The history of technology

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The inventors

Many historical books contain names of people who are considered to be the inventor of various innovations and this is no exception. These names are not always accurate since sometimes it is someone else who got the same idea before. For example Edward Jennings, was not the first to make smallpox vaccine[1] and several people made light bulbs[2] before Thomas Alva Edison came up with his version in 1880. This is partly due to the different sources list different inventors and partly because many inventors never managed to spread their innovations outside their own circle. The latter can be caused by many things beyond their own inability, such that the invention was made at a time when the world was not ready for it. What benefit did light bulb give us before we could generate electricity? Further many other inventions were surely invented earlier and by other people than are normally associated with each innovation, but these people did not have the ability and/or the means to realize, or spread their idea. However, it is usually a far greater achievement to realize an idea and also monetize it compared to just get it, so perhaps it is fair that those who succeed in this sometimes get the undeserved honour of being the inventor of the phenomenon. In addition, it is sometimes, in the literature, different bids on when something was invented. However, it is not surprising as there are several important dates in the inventive process, such as the day when the idea crossed the inventors mind, the day when the idea was realized in a working prototype, the day when the patent application was filed or the date when the product hit the market. So I ask you to have in mind that what is stated in this chapter regarding inventor and the dates of the inventions are not always consistent with other sources and/or with reality.

1. The method of inducing immunity against smallpox by smearing the secretions from a mildly diseased person in a wound was used in the early 1700s in particular in what is now called Turkey. Jenner's method, to instead smear cowpox was, however, considerably less dangerous.

2. One of them was the British man Joseph Wilson Swan, who in 1860 presented a working electric light bulb.

Technology development during 0-1700

There is a saying that goes: "Necessity is the mother of invention" and it is, in my experience, used when someone lacks a certain component and another component is used as a surrogate. In this context, the saying is true. Though if was true, in general, we would have seen a tremendous amount of innovations when need was greatest, before the 1700s, and then the amount of innovations would have declined. However, as seen in table 2-5 there were pretty little technical development between 0-approximately 1700. Excavations of an etruscan[3] upper class home, which burned down about 79 BC, has for example shown that, they had about the same things that could be found in a home in the same area a thousand years later. The home consisted of a detached villa with a basement that occupied a ground area of 150 sqm. It was built of brick and probably also the roof was covered with bricks. It had wooden details assembled with nails. There were doorknobs and other fittings of metal (bronze). Archaeologists also found plates, an olive press and wheat. From Etruscan tomb paintings we know that they produced and drank wine and that they hunted and fished. Tomb paintings also show that they used tables, chairs and carpets, and they entertained each other with singing, dancing, juggling and funny games. From other graves we know that they had art objects, axes, spears, large knives and helmets of bronze. Still other findings show that the cultivated wheat extracted and processed iron and used agricultural equipment in metal.

3. The Etruscans roughly lived in the area now called Tuscany (in present Italy). They had their heyday from 800-600 BC. From about the year 280 BC it became a part of the Roman Empire.

The Roman Empire is otherwise the most famous example of a culture that flourished around the year 0, and whose technology over trumped later cultures ditto (see table 1).

Table 1. Examples of technology in some for us very important areas, in addition to the previously described, we known existed in the Roman Empire.

Technic type	What
Transport	Big ships driven by rowing slawes, nation wide collective[4] transport system.
Comunication	Optical telegraphs, mail pidgeons, a nation wide system of mail riders.
Food	Water mills were used and different farming tools, spices, preservation methods such as salting, they baked bread, made wine and they used cutlery[5].
Energy	Wind (sail ships), falling water, animals and slaves.
Medicine	They operated, for instance, boone fractures and produced herbal medicines.
Buiding & construction	Multi floor housings, cupoles, cranes, elevators[6], water pipes[7], suer pipes[7], bath tubs, showers, swimming pools[8], saunas[8], doors, locks, central heating[9], valve bridges in stone, amfi theaters[5], reservoirs, nation wide road net[10], concrete, toos like axes, hammers, scissors, drills and pliers.
Materials	They made products[5] in, for instance, stone, iron, lead, silver, gold, glass, clay, leather and wool.

4. The Romans created about 250 BC a system of timetable controlled public transport traffic along the roads. The horse-drawn carriages became more advanced and resembled in the end those that appear in the Wild West movies, with two axes of which the front one could rotate and was attached to the towing horses.
5. In a Roman building complex, located in present Germany (Saalburg, see www.saalburgmuseum.de), it have been found various well-preserved objects made of wood, skin, glass, pottery, bronze and iron from the period 100-260, such as: advanced locks, swords, crossbows, shoes, helmets, trinkets, tools, cutlery, buckles, hardware, nails, horseshoes and chains.
6. Elevators were already part of Rome’s tall buildings before the year 0. In the Emperor's Palace (rebuilt after the fire in Rome year 64) there where such an elevator that could lift the traveller 40 m. The car hung in a rope, and was operated by three slaves who cranked a winch. Marks on the rope showed when the car arrived at a floor. At the bottom of the elevator shaft, there was a thick leather cushion that would capture the car softly, if the rope broke.
7. From archaeological findings in Pompeii we know that in Roman cities there where water pipes into different rooms in the house. In the ends of the pipes there were taps. And in a book written in 79 by the head of Rome’s waterworks it shows that the city had over 400 kilometres water mains in the form of tunnels and aqueducts.
8. During the Roman Empire, there were about five hundred public baths in Rome alone. These came from 312 BC, when the first aqueduct was finished. One of these, which was built in the early 200's, had two pools totalling 4 000 sqm. In one, the water was cold and the other it was lukewarm, in addition, there was a hot tub, two saunas, guarded locker rooms, sports and relaxation areas.
9. The central heating was designed so that hot smoke from a fireplace was led through channels in the floors and walls.
10. The Roman road network was covering the whole country. It was straight and 4-5 meter wide roads with paved ditches on each side. Earth excavation was removed and the roadbed was founded with boulders then the bed was filled with finer and finer gravel that was stamped into a smooth road surface. Along the road there were stops where passengers could get on/off and the horses could be replaced. Distances were marked at regular intervals (every thousand double-steps) trough milestones (mille = thousand in Latin), in which the distance to the nearest wagon stop was given.

Most other than the Romans lived, however, under simpler conditions. The History Museum in Stockholm has, based on excavations, made a model of the houses that they believe were in the town of Birka during its heydays in the 800s. Compared to Rome several hundred years before the proud city of Birka, however, looks like a collection of mediocre huts.

A house under construction.

Finished houses in the same model. All were small, one store high, without window openings and with holes for smoke evacuation under the ridge.

The areas where the technology evolved significantly, from 0 to 1700, was in the military and related areas with both civil and military benefits, such as transport, on land and at sea. This is probably because there was the first clear needs (defence of the country or the conquests of other countries), as well as someone who could not pay (the state). To some extent also luxury products were developed targeted to a rich minority of the population.
Of the major innovations that I know of, and that could be attributed to the 0-700 year period was paper probably the most important and it was an essential tool in the Chinese central government communication with the local representatives of the countryside.

Table 2. Timing, location, and (in some cases) the inventor of important and enduring innovations made between 0-700 years.

Technic type	0-100	101-200	201-	301-	401-500	501-	601-700
Transport					400s, Asia, The stirrup[12]		
Comunication		105, China, paper[11]					
Food							600s, Europe, the heavy plow[13]
Energy							
Medicine							
Build. & constr.							
Materials							
Science important for the technical development							657, India, the zero[14] is introduced, Brahmagupta

11. Paper conceded far more convenient texts than those that were written on clay tablets, stone, on wood or hide, for those who had not papyrus plants available.
12. The stirrup made it easier to stay on the horse and moreover he could also stand, and it in turn made it possible to ride faster. In addition, it was very beneficial in battles because the rider could hit to the side with more power without having to worry about falling off.
13. With heavy plows the farmers could turn the soil so their seeds could be placed in more energetic soil under the previously used and thus crop growth increased.
14. The Indies did not just invent zero but also the other nine digits we use, which was a huge advance over other systems:

Our numerals Roman numerals System with only one character

Though the numbers 1-9 excited before year 0. With zero we had, however, a complete system for describing all the numbers in a clear manner:

175	CLXXV (= 100+50+10+10+5)	~~IIII~~ ~~IIII~~

Also the innovations attributed to the period 700-1200 were often due to military demands (such as horseshoes, the compass, gunpowder and gunpowder rockets). Moreover some happened in communications through that the printing technology was improved (table 3) for the benefit of the Chinese state.

Table 3. Timing, location, and (in some cases) the inventor of important and enduring innovations made the years 701-1200.

Technic type	701-800	801-900	901-1000	1001-1100	1101-1200
Transport		800s, Europe, horse shoes[17], approx. 900 improved harness[17], 863, Eastern Europe , the Cyrillic alphabet[15]			Early 1100s, China, the compass[18]
Comunication				Ca 1045, china, Printing with movable types[16]	1102, Italy, Europes oldest paper document
Food					
Energy					
Medicin					
Buid.- & constr.					
Materials			Approx. 1000, South Asia, the spinning wheel[19]		
Science imp. for the technical development	820, Iran, algebraic[20] system, Ṃusa al-Chwarazmi				

15. The Cyrillic alphabet is used in for example Russia.
16. Printing with movable types (small pieces with a sign on each piece that was put together to a whole text) was not a major revolution for the Chinese, because they have thousands of different characters. But when the technology in the mid-1400s was "invented" in Europe, it was a greater success. Since we only have about thirty characters and also use quite a lot of signs for each word.
17. Horseshoes made that the horses' hooves were not torn as much and they also got better grip in the soil and thus could pull heavier loads. Harnesses of course existed before the 900's, but they were improved, which further increased the horses' ability to pull heavy loads.
18. Until the 1300s, a large part of the intercontinental transports were made on land, partly because those that where out on the open sea basically had no idea about in what direction they were going, especially when the sun had gone down and if it was not a starry night. But with the compass, the establishment of naval routes, faster and roomier merchant ships the marine transportations increased radically, see the chapter on transport.
19. The spinning wheel made it easier to turn the balls of, for example, sheep wool into threads, which in turn were braided together (woven) to fabrics.
20. Algebraic systems are used to solve equations.

Many of the innovations the subsequent 500 years, appears to have been to military benefits (such as watches, navigational aids, signal flags, better ships, various guns, rifles and hand grenades). Moreover, to the delight of the few who could afford to pay for luxury items, watches, glasses, and dental fillings were invented (table 4).

Table 4. Significant and lasting innovations 1201-1700. ? = Do not know.

Technic type	1201-1300	1301-1400	1401-1500	1501-1600	1601-1700
Transport			1440, Europe, the quadrant (navigational instrument). 1484, Portugal, the first European navigation manual and nautical calender.	About 1550, Germany, railroads[22], ?.	1700, England, useable steam engines, Newcomen. ?, the diving bell, ?.
Communication	The end of the 1200s, Europe, the mechanical tower clocks. 1290, Italy glasses.	1340, Italy, Europes first paper mill.	Early 1400s, signal flaggs.	1502, Germany, the pocket watch[21], Henlein.	1657, Holland, pendullum clock, Christian Huygens. 1663, 1692, France, woord book, French akademy.
Food					1672, ?, treshing machine, ?.
Energy					
Medicine			1450, dental fillings of gold.		
Build. & construct.		1328, sawmills.			1653, Germany?, piston pump, Otto van Guericke.
Materials				1586, Germany, mechanical loom.	
Science important for the technology dev.					"1614, Scotland, logarithmic tables[23], John Napier. 1637, France, the Cartesian coordinate system, René Descartes. 1683, Holland, precision microscope[24], Anton van Leeuwenhoek. 1662,?, General gas law, Boyle and Mariotte. 1678,?, The speed of light is calculated, Ole Römer. 1685?, Meteorological chart (wind map), Halley. 1687, England, "principa matematica" [25] published, Isaac Newton.

21. The early portable watches had only hour index. Much later they were supplemented with a minute index and even later with an index for seconds.
22. The first railway line was made of wood and used in a mine with horse-drawn carriages.
23. Logarithmic tables were important, before the calculators with a logarithm function, for those who wanted to understand the relationship between certain physical quantities, such as how long it takes to wear out a cutting tool in a lathe at different processing speeds.
24. There had been simple microscopes before Antony van Leewenhoek began to develop his better varieties. He constructed hundreds of microscopes and he was the first who saw germs (in 1675).
25. "Principa Matemathica" was a scientific book in which three of the fundamental laws of physics were described:
    1. Every body remains in its state of rest or uniform and rectilinear motion unless it by interacting forces is forced to change that state.
    2. The change of motion change is proportional to the force applied and it is directed along the straight line in which the force acts.
    3. Each force corresponds to an equal and opposite force, so that the mutually between two bodies acting forces always are equal and opposite.
    These mechanical laws were important to know for those who later designed for instance steam engines.

The reason that so little happened after the Roman Empire until the year 1700 may be that:

Economic constraints. They who possibly saw the need for technological development in the most important economic sector (agriculture) had probably seldom the skills, materials and tools needed to develop the technology. Still less did they afford to let someone more suitable person to do the development work. And those who could do it, as blacksmiths and other craftsmen, could not reasonably engage in things[1] they did not get paid to do.

The limitations of bartering. The trade was limited and the majority (often over 90%) lived by their own family's work in nature. Most of what was consumed came directly from their own production. For this majority the payment for goods sold was usually other goods. Barter would include the disadvantage that the system was very cumbersome for those who were specialized in manufacturing of a particular product, since they had to devote much time to succeed in exchange to what they needed to survive. Which resulted in that most did everything, and the overall productivity was low.

The transport limitations. Transport was time consuming and thus costly, therefore restricting the movement of goods to either cover the immediate area or very expensive goods destined for a small elite that could pay for long distance journeys. That limited the village's opportunities, and output from, specializes in an area.

Communication systems constraints. For new technologies to be born it requires that someone sees that innovation is technically possible. But most were tied to the family's work in nature (or another family's ditto) and they did not have the means to do some travelling. This meant that they were stuck in the local area and therefore could not see, much less embrace technological advances made elsewhere. In addition, they could not learn about achievements through reading about them or study them on TV.

Education system limitations. Today, we must all submit to training in a whole variety of subjects such as math, language, history, and more, before the actual work related training begins. But before public schooling was introduced, however, the children at an early age had to learn to do a job. This meant that they were forced from childhood to obey and submit to the existing methods. When they themselves had the opportunity to influence their production, they were probably so solid in earlier approaches that they did not reflected on the efficiency in their work.
Further, the contemporary higher education organized by the society aimed to make students carrier of the current civilization's cultural heritage and norms. The studies were concentrated on poetry and some important religious scriptures like, the Bible, the Quran, Avesta, Vedas, Tripikata, or Confucius writings. The research that, after all, was conducted by the wise researchers at the universities was primarily in the areas of science and math. This probably because it was considered to be cultivated and that such area requires only an analytical person, and since he was paid, he did not need any other reward than the glory and perhaps a better position. Which was an important reward system then and now.

Social constraints. Those who had the means to develop new technologies (the state and the upper class), were rather uninterested in doing that. It may be because they:
- Wanted to keep the distance to the working part of the population, such as farmers.
- Felt solidarity only with themselves, their family and the immediate circle, and as long as they had a good time, they saw no reason to do anything.
- Were only interested to seize as much as possible of the common cake, instead of increasing it. Then probably no one had even heard of a society where the cake was enough for everyone.

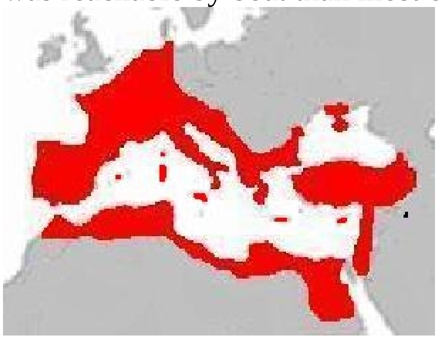
How is it then that the Romans successfully developed such advanced systems?

Economic constraints. Romans took home great wealth, which probably to some extent gained all citizens, which reasonably resulted in that ordinary people had more funds for development compared with other communities.

The limitations of bartering. The Romans lived largely in cities and they could not live directly from what the land gave. The Roman economy was to a far greater extent than most other previous and subsequent kingdoms depending on trade paid with coins. Coins made of brass, bronze, copper, silver and gold, were minted and distributed according to strict rules of weights, sizes, value and metal composition. They were so popular and valuable that they were used (or at least, they have been found) as far away as India.

A copper coin from the German part of the Roman Empire under Emperor Constantine II's reign (317-340 years). This coin did not cost more than 195 SEK in one of Stockholm coin shops in 2011, suggesting that the Roman coins still today are quite common.

The transport limitations. A major part of the more densely populated areas of the Roman Empire was reachable by boat than most other empires that have ever existed.



The Roman Empire during the year

Communication systems constraints. The Romans had public transportation throughout the country, which provided opportunities for citizens to look around.

Education system limitations. Roman Empire also had no public education, but it was common that children's of less affluent parents were trained in a primary school, which was called the Ludus litterarius. They could be anywhere, in private residences or on the street. They typically focused on the demands of everyday life: reading and writing. In addition, there were higher levels of education for those who had rich parents. Thus, the Romans probably were better educated than the citizens of most other kingdoms before compulsory schooling began to be introduced in the 1800s. In addition, it was reasonable to believe that their abundant supply of cheap labour (slaves) to the heavy chores that otherwise bound population at simple tasks, freed workers who had a managerial position in relation to the slaves who did the hard work. It probably meant that they both had time to think about more efficient methods and also to some extent had the power to implement changes.

Social constraints. No idea how it was regarding this point.

Technology developments during 1701 – 2000

Since the technology that we daily face differ very much from what someone faced in 1700, very much must have been invented afterwards. Some of the most significant innovations are listed in table 5.

Table 5. Significant and lasting innovations 1700 - 2000. ? = Do not know.

Technic type	1701-1800	1801-1900	1901-2000
Transport	1707,?, suspension, 1759, Great Brit., chronometer (portable precision clockwork), John Harrison. 1769, France?, steam wagon for city, Cognot. 1779, France, the velocipede (bicycle predecessor). 1781,?, the first successful experiments with steamers, Jouffroy. 1783, France, hot air balloon, Mongolfier. 1790, sextant (navigational instrument), Adams.	1803, Brit., locomotive, Richard Trevithick. 1803,?, paddle steamer, Robert Fulton. 1805,?, leaf springs, Obadiah Elliot. 1839, Brit., bicycle, Kirkpatrick Macmillan. 1839, USA, vulcanizing rubber (gave the rubber tire), Charles Goodyear. 1876, Germany, four-stroke petrol engine, Nikolaus Otto. 1877, USA, pneumatic brakes (used on trains and trucks). 1881, Germany, electric locomotives, ?. 1885, Germany, the car, Daimler and Benz. 1892, Germany, the diesel engine, Rudolf Diesel.	1903, the United States, aircraft, Wright brothers. 1907, France, helicopter, Paul Cornu (the first viable helicopter was German and came first in 1936). 1930, Brit., Jet engine, Frank Whittle. ?, Germany, rocket engine, Verner von Braun and others. 1957, Soviet, satellites, ?. 1970, USA, GPS, various persons.
Communication	1765,?, paper based on wood instead of rags, ?. 1780,?, reservoir pen, Scheller.	1812, Germany, cylinder printing press, F König. 1826, France, photography, Louis Daguerre. 1833, Germany, telegraph, Carl Gauss. 1837, the United States, better telegraph, Samuel Morse. 1839, Switzerland, electric bell, Carl August Steinheil. 1876, USA, telephone, Alexander Bell. 1858, United States-Brit., Transatlantic submarine cable, ?. 1867, the United States, the first useful typewriter, Christopher Latham Sholes. 1877, USA, phonograph (the first type of gramophone), Thomas Edison. 1895, Italy, radio, Gugliemo Marconi. 1895, France, moving images, the Lumière brothers.	1904, United States?, Electron tube, Ambrose Flemming. 1910, the United States, moving images with sound, Thomas Edison. 1915, the United States, traffic lights, ?. 1923, the United States, the portable radio, ?. 1936, Great Brit., Television broadcasts. 1947, the United States, the transistor, William Shockley. 1949, Great Brit?, Computer. 1958, USA, micro chip. 1960, USA, laser, Theodore Maiman. 1969, the United States, the forerunner of the Internet, various persons.
Food	The 1700s, Brit., horse-drawn seed drill and harrow, Jethro Tull.	1805, USA, chiller, Oliver Evans. 1811, France, food preservation, Nicolas Appert. 1834, USA, reaper, Cyrus Hall McCormick. 1864, France, pasteurization, Louis Pasteur.	1911, the United States, electric refrigerator for household use. 1994, the United States, genetically modified vegetables, various people.
Energy	1703, Germany, street lighting with oil lamps, ?. 1712, Brit., steam engine, Thomas Newcomen. 1800, Italy, battery, Alessandro Volta. 1745, Germany, capacitor, Edward von Kleist. 1778-88, Brit., improved steam engine, James Watt. 1792, Brit., gas lights, William Murdoch. 1800, Italy, battery, Alessandro Volta.	1813, Brit., the first real gasworks. 1831, Brit., Transformer, Michael Faraday. 1831, the United States, electric motor, Joseph Henry. 1848, Germany, gutta-percha isolation around electrical cables, Siemens. 1860, France?, lead battery, Gaston Plate. 1859, the United States, the first oil drilling ?. 1880, the United States, the first lasting light bulb, Thomas Edison. 1879, the United States, the first working hydroelectric plant, Thomas Edison.	1942, U.S. atomic reactor. 1960, the Soviet Union, the solar cell, ?.

