What is Research

…and how do we do it?

Kyle Bradbury

Duke ENERGY INITIATIVE

Definition

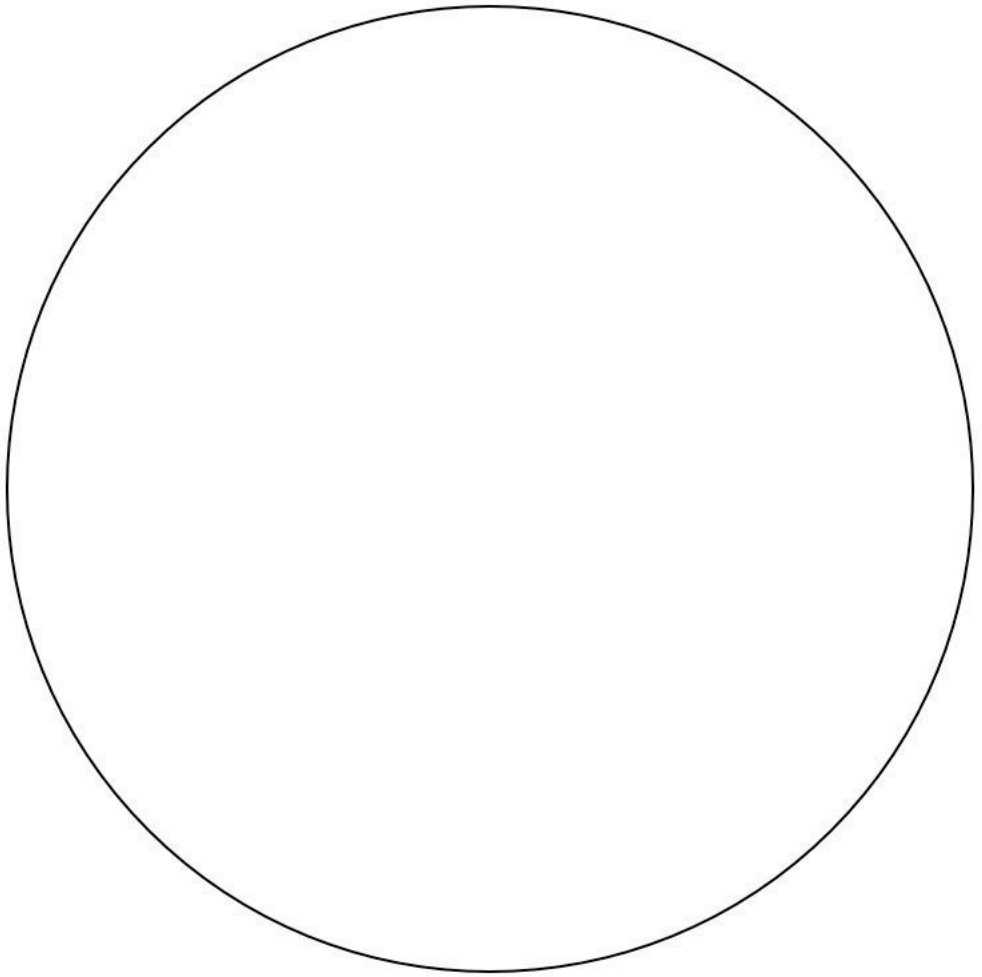
"…any creative systematic activity undertaken in order to increase the stock of knowledge, including knowledge about humanity, culture and society, and the use of this knowledge to devise new applications."

OECD Glossary of Statistical Terms, 2008

The Great Conversation

The School of Athens by Raphael

Adapted from Matt Might's,
The Illustrated Guide to a Ph.D.



Imagine a circle that contains **all of human knowledge**

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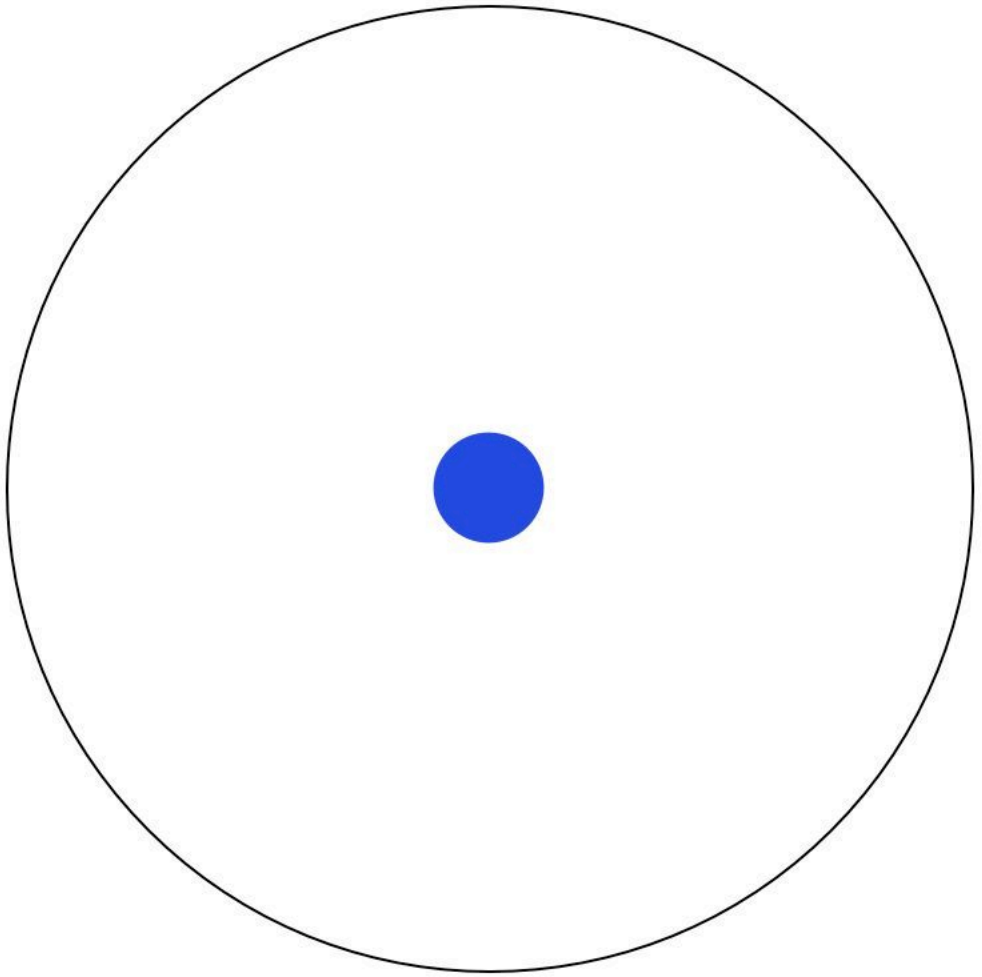

