Research, science & computers: computer science research

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From the Latin **scientia**, meaning **'knowledge'**

Science - definitions [1] [2]

- what is known, corpus of human **knowledge** (of something) acquired by study
- **knowledge**, learning, application
- is a systematic enterprise that builds and organises **knowledge** in the form of testable explanations and predictions about the universe
- refers to a body of **knowledge** that can be rationally explained and reliably applied

[1] Online Etymology Dictionary - http://www.etymonline.com/
[2] Merriam-Webster: http://www.merriam-webster.com/

Any of the specialised fields or disciplines - as psychology, sociology, anthropology, or political science - **that interpret human behaviour, institutions, society**, etc., on the basis of **scientific investigations** for which it may be difficult to establish strictly measurable criteria[3].

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[3]http://dictionary.reference.com/browse/soft+science

Any of the natural or physical sciences, as chemistry, biology, physics, or astronomy, in which **aspects of the universe are investigated by means of hypotheses and experiments** [4].

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[4] http://dictionary.reference.com/browse/hard+science

Soft vs Hard Science

The distinction between 'soft' and 'hard' science is mainly referred to **how strongly a hypothesis can be stated, tested and then accepted or rejected**.

Nowadays, this degree of difficulty is less related to discipline and more related to the specific question, so the terms 'hard science' and 'soft science' may be outdated.

Science - date of birth

It is difficult to establish when **science** began.

Someone suggested that **Paracelsus** may have started it with his important works in the fields of medicine and chemistry.

Others think **Leonardo da Vinci** was a good candidate because of his discoveries.

However, it is conventionally agreed that **Galileo Galilei** was the father of **modern science**.

Modern science is often traced back to the early modern period, in particular to the **scientific revolution** in the **16th/17th-century** in Europe.
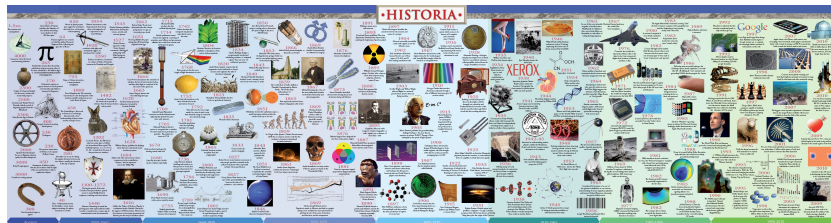
Too many scientists to mention.

A brief (not exhaustive) list with the most popular on the World Wide Web, follows.

- **name**: Leonardo di ser Piero da Vinci
- **born:** April 15th, 1452, Vinci, Italy
- **died:** May 2nd, 1519, Amboise, France
- **fields:** painting, anatomy, architecture, mathematics, engineering, botany, geology, astronomy

Considered one of the most **diversely talented individuals** in all of Western civilisation. Although he did not publish his findings, he made **substantial discoveries** in anatomy, civil engineering, optics and hydrodynamics.

- **name**: Philippus Aureolus Theophrastus Bombastus von Hohenheim (Paracelsus)
- **born:** Nov. 11th or Dec. 17th, 1493, Egg, near Einsiede, Old Swiss
- **died:** Sept. 24th, 1541
- **fields:** physic, botany, alchemy, astrology, occultism

He founded the discipline of **toxicology**. A revolutionary for insisting on using **observations of nature**, rather than looking to ancient texts.

- **name**: Galileo Galilei
- **born:** Feb. 15th, 1564, Pisa, Italy
- **died:** Jan. 8th, 1642, Arcetri, Italy
- **fields:** physic, mathematics, astronomy, philosophy, engineering

He played a major role in the **scientific revolution** during the **Renaissance**. Thought to be the greatest scientist of all time: '**father of modern science**, modern observational astronomy, modern physics'. Achievements: improvements to the telescope and consequent astronomical observations.

- **name**: Blaise Pascal

- **born:** June 19th, 1623, Clermont-Ferrand, France

- **died:** August 19th, 1662, Paris, France

- **fields:** mathematics, physic, philosophy

Pascal wrote in defense of the **scientific method**. He helped the creation of two major **areas of research**: projective geometry (at age of 16), & probability theory, strongly influencing the development of modern economics & social science.

