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Being a researcher

What is research and why we do it

Outline

- What is science?
- What is scientific research
- Why do we do research?
- Different kinds of research
- The role of research in society

Science

- From Latin *scientia—knowledge*
- **A systematically organized body of knowledge on a particular subject**
  - *biology* is the science that studies living organisms
  - *psychology* is the science that studies the human mind and its functions affecting behavior in given contexts
  - *computer science* (aka *informatics*) is the science that studies methods for computing (acquiring, storing, processing, communicating and reasoning about information), application of such methods, and the role of interactivity in natural and artificial systems, through the implementation, organization, management and use of computers, humans, and other resources — its broader context often goes under the term *Information and Communication Science and Technology (ICST)*

Science areas

- Natural sciences study the material world
- Social sciences study people and societies
- Humanities study humans in their historical, cultural, political context
- Economic sciences study the economic behavior of individuals and societies
- Formal sciences study theoretical formal systems (e.g., mathematics)
- Engineering is the science of construction of artifacts, both physical and logical
- Computer science/Informatics/ICST is both a formal science and engineering

Kinds of science, technology

- **Pure** (or **Basic**) science as opposed to **applied** science
  - Engineering, like medicine, considered to be an applied science
- **Technology** refers to the application of science in a particular area for practical uses
  - term comes from Greek, “techne” (skill)
  - collection of techniques, methods, and processes used in the production of goods or services, often through machines or other kinds of automated entities
- Terms **science and technology** often used together, and sometimes as synonyms
- Distinction between science and the application of science often fuzzy and even snobbish
- Continuous spectrum of activities

Science areas

- The European Research Council classifies science into three main categories
  - PE — Physical Sciences and Engineering
  - LS — Life Sciences
  - SH — Social Sciences and Humanities

SH

- SH1 Individuals, institutions and markets
- SH2 Institutions, values and beliefs and behaviour
- SH3 Environment and society
- SH4 The Human Mind and its complexity
- SH5 Cultures and cultural production
- SH6 The study of the human past

LS

- LS1 Molecular and Structural Biology and Biochemistry
- LS2 Genetics, Genomics, Bioinformatics and Systems Biology
- LS3 Cellular and Developmental Biology
- LS4 Physiology, Pathophysiology and Endocrinology
- LS5 Neurosciences and neural disorders
- LS6 Immunity and infection
- LS7 Diagnostic tools, therapies and public health
- LS8 Evolutionary, population and environmental biology
- LS9 Applied life sciences and biotechnology

PE

- PE1 Mathematics
- PE2 Fundamental constituents of matter
- PE3 Condensed matter physics
- PE4 Physical and Analytical Chemical sciences
- PE5 Materials and Synthesis
- PE6 Computer science and informatics
- PE7 Systems and communication engineering
- PE8 Products and process engineering
- PE9 Universe sciences
- PE10 Earth system science

PE6 Computer science and informatics: informatics and information systems, computer science, scientific computing, intelligent systems

PE6_1	Computer architecture, parallel, distributed and pervasive computing
PE6_2	Database systems and management
PE6_3	Formal methods, theoretical computer science including quantum information
PE6_4	Graphics, image processing, computer vision and visualization
PE6_5	Human computer interaction and interface
PE6_6	Speech and language processing, speech synthesis
PE6_7	Informatics, Web and information systems including information retrieval and digital libraries
PE6_8	Intelligent systems, multi agent systems, machine learning
PE6_9	Scientific computing
PE6_10	Simulation and modelling tools
PE6_11	Multimedia
PE6_12	Software, operating systems, development methods, languages, algorithms
PE6_13	Cryptology, security and privacy
PE6_14	Bioinformatics, biocomputing

Scientific research

- Research, from French *recherche—to go about seeking*
- OECD 2015 (*) defines scientific research as
  - creative and systematic work undertaken in order to increase the stock of knowledge –including knowledge of humankind, culture and society – and to devise new applications of available knowledge
- It aims at producing science

(*) http://www.oecd.org/publications/frascati-manual-2015-9789264239012-en.htm

More on scientific research

- The activity of a diligent and systematic inquiry or investigation in an area, with the objective of discovering or revising facts, theories, applications etc.
  The goal is to discover and disseminate new knowledge.