By the time you finish **elementary school**, you know a little

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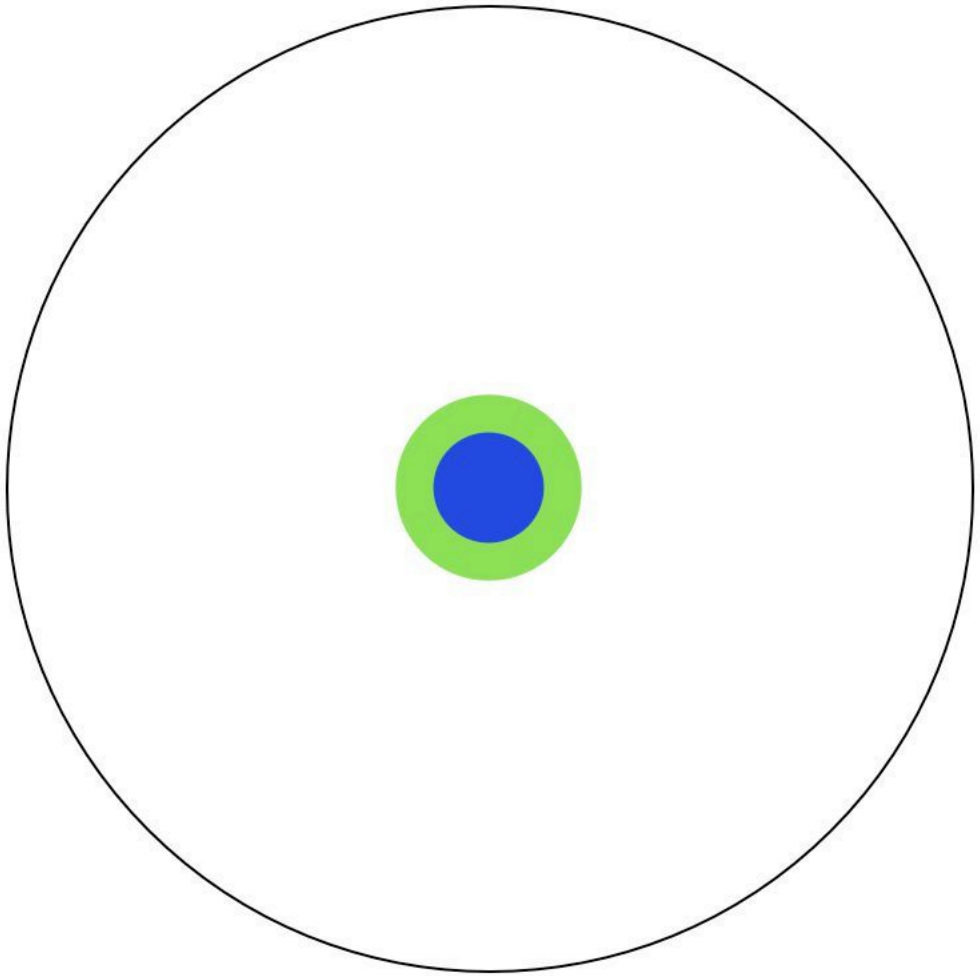

By the time you finish **high school**, you know a bit more

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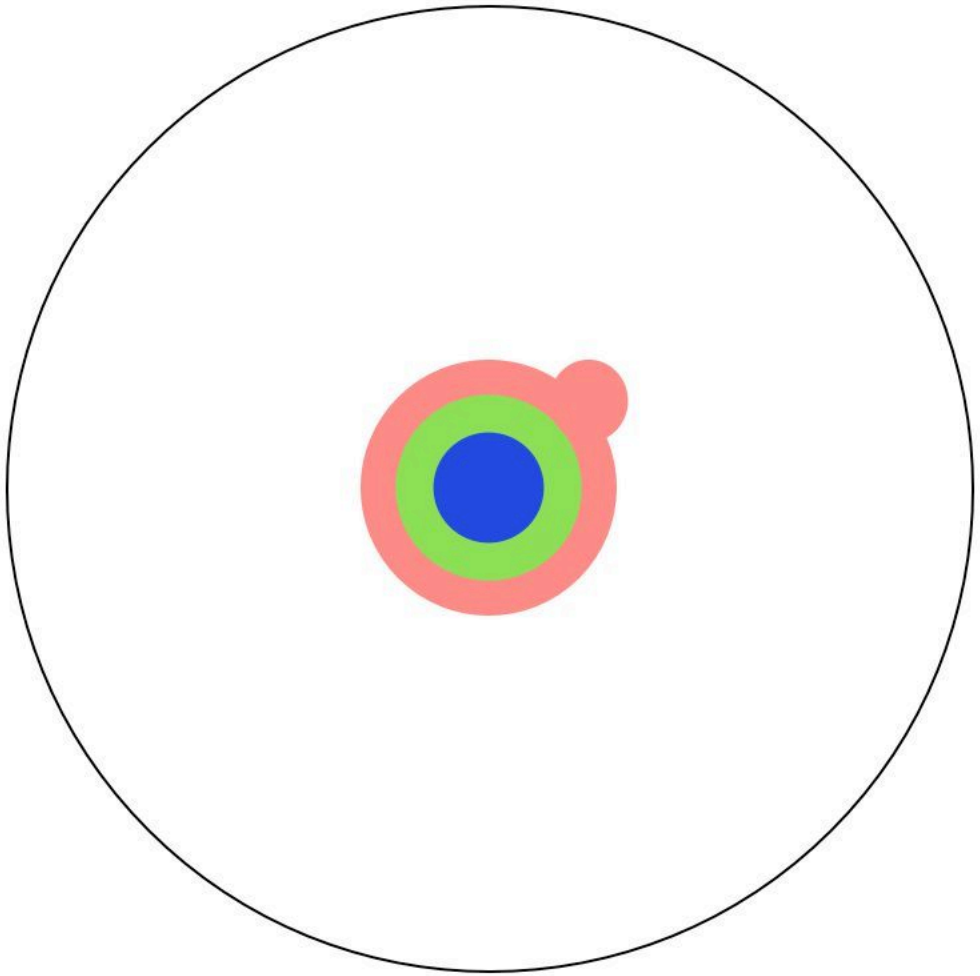

