

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



**Lifetime Learning Institute**

**March 18, 2021**

**Jay Labov**

National Academies of Sciences, Engineering, and Medicine (Retired)

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



**Lifetime Learning Institute**  
**September 24, 2020**

**Jay Labov**

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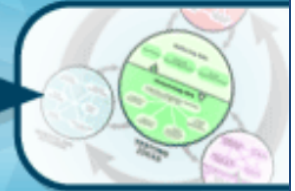
# Understanding Science

how science *really* works

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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 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.**

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

# 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:

- 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 often very expensive.

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

## 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
- Reliability of protocols – institutional review boards
- 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.

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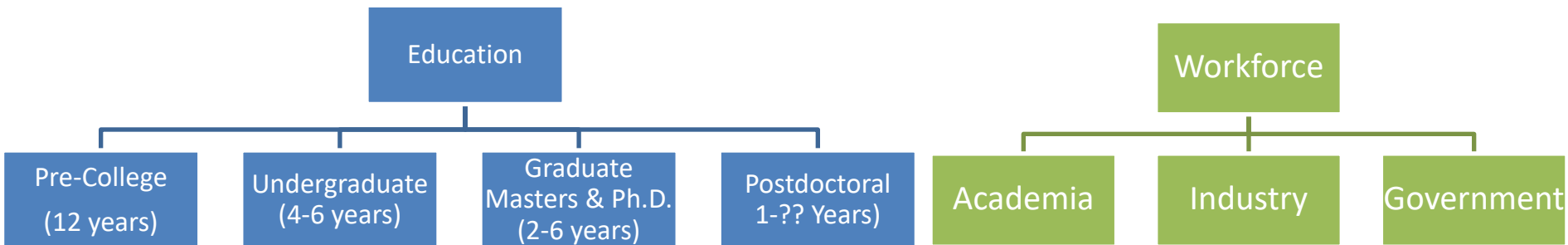


“If I have seen further than others, it is by standing upon the shoulders of giants.”