- Interestingly, it includes dissemination, and dissemination includes teaching

  - this is why universities do research and tachingh

Research is an irrepressible human aspiration

Fatti non foste a viver come bruti ma per seguir virtute e canoscenza

Ye were not form’d to live the life of brutes, but virtue to pursue and knowledge high

Dante Alighieri, The Divine Comedy
–Inferno Canto 26

Essential attributes of research

- Originality
- Rigor
- Significance

- quality of research defined by levels of ORS

Originality

- Outcomes of the research are novel
  - specific new findings
    - new ways of thinking about a subject
    - new ways of achieving known facts
    - new laws of nature
    - new mathematical theorems
    - new ways of doing things
- A level of novelty is an essential ingredient, although its degree may vary
  - e.g., survey works

Significance

- Outcome exerts, or has the potential to exert, an influence on society, industry, or other research
- Multi-faceted concept
    - it solves an open problem that is deemed important by society or by the scientific community
    - the creative process behind the research was especially challenging
    - high degree of uncertainty initially attributed to the problem solved
    - significant practical improvement in the way certain things used to be done
- From purely theoretical to very practical
- Embeds notions of transferability (to other research or to practice), or reproducibility (to other contexts and/or by other people)

Rigor

- Refers to the intellectual integrity of the research process and the way the results are demonstrated

- Intellectual precision, robustness, and appropriateness of the concepts and methods adopted within the outcome

- In the case of empirical research, this refers to the way experimental data are collected and analyzed

- For other kinds of research, it may refer to the rigor of the mathematical apparatus

Research and the progress of mankind

- The last 500 years witnessed a phenomenal and unprecedented growth in human power, mainly driven by scientific research — *Scientific Revolution*

- *During the last five centuries, humans increasingly came to believe that they could increase their capabilities by investing in scientific research. This wasn't just blind faith–it was repeatedly proven empirically. The more proofs there were, the more resources wealthy people and governments were willing to put into science.*