- **name**: Alessandro Giuseppe Antonio Anastasio Volta
- **born:** February 18th, 1745, Como, Italy
- **died:** March 5th, 1827, Como, Italy
- **fields:** physic and chemistry

Inventor of the **electrical battery** and the discoverer of methane that led others to conduct similar experiments which eventually led to the development of the field of electrochemistry.
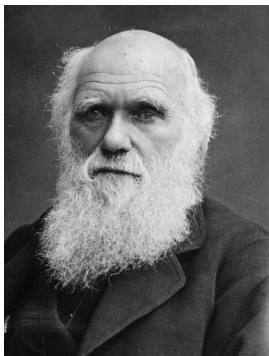
- **name**: Charles Robert Darwin
- **born:** Feb. 12th, 1809, The Mount, Shrewsbury, Shropshire, England
- **died:** April 19th, 1882, Kent, England
- **fields:** natural science, geology

He is best known for his contributions to **scientific evolutionary theory** believing that today's branching pattern of evolution resulted from a process that he called **natural selection**.

- **name**: Marie Curie

- **born:** Nov. 7st, 1867, Warsaw, Poland

- **died:** July 4th, 1934, Passy, France

- **fields:** physics and chemistry

She is known for her contribution to the development of the **theory of radioactivity**. As the 1st of the Curie family legacy of 5 Nobel Prizes, she was the 1st woman to win a Nobel Prize, the 1st person and the only woman to win the Nobel Prize twice, and the only person to have won it in two scientific fields.

- **name**: Alfred Nobel

- **born:** October 21st, 1833, Stockholm, Sweden

- **died:** December 10th, 1896, Sanremo, Italy

- **fields:** chemistry, engineering

Inventor of the **dynamite**, he had opened the door to **technological awards** (Nobel Prize), but did not leave any instructions on how to deal with the distinction between science & technology.
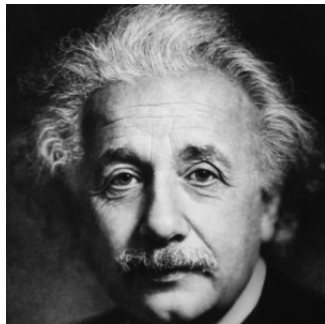
- **name**: Albert Einstein

- **born:** March 14th, 1879, Ulm, Germany

- **died:** April 18th, 1955 Princeton, USA

- **fields:** physics, philosophy

He developed the general **theory of relativity**, one of the two pillars of modern physics and known for its influence on the **philosophy of science.** His intellectual achievements/originality have made the word '**Einstein'** synonymous with '**genius'**.

- **name**: Ada Lovelace

- **born:** Dec. 10th, 1815, London, England

- **died:** Nov. 27th, 1852, London, England

- **fields:** mathematics

Known for her work on Charles Babbage's proposed **mechanical general-purpose computer**, the Analytical Engine. She was the first to recognise that the machine had applications beyond pure calculation, and to have published the first algorithm intended to be carried out by such a machine.

- **name**: Enrico Fermi

- **born:** September 29th, 1901, Rome, Italy

- **died:** November 28th, 1954, Chicago, Illinois, United States

- **fields:** physics, statistical mechanics

Nobel prize, he is one of the men referred to as the **'father of the atomic bomb'** as the inventor of the **first nuclear reactor**. He was widely regarded as one of the very few physicists to excel both theoretically and experimentally.

- **name**: Rita Levi Montalcini
- **born:** April. 22nd, 1909, Turin, Italy
- **died:** Dec. 30th, 2012, Rome, Italy
- **fields:** neurobiology

She was awarded the 1986 Nobel Prize in Physiology or Medicine for the discovery of **nerve growth factor**, a neurotrophic factor and neuropeptide involved in the regulation of growth, proliferation, survival of certain target neurons.

What do all these scientists share?

