BN4101R Research Methodology and Ethics

Mrinal Musib, Ph.D

Department of Biomedical Engineering

National University of Singapore

Bit about my education/experience

- Ph.D; Biomedical Engineering; University of Texas Medical School in San Antonio
- Senior Research Scientist: New York State University Medical School
- Consultant: Johnson and Johnson, Asia Pacific Regional Office, Singapore

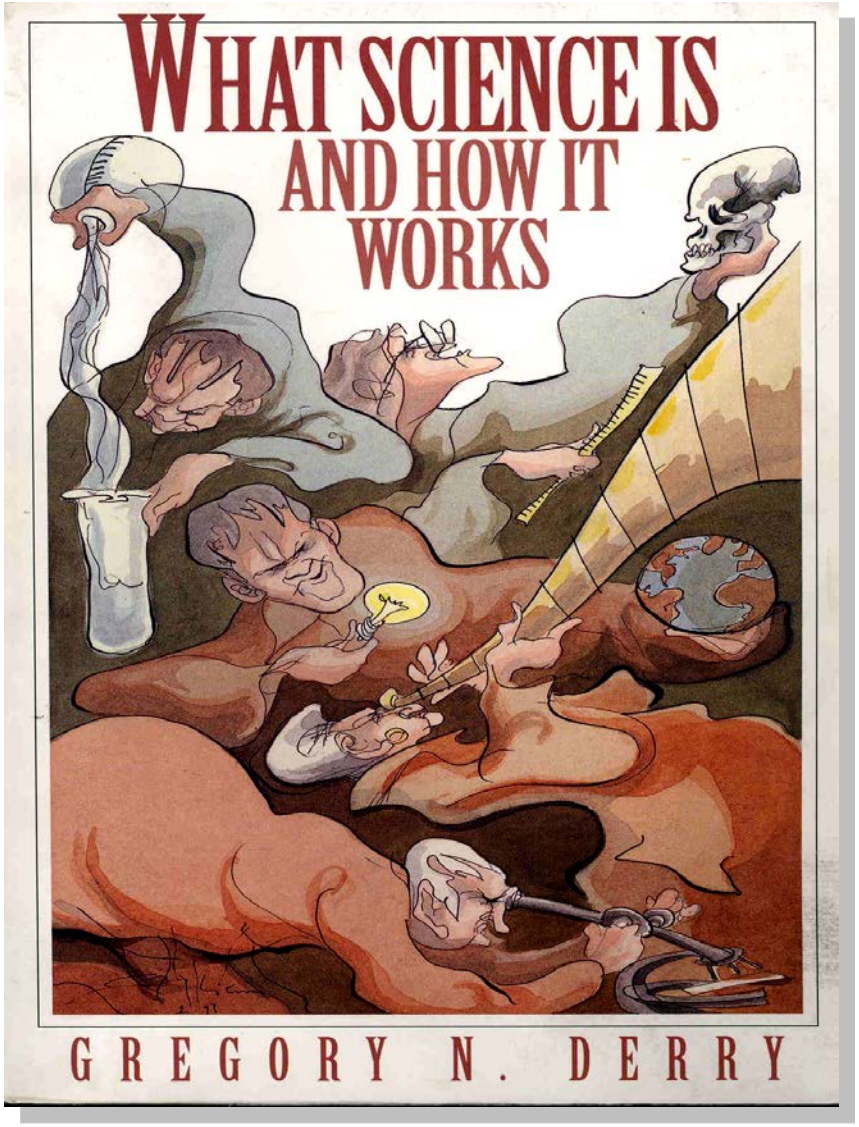
Let us understand…

What ‘science’ or ‘Research’ is and how it works

What we will learn today

1. What is science and how it works
2. The concept of “scientific method” and “methodological approaches”
3. Discriminate between “hypothesis”, “theory” & “laws”

