Random steps in the history of science
4.2.2011
Jarl-Thure Eriksson

Mnajdra Temple ca 3600 BC, Malta.
(J-T Eriksson 2012)
Intellectual skills were distributed into different brain areas in the primitive human being. Areas did not communicate.

The development of language facilitated cognitive thinking.

30,000 years ago a giant developmental leap in brain function:
Fantasy removed the human being from a stiff anchoring to the instant of reality.

Source: Steven Mithen, The Prehistory of the Mind
“Roots of the Western Culture”

Developments of the use of Metals

Copper

Bronze

Iron

Cultures elsewhere

Egypt

Babyl., Assy.

Phoenician

Hittites

Sumerian

Greece

Roman

Arabian

Western

Sumerian

Egypt

Babyl., Assy.

Hittites

Greece

Roman

Arabian

Western

Copper

Bronze

Iron

India

China

Mexico (Olmecc)

Peru (Huari)

Mesoam. (Maya)

New Mexico (Chaco)

India (Horappa)

China

Mexico (Olmecc)

Peru (Huari)

Mesoam. (Maya)

New Mexico (Chaco)

J-T Eriksson
The pyramids are in themselves architectural and structural wonders considering the age over 5 millennia.

Moreover they reveal features related to an astronomical calender.

Most cultures believed that heaven and star constellations had an influence on the future. Hence they observed the sky and recorded unusual events, cf. Chinese records of supernovas.
Origin of scientific thought: the Greek philosophers

Greek philosophy emerged in the 6th and flourished in the 4th century. Most famous are:
- Sokrates
- Platon
- Aristoteles

Features:
1. Initially based on argumentation and discussion.
2. Questions related to life and social needs.
3. Logics of language.
4. Contemplation over natural phenomena and deduction into mental models.

Impact
- Fundamental on human thinking and social interaction,
- Less successful in natural science due to the lack of empiric verification.
Magnetism, the mystery phenomenon

First compass used by the Chinese Emperor ca 200 BC
Pliny the Elder, b. 23 AD, died at the eruption of Vesuvius in 79 AD. Provincial governor of the Roman Empire. Natural philosopher, author.

Free translation: According to the author Nikander, Magnes is considered the inventor, as he noticed that the sandal buckle stucked to the iron tip of his shepherd’s staff, when herding his cattle on the slopes of the Ida mountain.
Peter Peregrinus description of the compass rose in the 13th century

Epistola de Magnete, 1269
The World goes around and around

After Columbus 1st trip to America in 1492 it was quite clear that the Earth was a globe.

Discrepancy in the Julian calendar led to new studies of the movements of the planets and the Earth in relation to the sun. This was one factor behind Copernicus’ Heliocentric theory, published in 1543, but known to the church already 1536.

Illustration of the planetary system with the Sun in the centre. From the book “De revolutionibus orbium coelestium” by Copernicus.
Leonardo da Vinci creating mental models of turbulence

The complex phenomena of Nature have to be studied and mentally processed before generalizing theories or mathematical models can be formulated.

Source: Leonardo da Vinci
Science and philosophy of the Enlightenment era

**Galilei**
1564-1642
Empiric method
Theory of motion

**Descartes**
1596-1650
Lawyer, philosopher
Anatomy
Consciousness
Analytic geometry

**Newton**
1642-1727
Mechanics & dynamics
Optics
Gravitation
Calculus

1604
Heliocentric Telescope
1637
Discours
1684
Nova Methodus
1687
Principia

1609
1684
1687
Isaak Newton

Isaak Newton, 1643-1729, English physicist

Impact:
- the laws of moving rigid bodies
- optics and the nature of light (corpuscle theory)
- the law of gravitation facilitating the calculation of the orbital movements of celestial bodies
Gottfried Leibniz, lawyer and librarian at the Library of Hanover.

Along with Descartes and Spinoza the most influential philosopher of the 17th century.

Mathematics was merely a hobby. Background problem: finding minima and maxima of a function.

