Aalto University

A!ENG Research Lab

This is a course on science and research

...but what do they actually mean and how they differ?

Marko Keskinen

14.4.2021

MARKO WHO?

I am expert in water, sustainability and integrated approaches, but not in science *per se*

→ On the contrary, stubborn pragmatist on it…

→ But I am super-interested in multi-, inter- and transdisciplinary approaches + in scientific and societal impact = that's why interested in this, too!

http://people.aalto.fi/marko_keskinen

twitter.com/keskma

WHO YOU?

You are too many for individual intro, so
let's do that with Zoom's reactions and chat

1) Select Yes/Now from reactions

- *Do you have a Research Plan already?*
- *Are you working full-time for your Doctoral Thesis?*
- *Have you already published something?*

2) Write to the chat your research theme / title of your Thesis

I thrive from interaction, which is more difficult in the online mode

→ *Please feel free to ask & comment any time, either by using 'Raise hand' function or writing your comment to the chat*

THE AIMS FOR THIS SESSION

1) Think hard what are: science & research

→ Key themes for this course – and for your doctoral research process!

→ Important to think how you understand them NOW: facilitates learning later on during the course (as much more on these coming)

2) Discuss in more practical terms about science & research

→ Basic vs. applied research; different research fields; disciplines

3) Go through your Research Plan and see how these two themes are visible (or not) there

→ May help you to find ways to revise/re-think your Research Plan

THE STRUCTURE

1) Science & research?

→ Getting the concepts right

2) Science & research in practice

→ Two basic steps + basic vs. applied research + disciplines

3) Some concluding thoughts

4) Working on your Research Plan, with Roza

1) SCIENCE & RESEARCH?

- Getting the concepts right first
  i.e. the theory part! :)

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SCIENCE & RESEARCH?

ME: Write down your own short definitions for
i) science and ii) research (6 min)

→ Definition as a text, but you can also use diagrams as support

WE: Discuss in Zoom's breakout groups (3-4 people)

→ Main similarities? And differences? Why? (6 min)

US: Discussing the definitions with all of us

SCIENCE & RESEARCH: YOUR VIEWS

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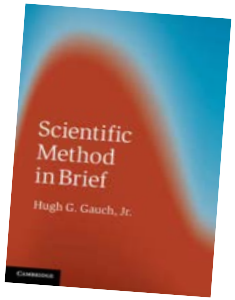
WHY THESE TERMS MATTERS?

Because we easily just start 'doing research' without understanding their general principles

→ *Gauch's (2012) "Scientific method in Brief" is nice, deep introduction to 'scientific method'*



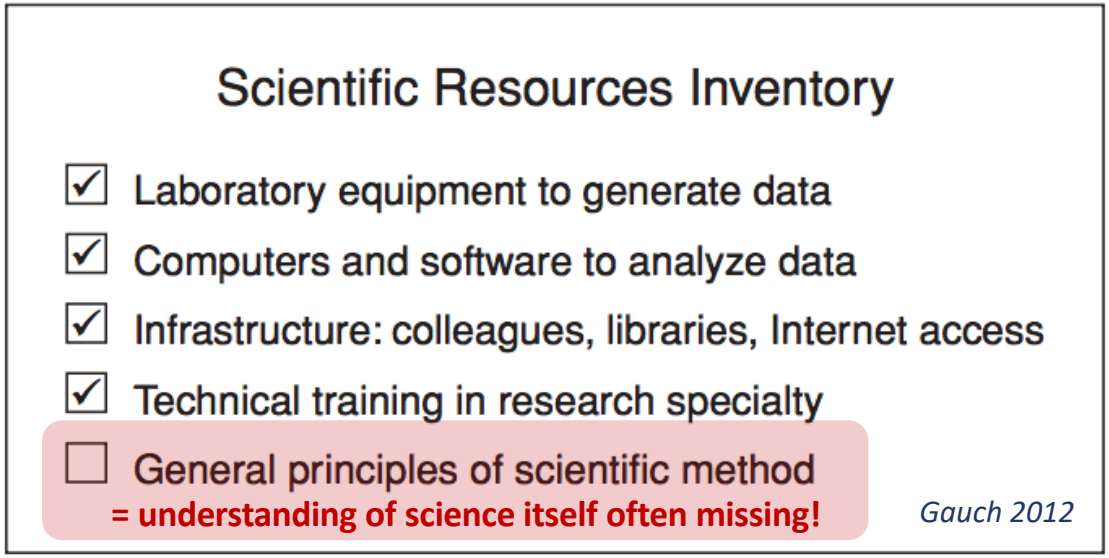


Figure 1.3 A typical resources inventory for a research group. The scientists in a given research group often have excellent laboratory equipment, computers, infrastructure, and technical training, but inadequate understanding of the general principles of scientific method is the weakest link. Ideally, a research group will be able to check off all five boxes in this inventory, and there will be no weak link.

SCIENCE?

SHORT:

"A systematically organized body of knowledge on a particular subject"

LONG:

"The intellectual and practical activity
…encompassing the systematic study
…of the structure and behaviour
…of the physical and natural world
…through observation and experiment"

Oxford Dictionary

The foundation you build on:

science and your discipline tells where you are coming from = gives you identity

→ **Your 'mother'!**

Note: there are some general principles on what science is (and hence what is **not** science)

Gauch 2012:
Scientific Method in Brief

Science's Four Claims

Rationality
Rational methods of inquiry use reason and evidence correctly to achieve substantial and specified success in finding truth, and rational actions use rational and true beliefs to guide good actions.

Truth
True statements correspond with reality:

Correspondence

External Physical World of Objects and Events	← →	Internal Mental World of Perceptions and Beliefs

Objectivity
Objective beliefs concern external physical objects; they can be tested and verified so that consensus will emerge among knowledgeable persons; and they do not depend on controversial presuppositions or special worldviews.

Realism
Realism is correspondence of human thoughts with an external and independent reality, including physical objects.

RESEARCH? *by Oxford Dictionary*

"The systematic investigation into and study of

…materials and sources

…in order to establish facts

…and reach new conclusions"

→ Research is thus essentially about 'doing science': increases the body of knowledge on a subject, as includes novelty i.e. new knowledge

RESEARCH? *by Ling & Yang 2012*

Note: Ling & Yang talk about "science" as something that is related but distinct from "engineering"

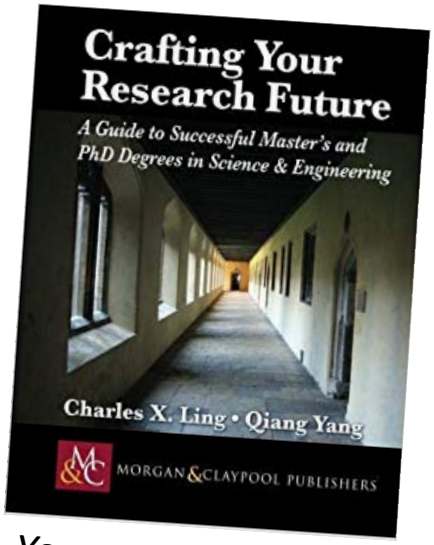
→ I talk about 'science of engineering' that your research contributes to (i.e. I don't make the same distinction)

"In natural science and engineering, 'research' can be loosely defined as…

… making **novel** and **significant** contributions to our understanding of the world,

… based on **reproducible observations** and **verifiable results**"

→ "Novelty and significance = key ingredients of research"

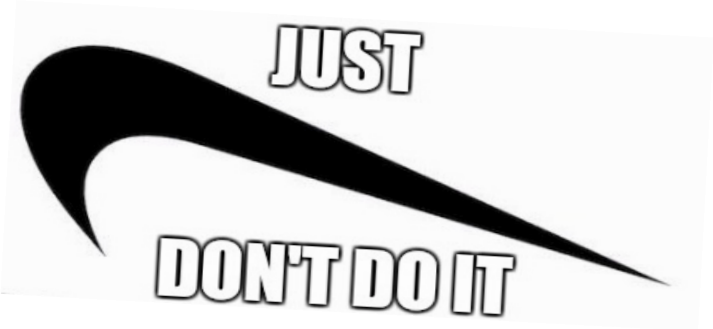


Your course book!

RESEARCH?

