How Science Works, Part 2:
What's Involved in Large-Scale Science

Lifetime Learning Institute
November 10, 2021

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How Science Works, Part 1:
Processes, Nature, And Limits

Lifetime Learning Institute
September 24, 2020

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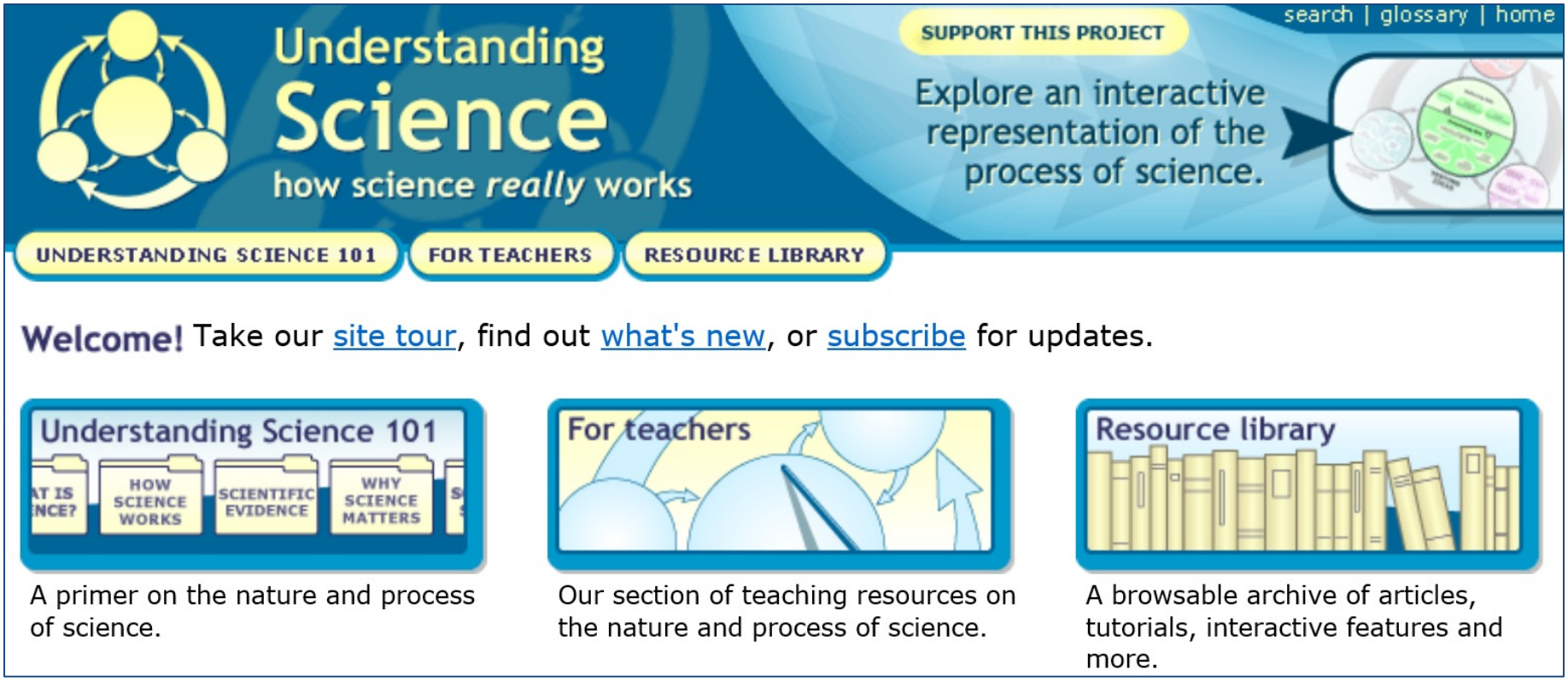

https://undsci.berkeley.edu/

1. What is Science?

- **Science focuses exclusively on the natural world. It does not deal with supernatural explanations.**
- **Science is a way of learning about and explaining what is in the natural world, e.g.,**
  - **how the natural world works,**
  - **how the natural world got to be the way it is.**
  - **predictions about the natural world of the future.**
- **Science is not simply a collection of facts; it is also a path to understanding.**
- **Science relies on testing ideas by figuring out what expectations are generated by an idea and making observations to find out whether those expectations hold true.**
- **Accepted scientific ideas are as reliable as the quality of questions asked and the level of rigor in testing those ideas.**
- **As new evidence is acquired and new perspectives emerge, these ideas can be, and often are revised.**

The moth predicted by Darwin:

Xanthopan praedicta
Madagascar

X. Morganii
Mainland Africa

New species has longest tongue of any insect
The Malagasy moth uses its giant proboscis to get into orchids.

