Funding of Science: Trends, Concerns, Open Issues

Paula Stephan

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Outline

- Note: focus on research conducted in the public sector at universities and public research organizations
- Costs
- Funding
  - Why support public science: rationale
  - Sources
  - Trends
- Concerns
- Alternative funding sources
- Ways to lower costs
- Open questions

Costs of Science:
Non-trivial

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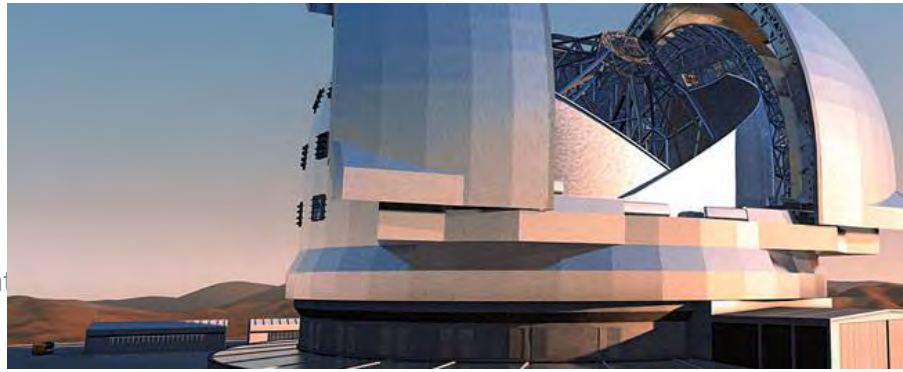
Costs of Science are Non-trivial

- Examples:
  - Telescope can cost $1 billion plus
    - E-ELT (European Extremely Large Telescope with a 39-meter main mirror) estimated cost of 1 billion euro, which was substituted for the even larger OLT (Overwhelmingly Large Telescope (100 meter aperture), with an estimated cost of 1.5 € billion) and will, funds permitting, be built in Cerro Armazones, a 3,000m-high mountain in Chile's Atacama Desert. First light scheduled for 2024.
  - ITER—which, if built, will cost more than double the estimated 5 € billion
  - LHC cost in excess of $8 bil
  - NMR $2 to $16 million



Small Scale

- Even “small” science has non-trivial costs
- Cost of researchers’ time as an example
  - Costs more than $400,000 a year to staff small lab in US before indirect with
    - 3 postdocs @ $53,000 each
    - 4 graduate students @ $35,000 each
    - 1 administrator $53,000
    - 1 PI 50% of time ($55,850)
- Note
  - In some countries, these are paid directly by the university or the organization
  - In other countries, such as the US, they are supported on grants
  - Some countries have a mixed strategy—researcher’s time is paid for by home institution but assistants, such as graduate students and postdocs, are paid for by grants:

$400,000 Is before

- Supplies—approximately $18,000 per researcher in lab
- Equipment catalogue has been opened
- Animal models--in case of biomedical research--have been purchased and cared for

Many Animals Used in Research

- Mice are king

- 90% of all animal models are mice—and there are indications that this is growing
- At least 20 million mice in use in labs
- Johns Hopkins University alone has 200,000

Even Mice Cost Money

- Off the shelf mouse costs $17 to $60
- Mutant strains cost $40 to $500-plus
- Cost $1900 to recover a strain from cryopreservation—that's where 67% of lab mice come from

- Designer mice with disposition for such diseases as obesity, alcoholism, Alzheimer's, diabetes, cost considerably more

Keeping mice

- Costs researchers per day: $.15 to $.20 (*per diem*)
  - Full cost to university is higher—Boston U estimates it to be $.50
- Can add up: one researcher was paying Stanford $800,000 a year for mouse upkeep
- At aggregate, spending about $1 billion a year keeping mice

Why Support Public Science? Rationale for Government to Pay

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Rationale

- Issues related to appropriability—basic research has multiple uses
  - Upstream research not only useful to those who perform the research
  - Also useful to others because it can lead to numerous outcomes—it has spillovers
- Performers are not able to capture all the benefits
- Moreover, benefits they could capture are often years away
- Means private companies have little incentive to engage in basic research
- Yet basic research is important to society
  - Contributes to economic growth
  - Contributes to other goals, such as defense and public health
    - Keith Pavitt used to say that the U.S.'s willingness to fund public research related to its fear of Communism and cancer

Risk

- Another reason for government support: basic research is risky
  - Kenneth Arrow pointed out more than 60 years ago that society has a tendency to underinvest in risky research
  - Without government support results simply may not be forthcoming— at least in the foreseeable future.
- Physicists have been searching for years for the elusive Holy Grail— a quantum theory of gravity.
- The lumpy nature of some research is another reason for public support. A tenth of an accelerator will not get you a tenth of a result. It is all or nothing.

Disclosure

- Basic research has more benefits to society if it is disclosed—made available to others
  - This is because research is non-rival: it is s not used up when used by others
- Priority reward system has developed in science that encourages researchers to disclose—but you can only disclose if you have the resources with which to do research!