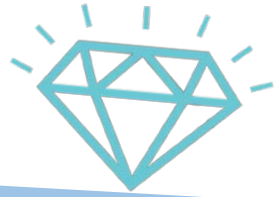
Research is your main activity i.e. the thing you do!

→ Yet, quite often engineers think you can 'just do it' i.e. research is just about collecting and analysing data with certain (pre-given) methods



→ But very important to think first systematically
i) what you do, ii) how & why you do it, and
iii) how your 'doing' actually relates to science,
i.e.adds novelty and significance to it

SCIENTIFIC WRITING?



This is critical to actually get your Thesis done, yet often forgotten (as it is 'just' about writing up the research)

→ **Your hidden gem!**

No dictionary definition! My suggestion:

"Translating your research into a scientific publication

…by clearly stating its novelty

…using established scientific methods

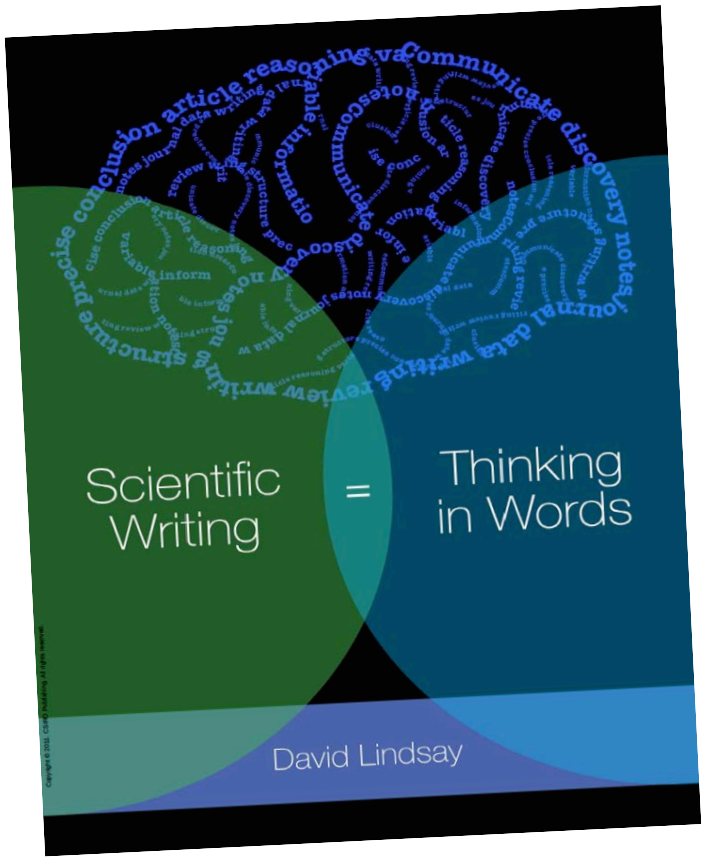
…following the rules and norms of your discipline

…in a way that your research can be re-created by a peer

with an aim of getting the whole thing published!"

And oh boy, it can take time (so be prepared!)

SCIENTIFIC WRITING: YOUR COURSE BOOK!



- 99% of scientists agree that writing is an integral part of their job as scientists (while very few have had any formal training in it)
- Only about 10% enjoy writing; the other 90% consider it a necessary chore.

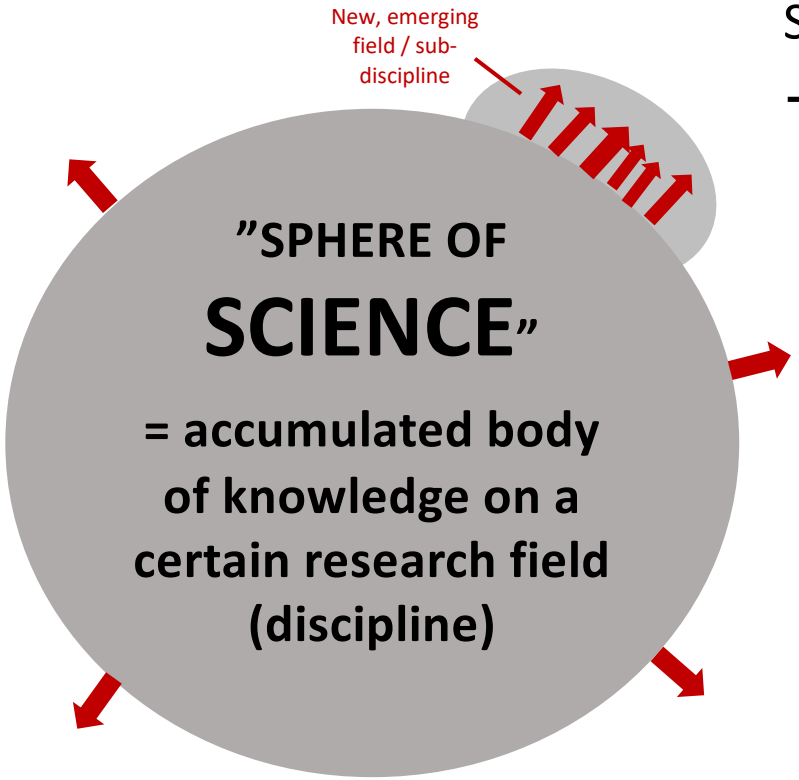
→ Not easy, but very important!

Good scientific writing:

- Precise
- Clear
- Brief

Requires a combination of focused thinking, accurate writing & well-defined structure!

SCIENCE, RESEARCH & SCIENTIFIC WRITING

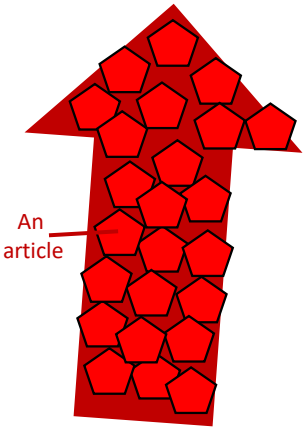


Sphere = **SCIENCE** i.e. accumulated body of knowledge

→ Discipline = that knowledge on a certain field (each discipline thus has its own sphere)

Arrows = new **RESEARCH** that creates novel knowledge to that body of knowledge

Several arrows pushing to the same direction = new, emerging field



An arrow consists of several **articles** that study the same theme and thus produce together new knowledge on it

Note: simplified visualisation by Marko

SCIENTIFIC WRITING = the structured process to communicate your research and its novelty so that it can be added to the body of knowledge

QUESTIONS? COMMENTS?

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Break

2) Science & Research in practice

- Two basic steps of doing research
- Basic vs. applied research
- Standing on the shoulders of giants
- Disciplines + multi-, inter- and transdisciplinarity

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RESEARCH: TWO BASIC STEPS

Note: by Marko so subject to discussion

FIRST: theoretical basis

Key theories (and related assumptions!) you build your research on:
usually defined by your discipline

→ Critical for research, but often not very thoroughly thought of (as 'given')

Theoretical basis helps then to recognise **analytical frameworks/approaches** that you can use to structure your research

→ Defines the system you focus + provides a way for categorisation its elements

SECOND: research practice i.e. methods

Actual research methods –quantitative and qualitative- that you use

→ These are used both to collect the data and to analyse it

ECONOMICS:
what is the monetary value of apple?

MACRO-ECONOMICS

INT'L TRADE FLOW ANALYSIS

STATISTICAL ANALYSIS ON TRADE STATISTICS

MICRO-ECONOMICS

ENGINEERING:
how to make good juice out of apple?

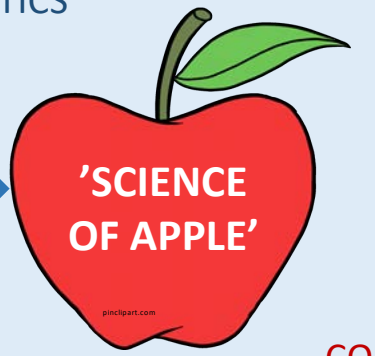
BIOPROCESS ENGINEERING

OPTRONICS-BASED QUALITY CONTROL METHOD FOR JUICE EXTRACTION

MECHNICAL JUICING

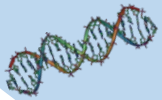
MECHANICAL ENGINEERING + PHOTONICS

THEORETICAL BASIS | **ANALYTICAL FRAMEWORKS / APPROACHES** | **METHODS FOR COLLECTING & ANALYSING DATA**



Note: simplified example by Marko

GENETICS



GENE MANIPU-LATION

POLYMERASE CHAIN REACTION

CONTENT ANALYSIS OF BLOG POSTS ON APPLES

FUNCTIONALISM
(focusing on social structure)

BARTHES' META-LANGUAGE

POST-STRUCTURALISM
(plurality of meaning)

BIOLOGY:
what is, actually, an apple?