The Malagasy moths take the prize here, with proboscises that measure 6.6 centimeters (2.6 inches) longer on average, as seen in the picture above. Adding to their legend, the team also reported finding one individual *praedicta* specimen with a proboscis that measured a whopping 28.5 centimeters (11.2 inches) when fully stretched, which would constitute “an absolute record” for any moth tongue ever measured.

New species has longest tongue of any insect | Science | AAAS

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Science isn't a tall stack of hard facts; it's a difficult and deeply human process that lurches toward an approximation of the truth.

Joel Achenbach
Washington Post, page A1
July 24, 2014

http://www.washingtonpost.com/national/health-science/bicep2-experiments-big-bang-controversy-highlights-challenges-for-modern-science/2014/07/23/707bc9e6-02c6-11e4-b8ff-89afd3fad6bd_story.html

2. Processes of Science: How Scientific Hypotheses are Developed

(Group Participation)

3. What constitutes scientific evidence (the nature and limits of science)?

Is there anything that science is incapable of investigating?

4. Changing Approaches to Science Education Nationally and in Virginia

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General Topics We Will Consider During this Session:

Modern science is an Interconnected Enterprise.

Modern science is often very expensive.

Modern science has increasing levels of both internal and external regulation and quality controls.

Putting these principles into context.

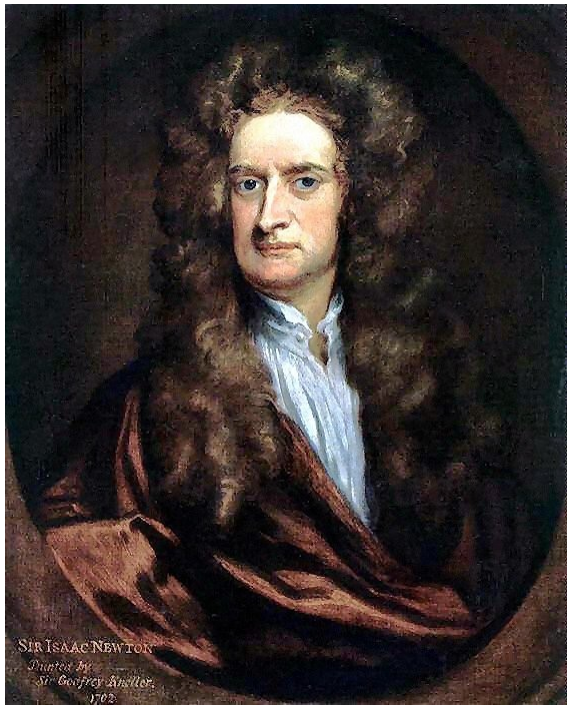
General Topics We Will Consider During this Session:

Modern science is an Interconnected Enterprise:

- Relies on previous results as well as new insights
- Education and Workforce Issues
- Diversity and Inclusion
- Increasing globalization
- Increasingly multidisciplinary and interdisciplinary

Modern science is an Interconnected Enterprise:

