\*Second, a substantial number of techniques emerge with fairly little base in the understanding of the   
natural phenomena. The first Industrial Revolution -- and most technological developments preceding it -- had little   
or no scientific base. It created a chemical industry with no chemistry, an iron industry without metallurgy, power   
machinery without thermodynamics. Engineering, medical technology, and agriculture until 1850 were pragmatic   
bodies of applied knowledge in which things were know to work, but rarely was it understood why they worked.   
This meant that often people did not know which things did not work: enormous amounts of energy and ingenuity   
were wasted on alchemy, perpetuum mobiles, the stones of the wise and fountains of youth. Only when science   
demonstrated that such pipedreams were impossible, research moved into a different direction. Moreover, even   
when things were known to work, they tended to be inflexible and slow to improve. It was often difficult to   
remove bugs, improve quality, and make products and processes more user-friendly without a more profound   
understanding of the natural processes involved. It was in this regard that the inventions after 1870 were different from the ones that preceded it. The   
period 1859-1873 has been characterized as one of the most fruitful and dense in innovations in history. From the point of view of useful knowledge that mapped into new technology, this   
view is certainly correct. The second Industrial Revolution accelerated the mutual feedbacks between these two forms of knowledge or between Ascience@ (very broadly defined) and technology.

\*Even before 1870, some natural processes were sufficiently understood to provide some guidance as to how to make technology more effective. And certainly after 1870 there was still a role to

play for luck, serendipity, and Atry-every-bottle-on-the-shelf@ type of inventions. Yet degree is everything here, and the persistence and acceleration of technological progress in the last third of the nineteenth century was due increasingly to the steady accumulation of useful knowledge. Some of this knowledge was what we could call today Ascience@ but a lot was based on less formal forms of experience and information. Inventors like Edison and Felix Hoffman relied on some of the findings of formal science, but a lot more was involved. As a result, the second Industrial Revolution extended the rather limited and localized successes of the first to a much broader range of activities and products. Living standards and the purchasing power of money increased rapidly, as the

new technologies reaches like never before into the daily lives of the middle and working classes.

\*The other aspect of the second Industrial Revolution worth stressing is the changing nature of the

organization of production. The second Industrial Revolution witnessed the growth in some industries of huge economies of scale and Athroughput@ (to use Alfred Chandler's well-known term). Some vast concerns emerged, far larger than anything seen before. This change occurred because of ever more important economies of scale in manufacturing. Some of these were purely physical such as the fact that in chemicals, for instance, the cost of

construction of containers and cylinders is proportional to the surface area while capacity is proportional to

volume. Since the first depends on the square of the diameter and the latter on the cube, costs per unit of output decline with output. With the rise of the chemical industry, oil refining, and other industries using containers, as well as engines of various types, size began to matter more and more. Some economies of scale were

organizational, such as mass production by interchangeable parts technology. Others were more in the nature of marketing advantages, or even the ruthless pursuit of monopolies. Yet it should be stressed that even with rise of giant corporations such as Carnegie Steel, Dupont, Ford Motors, and General Electric in the U.S. and their

equivalents in Europe, these firms employed but a small fraction of the labor force.

\*The consequence of changing production technology was the rise of technological systems (Hughes, 1983, 1987). Again, some rudimentary Asystems@ of this nature were already in operation before 1870: railroad and telegraph networks and in large cities gas, water supply, and sewage systems were in existence. These systems expanded enormously after 1870, and a number of new ones were added: electrical power and telephone being the most important ones. The second Industrial Revolution turned the large technological system from an

exception to a commonplace.

\*STEEL = By 1850, the age of iron had become fully established. But for many uses, wrought iron was

inferior to steel. The wear and tear on wrought iron machine parts and rails made them expensive in use, and for Joel Mokyr

many uses, especially in machines and construction, wrought iron was insufficiently tenacious and elastic. The problem was not to make steel; the problem was to make cheap steel. As is well-known, this problem was

definitively solved by Henry Bessemer in 1856. The growth of the steel industry following his invention has come in the popular mind to symbolize the technology of the second Industrial Revolution, and while steel was of

course of great significance, such emphases tend to blur the advances in many other industries.