Sources and Funding trends over time for public science

Example from US

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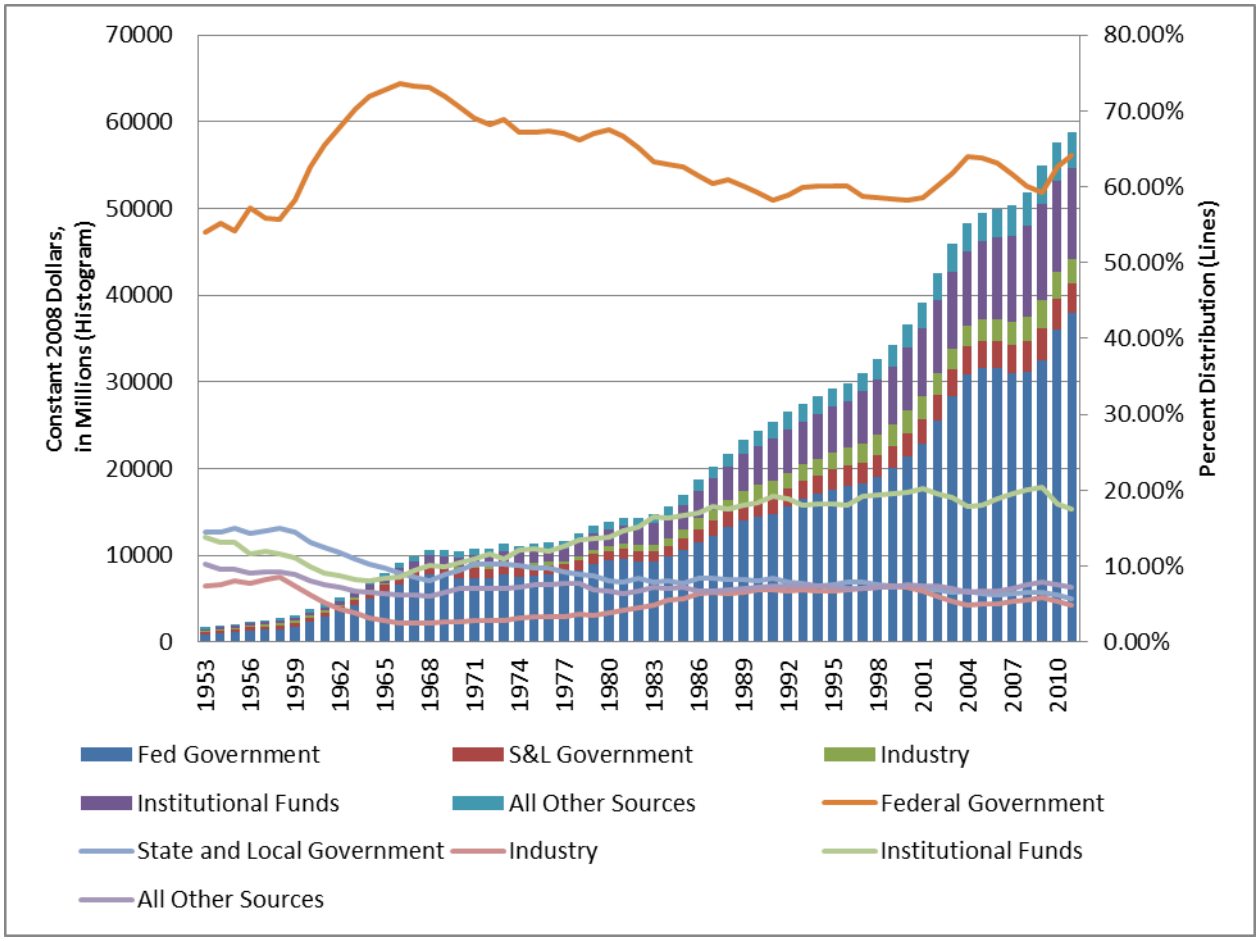
Support for Academic R&D by Sector US 1953-2010



Patterns

- Majority of funds come from federal government
- Increasing portion come from universities themselves
- Industry supports research in universities at a rate of about 5%
- “Other” sources are slightly increasing—nonprofits are a portion of this

Distribution of Government Funds

- Often done by peer review
- Funding is for 3-5 years depending on country and agency
- Grants can be reasonably large:
  - In US, NIH grant is in neighborhood of $500,000 to $750,000 as example