Table 5. Continued.

Technic type	1701-1800	1801-1900	1901-2000
Medicine	1770's, Brit. , medicine for heart failure, William Wintering. 1796, Brit., smallpox vaccine, Edward Jenner.	1816,?, stethoscope, Rene Laennec. 1831, chloroform, Samuel Guthrie / Justus van Liebig. 1842, USA, ether anaesthesia, Crawford Long. 1842, Austria, disinfection before surgery, Semmelweis. 1865, cleaning of wounds with carbolic acid, Joseph Lister. 1874, Germany, aspirin, Herman Kolbe. 1895, Germany, the X-ray machine, Wilhelm Röntgen. 1896, Italy, blood pressure cuff, Scipio Riva-Rocci.	1928, Brit., penicillin, Alexander Fleming. 1929, Germany, electro-encephalography, Hans Berger. 1953, USA, outpatient vaccine. 1957, Brit., ultrasound, ?. 1967, South Africa, heart transplant, ?. 2000, USA, draft map of the human genome, various persons.
Building- & construction	1750, USA, lightning conductor, Benjamin Franklin. 1771,?, twist drill, Cooke. 1774, Brit., water closet, ?. 1776,?, planer, Hatton. 1777, France, central heating with hot water, Terrebonne Main.	1805, Brit., Band saw, Newbury. 1822,?, the road roller Patterson. 1866, Sweden, dynamite, Alfred Nobel.	
Materials	1709, Brit., iron with coke, Abraham Darby. 1733, Brit., quick shuttle for looms, John Kay. 1740-50, Brit., crucible steel process, B Huntsman. 1746, Brit. method for producing sulphuric acid, John Roebuck. 1765, Brit., spinning machine, James Hargreaves. 1785, Brit., bleach, Berthollet. 1786, the first workable mechanical loom, E Cartwright. 1789, Brit., rails of steel. 1793, USA, cotton ginning machine, Eli Whitney.	1823, Brit., waterproof fabric, Charles Macintosh. 1826, Germany, aluminium, Wöhler. 1856, Brit., steel fabrication, Henry Bessemer. 1846, USA, sewing machine, Elias Howe. 1879, Brit, Thomas method (steel from iron ore with phosphorus), ?. 1884,?, art silk, Count de Chardonnet. 1890, Russia, electric arc welding, Nikolai Slavianov.	Mainly USA, all plastics, various inventors.
Science important for the development	1714, Germany, temperature scale, Gabriel Fahrenheit. 1768, Switzerland, integral calculus, Leonhard Euler. 1727,?, The discovery that silver oxides are photosensitive (important for photography's emergence), Schulze. 1785,?, coulomb's law, Charles Coulomb. 1795, France, the metric system, ?.	1820, Denmark, electromagnetism, C H Oersted. 1827, Germany, ohms law, Georg Ohm. 1831, Brit., principles of electric motors, transformers and generators, Michael Faraday. 1834, Brit., mechanical computer, Charles Babbage.	1938, Germany, the fission of uranium atoms, Otto Hahn and Fritz Strassmann.

Even at the end of the period discussed here, there were people who came up with inventions that someone thought ware so fundamentally different from previous technology that it would be possible to get a patent on them (chart 1).

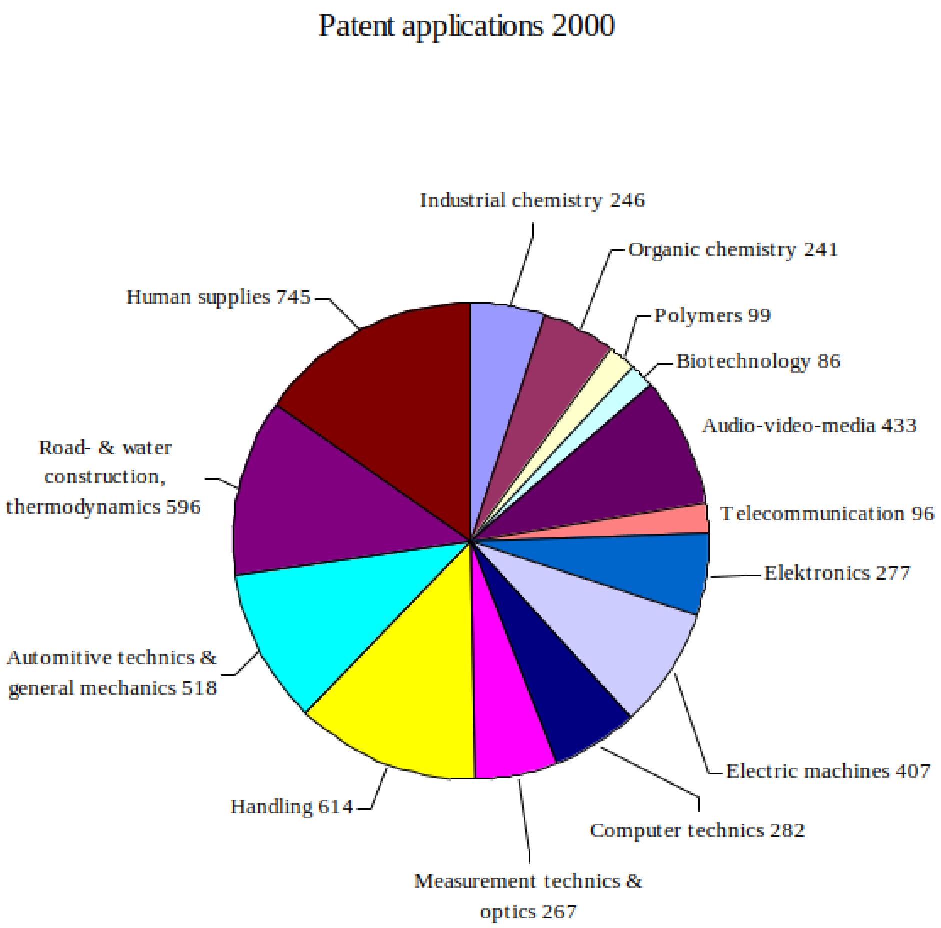


Chart 1. How the 4920 Swedish patent applications, lodged at the Patent Office in 2000, were distributed among different areas, according to the International patent classification (data from the Patent and Registration Offices website). The figure after the names of each category indicates the number of patent applications.

Why was so much invented in the North-western and Central Europe?

Though the civilizations of China, India and the Muslim world were superior to Europe long before. Maybe because:

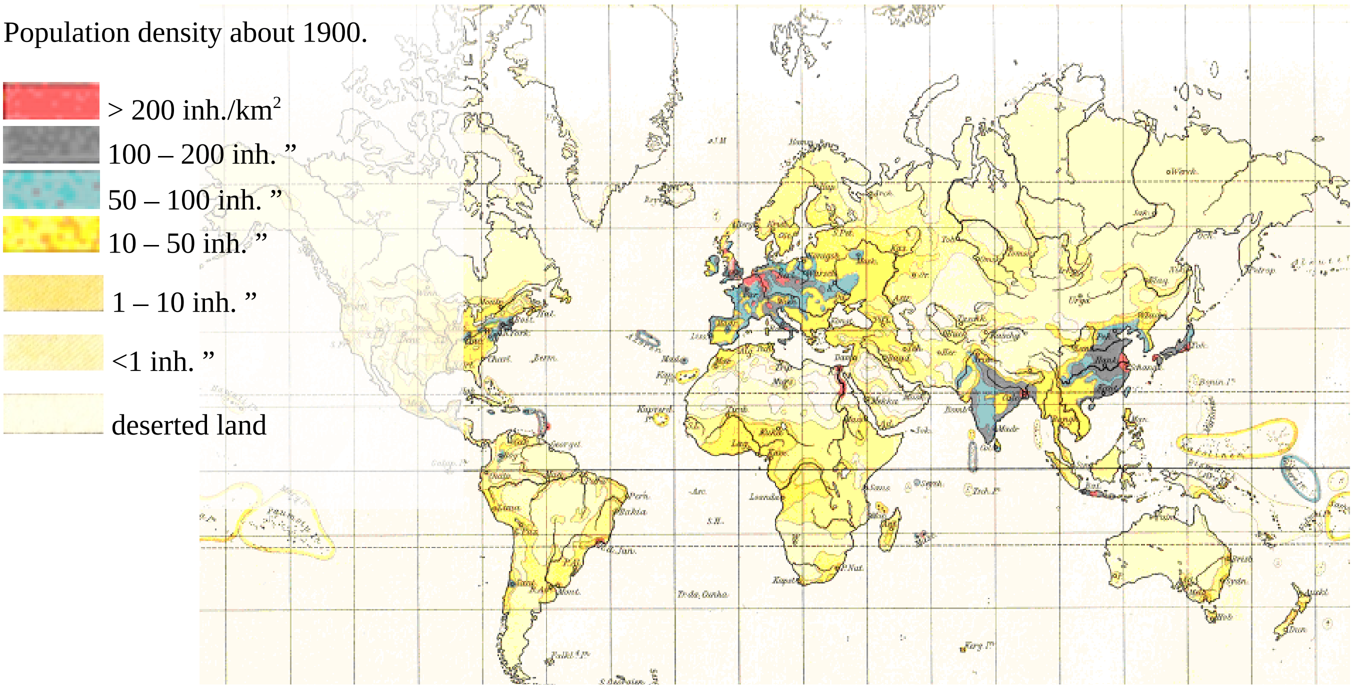
Economic constraints.
- The wealth in Britain, in particular, shipped home from the colonies generated revenue to the country. Which in turn resulted in that there were money to invest in industrial production and there were people with money to consume the products manufactured.
- Natural resources in the area were varied and include fairly large supplies of hydropower and important elements such as iron, copper, clay, limestone, wood and coal.
- Europeans had fewer children than in other civilizations. This is mainly due to the relationships formed later and thus they had less time in which to conceive children. The effect of this was that the population increase was not greater than that it usually was a food reserve for natural disasters and crop failures. This in turn meant that these disasters had less devastating effects than in other parts of the world.
- The area has a regular and abundant supply of water in the form of rain. Unlike from the competing civilizations which were mainly located in the drier areas watered by large rivers, with related future demands for irrigation of fields and a greater risk of dehydration.
- Efficiency measures in agriculture conducted in north-western Europe, beginning in the 1700s (see food), freed labour ready for other tasks.
- The potatoes that came to Europe with the Spanish sailors, were spread over the region from the late 1700s and since a couple of potatoes can produce enough potatoes to a whole meal for one person, it led to that the amount of food increased and thus the farms could feed more people who were not farmers.
- Jennings method of smallpox vaccine were used on a large scale in the UK in the early 1800s, which led to more people survived (see Medicine) and it further increased the supply of labour.

The limitations of bartering.
- Due to the above, there was a widespread urbanization of the region. For example, 1801 - 1851 the population in London increased from 959 000 to 2 362 000[26] persons. Since the urban population could not live on what the nature had to offer, they were forced to find other ways to support themselves, primarily some form of manufacturing, which undermined the self-sustenance and thus the barter.

The transport limitations.
- The relatively densely populated area in northern Europe meant that producers had close to a large amount of potential customers.
- Europe has a very long coastline which has the effect that a larger portion of the population could be reached by sea transports than in competing areas.
- The large number of rivers made it easy to transport goods to cities in the interior.
- During the period a large number of canals and later railroads where built which further improved transportation.

26. English Industrial Cities of the Nineteenth Century: A Social Geography by Richard Dennis, Cambridge University press, 1984).

Communication systems constraints.
- The region was, unlike competing regions, not surrounded by desert, tropical rainforest and mountains (the latter with a few exceptions). This meant, first, that there was a large land mass and population that to some extent could take part in the advanced civilization building, and secondly that there were no nomadic people who constituted a threat against this.
- Northwest Central Europe was densely populated, which further increased the possibilities for exchange of information.
- During the period the ability to travel and communicate in the region increased (see the chapters on transportation and communication).



Population density about 1900.

Education system limitations.
- During the Industrial Revolution public schooling was introduced in the region.
- From 1794 and onwards public technical universities and other technical schools started throughout Europe.
- The climate in Central Europe is more variable and in the northern part the winters are so cold that agriculture and the like are impossible during a large part of the year. This in turn meant that there was a need for more technical solutions compared to if the climate had been more constant. These generally present needs, probably gave rise to more interest in technology among the general public.

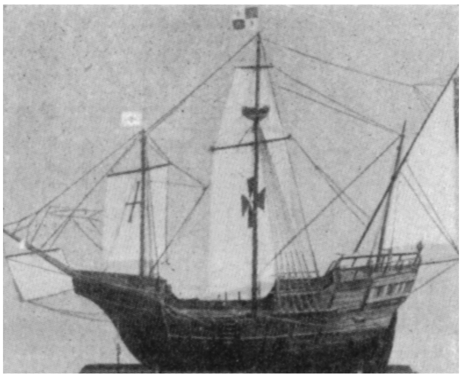
Social constraints.
- It was not as unseemly in the European elite to indulge themselves to technology or agriculture as it was for the elite in other parts of the world. This since Europe earlier was so poor and undeveloped that they had to be confronted with such banalities.
- The large amount of relatively equal states close to each other, called for competition.
- The Christian view of work that appears in bible verses like: "Six days you shall work, but on the seventh day you shall cease to work, so that your ox and your donkey may rest and the slave woman's son and the stranger may be refreshed." (2 Exodus 23:12), "The lazy desire becomes his death, because his hands refuse to work." (Proverbs 21:25) and "Let him work – that’s what he is made for, and if he do not obey, then put him in fetters.”(Sir 33:30).

The majority of the reasons proposed above may explain why the industrial revolution took place in Europe, but not when it happened. The triggering factors are among the events and processes that preceded the Revolution, the introduction of the smallpox vaccines, or the shipments of wealth from the colonies, or the improvements in agriculture, or ...

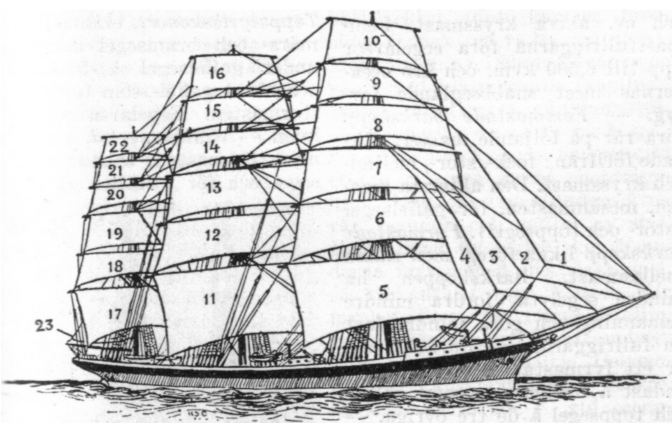
Transportation

Boats existed long before the year 0 in our era. And they were in several respects superior to all land-based transport. It probably began with rafts of interconnected tree trunks, via canoes made of hollowed tree trunks to real ships. These early boats had some significant drawbacks such as that: they probably were heavy relative to their size, they were unstable since the size of the keel probably was limited, they required pretty much manual labour and the load capacity was very limited. Longer distances and/or larger shipments required other boats. The problem with that they required pretty much manual labour was solved in two ways, one was to provide the boats with sails. There are images that show that the Egyptians were sailing about 3200 BC. The second method was to provide the boats with a great number of rowers. Since the early yachts could not sail besides in tailwind the first sailing ships was usually a combination of these two techniques. The development continued with sailing vessels like:

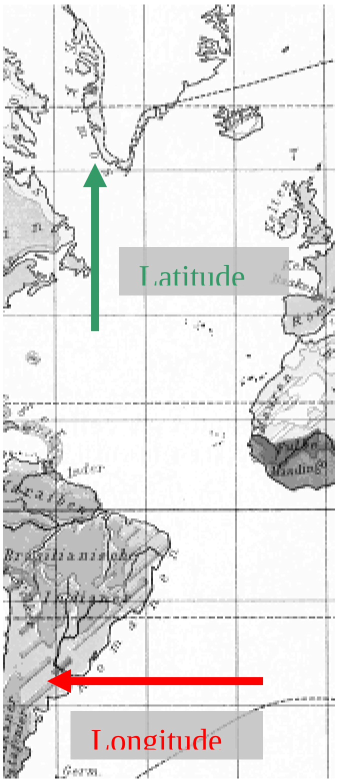
Long boats, which was a type of ships that has evolved over several centuries and perfected by its most famous users, the Vikings, in the 900's. Typical size 22 x 5 m, speed ≤ 10 knots, 30 rowers.



The caravel, which was developed by the Portuguese in the 1300s (size about 20-50 x 9 m). This type of vessels were used by both them and the Spaniards when they conquered the New World. The ship to the left is a model of Columbus caravel 'Santa Maria'.



Full rigs, which were developed in the 1700s, when the professional sailing ships peaked regarding performance. They are characterized by having at least three masts with square sails on each one. In ideal wind, they could get up to a speed of, like, 16 knots.
There were more than full-rigged ship and the largest (Prussia) weighed 11 150 tons (full load), had five masts, 6 806 m^2 sails area and was 147 m long including bowsprit.



Navigation at sea:
The sun's position was for a long time central for navigation at sea. In addition to that it with it’s motion across the sky indicates the east and west, the angle between the ship and the sun's arc of motion gives the latitude vessel.
Astrolabe was until the advent of the compass the main instrument for navigation at sea. It was invented in ancient Greece. The instrument is similar to a sextant and was used to measure the angle between two stars or one star and the horizon. With this information, in combination with a star map one could, to some extent, calculate the longitude.
In the 1100s the Chinese began to produce reliable and convenient compasses and thus the sailors had a tool to know that they were on the right course. But the knowledge that a floating magnetic needle always pointss in the same direction, however, the Chinese (and perhaps others) have had since long ago.
The Earth is round, but maps are flat. It can for example be solve by stretching out the world at the poles (cylindrical projection), or by making a circular map (conical projection). The former, called the Mercator projection, after a famous 1500's cartographer, has the disadvantage that same distance looks longer nearer the poles than near the equator, but the advantage is that the latitudes and longitudes appear as straight and perpendicular lines. And a straight course will be straight on the map.
The sextant, was developed in the 1700s and it was used to determine the sun's height above the horizon. With that information in combination with the knowledge of the time (in for instance Greenwich) it was easy to fairly accurately calculate the longitude. The problem was that it was not possible until the Briton Harrison in 1765 invented the portable clocks that kept time with even on rocking boats and during the long period of time that an Atlantic crossing takes.
The Global Positioning System (GPS) was developed for the U.S. military and was introduced in the latter part of the 1900s. It is based on a number of satellites hanging in space around Earth. Each satellite transmits its position with a radio signal that also contains data about when the signal was transmitted. The GPS receiver measures when the signal arrives and calculates the time taken for the signal to reach the receiver and with that information it then calculates the distance to the satellite. By taking in the signal from a number of satellites, it can determine it’s position.

But even great and fast sailing vessel has the disadvantages that:
- It was difficult and sometimes impossible to take them through confined spaces such as rivers. This disadvantage was particularly evident when the Suez Canal was opened and steamships got a huge shortcut to Asia.
- If it is not blowing, the journey could take a long time and it was always difficult to plan the travel time.
- Pure sailing ships were difficult to park beside the quay, which meant that they often had to anchor outside them. This in turn meant that loading and unloading was time consuming as it was done with rowboats.
- They needed lots of people to tear down the sails quickly in the event of sudden storms.

Experiments with steam-powered vessels began in the 1770s, which basically solved these problems.

The boat in the foreground is a modern ship with a diesel engine, which still have to compete with the ship behind, which is powered with a steam engine.

Initially there where only paddle steamers and they were used for river and coastal transports and as tug boats, but the propeller and energy-efficient machines about 1815 allowed ocean cruises. A disadvantage of steamboats on the longer routes, however, was that they had to bunker coal along the route. That problem was solved with larger vessels, more efficient steam engines and the Suez and Panama canals.

Steamships, in turn, began to be replaced by diesel-powered ships in the second half of the 1920s. The main drawbacks with steamships were probably:

- To create the steam that was necessary, it required that someone fired in the pan a long time before it was time to start the engine.
- Shovelling coal was a hard and unpleasant work because the coal dusted and it was moved by hand from the coal boxes to the boiler.
- The smoke from the boilers was sooty and smelly.
- Coal is bulkier than diesel oil.

With the advent of diesel engines shipbuilding technology had more or less reached its perfection, and even today, many vessels have a similar design as those built in the 1920s.