\*Cheap steel soon found many uses beyond its original spring

and dagger demand; by 1880

buildings, ships, and railroad tracks were increasingly made out of steel. It became the fundamental material from which machines, weapons, and implements were made, as well as the tools that made them.

Steel's spectacular success after 1860 should not obscure important advances in other stages of the iron industry. In the blast furnaces, which smelted iron ore to produce pig iron, coke had long been the standard fuel by the 1850s. Most furnaces at that time were about 40-50 ft. high and heated the ore to about 600oF. Following the discovery of ore fields in the Cleveland district in Northern Yorkshire in England, a set of improvement

occurred which greatly increased the efficiency of the blast furnaces. Their height was gradually increased to 80 feet and more; temperatures were raised to about 1000oF.; waste gases were recycled; and blowing engines were introduced. American inventors added a number of other improvements, such as "hard driving" (blowing large volumes of air at high pressure through the furnace); improved blowing engines; and direct casting of the pig iron into the steelworks.

\*Chemicals: In chemistry, Germans took the lead. Although Britain still was capable of achieving the lucky occasional masterstroke that opened a new area, the patient, systematic search for solutions by people with formal scientific and technical training suited the German traditions better. Other famed

German chemists, such as Friedrich Wöhler, Robert Bunsen, Leopold Gmelin, August von Hofmann, and

Friedrich Kekulé von Stradonitz, jointly created modern organic chemistry, without which the chemical industry of the second half of the nineteenth century would not have been possible. It was one of the most prominent examples of how formal scientific knowledge came to affect production techniques.

\*Despite German dominance, it was an Englishman, William Perkin, who by sheer luck made the first major discovery in what was to become the

modern chemical industry. Perkin, however, was trained by the German von Hofmann, who was teaching at the Royal College of Chemistry at the time, and his initial work was inspired and instigated by him. The eighteen year old Perkin searched for a chemical process to produce artificial quinine. While pursuing this work, he accidentally discovered in 1856 aniline purple, or as it became known, mauveine, which replaced the natural dye mauve. German chemists succeeded in developing indigotin   
  
(synthetic indigo, perfected in 1897). and sulphuric acid (1875). Soda-making had been revolutionized by the   
Belgian Ernest Solvay in the 1860s. In explosives, dynamite, discovered by Alfred Nobel, was used in the   
construction of tunnels, roads, oilwells, and quarries. If ever there was a labor-saving invention, this was it.

\*In the production of fertilizer, developments began to accelerate in the 1820s. Some of them were the   
result of resource discoveries, like Peruvian guano which was imported in large quantities to fertilize the fields of   
England. Others were by-products of industrial processes

\*Electricity: Like chemistry, electricity was a field in which totally new knowledge was applied to solve   
economic problems. The economic potential of electricity had been suspected since the beginning of the   
nineteenth century.

\* the American Joseph Henry, Michael   
Faraday invented the electric motor in 1821 and the dynamo in 1831. The first effective application of electricity   
was not in power transmission, but in communication. The telegraph was associated with a string of inventors the most important of whom were S.T. von Soemmering, a German, who demonstrated its capabilities in 1810

\*The telegraph, together with the railroads, was an early example of a technological system, a com-  
bination of separate inventions that had to be molded together. Just as the strength of a chain can never be greater   
than that of its weakest link, the efficiency and reliability of a system can never be greater than that of its weakest   
component.

\*Before the telegraph could become truly functional, the physics of   
transmission of electric impulses had to be understood. Physicists, and above all William Thomson (later Lord   
Kelvin), made fundamental contributions to the technology. Thomson invented a special galvanometer, and a tech-  
nique of sending short reverse pulses immediately following the main pulse, to sharpen the signal In this close collaboration between science and technology, too, telegraphy was clearly a   
second generation technology.