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Concerns

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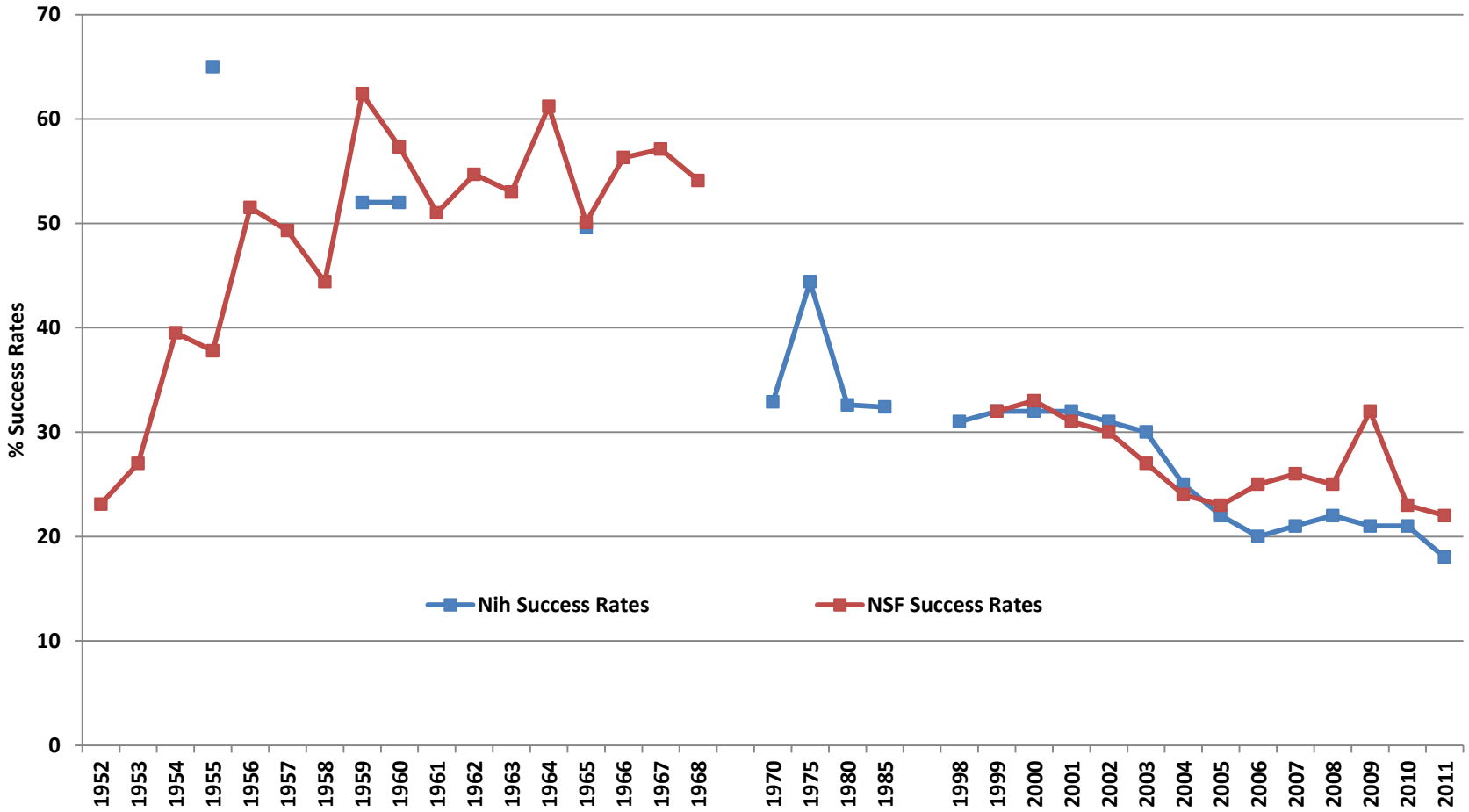
Concerns

- Concern that it is increasingly difficult for researchers to get funding; success rates are declining
- Concern that funding agencies are increasingly risk averse
- Concern that large number of early career scientists find it increasingly difficult to find a research position

NIH and NSF Success Rates Available Years



NSF rates for 1952-1968 are for the Division of Biological and Medical Sciences

Risk Aversion

- Evidence that agencies and applicants are increasingly risk averse
- Encouraged by
  - Sheer scale of operation—number of R01s NIH receives grown by a factor of 10 in 50 years; similar at NSF
  - Increasing reliance on bibliometric measures for evaluating proposals—increasingly easy to obtain; appealing way to evaluate large number of proposals—yet bibliometric measures undervalue characteristics associated with risk taking, such as novelty
  - Declining success rates—if you can only fund a few, be sure you are funding projects that will be "successful" in terms of outcomes

James Rothman Expressed Concern on Risk Aversion (NPR)

- Rothman told interviewer that "he was grateful started work in the early 1970s when the federal government was willing to take much bigger risks in handing out funding to young scientists"

"I had five years of failure, really, before I had the first initial sign of success. And I'd like to think that that kind of support existed today, but I think there's less of it. And it's actually becoming a pressing national issue, if not an international issue." Nobel Laureate, Physiology or Medicine, 2013

What's Inefficient?

- Composition of research portfolio:
  - If everyone is risk averse when it comes to research there is little chance that transformative research will occur and that (eventually) the economy will reap significant returns from investments in research and development.
  - Incremental research yields results, but in order to realize substantial gains from research not everyone can be doing incremental research.

