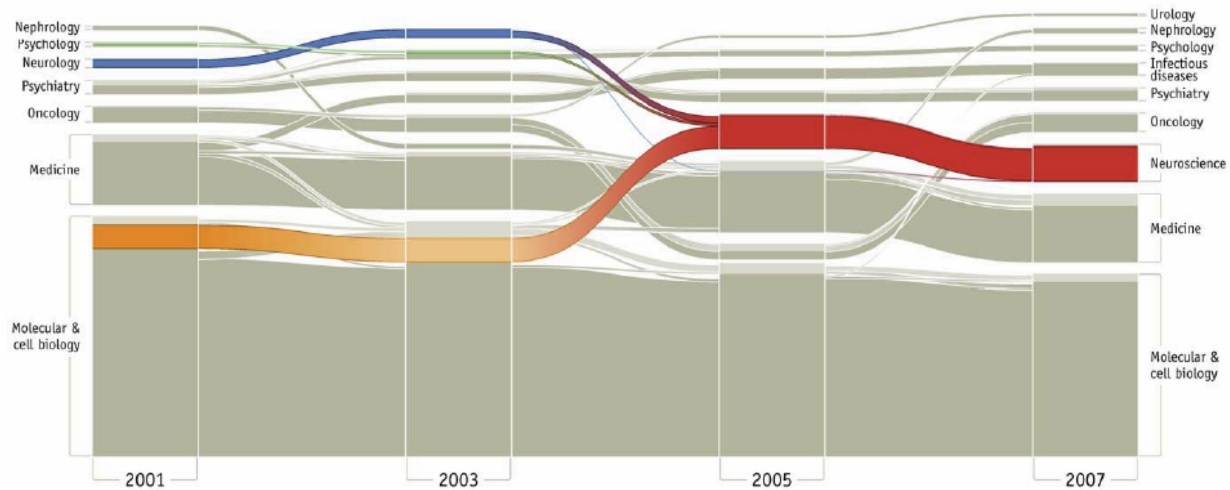

Figure 3. Mapping change in science. This set of scientific fields show the major shifts in the last decade of science. Each significance clustering for the citation networks in years 2001, 2003, 2005, and 2007 occupies a column in the diagram and is horizontally connected to preceding and succeeding significance clusterings by stream fields. Each block in a column represents a field and the height of the block reflects citation flow through the field. The fields are ordered from bottom to top by their size with mutually nonsignificant fields placed together and separated by half the standard spacing. We use a darker color to indicate the significant subset of each cluster. All journals that are clustered in the field of neuroscience in year 2007 are colored to highlight the fusion and formation of neuroscience.
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Rosvall and Bergstrom 2011, http://www.plosone.org/article/info:doi/10.1371/journal.pone.0008694

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Google Effects on Memory: Cognitive Consequences of Having Information at Our Fingertips

Betsy Sparrow,[1]* Jenny Liu,[2] Daniel M. Wegner[3]

The advent of the Internet, with sophisticated algorithmic search engines, has made accessing information as easy as lifting a finger. No longer do we have to make costly efforts to find the things we want. We can "Google" the old classmate, find articles online, or look up the actor

The advent of the Internet, with sophisticated algorithmic search engines, has made accessing information as easy as lifting a finger. No longer do we have to make costly efforts to find the things we want. We can "Google" the old classmate, find articles online, or look up the actor who was on the tip of our tongue. The results of four studies suggest that when faced with difficult questions, people are primed to think about computers and that when people expect to have future access to information, they have lower rates of recall of the information itself and enhanced recall instead for where to access it. The Internet has become a primary form of external or transactive memory, where information is stored collectively outside ourselves.

as Google and databases such as IMDB and the information stored there, has become an external memory source that we can access at any time.

Storing information externally is nothing particularly novel, even before the advent of computers. In any long-term relationship, a team work environment, or other ongoing group, people typically develop a group or transactive memory (*1*), a combination of memory stores held directly by individuals and the memory stores they can access because they know someone who knows that information. Like linked computers that can address each other's memories,

[1]Department of Psychology, Columbia University, 1190 Amsterdam Avenue, New York, NY 10027, USA. [2]Department of Psychology, University of Wisconsin–Madison, 1202 West Johnson Street, Madison, WI 53706, USA. [3]Department of Psychology, Harvard University, 33 Kirkland Street, Cambridge, MA 02138, USA.

