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Innovation

A Historical Perspective

April 3, 2022

1 The Great Cycles of Capitalism

1.1 The Steam Engine

The steam engine provides power for factories and fuelled unprecedented economic growth

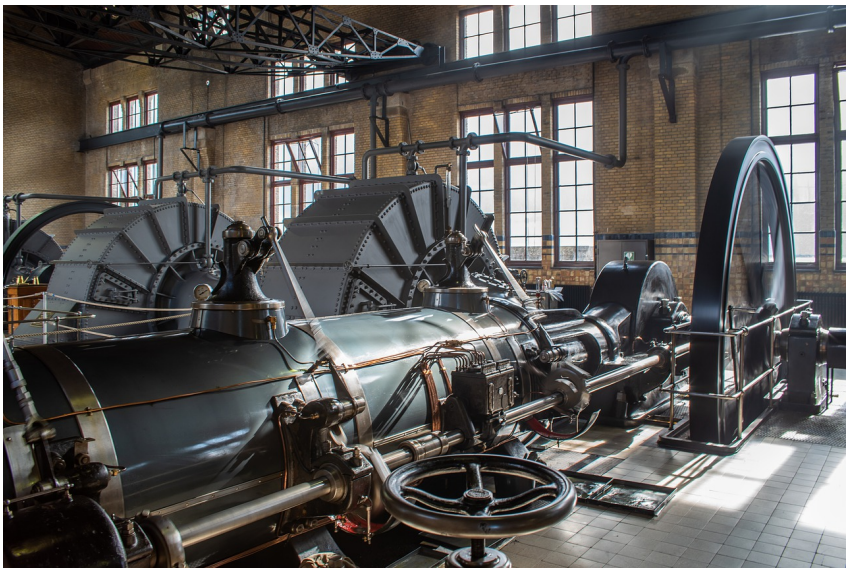


Figure 1: *Steam Engine in factgory — image by Kobus van Leer from* `pixabay.com`

The Steam Engine
Key dates

- Taqi al-Din in 1551 and Giovanni Branca in 1629 describe a steam engine
- Thomas Savery (1698) invents steam pump and in 1712 Thomas Newcomen invents the first practical steam engine
- invention of the steam engine with separate condenser by James Watt in 1765
- Ivan Polzunov (1766) builds the first two-cylinder steam engine
- explosive economic growth since the early 1800s
- The "Panic of 1857", 1866, and "The Panic of 1873", that initiated the "Long Depression"
- Karl Marx writes "Das Kapital" in 1867

1.2 The Train

The Train

Figure 2: *The Train provided reliable mass transport — image Image by Erich Westendarp from* `pixabay.com`

The Train

Key Dates

- 1804: first train (it pulled 25 tonnes of iron material and 70 people over the distance of 10 miles)
- First commercial steam train (Stephenson's "The Rocket") managed to reach speed of 96 km/h.
- about 40% of the world's cargo go still by train (ecological and efficient)
- end: "The Panic of 1901" and ultimately WWI

1.3 The Internal Combustion Engine, Electricity and Magnetism

The Internal Combustion Engine

Fuelled exponential economic growth and provided individual transport

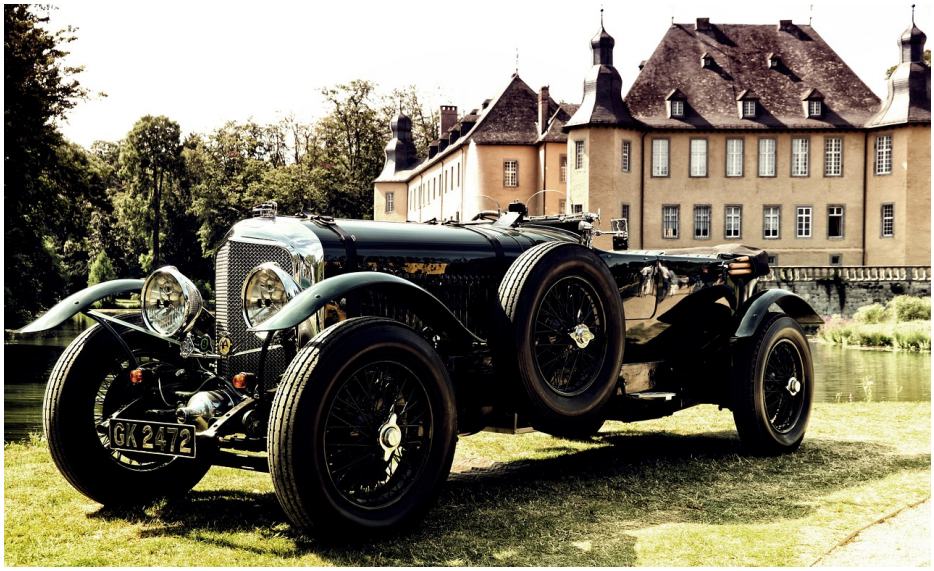


Figure 3: *The internal combustion engine gave rise to reliable individual transport — image by S. Hermann & F. Richter from* `pixabay.com`