No matter how effective a ship is, it has the disadvantage that it can only travel in the water. To reach human habitations however one has, apart from in Venice, always have to use land transports.
People have ridden horses in battle and used to them pull wagons, in several places in China and the Orient, for at least 8 000 years. In China, the horse cart already well developed in the 1300s BC, and then it has not changed that much further. The biggest step stones after the year 0 regarding the use of horses are probably:

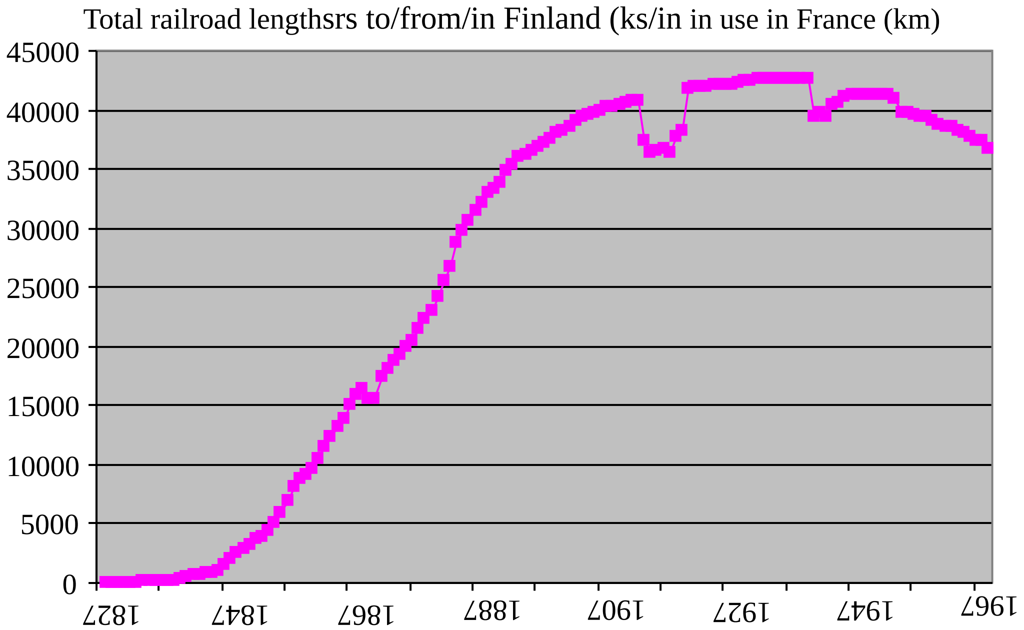
- When the Mongols introduced the stirrup on the 300's, which meant that the riders had easier to stay in the saddle.
- In the 800s the horseshoes were invented and with these the horse's hooves were less torn and they could pull heavier loads.
- Someone in the 900s made a major modification of the harness that allowed the horses to pull heavier loads.
- Strong working horses were developed with time, however, these were used at first mainly in warfare (in agriculture, it was common to use oxen until the 1700s, because they were stronger and probably cheaper).

Horse-drawn vehicles, however, had a number of severe limitations, of which the most important were:

- Horses can’t pull heavy loads, especially uphill.
- They had a hard time slowing down heavy load in a downhill slope. It was solved in some cars, like horse-drawn trams, through brakes on the wheels.
- Horses need to sleep long before the coachman.
- They can’t run fast more than a short distance.

The three of these disadvantages is more or less eliminated if the horse instead pulls a barge on a stream, since streams have no up hills and barges required relatively little force to be pulled. The downside is that the water is not always where you want it, or it is too shallow. This has long been solved by digging channels. An early example of a large channel for transport was the 2 500 km long Grand Canal in China built in the 400's, BC.
In addition to that the channels require a lot of work to be built there is also the problem that they are best suited for flat ground. Those who intend to make a channel in ascending terrain are forced to dig shafts or tunnels, which are extremely labour intensive, especially before the dynamite existed. A similar problem faced those who wished to make rivers and lakes navigable past waterfalls. The problem with altitude was solved by building locks. In Sweden, we began to build locks in the 1500s.
But the European channel construction golden age lasted from the 1700s until the construction of railways began on a large scale. For example, the construction of the Suez Canal began in 1859 and it opened to traffic ten years later.

Railway construction busted channel construction since the former was much easier and in addition tracks could be laid almost anywhere. The first railways were built in German mines during the 1500s. There they used rails of wood and had horses pulled the carts along the mine shafts. The first real railroad also had wooden rails and the train was pulled by horses. It was built in 1758 in the UK. The Briton Richard Trevithick built a high pressure steam engine with significantly higher power than his countryman Thomas Newcomen engine and he built in 1804 the world's first steam locomotive. The maiden voyage it pulled ten tons of iron and 70 passengers. In 1825 the first real steam-powered passenger train was presented. At first people probably were a little afraid of the railroad and its possibilities, as the British Parliament in 1836 decided on a law that limited the trains speed to 8 km/h, but the railroad was a success and already in 1850 about 2 920 km of railways was built in France alone (figure 2). In Germany there was at the same time, 5 860 km, 850 km in Belgium, Italy 620 km, and Denmark there were 30 km rails.



In the 1870s, several important innovations that probably fueled the interest in building railways:
- Steel rails (withstands heavier trains than iron rails).
- Electrical signaling (admitted several trains on the same track).
- Air brakes (better braking).

Chart 2. The total length of used railway lines in France regardless of track width, between the years 1827-1967 according to Brian R. Mitchell (International historical statistics, first edition, The Macmillan Press Ltd, UK). The decrease in 1871 was due to that the French lost Alsace to the Germans. There were also small drops around 1915 and 1940 due to the wars. The downward trend after World War 2 is due to that the needs of railway decreased with the increase of mass motoring.

In the early days of railroads, they were built largely by private initiatives between the larger towns, but over time it became a state responsibility and they saw it as a means to populate the wilderness and increase prosperity in poor parts of the country. Examples of the latter were the U.S. transcontinental railways were built in 1864 and 1890 to transport goods and people to the west of the country, and the Siberian railway, which began to be built in 1891.
In the 1920s, European Rail reached its peak concerning the total track length and 1926 there were over 960 000 km rails in the free part of the world (table 6).

Table 6. Data from the Tidens Calendar 1927 (Tidens förlag, Stockholm, 1926). Only the countries that, according to various sources, were wholly independent states are included in the table.

Name at the time	Size (km^2)	Inhabitants (millions)	Railway length/inh. (m/pers.)	Railway length 1926 (in 10 km)
Abyssinia (Ethiopia)	900 000	9.5	0.73	693
Afghanistan	650 000	11	no data	no data
Albania	30 000	0.85	3.53	300
Andorra	450	0.005	no data	no data
Arabia	no data	no data	no data	One railroad
Argentina	2 790 000	10	3.73	3727
Belgium	30 440	7.8	1.29	1005
Bolivia	1 590 000	3	0.81	242
Brazil	8 511 000	30.6	0.98	3010
Bulgaria	103 100	5.1	0.52	265
Chile	751 500	3.9	2.12	825
Colombia	1 283 000	6.6	0.25	164
Costa Rica	50 000	0.5	2.14	107
Denmark	44 300	3.5	1.42	497
Dominican rep.	50 000	0.9	1.1	99
Ecuador	307 000	2	0.53	105
Egypt	935 300	14	0.31	440
Estonia	47 550	1.2	0.89	107
Finland	388 500	3.5	1.3	454
France	551 000	40.4	1.04	4191
Guatemala	127 000	6.2	0.2	124
Greece	113 000	2	1.23	246
Honduras	100 250	0.773	1.29	100
Italy	309 700	40	0.52	2091
Japan	677 400	85	0.25	2112
Yugoslavia	249 000	12.5	0.73	917
China	11 100 000	440	0.03	1154
Cuba	114 500	3.4	3.03	1029
Latvia	65 800	1.9	1.48	282
Liberia	95 400	1.75	no data	no data
Liechtenstein	139	0.012	no data	no data
Lithuania	56 100	2.2	0.73	160
Luxembourg	2 600	0.275	1.96	54
Mexico	1 969 000	14.2	1.61	2289
Monaco	21	0.022	no data	At least one railroad
Netherlands	40 800	7.4	0.49	366
Nepal	140 000	5.6	no data	no data
Nicaragua	127 000	0.64	0.53	34
Norway	323 800	2.8	1.24	346
Paraguay	253 100	0.8	0.63	50
Peru	1 355 000	5.5	0.61	334
Persia (Iran)	1 650 000	5.6	0.1	56
Poland	388 300	29	0.7	2019
Portugal	92 000	5.6	0.61	343
Romania	294 200	17.5	0.67	1178
Russia	21 200 000	140	0.53	7362
Salvador	34 000	1.6	0.26	41
Switzerland	41 300	4	1.32	527
Siam (Thailand)	500 000	9.7	0.26	248
Spain	505 000	21.9	0.71	1559
United Kingdom	244 800	45.2	0.85	3829
Sweden	448 460	6.1	2.52	1540
Czechoslovakia	140 400	14.2	0.96	1362

Turkey	887 200	12	0.25	296
Reich	470 700	62.5	0.92	5725
Hungary	92 900	8.4	1.02	858
Uruguay	186 000	1.6	1.66	266
USA	8 000 000	114	3.55	40451
Venezuela	1 020 400	3	0.35	106
Austria	83 800	6.6	1.06	702

Steam locomotives were used for a long time, but steam cars never became a success. It is probably due to that steam engines were pretty well suited for use in locomotives, because the drawback that it takes so long to heat the boiler had little significance when trains runs almost constant. Furthermore, it did not take so much extra energy to lug all the coal needed and train stability made it pretty comfortable to shovel coal even when rolling. Moreover steam train could do pretty high speed (the current speed record is 202.7 km/h and was set in 1938 by the British locomotive Mallard). The disadvantages that steam locomotives after all had, made that electrified railways began to be built, the first one was built 1881 in Germany. But in many places they did not electrify the railways, instead diesel locomotives are used. Whatever type of locomotive used, however, railways have a number of disadvantages, of which the principal are:

- The trains are bound to the track and they can not make any detour from this and just a few transports can go from door to door by train.
- It is quite energy-and labour-intensive to drive a train, so it requires large transport volumes to be profitable.
- The trains can not run past each other on a track, so it is necessary that they follow a strict timetable.

The first deficiency was dissolved in part by the cycle. Around 1600 man started to experiment with that kind of transport means. Most, however, had 3-5 wheels, making them quite difficult to control and expensive to produce, and they didn’t gain any popularity.

In 1779 a bicycle-like thing was constructed in France. It was almost entirely made of wood and it was kicked with the feet. There was no steering, one had to lean sideways to change direction. Approximately in 1816 the German Baron Carl von Drais developed the idea by providing the device with a device on which one could turn the front wheel. In 1839 the British Kirkpatrick MacMillan introduced rods on the rear wheel driven by levers. McMillan’s bike was difficult to ride. One from this angle better solution came from the Frenchman Michaux when he put cranks and pedals directly to the front wheel hub. A disadvantage of this was that every revolution of the pedals the spinning wheel just rotated one lap, which forced the drive wheel to be big, otherwise the cycle would have been a very slow vehicle. This meant that the front wheels were huge, up to 1.5 m in diameter (high wheelers).

The large front wheel and small back wheel made the bike easy to tip forward, with the risk of serious injury. To avoid that many variations of high wheelers were introduced during this period. However, they still ran the bike on the steering front wheel. Brakes were introduced in the 1860s, chain drive was first used in 1869 and rigid metal spokes came in the 1870s. In 1885, John Kemp Starley designed a bike with the same size wheels, saddle and pedals in the middle that was perched on a large sprocket that drove a chain to a smaller sprocket on the rear wheel. Thus the modern bike was born! With the exceptions that the air-filled tires were not introduced until 1888 (they were invented in 1845 by William Thomson) and the first gear mechanism was patented in 1896. So in the second half of the 1890s, one can say that the bike was fully developed.

All the drawbacks of trains, however, were solved with the invention of cars, trucks and buses. The first real car was developed by the German Carl Benz and it was first run in 1885. But it looked more like a rickshaw than a car.

Benz had many followers, and even before the year 1900 a number of technical solutions that today characterizes a car were introduced, such as the steering wheel and air-filled rubber tires. The following decade a number of innovations came, such as battery, drum brakes and the ability to control the speed using a throttle.

In 1908 the T-ford was launched. It was based on a framework of steel beams with bodywork partly made of wood. The engine had four-cylinders with a maximum output of about 20 hp and the gearbox had two gears, which could push up the car to about 65 km/h.

Before the year 1930 a great deal of today's automotive technology was introduced, such as: covered body, alternator, starter motor, electric lighting, brakes on all four wheels, front wheel drive, compressor, self carrying body structure, hydraulic telescopic dampers, hydraulic brakes, wipers and automatic transmission.

Citroen B11 went on sale in 1934 and the company continued to sell it until 1957. From the outset, it had self-supporting all-welded body, front-wheel drive, independent suspension and hydraulic brakes.

Then did not happen so much with the car technology until the 50's, when many convenience-enhancing solutions were launched. For example: power-assisted braking and steering systems, electric windows, electrically adjustable seats, air conditioning, fuel injection and seatbelts. Then it happened not so much again until the electronics made its foray into the automotive world with innovations such as airbags and anti-lock brakes (80s) and computer-based networks (90s).
Throughout the time automobiles has existed, the number has increased steadily all over the world (for example, in the UK, chart 3), apart from periods of war like during World War II.

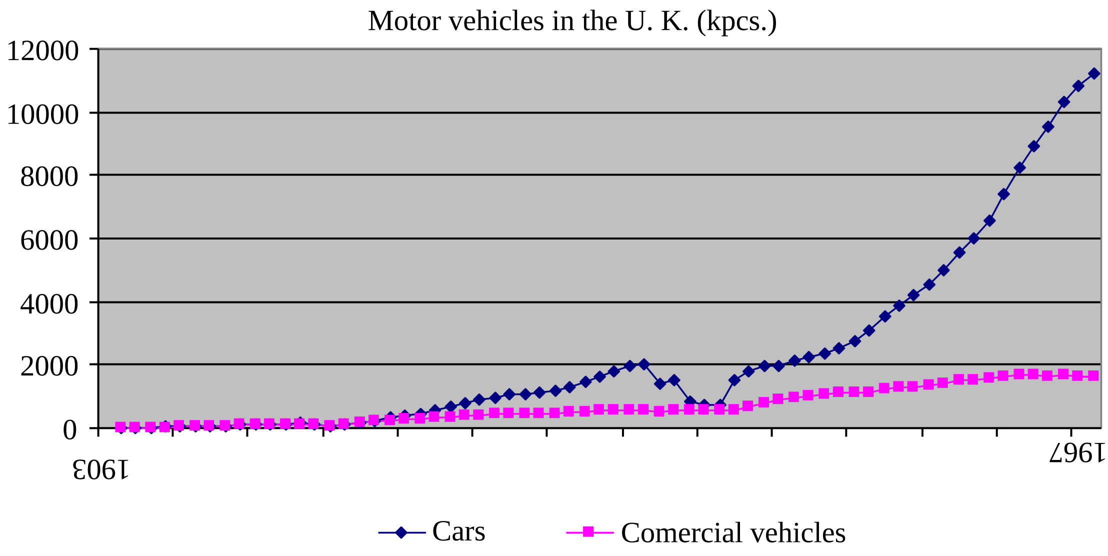


Chart 3. The number of motor vehicles in use in Great Brittan between 1903-1969 according to B. R. Mitchell.

We also travel a lot more (in 1900 an average Swede travelled about 230 km/year, today we travel an average of 12 810 km/year and 78% of the trips are made by car). With increased car use, the infrastructure around the cars has also increased, in the form of more and better roads (between 1900 and 1990 the total length of public roads increased from 54 800 km to 98 600 km), more traffic laws and traffic police (see chart 4), more traffic lights, higher oil imports (chart 5), et cetera.

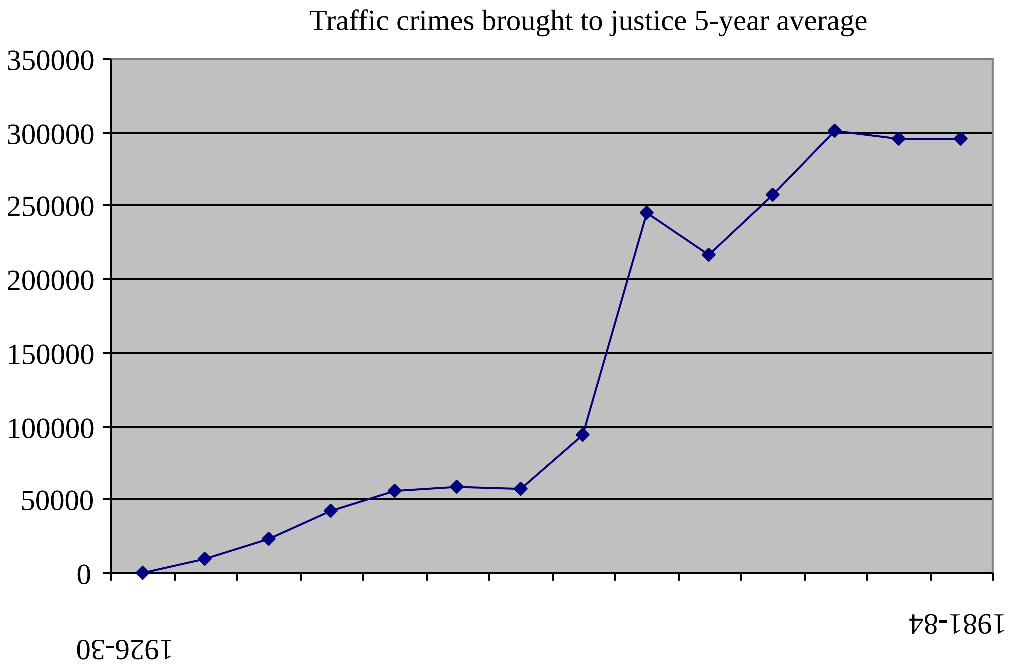


Chart 4. The number of traffic offences that were subject to legal actions according to Hans v Hofer (Brott och straff i Sverige Historisk kriminalstatistik 1750-1984 Diagram, tabeller och kommentarer, Statistiska Centralbyrån 1998= Crime and Punishment in Sweden Historical crime statistics 1750-1984 Graphs, tables and comments, SCB 1998).

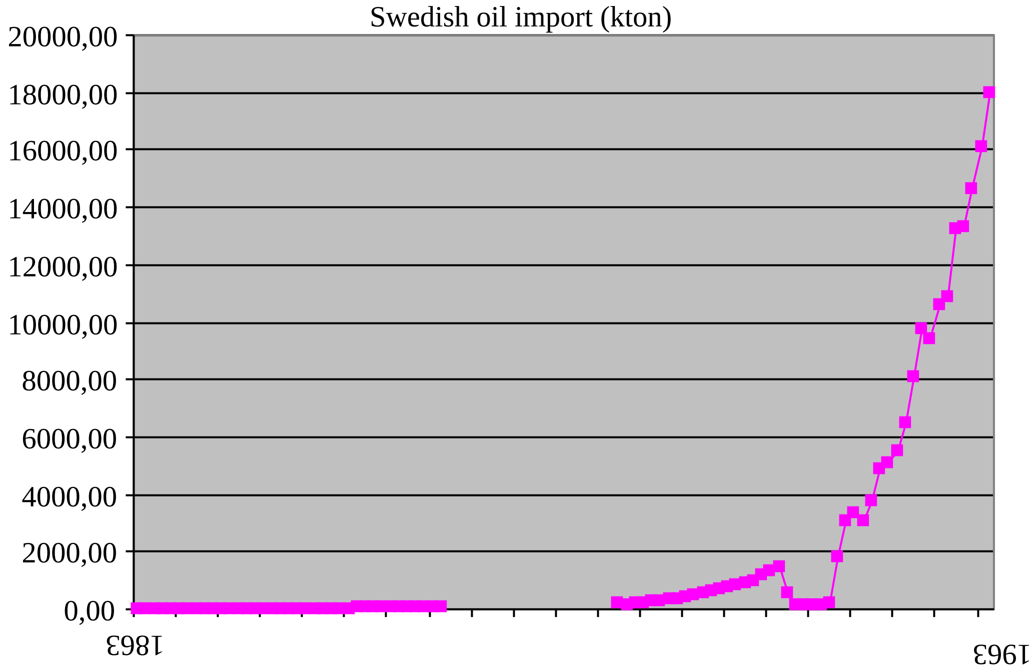


Chart 5. Oil imports to Sweden according to BR Mitchell (fourth edition). The empty field 1909-1919 is due to lack of data. Note that the import also included oil used for heating, which was a major application during the late 50's and the 60's).

Motor vehicles have a major drawback in that they move on the ground. The disadvantages of this are that:

- The vehicle speed is limited by the road's curves and bumps.
- There may be obstacles that stop up and/or causes accidents.
- The roads follow the terrain, not the shortest route between the departure and arrival.
- They can normally not cross lakes and rivers other than on bridges or if they are transported by boat.

These drawbacks are eliminated, more or less, with vehicles travelling in the air. Aside from some early experiments with wings, gliding from the cliffs, balloons and failed flying machines, aviation history is considered to begin in the U.S. with the Wright brothers, though there are, however, some debate about whether they really were the first or not.