With a **bachelor's degree**, you gain a specialty

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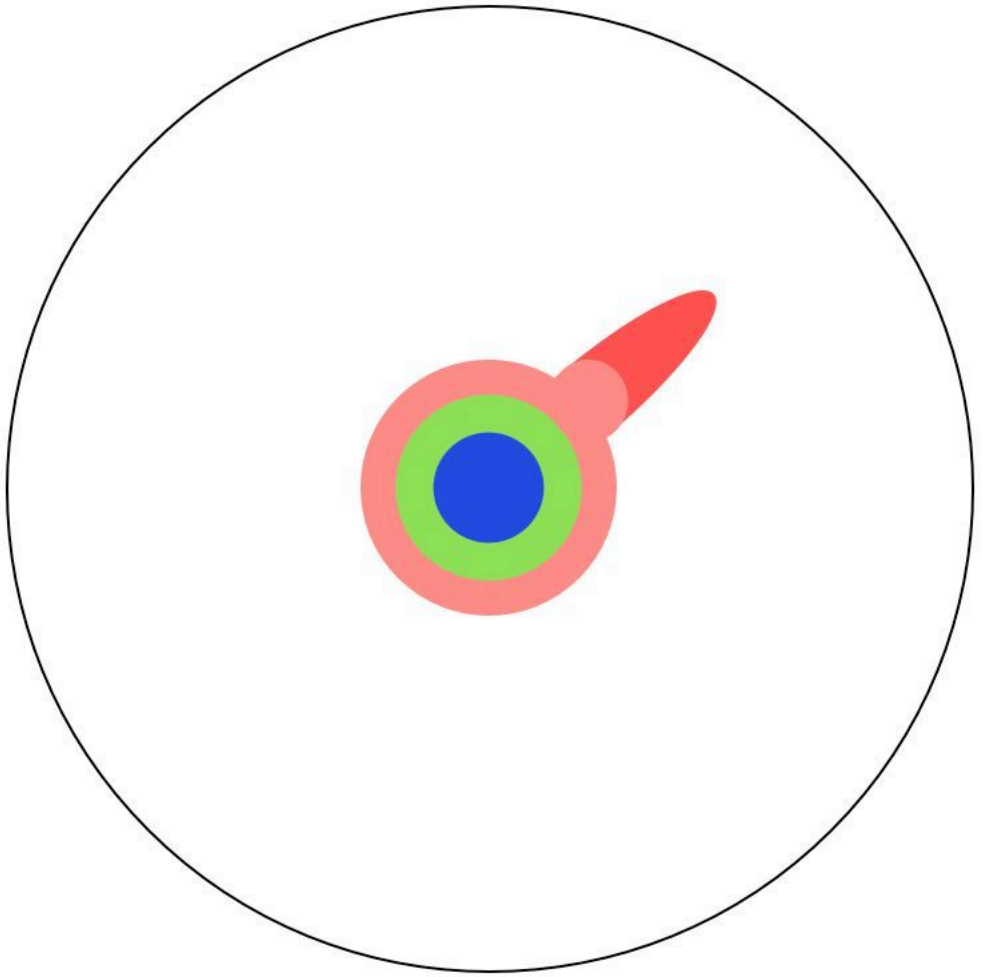

A **master's degree** deepens that specialty

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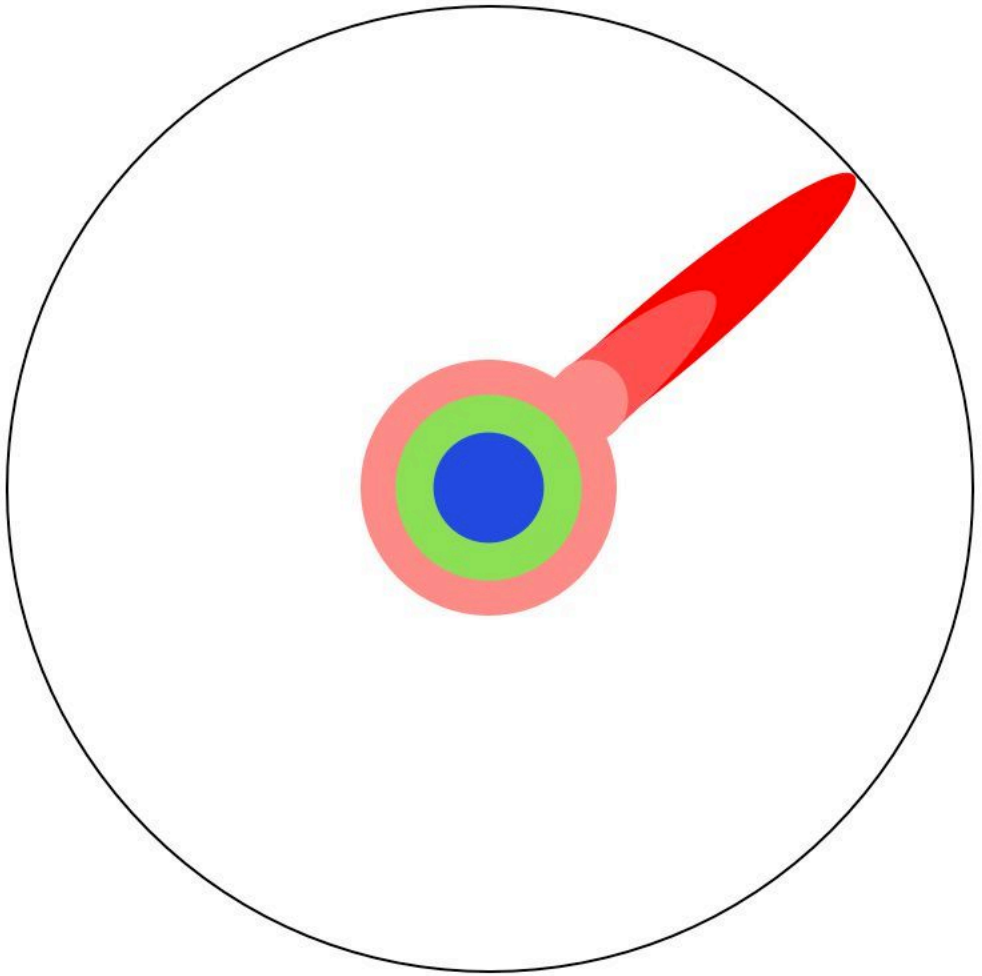