1. What Science is and how it works



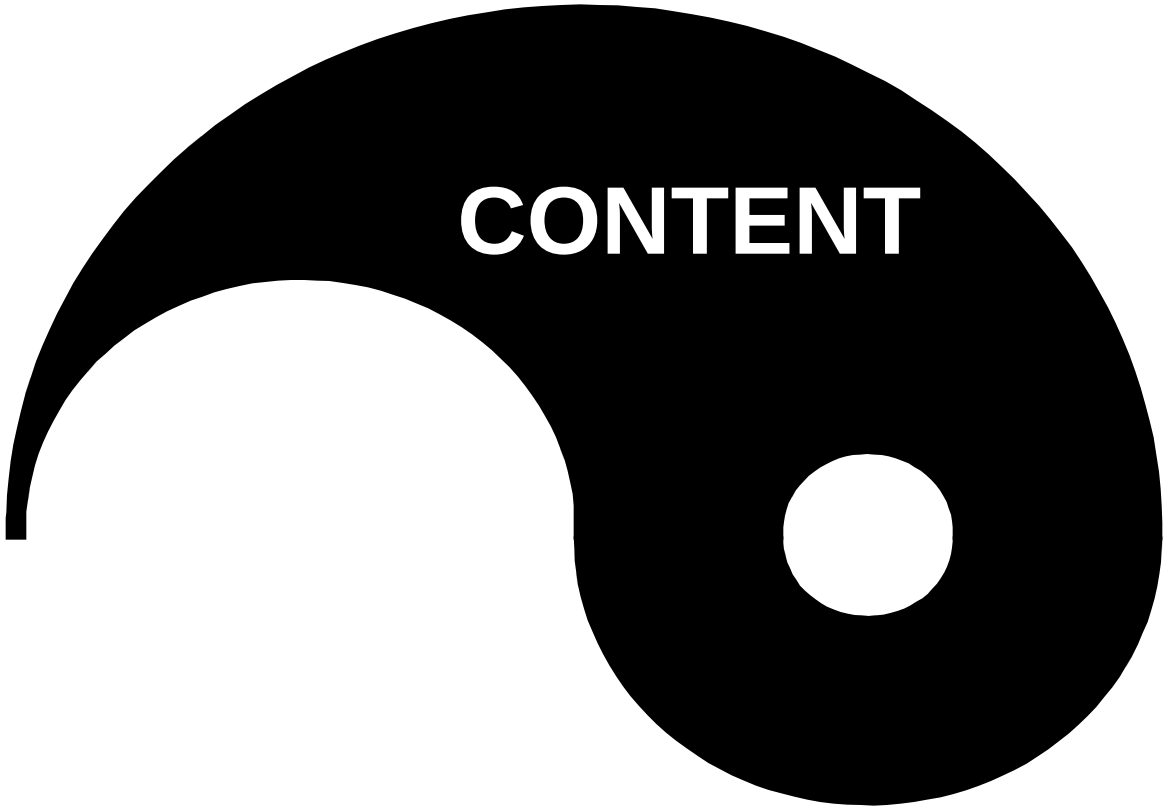
What Science is and how it works

The pursuit of knowledge and understanding
from the Latin term scientia, which means knowledge

Science is:

- a process for evaluating empirical and experimental knowledge
- a global community of scholars, and the organized body of knowledge gained by this process and carried by this community (and others).