Research - intuitive definitions

- it should be about some **problem that encourages enthusiasm** (for you) and interest (for others)
- it is often generated from the thought '**what we have got so far - from the past - is not good enough or right - we can do it better...**'
- work that leads to a **meaningful contribution**
- it generates a **better solution** to a problem

- careful or **diligent search**
- studious **inquiry** or examination
- **collection of information** of a particular subject
- **investigation**/**experimentation** aimed at the discovery & interpretation of facts, revision of accepted theories/laws in the light of new facts, or practical application of such new/revised theories/laws

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[5]Merriam-Webster

- **investigation** of past work and effort in the **present** that will help others in the **future**
- a set of **opposites**
  - fun and frustration
  - small steps and large insights
  - building on others' work and contributing your own work
- finding or developing something new that expands **human knowledge**

What Research is not

- playing with technology
- book report
- programming project
- doing what others have already done
- a literature Review
- information gathering
- transportation of facts

However, each of these can be done as part of the research process

Who does research

- Undergraduate students
- Graduate Students
  - Masters Degree (lower standard)
  - Ph.D. Degree (higher standard)
- Researchers at universities
  - Post-Doctoral students
  - Faculty members
- Researchers in industry
  - Research scientists
  - Many other technical workers

Research means above all finding or developing something new that expands **human knowledge**
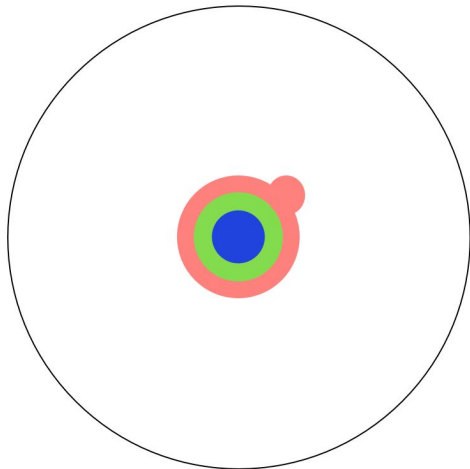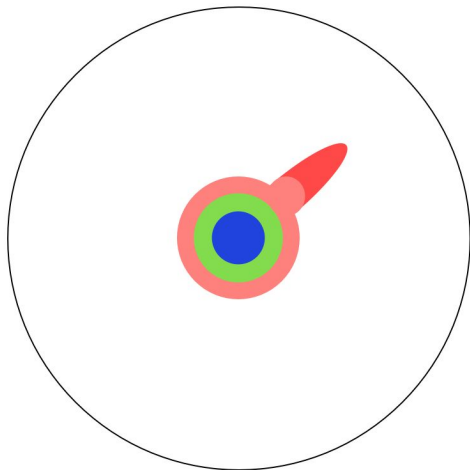