Reading research papers takes you to the **edge of human knowledge**

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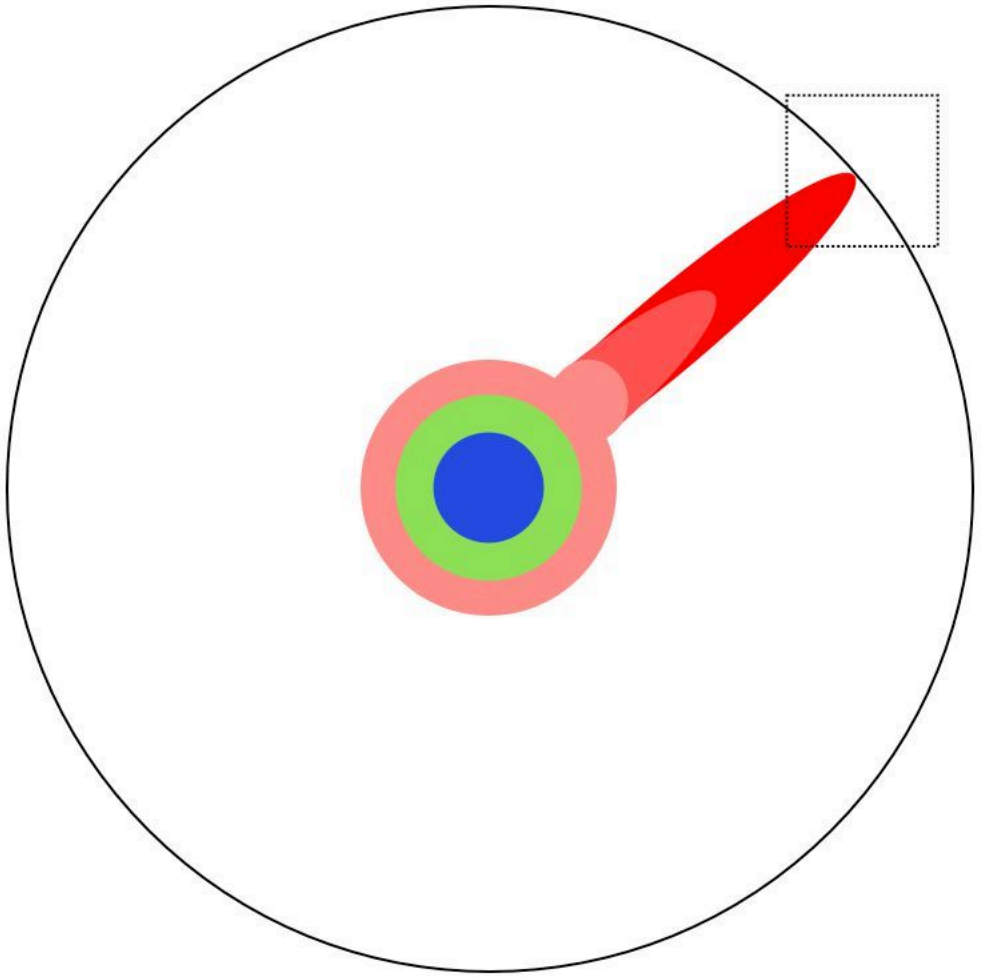

Once you're at the boundary, you focus

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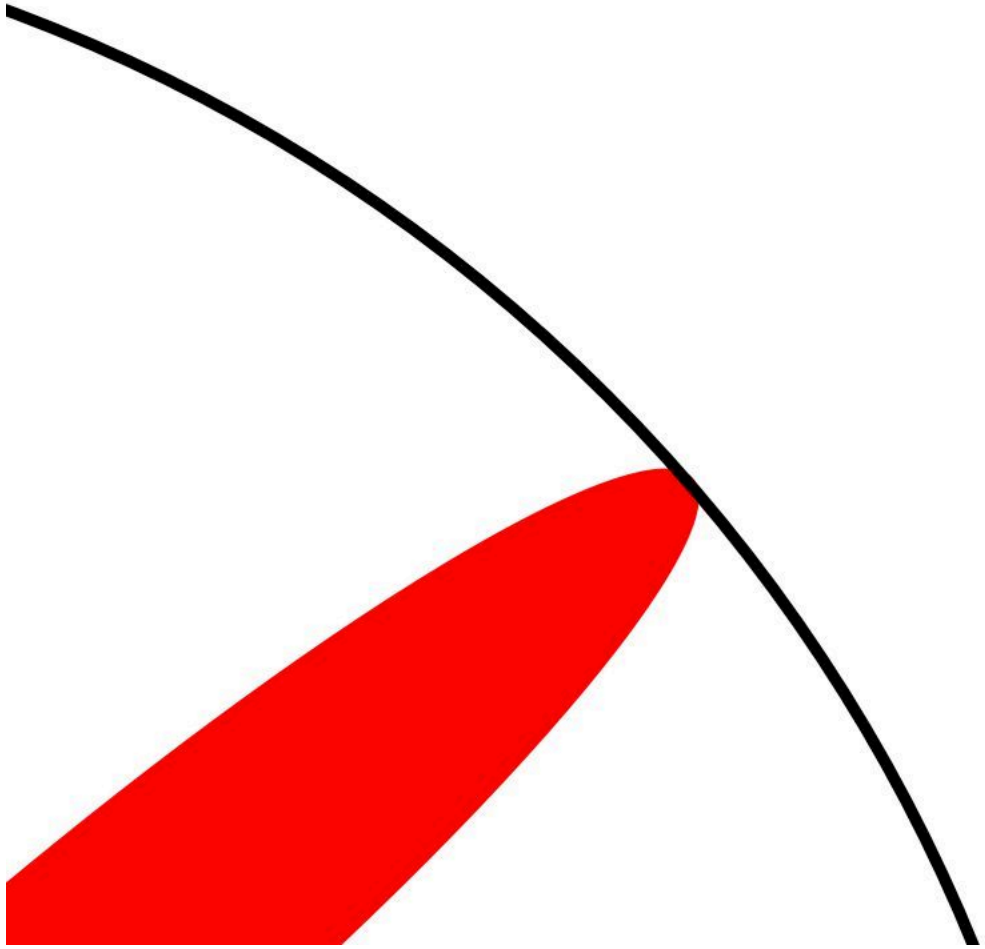