EVOLUTIONARY BIOLOGY

SOCIOLOGY:
how has apple shaped our society?

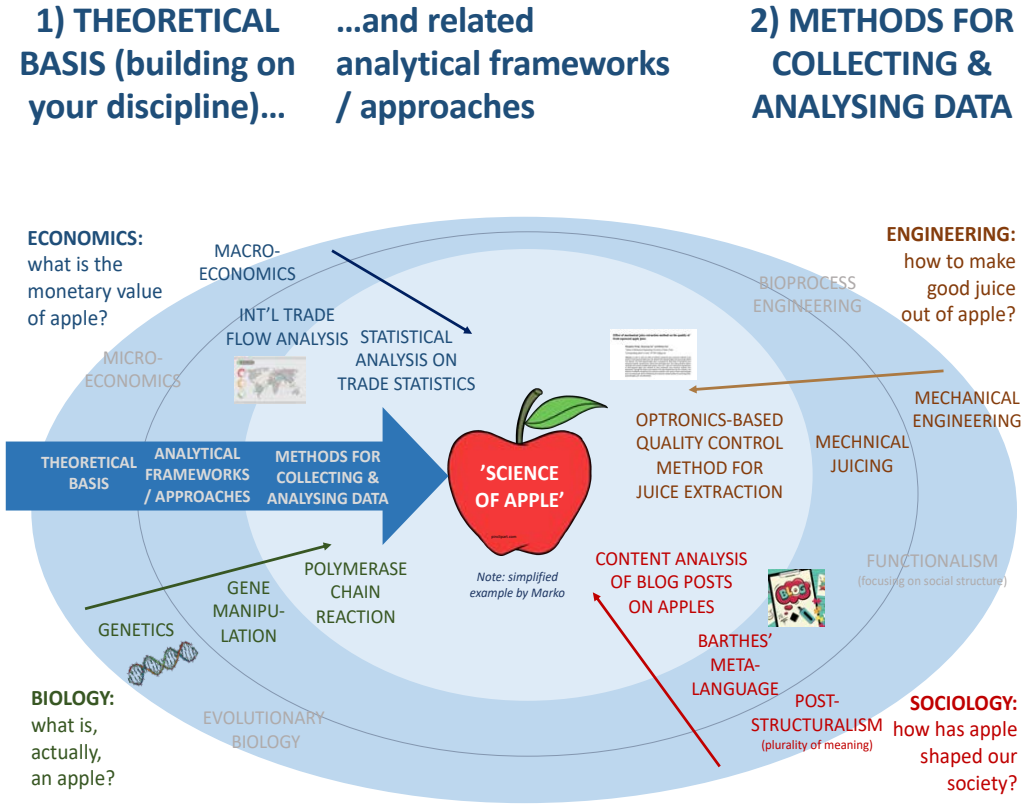
RESEARCH: TWO BASIC SPHERES

Suggestion by Marko so subject to discussion

Majority of your time goes on the inner sphere i.e. carrying out the research through different methods

→ Yet, important also to understand your theoretical basis and possible analytical framework(s) you use

→ Note: these often 'given' by e.g. your Thesis Advisors



BASIC VS. APPLIED SCIENCE? *by Ling & Yang 2012*

"In (natural) science, the emphasis is on
discovering new theories, paradigms, approaches,
algorithms, simulations, experiments etc.,

BASIC SCIENCE

...while in engineering, the emphasis is to
solve real-world problems with new technologies,
designs, processes, methods, models, testing etc."

APPLIED SCIENCE

→ "Novelty and significance key ingredients in both"

BASIC VS. APPLIED SCIENCE? *simplified by Marko*

BASIC (or core, or 'pure') = finding out how things work

→ Driven by curiosity and seeking for new knowledge: *'science for scientists'*

APPLIED = solving a specific problem with the help of scientific knowledge (usually created by basic science)

→ Driven by problem-solving (and thus influenced partly by drivers outside science): *'science for the society'*

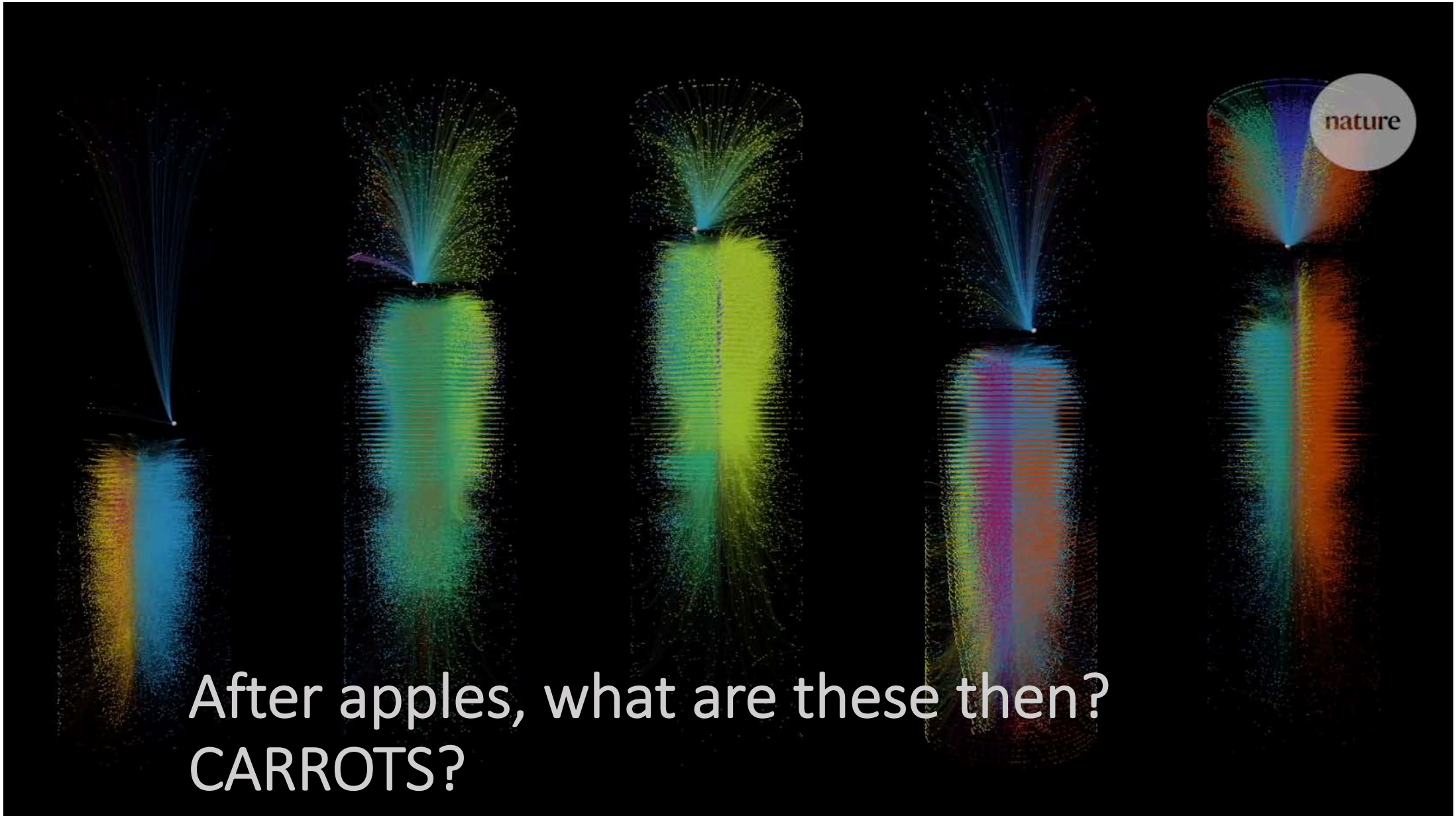
DISCIPLINE? a certain branch of knowledge / field of study