- **Relies on previous results as well as new insights**

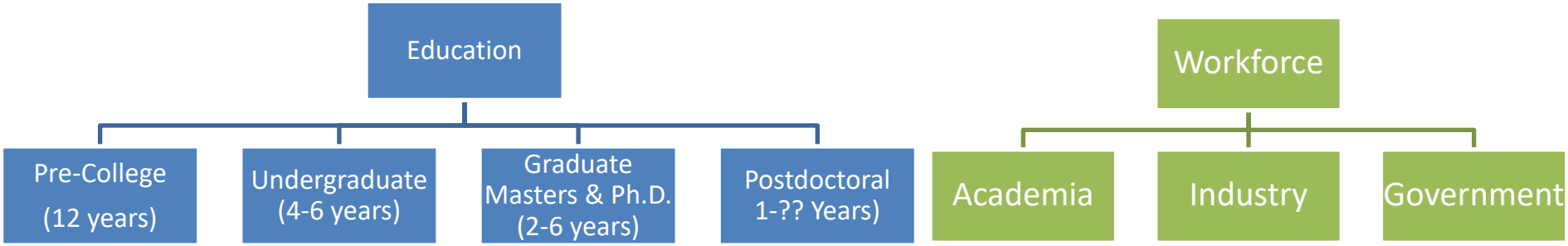


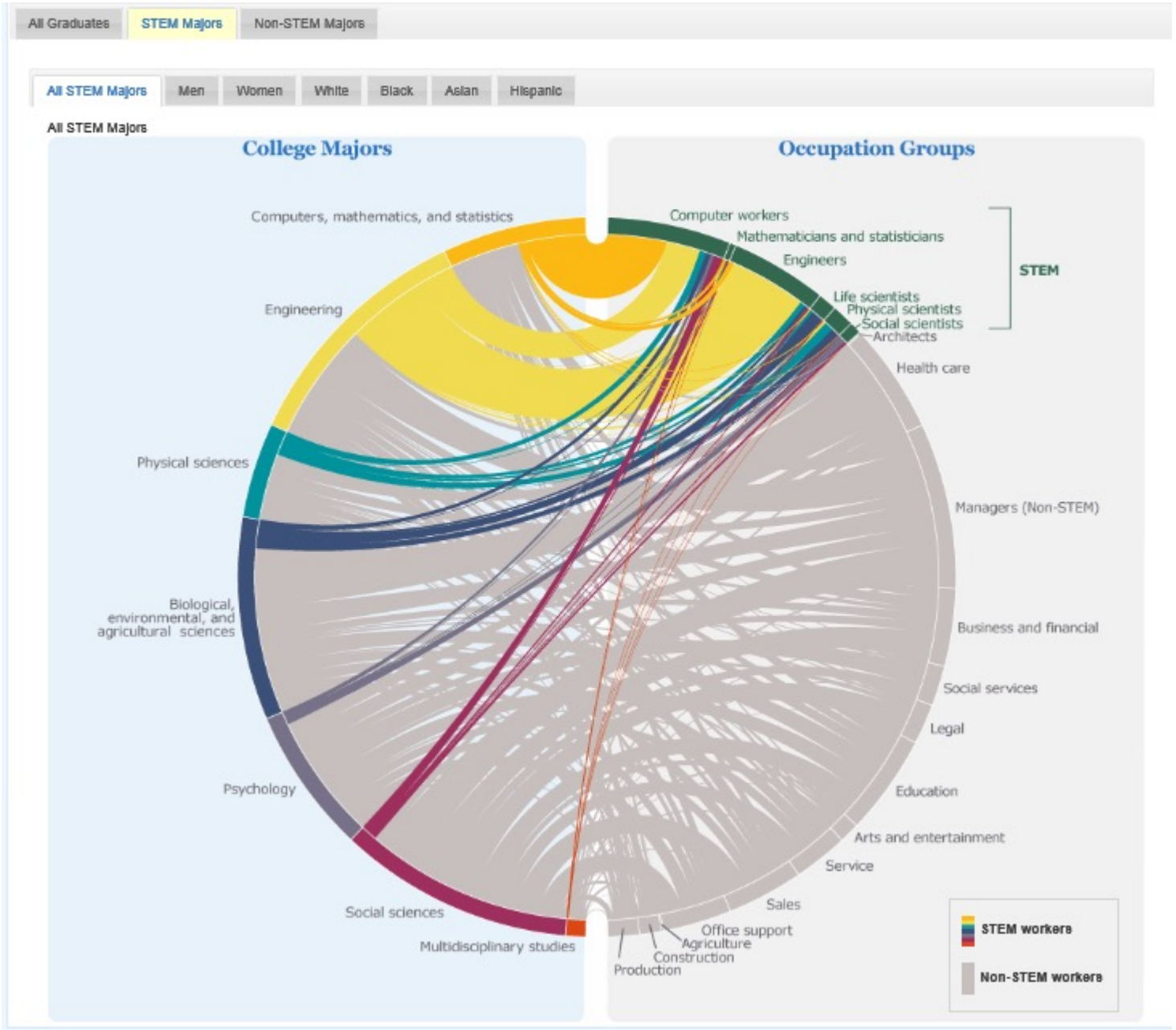
"If I have seen further than others, it is by standing upon the shoulders of giants."