The brothers built and tested in the early 1900 century a number of variations of gliders. When they did not succeed, they built their own wind tunnel and tested a number of different wing and rudder designs and their own combustion engine. They made the first controlled flight journey with a powered craft that was heavier than air (as distinct from balloons and gliders) in December 1903 and it was 8 km long. The aircraft, however, had a number of shortcomings, such as that it was very unstable. Later prototypes they built were more stable, but they still lacked essential things like landing gear.
With the launch of the first generation of American civilian jet aircraft, the Boeing 707-120, the civil aviation was more or less fully developed. It took only six years after the very first civil jet aircraft, DeHaviland Comet, came until Boeing 707-120 was introduced. It is still used today and its main performance, from a traveller’s point of view, i.e. cruising speed, is quite close to modern followers (table 7).

Table 7. Typical performance for the first civil jets and an early follower compared to more modern ones. Data like cruising speed, range and number of passengers vary for the same aircraft depending on the choices that the airlines do.

	DeHaviland Comet 1	Boeing 707-120	Boeing 747-400	Airbus 380-800
Crew:	4	3-4	2	2
In active service:	1952-54	1958-	1989-	2007-
Manufactured:	1949-1954	1954-1978	1988-2007	2005-
Ving area:	197.0 m²	226.3 m²	524.9 m²	845 m²
Empty weight:	34 200 kg	55 589 kg	180 755 kg	277 000 kg
Max. start weight:	73 470 kg	116 575 kg	362 875 kg	560 000 kg
Nominal speed:	790 km/h	897 km/h	920 km/h	955 km/h
Distance with max. fuel:	5 190 km	8 485 km	12 900 km	14 815 km
Capacity (no. of passanger):	56-109	110-179	-624	840

Around the same time that the first jet aircraft became operational air traffic increased dramatically (chart 6 a + b).

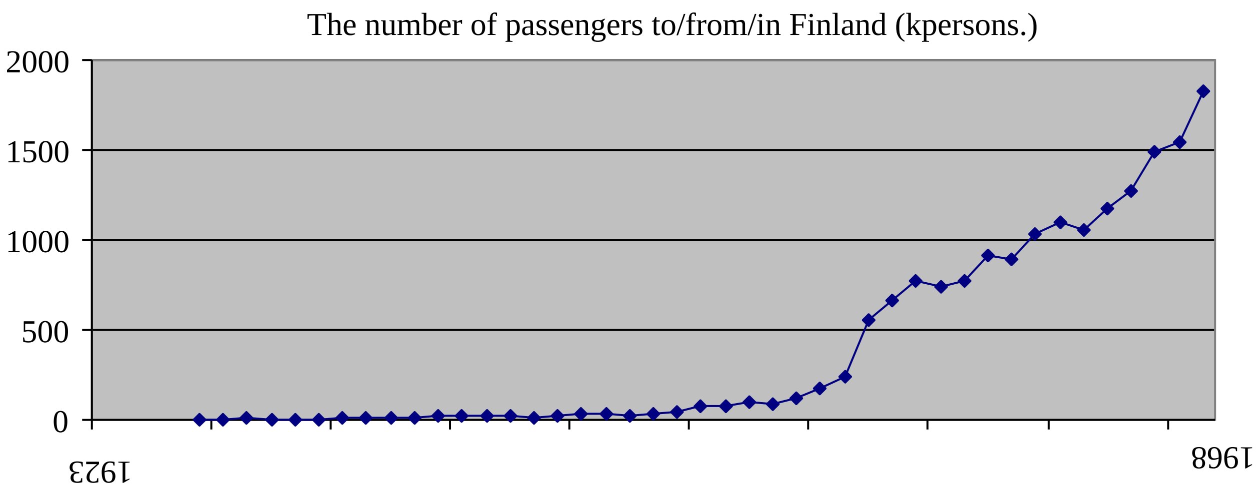


Chart 6a. Air plane passenger’s to/from/in Finland according B. R. Mitchell.

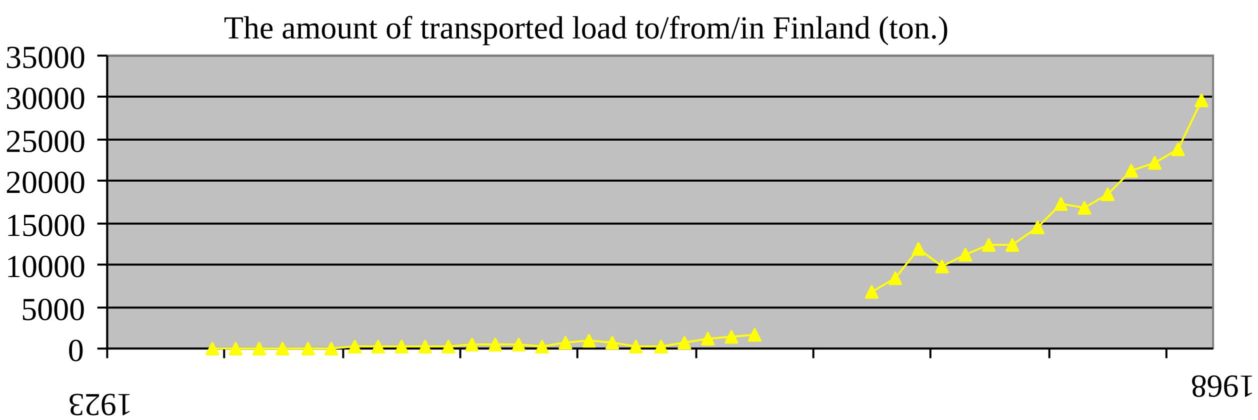


Chart 6b. Air freight load to/from/in Finland according B. R. Mitchell. Data is missing from the period 1951-1954.

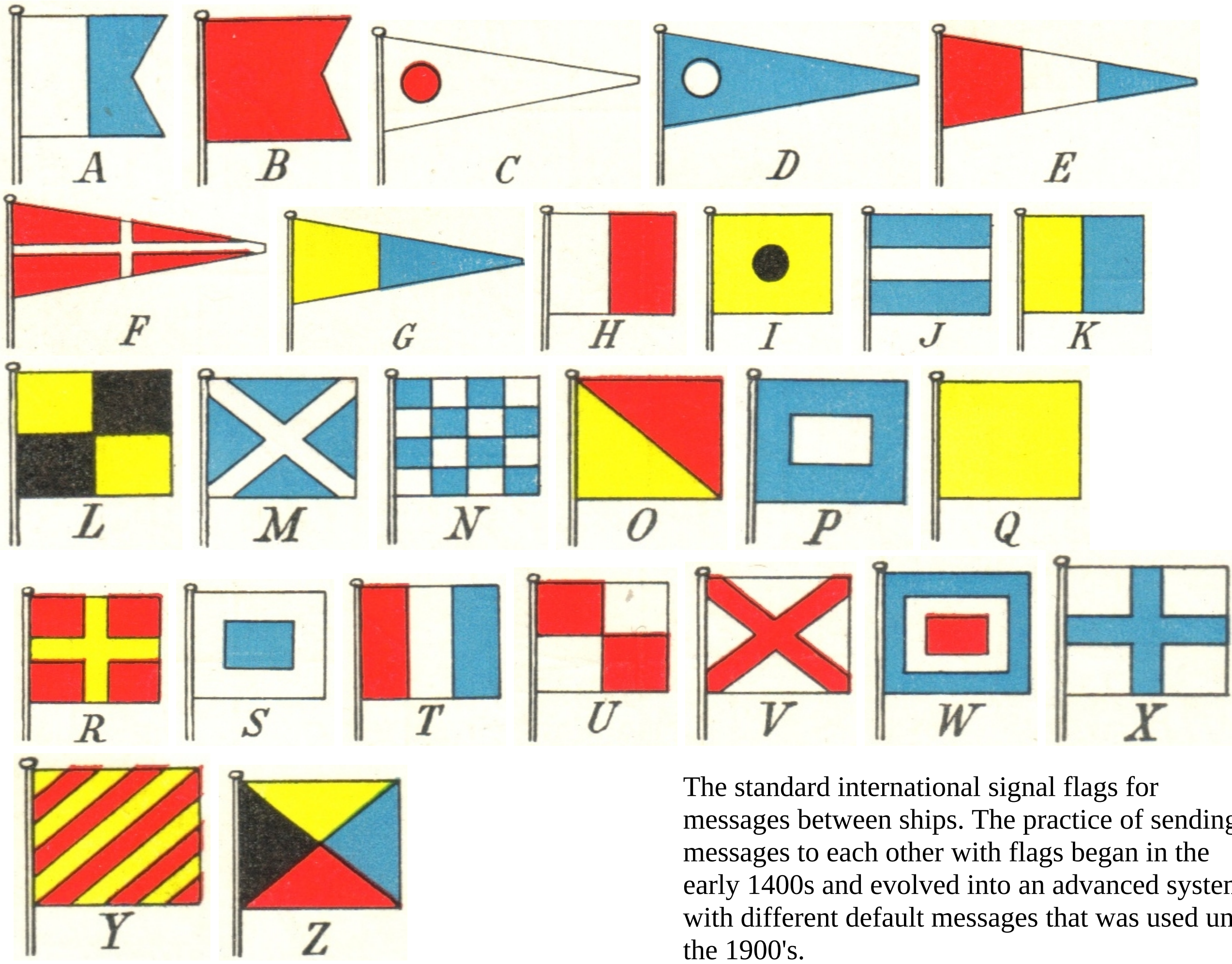
Today we can travel relatively fast and comfortably on or through all the earth media, except solid materials such as rock and soil. And modern engineers does not focus on new transportation methods, but rather to refine existing systems and devices to make them more energy efficient, comfortable and above all, cheaper to manufacture.

Communications

For most of human history, we have been forced to transfer all messages from mouth to mouth. The distance between the senders to the receiver could only be extended by couriers who went from the one to the other. A fundamentally important development step, the courier took, that instead of verbally convey the message, delivered in the form of objects with symbolic value, as a severed horse head, a bouquet of flowers, or a stone with signs. Even today we use that form of communication where we write down signs on a piece of paper, put it in an envelope, franking and posting it. We thus let the mail service do the courier work from us to the recipients.

We have also for tong time used a whole host of different methods to avoid travel from one place to another in order to communicate messages, such as light, fire, smoke, or drum signals. Among other things, networks of semaphores were in the late 1700's built in several countries, such as France, Sweden and the USA. These networks were used to the middle of the following century. Semaphore communication was faster than sending couriers and less sensitive to disturbances compared to other systems like light signals, and it required no fuel. But they were dependent on good weather and it took a fairly dense network of semaphore stations because one had to see between them with binoculars. Therefore, they were significantly more expensive than the system (the telegraph) that would compete with semaphores in the latter part of the 1800s. However, there are still live versions of other visual systems in the form of light houses, traffic signals and signage.

In the foreground a replica of a semaphore station, in the background the TV-tower in Stockholm.



The standard international signal flags for messages between ships. The practice of sending messages to each other with flags began in the early 1400s and evolved into an advanced system with different default messages that was used until the 1900's.

In all other types of communication outside sight and hearing distance, it is something other than a human being or human minds that carry the message between the parties. The oldest of these transmission media is the letter doves. They were apparently used in several of the ancient civilizations before our era, such as in China, Paranoiac Egypt, Ancient Greece and the Roman Empire. Until that radiotelegraphy was invented, we used pigeons especially for sending messages from ships at sea and from military in the field. The principle of the communication was that pigeons always want to fly home and that they are very good in finding their way back, no matter where they start. The disadvantages were that they can orient wrong, being eaten by other birds or die in some other way, and above all that the system only works in one direction. At the German siege of Paris 1870-1871, this later problem was solved in part by that the besieged sent the pigeons with balloons. Of the 381 pigeons that were sent from Paris, 302 were found by French forces and sent back with messages, 59 of them reached their destination in Paris with a military message.

One of the earliest systems for transmission of messages with the help of electrical wires was constructed by the Germans Carl Friedrich Gauss and Wilhelm Weber in 1833. The system consisted of a generator, a switch that could change the direction of the electric flow, a two pole cable (1 km) with a galvanometer at the other end. The galvanometer pointer was veering in different directions depending which mode the switch was set on. And the inventors designed an alphabet consisting of combinations of the three modes: the galvanometer pointer in the right, middle or left.

The system that was accepted by the market and got commercially spread was, however, developed by the American Samuel Morse and was patented in 1837. The principal differences between his system and the former were:

- The alphabet consisted of combinations of long and short signals.
- The long and short signals were created by a "switch" that was pushed down to the leading position different lengths of time.
- The receiver heard the short and long signals through a loudspeaker.
- Both transmitter and receiver have the same equipment, so the communication could go both ways.

Morse's telegraph system quickly captured the U.S., and in 1861 messages were sent across the country. Five years later, there was a working telegraph line between the UK and U.S. When the telegraph line across the Pacific was completed in 1902, there was a telegraph system around the globe.
But this system also had some significant drawbacks:

- Only one message at a time send could be sent in each pair of wires.
- It required telegraph wires.
- It was difficult to parse/send Morse signals, so it required specially trained personnel.

Despite that the number of telegrams increased, even after the phone system was introduced (chart 7 and 9).

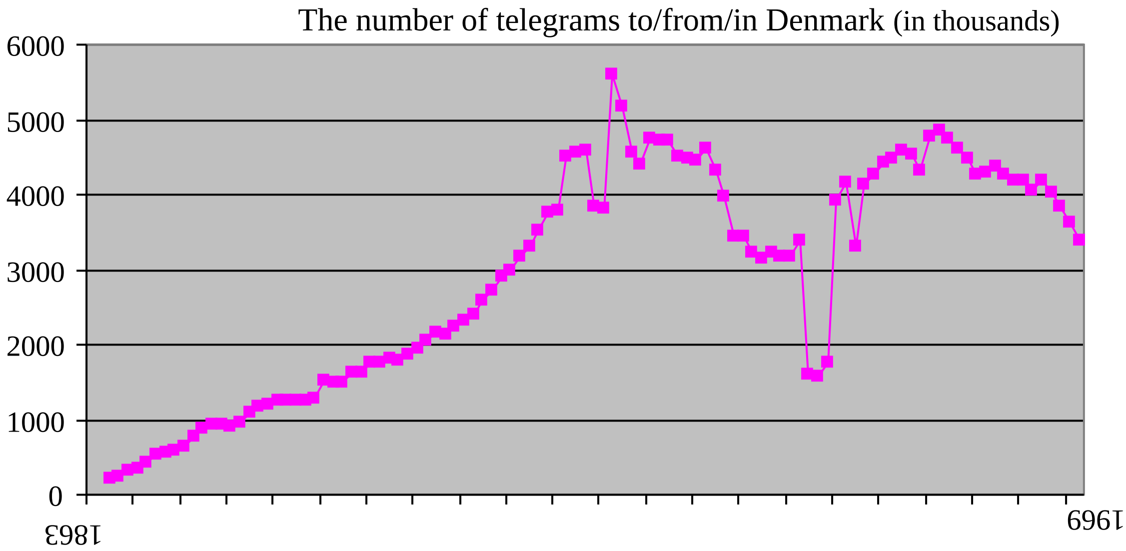


Chart 7. The number of telegrams to/from/in Denmark between 1863-1969, according to BR Mitchell.

To solve the first problem one either had to build a system with much more pairs of wires, just as they later did with telephones, or encode the messages so that each recipient knew what was meant for them or was not. They chose the latter and developed coding devices (telex machines). These machines also solved the third problem with the need for telegraphers, because the operators of telex machines wrote down the message on a standard keyboard. The Telex machines then in turn translated the text to a punched tape, which in turn was fed into a reader/sender device. The receiving telex machine then wrote out the text on a paper. The telex network was expanded to a large number of users and was used on a large scale until the end of the 1980s. Nowadays, however, it is more or less closed all over the world. Mainly because of the competition from the much simpler fax devices that can send a copy of any paper over a normal telephone line.

A solution to the second problem would be to send messages wirelessly. The first wireless message is considered to be sent in 1896 by the Italian Guglielmo Marconi and it was received by his colleagues around 6 km away.

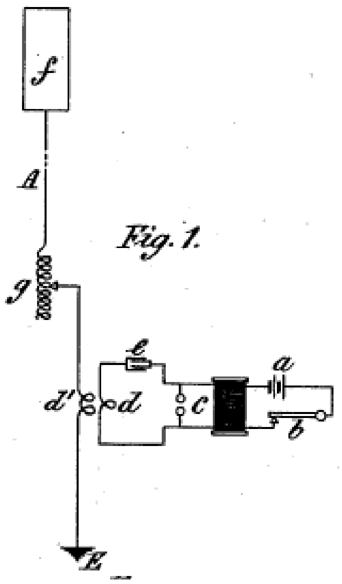


Figure 1. The description of the transmitter in Marconi’s patent application, wherein:

a = source,
b = breaker,
c = coil with two windings,
e = capacitor,
d = a coil with two windings, in the winding of the capacitor circuit there is a gap,
g = coil with a variable number of windings,
A / f = antenna,
E = ground.
When b closes e is charged, then discharged creates a spark in d, which in turn creates a brief electric pulse in the secondary winding, i.e. a high-frequency alternating current. This current pulse is spread in the air through the antenna.

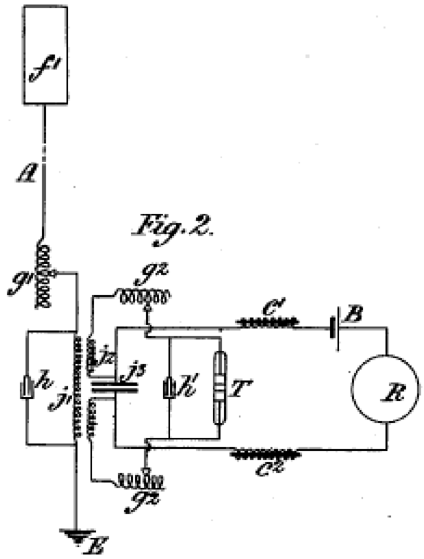
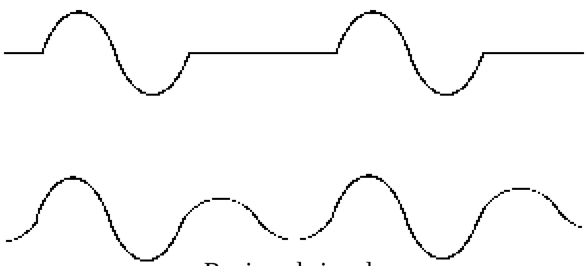


Figure 2. Receiver, wherein:

A / f = antenna,
g1 = a coil,
h = capacitor,
j^1 and j^2 = a coil with two windings, of which the other is split in two parts,
j3 = capacitor,
B = battery,
R = relay, which controls, for example a pointer instrument.
T = a tube with metal powder between two poles, when affected by electric waves the resistance of the metal powder decreases.
g^2 and C = coils.
E = ground.
The purpose of this set-up is to create a circuit that oscilates, whith an oscillation frequency that could be adjusted to fit the transmitter. When the signal comes it decharges j^3, and thus activates the relay.

Transmitted signal



Recieved signal

Transfer principle:
The transmitter was either silent or transmitting a signal. The receiver, however, was set to constantly swing with the same frequency as the transmitter signal. Once it got a signal the height of the swing got higher, i.e. the amplitude increased. This increase was sent, through the relay, to the instrument.

Marconi's system had a number of deficiencies, of which the principal was, in addition to that the messages consisted of Morse code, that it was based on an amplitude modulated carrier wave (AM band). This means that the sound (e.g., the Morse code) transferred by the amplitude of the carrier frequency, was varied at the same rate as the Morse code. This meant that the transfer was very sensitive to disturbances if not the broadcasts were made with extremely high power. The system improved considerably when the American Lee De Forest in 1906 invented the radio tube which was beneficial both to enhance the signals and partly to create the carrying wave.

One of the first commercial uses of his radio system was radio beacons for air traffic. The system was used until the beginning of the 1960s. Another early use was to send messages between ships and shore. The most famous example of this was the messages that were sent from the Titanic during its sinking in 1912.
Radio broadcasts began in California 1909th. 1925 the Americans Kellog and Rice invented the type of loudspeakers that dominates still today. Frequency Modulation (FM) was invented in 1933. With this technology, the carrier wave frequency changed a little all the time and the actual sound was in the frequency difference. It made the broadcasts much less sensible to interferences and thus they got better quality and the transmitter power could be reduced. Furthermore during the 30's, the number of radio stations increased. Overall, this probably had a big impact on that the amount of radio receivers increased rapidly (chart 8).