*To whom correspondence should be addressed. E-mail: sparrow@psych.columbia.edu

in two within-subject conditions (*4*). Participants answered either easy or hard yes/no trivia questions in two blocks. Each block was followed by a modified Stroop task (a color-naming task with words presented in either blue or red) to test reaction times to matched computer and noncomputer terms (including general and brand names for both word groups). People who have been disposed to think about a certain topic typically show slowed reaction times (RTs) for naming the color of the word when the word itself is of interest and is more accessible, because the word captures attention and interferes with the fastest possible color naming.

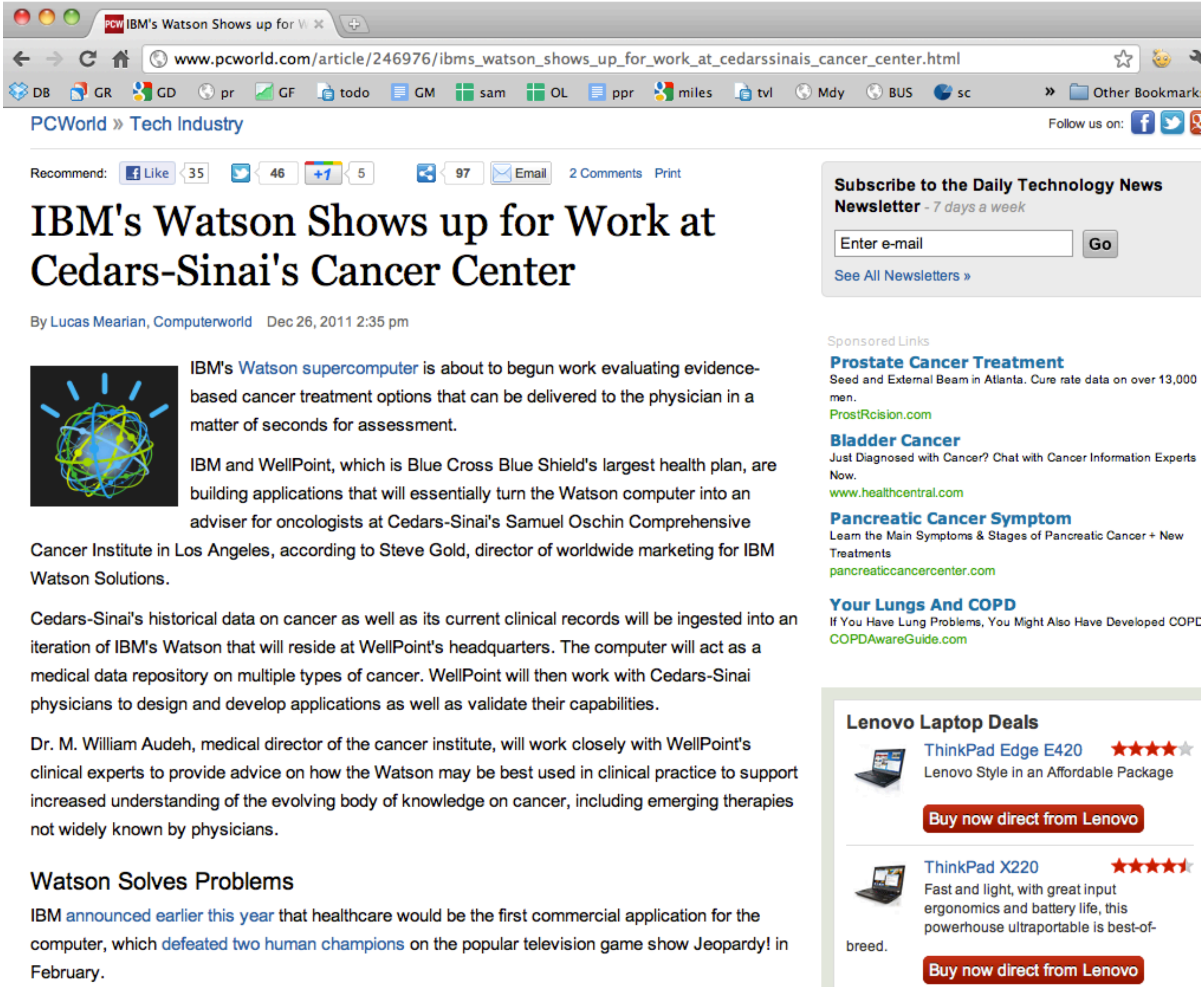
Paired within-subject t tests were conducted on color-naming reaction times to computer and general words after the easy and difficult question blocks. Confirming our hypothesis, computer words were more accessible [color-naming RT mean (M) = 712 ms, SD = 413 ms] than general words (M = 591 ms, SD = 204 ms) after participants had encountered a series of questions to which they did not know the answers, $t(68) = 3.26$, $P < 0.003$, two-tailed. It seems that when we are faced with a gap in our knowledge, we are primed to turn to the computer to rectify the situation. Computer terms also interfered somewhat more with color naming (M = 603 ms, SD = 193 ms) than general terms (M = 559 ms, SD = 182 ms) after easy questions, $t(68) = 2.98$, $P < 0.005$, suggesting that the computer may be primed when the concept of knowledge in general is activated.