Sir Isaac Newton

# Modern science is an Interconnected Enterprise:

## ➤ Education and Workforce Issues

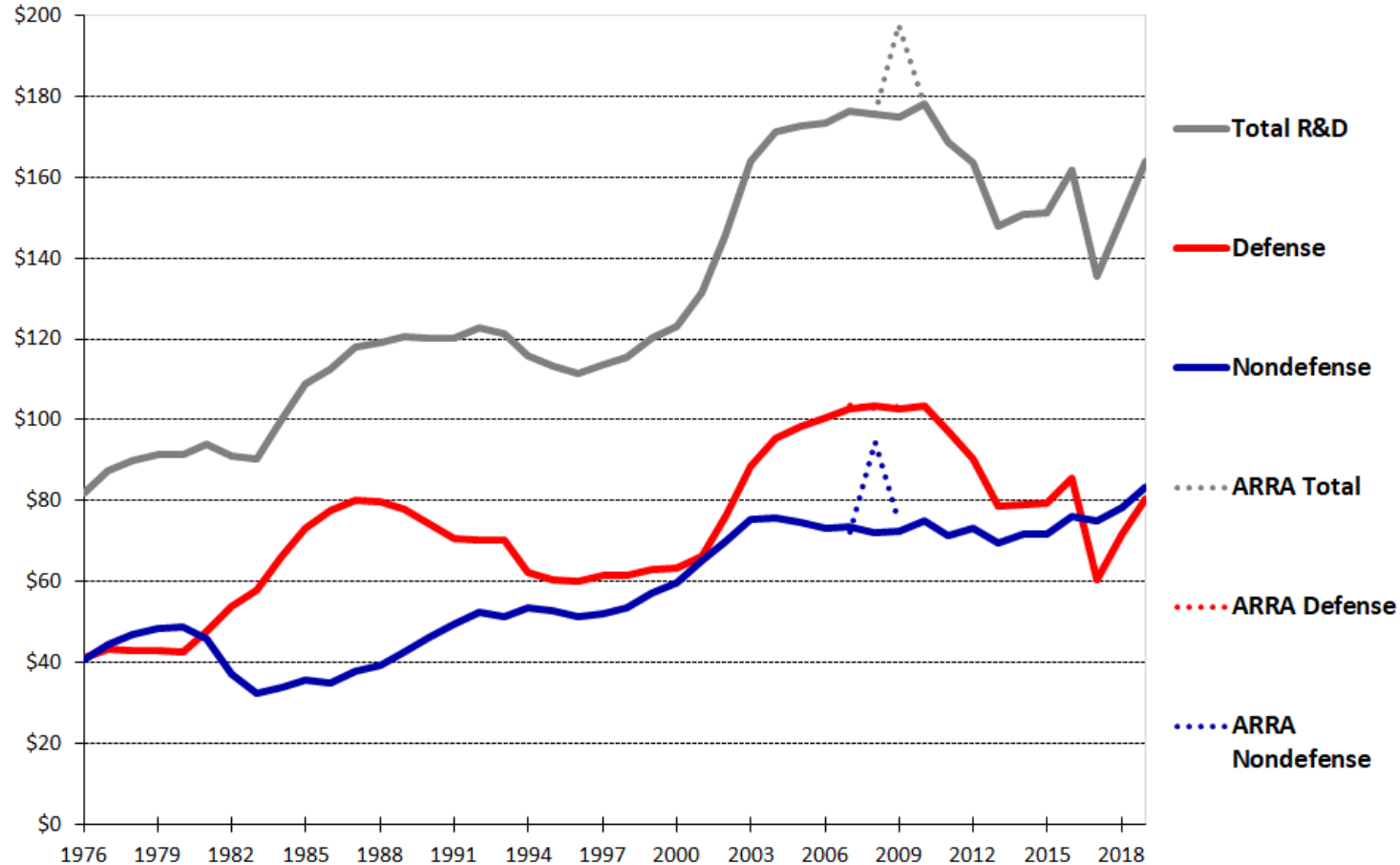


- Diversity and Inclusion
- Increasing globalization
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# Modern science is often very expensive.

## Trends in Federal R&D, FY 1976-2020

in billions of constant FY 2020 dollars



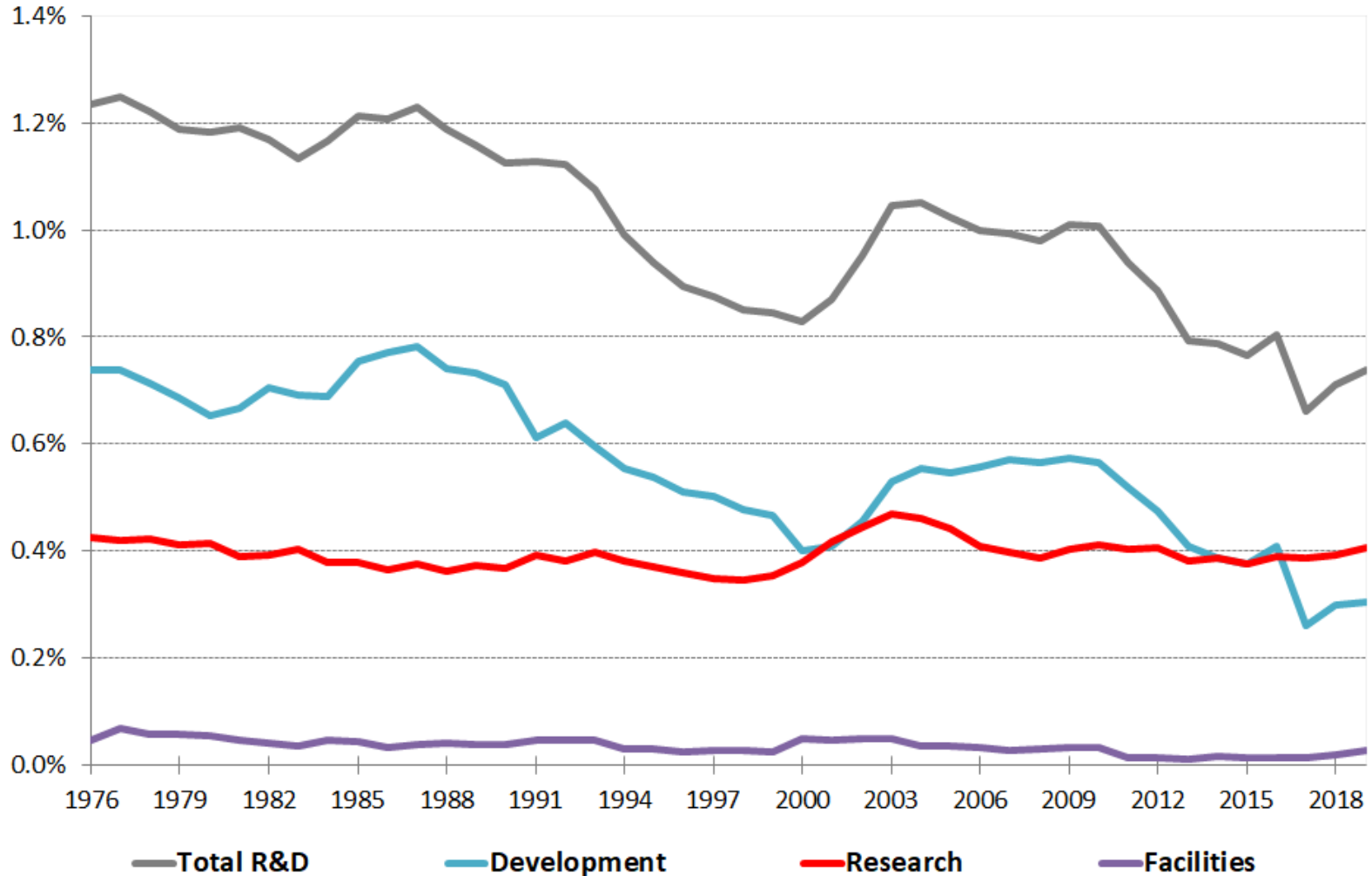
Note: Beginning in FY 2017, federal agencies have revised what they consider to be R&D. Late-stage development, testing, and evaluation programs, primarily within the Defense Department (6.7), are no longer counted as R&D.