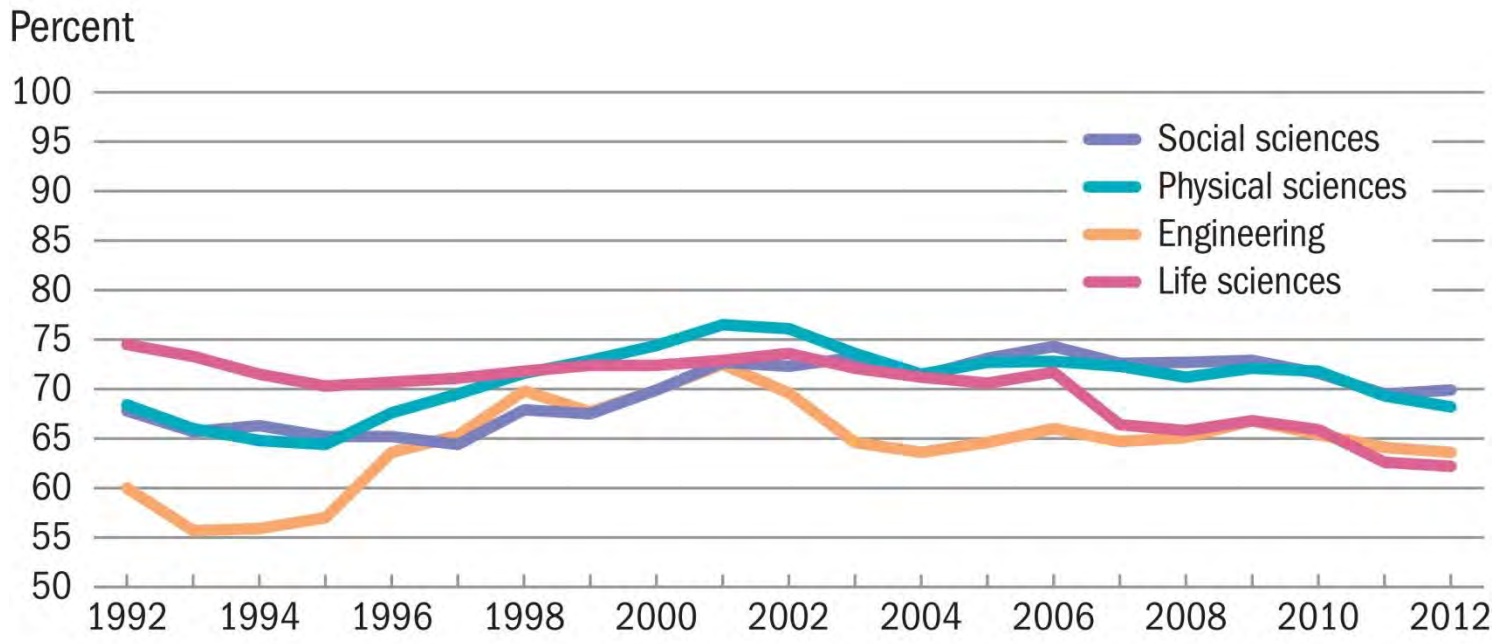
Risk Aversion

- Concern not limited to US
- ERC is concerned that it is risk averse
- Wellcome Trust has had the concern
- ERC has had an experts' group charged with, among other tasks, ways to increase risk taking

Job Market for Young Scientists

- Tight in many countries
- True for many countries in Europe
- Definitely true in the US
  - Some is related to overall macro economic conditions
  - Some related to “overtraining” relative to positions—especially in the biomedical sciences

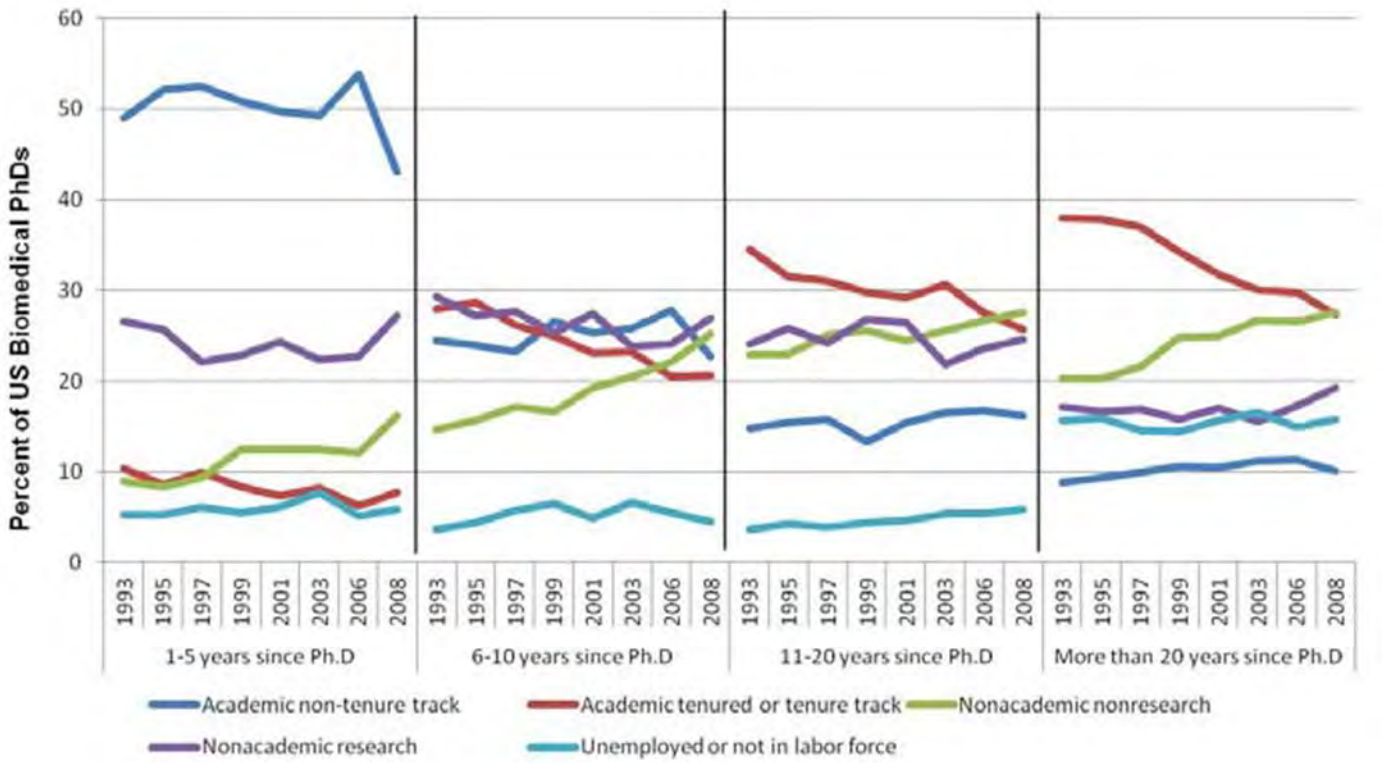
Definite commitments at doctorate award, by science and engineering fields of study: 1992–2012



NOTE: Definite commitment refers to a doctorate recipient who is either returning to pre-doctoral employment or has signed a contract (or otherwise made a definite commitment) for employment or a postdoc position in the coming year.

Related detailed data: tables 42, 43.

Employment Outcomes by Cohort Biomedical Sciences



Future:
Additional funding?

Increased Funding

- Increased funding would provide relief
  - *Note: it is not answer to solving some inherent problems that have led system, with its positive feedbacks, to be unstable*
  - *To address these, incentives and costs must change*
  - *But not today's topic!*
- Where would it come from, if funding were to increase?