Sapiens–A Brief History of Human Kind, Y. N.Harari

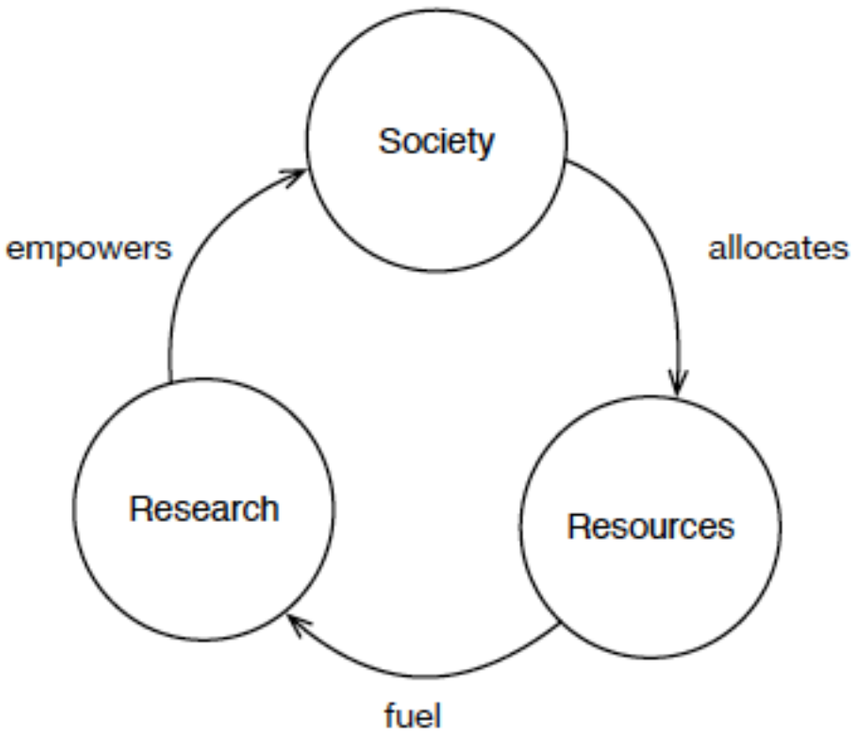
Science vs traditional knowledge

- Willingness to admit ignorance (*we know that we don't know everything, and accept that something we think we know proves to be wrong*)

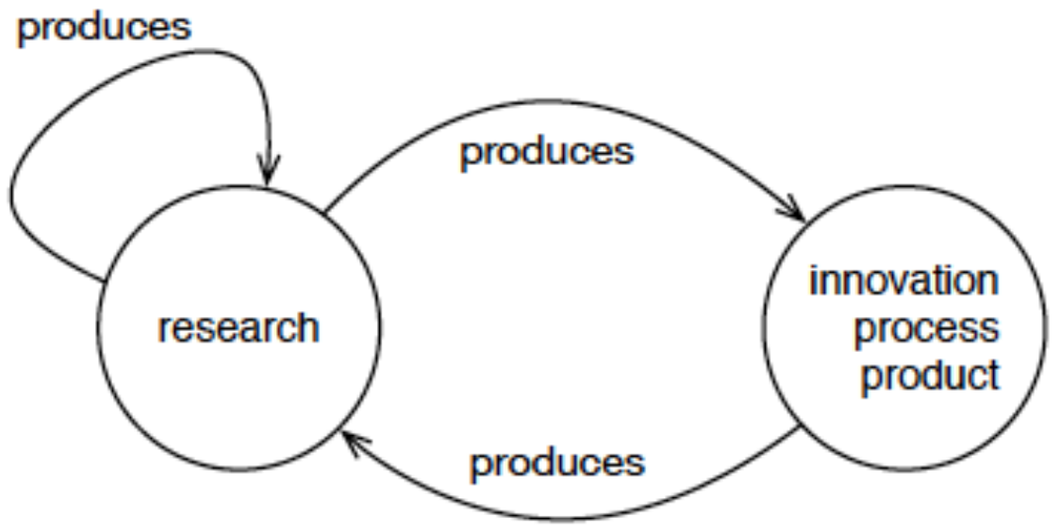
- Centrality of observation and mathematics, the pillars of science

- The use of knowledge to empower mankind (*Scientia potentia est — Francis Bacon)*

Scientific research and society



Research feedback loop

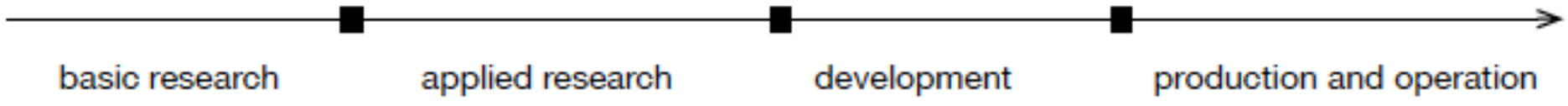


More on basic vs applied science/research, or science vs technology

- Distinction can be traced back to end of WW2 (V. Bush, advisor to President Roosevelt
    - *basic research — BR* "performed without thought of practical ends"
        - aka "blue sky", curiosity-driven, high-risk
            - creativity needed to develop BR would be lost if research is finalized research to a premature attention to its practical usage
- *applied research* — problem driven
    - further downstream step: pre-competitive research
        - less risky and more predictable

Role of basic research (V. Bush)

- BR pacemaker of technological progress
- Investments in BR needed for a society to be competitive
- Discoveries of BR taken up by AR that makes discoveries exploitable
- BR prerequisite for AR, which leads to new development, production, and operation