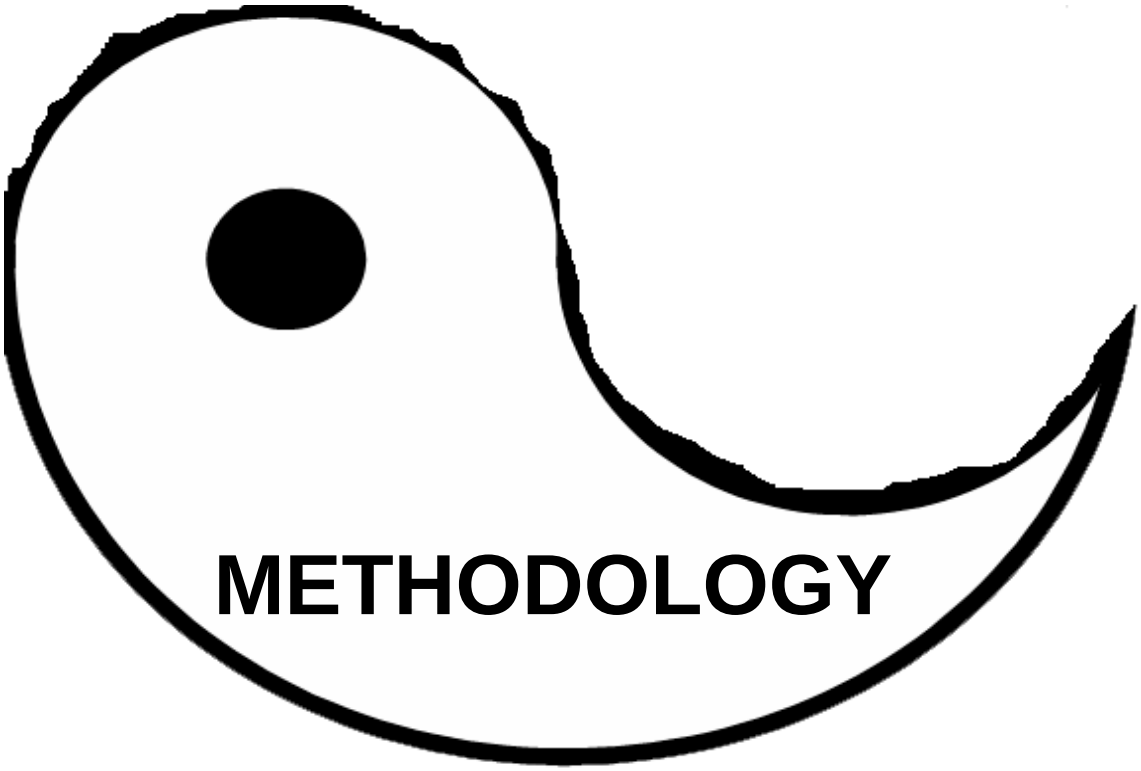
Content (alone) is not Science



Sum total of all facts, definitions, theories, techniques and relationships found in all of the individual scientific disciplines