Electricity and Magnetism

Fuelled exponential economic growth and provided a plethora of applications and appliances

Figure 4: *Electricity and Magnetism provided lightbulbs, radio, and all kinds of powered appliances — image by PublicDomainPictures from* `pixabay.com`

The Internal Combustion Engine, Electricity and Magnetism
Key Dates

- 1805 Humphry Davy invets the "carbon ark" (electric light)
- 1832: first DC electro-motor (William Sturgeon); 1837
- 1885: first practical gasoline automobile by Karl Benz
- Ford T (since 1908)
- Automation both at home and in the factory due to electricity and magnetism
- end: "Wall Street Crash of 1929", that initiated the "Great Depression" and ultimately WWII.

Automobiles and the Petro-Chemical Industry
Fuelled exponential economic growth

Figure 5: *The petro-chemical industry — image by Frauke Feind from* `pixabay.com`

Automobiles and the Petro-Chemical Industry
Key Dates

- Technological improvements on cars and their production
- First oil wells in USA (1846), Poland (1853), Romania (1857)
- First modern oil well (1854) and first oil refinery (1856) by Ignacy Łukasiewicz
- 1600 BCE: Mesoamericans used natural rubber for balls, bands, and figurines
- 1856: first man-made plastic by Alexander Parkes
- 1872: invention of polyvinyl chloride (PVC)
- 1923: Durite Plastics Inc. produced phenol-furfural resins
- 1930s: production of polystyrene (PS) and PVC by BASF
- 1933: polyethylene discovered by Imperial Chemical Industries (ICI) – Reginald Gibson and Eric Fawcett.
- 1941: polyethylene terephthalate (PET) discovered by Calico Printers' Association (a replacement for glass in many applications)

- 1954: polypropylene by Giulio Natta
- 1957: production of polypropylene
- 1954: expanded polystyrene (building insulation, packaging, and cups) invented by Dow Chemical.
- end: 1973–74 stock market crashes

1.4 The Electronic Computer and the Internet

The Electronic Computer

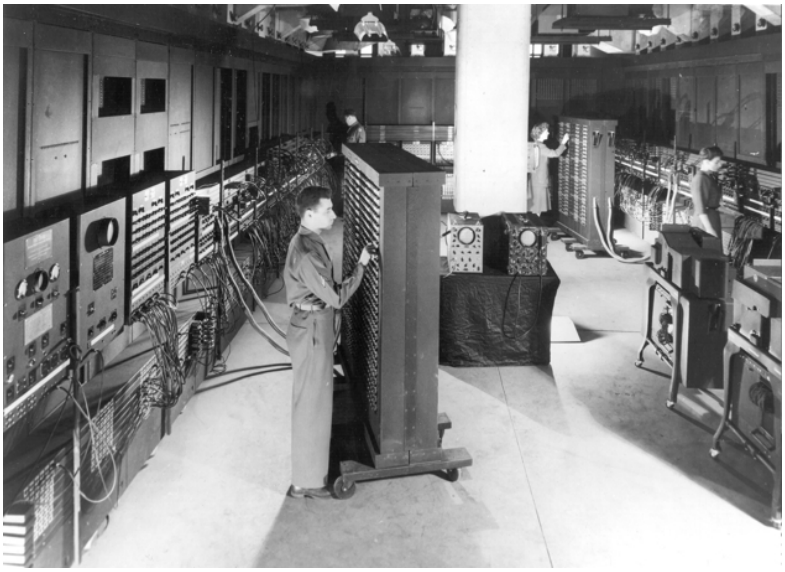


Figure 6: *The ENIAC (Electronic Numerical Integrator and Computer) — image by Unidentified U.S. Army photographer - Public Domain*