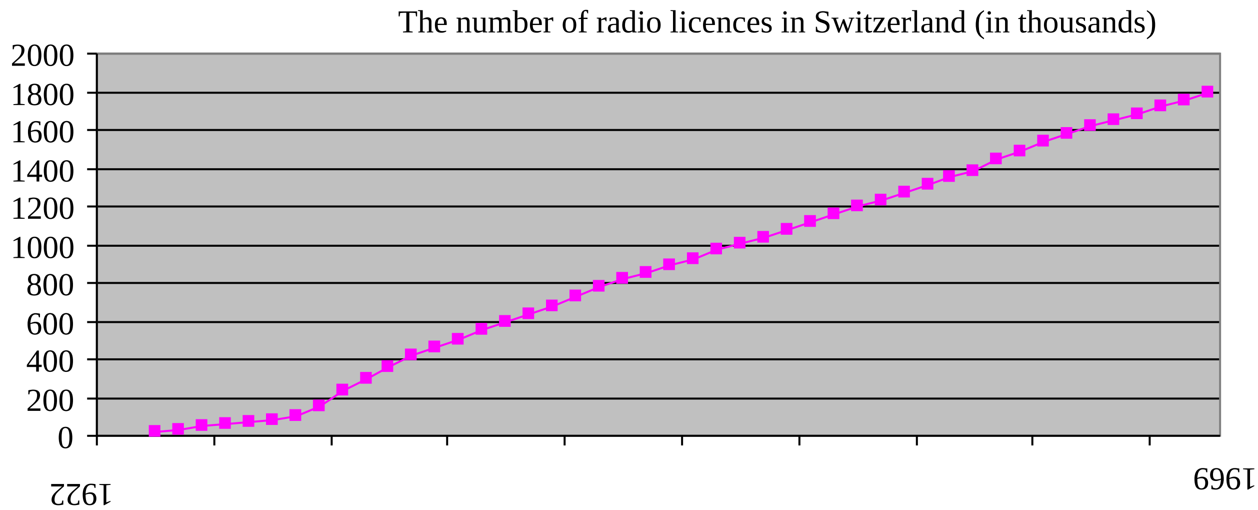


Chart 8. The number of licenses for possession of radio receivers in Switzerland 1922-1969, according to BR Mitchell.

Subsequently, it has not happened so much with radio technology besides that transmitters and receivers could be made considerably smaller when the semi-conductors[27] replaced the radio tubes.

27. Semiconductor devices consist of a base material that conducts electricity "semi well". In semiconductors childhood germanium was used as the basic material, but today silicon is most widely used. In the most basic semiconductor device (the diode), there are two thin layers of other material on the base material. The purpose of it is to make the component leading when one particular side is connected to the positive terminal and the other to the negative, but not leading when contacted in the opposite way. The component is useful for those who, for example, want to transform an alternating current into a direct current. With multiple layers and/or several diodes one can achieve almost all the other components that modern electronics constitute of, such as LEDs and transistors. The latter variety is composed basically of two diodes and it has the features that you can control how conductive the component should be from + to - by changing the voltage "across" the current direction. With millions of interconnected transistors we have advanced components such as computer processors.

The telegraph in 1876 got a competitor, when the American Alexander Graham Bell received a patent for a phone system. The system was based on a microphone, which basically looked like a small speaker. Sound waves made the speaker diaphragm oscillate which produced a current in the coil around the magnet, which in turn passed through a cable to the speaker on the receiver. Either the two phones were directly connected or there was at least one telephone station in between them. These consisted of panels with a power outlet for each subscriber. When a subscriber wanted to call he/she rotated a crank that sat on a generator, generated a current that made it ring in the telephone station. The operator answered and asked where the subscriber desired to be connected. If the recipient was served by the same telephone station, the operator called him and told that he had a call and the connected a cable between the power outlets of the caller and the receiver. If the receiver was connected to another telephone station the operator had to instead transfer the call to that station. When the call was finished the talkers again rotated the crank so that the operator heard that the call had ended and he removed the cord between the outlets. Apparently the system had a lot of deficiencies, in addition to the obvious cumbersome arrangement, the power generated by the microphone was very small, resulting in poor sound quality. In addition, the devices were large and they were equipped with a fixed microphone, which made it quite uncomfortable to use it. In particular, as the microphone on the first phones also served as speaker. The major milestones on the way to today's phone system were as follows:

- A year after the first phones Bells company released phones with a loose speaker that was connected to the unit via a cable.
- The Swede Lars Magnus Eriksson in 1880 designed a better microphone, then an even better one and then in 1903 the type of microphone that became standard for a long time. It worked so that the sound vibrations made carbon grains in the microphone move and this in turn varied the resistance of the microphone. The DC voltage sent into the microphone came out as a varying voltage that could drive the speaker at the other end of the wire. Resulting in better sound since the energy was no longer generated by the speakers.
- 1892 a design with speaker and microphone in one unit was invented by Eriksson.
- Approximately in 1915 the automatic telephone station came, which allowed the subscribers to connect themselves through rotating a disc on the telephone set. The disc had a hole for each digit 0-9. The longer the disc was spinning the higher figure and the more pulses in the telephone station. Most major cities were automated by 1930, but calls between the cities still needed to be connected by operators.
- In the 1950s, came fully automated telephone systems.

Then the phone from the user's point of view was more or less fully developed. And almost every year that passed, the number of calls has increased (chart 9). The main remaining deficiency was then that the phones were physically attached to the phone jack or its vicinity. This problem was solved with the advent of mobile phones.

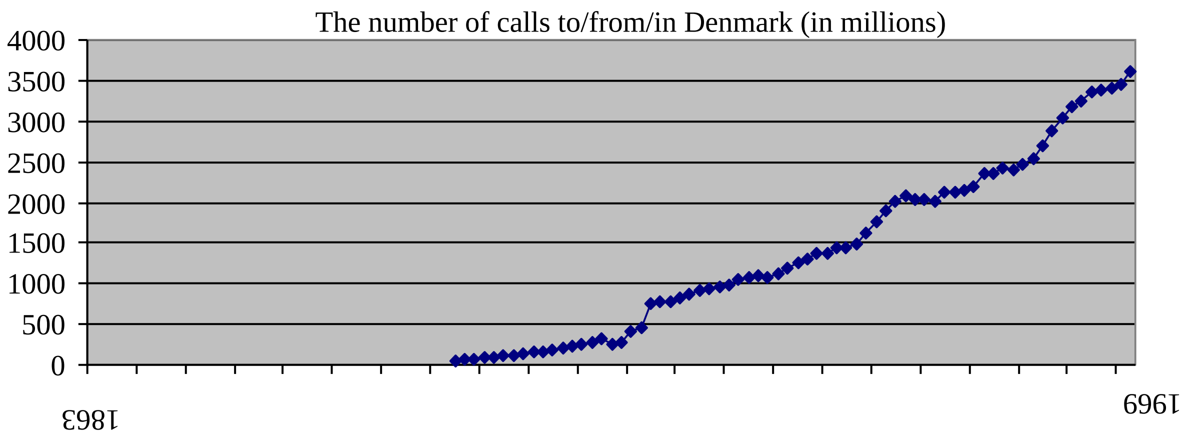


Chart 9. The number of phone calls to/from/in Denmark between 1863-1969, according to B. R. Mitchell.

The world's first mobile phone system with automatic connection to the public telephone network (System Laurén) was founded by the Swedish National Telecom (Televerket) in 1956 and it covered Stockholm and Gothenburg. The system was based on that each subscriber had a transmitter with power enough to reach the telephone station, even if the distance was quite far. The system was in upgraded versions still in use until 1987, and when it peaked it had 20 000 subscribers.
1981 opened the Nordic National Telephone companies the world's first modern, fully automated and nationwide cellular network (NMT 450). It was based on a network of radio transmitters, each covering a smaller area, which enabled handsets with lower transmission power, which thus could be smaller and with longer talking time without draining the batteries.
NMT was an analogue system, making transmissions sensitive to disturbances, since all signals real signal as well as noise was transferred to the receiver. Unlike digital systems which convert the real signal to a code. In 1992 started the Swedish National Telecom the first digital system (GSM) and it became a standard agreed in several European countries. This standard was also rapidly taken up by countries outside Europe, making it a world standard.

To hear is nice but to see and hear is, by many, considered to be even more entertaining.
Already in 1908 the British gentleman Alan Archibald Campbell-Swinton published a letter in the journal Nature in which he described how the images could be transmitted by using a cathode ray tube as both sender and recipient. Then there was some experimentation, but the first actual transmission of moving images through a cable was carried out 1925 by another British man, John Logie Baird. Since the system contained a number of rotating discs to scan the image and converting it to electrical impulses, the images were updated slowly. With the result that all the movements looked very jerky. Moreover, the clarity of the details was lousy. Four years later, the American Philo Farnsworth created a system that could scan the subject in the same way as a modern television camera. In the 1940s, the technology was so advanced that TV shows was regularly sent out in the USA. Television broadcasting in colour began in the early 50's. In the 50s it was many countries that embraced the technology and built up the TV system and people bought TV receivers (chart 10).

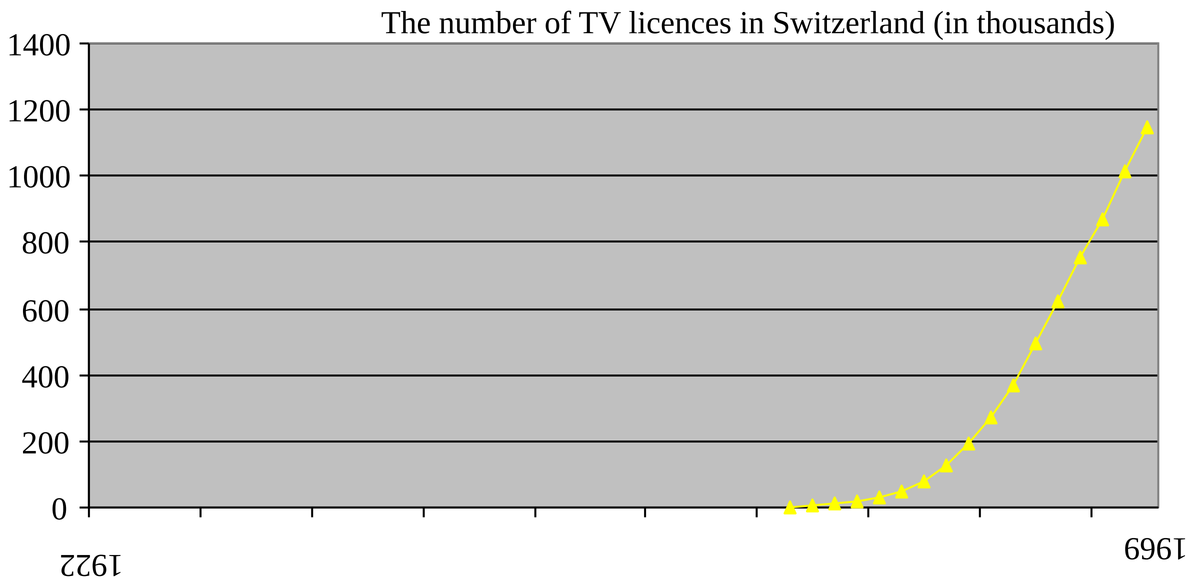


Chart 10. The number of licenses for possession of TV sets in Switzerland1922-1969, according to BR Mitchell.

The last major event in the communications sector was the emergence of the Internet and it was born soon after the "modern" computer technology in the 50's. There were a few computers even before then, but they were huge, slow, expensive, and energy-and maintenance-intensive because they were based on relays and/or radio tubes. But after John Bardeen, Walter Brattain and William Shockley at Bell Labs in the U.S. in 1948 invented the transistor, emerged the ability to make smaller, faster, cheaper, more reliable and more energy-efficient computers. Even better, they were after Robert Noyce in 1958 invented the integrated circuit. This was during the Cold War and the United States invested, through a governmental source of funding for military research: Advanced Research Projects Agency (ARPA), big money on building computers that could be used to develop better weapons. Soon they coupled more of these computers together and they started to communicate, i.e. give and receive data via a cable. A scientist (Paul Baran) suggested in 1962 that the data to be transferred should be divided into small packets with individual addresses, which could take any route through a network of interconnected computers, to the recipient. Where the pieces were reassembled. This way the communication could proceed even if parts of the network had been knocked out by Soviet bombs. The idea was developed at some institutions, ARPA liked the idea and financed in 1969 a network of four nodes, dubbed ARPANET.

ARPA had started extensive research across the United States and now wanted to investigate whether it was possible to save resources by allowing different contractors to share the computing power over a network (computer time was in late 1960 - 's still a scarce and precious resource). But one major problem was how to get universities previously incompatible mainframe computers to talk to each other. The solution was Interface Message Processor (IMP), a kind of standard interface or "router", which allowed a large amount of hardware and software to work together over the ARPANET. As early as January 1971, the network had 13 nodes, and in April 1972 the number had risen to 23. Scientists soon discovered that the network was also an excellent tool for sending messages to each other, resulting in the E-mail feature. In the same year scientists from different countries began to work on one addressing and transmission format that would work even in much larger scale and in 1974 the first version of the Transmission Control Protocol (TCP) and Internet Protocol (lP) were finished. But not until the late 80’s all network owners, authorities and companies finally agreed that it was these formats that should apply to all networks.

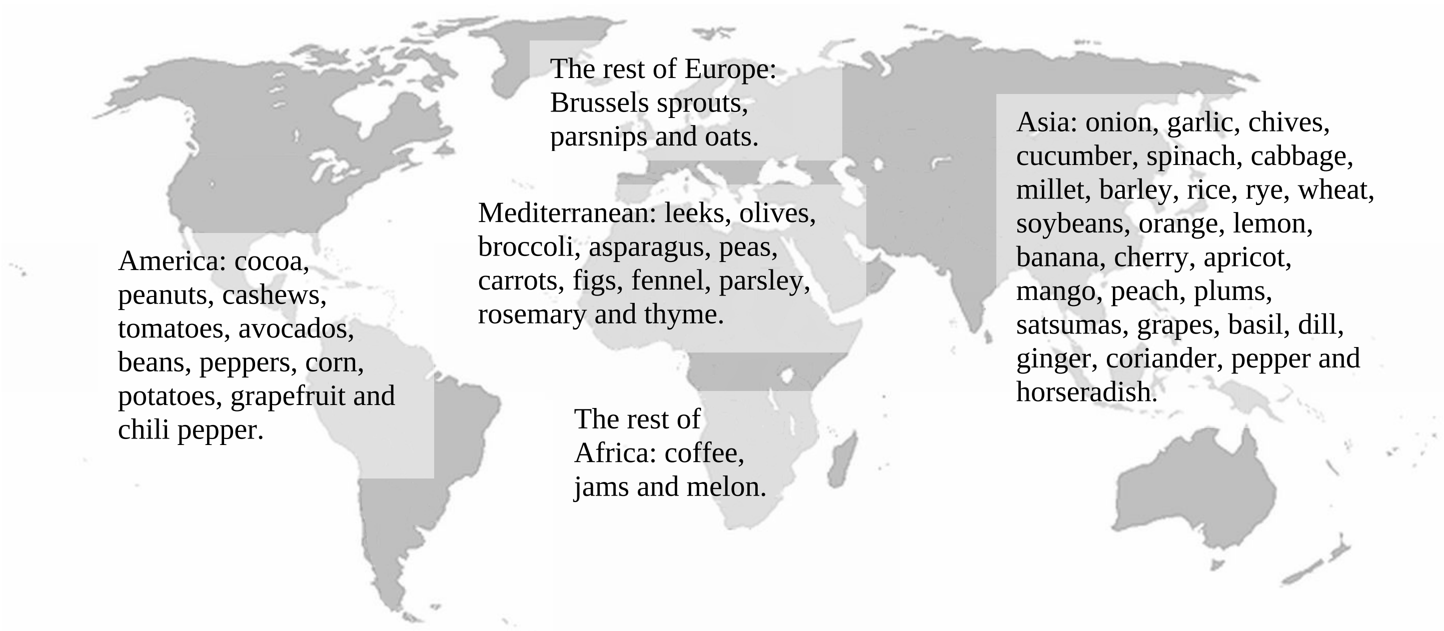
Now we can more or less everywhere receive and send moving colour images accompanied with sound. Moreover, we can to some extent interact in some video games and systems for transferring three-dimensional images has started. Thus, there is probably not much more that we could wish to communicate with these senses, in addition to if it was possible to create and transmit three-dimensional environments that we could walk around in. Other minds however are less satisfied, except for a few examples of vibrating handles to video games and the like.

Food

Two thousand years ago many of the farmer’s tools, such as fish net, fish hook, mill, harrow and plow were already invented. The technique was similar to those 1700 years later, it was even so that a Roman handbook in gardening, horticulture, animal husbandry, beekeeping and food handling was used until the 1800's. It was written by Lucius Junius Moderatus Columella, in the first century. And they used the land (i.e., practiced agriculture and/or had livestock) in the same parts of the world as today. Apart from that a few areas have been added:

- On the African savannah, Brazil, eastern U.S., central parts of Scandinavia, parts of Russia and Ukraine farming began after year 0.
- Western United States, Argentina, parts of South Africa, New Zealand and Australia wasn’t cultivated on a large scale until after they had been colonized by Europeans.

The origin of a selection of useful plants, where this to some degree of certainty, been possible to determine:



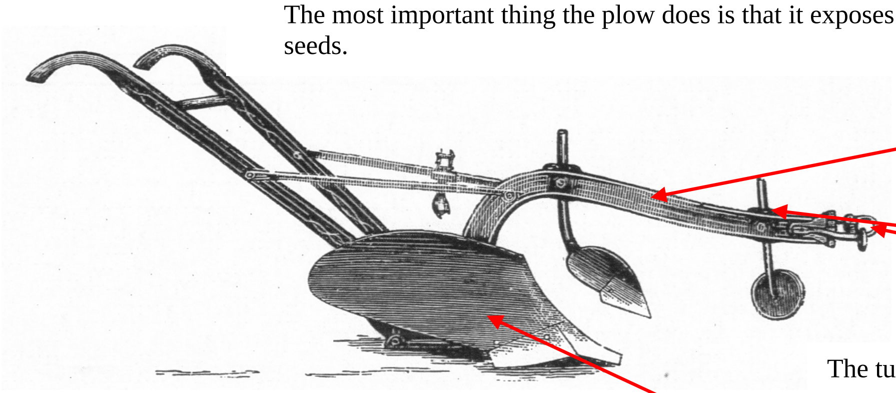
In the agricultural field of technology, it seems to more bids than the origin of various innovations than in other areas. It may be because innovations by the peasants in many places were very poorly documented. Several authors argue that many advances are coming from the UK, but also the British enhancers of agriculture appear to have got much inspiration from trips to farms on the continent. In order not to trample any nationality on the toes is, in broad terms, only the technical development in Sweden is described below. Sweden began officially to become interested in the development of agriculture in the 1700s, when the Vetenskapsakademin (Academy of Sciences) was established and given responsibility of such matters among other things. In 1813 then King Karl XIV wanted to invest more heavily in agricultural technology and he helped himself with money to the founding of the Kungliga Skogs- och lantbruksakademien (Royal Institute for Agriculture and Forestry). It was tasked to study what happened in the field, primarily in the UK, and disseminate this knowledge on to farmers through agricultural shows and local household societies. In 1840 Ulna Agricultural Institute, Sweden's first university in the agricultural area, was founded.

These efforts by the state appear to have had an effect, since the most important agricultural tools and cultivation practices in Swedish agriculture were refined:

- From the mid 1600s and onwards farmers in Sweden gradually went from harvesting with a large knife to harvesting with a scythe. With the effect of the work went faster (given that the field was not so rocky that the scythe was broken).

- In the early 1700s came plows[28] with the cutting part (the turntable) made of iron instead of wood. Its major advantage over plows with the turntable made of wood was that they slipped more easily through the soil. Which had the effect that fewer animals were needed to pull them which in turn led to a smaller need for feed, which in turn increased the acreage that could be used for cereals. The disadvantage of iron was that it was expensive, but in the 1700s iron became cheaper due to better production methods.

28. Plow from the early 1900's, with a turntable made of iron. My uncle use such until the end of the 1900s to dig up his potato field, but then he pulled it using the tractor. Today plows do not have v-shaped turntables and also have more turntables (since a tractor can pull a lot more than a horse).
The most important thing the plow does is that it exposes unused nutrient-rich soil for the seeds.

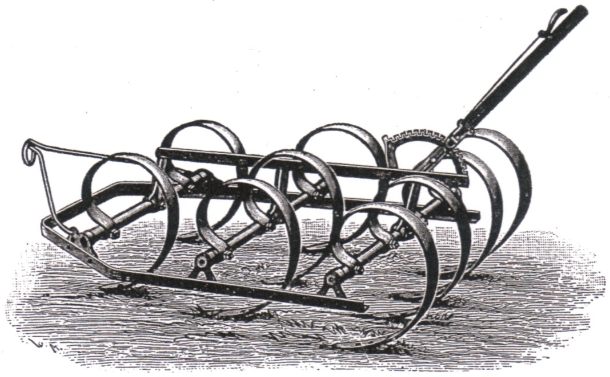


- It was realized that instead of always growing the same crop on the same field, and every two years to let the field’s rest[29] (fallow) one could change between different crops, which meant that the land needed to rest more seldom.

29. One of the biggest problems with growing crops is that it requires a lot of nutrients from the soil to give good return, the soil is drained on precisely what the crop needs. This problem can be solved through:

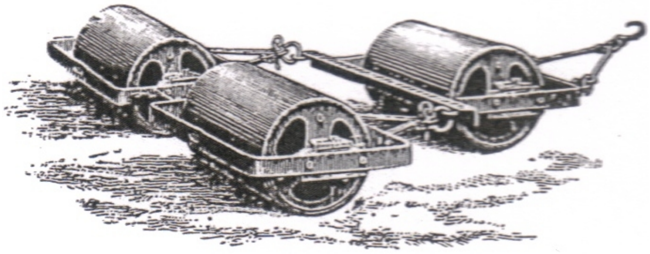
- Constantly growing on previously uncultivated land (slash and burn). The problem with it is that the land in many places isn’t sufficient for such a luxury.
- Stirring the soil so that "healthy" soil is in contact with the seeds. For this purpose we use plows.
- Supplying nutrition. This can be done by plowing down plant parts in the soil, or to fertilize. Normally farmers do both, but the problem with the latter was to get together enough and sufficiently nutritious fertilizer. This was solved more or less permanently in the early 1900s with the invention of artificial fertilizes.
- Switch between crops that take up some different things and/or require less nutrition than what the plowed down plant parts gives when composting.
- Only grow plants that require little nutrients, such as potatoes. The problem with it was that at first it was an unknown plant and later that all soils are not suitable for potatoes, and the failure to store potatoes as good as we then managed to store grain.