This is what is usually taught in science text books

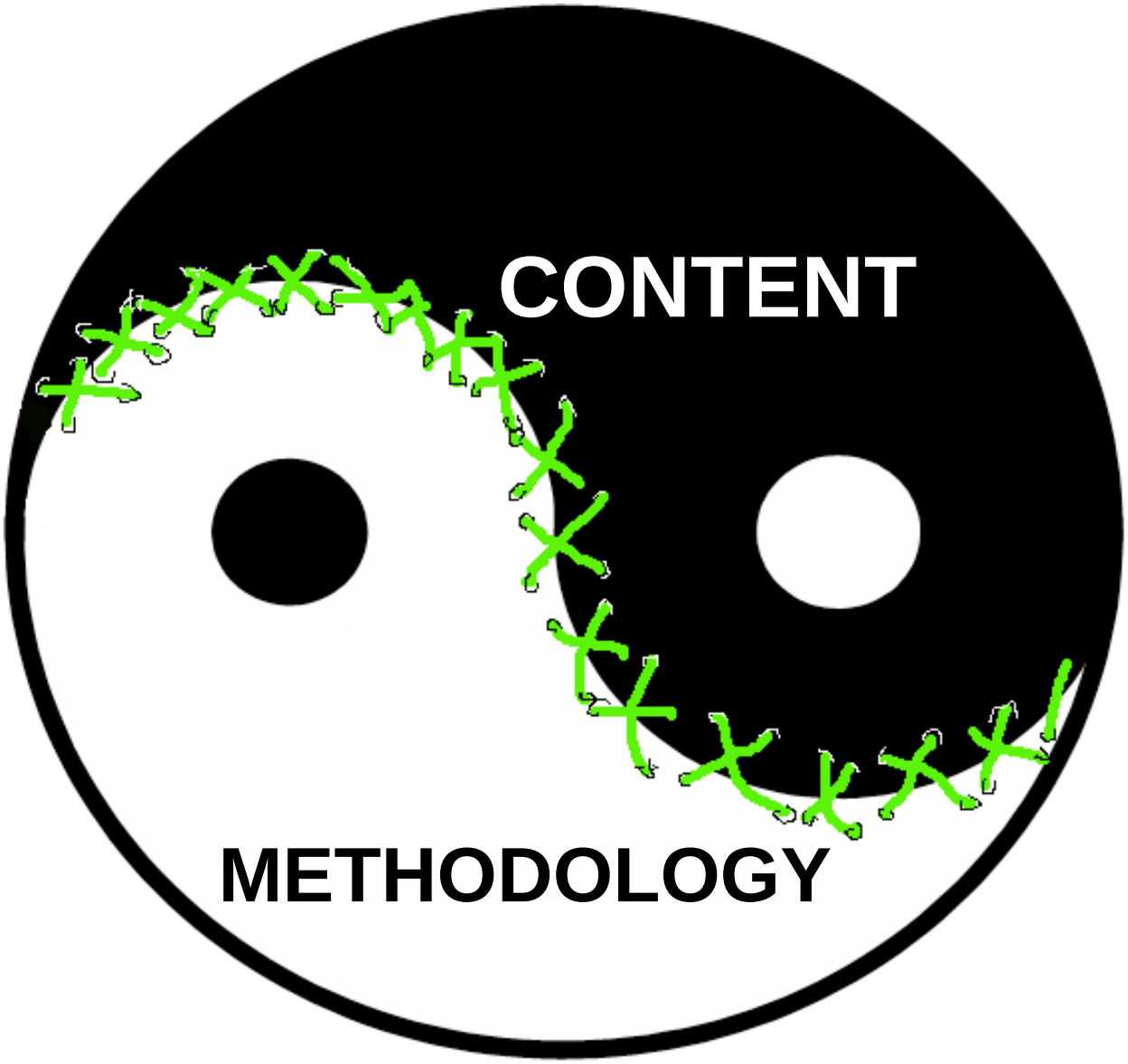
Methodology (alone) is not Science



Activity going on in the laboratories and fieldwork

Learning technologies and shopping for methods ("exposure") does not make you a scientist

What Science is



SCIENCE is Content and Methodology that are inseparably intertwined

Characteristics of Science

- Coherent understanding of observations
- Growth and progress in understanding (ideas change over time, reinterpretation in new light)
- Rigorous logic, strict chain of deductive reasoning (ideally without gaps and weak spots)
- "Organised and constructive skepticism" (peer review, criticism and judgement to weed out bogus results
- Standing on the "shoulders of giants" , building on previous work, acknowledging it

From Gregory N. Derrry's book

2. Research is..

Research is an active, diligent and systematic

process of inquiry

to

discover, interpret or revise

facts, events, behaviors, theories, or

to make practical applications

with the help of such facts, laws or theories

Research Methodology

Experimental

- Chemical, biological, electrical, mechanical etc
- Laboratory-based or field
- Hands-on

Theoretical

- Computer-based
- Simulation, modeling, calculations
- Link to actual data?

Case studies

- data and literature review

4 steps of scientific Method

1. **Observe** some aspect of the universe

2. Invent a working assumption, called a ***hypothesis***, consistent with what you have observed

3. Use the hypothesis to make **predictions**

4. **Test** those predictions by experiments or further observations, modify hypothesis in the light of your results

Repeat steps 3 and 4 until there are no discrepancies between theory and experiment and/or observation.

A Hypothesis is..

A limited statement regarding cause and effect in specific situations (**guesstimation**)

It also refers to our state of knowledge before experimental work has been performed and perhaps even before new phenomena have been predicted

A hypothesis is basically a working assumption

Without a hypothesis you lack the intellectual basis for doing research

Advantage of the Scientific Method

- One does not have to believe a given researcher
- One can redo the experiment and determine whether his/her results are true or false
- The conclusions will hold irrespective of the state of mind, or the religious persuasion, or the state of consciousness of the investigator and/or the subject of the investigation

3. A scientific theory or law

• A hypothesis or a group of related hypotheses, which has been confirmed through repeated experimental tests

Theories in physics are often formulated in terms of a few concepts and equations, which are identified with "laws of nature," suggesting their universal applicability

Accepted scientific theories and laws become part of our understanding of the universe and the basis for exploring less well-understood areas of knowledge

Theories

”Theories are not easily discarded”
New discoveries are first assumed to fit
Into the existing theoretical framework

It is only when, after repeated experimental tests, the new phenomenon cannot be accommodated that scientists seriously question the theory and attempt to modify it.