Sir Isaac Newton

Modern science is an Interconnected Enterprise:

- **Education and Workforce Issues**

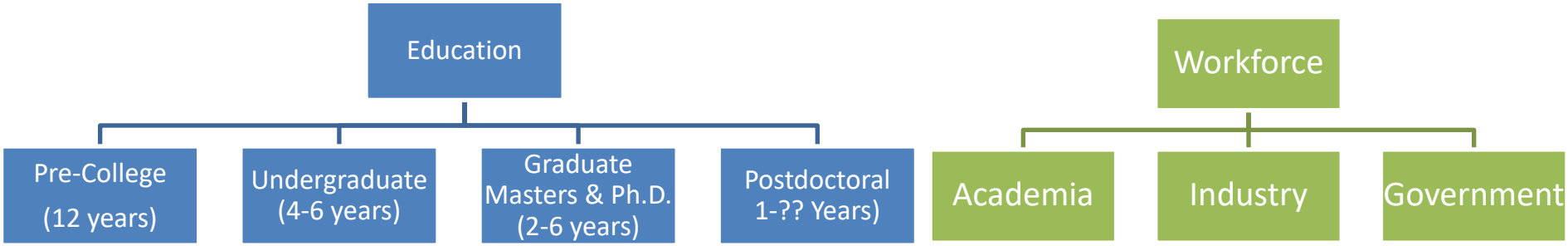




https://www.census.gov/dataviz/visualizations/stem/stem-html/

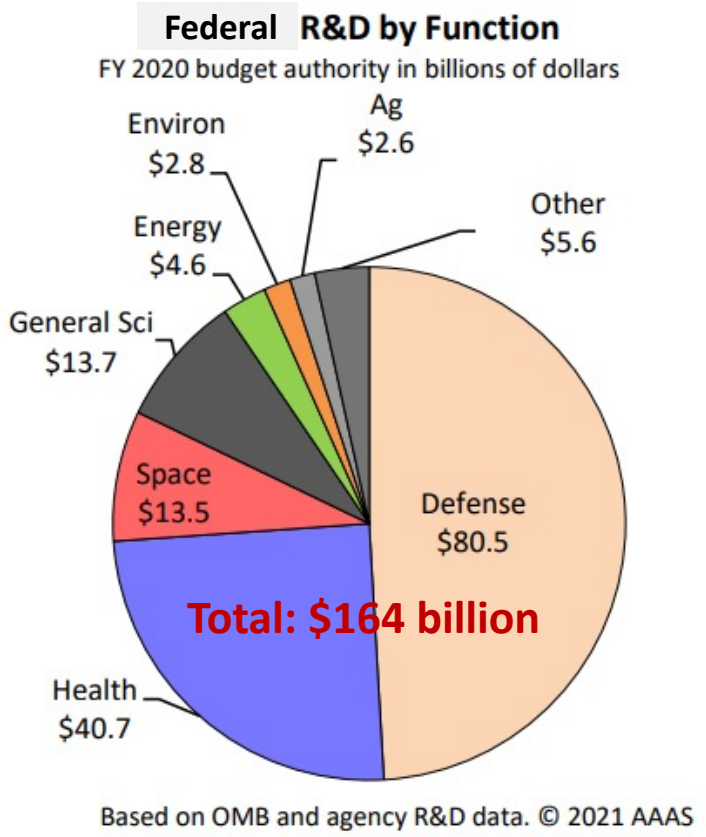
Modern science is an Interconnected Enterprise:

- Education and Workforce Issues



- Diversity and Inclusion
- Increasing globalization
- Increasingly multidisciplinary and interdisciplinary

Modern science is often very expensive.