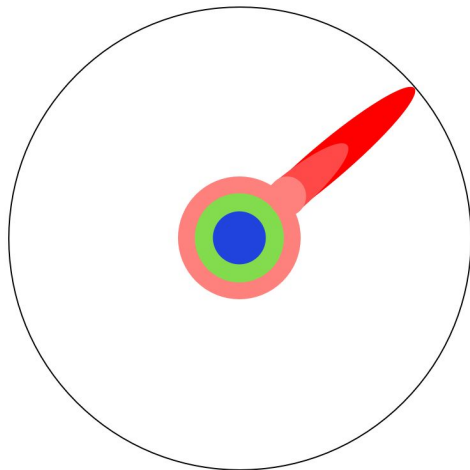[6]Adapted from: http://matt.might.net/articles/phd-school-in-pictures
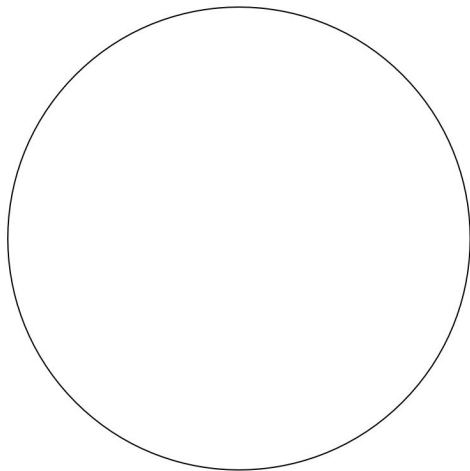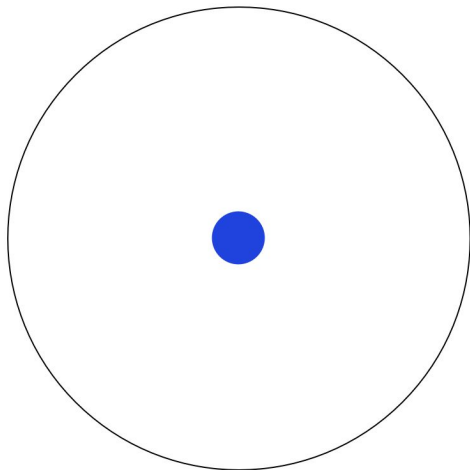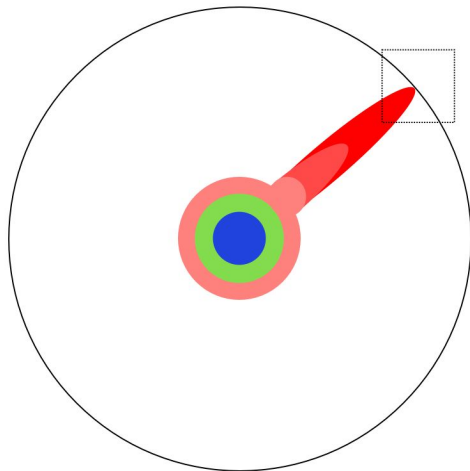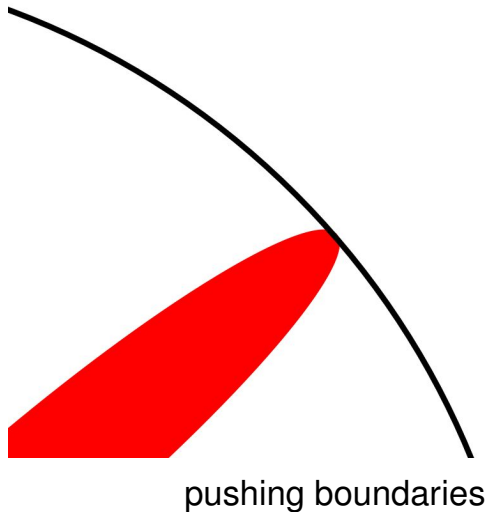