Critics

- Progress from initial ideas or theory to practice NOT linear
- Perpetual feedback loop
  - from practice to ideas and from ideas to practice
- Snobbism: no distinction between first/second class
  - all kinds of research are equally challenging, valuable and respectable

Different flavors of research

- Theoretical
- Experimental
- Constructive: new artifacts (process/product)

- ICST research comprises all of them, and they are equally valuable and respectable
- ICST is both a natural science, a formal science, and engineering

Research in modern society

Country	%GDP spending	Total spending (US$ billions)	#Researchers	%Female
Rep. Korea	4.3	73	6800	19
Israel	4.2	12	8250	unspecified
Switzerland	3.2	14	4450	32
Germany	2.9	110	4300	28
USA	2.7	476	4250	unspecified
France	2.3	61	4200	27
Singapore	2.2	10	6700	30
China	2	370	1000	unspecified
UK	1.7	44	4200	37
Canada	1.7	28	4500	unspecified
Italy	1.3	29	2000	36
Russian Fed.	1.1	40	3000	41

Data source UNESCO http://uis.unesco.org/

Research and innovation

- The triple helix model of innovation
  - three main actors **academia**, **industry** and **government** interact to foster economic and social development
  - each of them has an ‘initial role’:
    - universities engaged in basic research
    - industries producing commercial goods
    - governments regulating markets
- as interactions increase within this framework, each component evolves to adopt some characteristics of the other institution, which then gives rise to hybrid institutions

https://en.wikipedia.org/wiki/Triple_helix_model_of_innovation

University-industry interactions

- Research results picked up by industry
- But also problems from industry become research targets
- Movement of people from the two sectors is main driver
  - PhDs and researchers moving to industry
  - People moving from industry to university
  - Patents, start-ups and spin-offs

University patents: who owns them?

- It varies across countries
  - USA: ownership is presumed to be with the university for novel results of research
    - main motivation is to facilitate exploitation of government-funded research results by transferring ownership from the government to universities who could then license the IP to firms
  - Italy: ownership by the researcher; researcher may decide to transfer right to University
  - Germany: remuneration is split between the employer and the employee. The university receives a portion for providing the space, equipment and organization that make the invention possible. The inventor or inventors receive 30% of all earnings and are cited in the patent by name in perpetuity, even if the university is the applicant

University-government interactions

- In Europe government has a high influence on universities and the research they conduct by being the main source of funding

- In USA universities have a higher degree of independence although they also receive public funding

Government-industry interactions

- Government can support industrial research through special programs, may require that both industry and academia cooperate

- Government establishes intellectual property law and its enforcement

Start-ups

- A start-up is an entrepreneurial venture which is a newly emerged business venture that aims to meet a marketplace need, want, or problem by developing a viable business model around products, services, processes or platforms

- It is designed to effectively develop and validate a scalable business model

- Start-ups do have high rates of failure, but the minority that have gone on to be successful includes companies that have become large and influential

- Example of startup from research: research done as PhD student may result in a new, independent start-up

World's Top 10 Startups

		Value in US$ billions
1	Uber	51.0
2	Xiaomi	46.0
3	Airbnb	25.5
4	Palantir	20.0
5	Snapchat	16.0
6	Didi Kuaidi	16.0
7	Flipkart	15.0
8	SpaceX	12.0
9	Pinterest	11.0
10	Dropbox	10.0

Spin-off

- A spin-off may be generated by any organization
  - e.g., a corporate spin-off is a corporate transaction forming a new company or entity
- A university spin-off is a company founded on the findings of a member or by members of a research group at a university
- Universities may retain a share
- E.g., https://www.polimi.it/en/scientific-research/research-at-the-politecnico/technology-transfer/spin-off/

Summary

- What is science, research, scientific research
- Research and knowledge construction
- Research and its applications
- Research and society