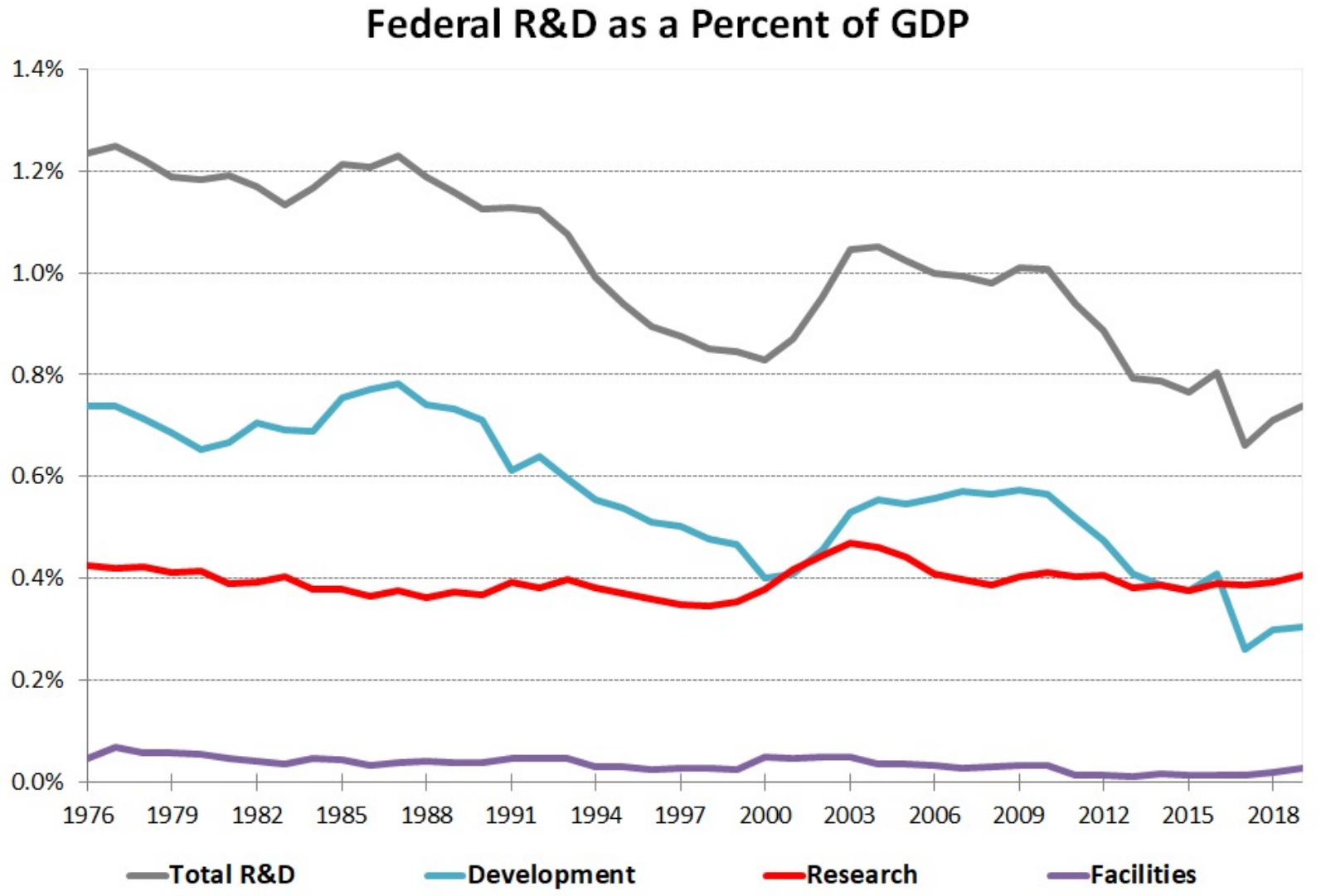


- In the US, [federal support] generally only accounts for about 36% of the funding, and the majority of that budget is spent on basic research and military research and development.
- The largest research funding comes from private companies. Of the corporate entities offering research grant funding the pharmaceutical companies are the largest [$71.4 billion in 2017].

Sources: Research Grant Funding - Problems With Funding in Science (explorable.com)
Drugmakers say R&D spending hit record in 2017 | BioPharma Dive

- Public and private sources of funding as both leading and trailing indicators
- Public acceptance of science to allow it to continue

Modern science is often very expensive.



Note: Beginning in FY 2017, federal agencies have revised what they consider to be R&D. Late-stage development, testing, and evaluation programs, primarily within the Defense Department, are no longer counted as R&D.