Moore's Law

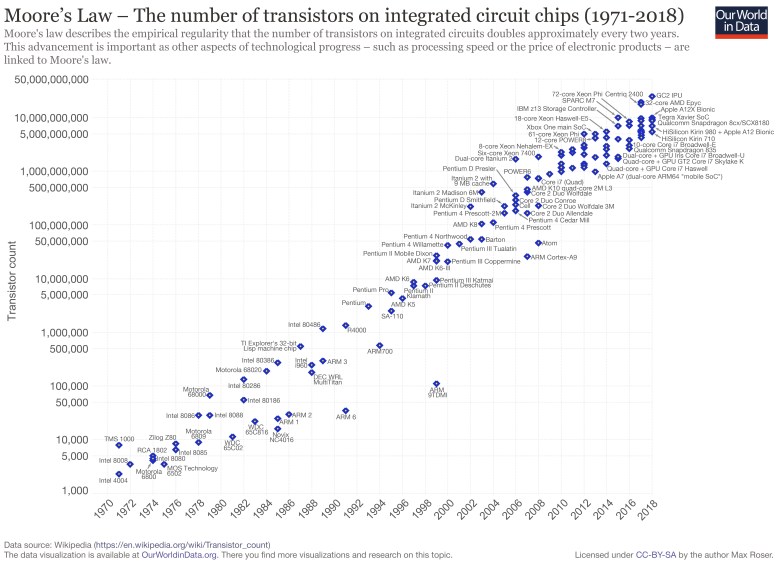


Figure 7: *Moore's Law — image Wikimedia Commons* `wikipedia.org`

The Computer: Key Dates

- Charles Babbage's Analytical Engine (1930s) and Ada Lovelace's code for it in 1843
- first computers: ABC in 1942, Collossus 1943
- 1946: ENIAC, first programmable general purpose computer
- 1952: IBM sells first mainframe
- 1953: Hard-disk
- 1959: metal–oxide–semiconductor field-effect transistor (MOSFET), invented by Mohamed Atalla and Dawon Kahng
- 1968: Network of Networks (UCLA) with Telnet, FTP, messaging and email — The ARPA-net in 1977 (now "the Internet")
- 1973: C (by Dennis Ritchie in the Bell Labs)
- 1980: DOS
- 1989: WWW is developed and used in CERN
- 1993: IBM Simon (first smart-phone)
- 2000: Nokia 3310
- end: Dot-Com Bubble of 2000 and the 2008 Global Meltdown

2 The Future

2.1 Kondratiev

Kondratiev (1935)

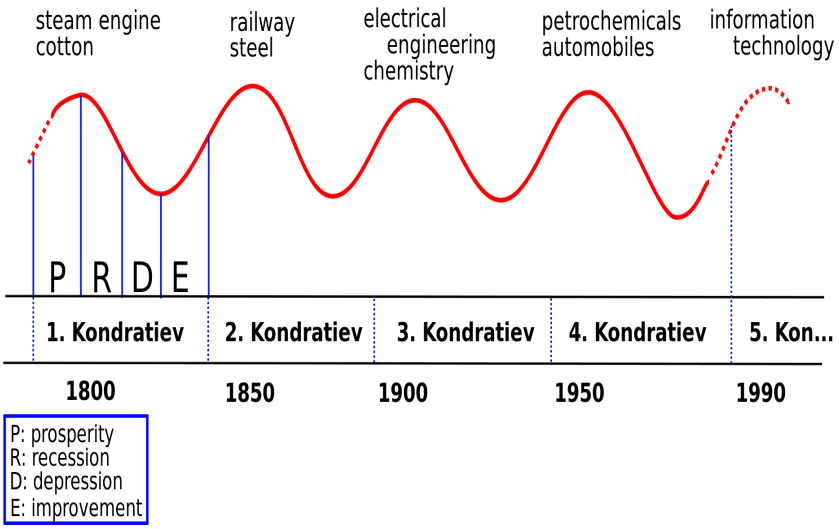


Figure 8: *Kondratiev waves — image By Rursus - Own work, CC BY-SA 3.0,* `https://commons.wikimedia.org/w/index.php?curid=7833300`.

2.2 The Scientific Method

The Scientific Method

Aristotle (384–322 BCE, Greece) can be seen as the father of the scientific method, because of his rigorous logical method which was much more than natural logic. But it is fair to credit Ibn al-Haytham (aka Alhazen — 965–1039, Iraq) to prepare the scientific method for collaborative use. His emphasis on collecting empirical data and reproducibility of results laid the foundation for a scientific method that is much more successful. This method allows people to check each other and confirm or reject previous results.

However both the scientific method and the word "scientist" only came into common use in the 19$^{\text{th}}$ century and the scientific method only became the standard method in the 20$^{\text{th}}$ century. Therefore, it should not come as a surprise that this became also a period of inventions and development as never seen before.

Indeed, while previous inventions such as fire, agriculture, the wheel, bronze and steel might not have followed explicitly the scientific method

they created a society ready to embrace the scientific method and fuel an era of accelerated innovation and expansion. The internal combustion engine, electricity and magnetism fuelled the economic growth as never seen before. The electronic computer brought us to the 21th century and now a new era of growth is being prepared by big data, machine learning, nanotechnology and –maybe– quantum computing.