You push at the boundary for a few years

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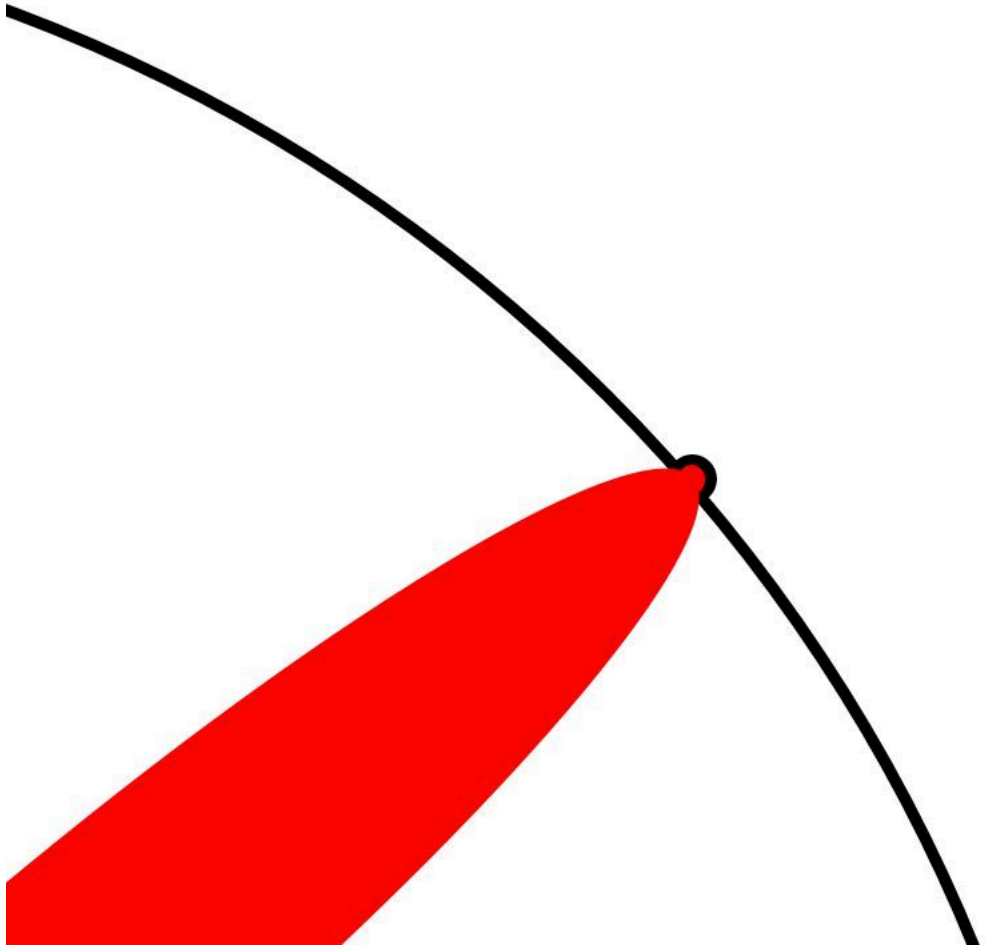

Until one day, the boundary gives way

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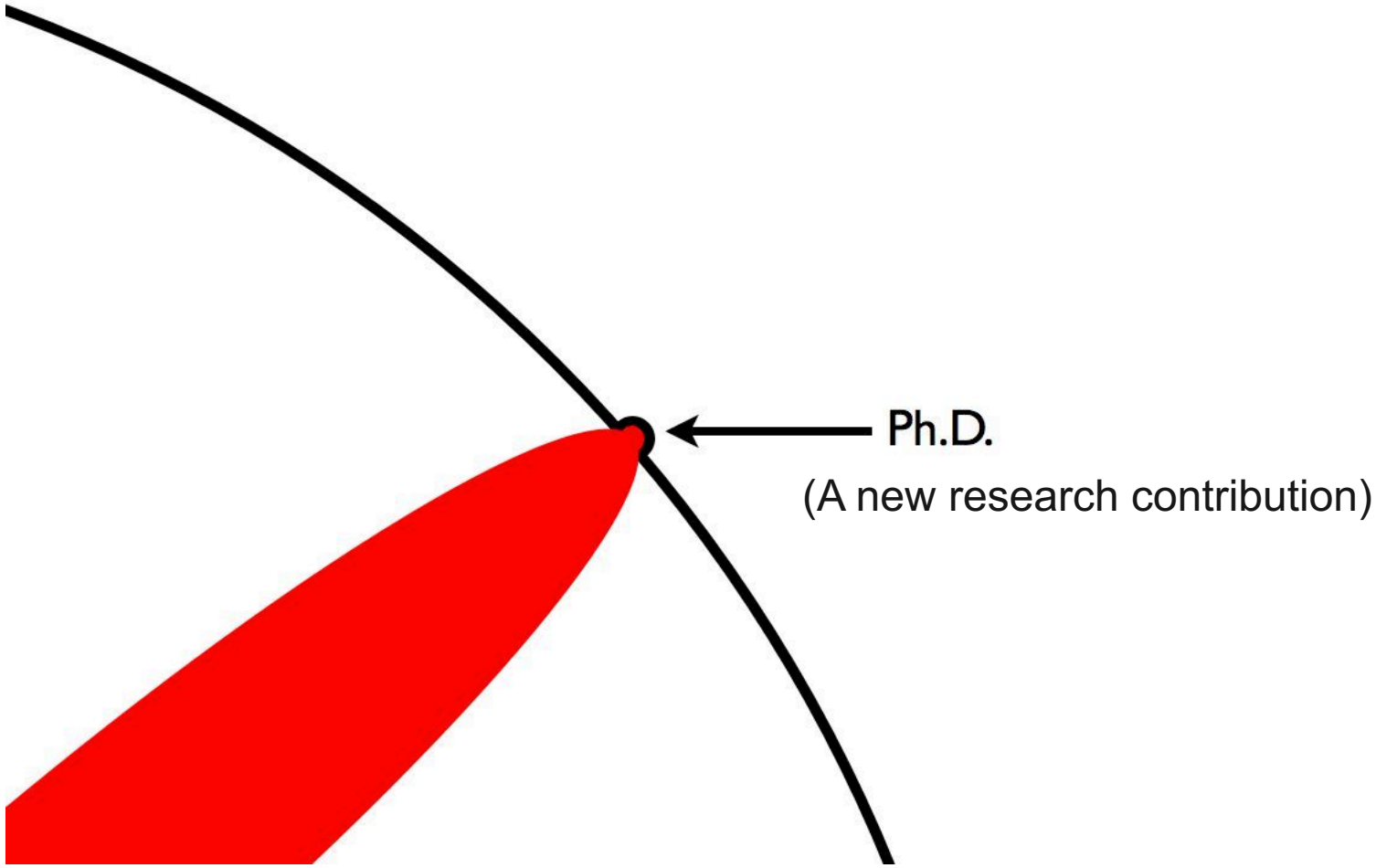

And that dent you made is called a Ph.D.