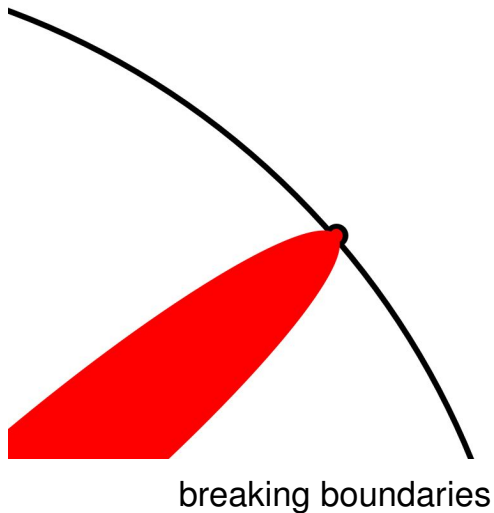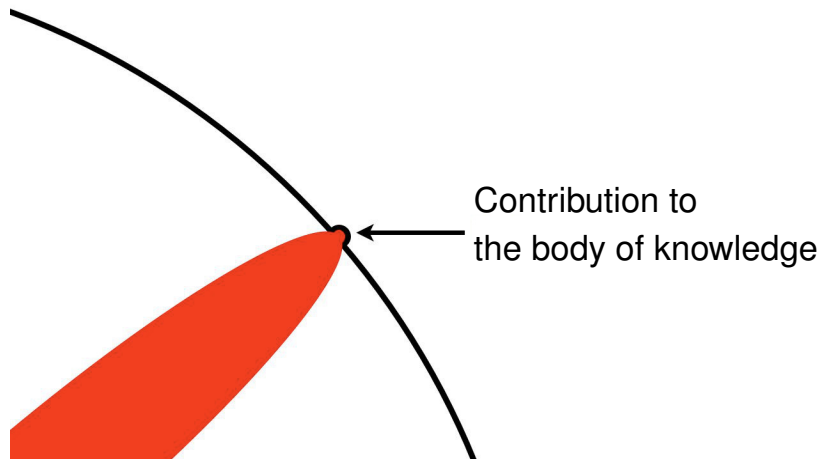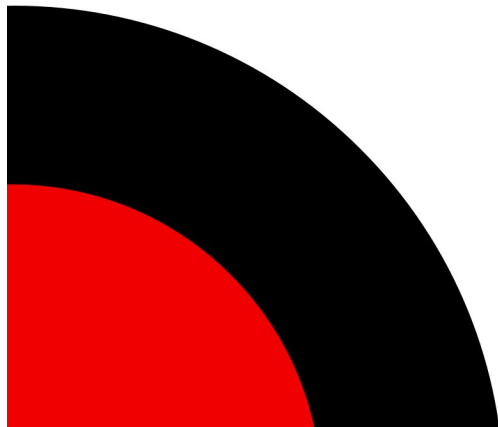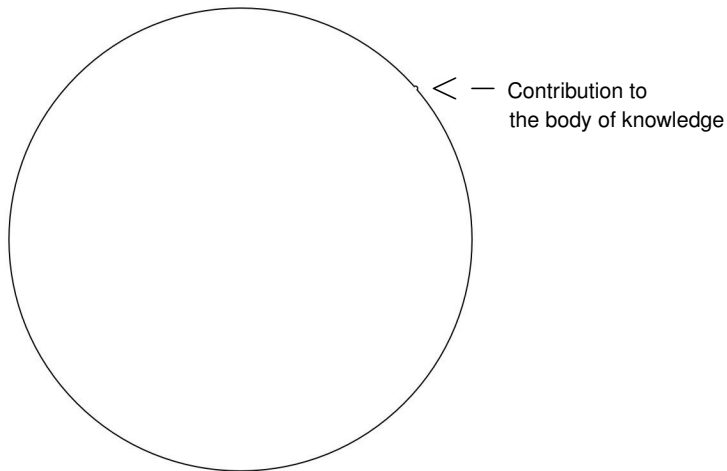
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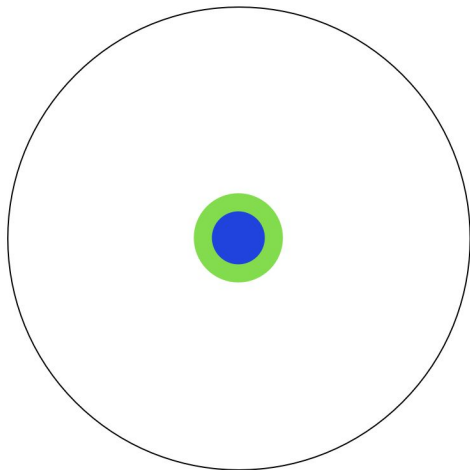
high school