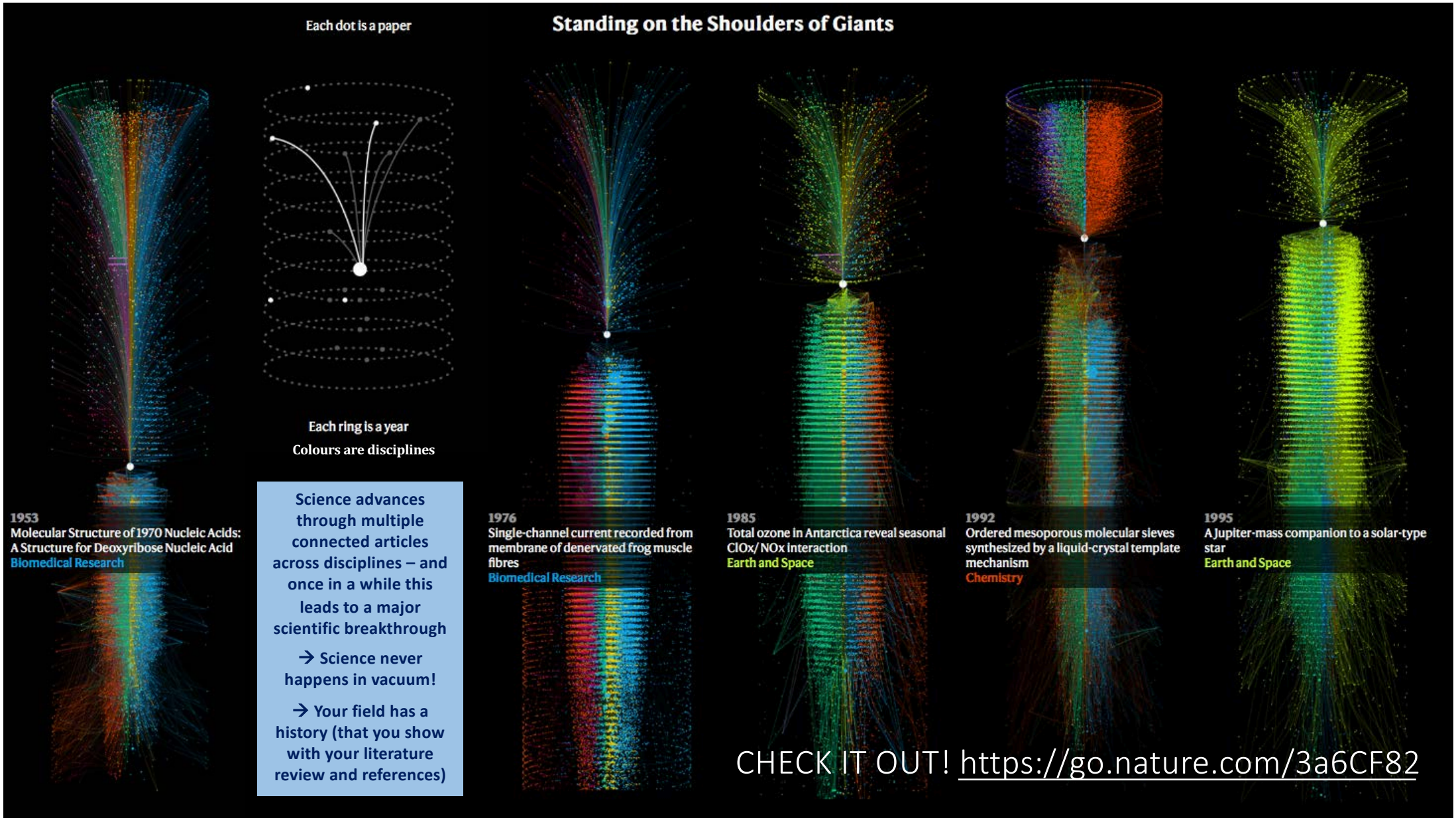
Science & research organised through disciplines

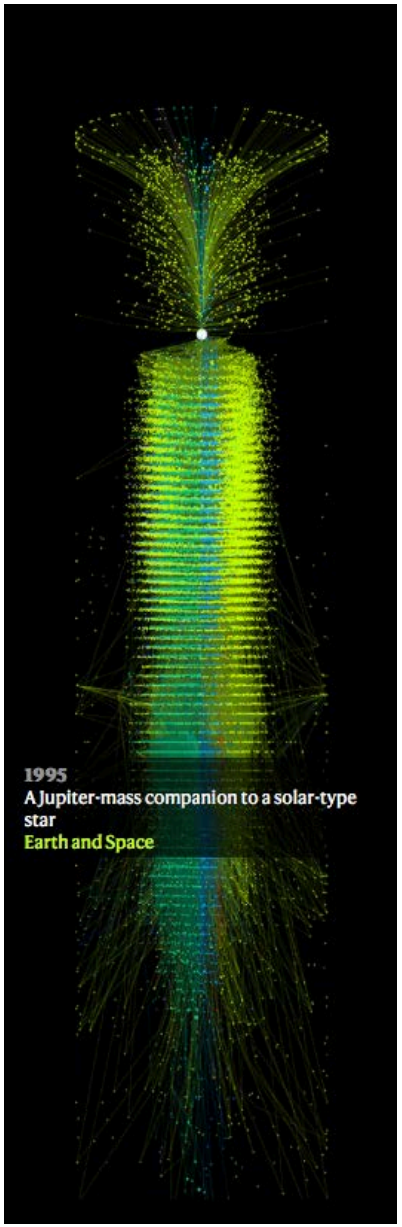
Disciplines are defined by their core conceptions and assumptions as well as by the acknowledged methods
= a discipline relies on a set of certain theories, analytical frameworks and methods (can be found from journals)

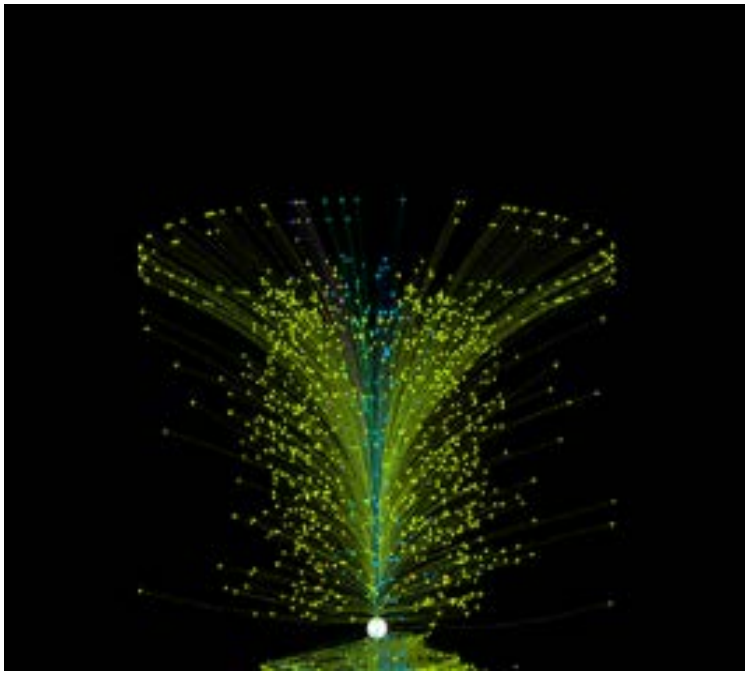
→ **A discipline thus provides the scientist with an identity and certain standard**: maintains an institutional order and has its own professional standards as well as publication and education procedures.

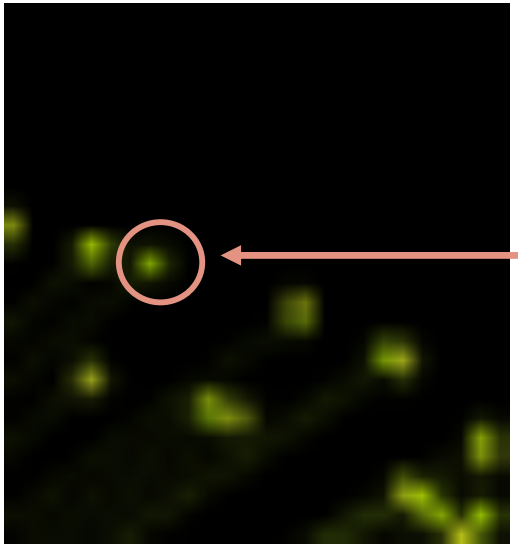
Attwater et al. 2005; Keskinen 2010


nature
After apples, what are these then?
CARROTS?