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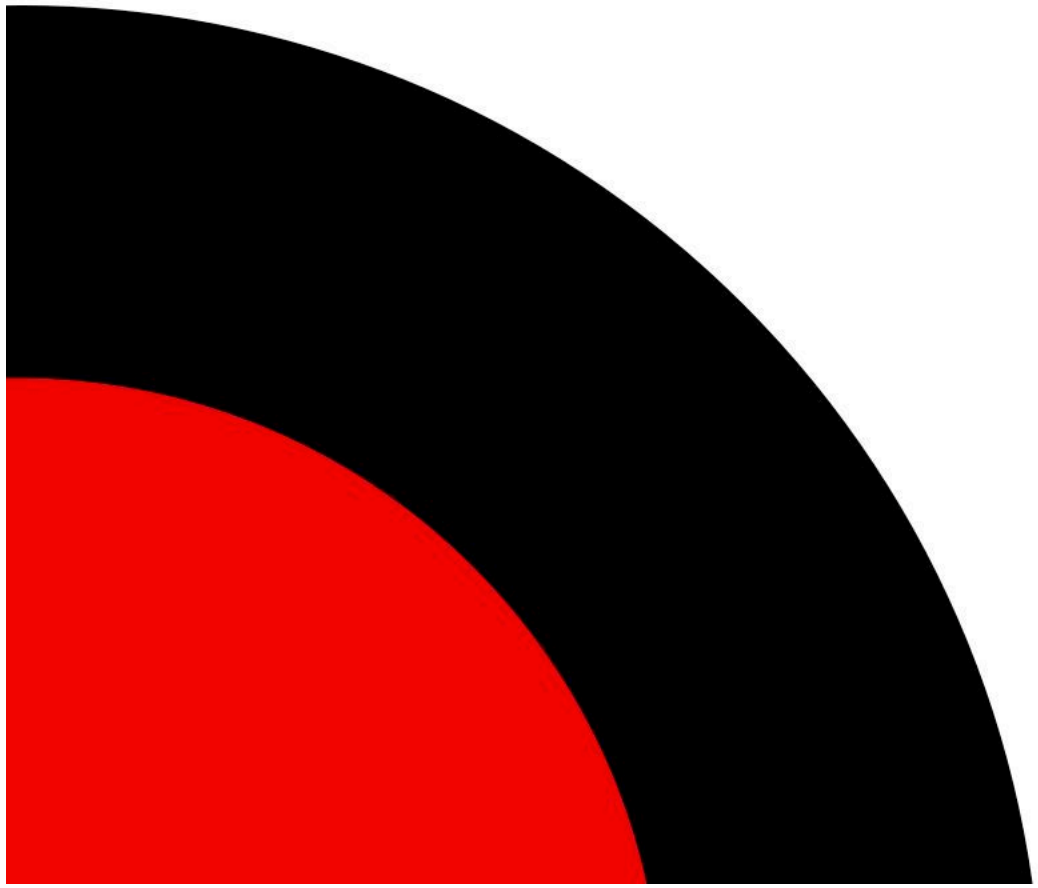

Of course, the world looks different to you now

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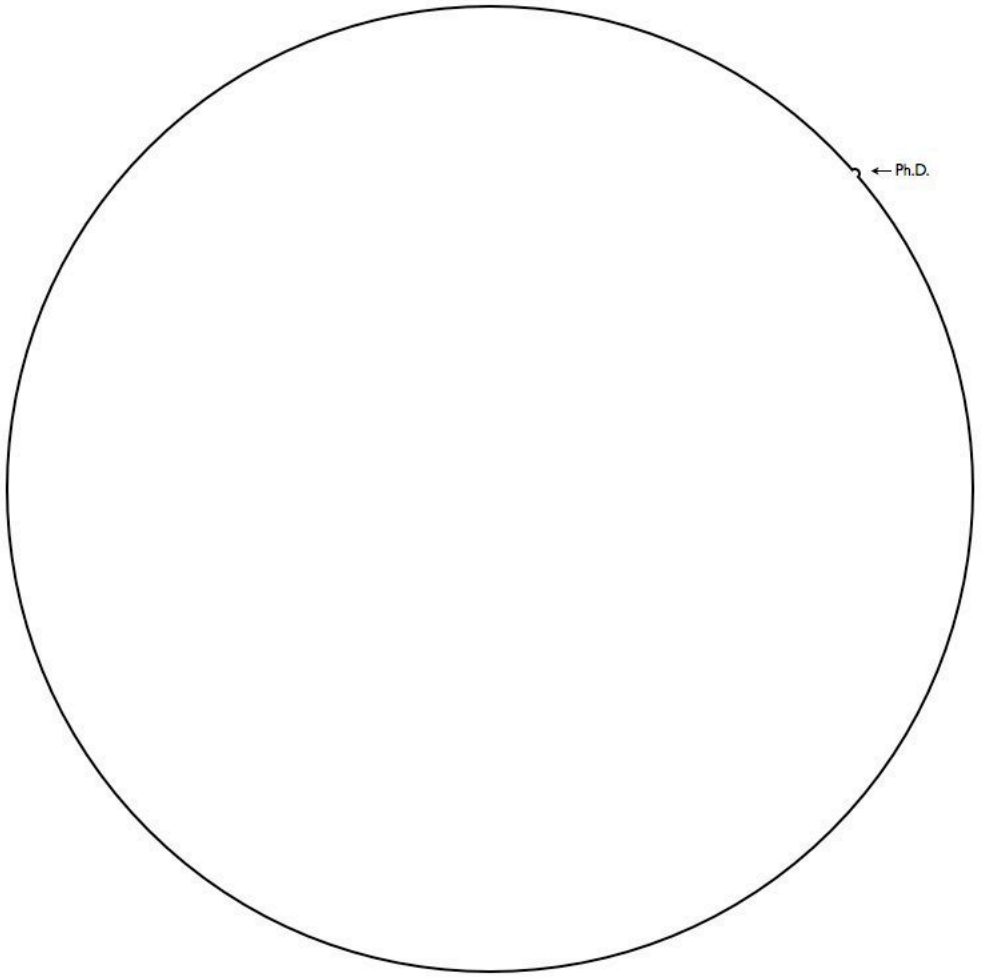
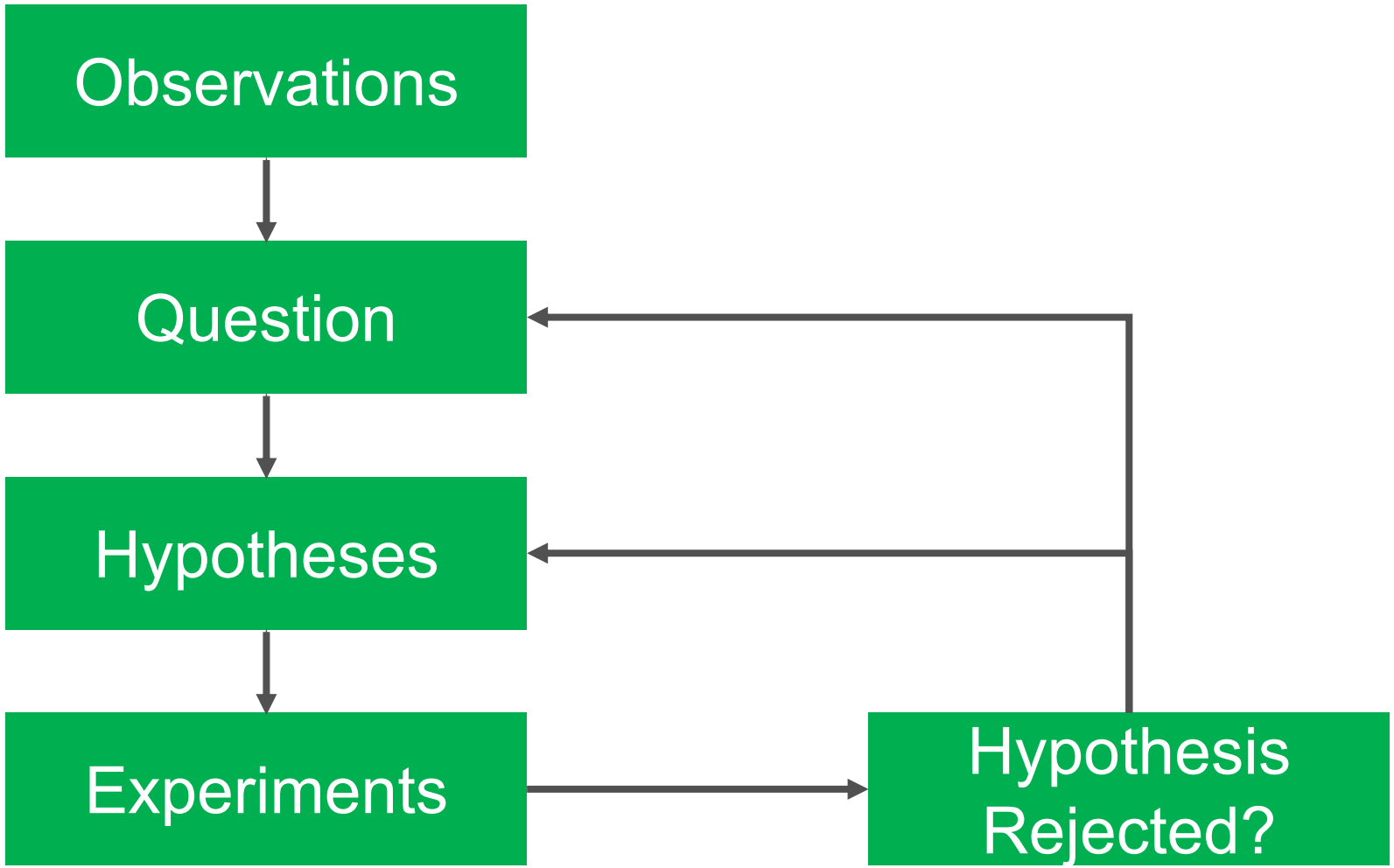