Sources

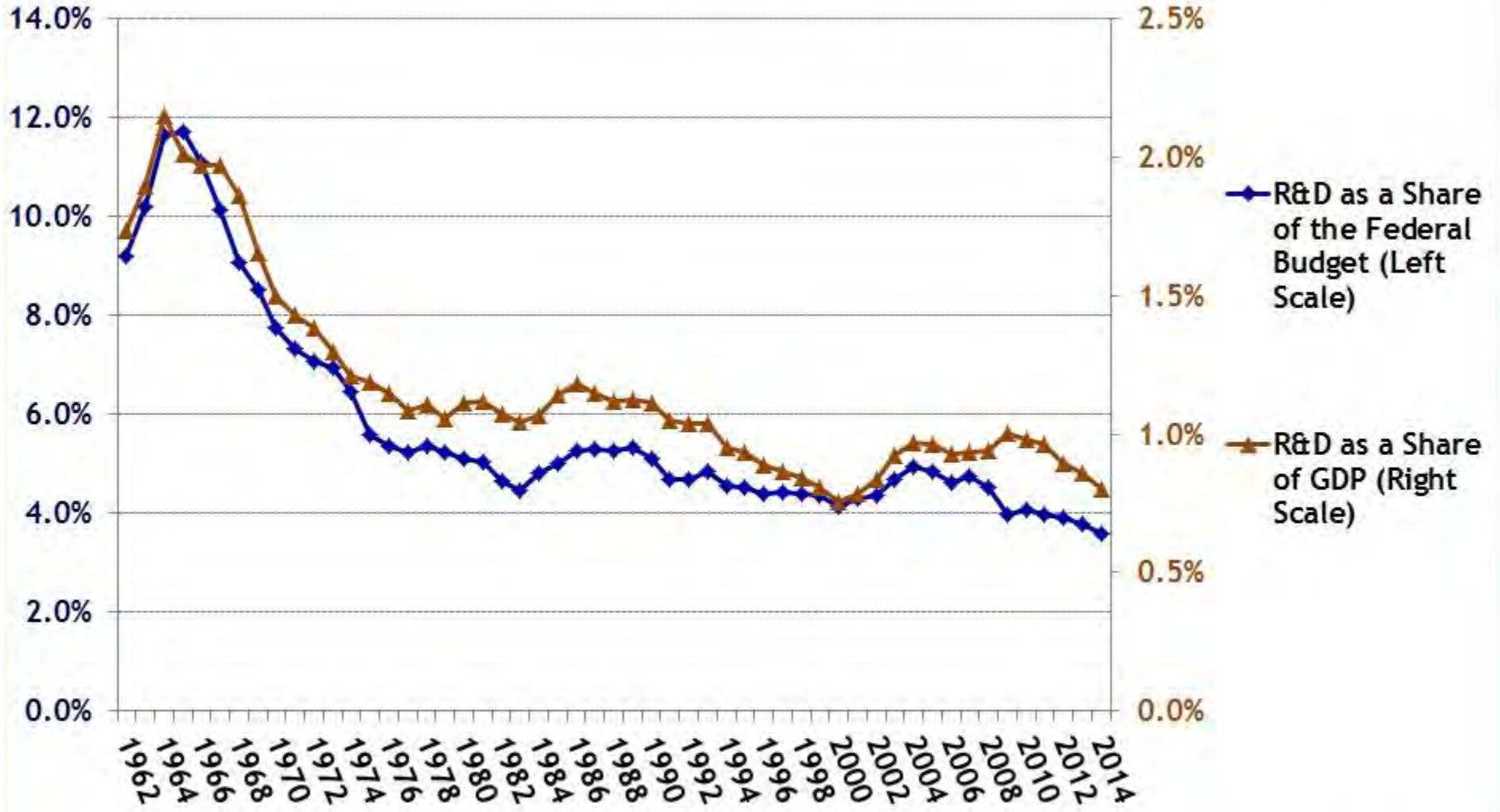
- Traditional Sources
  - Government
  - Industry
  - Universities
  - Private donors
- New Sources
  - Securitization
  - Crowdfunding

Funding from Government

- Significant increase in Federal funding in US is not likely to occur given current mood in Congress
- At European level, increased funding also unlikely to occur; ERC, for example had its budget cut; got it reinstated but Horizon 2020 has budget cuts