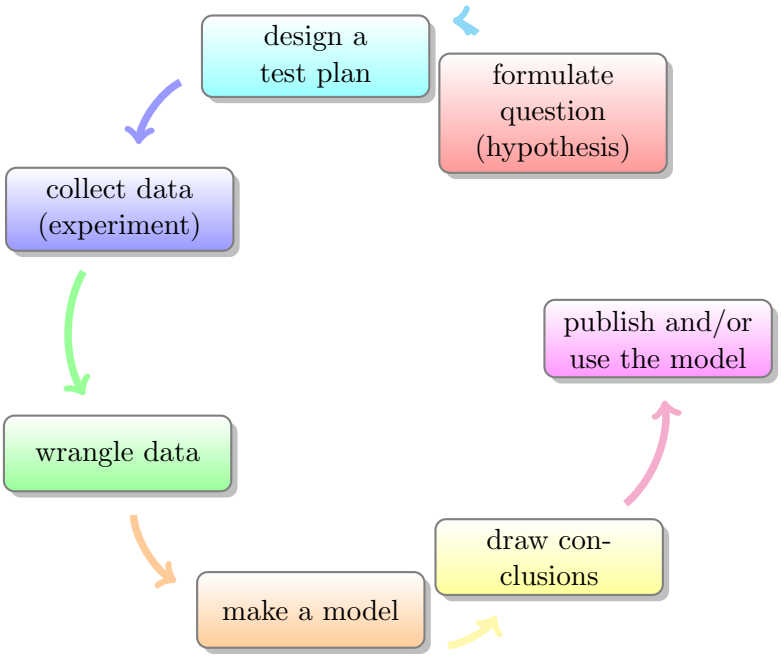


Figure 9: *The steps in the scientific method for the data scientist.*

2.3 The Next Wave

The Next Large Trend Candidates

1. artificial intelligence, machine learning, big data, and robotic process automation;
2. nano technology
3. biotechnology, and
4. quantum computing;

2.3.1 Artificial Intelligence and Machine Learning

AI and ML
Self Driving Cars

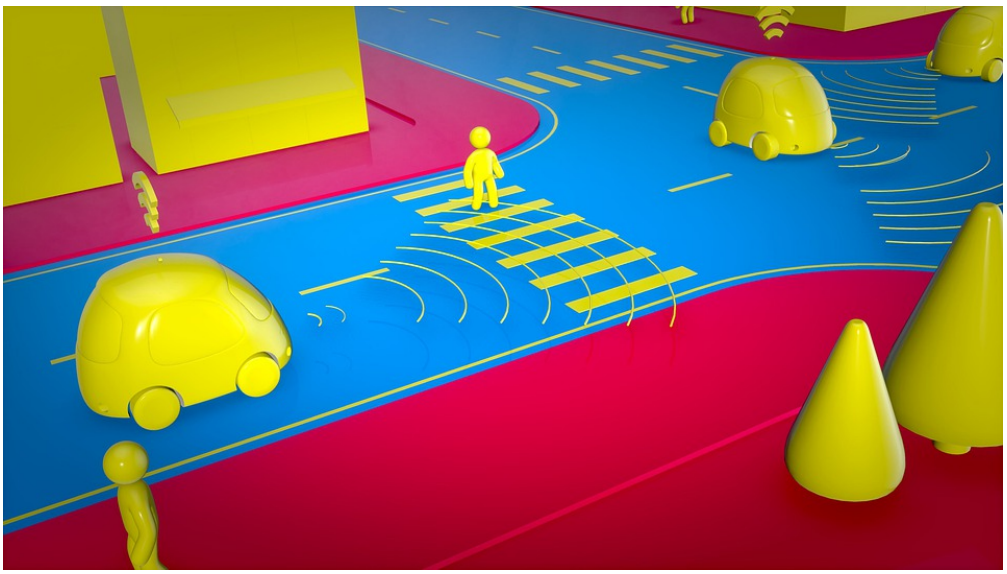


Figure 10: *Self driving cars will become commonplace — image by Julien Tromeur from* `pixabay.com`.