- After the earth is plowed it should, if it is cereals that shall be planted, be mashed further and in addition it should be smoothed and small ditches has to be made to put the seeds in. When the seed is in the soil a tool is needed to cover them with soil. For these purposes we have for long time been using cultivators. In its simplest form a harrows consists of split pine logs with stumps of branches left. At the end of the 1700s cultivators with curved sticks of iron had its breakthrough. It made the cultivation process go faster.



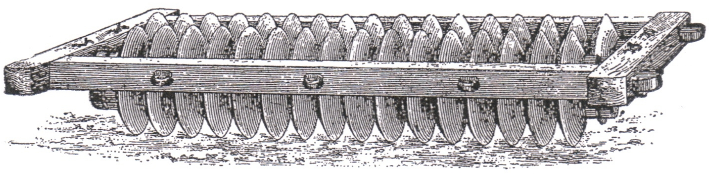
Cultivator from the beginning of the 1900s, completely made of iron with adjustable pegs. Basically modern cultivators looks similar. Sometimes they farmers puts rocks on them to make them go deeper.

- It is advantageous to flatten the soil more than the cultivator does and after that the seed is in the earth it is also advantageous that the surface is flattened further. To do that farmers use compactors. This tool consists, in its simplest form, of a block of wood that is rolled across the field. They became common in the 1700s and their ability to crush hard clods increased when the log surface was patterned, for example by nailing triangular ribs on it.



Flat compactor from the beginning of the 1900s.

Ring compactor from the same time. This one is very much like the compactor my uncle used at the end of the last century. It is better because it breaks up clods efficiently, and keeps the soil surface more aired.



- The state decided that the peasants should exchange of land with each other so that the estates became more consistent and therefore more efficient to use. The cause of the shattered estates was that, in all fairness, for a long time, the distribution of estates and/or the village community, had shared both the good and the bad parts fraternal so that everyone got the same amount of each. With the effect that each had small stripes of fields, meadows and forests here and there.
"Storskiftesstadgan" ((the law about big shifts) from 1757 limited each farms fragmentation to a maximum of four strips (=shifts) per farm. This attempt did not give as much as the authorities had hoped, therefore another attempt was done 1803 and additionally other one in1827. But even today the shifting is not fully implemented, for example, I myself partly own five small pieces of forest land with weird dimensions like 970 x 30 m.

Even in the 1900s, several important steps in the development of Swedish agriculture were taken:

- The first tractor with a combustion engine came to Sweden in 1905. But it took longer for the tractor to be established on the market compared to trucks, buses and cars. Since the farmers preferred the horses as they:
- Had access to cheap feed.
- Knew how to deal with animals.
- Had the space to house a horse.
- As a rule, were not in need of high transport speeds (tractors do not do more than 30 km/h).
- Had the benefit of the horse's off-road capabilities in their forestry work.
- Had use of the manure.

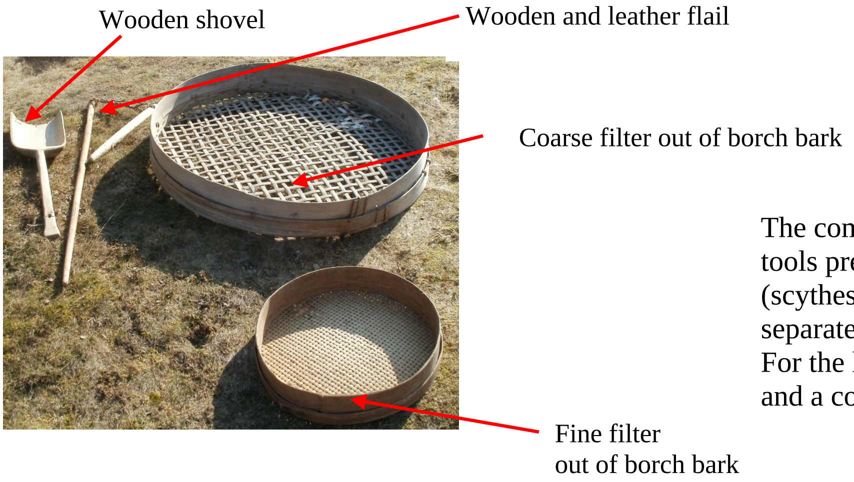
So many farmers, like my uncle did not buy a tractor until the 50's. The main advantages of tractors in agriculture were probably those they:
- Could pull more than horses.
- Don’t get tired.
- Could lift the processing unit during transport to and from the field.
- Had a power take out (PTO) that could power for instance a manure spreader.

- Artificial fertilizers, i.e. nitrogen powder which is extracted from the air through using electricity. The method was invented by the Norwegians Birkeland and Eydes and its advantages over natural fertilizer were probably that it:
  - Is less unhygienic.
  - Doesn’t smell bad.
  - Guaranteed not contain dangerous contaminants.
  - Was easier to spread.
  - Could be spread more evenly.
  - Was stored in "handy" 50-kg bags.
  - Had a long shelf life.
  - Where weight efficient.
  - Kept consistent quality.
  - Was available in abundance for all farmers (who could afford to buy it).

- Sowing machines are devices that mechanically release the seeds relatively smooth and in straight lines with a sufficient distance over the field, in contrast to when spreading by hand. This meant that the seed is used efficiently.

- Manure spreaders, spreads the manure in a much more even layer over the field, compared to what can be achieved with a shovel. The first working automatic spreaders were constructed by the Canadian Joseph Kemp in 1875. But it took to the 1900s before the machines reached Sweden.

- The first combine harvester, i.e. a machine that both cuts off the bristles and separates the seeds from the plant, came to Sweden from the U.S. (International Harvester) in 1928. But they did not become common in Swedish agriculture until much later. The early combined harvesters were pulled across the field with a tractor, but the harvesting and threshing mechanism was driven by its own engine.



The combined harvester replaced both the tools previously used to cut the bristles (scythes or sickles) and the tools used to separate the seeds from the rest of the plant. For the latter they earlier used a shovel, flail and a coarse and a fine filter.

- Silage balls. As well known cows and horses eat grass, but in the winters there were no grass, so they were forced to eat the dry and boring hay. This to someone realized that the grass can be preserved (stored oxygen-free). This conservation technology is relatively old (see below), but the boom in the area, however, came in the end of the 1900s, when it came tractor-drawn machines that gathered grass directly on the field, made balls out of it and wrapped them airtight in plastic film. This way, the farmers had "portions" of food that was easy to transport without that the preservation was broken and also it did not require a storage silo, but instead could be stored anywhere.

This resulted in combination with lowering of lakes, draining of swamps conversion of pastures to fields and other measures that increased the acreage to that the agricultural production increased (chart 11).

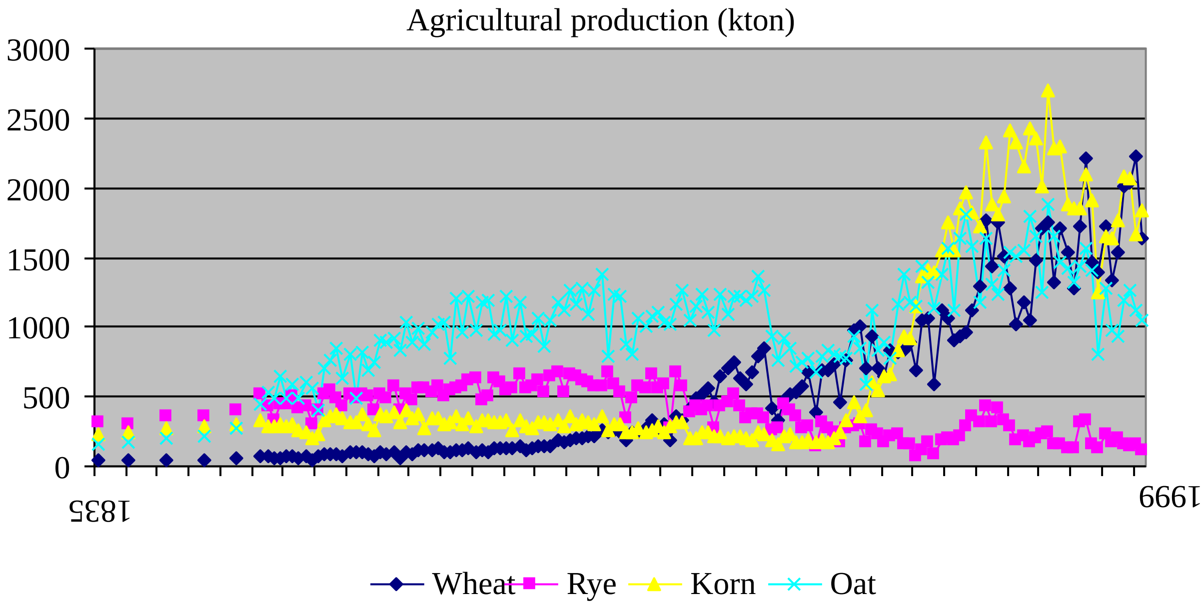


Chart 11. The Swedish production of some major crops 1835-1900 according to BR Mitchell, 1900-1999 according to SCB (Statistics Sweden).

When the crops are fully grown and harvested, it shall be stored for as long as possible, preferably until it is possible to harvest again. Most of the preservation methods we use today are far older than 2000 years. Even before the year zero, we added grain/fish/meat and vegetables in the sun for it to dry, we rubbed fish and meat with salt and/or smoked them, took advantage of the cold cellars/caves and laid fruit/vegetables in vinegar or honey. The methods then added are preservation[30], pasteurization[31], fridges[32], freezing in frezers[33], freeze drying[34], vacuuming and radioactive irradiation. Regardless of the method used, the aim is to keep the bacteria’s down so they do not become so numerous that the food is inedible (see table 8).

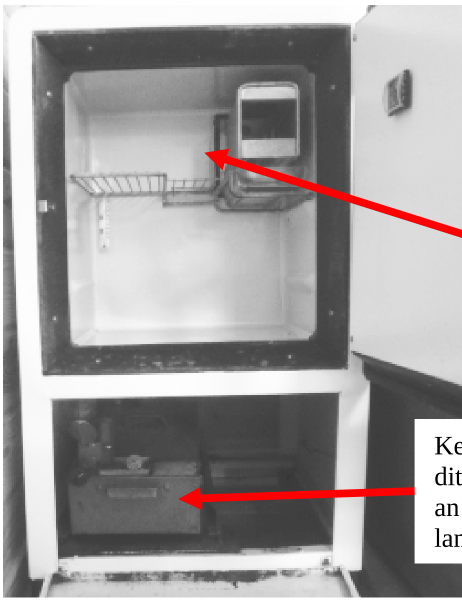
Although we have come a long way towards the perfect food systems, they have yet a lot to be desired. Apart from problems with that the ecological sustainability and the problems with that food is destroyed, I believe that the knowledge about how to optimize the taste for everyone's personal taste buds and appetite for the moment, are poorly developed. Furthermore, there are still few good surrogates for costly food and flavouring agents. Finally, to my knowledge, the cultivation of the marine supply of vegetarian food is limited to very few species.

30. In 1810 presented the Frenchman Nicolas Appert the preservation technique. Another Frenchman Peter Durant developed the technology and made so that the first metal canning jar was produced a year later.

31. The French chemist Luis Pasteur was very prominent in his days, and he was hired by various French food companies to save beer and wine from being destroyed by micro organisms. Pasteur solved the problem in 1860 when he developed an efficient method (pasteurization), which consisted of that the liquid was heated to 70° C, which killed the organisms. The technology has been of great benefit also for the conservation of other liquids such as milk.

32. The first refrigeration machine was built back in 1805, but the technology has since been developed by a number of inventors before General Electric in 1911 launched the household refrigerator.

My kerosene refrigerator from, like, 1940 that I still use. The refrigerator type was developed as a thesis atKTH (The Royal Institute of Technology) by Baltzar von Platen and Carl Munter in 1925. In general, the refrigerator operates so that when the gas in the cooling circuit is compressed into a liquid it gives off the heat and when liquid then expands again and becomes a gas it picks up heat. In the kerosene refrigerator the increase in pressure in the gas is done using the temperature increase caused by a kerosene lamp. The heated gas rises and then ends up in the cooler that is mounted on the back of the cabinet. In the cooler, the heat, and this, combined with the increased pressure causes the gas to liquefy. The liquefied gas is then pressed further in the system so that it reaches an expansion valve, and then an expansion chamber within the refrigeration compartment. When liquid flows through the expansion valve into the larger space it becomes gas again. In this transition, it sucks up heat from the surrounding area and thus it becomes cold in the refrigerator.



33. The American Clarence Birdseye invented and commercialized in 1929, the freezing of foods, after finding that the people of the Arctic kept fresh fish and meat in barrels of sea water quickly frozen by the arctic temperatures.

34. In the 1930s, the process freeze drying was developed by the Swiss company Nestlé and they launched instant coffee in 1938. But Indians in Peru's mountains are said to have freeze dried food long through just letting it be in the thin, cold air.

Table 8. A comparison between different preservation methods for food.

	principle	How do you	Durability	Advantages	Disadvantages
Drying	When drying the water disappear, and thus the bacteria's can not multiply.	The food, for example, can dry in the sun.	Long if the food remains dry.	It is easy and the food can be stored at room temperature.	It alters the taste and texture, which can also be a benefit as in the case of dried ham.
Smoking	Smoking also makes the water disappear.	The food, e.g. fish, is placed in a smoke filled container.	Fairly short.	Some foods are considered to get tastier.	Smoke may perhaps provide unhealthy substances.
Mixed with salt	The salt kills the bacteria's.	Meat/fish is stored in salty water and/or salty water is injected into it.	Fairly short.	The salt may enhance the flavour of some foods.	Foods that are salted so that they do not need to be kept cold are very salty.
Mixed with acid	Acid (e.g. acetic acid) also kills bacteria's.	The vegetables are laid in a mixture of water and vinegar.	Long, if the acidity is high enough.	It requires no special equipment.	The food tastes like vinegar.
Mixed with sugar	Likewise sugar.	The fruit is boiled with sugar.	Long if there is enough sugar.	”	The calorie content is high.
Preservation	Bacteria die of heat and there is so little air in the packaging that the surviving bacteria reproduce slowly.	The cans are heated, the air in them expands and flows out, and then the lid is closed.	Long.	Unopened cans can be stored at room temperature.	Requires special equipment and canned food does often not taste as fresh ones.
Pasteurization	Bacteria's are killed by heat.	The liquid is heated to 70° C.	Short, but often combined with cooling (as for milk).	The alternative for milk is to preserve it, which alters the flavour even more, and such products are more expensive.	The pasteurisation can alter the flavour slightly. In particular, the high-temperature pasteurized milk.
Cooling	The cold makes the bacteria multiply slowly.	The food is put in the refrigerator.	Short for most foods.	Affect the taste very little.	Requires a refrigerator.
Freezing	The bacteria multiply even slower.	The food is placed in the freezer.	Very long if it is sufficiently cold (colder than normal freezers).	Easy for anyone who has a freezer and the method often affects the taste only slightly.	Requires freezer. Some foods taste worse after freezing.
Vacuum packaging	There is so little air in the packaging that the bacteria reproduce slowly.	The air is sucked out, and then the lid is closed.	Short.	Extends shelf life compared to non-vacuum-packed products.	Requires special equipment and vacuum packed food often need to be stored cold anyway.
Lyophilization	The water disappears without the shape of the foodstuff changes.	The food is frozen then the air is sucked out of the freezer.	Long.	The weight decreases and the food can be stored in room temperature.	Requires special machines, freeze-dried food is expensive and taste changes.
Radioactive radiation	The rays kill bacteria.	Do not know.	Do not know.	It causes less vitamin loss than other methods.	Do not know.

Energy

Energy is what makes all processes continue. The main and oldest source of energy we have is the sun, but in addition man has long been used wood to create heat/light. With the matches, invented by Briton John Walker in 1827, the handling developed significantly.
A major disadvantage of wood as fuel, however, is that in some parts of the world there were a limited amount of it in relation to needs and also the fact that it wear out pretty quickly, which in turn led to that the volumes that must be dealt with was big. Coal made it somewhat easier because it contains twice as much energy as wood and in some countries it could be found in large quantities. Therefore, coal was used in some countries for a long time. Excavations of the ruins of a Roman baths in Britain showed that the Romans warmed them with coal. But after the Romans left Britain in 410 the technique seems to have been forgotten until the 1200s.

During the 1700s, a number of advances happened in coal mining, for example, people began to test drill in order to find suitable locations for mines instead of just digging "randomly" and, so far as we know, in 1712 the world's first viable steam engine was constructed by Thomas Newcomen to pump up water from a coal mine. With this, albeit unwieldy machine, we had for the first time mechanical power where you need it, not where it was available (like a waterfall). These advances, combined with that in the middle of the 1800s the steam engines were introduced on a broad front in the industry, on ships and to operate railway trains, resulted in that coal mining increased hugely (chart 12).

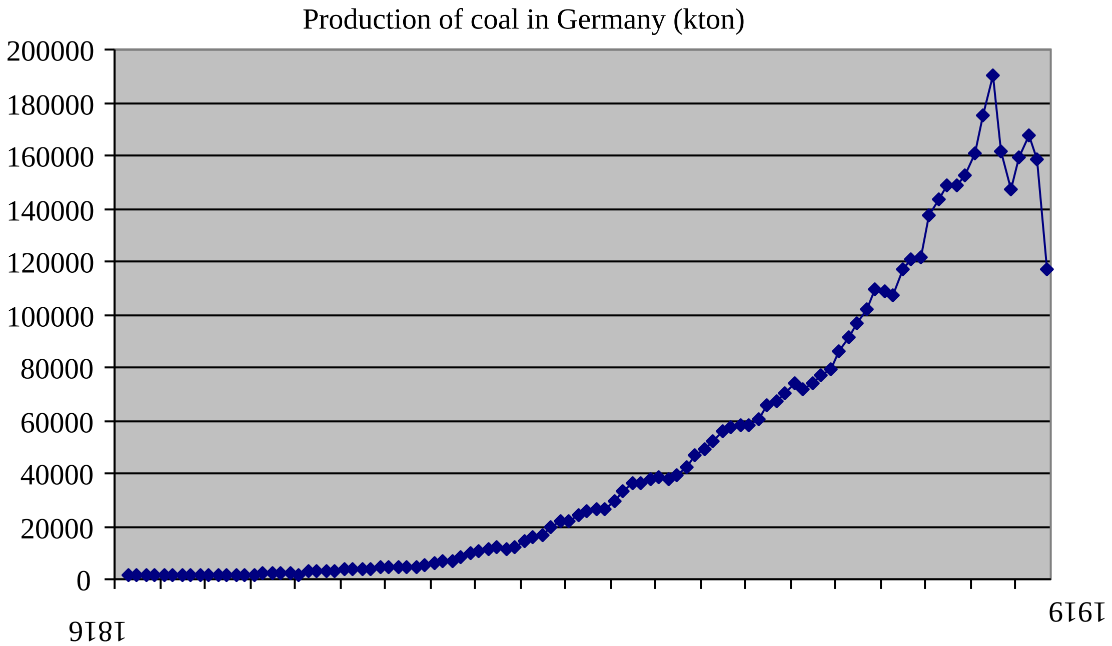
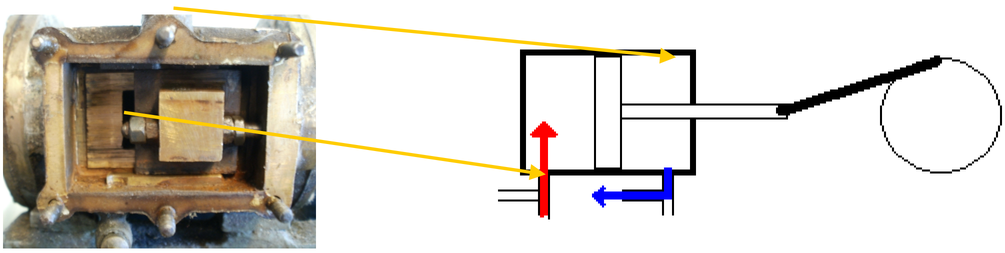


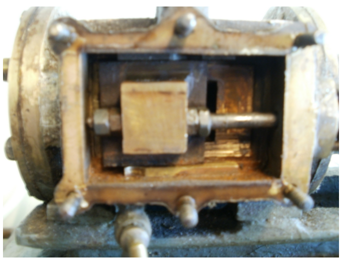
Chart 12. The German production of coal 1816-1919 according BR Mitchell. The decrease at the end of the period is likely due to that the World War I was going on then, so the Germans had other things to do than to mine coal. Because of the loss of the war, Germany's lost some parts of the country, which may explain that the production did not subsequently recover.