bachelor degree

master degree

research papers

focus

pushing boundaries

breaking boundaries

Contribution to
the body of knowledge

The big picture of knowledge

$<$ — Contribution to the body of knowledge

Science vs. Engineering[7]

Science

- mathematics & logic
- physics & chemistry
- biology
- psychology & sociology
- geology & astronomy

Engineering

- civil
- chemical
- electrical
- mechanical
- technology

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[7]Engineering is the field of application of sciences and practical knowledge for designing, inventing, building and improving machines, components, material and processes.

Computer science?

Software/Hardware engineering?

- the **science** that deals with the **theory** and **methods** of **processing information** in digital **computers**, the design of computer hardware and software, and the applications of computers[8].

- the study of the **design** and operation of computer **hardware** and **software**, and of the application of computer **technology** to science, business, and the arts[9].

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[8]http://dictionary.reference.com/browse/computer+science
[9]The American Heritage® Science Dictionary

- The study of **computing, programming**, and **computation** in correspondence with computer systems. This field of study utilises theories on how computers work to design, test, and analyse concepts. Computer science usually has a stronger **mathematical foundation** than a scientific one and on some occasions may not focus directly on computers and their systems[10].

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[10]http://www.businessdictionary.com/definition/computer-science.html

- The **scientific** and practical approach to **computation** and its **applications**. It is the systematic study of the feasibility, structure, expression, and mechanisation of the methodical procedures (**algorithms**) that underlie the acquisition, representation, processing, storage, communication of, and access to **information**, whether such information is *encoded as bits in a computer memory or transcribed in genes and protein structures in a biological cell*[11].

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[11] Boston University Department of Computer Science.

"Computer Science is no more about computers than astronomy is about telescopes"
(Michael R. Fellows).

"When people think about computer science, they imagine people with pocket protectors and thick glasses who code all night."
(Marissa Mayer)

"Computer science... differs from physics in that it is not actually a science. It does not study natural objects. Neither it is, as you might think, mathematics; although it does use mathematical reasoning pretty extensively. Rather, computer science is like engineering; it is all about getting something to do, rather than just dealing with abstractions, as in the pre-Smith geology"
(Richard Feynman).

- **computational complexity theory**:

    Turing machines, the Halting problem

- **algorithmic complexity theory**:

    P = NP ?

- **formal language theory**:

    the Chomsky hierarchy, formal semantics

- **database theory**:

   *the relational model, query languages*

Computer Engineering

- **the Von Neumann architecture**:
    the basis for digital computers

- **parallel processors**:
    new generation of multi-core machines

- **distributed computers**:
    prerequisite of the Internet and grid computing

Empirical approach: *quantification, measurement, comparison*

- **lives are at risk** $->$
  automatic pilot, nuclear power plants
- **huge amounts of money are at risk** $->$
  airplane crashes, insurance companies
- **corporate success/failure is at risk** $->$
  telephone billing, trading companies
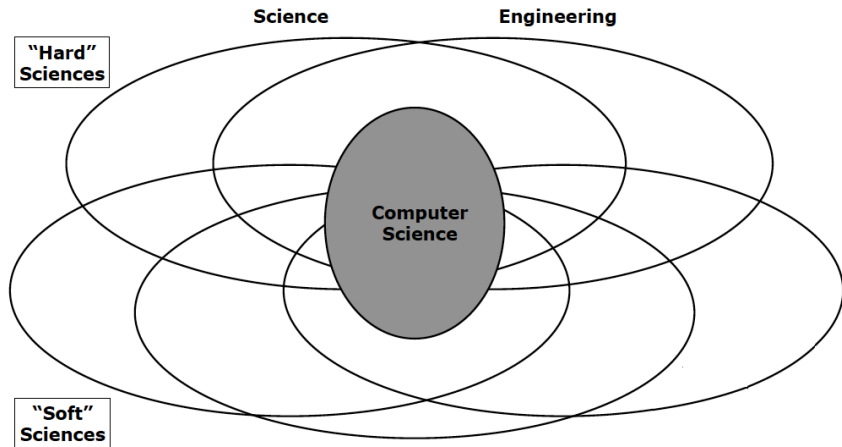
What Computer Science is not

- building/fixing computers
- writing software
- learning how computer/SW work

Computer Science is not about the tools used to perform computation but how such tools are used, and what is found out when they are used.

The solution of many C.S. problems may not even require the use of computers (just pencil & paper).

What about research methods for Computer Science?

'The' scientific method....

Suggested readings

- Chalmers, Alan. What Is This Thing Called Science? (University of Queensland Press, Open University press, 4th edition, 2013.)
- Bronowski, Jacob. Science and human values (Harper Perennial, 1990)
- Thomas S. Kuhn, The Structure of Scientific Revolutions (University of Chicago press, 1962)
- John, Gribbin, The Scientists: A History of Science Told Through the Lives of Its Greatest Inventors (Random House Trade Paperbacks, 2004)
- Dava Sobel, Galileo's Daughter: A Historical Memoir of Science, Faith and Love (Penguin Books NYC, 2000)
- Lisa Jardine, Ingenious Pursuits: Building the Scientific Revolution (Anchor, 2000)
- Patricia Fara, Science: A Four Thousand Year History (Oxford Uni. Press, 2009)
- J. Glenn Brookshear, Computer science: an overview (Addison Wesley, 1993)