\*The use of electricity as a prime means of transmitting and using energy was technically even more   
difficult than the development of the telegraph. Before it could be made to work, an efficient way had to be devi-  
sed to generate electric power using other sources of energy; devices to transform electricity back into kinetic   
power, light, or heat at the receiving end had to be created; and a way of transmitting current over large distances   
had to be developed. In addition, electricity came in two forms, alternating and direct current, and a decision had   
to be made regarding which of the two forms was to dominate.

\*Electric generators were crucial. Although Davy had shown as early as 1808 how electricity could drive   
an arc lamp, apart from lighthouses it was not widely used in lighting. Following the discovery in the mid 1860s   
of the principle of the self-excited generator by C.F. Varley and Werner von Siemens, the Belgian Z. T. Gramme   
built in 1870 a ring dynamo, which produced a steady continuous current without overheating. Gramme's   
machine substantially reduced the cost of alternating current. The vacuum problem was solved in 1865, when   
Hermann Sprengel designed a vacuum pump. Only then could the arc lamp be made practical. In 1876 a Russian   
inventor, Paul N. Jablochkoff, invented an improved arclamp (or "candle"), which used alternating current. Subse-  
quently factories, streets, railway stations and similar public places began to replace gaslight with arc light. In   
1878, Charles F. Brush of Ohio invented a high-tension direct-current lamp, which by the mid-1880s had come to   
dominate arc lighting. Inventors such as Thomas Edison and George Westinghouse realized that electricity was a   
technologic al network, a system of closely interconnected compatible inventions. In this regard it resembled gas   
lighting systems, but electricity was recognized to be a general system of energy transmission. Edison was   
particularly interested in systems of technology, and his ability to see the holistic picture and to coordinate the   
research effort of others were as developed as his own technical ingenuity

\*The use of electricity expanded quickly in the 1870s. A miniature electric railway was displayed at the   
Berlin exhibition in 1879; electric blankets and hotplates appeared at the industrial exhibition of Vienna in 1883; and   
electric streetcars were running in Frankfurt and Glasgow by 1884. The early 1880s saw the invention of the   
modern lightbulb by Joseph Swan in England and Thomas A. Edison in the United States. An electric polyphase   
motor using alternating current was built by the Croatian-born American Nikola Tesla in 1889, and improved   
subsequently by Westinghouse.

\*Tesla=s polyphase motor and the Gaulard-Gibbs   
transformer solved the technical problems of alternating current and made it clearly preferable to direct current,   
which could not overcome the problem of uneconomical transmission. Led by Westinghouse and Tesla, the   
  
forces for alternating current defeated those advocating direct current, led by Edison. By 1890, the main technical   
problems had been solved; electricity had been tamed. What followed was a string of microinventions that   
increased reliability and durability and reduced cost. All the same, the effects of electricity on manufacturing productivity were slow to be realized, as factories only slowly learned the advantages of electricity as a form of   
industrial power

\*Transportation. By 1870 the application of steam power to transportation was hardly a novelty, and they   
were properly speaking products of the first Industrial Revolution (though the screw propellor and the marine   
steam engine were both perfected in the 1850s). Railroads became faster, safer, and more comfortable during the   
second Industrial Revolution but these resulted from microinventions rather than from big breakthroughs. The   
  
only truly discontinuous changes to railroads in this period were the application of new power sources: the Diesel   
  
engine, invented in 1897 by Rudolf Diesel and the use of electrical locomotives. Rudolf Diesel was a good   
  
specimen(örnek,simge) of the Anew inventor@, an engineer trained in science, a "rational" inventor, in search of efficiency   
above all else. He started off searching for an engine incorporating the theoretical Carnot cycle, in which   
maximum efficiency is obtained by isothermal expansion so that no energy is wasted, and a cheap, crude fuel can   
be used to boot (originally Diesel used coal dust in his engines). Isothermal expansion turned out to be impossible,   
and the central feature of Diesel engines today has remained compression-induced combustion, which Diesel had   
at first considered to be incidental (Bryant, 1969).Although some electrical railroads were in operation by 1914,   
wholesale electrification and the conversion to Diesel occurred much later.