Based on AAAS analyses of historical OMB and agency data. R&D includes conduct of R&D and facilities. | © AAAS 2020

➤ Public and private sources of funding as both

# Modern science is often very expensive.

## Federal R&D as a Percent of GDP



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# Modern science is often very expensive.

## U.S. government share of basic research funding falls below 50%

*Science*: March. 9, 2017

For the first time in the post–World War II era, the federal government no longer funds a majority of the basic research carried out in the United States. Data from ongoing surveys by the National Science Foundation (NSF) show that federal agencies provided only 44% of the \$86 billion spent on basic research in 2015. The federal share, which topped 70% throughout the 1960s and '70s, stood at 61% recently as 2004 before falling below 50% in 2013.

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

[Source: Data check: U.S. government share of basic research funding falls below 50% | Science | AAAS \(sciencemag.org\)](http://www.sciencemag.org)



**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*

# NSF Standard Merit Review Criteria

Intellectual Merit

**What is the potential for the proposed activity to advance knowledge and understanding within its own field or across different fields?**

Broader Impacts

**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)**

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## The Top Retractions of 2020

By *Retraction Watch*

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



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

## What is research misconduct? European countries can't agree

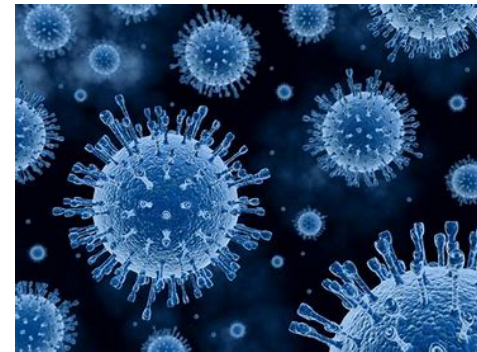
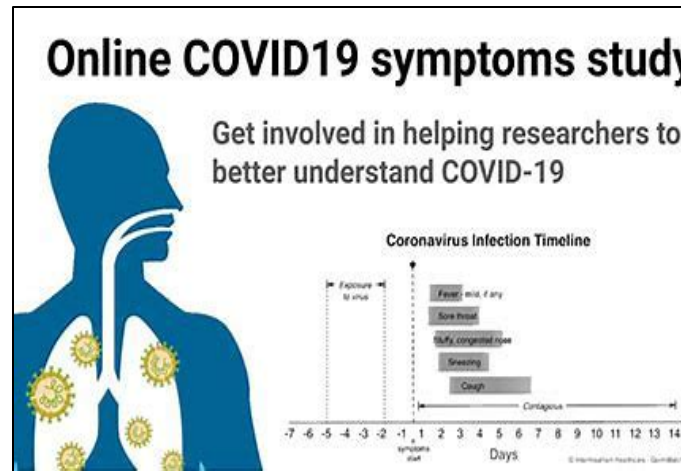
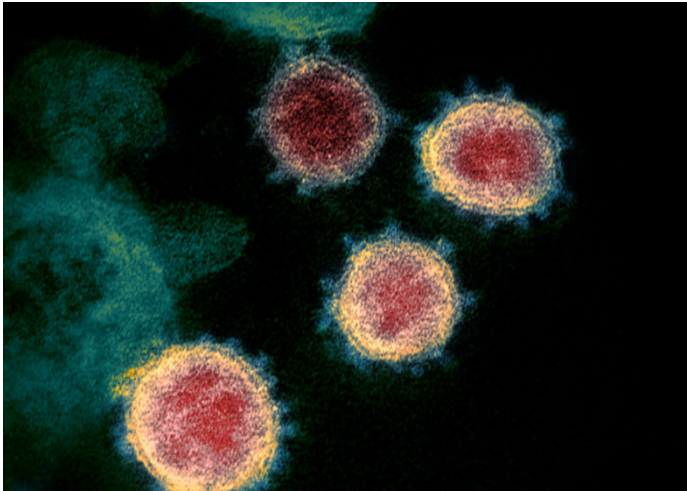
By **Cathleen O'Grady** | Mar. 10, 2021 , 12:55 PM

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 \(sciencemag.org\)](#)



# 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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# 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

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Thank you!!  
Questions??