Based on AAAS analyses of historical OMB and agency data. R&D includes conduct of R&D and facilities. |

Modern science has increasing levels of both internal and external regulation and quality controls.

- Differences between basic and applied research
  - Intellectual merit and broader impact requirements

Intellectual Merit and Broader Impact Statements

NSF Design, Service and Manufacturing Grantees and Research Conference

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NSF Standard Merit Review Criteria

Intellectual Merit	Broader Impacts
What is the potential for the proposed activity to advance knowledge and understanding within its own field or across different fields?	What is the potential for the proposed activity to benefit society or advance desired societal outcomes?

Modern science has increasing levels of both internal and external regulation and quality controls.

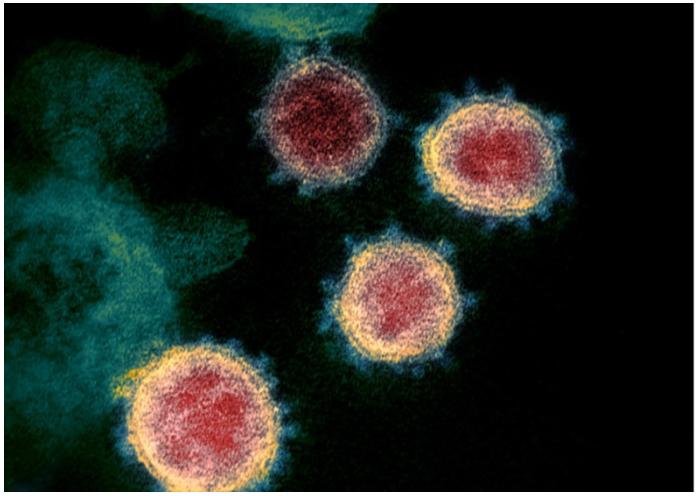
- **Reliability of protocols – institutional review boards**

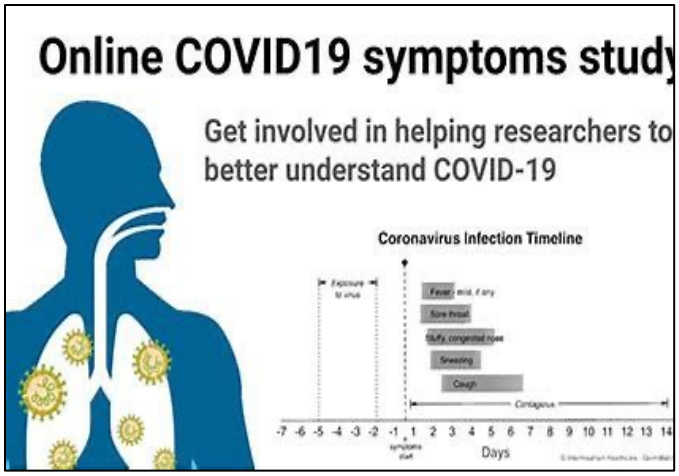
Phase	No. Subjects	Primary Goal
0	10-15	Optional exploratory trials to determine if agent acts as expected in human subjects
I	20-100	Dose-ranging on healthy volunteers for safety
II	50-300	Testing of drug on participants to assess efficacy and side effects
III	300-3,000+ (depending on disease studied)	Testing of drug on participants to assess efficacy, effectiveness and safety
IV	Varies by study population	Post-distribution surveillance in public

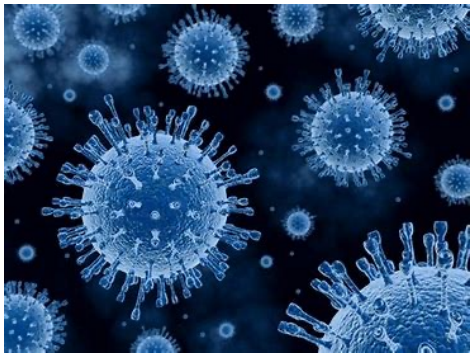
Modern science has increasing levels of both internal and external regulation and quality controls.

- Use of controls:
  - Blind vs. double-blind
- Ethical considerations, including informed consent
- Publication/distribution of findings and sources of error (both non-intentional and intentional)

Putting these principles into context:
Research, development, and testing of COVID vaccines.