\*Changes in ships were more drastic. Despite the rather amazing improvement in sailing ships resulting in   
the famous clipper ships, wind power was destined for niches in sports and leisure boats. First, after 1870   
increasingly ships were built of steel. This made it possible to build larger ships. Since the maximum speed of a   
ship is proportional to the (square roots of) the water line, and iron and steel ships could be made much larger   
than wooden ships, ships grew bigger, more powerful, and faster at unprecedented rates.

\*The classic case of a novel combination of known techniques laced with a number of important original   
contributions was the development of the automobile. The internal combustion engine was first suggested by   
Huygens in the seventeenth century. In 1824, Sadi Carnot had described the limitations of the steam engine as an   
energy source and pointed to heated air as the best potential means to generate motive power. Despite prolonged   
research efforts, it turned out to be difficult to employ steam power for carriages. During the nineteenth century   
dozens of inventors, realizing the advantages of an internal combustion engine over steam, tried their hand at the   
problem. Interestingly, the four-stroke principle had been recognized earlier as the only way in which a Lenoir-  
type engine could work efficiently. The "silent Otto," as it became known (to distinguish it from a noisier and less   
successful earlier version), was a huge financial success. The advantage of the gas engine was not its silence, but   
that, unlike the steam engine, it could be turned on and off at short notice.

\*Otto's gas engine was soon to adopt a new fuel. Somewhat earlier, in the 1860s, the process of crude oil   
refining using a method called cracking was developed. At that time the main interest was in lubricants, paraffins,   
and heavy oils, with petrol or gasoline considered a dangerously inflammable by-product. In 1885 two Germans,   
Gottlieb Daimler and Karl Benz, succeeded in building an Otto-type, four-stroke gasoline-burning engine,   
employing a primitive surface carburetor to mix the fuel with air. Benz's engine used an electrical induction coil   
powered by an accumulator, foreshadowing the modern spark plug.

\*The conquest of the air is an excellent example of how formal knowledge about nature and pragmatic   
experience combined to produce one of the most dramatic macroinventions of all times, namely the Wright   
brothers= celebrated heavier-than-air flight at Kitty Hawk in 1903. The Wright brothers had access to and used   
the knowledge on aerodynamics that had been accumulating since the pathbreaking work of George Cayley early   
in the nineteenth century in part through the advice of Octave Chanut, one of the leading aeronautical engineers of   
his time. At the same time they were skilled mechanics who had earned their spurs as bicycle repairmen in   
Dayton. The development of the airplane in many ways is paradigmatic of the new mode of technological   
progress that emerged with the second Industrial Revolution: formal and informal knowledge combining together   
  
to produce a discontinuous Aevent@ followed by decades of microinventions which eventually produced a major   
industry, with further technological progress stagnating when most of the obvious improvements were exhausted.

\* In textiles, progress after 1870 was gradual and not marked by great   
breakthroughs. One major innovation that came to its own in this period was the sewing machine.

\*Conclusions. The second Industrial Revolution was, in many ways, the continuation of the first. In many   
industries there was direct continuity. Yet it differed from it in a number of crucial aspects. First, it had a direct   
effect on real wages and standards of living which clearly differed significantly in 1914 from 1870. Second, it   
shifted the geographical focus of technological leadership away from Britain to a more dispersed locus, though   
leadership remained firmly the monopoly of the industrialized Western world. Finally, by changing the relation   
between knowledge of nature and how it affected technological practices, it irreversibly changed the way   
technological change itself occurs. In so doing, what was learned in these years prepared the way for many more   
Industrial Revolutions to come.

\***social Darwinism**, the theory that human groups and races are subject to the same laws of [natural selection](https://www.britannica.com/science/natural-selection) as [Charles Darwin](https://www.britannica.com/biography/Charles-Darwin) perceived in [plants](https://www.britannica.com/plant/plant) and [animals](https://www.britannica.com/animal/animal) in nature. According to the theory, which was popular in the late 19th and early 20th centuries, the weak were diminished and their [cultures](https://www.merriam-webster.com/dictionary/cultures) delimited while the strong grew in power and cultural influence over the weak. Social Darwinists held that the life of humans in society was a struggle for existence ruled by “survival of the fittest,” a phrase proposed by the British philosopher and scientist [Herbert Spencer](https://www.britannica.com/biography/Herbert-Spencer).