Each dot is a paper
Standing on the Shoulders of Giants
Each ring is a year
Colours are disciplines
1953
Molecular Structure of 1970 Nucleic Acids: A Structure for Deoxyribose Nucleic Acid
Biomedical Research
1976
Single-channel current recorded from membrane of denervated frog muscle fibres
Biomedical Research
1985
Total ozone in Antarctica reveal seasonal ClOx/ NOx interaction
Earth and Space
1992
Ordered mesoporous molecular sieves synthesized by a liquid-crystal template mechanism
Chemistry
1995
A Jupiter-mass companion to a solar-type star
Earth and Space
Science advances through multiple connected articles across disciplines – and once in a while this leads to a major scientific breakthrough
→ Science never happens in vacuum!
→ Your field has a history (that you show with your literature review and references)
CHECK IT OUT! https://go.nature.com/3a6CF82



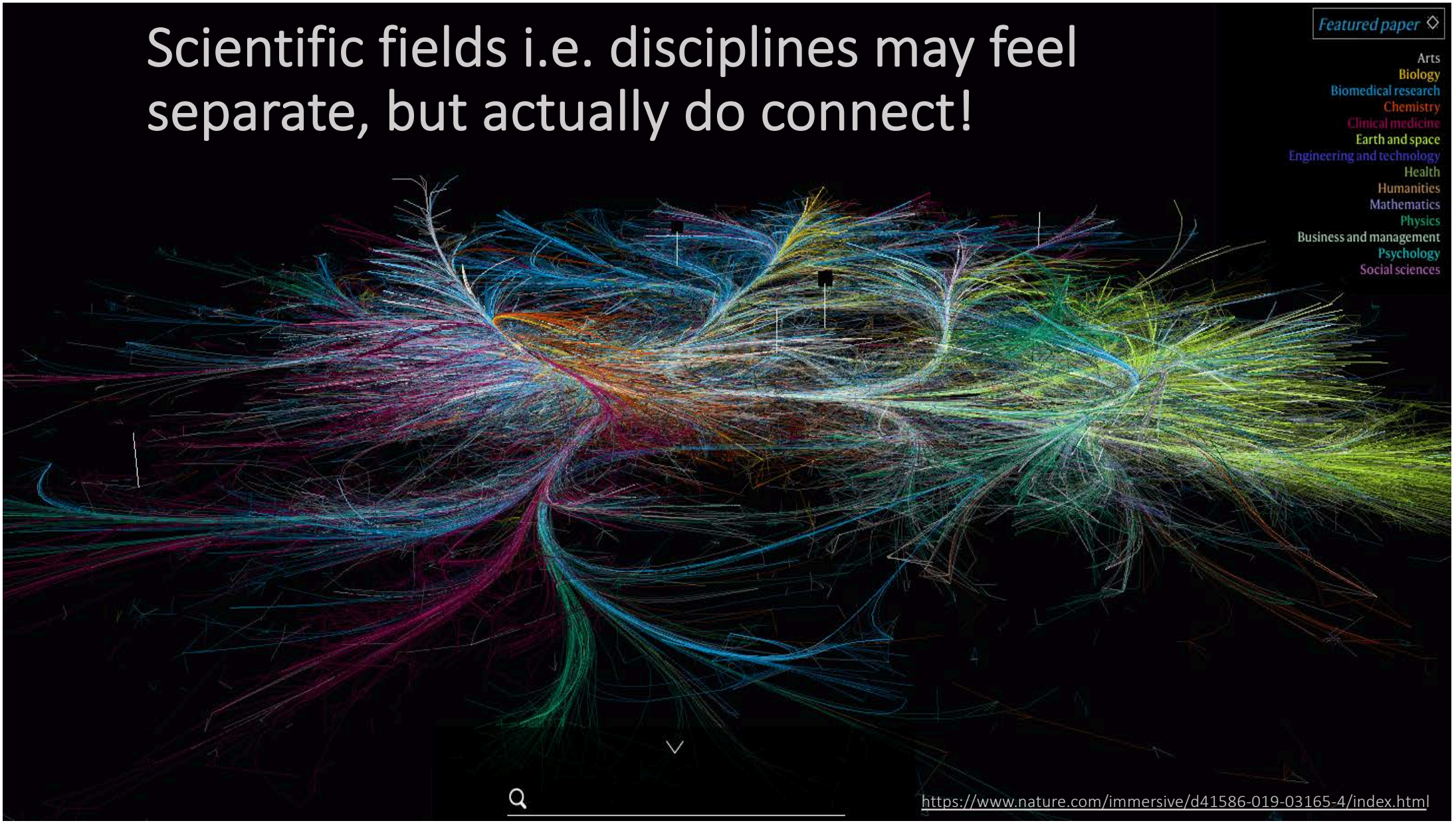




Where is your breakthrough article then?

→ Important to understand that you indeed stand on the shoulders of giants – and that you are not (yet) a scientific giant yourself

Scientific fields i.e. disciplines may feel separate, but actually do connect!

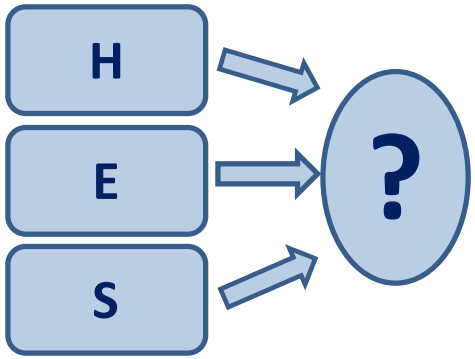


https://www.nature.com/immersive/d41586-019-03165-4/index.html

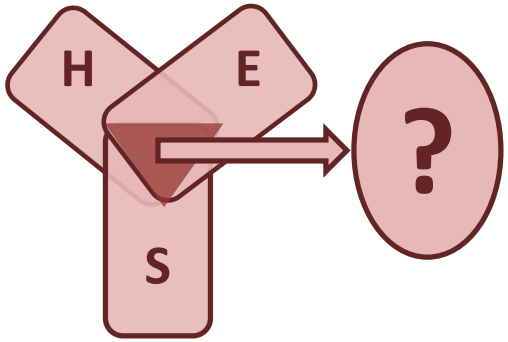
MULTI- / INTER- / TRANSDISCIPLINARITY?

Bringing different disciplines (+ other forms of knowledge) together

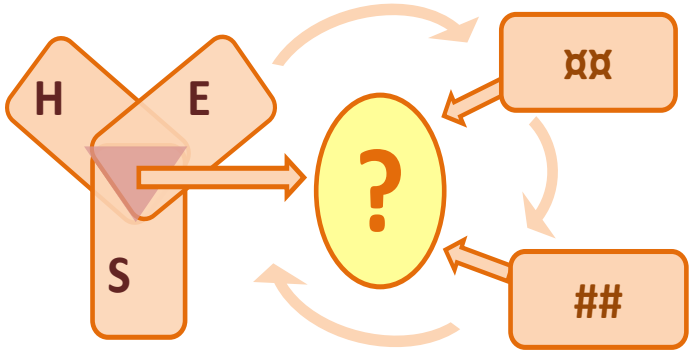
→ Not our main topic, and you should not worry too much:
if you got interested, you can find more e.g. from my Doctoral Thesis



MULTIDISCILINARITY



INTERDISCILINARITY



TRANSDISCILINARITY

Keskinen (2010): https://bit.ly/MarkoThesis

QUESTIONS? COMMENTS?

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3) Some concluding thoughts

MY POINT & MY CATCH

THE POINT: science, research and scientific writing
are all critical for your doctoral research!

→ Yet, important to realise they are different things,
although closely linked

THE CATCH: you are now part of (largely secret)
Community of Science – enjoy!

→ Peer review process one critical element in that,
so do enjoy it as well (even when getting that rejection)

WHO ARE YOU, THEN?

Researcher?