Leibniz infinitesimal definitions (dx, dy) were more formal and logic than the nomenclature developed by Newton.
Large scale systematization

Carl Linnaeus, 1707-1778, Swedish naturalist
- studied medicine, lecturer in botany
- thesis on plant sexuality in 1729
- visit to Holland in 1936 resulted in the maturation of the great idea of organizing plants according to their reproduction mechanism
- Systema Naturæ first published in 1738

Dmitrij Mendelejev, 1834-1907
- Russian chemist
- professor at universities in St Petersburg 1864-90
- published his first version of the Periodic System in 1869

Notes by Mendelejev

Charls Darwin, 1809-1882, English naturalist
- medical studies
- interest in botany
- journey of the Beagle, 1831-36
- publication of The Origin of Species in 1859
Key persons in the development of electromagnetic theory
Dalton (1766-1844) “Atoms”

Faraday (1791-1867) Fundamentals of electricity and magnetism

Maxwell (1831-1879) Electromagnetic theory

Einstein (1879-1955) Theory of Relativity Photons

Heisenberg Quantum mechanics Uncertainty principle

Bardeen Transistor Theory of superconduct.

James Watt (1736-1819) Steam engine

Daguerre (1787-1851) Photography

Edison (1847-1931) Electric bulb Phonograph Motion Picture

Orville Wright (1871-1931) Motor Aeroplane

Marconi (1874-1937) Wireless Telecomm
Number of ground breaking technical inventions. Periods of 5 years

Edison and his electric light bulb, 1878

Phonographe, 1877

Cinematographe, 1894

Bell’s telephone, 1876
From Volta and Ampere to Maxwell and Einstein:
The development of electromagnetic theory

- **Volta electric pillar battery**
- **Faraday’s induction law**
- **Thomson/Kelvin Electric flux**
- **Maxwell’s “Treatise..” Maxwell’s 4 laws**
- **Einstein’s Special relativity**
- **Oersted finds the connection between e-current and m-field**
- **Gauss theorem**
- **Heaviside’s equ. of moving charge**

Source: J-T Eriksson
The roots of Special Relativity

Oliver Heaviside’s equation of field contraction of a moving charge, 1888

\[ \epsilon E = \frac{q}{r^2} \frac{1 - (v^2/c^2)}{[1 - (v^2/c^2)\sin^2\theta]^{3/2}} \]

Mathematical formalism of late 19th century:

<table>
<thead>
<tr>
<th></th>
<th>Maxwell</th>
<th>Quaternions</th>
<th>Heaviside</th>
<th>Vectors</th>
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<tr>
<td></td>
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<tr>
<td>(A)</td>
<td>[ a = \frac{dH}{dy} - \frac{dG}{dz} ]</td>
<td>[ \mathcal{B} = \nabla \times \mathcal{A} ]</td>
<td>[ \mathcal{B} = \text{curl} \mathcal{A} ]</td>
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<tr>
<td></td>
<td>[ b = \frac{dF}{dz} - \frac{dH}{dx} ]</td>
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<tr>
<td></td>
<td>[ c = \frac{dG}{dx} - \frac{dF}{dy} ]</td>
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<tr>
<td>(A')</td>
<td>[ \frac{da}{dx} + \frac{db}{dy} + \frac{dc}{dz} = 0 ]</td>
<td>[ \nabla \times \mathcal{B} = 0 ]</td>
<td>[ \text{div} \mathcal{B} = 0 ]</td>
<td></td>
</tr>
</tbody>
</table>

Source: Hunt, The Maxwellians, Cornell UnivPress

Tampere University of Technology Jarl-Thure Eriksson 4.2.2011
General Relativity

The General Relativity theory was published by Einstein at the end of 1915.

The theory gives a geometric explanation of gravitation, meaning that a massive body causes a distortion of space-time, a 4-dimensional coordinate system in accordance with Special Relativity.

The theory is a cornerstone in modern cosmology.

\[ G_{\mu\nu} + \Lambda g_{\mu\nu} = \frac{8\pi G}{c^4} T_{\mu\nu} \]

Einstein field equations

Planck presenting the Planck-medal to Einstein in 1929.
Dirac in December 1933 with Heisenberg (Nobel 1932) and Schrödinger (co-winner 1933). Mother Flo next to Dirac.