The Singularity

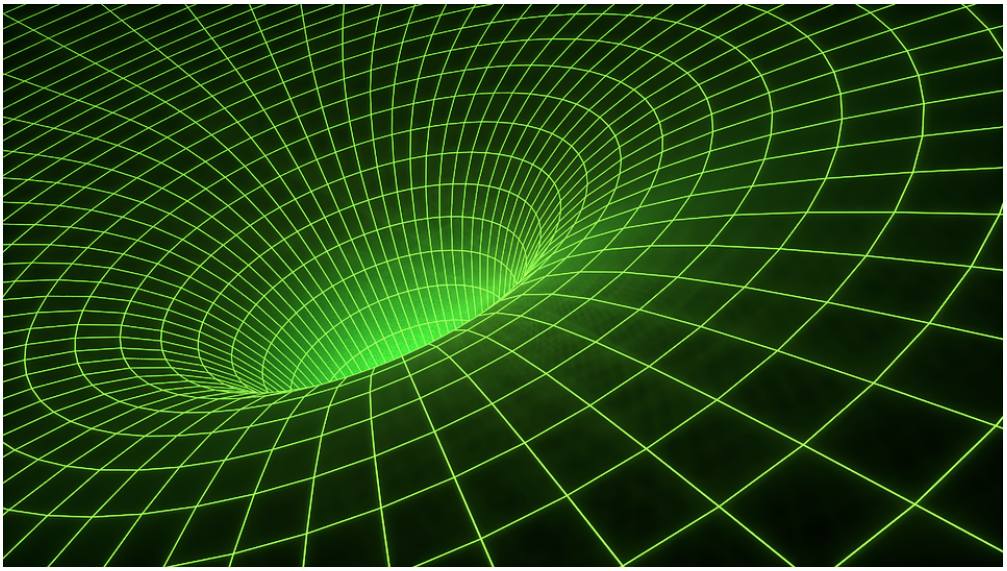


Figure 11: *The singularity occurs when a machine will be able to improve on itself faster and faster — image by Johnson Martin from* `pixabay.com`.

AI and ML
Face recognition is possible even when people are maksed

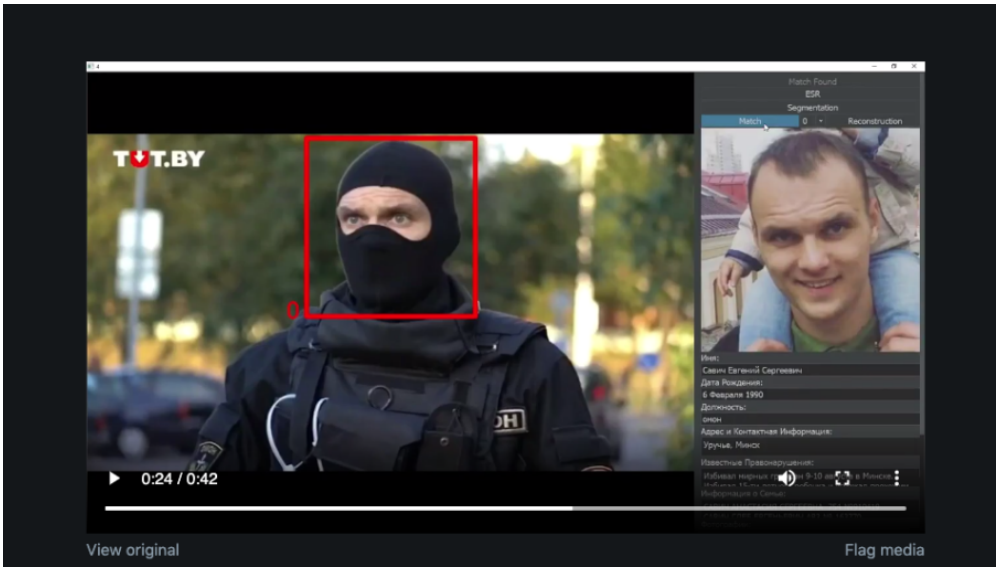


Figure 12: *Police brutality under scrutiny: masked OMON police unmasked by AI.*

2.3.2 Nano Technology

Nano Technology
Vanta Black or Black 3.0

Figure 13: *Vanta Black and similar coatings use nano technology – source:* `https://www.coating.co.uk/vantablack-coating`.

Nano Technology
Graphene

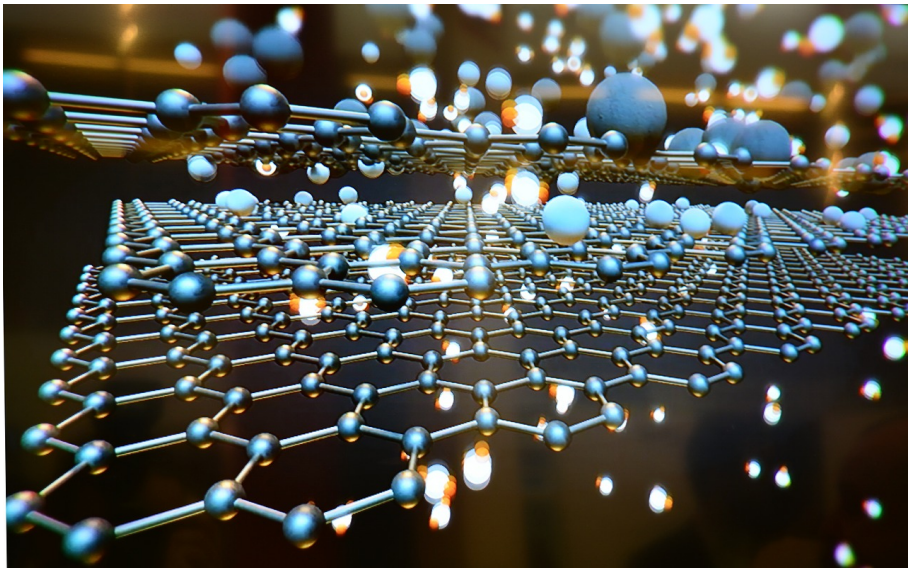


Figure 14: *Graphene — image: Image by seagul from* `pixabay.com`.