Federal R&D in the Budget and the Economy

Outlays as share of total, 1962 - 2014

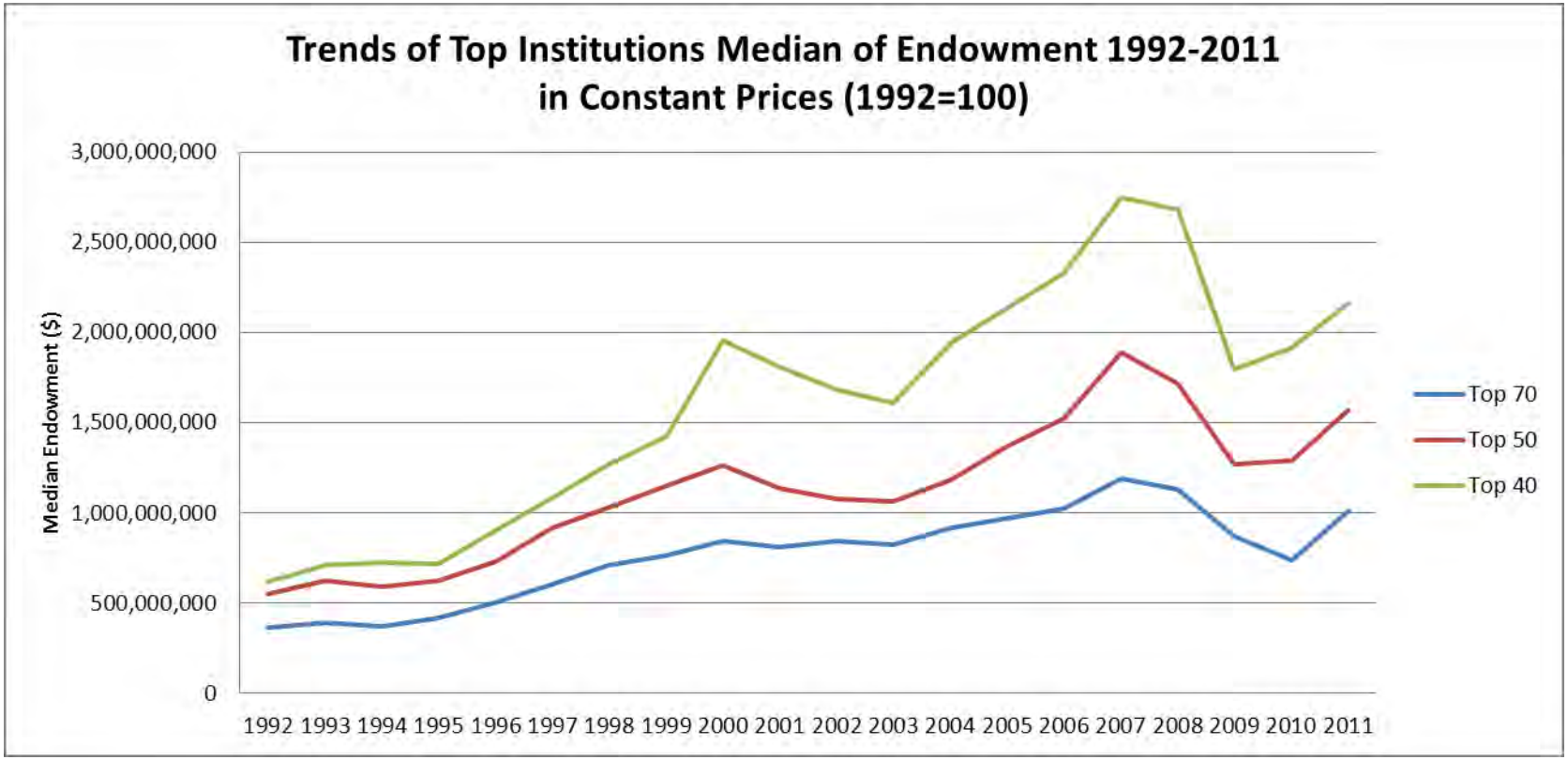


Source: *Budget of the United States Government, FY 2014.* FY 2013 data do not reflect sequestration. FY 2014 is the President's request.

AAAS

Other Sources?

- Industry may step up funding, but unlikely to provide a significant increase—hovers around 5%
- Funds from technology transfer—hear about the "big" deals but they are rare and impact only a few universities; most universities spend more on technology transfer offices than they bring in
- States and local governments: picture is not encouraging—now contribute less than 6%
- Endowments: highly cyclical, generally "dedicated," low spending rules
- Endowments in Europe play a minimal role


Trends of Top Institutions Median of Endowment 1992-2011
in Constant Prices (1992=100)
Median Endowment ($)
3,000,000,000
2,500,000,000
2,000,000,000
1,500,000,000
1,000,000,000
500,000,000
0
1992 1993 1994 1995 1996 1997 1998 1999 2000 2001 2002 2003 2004 2005 2006 2007 2008 2009 2010 2011
Top 70
Top 50
Top 40

The New York Times

"Billionaires With Big Ideas Are Privatizing American Science"
New York Times, March 15, 2014

Funding from Nonprofits

- Now contributes more than industry—6% vs. 5%
- Has grown in recent years
- Likely to continue to grow as more wealthy individuals make bequests to universities and foundations in support of research
- Impressive—but a small amount (at most $2 billion a year)—compared to federal funding
- Rare in Europe

David M Koch Institute for Integrated Cancer Research: MIT

$100 million gift from Koch

A Panacea?

- Concerns:
  - Much is targeted, often translational; raises question of who will fund basic research?
  - Incentives for universities to focus skills and research on rich and diseases that interest them, hoping to convince grateful patients to support research
  - Augments imbalance in US research portfolio that deemphasizes physical sciences and engineering in favor of biomedical sciences
  - Philanthropy “answer” to research funding less readily available to some publicly funded and non-elite institutions
  - Less prevalent in Europe

Funding from Securitization

- The Andrew Lo model, first presented in *Nature Biotechnology* 2012
- Idea: Use securitization techniques to raise funds from private sector to support biomedical research in firms
- Possibility of eventually extending concept to university research and to other fields
  - Combine many risky projects into one financial entity—provides "de-risking"
  - Allows a single entity to raise capital for projects by selling bonds and securities (200 times bigger)
  - Bonds and securities can have different risk levels and thus appeal to broader range of investors.