Paul Adrian Maurice Dirac, 1902-1984
- relativistic model of the electron, Dirac equation, 1927, prediction of the positron
- Dirac delta function
- the Monopole prediction
- Fermi-Dirac statistics
- Dirac large number hypothesis

Mathematical formulation
The Dirac equation in the form originally proposed by Dirac is:

\[
\left( \beta mc^2 + \sum_{k=1}^{3} \alpha_k p_k c \right) \psi(x, t) = i\hbar \frac{\partial \psi(x, t)}{\partial t}
\]

where
- \( m \) is the rest mass of the electron,
The transistor

John Bardeen in 1988 at a Nobel Summer Seminar in Northern Sweden

The original patent of the transistor, filed June 17, 1948. Only Bardeen’s and Brattain’s names mentioned. Shockley’s missing due to a dispute concerning the final design.
Anatomy and brain

Andrea Vesalius, 1514-1564, anatomist and artist, well-known for his detailed anatomic pictures

Classical Vesalius drawing of the human brain, mid 16th century
Left brain, right brain

Left cortex hemisphere ("syntax" cognition)
- language, linear reasoning (grammar, vocabulary)
- arithmetic skills, basic mathematical abilities
- logic, analytic control

Right cortex hemisphere (creative cognition)
- intuition, large pattern recognition, reasoning
- mathematical estimation, numerical comparison
- language accentuation, intonation
- processing visual and musical stimuli
- facial perception
- artistic ability
Seeing beyond the syntax door: Consciousness

Can a machine (computer) see a meaning?

A big question of the human mind is, how we put signals from our senses in a context and see continuity and meaning instead of symbols or landscapes.

To a computer the Chinese symbol for horse is just a collection of lines, to a person mastering the Chinese language it is a horse. When we read a book, we immediately think of the meaning of words and sentences, not the letters.

Our subconscious put the read text in a context, that we consciously experience as a reality, a narrative of real occasions.

This is a hard nut to crack for artificial intelligence.

Source: Scientific American
Ancient female scientists

Hypatia, 415-355 BC
- daughter to the head librarian of the Alexandria Library
- natural philosophy, geometry, astronomy
- wide correspondence with the Mediterranean culture circuits
- designed an astrolob for navigation

2300 BC

En Hedu’anna, ~2354 BC
-- priestess of Moon worship
-- made tables of moon movements

400 BC

Theano, 5th century BC
-- wife of Pythagora
-- writings about children’s mind
-- writings about the Golden Cut

300 BC
**Historic female scientists**

**Caroline Herschel**  
1750-1848, Saksa/GB  
- sister of William Herschel  
- astronomer  
- focused her research on Nebulas, of which she made a famous table system

**Sofia Kovalevskaya**  
1850-1891, Russia/Germany/Sweden  
Mathematician  
- protege of Weierstrasse  
- partial diff. equations  
- the rings of Saturn  
- third female professor in Europe (Stockholm)

**Sophia Germain**  
1776-1831, Germany  
Mathematician  
- model of elasticity  
- studied the orbit data of Uranus  
- predicted the planet Neptunus

**Ada Byron**  
Countess of Lovelace  
1815-1850, GB  
- assistant to Babbage  
- invented the 1st data program

**Emma Noether**  
1882-1935, Germany  
Mathematician  
Noether’s theorem on conservation (eg. energy)
Female Nobelists

Marie Curie, nee Sklodowska
1867-1934, Poland/France
- chemist
- Nobel Prize in Physics 1903 for the discovery of radioactive radiation, with Pierre Curia end Henri Bequerel
- Nobel Prize in Chemistry 1911 for radium enrichment

Barbara McClintock, 1902-1992, USA
Nobel Prize in Medicine in 1983, ”jumping genes”
Pieneer in bioscience and genetics

Rita Levi-Montalcini, 1909-, Italy/USA
biochemist
Nobel Prize in Medicine in 1986, ”growth of nerve cells in the fetus”
Lise Meitner, 1878-1968, Germany
Physicist
Studied under Boltzmann in Vienna, PhD 1907

Professor at Berlin University, laboratory in the Keiser-Willhelm Institute

Discovered the first atomic fission reactions in 1938 in cooperation with Otto Hahn (Nobelist 1944)

Refugee in Stockholm due to the Nazis
Females without a Nobel Prize

Rosalind Franklin, 1920-1957, Great Britain
PhD Cambridge 1945, physical chemistry
Focus: X-ray diffraction analysis

Franklin developed a procedure to prepare DNA-samples for x-ray diffraction analysis. Diffraction images hinted of a spiral structure and offered means to measure the molecule. She reported her results to the King’s Medical Research Council in 1952. Crick realized the DNA double helix structure from the report.