Comparison using a repeated measures anal-

have later access to—as they might with information they could look up online (*4*). Participants were tested in a 2 by 2 between-subject experiment by reading 40 memorable trivia statements of the type that one would look up online (both of the new information variety, e.g., "An ostrich's eye is bigger than its brain," and information that may be remembered generally, but not in specific detail, e.g., "The space shuttle Columbia disintegrated during re-entry over Texas in Feb. 2003."). They then typed them into the computer to ensure attention (and also to provide a more generous test of memory). Half the participants believed the computer would save what was typed; half believed the item would be erased. In addition, half of the participants in each of the saved and erased conditions were asked explicitly to try to remember the information. After the reading and typing task, participants wrote down as many of the statements as they could remember.

IBM Watson

- http://www.youtube.com/watch?v=FC3IryWr4c8
- Test matches: http://www.youtube.com/watch?v=7kOEmupSHB8&feature=channel



IBM's Watson Shows up for W

www.pcworld.com/article/246976/ibms_watson_shows_up_for_work_at_cedarssinais_cancer_center.html

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IBM's Watson Shows up for Work at Cedars-Sinai's Cancer Center

By Lucas Mearian, Computerworld Dec 26, 2011 2:35 pm

IBM's Watson supercomputer is about to begun work evaluating evidence-based cancer treatment options that can be delivered to the physician in a matter of seconds for assessment.

IBM and WellPoint, which is Blue Cross Blue Shield's largest health plan, are building applications that will essentially turn the Watson computer into an adviser for oncologists at Cedars-Sinai's Samuel Oschin Comprehensive Cancer Institute in Los Angeles, according to Steve Gold, director of worldwide marketing for IBM Watson Solutions.

Cedars-Sinai's historical data on cancer as well as its current clinical records will be ingested into an iteration of IBM's Watson that will reside at WellPoint's headquarters. The computer will act as a medical data repository on multiple types of cancer. WellPoint will then work with Cedars-Sinai physicians to design and develop applications as well as validate their capabilities.

Dr. M. William Audeh, medical director of the cancer institute, will work closely with WellPoint's clinical experts to provide advice on how the Watson may be best used in clinical practice to support increased understanding of the evolving body of knowledge on cancer, including emerging therapies not widely known by physicians.

Watson Solves Problems

IBM announced earlier this year that healthcare would be the first commercial application for the computer, which defeated two human champions on the popular television game show Jeopardy! in February.

We have demonstrated the discovery of physical laws, from scratch, directly from experimentally captured data with the use of a computational search. We used the presented approach to detect nonlinear energy conservation laws, Newtonian force laws, geometric invariants, and system manifolds in various synthetic and physically implemented systems without prior knowledge about physics, kinematics, or geometry. The concise analytical expressions that we found are amenable to human interpretation and help to reveal the physics underlying the observed phenomenon. Many applications exist for this approach, in fields ranging from systems biology to cosmology, where theoretical gaps exist despite abundance in data.

Might this process diminish the role of future scientists? Quite the contrary: Scientists may use processes such as this to help focus on interesting phenomena more rapidly and to interpret their meaning.

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Supporting Online Material

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The Automation of Science

Ross D. King,[1*] Jem Rowland,[1] Stephen G. Oliver,[2] Michael Young,[3] Wayne Aubrey,[1] Emma Byrne,[1] Maria Liakata,[1] Magdalena Markham,[1] Pinar Pir,[2] Larisa N. Soldatova,[1] Andrew Sparkes,[1] Kenneth E. Whelan,[1] Amanda Clare[1]

The basis of science is the hypothetico-deductive method and the recording of experiments in sufficient detail to enable reproducibility. We report the development of Robot Scientist "Adam," which advances the automation of both. Adam has autonomously generated functional genomics hypotheses about the yeast *Saccharomyces cerevisiae* and experimentally tested these hypotheses by using laboratory automation. We have confirmed Adam's conclusions through manual experiments. To describe Adam's research, we have developed an ontology and logical language. The resulting formalization involves over 10,000 different research units in a nested treelike structure, 10 levels deep, that relates the 6.6 million biomass measurements to their logical description. This formalization describes how a machine contributed to scientific knowledge.