But Concerns

- Securitization could provide funds for research with tangible goals such as cure for specific type of cancer, new drug for treatment of diabetes Type 2
- But far more challenging to use such a financial instrument to fund basic research—if not goal oriented and no intellectual property is likely to emerge in foreseeable future
- Yet such research contributes greatly to our understanding and is most at risk of being cut by funding agencies

Crowdfunding

- Private sector has had some success in raising funds from crowdfunding for technology projects. Most well known is KickStarter. (Colombo, Rossi-LamastraFranzoni et Franzoni)
- Some platforms are beginning to emerge for scientists working in the public sector

Crowdfunding for Scientists in the Public Sector

- Several platforms have been created
  - https://walacea.com/
  - http://www.petridish.org/ (does not work!) https://en.wikipedia.org/wiki/Petridish.org
  - https://experiment.com/
  - http://www.rockethub.com/
  - #SciFund Challenge

- Source: http://www.theguardian.com/science/2015/jan/02/crowdfunded-science-scientists-fund-research

Characteristics

- Small sums (experiment.com) most projects are around $2,000 to $5,000
- Latest round of SciFund challenge 23 projects raised $55,272
- Most participants are students on experiment.com
- Many applied projects; many directed at health or environmental outcomes
- Suitable for starting a research project in some instances, especially in a research environment where start up funds are not available
- Requires “effort” on part of participants—”building an audience or ‘fanbase’ and actively engaging with that audience” increases funding (SciFund conclusion)

Some Projects Large; Offer Vicarious Satisfaction

- Lunar Mission One has raised $1 million to construct a moon lander. Contributors can send a strand of hair to the moon
- Penn State team trying to raise $400,000 for its Lunar Lion Project;

Applicability for Basic Science?

- Franzoni et al. conclude that CF more suitable for applied projects, which are close to market delivery;
- Calls into doubt the suitability of CF as a means for funding basic research in the public sector
- For time being, prediction is that funds will be available for
  - Small projects with environmental focus
  - Student projects
  - Health related/clinical trial projects—may be bigger
  - “Dream” projects

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Costs: Lower?

Possible Ways to Reduce Costs

- Outsourcing of research
- Increases in efficiency of equipment in lab
- Increase efficiency in using equipment—sharing equipment between labs and institutions;
- Renting labs—avoiding fixed costs
- Crowdsourcing labor costs
- Other?

Outsourcing

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Cyagen

- Purveyor of engineered mice
- Engineered in China
- Distributed through California
- Cost: approximately $28,000 for specified mouse—for this you get at least two, which can be bred
- Time frame—if all goes "perfectly," 8 months; often longer
- http://www.cyagen.com/service/knockout-knockin-mouse.html

Postdoc or Purchase?

- PI stated it was cheaper to have Cyagen produce the mouse than to hire a postdoc to create a mouse:
  - Must train postdoc; wait for results—"if he would give me an animal model in a year I would be thrilled." Highly uncertain and take minimum of 8 months—pay them $39,000 a year plus fringe benefits
  - Order from Cyagen; guaranteed that you will get a mouse, although not necessarily in the timeframe one would hope for

Zymergen

- "Zymergen uses a combination of robots and proprietary software to build and test thousands of new strains of DNA at a time, accomplishing in a matter of days what the company says might ordinarily take postdoctoral researchers in a lab around a year.
- CEO Joshua Hoffman put it this way: "Most labs look like they did in the 19th century, barring clothing and gender diversity. The work is manual, slow and prone to errors."
- Has resources: $44 million in 2 rounds of funding from 10 investors

http://recode.net/2015/06/16/synthetic-biology-startup-zymergen-emerges-from-stealth-with-44-million/

FedEx Crystallography

- Express the crystal
- Use remote access to operate the beamline at the synchrotron
- Note: remote access now common in use of telescopes and gathering data