OR

Scientist?

For me, the moment you become a scientist is when you master the scientific principles and understand your own discipline(s) – and can prove it

→ Usually after you become a Doctor of Science (in Technology)!

Are there differences in their connotations?

Can you be both? Does your identity/role change over time?

1% makes a difference

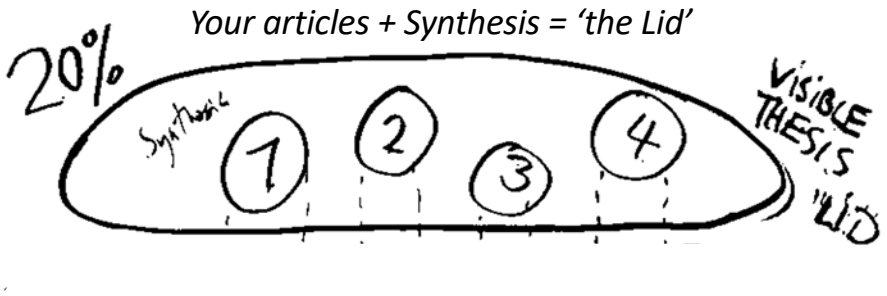
You don’t have to think these kinds of fundamental things all the time

→ Most of your time should go to doing research

But already using just 1% of your research time to think these themes makes a difference!

LEARNING PROCESS VS. THESIS

= 'Learning Pot' vs. its 'Lid'



The focus on your work is very likely on your Doctoral Thesis i.e. articles & synthesis + related course work

→ *Natural, as these are indeed needed to get our degree done*

→ *Form the **visible 'Lid'** of your work*

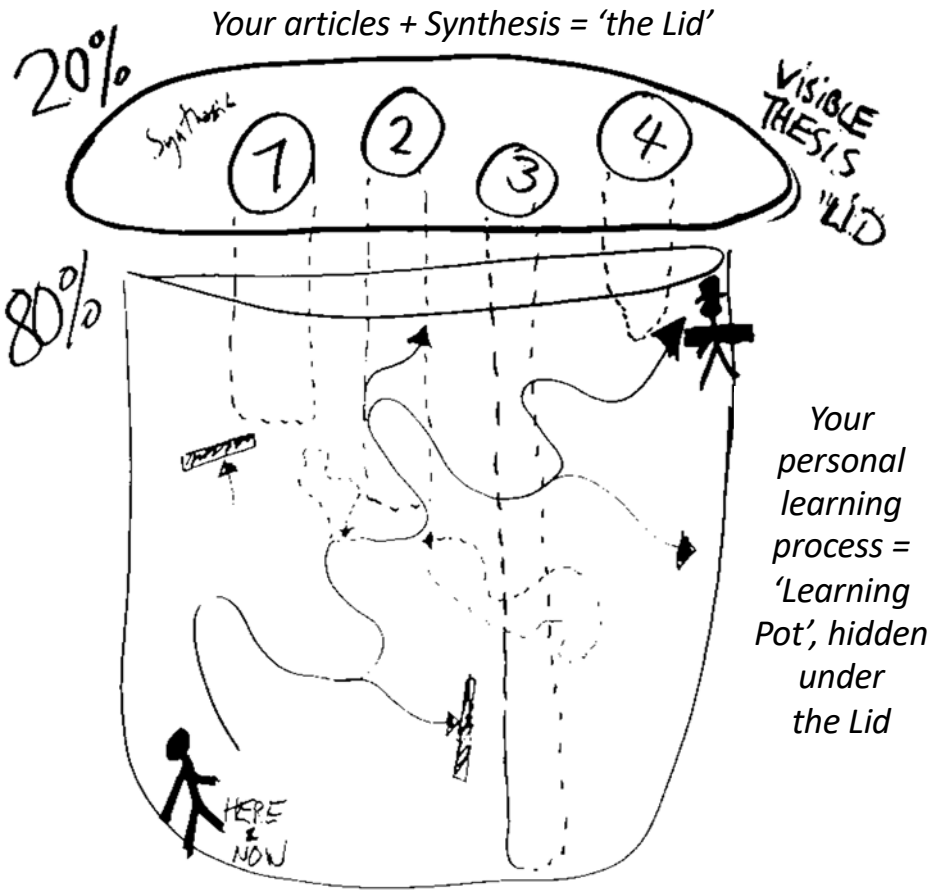
LEARNING PROCESS VS. THESIS

Yet, ultimately your Thesis journey is a **personal learning process**

→ Majority of time goes to this, with dead-ends and detours: they typically teach you the most

→ Yet, these not visible in your Thesis
(as all things new to you are not novel to your discipline)

→ My non-scientific hypothesis: the visible Thesis ('the Lid') shows only 20% of your actual learning



THANK YOU!

Remember: doing your Doctoral Thesis is a long journey,
so do enjoy all the successes and celebrate the failures!

…and also think regularly what you have learned,
as this learning process is usually more important for
your future than just getting those articles published

http://people.aalto.fi/marko_keskinen
twitter.com/keskma

QUESTIONS? COMMENTS?

You will continue at 15.30 with Roza

→ Take your Research Plan ready

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4) Your Research Plan, with Roza

- Re-visiting your own Research Plan:
  how does it look like based on the discussion
  during this session? Any need for revision?

→ *If you don't have yet Research Plan,*
think these issues more generally

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Working with your Research Plan

1) Do you know what is your scientific field/discipline?

→ If not, you get an idea by going through your key references, research scope and key concepts

2) Your research process?

→What are your **two steps** i.e. i) theoretical basis and analytical frameworks, and ii) research methods?

3) How your research contributes to your field i.e. **what is your NOVELTY and SIGNIFICANCE?**

Working with your Research Plan

FIRST: think about and write down these three **independently**, based on you Research Plan: 6 minutes

→ *You can also re-visit the slides, if needed*

THEN: get into **small groups** (3-4) and discuss: 12 minutes

→ *Key similarities & differences? Does this make sense?*

FINALLY: Discussion together with **everyone**:
major remarks, comments, criticism?