Crick, Watson and Wilkins shared the Nobel Prize in Medicine in 1962. Before that Franklin had already died in cancer.
Females without a Nobel Prize

Jocelyn Bell Burnell, b. 1943 in Northern Ireland  
Alma Mater: Glasgow, Cambridge  
Mentors: Antony Hewish, Fred Hoyle  
Achievement: First discoverer of Pulsars in 1967.
Hewish received the Nobel Prize in Physics in 1974.

Jocelyn Bell Burnell, 2014  
Courtesy The Royal Society of Edinburgh
The Humboldtian doctrine

Wilhelm von Humboldt
1767-1835, German linguist.
Founder of the Berlin University in 1811.
Minister of Education.

Humboldt-doctrine: University education should be based on scientific research.

(Brother of famous geographic explorer Alexander von Humboldt)
The University time line

Before 1800:
- theology, rhetoric, humanities
- medicine, astronomy

1800-century:
- research and teaching (Humboldt)
- order of natural systems
- biology, geography

1900-1950:
- scientific breakthroughs (physics, chemistry, bioscience)
- university available for all

After the 50ies:
- research becomes a substantial economic factor
# Great Minds providing Scientific Strength

<table>
<thead>
<tr>
<th>Century</th>
<th>Country</th>
<th>1600</th>
<th>1700</th>
<th>1800</th>
<th>Early 1900</th>
<th>Characteristics</th>
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<tbody>
<tr>
<td>Great Britain</td>
<td>Gilbert Newton Locke</td>
<td>Davy Dalton Cavendish</td>
<td>Faraday Kelvin Joule Maxwell Rayleigh</td>
<td>Thomson Dirac Rutherford Chadwick</td>
<td>Empiric method Scientific communication</td>
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<td>France</td>
<td>Pascal Descartes</td>
<td>Laplace Lagrange Legendre Coulombe Buffon d’Alembert</td>
<td>Ampere Poincare Galois Bequerel</td>
<td>Curie Neel deBroglie</td>
<td>Mathematics Analytical models</td>
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<td>Germany Austria</td>
<td>Kepler</td>
<td>Leibniz Kant</td>
<td>Humboldt Hertz Gauss Helmholtz Weber Bolzmann</td>
<td>Planck Einstein Heisenberg Pauli Schrödinger</td>
<td>Theoretical strength Experimentation</td>
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<td>USA</td>
<td>Franklin</td>
<td>Henry Gibbs Michelson Millikan</td>
<td>Compton Anderson Lawrence Bardeen Faynman Bethe</td>
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<td>Practical (inventions) Funded research</td>
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<td>Italy</td>
<td>Galilei</td>
<td>Galvani Volta</td>
<td>Marconi</td>
<td>Fermi</td>
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<td>Huygens Leeuwenhoek</td>
<td>van der Vaals Lorentz</td>
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<td>Denmark</td>
<td>Tycho Brahe Rømer</td>
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<td>Bohr</td>
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<td>Gadolin Berzelius</td>
<td>Arrhenius</td>
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<td>Geology Chemistry</td>
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</tbody>
</table>
Physics and higher mathematics

Change

Conservation

Accumulation

Change of mass: \( \frac{dm}{dt} \)

Momentum: \( p = m v \)

Energy: \( W(1/2mv^2) \)

Action: \( I = \int W dt \)

Derivation and Integration

Power: \( p = \frac{dW}{dt} \)

Physical quantities in use

Source: J-T Eriksson
The hierarchy of complexity

COURTESY: WALTER KARPLUS
The complexity of scientific disciplines

- Biology
- Psychology
- Sociology
- Philosophy
- Information-theory
- Cognitive processes
- Language
- Culture
- Social interaction
- Ethics
- Logics
- Mathematics
- Exact sciences
- Chemistry
- Physics
- Biology
- Physiology & medicine
The big questions

In science

1. What are the forces behind the expanding Universe?
2. Why doesn’t relativity work on the atomic scale?
3. Is there a mentally comprehensible “theory of everything”?
4. Can we build computable models of how DNA, RNA, proteins, etc. interacts?
5. Can consciousness be explained rationally?

In life

1. Can conflicts be prevented before becoming global catastrophes?
2. Can the population growth be controlled?
3. How to establish democratic rule in totalitarian regions?
4. How to manage world economy?
5. What measures should be taken to secure a sustainable environment?