Keep pushing.

So, don't forget the bigger picture

Scientific Method

Based on the definition by Karl Popper



Attempts to prove the hypothesis incorrect

Scientific Method

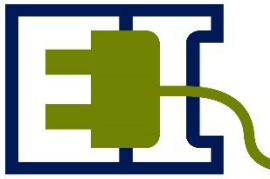
Based on the definition by Karl Popper

Hypotheses can NEVER be verified; only falsified

Assuming the methods are sound, if an hypothesis is not falsified 1,000 times, but is falsified once, the hypothesis must be considered incorrect

Theories that have been tested, but not falsified are our best understanding of the world at present (but could be proven false tomorrow)

What questions can we answer through science?



	Can we answer this type of question through science?
If I do this, what will happen?	**YES**
Why do the rules operate that way?	**NO**
Should I do it?	**NO**

Richard Feynman

Basic Research

- Purpose: expand knowledge
- Curiosity driven
- May not result in an invention or a solution to a practical problem

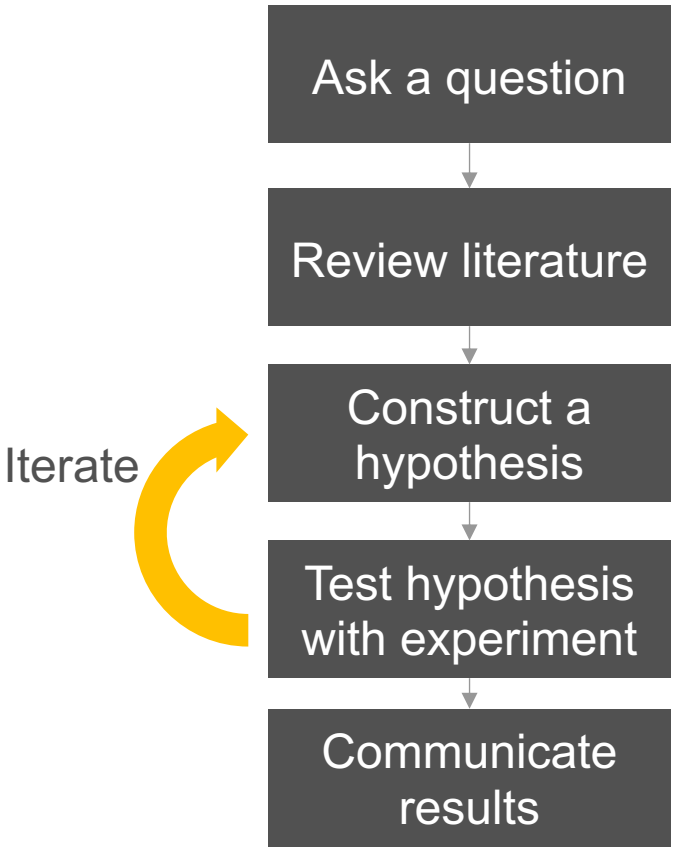
Example:
Are atoms composed of even smaller particles?

Applied Research

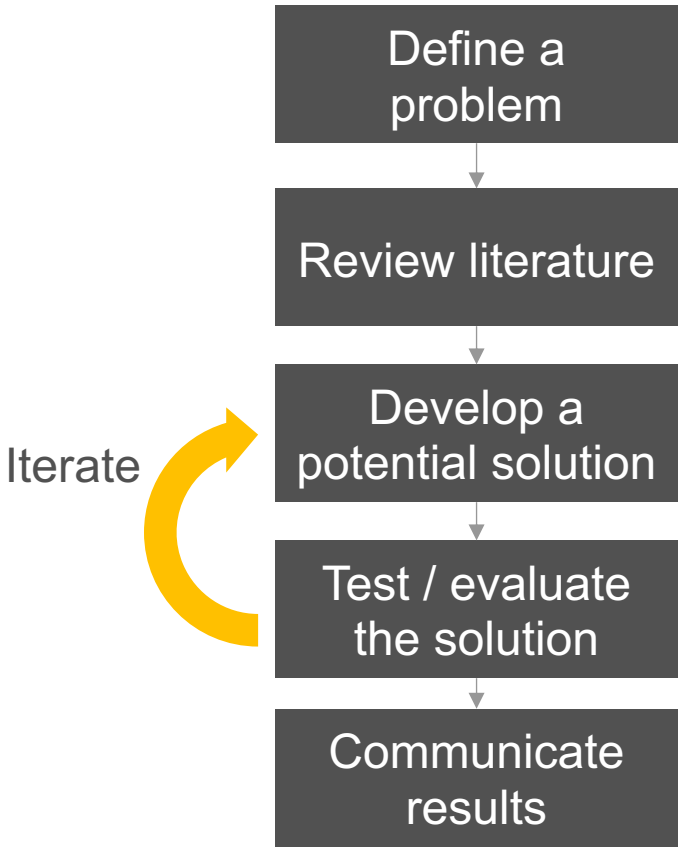
- Purpose: answers specific questions aimed at solving practical problems
- Often creates new processes, products, and technologies

Example:
How can atoms be used to create energy?