Nano Technology

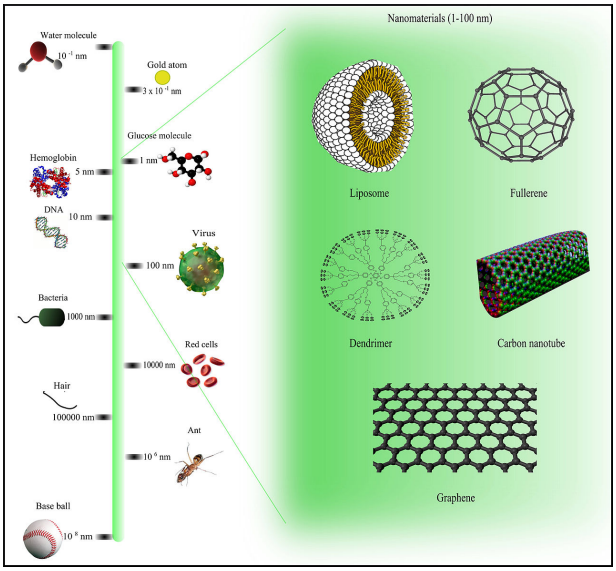


Figure 15: *Nano material sizes — source: By Sureshbup - `http://www.mdpi.com/1422-0067/15/5/7158`, CC BY-SA 3.0, `https://commons.wikimedia.org/w/index.php?curid=32395880`.*

Nano Technology

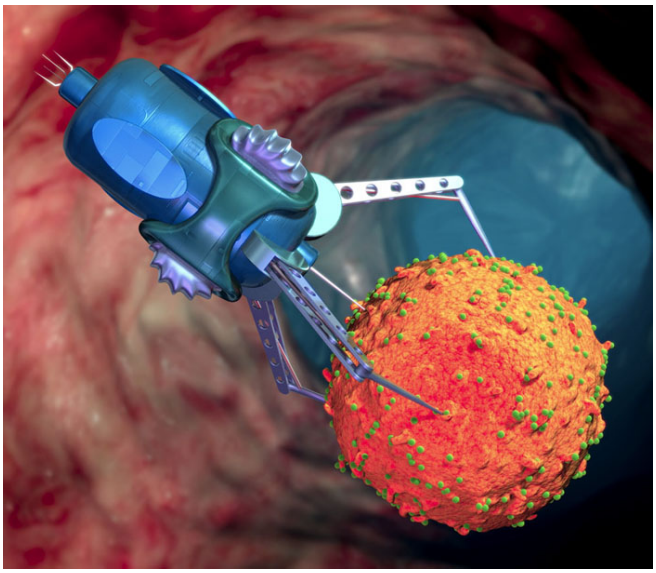


Figure 16: *Nano robots — source: `https://www.yaabot.com/23051/nano-robots-medicine-miniscule-wonders/`.*

2.3.3 Biotechnology

Biotechnology and genetic manipulation is as old as farming: more than 10,000 years

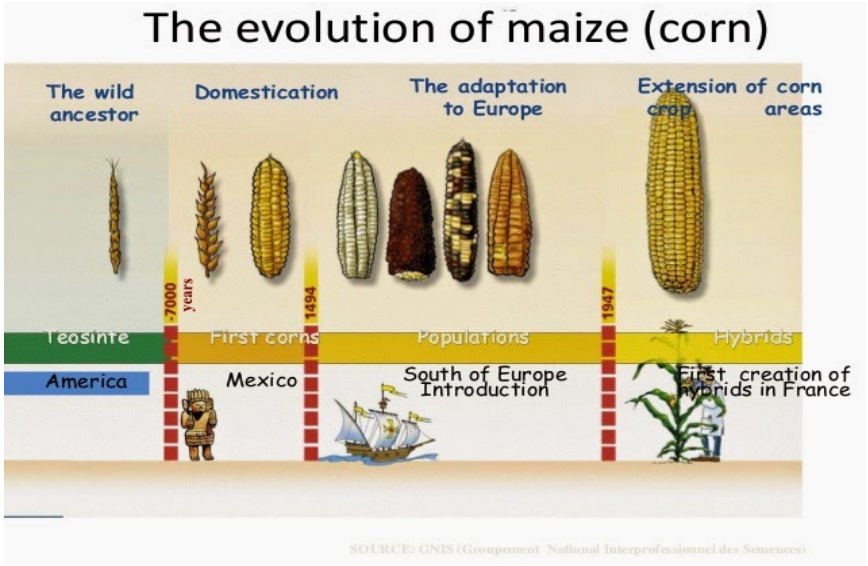


Figure 17: *the guided evolution of corn — source: unknown.*

Biotech

What

- Recombinant DNA
- Cloning
- Stem Cell Therapy
- Designer Drugs
- Genomics & genetic engineering

