Research Methodology

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How intuition fails

- Theory
  - Calculation extremely difficult
  - Or technically impossible (requires incorrect assumptions)
  - Or results different from expected
- Computation – similar to theory
  - Code too complicated
  - Hardware/software unsuitable
  - Results different from expected
- Experiment
  - Instrument not up to it/not available
  - No one knows how to run it properly
  - Results different from expected

When intuition fails

- Do not give up!
- It is very common
- Only those who try, fail
- Perhaps the goal should be modified
- Or a new technique should be tried
- Or the idea itself was not right
- Try other approaches, or other problems

Reductionism

- Philosophy: A complex system is the sum of its parts
- Three main types:
  - Ontological
  - Methodological
  - Theory
- Ontological reductionism:
  - Materials → crystals/molecules → atoms → protons and electrons → quarks etc
  - Living beings → molecules → atoms
- Methodological reductionism:
  - Explanation using smaller systems
  - "to reduce the world of physical phenomena to a finite set of fundamental equations." – Freeman J. Dyson

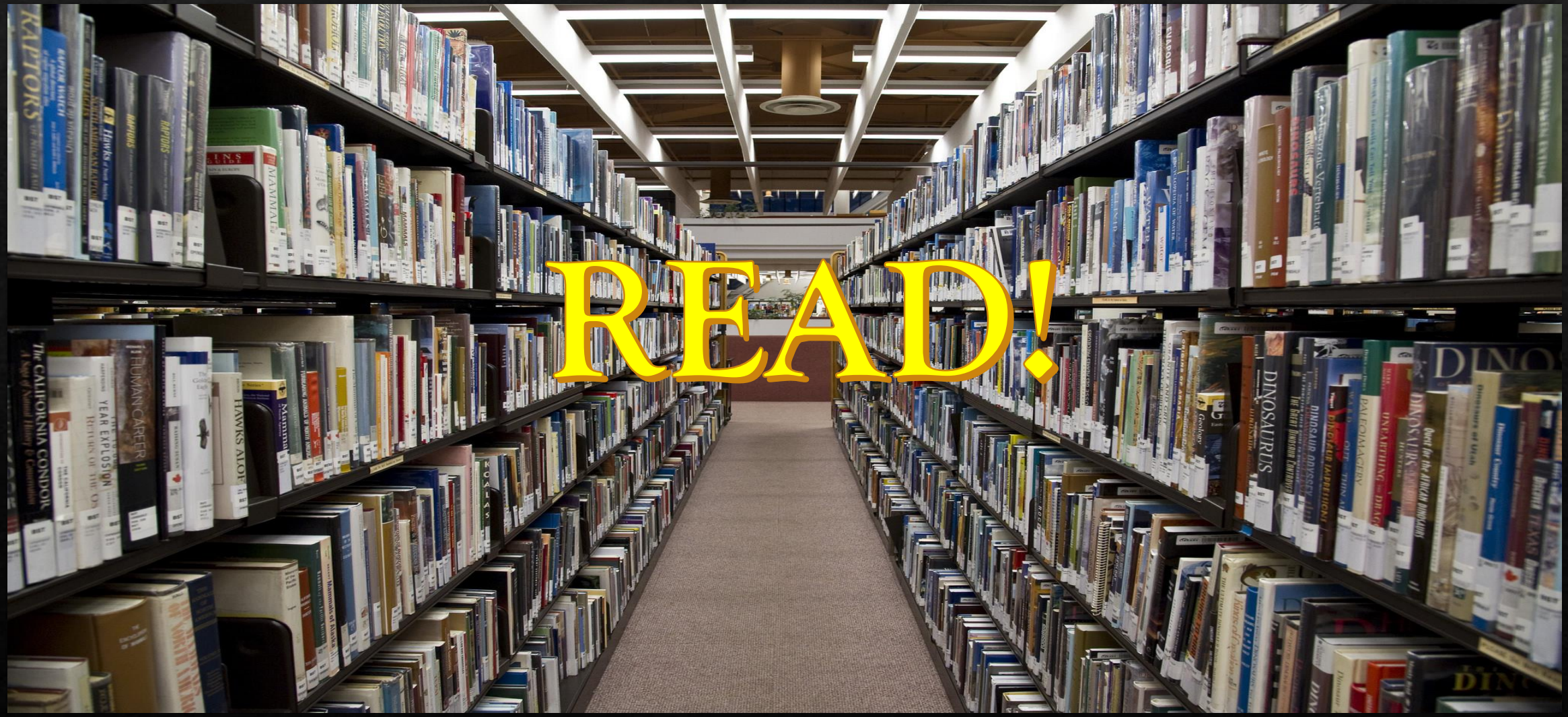
Reductionism

- More examples of methodological reductionism:
  - Solar system reduced to the Sun and the planets and satellites
  - Temperature and other properties of gas reduced to molecular interactions
  - Psychological phenomena to chemical and physical processes in the brain
  - Biology to physics and chemistry – electrical and chemical processes
  - All physical processes can be described by four fundamental interactions
- Theory reductionism:
  - New theories do not replace old theories, but breaks it down to more basic terms
- Apply to search for problems (Methodological reductionism)
- Break problem into smaller components
- Understand part of the system or problem

Other ways of finding problems

- Serendipity (making valuable discoveries without searching for them)
- Famous serendipitous discoveries
  - X ray – Wilhelm Roentgen
  - Penicillin – Alexander Fleming
  - CMBR – Arno Penzias and Robert Wilson
  - Pulsars – Jocelyn Bell Burnell
  - H pylori – Barry Marshall and J. Robin Warren
- 33% to 50% of all scientific discoveries are unexpected
- Scientists are not passive recipients of the unexpected; rather, they actively create the conditions for discovering the unexpected. – Kevin Dunbar and Jonathan Fugelsang

How to prepare?



Sources

- Books
  - Provides background knowledge
  - Can provide a big picture
  - Usually not up to date
- Journal articles
  - Current research (if recent)
  - Established research (if old and famous)
  - Validated by peer review
- Preprints
  - Fresh research
  - Not validated by others
- Seminar and conference talks
  - Occasionally, insights not found elsewhere

Thank you!