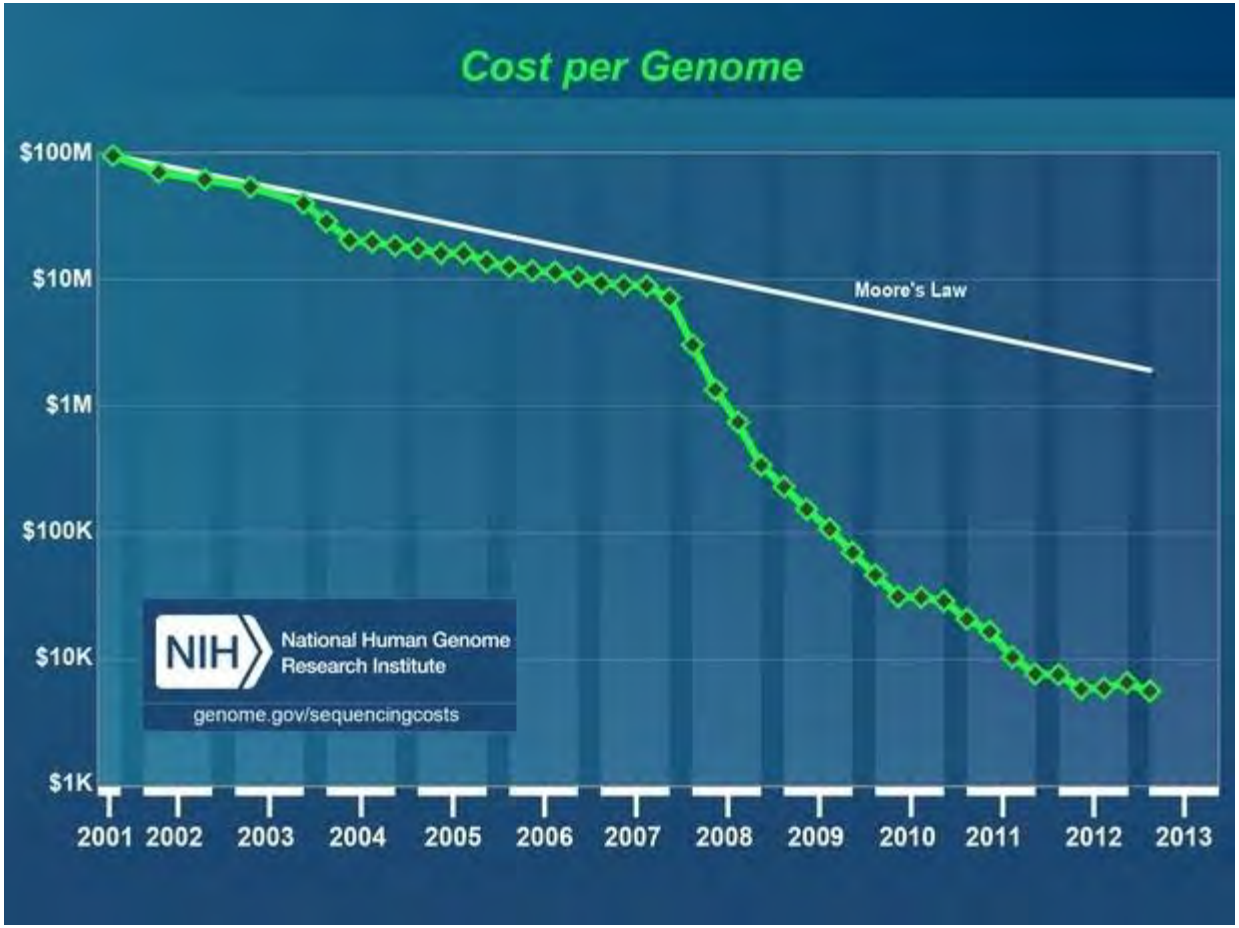
Central Experimental Facility

- Creation of central experimental facility that will do experiments for the scientist CEF—Cambridge proposal

Lower Costs: More Efficient, less expensive equipment

Examples

- 3-D Printers
- Sequencing breakthroughs


Cost per Genome
$100M
$10M
$1M
$100K
$10K
$1K
Moore's Law
NIH
National Human Genome Research Institute
genome.gov/sequencingcosts
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013

New Equipment, Lower Costs

- Sequencing traditionally done at “core” facilities— in 2010 half of 1400 sequencing machines in world were at 20 large academic or government centers (Matthew Harper)
- New equipment has potential to decentralize and democratize process: Companies are betting on it
  - In February of 2012 Oxford Nanopore introduced a device the size of a USB memory stick called a MinION, which when introduced could deliver 150 megabases of DNA sequences per hour.

Small Scale: MinION Sequencer

Introduced in February 2012 byOxford Nanopore

Price: $900

Disposable—runs for 6 hours—150 million base pairs

Larger version: GridION

Updated—of course!

Now gain access by joining MinIon Access Program for $1000…announced Jan.2015

http://www.wired.co.uk/news/archive/2012-02/20/minion-dna-sequencer

Community Labs

- Biohackers in the news
  - http://www.forbes.com/sites/techonomy/2011/10/25/citizen-science-takes-off-could-community-labs-hatch-the-next-generation-of-bio-innovators/
  - http://genspace.org/blog/
  - Some of equipment comes from “firesales” from failed pharmaceuticals
  - Most suitable for scientists who do not have a “home” base, such as a research institute or university

Renting a bench

- http://www.sciencemag.org/content/348/6240/1196.full
- Eliminates fixed costs
- Designed for small startups but could be used by researchers in public sector

Crowdsourcing

- For pay—Amazon Mechanical Turk
- Gamification—Foldit, Phylo
- As a volunteers
  - Type of work that is done tends to be low-skilled (Sauermann and Franzoni)
  - Cost savings: Sauermann and Franzoni examine 7 projects on Zooniverse and estimate volunteered labor worth about $1.5 million
- In addition to lowering costs, dramatically increase amount of data available, etc. and increase speed since “crowd” works in parallel

Open Issues

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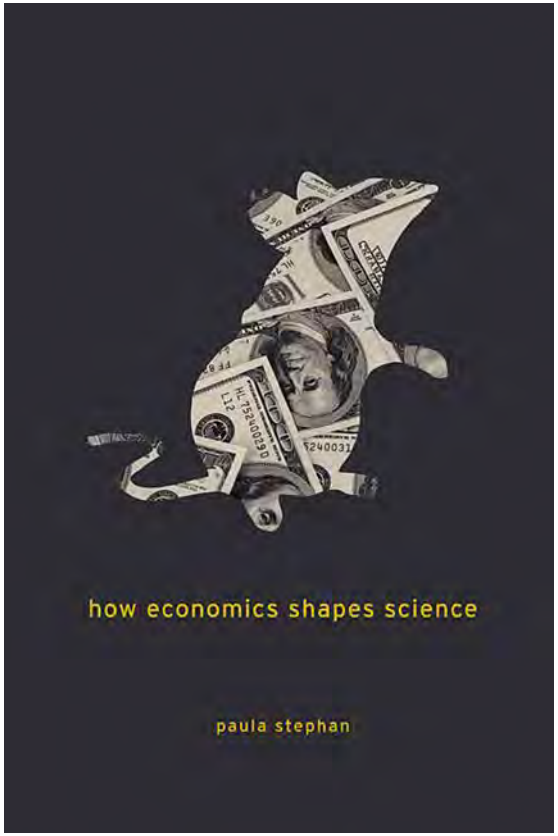
Open Issues

- How effective are new funding models?
  - Who is using them?
  - How much are they raising?
  - Are funds successfully leveraged?
  - Does CF increase risk taking, as some argue?
  - Are they especially attractive to young researchers?
- Who is using cost saving measures?
- What do innovations do to the capital-labor ratio in labs?
- How are labs restructuring in terms of personnel?
- Do new funding models increase risk taking?

Drawn from



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Questions/Comments

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