Scientific Method



Engineering Design Process



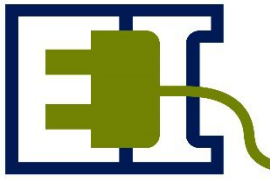
During iteration…

- Correct misunderstandings
- Read more
- Discuss with others
- Refine methods

Good research…

1. Considers and/or builds on past work (while pushing innovation)
2. Can be replicated by others
3. Is as independent and unbiased as possible
4. Will sometimes lead to dead ends, but those are valuable, too
5. Is produced by genuinely interested research teams

Research best practices



Machine learning experiment checklist

Paper/writeup checklist

Tools for research

Searching

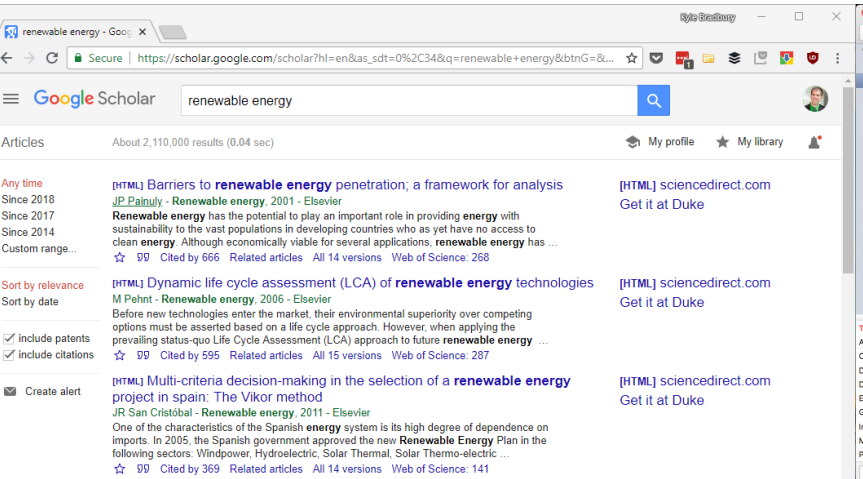
Organizing

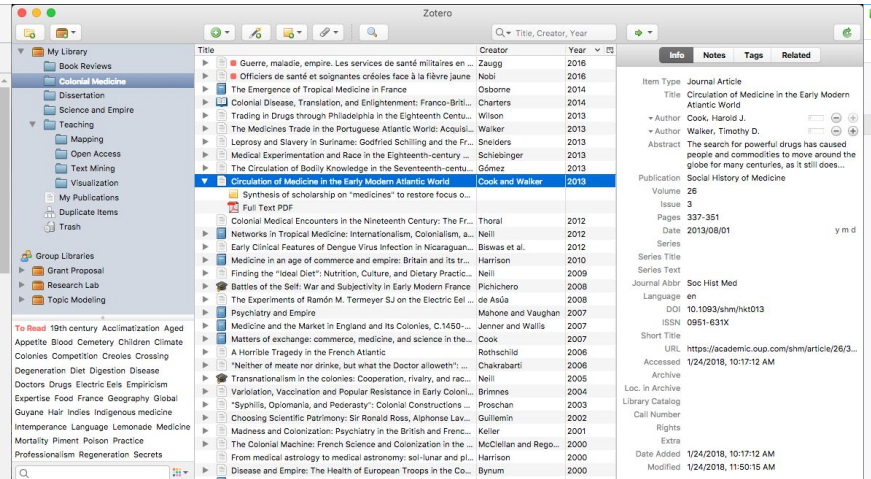
Synthesizing / Recording

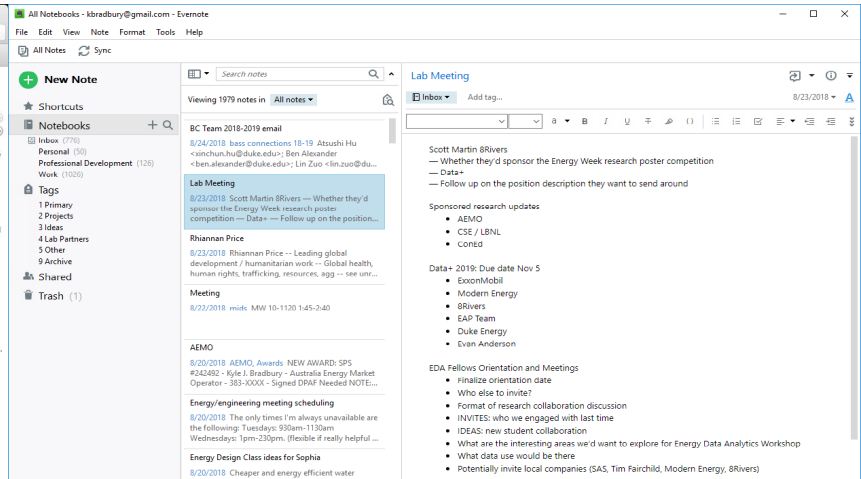
Scholarly literature search engines
(Google Scholar, Scopus, Web of Science)

Reference manager
(Zotero, Mendeley, Endnote)

Note taking software
(Evernote, OneNote)







Literature Reviews

How to read a research paper

1. Read the abstract
2. Understand any key figures
3. Read the conclusion
4. Re-read technical details to clarify anything that wasn't clear

What if I don't understand?

1. It's OK! It happens to us all
2. Read online
3. Look for a review article or textbook chapter on the topic
4. Search for acronym/jargon meaning
5. Remember: some papers are written terribly

Pautasso, M., 2013. Ten simple rules for writing a literature review. *PLoS Comput Biol*, *9*(7), p.e1003149. (link)

Summarizing a research paper

1. What is the question/problem being addressed and why is it important?
   - Mention the key takeaways at the beginning
2. What was being tested/investigated?
3. What methods were used and how did they work?
4. What were the findings? Were they significant, and if so, how so?
5. How was this different from other work (what was the unique contribution)?

USE FIGURES – can copy them from the original paper with an appropriate citation

“What I see in Nature is a magnificent structure that we can comprehend only very imperfectly, and that must fill a thinking person with a feeling of humility.”

Albert Einstein