Aalto University

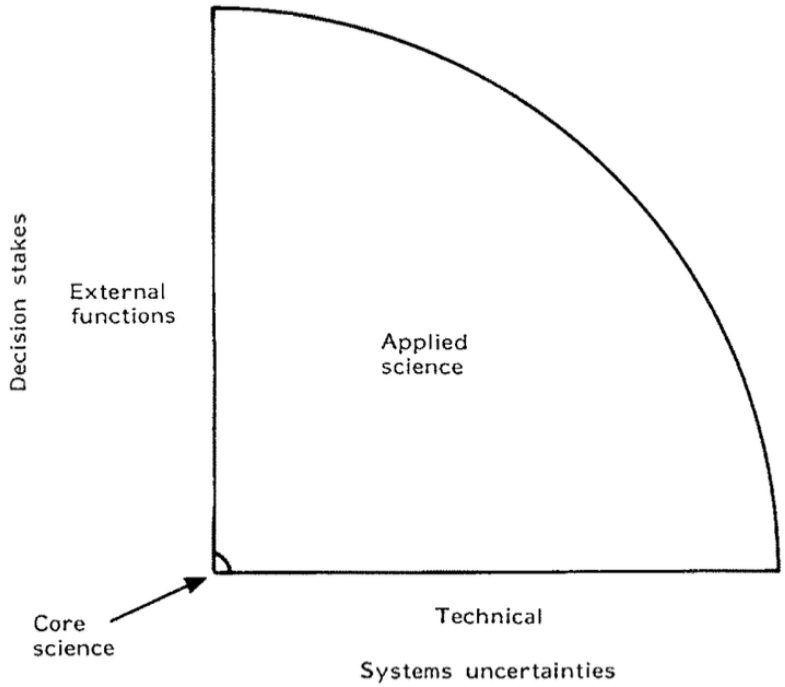
A!ENG Research Lab

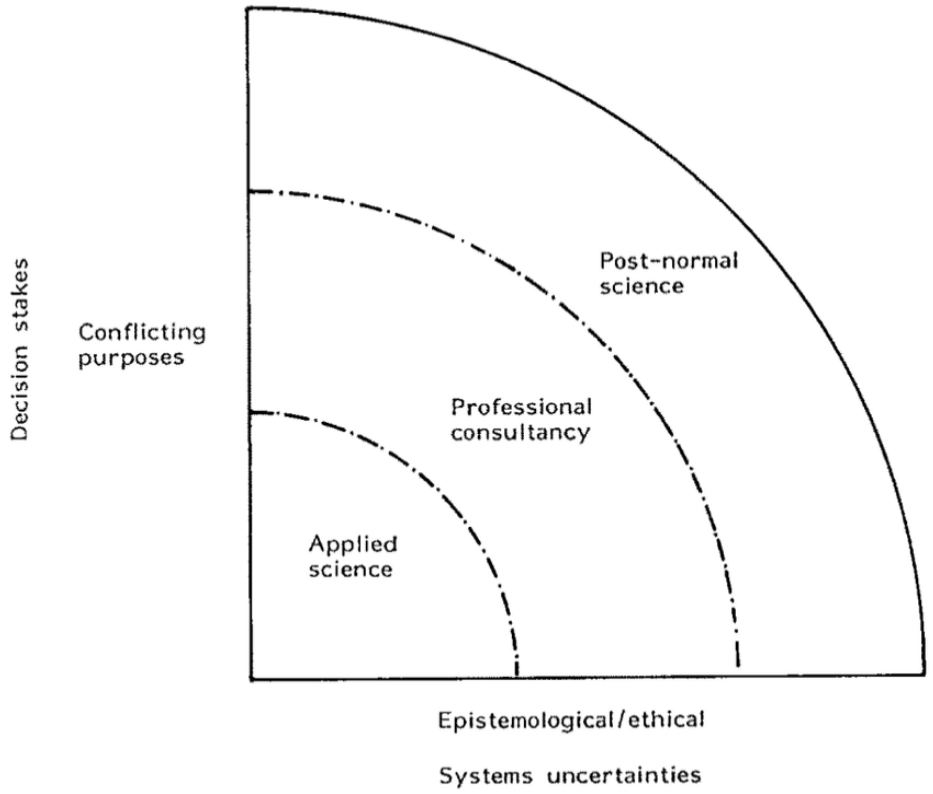
This is a course on science and research

...but what do they actually mean and how they differ?

ADDITIONAL SLIDES

BASIC VS. APPLIED ... VS. POST-NORMAL SCIENCE





For more: Kuhn (1962): The Structure of Scientific Revolutions; Funtowicz & Ravetz (1993). Science for the post-normal age.

NORMAL VS. POST-NORMAL SCIENCE

- The grand challenges of humanity (e.g. climate change, increasing inequality) call for science also to get engaged in planning and decision-making

  → Post-normal science / inter- and transdisciplinary science

Normal science = ”unexciting, indeed anti-intellectual routine puzzle solving by which science advances steadily between its conceptual revolutions.
In this ‘normal’ state of science, uncertainties are managed automatically, values are unspoken, and foundational problems unheard of.

Post-normal science = ”a new, enriched awareness of the functions and methods of science, where uncertainty is not banished but is managed, and values are not presupposed but are made explicit. The model for scientific argument is not a formalized deduction but an interactive dialogue.

For more: Kuhn (1962): The Structure of Scientific Revolutions; Funtowicz & Ravetz (1993). Science for the post-normal age.

’Society has problems, universities have departments’

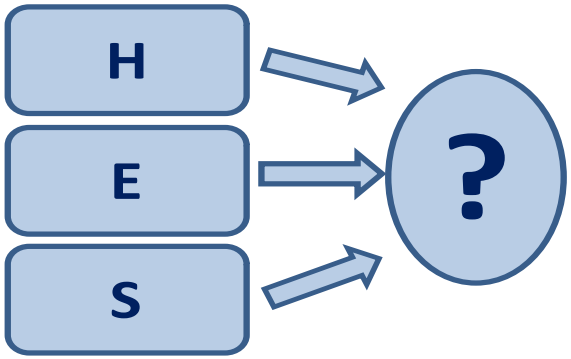
(Scholz & Marks 2001)

- Research solving societal problems needs to move from multi-disciplinarity towards inter- and transdisciplinarity

  → MULTI: joint problem, but looked from disciplinary view points. Hence, **cooperation the key**, but you remain in your comfort zone.

  → INTER: not only bringing different disciplines together, but taking a problem-specific view with methods suitable for the specific purpose. Hence, requires more as you need to **get out from your own disciplinary comfort zone.**

  → TRANS: considering also other, non-scientific forms of knowledge (particularly local/traditional knowledge). This **requires most from the scientists** as you have to change your idea about the ’quality’ of knowledge.

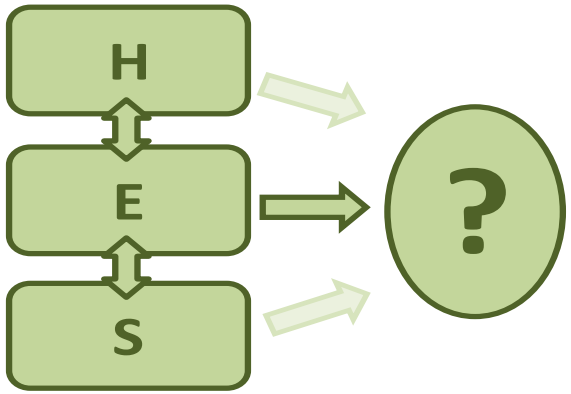


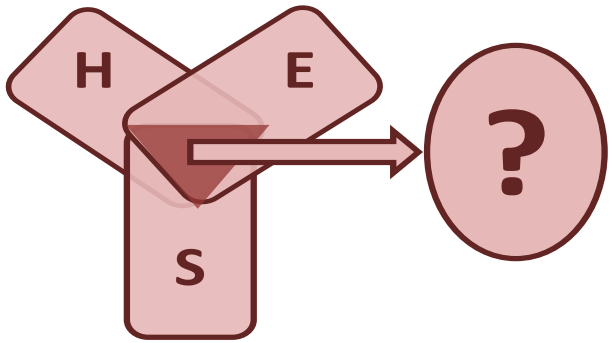
MULTIDISCIPLINARITY

Problem analysed through different disciplines, with experts working as one team but still using their own disciplinary methods

CROSSDISCIPLINARITY (NON-EGALITARIAN)

Problem analysed by the team mainly through one discipline, but adapting and using methods and expertise from different disciplines

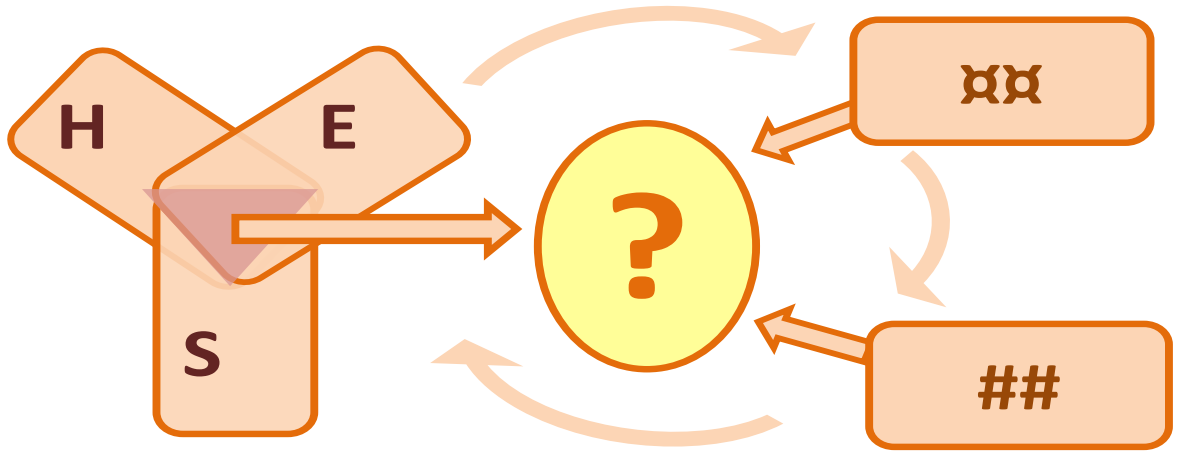




INTERDISCIPLINARITY

Problem analysed with the help of methods developed by the team for this particular problem, integrating knowledge, theories and methods from different disciplines

TRANSDISCIPLINARITY:
Collaborative, dynamic problem solving approach crossing both disciplinary boundaries & different forms of knowledge production



For more, see Marko's Doctoral Thesis (particularly pages 27-32):
http://bit.ly/1A2n83k

INTERDISCIPLINARITY IN AALTO?