Computers are playing an ever-greater role in the scientific process (*1*). Their use to control the execution of experiments contributes to a vast expansion in the production of scientific data (*2*). This growth in scientific data, in turn, requires the increased use of computers for analysis and modeling. The use of computers is also changing the way that science is described and reported. Scientific knowledge is best expressed in formal logical languages (*3*). Only formal languages provide sufficient semantic clarity to ensure reproducibility and the free exchange of scientific knowledge. Despite the advantages of logic, most scientific knowledge is expressed only in natural languages. This is now changing through developments such as the Semantic Web (*4*) and ontologies (*5*).

A natural extension of the trend to ever-greater computer involvement in science is the concept of a robot scientist (*6*). This is a physically implemented laboratory automation system that exploits techniques from the field of artificial intelligence (*7*–*9*) to execute cycles of scientific experimentation. A robot scientist automatically originates hypotheses to explain observations, devises experiments to test these hypotheses, physically runs the experiments by using laboratory robotics, interprets the results, and then repeats the cycle.

High-throughput laboratory automation is transforming biology and revealing vast amounts of new scientific knowledge (*10*). Nevertheless, existing high-throughput methods are currently inadequate for areas such as systems biology. This is because, even though very large numbers of experiments can be executed, each individual experiment cannot be designed to test a hypothesis about a model. Robot scientists have the potential to overcome this fundamental limitation.

The complexity of biological systems necessitates the recording of experimental metadata in as much detail as possible. Acquiring these metadata has often proved problematic. With robot scientists, comprehensive metadata are produced as a natural by-product of the way they work. Because the experiments are conceived and executed automatically by computer, it is possible to completely capture and digitally curate all aspects of the scientific process (*11*, *12*).

To demonstrate that the robot scientist methodology can be both automated and be made effective enough to contribute to scientific knowledge, we have developed Robot Scientist "Adam" (*13*) (Fig. 1). Adam's hardware is fully automated such that it only requires a technician to periodically add laboratory consumables and to remove waste. It is designed to automate the high-throughput execution of individually designed microbial batch growth experiments in microtiter plates (*14*). Adam measures growth curves (phenotypes) of selected microbial strains (genotypes) growing in defined media (environments). Growth of cell cultures can be easily measured in high-throughput, and growth curves are sensitive to changes in genotype and environment.

We applied Adam to the identification of genes encoding orphan enzymes in *Saccharomyces cerevisiae*: enzymes catalyzing biochemical reactions thought to occur in yeast, but for which the encoding gene(s) are not known (*15*). To set up Adam for this application required (i) a comprehensive logical model encoding knowledge of *S. cerevisiae* metabolism [~1200 open

[1]Department of Computer Science, Aberystwyth University, SY23 3DB, UK. [2]Cambridge Systems Biology Centre, Department of Biochemistry, University of Cambridge, Sanger Building, 80 Tennis Court Road, Cambridge CB2 1GA, UK. [3]Institute of Biological, Environmental and Rural Sciences, Aberystwyth University, SY23 3DD, UK.