\*Why was the invention of the electric light bulb so important to US businesses?

More than 150 years ago, inventors began working on a bright idea that **would have a dramatic impact on how we use energy in our homes and offices**. This invention changed the way we design buildings, increased the length of the average workday and jumpstarted new businesses

\*The American Industrial Revolution (IR) is considered as the Second IR (IR2) which creates rural to an urban society. Great   
inventions during the IR2 are electricity, internal combustion engine, the chemical industries, petroleum and other chemicals,   
alloys, electrical communication technologies, and running water with indoor plumbing. The development of steel and oil   
refining has affected US industry. Transportation and communications technology has changed business practices and daily life   
style of many people. Inventions of medicine and medical instruments have reduced the rates of infections and death from   
many diseases and public health has improved greatly. Global political, economic, and social systems have widely changed   
very rapidly. Between 1820 and 1920 about 33 million people, mainly labors, have migrated to the USA for seeking greater   
economic opportunity and cities become overcrowded. Low wage, dangerous working conditions, long working hours, child   
labor, discrimination in wages, etc. have created labor dissatisfaction. Moreover jobless and wage cut of labors railroad strike   
has broke out in many cities of the USA.

\*The period 1860–1914 is called the Second Industrial   
Revolution (IR2) or the US IR due to the invention of a large   
number of new technologies, such as electricity, internal   
combustion engine, the chemical industries, alloys,   
petroleum and other chemicals, electrical communication   
technologies (telegraph, telephone and radio), and running   
water with indoor plumbing [42]. During the IR2, the   
inventions and innovations were science-based that were   
centered on iron and steel, railroads, electricity, and   
chemicals [6]

\*Vaclav Smil (1943–), a Czech-Canadian scientist and policy   
analyst, called the period 1867–1914, “The Age of Synergy”,   
during which most of the great inventions and innovations were developed [99]. The IR2 is the creation of a modern   
industrial economy, advancements of steam power, and   
transportation, and new era of communication. The start of   
the IR2 is often attributed to Samuel Slater (1768–1835), an   
early English-American industrialist, who opened the first   
industrial mill in Beverly, Massachusetts of the USA in 1790.   
He introduced a vital new technology in the USA and was   
known as the “Father of the American Industrial Revolution”

\*In 1783, the USA won its Independence against Britain. After   
the independent it had been imported most of the   
  
manufactured goods from Britain. The domestic production   
of the country was poor and it also suffered shortage of labor.   
The story of the US IR is an epic tale, full of heroes and   
heroines, villains and vagabonds, accomplishments and   
failures, sweated toil and elegant mechanisms, grand visions

and unintended consequences. In 1807, Robert Fulton (1765–1815), an American engineer   
and inventor, used steam power to create the first steamboat   
on the Hudson River that changed the way and the speed [16].   
The use of steam-powered railways, boats and ships had   
increased dramatically. More industries used interchangeable   
parts and machinery in steam powered

\*Thomas Alva Edison (1847–1931), an US inventor, created   
revolutionary new technologies, such as light bulb, mass   
communication, phonograph, kinetograph (motion-picture   
camera), and electric dynamo in the 1880s [102]. By 1874,   
Alexander Graham Bell (1847–1922), a Scottish-born   
  
scientist and American inventor, invented telephone. He   
founded the American Telephone and Telegraph Company   
(AT&T) in the USA in 1885

\*Charles Babbage (1791–1871), an English mechanical   
  
engineer considered the “father of the computer”. He   
invented the first mechanical computer in the early 19th   
century. The invention of the computer brings blessings in   
the IR2 [47].