With the steam engine, we took a few fundamentally important steps in the use of energy, since it was a process that converted one form of energy into another form, which in turn drove something that performed a useful work.
Newcomens steam engine worked so that a counterweight made a piston rise. When the piston was at top of the cylinder, the cylinder was filled with steam. Then it was cooled with water vapour. This meant that the air shrank, which in turn is "sucked" down the piston.

Before steam: Coal/logs	→	heat + light				
Before steam: running water			→			movement
With steam: coal	→	heat	→	steam	→	movement
Over pressure steam: coal	→	heat	→	pressurized steam	→	more movement
With Otto engine: gas	→	gas-spray	→	explosion	→	movement
With Diesel engine: diesel	→	diesel-spray	→	explosion	→	movement

The steam engine was improved a lot by Newcomen's compatriot James Watt, what he did was:
- 1778 to design the crank movement that turned the linear piston motion into a rotating one.
- 1778 to build the first expansion steam engine (like the one below but without the shuttle valve).
- 1788 to create the shuttle valve.





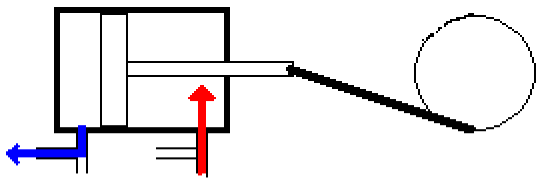
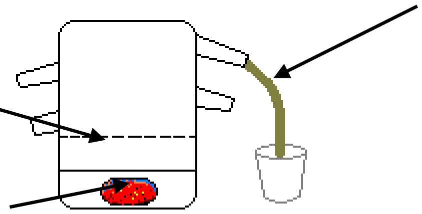


Photo of the shuttle valve and installation diagrams for Watt's improved steam engine. The shuttle valve increased the steam engine power very much because it turned the return stroke to a working movement.

Coal also had some drawbacks such as the lack of systems to automatically dispense it into the combustion, i.e. someone had to shovel it into the fireplace. But that was not what made us start extracting oil. It was instead to get components such as kerosene (for kerosene lamps), paraffin's (for preserving food), and various oils (lubricants).

Schematic sketch of the early oil refineries



Oil contains about 1.7 times as much energy as an equivalent quantity of coal. As seen in chart 13 the oil production was started much later than the production of coal. This despite the fact that oil production started quite early in Russia. It was partly due to Alfred Nobel (who later founded the Nobel Prize) and his big brothers Ludvig and Robert Nobel, because they1875 invested money in the nascent Russian oil industry in Baku. The supply of oil was huge, the difficulty was foremost to transport it. When the Nobel brothers arrived the oil was taken up by hand and it was transported in barrels that were shipped with donkeys. The brothers spent a lot of effort into improving the transports and they built Russia's first pipeline and commissioned the world's first oil tanker. Robert, Alfred and Louis also started an oil company after a few years, Russia's largest company and one of the world's largest oil producers, but it disappeared with the Russian Revolution.

Chart 13. The Russian oil production 1859-1969 according BR Mitchell. As we know, the country's borders has changed some during the period due to the wars that they were involved in, but it should not have affected the production of oil significantly, since the new areas were not known for any major oil production. However, a slight decline can be noted during and after the Russian Revolution. Moreover data is missing during World War II.

In addition to coal and oil, there is also a lot of natural gas in the ground. The natural gas production (chart 14) started even later than the oil production. The earliest notes about natural gas production, in the land which today is the world's largest natural gas producer (Russia), are from 1913. Natural gas was used, and still is used in many countries for home heating and as fuel for stoves and water boilers. In addition, it was earlier even used in lamps.

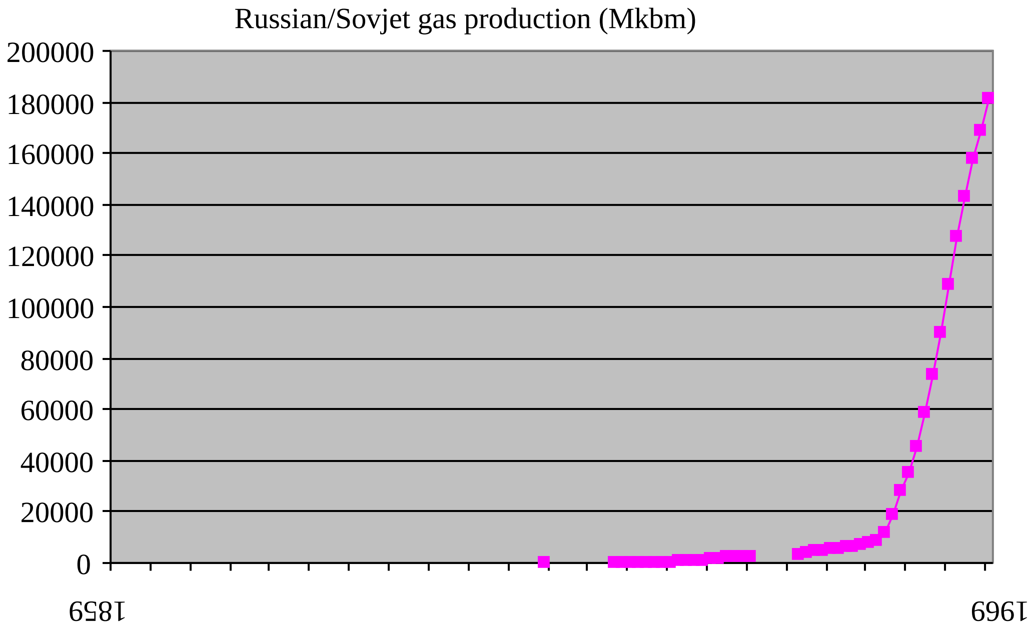


Chart 14. The Russian natural gas production 1859-1969 according BR Mitchell.

In addition the sun and combustion of various materials, the main sources of energy are the wind (which sailing ships and windmills have used for a long time) and running water.

In Southern Europe and China waterwheels have been in use since before the year 0. They were used to drive the hammer forges, mills and sawmills.

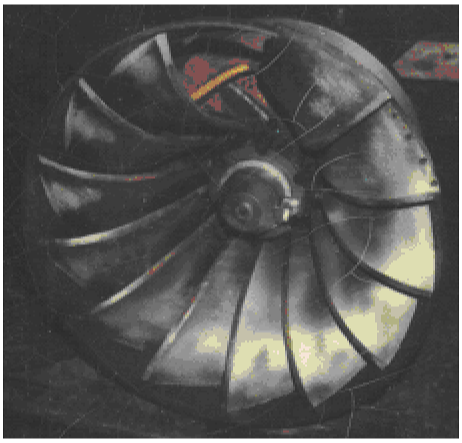
This waterwheel in Gustavsberg was built in 1895 to generate power for a mill that was grinding raw materials for the adjacent porcelain factory.

With the industrial development waterwheel came to power large industries like textile mills, rolling mills and mechanical workshops. When water turbines were introduced in the 1870s, it became possible to get more energy out of the waterfalls and in addition higher fall heights could be used, but the industry was still forced to be close to the waterfall.

There was a great need to transport the power to other places. The first variants of transmissions were purely mechanical. The Swede Christopher Polhem did in the early 1700s a transmission of linked wooden rods transporting energy from a waterwheel to a mine some kilometre away. It did, however, break quite often, so the steam engines out-competed this solution fairly quickly.
But with the development of knowledge about electricity that emerged in the 1800s[35] hydropower got a major boost.

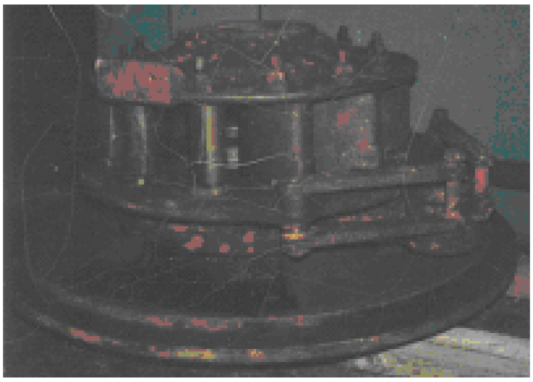
35. There was even before the 1700s people who had noted various electrical phenomena, but when the Dutchman Pieter van Musschenbroek 1745 invented the so-called leiden bottle (a glass bottle lined with metal foil attached to an electrode), the researchers were able to store electricity, which led to the development really began.
1796 the Frenchman André-Marie Ampère clarified the principles of electrical voltage and current.
1800 the Italian Alessandro Volta created a method to generate electricity by putting a pile of alternating layers of silver and zinc plates in salt water (i.e. the electric battery was born).
1820 the Dane Hans Christian Öhrsted, by chance, discovered the electromagnetism as the needle on a compass that he happened to have on his table moved, when he was experimenting with electricity.
1827 the German Georg Ohm described the relationship between voltage, current and resistance, i.e. $U = I \times R$.
1831 the Briton Michael Faraday found that if a power cable was wound as a coil and taken through a magnetic field current was formed in the cable. The discovery, he developed to the first generators, electric motors and transformers.

The very first, very simple, hydroelectric power plant was built in 1879 at Niagara Falls, USA. The plant consisted of a waterwheel with a DC generator and the generated enough power to run a few light bulbs. The next important step in the development of hydropower plants was taken in 1895 by George Westinghouse, who built plants with an AC-generator[36] in the same place. After that, development has continued, but despite that, most hydropower plants in the world were built in the 1950s and 1960s.



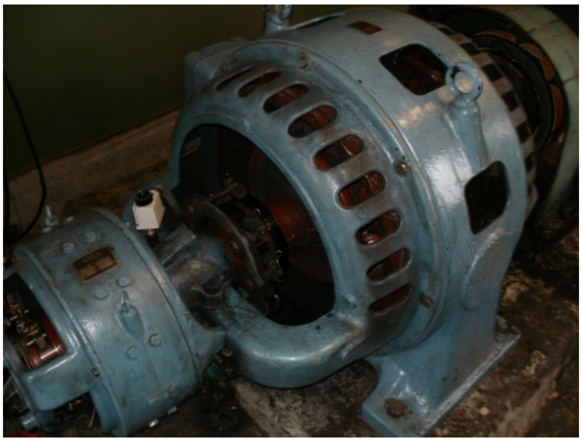
Damaged Francis turbine from 1963.

Samuel B Howd patented the first practical turbine in 1838. But with Francis turbines, the big breakthrough came for water turbines, because they had much better performance than its predecessors. The turbine type was constructed in the United States by the Briton James B. Francis, from about 1840-55. Even today, Francis turbines are the most common turbine type in hydropower stations throughout the world.



The vanes to the turbine above.

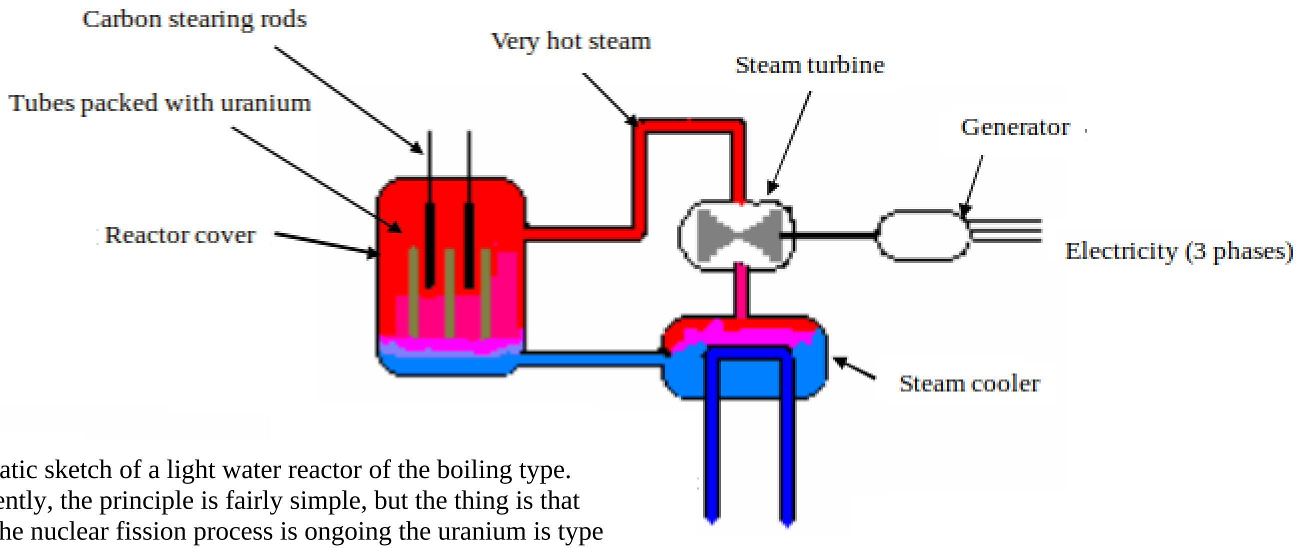
The vanes are like a garland around the turbine wheel. First, they direct the water flow against the wheel and also regulates the amount of water flowing. But early Francis turbines had fixed vanes. The variable vanes were later developed by the Briton James Thomson.



On the whole hydroelectric equipment of today lokks much like they did 100 years ago, the difference lies mainly in that the control system has become more sophisticated with the help of electronic sensors and control computers. My generator, for example, was built in 1932 and is still in commercial operation with equivalent performance as newer ones.

36. The advantage of AC is that it can be transformed to high voltage and the higher the voltage, the less current and hence the less losses in the cables. This is because the power loss $P_{loss} = U \times I = R \times I \times I = R \times I^2$, where I is the current through the cable and R is its total resistance.

In 1942, a team in the United States succeeds in making the first self-sustaining nuclear reaction and nine years later produces a research plant in the United States produced electricity for the first time. But it didn’t give more energy than to power four light bulbs. The world's first large-scale nuclear power plants started in the U.S. 1957. The plant supplied the Pittsburgh area with electricity. Most of the early nuclear reactors boiled heavy water and therefore they were called heavy water reactors. In heavy water, the hydrogen atoms have a neutron in the nucleus in addition to the usual proton. The advantage of heavy water is that the slowing down of the neutrons is much reduced compared to in plain water, allowing the nuclear reaction to be maintained even if one not use enriched uranium (enriched uranium = the atoms are supplied with more neutrons through neutron bombardment, with the effect that they decompose more easily). Heavy water reactors are now scrapped. The majority of the nuclear reactors that are in operation today are called light water reactors because they boil normal water. They were built in the 1970's and 80's and they are both more fuel efficient and produce far more power than the old heavy-water reactors.



Schematic sketch of a light water reactor of the boiling type. Apparently, the principle is fairly simple, but the thing is that when the nuclear fission process is ongoing the uranium is type 2 700° C hot and it stays so hot for several years. This means that the reactor can produce an enormous amount of power. For example, the largest Swedish reactor, Forsmark 3, makes about 15% of all the electricity produced in Sweden. And in other countries, mainly France, nuclear power accounts for the bulk of electricity production.

There is still a lot of development in the nuclear field, the efficiency is increased and they become safer, including such as making them independent of pumps to get the cooling water into the reactor.

In addition, intensive development of energy systems in general is ongoing, for example, we are waiting for thin film batteries, more efficient solar cells and nuclear fission.

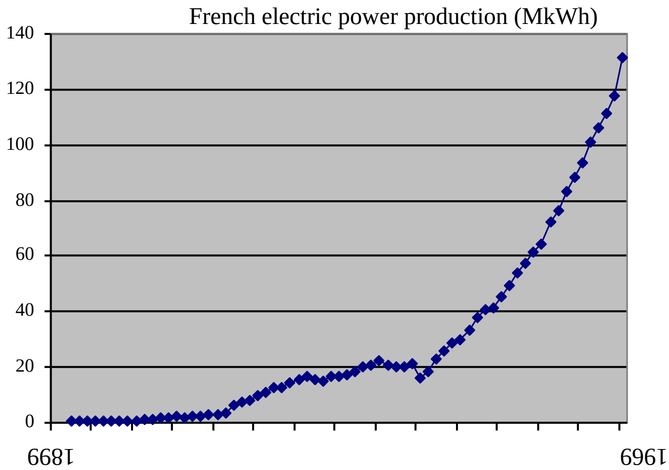


Chart 15. The French electricity generation 1900-1969 according to BR Mitchell. Thus, during the period when water power was built the most. Although France now has many hydropower plants over 70% of French electricity is generated in nuclear power plants.

Medicine

The medical development concerns actually most of us living today mainly in the event that we or a loved one is in the need of care. In addition, it may be reassuring to know that if that is the case, there is qualified help available. But those who lived in Sweden until the 1900s risked more or less constantly suffering from horrible diseases that quickly could end their lives (chart 16).

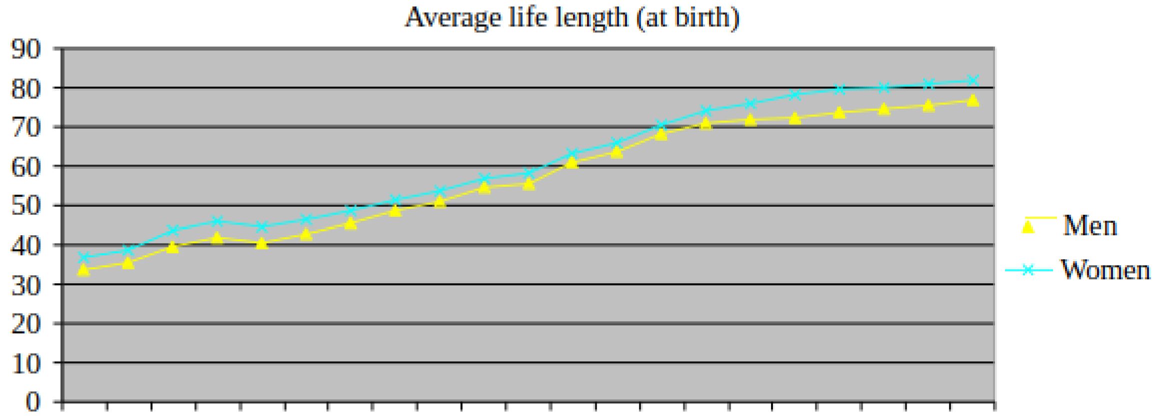


Chart 16. The average life length expectancy in Sweden from the year when the population statistics began 1751 to 2000. Data from Statistics Sweden's website.

The first important step to the medical security we have today was taken in the 1770s when the Briton William Wintering showed that the herb digitalis (foxglove) contained a substance which is active against heart failure (formerly called dropsy), which without treatment, often led to death.

The second important step was taken by his countryman Edward Jenner when he introduced a good method of vaccination against smallpox. Smallpox was a painful illness with blisters that often cover most of the body and usually led to death. During the severe epidemics of 1779 and 1784 it killed 15 000 and 12 000 people in Sweden alone. But after the vaccination was introduced this disease disappeared almost completely. For example, in 1861, only 193 persons in Sweden died of smallpox.

As in so many other disciplines a number of very important things happened in the 1800s. And this science went during the century from that most treatments consisted of taking out blood from the patients, regardless of the kind disease, to a variety of effective treatments for many of the then common and serious diseases. People realized that there are tiny little creatures, such as bacteria, and that these are the cause of a whole host of diseases and treatment complications. The Austrian Semmelweis investigated why so many women died in childbirth in a section and not on another, and realized that it was because the doctors on the first section went between births and autopsies without washing in between. After he had found this out, he advocated disinfection before surgery. Joseph Lister went down in history because he realized that what Luis Pasteur pointed out, namely that there are micro organisms floating around in the air, and it can explain the many infections in open wounds. He prescribed therefore airtight packaging of wounds and disinfection with carbolic acid. When he introduced the treatment after amputations the mortality decreased from 43% to 15%.

Besides this, it can be mentioned that:

- 1806 the German chemist Serturner produced morphine, which still is an effective and common mean for pain relief.
- In 1820 quinine was produced. Quinine was and still is an important tool in the fight against malaria.
- 1853 the syringe was invented by C Pravaz, it meant that medications, vaccines, and more could be added to the body in a faster and many times better way.
- 1863 the Frenchman Casimir Davaine discovered the anthrax bacterium.
- The leprosy bacteria were demonstrated later by the Norwegian doctor Armeur Hansen.
- 1867 the German Julius Conheim showed that the response formed in ulcers consists of white blood cells.
- 1879 the Russians Ilya Metjnikov showed that the white blood cells fights the bacteria's.
- 1877 the French chemist Luis Pasteur succeeded to manufacture vaccines against anthrax.
- 1891 the German physician Robert Koch showed the TB bacterium.
- Another German physician Emil von Behring showed, the year before, that when bacteria's are injected into the bloodstream, the body creates antibodies that fights the bacteria's and so he created a method of combating diphtheria (i.e., a vaccine).
- 1896 The first synthetic medicine was introduced: aspirin by the pharmaceutical company Bayer.

Even in the 1900s a lot of pioneering work has been done in surgery, pharmacology (drugs), oncology (cancer treatments), et cetera. The most important of these was probably done in 1928 by the Briton Alexander Fleming, when he realized that a kind of mold could kill bacteria, which was the first and most important step to the advent of penicillin.