Sources of images:

New Images of Novel Coronavirus SARS-CoV-2 Now Available | NIH: National Institute of Allergy and Infectious Diseases

images of covid research - Bing images

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Number of Subjects in Phase III Clinical Trials of Various COVID-19 Vaccines

Manufacturer	Type of Vaccine	Number of Adult Subjects	Test Locations
Pfizer	mRNA	46,331	Argentina, Brazil, Turkey, South Africa and the United States
Astra-Zeneca	Traditional	23,848	UK, Brazil, and South Africa
Moderna	mRNA	28,207	United States
Johnson & Johnson	Traditional	43,783	South America, United States, South Africa

TheScientistDaily

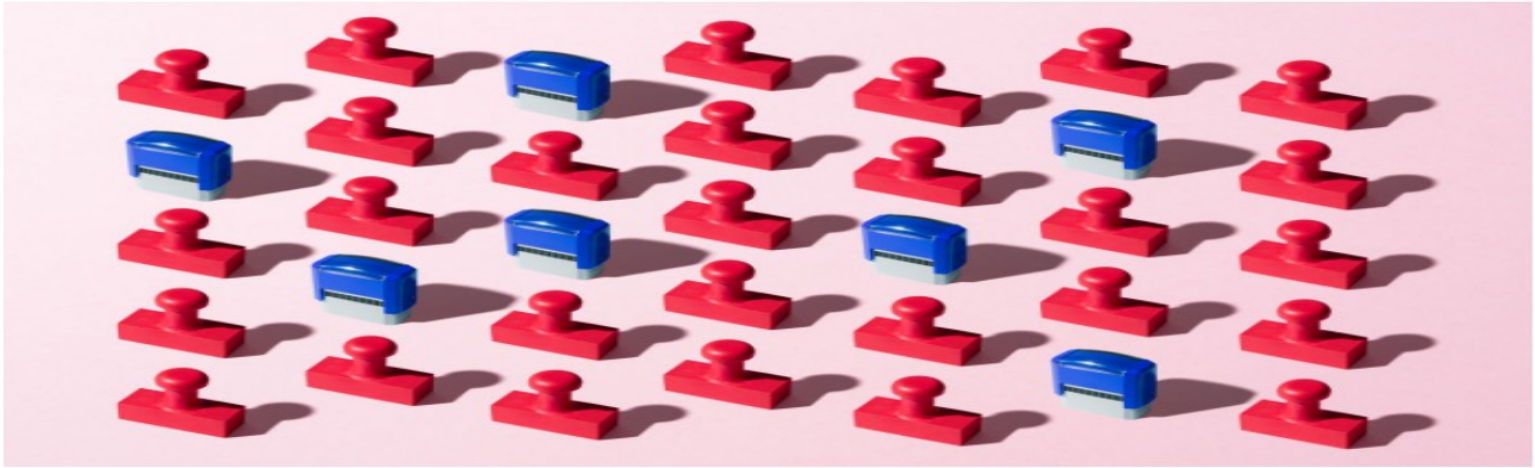
December 22, 2020

The Top Retractions of 2020

By *Retraction Watch*

The *Retraction Watch* team takes a look at the most important publishing mistakes this year.

Science



MIRAGEC/GETTY IMAGES, EDITED BY E. PETERSEN/*SCIENCE*

What is research misconduct? European countries can't agree

By **Cathleen O'Grady** | Mar. 10, 2021 , 12:55 PM

In Sweden, a national code takes 44,000 words to define research misconduct and discuss scientific values. Next door, Norway's equivalent is a brisk 900 words…A new analysis of scientific integrity policies in 32 nations has found widely varying standards and definitions for research misconduct itself, despite a 2017 Europe-wide code of conduct intended to align them.

What is research misconduct? European countries can't agree | Science | AAAS (sciencemag.org)

A Closing Thought:

"For me, I am driven by two main philosophies: know more today about the world than I knew yesterday and lessen the suffering of others. You'd be surprised how far that gets you."

– Neil deGrasse Tyson

Vielen Dank!

Merci!

Ευχαριστώ!

Thank you!!

谢谢！

شكرًا لك!

감사합니다!

Asante!

Děkujeme!

धन्यवाद

¡Gracias!

תודה!

ありがとうございました!

Obrigado!

Спасибо!