\*American railroad travel was more comfortable for   
  
adjustable upholstered seats. Railroads helped for low-priced   
transportation of materials and products. Cheap coal helped   
to develop steam locomotives. By 1850, more than 14,000   
km of railroad lines had been built in the USA [108].

\*At the end of the IR2, higher wages and improved conditions   
in cities raised the standard of living for urban workers. The   
scale of the standard of living in the USA was huge biggest   
than that was during the IR1 in England [43]. The companies   
of Germany and the USA started to sell their goods all over   
the world. Scientific discoveries and inventions in the IR2   
rapidly changed social structures, such as scientific thought,   
art and culture, architecture, and life style

\*During the IR2 the USA has a diverse nation. In 1877, total   
population of the USA was just 47 million. Birth rate was   
very high; 15% of married women had 10 or more children,   
and another 22% had between 7 and 9. Half of the total   
population was aged 20 or less. In 1900, the US population   
became 76.2 million [106]. The birth rate was also very high   
in Britain. The population in London was 0.96 million by   
1800, 1.4 million by 1815, 3 million by 1860, and 6.5 million   
by 1900 [48]

\*In 1870, globally there was no electricity in the houses. In   
night, rooms were lighted with candles and oil lamps.   
Cooking was done by biomasses and stoves. Rooms were   
dark and unhealthy with smoke and polluted air. Water for   
cooking and other household works, and remove of   
  
wastewater was carried out by the housewife

\*In the late 19th century the USA was a society without social   
security. Medicare, antibiotics, health insurance, radio,   
television, computers, airplanes, and automobiles had   
invented during the IR2. After the invention of telephone   
there were only 9 in the entire USA. The US government had   
only 22,000 federal employees excluding military and post   
office. There was no civil service system and no income tax   
in the country [112].

\*The late 19th century, from the 1870s to about 1900, is called   
the “Gilded Age” by Mark Twain and Charles Dudley Warner   
which they meant that the period was glittering on the surface   
but corrupt underneath. During this period there were greedy,   
corrupt industrialists, bankers and politicians who enjoyed   
extraordinary wealth and opulence at the expense of the   
working class. Most of the working class lived below the   
poverty level [81].

\*On the other hand, during the IR2 agrarian society were   
transformed into an urban society dominated by industrial   
corporations, the creation of a modern industrial economy,   
development of national transportation and communication   
network, a managerial revolution transformed business   
operations, etc. Also during the IR2 there were some   
turbulence, such as labor violence, rising racial tension militancy among farmers, and discontent among the   
  
unemployed in the society. By 1900, one in 200 US   
populations was addicted to opiates or cocaine.

\*As the production advances, the need for laborers grew   
rapidly in the industrialized countries. Adults (men and   
women) and children worked in factories, coal mines, and   
mills. More than 33 million people entered the ports of the   
USA, massive from Europe. Immigrants and their children   
totaled 30–40% of the white population in the USA. Urban   
populations grew very quickly because of the vast migration   
to cities from rural areas. America is considered as a nation   
of immigrants or a “melting pot” [61]. Gas and water supply,   
and sewage systems in large cities were advanced. Wages for   
workers in Europe and America increased after 1870. As   
transportation costs reduced, prices for manufactured goods   
became lower

\*Karl Marx (1818–1883), German journalist, and his co-  
author Friedrich Engels (1820–1895), a German political   
thinker, son of a textile mill owner, wrote ‘The Communist   
Manifesto’ in 1848. This book made bold steps to create the   
new industrial economy and the breakthroughs in industrial   
technology [73]. They blamed the system of industrial   
capitalism for horrible conditions in factories. They   
demanded that the IR1 had enriched the rich but made   
insolvent the poor. They showed logically that government   
control factories, mines, railroads, and other key industries   
that would end poverty and promote equality which they   
called socialism [114]. Later they demanded that all land,   
mines, factories, railroads, and businesses, would be owned   
by the people which they called communism [33]

\*capitalism = an economic and political system in which a country's trade and industry are controlled by private owners for profit, rather than by the state.