These and other innovations and actions have led to that illness and deaths in a lot of nasty diseases have declined dramatically from the late 1800s (chart 17). In addition to purely medical reasons for the increasing life expectancy it is also due to engineering step stones such as the introduction of water supply systems and sanitation in urban areas from the mid-1800s (chart 18). The improved hygiene decreased the incidence of diseases caused by bacteria, especially in drinking water, such as cholera. For example, in 1834, 4.5% of Stockholm's population died in cholera (the water pipe system opened in 1861). In addition, some could be explained with that as our economy got better, people could afford more and better food.

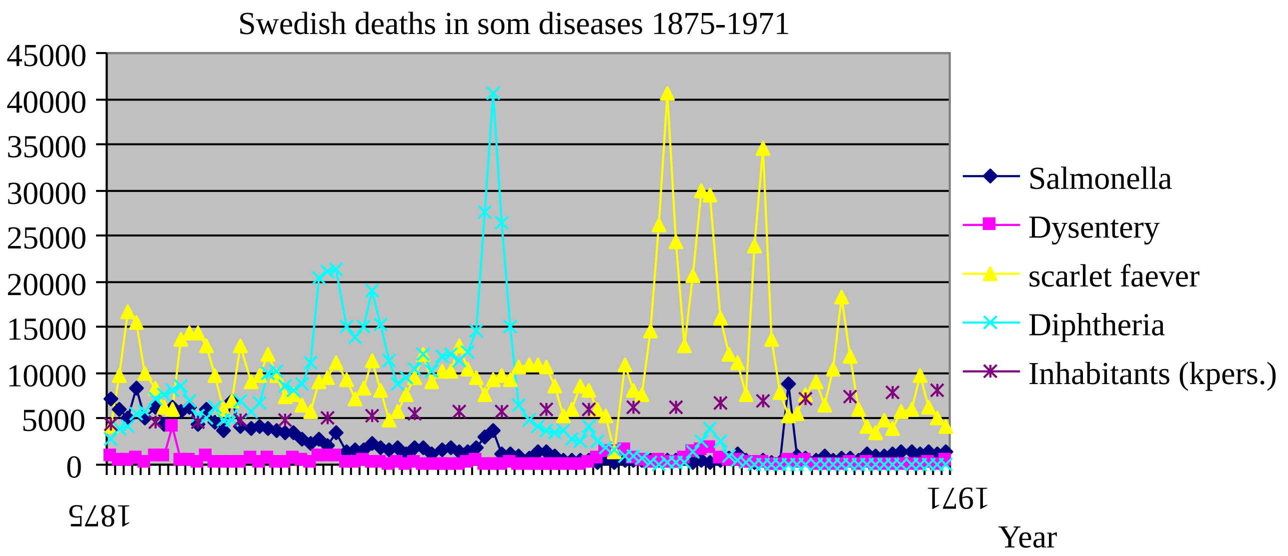
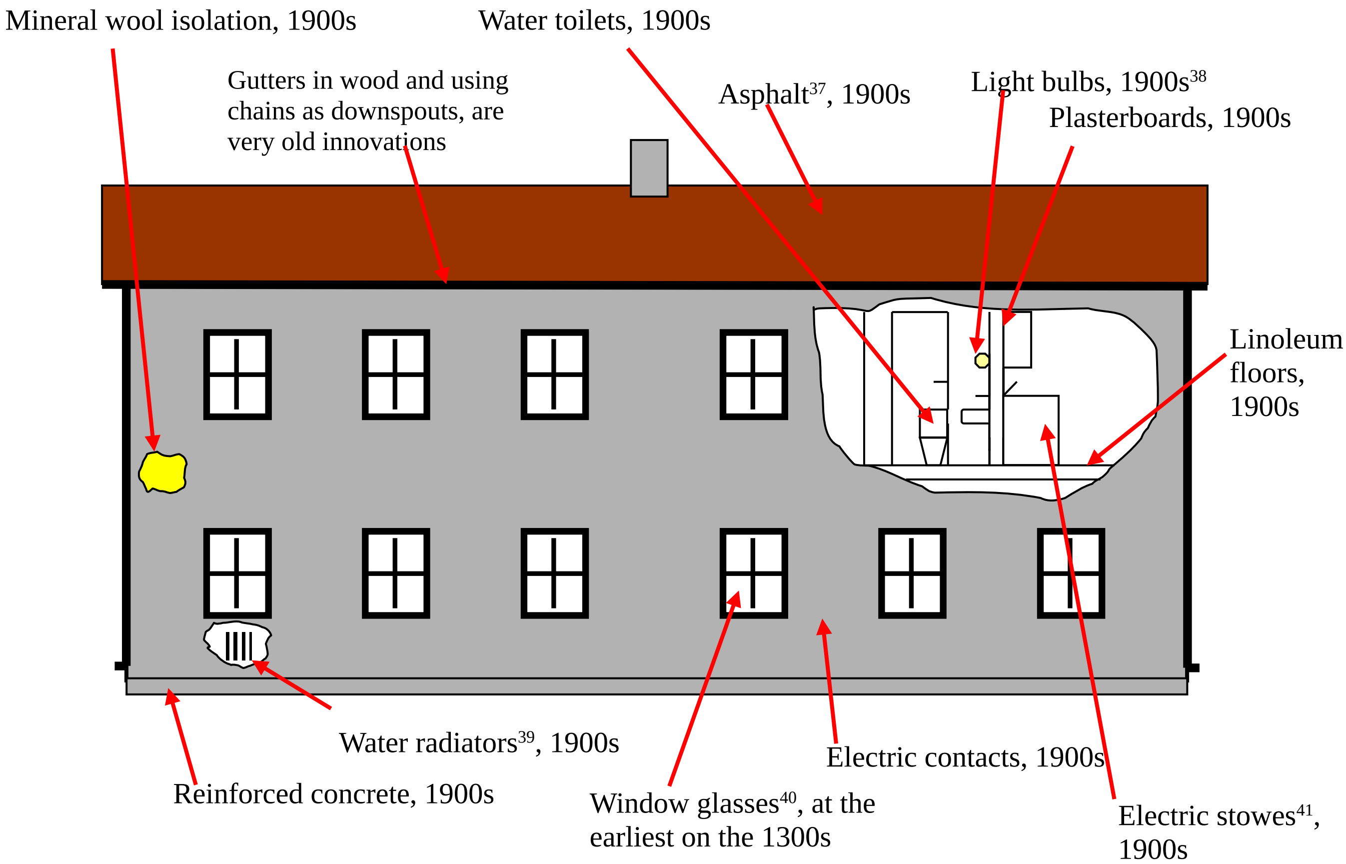


Chart 17. The yearly number deaths in some illnesses in Sweden 1875-1971.

Building & construction

Even before the year 0 a large part of the building construction techniques still used, were already invented (table 1). The main differences between the current Swedish houses and the ones the Romans perhaps lived in are (the time indicates when the technology began to be used by Swedish builders):



37. Asphalt began to be put on roads in the United States from 1872 and onwards, but it is unclear when we began to manufacture asphalt cardboards. The material asphalt is the last remaining in the refining of crude oil, i.e. the thickest fraction at the bottom of the pan after all other fractions have been evaporated.
38. Bulbs were made from the 1880s. The early bulbs, however, had a filament of carbon, and this made the glass partly blackened with time and only about 5% of the electrical energy became light, which was a big disadvantage because the power was expensive. So the manufacturers invested heavily in the development of better filaments. In Germany alone about 7 000 patents were applied for in the subject of light bulbs, between 1900 and 1912. In 1914 the American company General Electric launched the 'final' solution with filament of tungsten. Before that, people had used kerosene lamps and before that oil lamps, candles and resin-rich pine needles.
39. Before water elements, houses were heated with fireplaces, kerosene stoves, iron stoves and tiled stoves. The latter led to a big change in Swedish homes in the 1800s. Since they made it much easier and cheaper to heat multiple rooms. This in turn had the effect that everybody did not have to sleep in the kitchen.
40. Window glass came from France. It was made from molten glass that was blown out into a bubble which was rotated until it became flat. Then a rectangular glass was cut out.

41. Before the gas stoves and electric stoves the main source of energy for cooking in Sweden was wood. Until the 1860s, we burned the clogs in the fireplace. But then the iron stoves gradually took over as they:
- Where more fuel efficient.
- Gave heat longer and the heat was more stable.
- Created less smoke.
- Had a built-in oven.

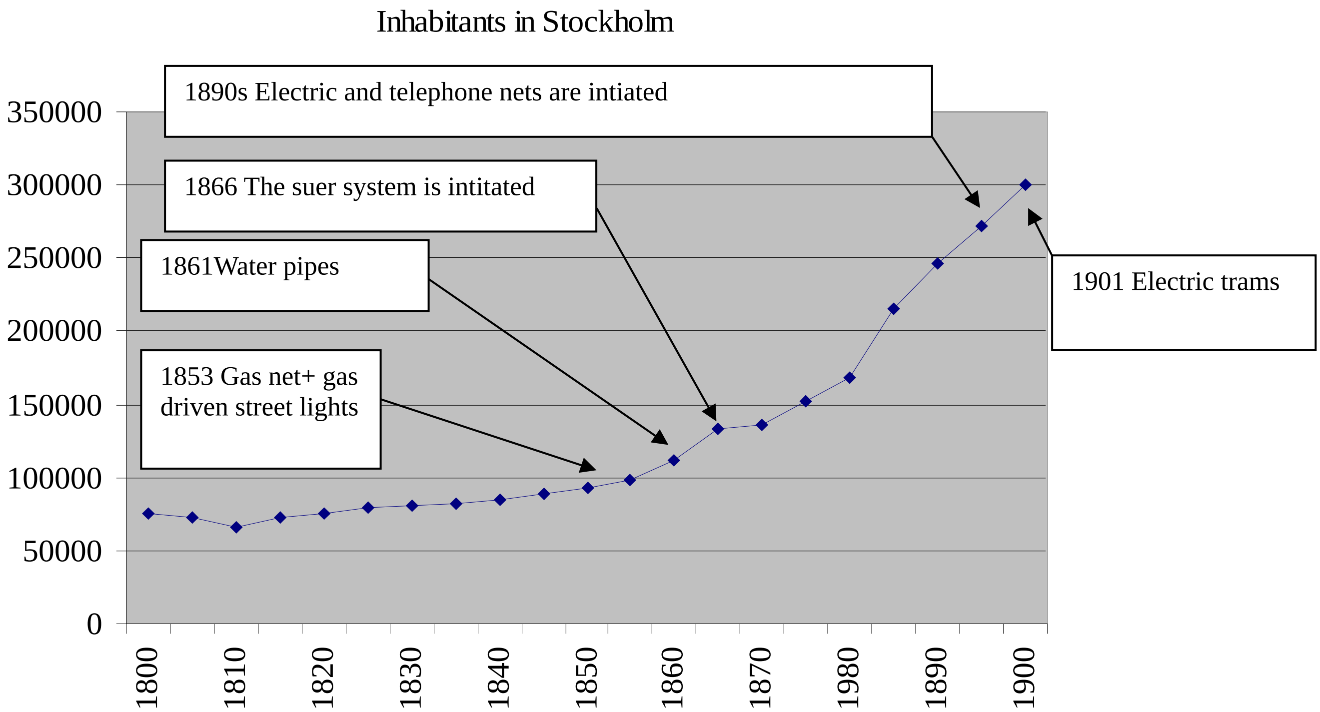


Chart 18. The population in Stockholm during the 1800s (Lars Nilsson, Historisk tätortsstatistik, Stads- och kommunhistoriska institutet, Stockholm 1992= Historical urban statistics, Urban and Municipal Historical Institute), with the data about when a number of important technical systems began to be built or put into service.

Oddly enough, we have along the way from the time when we lived in very humble abodes to today's modern homes, probably arguably liking, had a setback regarding buildings embellishments. What is ugly/beautiful is a matter of taste, but there seems to be less detail in today's buildings that are only there for the sake of beauty, compared with the buildings that are, say, 100 years old. Although it’s never been easier to make ornaments. Why is that so?

Materials

Until the advent of industrialism most made their clothes within their household or by someone in the neighbourhood, of what was to available, such as hides, furs, wool, linen or cotton. Regardless of if the thread was made of linen, cotton or wool the fibres must first be harvested and assembled into threads. Next, the threads have to be woven together into a piece of cloth, which is then cut and stitched to the garment.

Traditional tools for harvesting (cutting), carding, spinning and weaving sheep's wool.

In 1733 the speed weaving was suddenly dramatically up-speeded with the invention of a shuttle (John Kay, UK) that could be pulled through the transverse threads much faster. The weaving went so fast that there was a shortage of threads, which speeded up the construction of improved spinning machines. Which in turn made the weaving a bottleneck, until the American Edmund Carthwright 1787 built the first steam-powered weaving machine. This together made fabrics cheaper to manufacture and this increased the demand for cleaned cotton. This was solved when the cleaning machine was invented in 1792 in the United States by Eli Whitney. 1805 the Frenchman Joseph Marie Jaquard designed a weaving machine that was controlled by punch cards, which meant that one could change pattern just by simply replacing the punch card. With these inventions the production of cloth was about the same as today, and the production in the UK cotton industry increased (chart 19). Though still the manufacture of clothing was completely manual until the sewing machine was invented in 1846 and then developed further by Isaac Singer, 1851, when he unveiled a machine that was quite similar to today's sewing machines. Somewhat later (like 1870) the population in the Swedish countryside, to some extent, could buy ready-made formalwear from local tailors (Nordiska Museet list of questions from 1941 about when industrial products began to spread over the countryside) and factory-made shoes.

Chart 19. The British consumption of raw cotton, 1750-1899 according BR Mitchell.

The metals that could be produced at the time of Christ's birth were silver & gold (in jewellery and coins), copper (in tools, etc.), brass and bronze (alloys used in jewellery, ornaments and utensils), iron (tools) and lead (pipelines). Then not so much happened in metallurgy until the 1700s (see table 9), except that some elements such as arsenic, bismuth and platinum were isolated, and that the processes for iron making were improved. The most important development step in that respect was probably when the Briton Henry Bessemer in 1855 patented the idea to blow air on the molten iron after it arrived from the blast furnace. The point of it was that the naturally occurring carbon was reduced to below 2.1% and thus he had steel.

	Used the year 0
	Between 0 - 1699
	1700s
	1800s
	1900s
	Not yet isolated

Hydrogene 1 1766																		Helium 2 1895
Litsium 3 1817	Beryllium 4 1797														Nitrogen 7 1772	Oxygene 8 1774	Fluorine 9 1886	Neon 10 1898
Sodium 11 1807	Magnesium 12 1755												m 13 1825	14 1824	Phosphorus 15	Sulfur 16	Chlorine 17 1774	Argon 18 1894
Potassium 19 1807	Calcium 20 1808		Skandium 21 1879	Titanium 22	Vanadium 23 1801	Chromium 24 1797	Manganese 25 1774	Iron 26	Cobalt 27 1735	Nickel 28 1751	Copper 29	Zinc 30	Gallium 31 1875	Germanium 32 1886	Arsenic 33	Selenium 34 1817	Bromine 35 1826	Krypton 36 1898
Rubidium 37 1861	Strontium 38 1790		Yttrium 39 1794	Zirkonium 40 1789	Niob 41 1801	Molybdenum 42 1778	Teknetium 43 1937	Rutenium 44 1844	Rhodium 45 1803	Palladium 46 1803	Silver 47	Cadmium 48 1817	Indium 49 1863	Tin 50	Antimony 51	Tellurium 52 1782	Iodine 53 1811	Xenon 54 1898
Cesium 55 1860	Barium 56 1808		Lutetium 71 1907	Hafnium 72 1923	Tantal 73 1802	Tungsten 74 1783	Rhenium 75 1925	Osmium 76 1803	Iridium 77 1803	Platinum 78	Gold 79	Mercury 80	Tallium 81 1861	Lead 82	Bismuth 83	Polonium 84 1898	Astatine 85 1940	Radon 86 1900
Francium 87 1939	Radium 88 1898		Lawrencium 103 1961	Rutherfordium 104 1964/69	Dubnium 105 1967/70	Seaborgium 106 1974	Bohrium 107 1976	Hassium 108 1984	Meitnerium 109 1982	Darmstadtium 110 1994	Röntgenium 111 1994	Copernicium 112 1996	113	114	115	116	117	118
Lantan 57 1839	Cerium 58 1803	Praseodym 59 1895	Neodym 60 1895	Prometium 61 1945	Samarium 62 1879	Europium 63 1901	Gadolinium 64 1880	Terbium 65 1843	Dysprosium 66 1886	Holmium 67 1878	Erbium 68 1842	Tulium 69 1879	Ytterbium 70 1878					
Aktinium 89 1899	Torium 90 1829	Protaktinium 91 1917	Uran 92 1789	Neptunium 93 1940	Plutonium 94 1940	Americium 95 1944	Curium 96 1944	Berkelium 97 1949	Californium 98 1950	Einsteinium 99 1952	Fermium 100 1952	Mendelevium 101 1955	Nobelium 102 1958					

Periodic table, with data about when each element was isolated and its atomic number = number of protons in each nucleus.

Rubber got its breakthrough when the American Goodyear in 1839 received a patent on a way to process natural rubber so that it was not so sticky and difficult to work with and the process also made the products more sustainable. The process was called vulcanization and it is still used today.

Vulcanization = natural rubber + sulphur + high pressure + heat.

The first plastic-like material produced in large scale was celluloid. It was based on plant fibres that were dissolve into a homogeneous batter by adding camphor. Celluloid was produced for the first time by the American John Hyatt in 1869. It was used, among other things, to make billiard balls as a substitute for ivory (ivory was expensive and ivory balls were never perfectly round). Unfortunately, the material is very flammable.
The first real/synthetic plastic material (i.e. with only chemically manufactured ingredients, apart from reinforcement) was patented in 1907 by the Belgian Leo Baekeland. It was called Bakelite and it’s actually still manufactured.

Bakelite = acid phenol formaldehyde + gas + pressure + wood flour (as "reinforcement").

The first synthetic rubbers, Buna S and Buna-N was produced by German chemists during the World War I, because they had a shortage of natural rubber (the British blocked the supply of natural rubber, which meant that the Germans could not produce automobile tires, etc.).

Table 9. Examples of common materials and how long they have been utilized by man.

Material	Year 0	1800	1900	2000	Used today example
Cotton	X	X	X	X	Clothes
Lin	X	X	X	X	Clothes
Silk	X	X	X	X	Clothes
Wool	X	X	X	X	Clothes
Paper		X	X	X	Books, magazines
Aluminium			X	X	Vehicle components, beer cans
Lead	X	X	X	X	Automotive batteries
Bronze (type 90% copper +10% tin)	X	X	X	X	Bearings, bushings
Cast iron (iron +> 2.1% carbon (often about 4% carbon + approximately 2% silicon)	X	X	X	X	Machine components
Gold	X	X	X	X	Jewellery, coating connectors
Silicon			X	X	Electronic circuits
Steel (iron + ≤ 2.1% carbon + possible. Alloying elements such as manganese)			1855	X	Vehicles, buildings
Copper	X	X	X	X	Electric cables
Magnesium			X	X	Vehicle components
Nickel		X	X	X	In stainless steel
Stainless steel (iron + 12-30% chromium + nickel, often 7-30%)				1912	Building components
Silver	X	X	X	X	Jewellery
Tin	X	X	X	X	Soldering of electronics
Zinc	X	X	X	X	Moulded components
Graphite / carbon	X	X	X	X	Pencils
Vinyl chloride plastic (PVC)				1900s	Tubes, profiles
Polystyrene (PS)				"	Disposables
Methyl methacrylate plastic (PMMA)				"	Signs
Polycarbonate (PC)				"	window boxes
Phenyleneoxy plastic (PPO)				"	Cases of such appliances
Low density polyethylene (LDPE)				"	Automotive components
High density polyethylene (HDPE)				"	Pouches
Polyoxymethylene (POM)				"	Household goods
Polypropylene (PP)				"	Cogwheels
Polyamide (PA, Nylon)				"	Car parts
Polyphenylene sulfide (PPS)				"	Cogwheels
Polytetrafluoroethylene (PTFE, Teflon)				"	Covers
Phenol-formaldehyde plastic (PF)				"	Gaskets
Urea Formaldehyde plastic (UF)				"	Covers
Epoxy (EP)				"	Electric components
Polyurethane (PUR)				"	Castings
Natural rubber (NR)	X	X	X	X	Car tires
Styrene rubber (SBR)				1900s	Car tires, etc.
Butyl rubber (IIR)				"	Inner tubes of tires
Ethylene-propylene rubber (EPDM)				"	Sealings for buildings
Nitrile (NBR)				"	Oil hoses
Chloroprene rubber (CR)				"	Bellows
Styrene-butadiene thermoplastic elastomer (SBS)				"	Shoe soles
Olefin thermoplastic elastomer (TOE)				"	Fins
Urethane thermoplastic elastomer (TPU)				"	Hot melt
Ester-ether thermoplastic elastomer (TPAE)				"	Track for snowmobiles
Soft PVC				"	Floor mats