Aalto University's old strategy clearly recognised both multi- and inter-disciplinarity: new strategy talks basically about the same thing, but calls interdisciplinary 'multidisciplinary collaboration'…

→ Interdisciplinarity very important at Aalto (see our MiD strategy proposal)!

SOCIETAL: solving the major challenges of our society requires out of the (disciplinary) box –thinking

ACADEMIC: new scientific innovations (and even new disciplines) emerge often from scientific boundaries

EDUCATIONAL: students should be given broad, systemic view + complement that with specific expertise

What is theory?

Theory = "an 1) **attempt** to 2) **make sense of** the world through 3) **generalizations** of 4) **empirical** phenomena"

→ "an ongoing pragmatic process of 'puzzling out' and problem-solving that draws on existing ways of understanding what the phenomenon 'is a case of' "

(Timmermans & Tavory 2012)

What is theoretical framework?

Explains your way to frame your research

→ Based on existing concepts and theories on your theme:
provides foundation for you and the reader

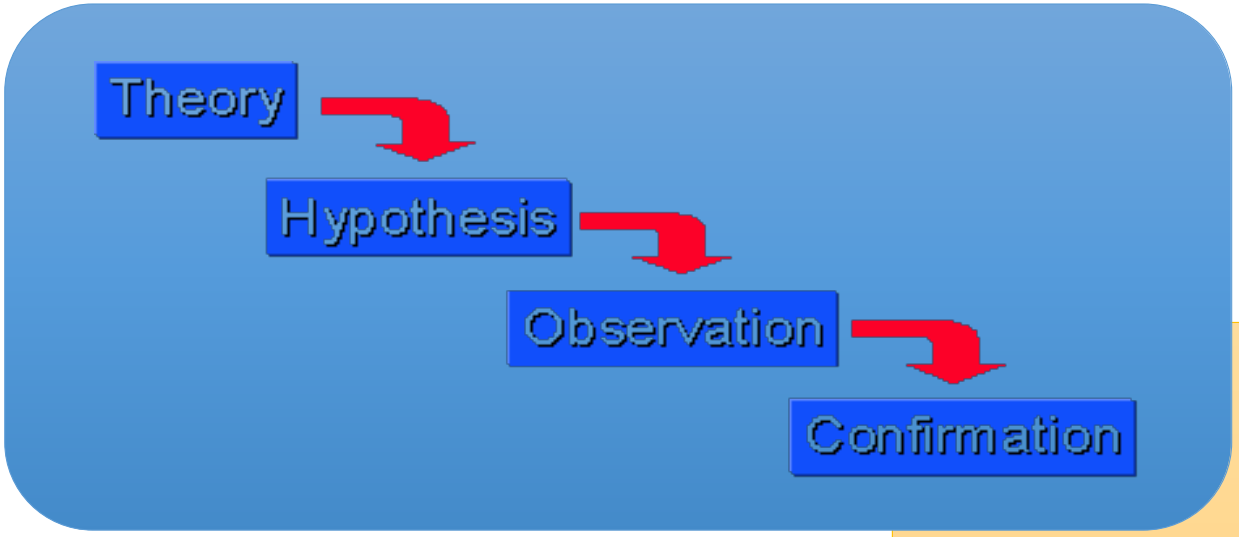
→ Based also on your research questions:
theoretical framework allows you to answer those!

Often a diagram very handy way to describe it

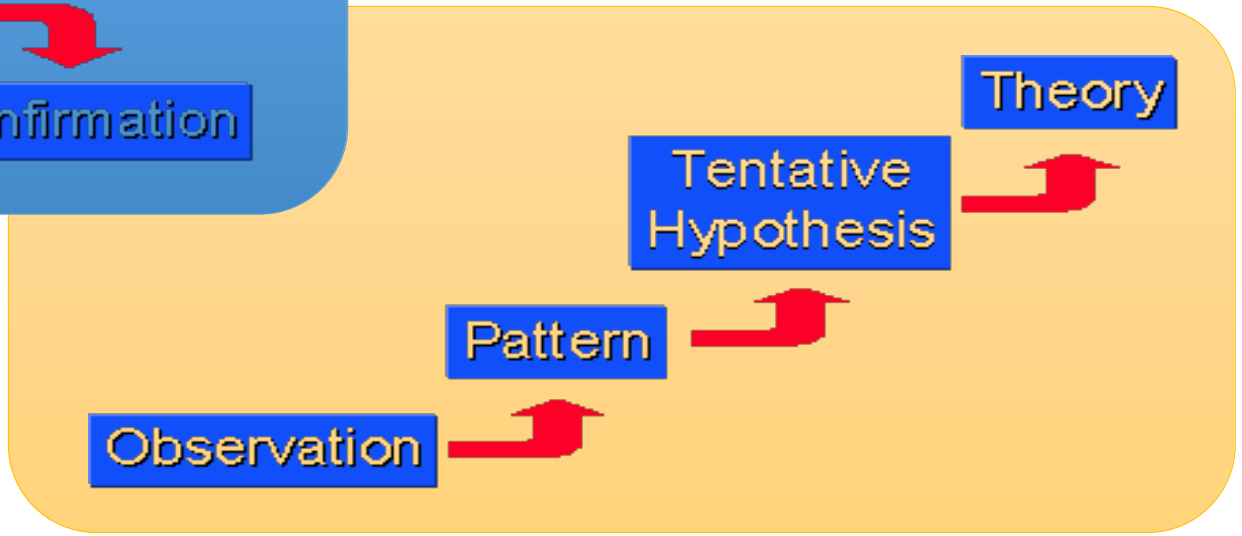
→ Allows you to define –and others to see– your key elements
as well as the main linkages and boundaries related to your research

(http://libguides.usc.edu/writingguide/theoreticalframework)

Inductive vs. deductive reasoning



WHICH ONE IS WHICH?

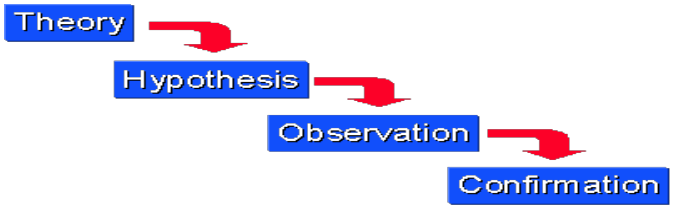


WHICH ONE YOU NORMALLY USE?

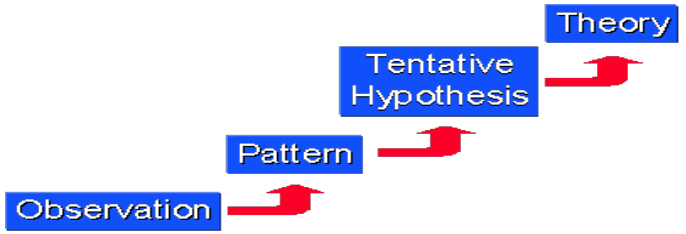
(https://www.socialresearchmethods.net/kb/dedind.php)

Inductive vs. deductive reasoning

Deductive = top-down
i.e. from general to specific



Inductive = bottom-up
i.e. from specific to general



EXTRA: abductive reasoning i.e. finding best possible explanation for a phenomena through logical reasoning

→ Inductive reasoning = more open-ended & exploratory

→ Deductive reasoning = more narrow, with focus on testing or confirming hypotheses

(https://www.socialresearchmethods.net/kb/dedind.php)

SCIENCE + RESEARCH = SCIENTIFIC METHOD

A book 'Scientific Method in Brief' by Hugh G. Gauch, Jr.

→Essentially trying to think & explain how to 'do' science

→ Point: general principles of scientific method + specific research techniques = successful science

Presents nicely the general principles common to all (at least most) disciplines and research fields

→ *Deductive and inductive logic, probability, parsimony (i.e. principle of simplicity) + hypothesis testing*

→ *Science's presuppositions, limitations, ethics, and 'four bold claims' of rationality, truth, objectivity & realism*