Why

- less pesticides, $C0_2$, etc.
- better and more crops
- better plant and animal health
- better human health

The Holy Grail

Figure 18: *The holy grail of Biotechnology — source: unknown.*

2.3.4 Quantum Computing

Quantum Computing

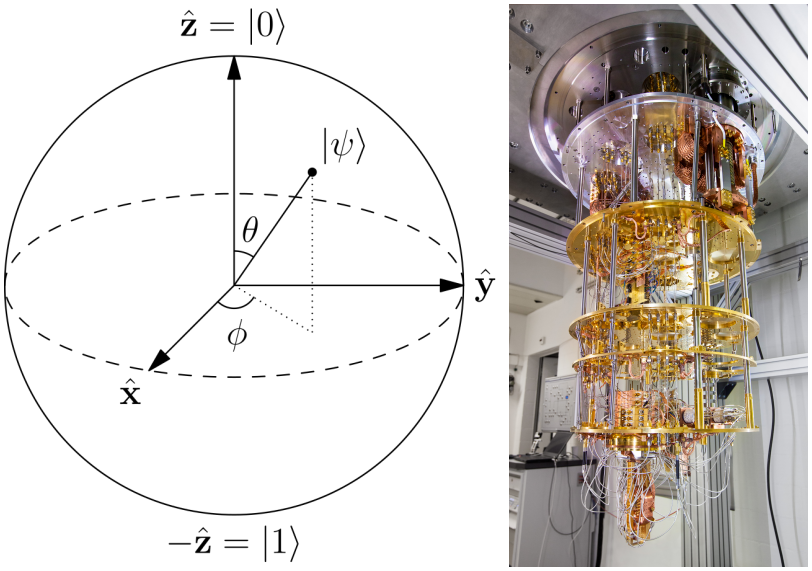


Figure 19: *Quantum Computers. – Source: Wikimedia*

Potential of Quantum Computers

Quantum Computers do not violate the Church-Turing Thesis, but . . .

- Adiabatic Optimization (D-Wave)

  - optimizations
  - ... but there is also the Quantum Monte-Carlo (QMC) technique for classical computers
- Shor's Alogorithm (1994): factor numbers
  - break most of today's encryption
  - ... including today's blockchain technology
- Lov Grover's (1996): invert functions without prior knowledge of the function
  - searching in unstructured data
- Solve large linear systems
  - solve ODE and PDE systems
  - regressions
  - machine learning

3 Conclusions

Life Expectancy over Time

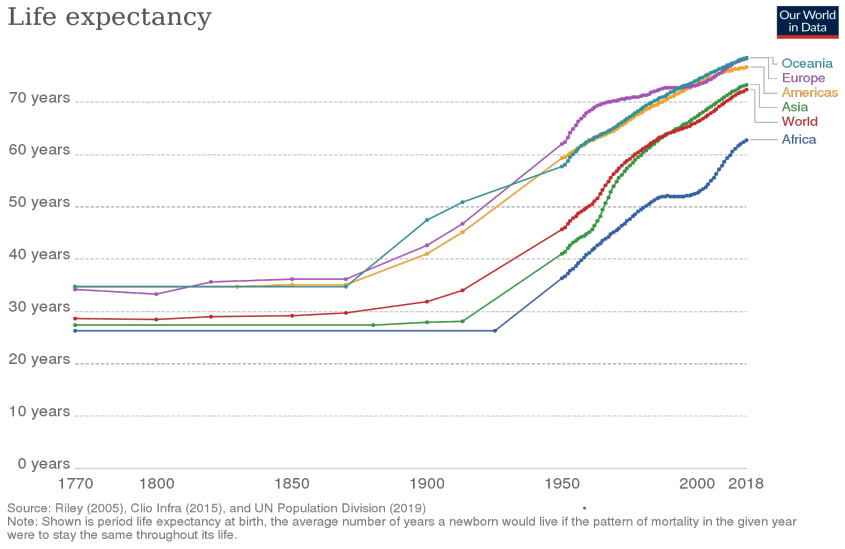


Figure 20: *The evolution of life expectancy over time — image by Max Roser -* `https://ourworldindata.org/life-expectancy`*, CC BY 4.0,* `https://commons.wikimedia.org/w/index.php?curid=83546093`