Testing hypotheses and Theories

- Experimental tests may lead either to the confirmation of the hypothesis or its ruling out

- A hypothesis has to be ruled out or modified if its predictions are clearly and repeatedly incompatible with experimental data

- Experiments may test the theory directly (for example, the observation of a new particle) or may test for consequences derived from the theory using mathematics and logic

- To be credible a theory must be testable, or even falsifiable

Common Mistakes

- Being BIASED
- Ignore Consensus backed by experimental results and acknowledged by members of the scientific community
- To ignore or rule out data which do not support the hypothesis
- Failure to estimate quantitatively systematic errors and all errors

Ockham's Razor

William of Ockham (14th century):

``Pluralitas non est ponenda sine neccesitate'',

``Multiplicity should not be placed without necessity”

If you have two theories, choose the one that is simpler, still explains the experimental data.

Observation: the street is wet

Its just a theory – or is it ?

A hypothesis is a working assumption.
Typically, a scientist devises a hypothesis and then sees if it “holds water" by testing it against available data (obtained from previous experiments and observations)

If it does, the scientist declares it a theory.
To a scientist a theory is a conceptual framework that explains existing observations and predicts new ones [Sun rise, gravity]

Truth and Proof in Science

Experiments sometimes produce results which cannot be explained with existing theories

<u>In this case it is the job of scientists to:</u>

- Explain all the observations and experiments the old theory did *and*, in addition, the new set of facts which lead to their development.
- Define new theories (devour and assimilate old ones)
- Repeatedly test existing theories in order to probe how far they can be applied.

Science

- Growth and progress in understanding
- Coherent understanding of observations
- Rigorous logic and chain of reasoning
- “Organized skepticism” (peer review and criticism)
- Standing on the “shoulders of giants” - previous work

From Gregory N. Derrry’s book

A successful research design

1- Hypothesis
2- Aims
3- Rational
4- Innovation
5- Significance
6- Literature review
7- Team members
8- Materials and Methods
9- Research plan
10- Documentation
11- Statistical analysis
12- Interpretation
13- Conclusion

“Organised skepticism”

Documentation, reproducible and replicable
The data published must be comprehensive and complete. Consequently, it is a common practice for other scientists to attempt to repeat the experiments in order to duplicate the results.

Archiving
Researchers are expected to practice scientific data archiving in compliance with the policies of government funding agencies and scientific journals. Detailed records of their experimental procedures, raw data, statistical analyses and source code are preserved in order to provide evidence of the effectiveness and integrity of the procedure and assist in reproduction.

Furnishing the data
When additional information is needed before a study can be reproduced, the author of the study is expected to provide it promptly. If the author refuses to provide information, it is called data withholding

"Never theorize before you have data. Invariably, you end up

twisting facts to suit theories

instead of theories to suit facts."

-Sherlock Holmes

Some Reading

References

1. Wilson, E. Bright. An Introduction to Scientific Research (McGraw-Hill, 1952).
2. Kuhn, Thomas. The Structure of Scientific Revolutions (Univ. of Chicago Press, 1962).
3. Barrow, John. Theories of Everything (Oxford Univ. Press, 1991).
4. Gregory N. Derry. What Science is and how it works (Princeton University Press 2002
5. E.Brian Davies. Science in the Looking Glass (Oxford University Press 2003)
6. James Robert Brown. Who Rules in Science (Harvard University Press 2001)
7. Terry Pratchett, Ian Stewart & Jack Cohen. The Science of Discworld III: Darwin's Watch. Ebury Press 2005
8. Wikipedia, some unedited articles and chapters with further references