*To whom correspondence should be addressed. E-mail: rdk@aber.ac.uk

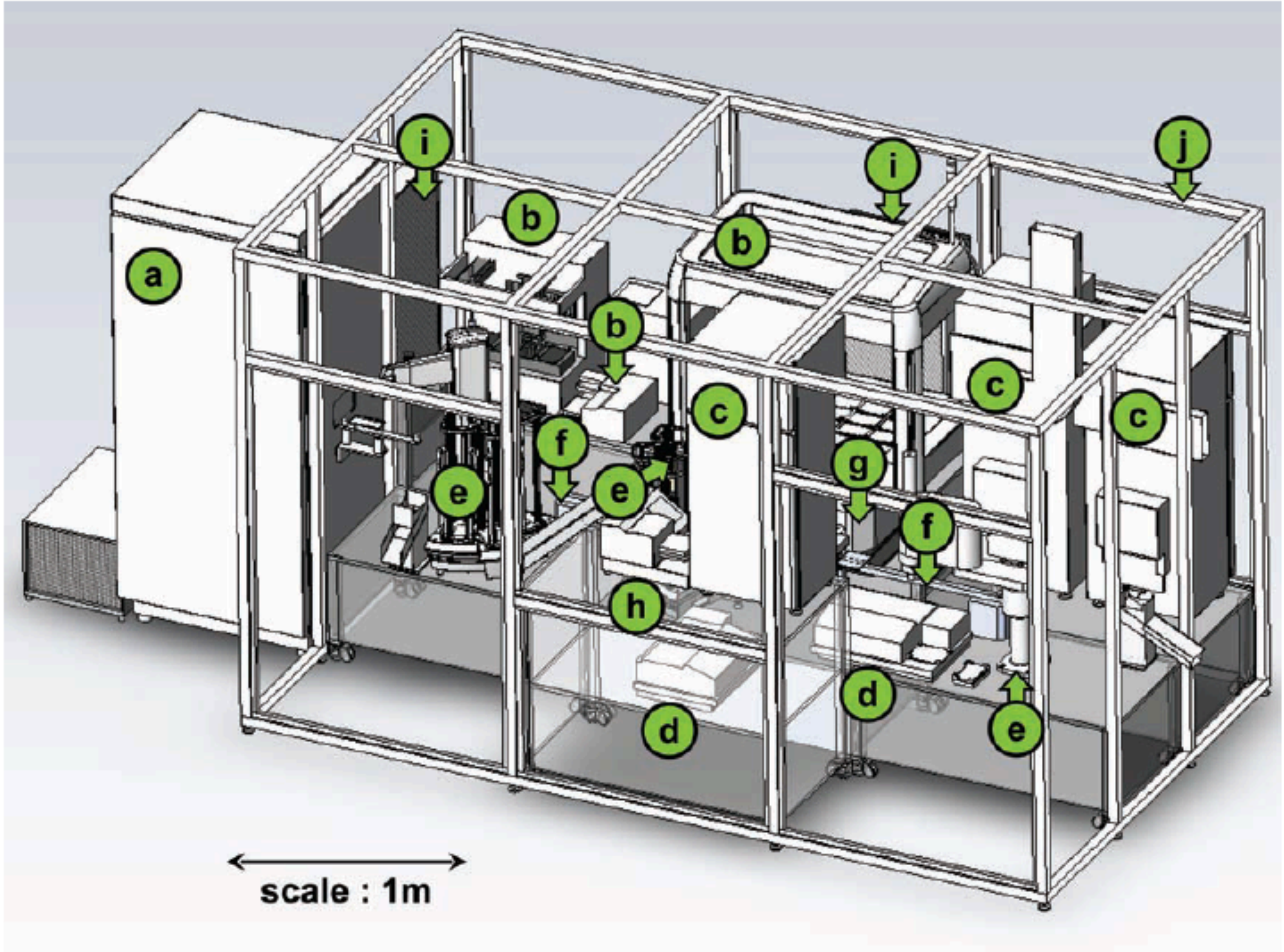

Fig. 1. The Robot Scientist Adam. The advances that distinguish Adam from other complex laboratory systems are the individual design of the experiments to test hypotheses and the utilization of complex internal cycles. Adam's basic operations are selection of specified yeast strains from a library held in a freezer, inoculation of these strains into microtiter plate wells containing rich medium, measurement of growth curves on rich medium, harvesting of a defined quantity of cells from each well, inoculation of these cells into wells containing defined media (minimal synthetic dextrose medium plus up to four added metabolites from a choice of six), and measurement of growth curves on the specified media. To achieve this functionality, Adam has the following components: a, an automated –20°C freezer; b, three liquid handlers (one of which can separately control 96 fluid channels simultaneously); c, three automated +30°C incubators; d, two automated plate readers; e, three robot arms; f, two automated plate slides; g, an automated plate centrifuge; h, an automated plate washer; i, two high-efficiency particulate air filters; and j, a rigid transparent plastic enclosure. There are also two bar code readers, seven cameras, 20 environment sensors, and four personal computers, as well as the software. Adam is capable of designing and initiating over a thousand new strain and defined-growth-medium experiments each day (from a selection of thousands of yeast strains), with each experiment lasting up to 5 days. The design enables measurement of OD_{595nm} for each experiment at least once every 30 min (more often if running at less than full capacity), allowing accurate growth curves to be recorded (typically we take over a hundred measurements a day per well), plus associated metadata. See the supporting online material for pictures and a video of Adam in action.

Homework

- Readings for lecture 3 (L03) on ctools
  - Alon "How to choose a good scientific problem"
  - Gladwell, "In the air: Who says big ideas are rare?"
- Literature survey due 2pm Fri Feb/3
- FYI, the full Beveridge book The Art of Scientific Investigation is in the root folder Resources