Life Expectancy vs GDP per capita

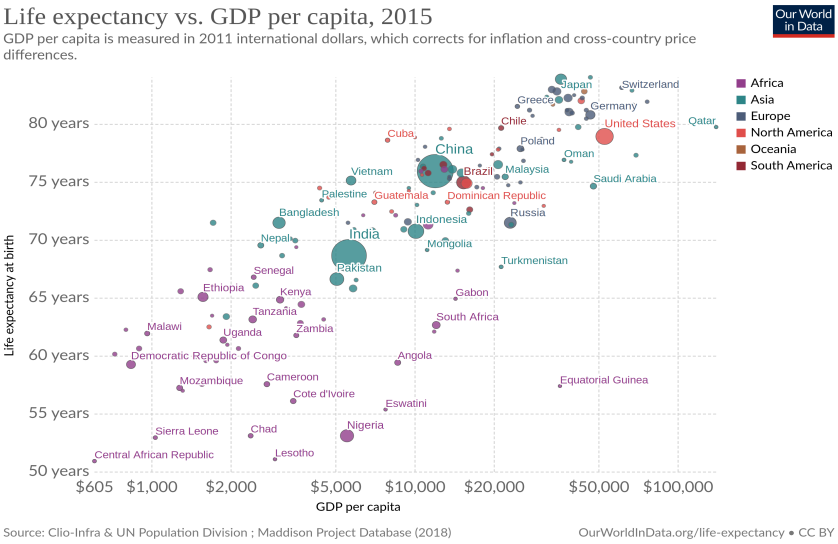


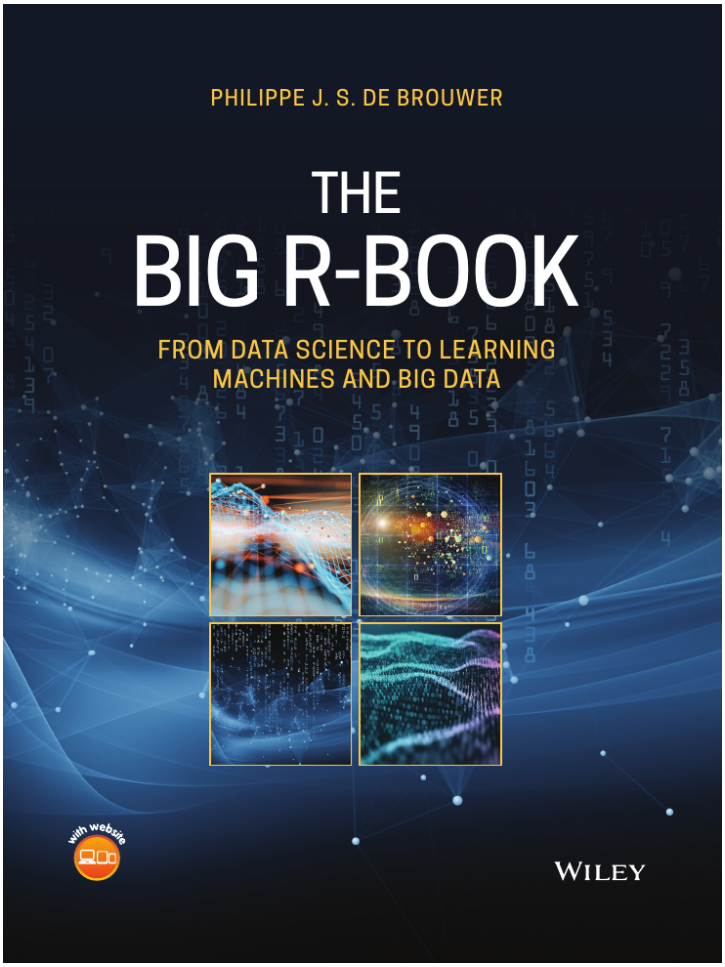
Figure 21: *Life expectancy vs GDP per capita.* – *Source:* `https://ourworldindata.org`

1. The scientific method works, and is able to make this world a better place
2. Data Science and related subjects such as Big Data, Machine Learning (and Artificial Intelligence) are our best bet towards a new wave of development, exponential growth and wealth creation
3. . . . and "The Big R-Book" will help you to master the subject.

The Big R-Book: from Data Science to Learning Machines and Big Data

1. Introduction
2. Starting with R and Elements of Statistics
3. Data Import
4. Data Wrangling
5. Modelling
6. Introduction to Companies
7. Report

8. Bigger and Faster R
9. Appendices



Nomenclature

AI artificial intelligence, page 10

AIML artificial intelligence and machine learning, page 10

BASF Badische Anilin- und SodaFabrik, page 6

BCE before common era, page 6

$C0_2$ carbon dioxide, page 15

DOS disc operating system, page 8

ENIAC Electronic Numerical Integrator and Computer, page 7

FTP file transfer protocol, page 8

IBM International Business Machines Corporation, page 8

ML machine learning, page 10

MOSFET metal–oxide–semiconductor field-effect transistor, page 8

OMON Special Purpose Mobile Unit – Russian and Belarusian police force, page 12

PS polystyrene, page 6

PVC polyvinyl chloride, page 6

UCLA The University of California, Los Angeles, page 8

WWI World War I, page 3

WWW world wide web, page 8