\*American inventors produced many new machines that could   
be applied to industry as well as to agriculture. Oliver Evans   
(1755–1819), an American inventor, engineer and   
businessman designed a steam engine more powerful than   
that of James Watt [55].   
  
Humphrey Davy (1778–1829), a Cornish chemist and   
  
inventor, had demonstrated its lighting capabilities as early as   
1808. In 1831, Cyrus McCormick (1809–1884), an American   
inventor and businessman, invented harvesting machine that   
boosted American wheat production. In 1837, Samuel F. B.   
Morse (1791–1872), a New England painter and inventor,   
first sent electrical signals, the biggest increase in the speed   
of communication in human history, over a telegraph. It is the   
communication process using wires with electricity. The   
telegraph instantly sent messages within seconds to the entire   
USA and even in the UK. Very soon continents were linked   
with undersea cables and whole world came with telegraph   
communication. By 1966, Western Union, the leading   
  
telegraph company had more than 2,000 telegraph offices In 1846, Elias Howe (1819–1867), an American inventor,   
invented the sewing machine In 1876, Scottish-  
born inventor Alexander Graham Bell (1847–1922) patented   
the telephone. By the end of the 1800s, Bell Telephone   
Company had installed more than one million telephones. In   
1901, Italian inventor Guglielmo Marconi demonstrated the   
first transatlantic signal using Morse Code and Wireless   
Telegraphy. In 1906, the first human voice signal was   
transmitted across the Atlantic through radio transmissions   
using the airwaves

\*Typewriters with various keyboards had been invented as   
early as 1714 by English inventor Henry Mill (1683–1771)   
[109]. In 1867, Christopher Sholes (1819–1890), an   
  
American inventor, invented typewriter with QWERTY   
  
keyboard [50]. In 1877, Thomas Alva Edison invented   
Phonograph in the USA. He also created light bulb in 1879   
and Joseph Swan (1828–1914), English physicist, chemist,   
and inventor, invented carbon paper light in 1860 in Great   
Britain, and opened homes and cities to electric lights [112].   
In 1885, a German engineer, Gottlieb Daimler, invented a   
light, portable internal combustion engine [113]. In 1903,   
Orville and Wilbur Wright of the USA made the first airplane

\*Richard Jordan Gatling (1818–1903), an American inventor,   
invented the Gatling Gun in 1862. This was the first   
automated machine gun [60]. In 1866, Robert Whitehead   
(1823–1905), an English engineer, produced the first self-  
propelled underwater missile naval torpedo. It had speed to   
13 km/h and could hit a target 640 m away [44]. Mathematics   
played a significant role in the development and application   
of scientific inventions. During the IR1 and IR2 many   
mathematicians had developed science

\*During the IR1 textiles, railroads, coal, and iron had   
developed. Iron and steel, coal, and railroads developed at the   
beginning of the IR2 and later developed chemicals,   
electricity, paper, and petroleum

\*Abundance of steel helped to   
spur the IR2 in the USA

\*In 1857, Sir Charles William Siemens (1823–1883), a   
German-British engineer and entrepreneur, developed 70–80%   
heat saving furnace. In 1865, French engineer Pierre-Émile   
Martin (1824–1915) for the first time used Siemens’s furnace   
to produce steel. By 1880, the cheap steel used to build   
buildings, large bridges, railroads, skyscrapers, and large   
ships. Steel cable, steel rod, and sheet steel were produced   
for household use. Steel was used to make guns, tanks,   
armored fighting vehicles and naval ships. The US steel   
industry production increased 68,000 tons in 1870 to 4.2   
million tons in 1890

\*Refine of crude oil produces kerosene which used in lamp to   
produce light or used as fuel. In 1859, Edwin Drake (1819–  
1880), an American businessman, used steam engine to drill   
for oil near Titusville, Pennsylvania. By the 1880s oil wells   
produced 25 million barrels of oil in Pennsylvania and West   
Virginia [104].

\*In 1863, John D. Rockefeller (1839–1937), an American oil   
industry business magnate, industrialist, and philanthropist,   
entered the growing oil industry and eventually founded   
Standard Oil Company in 1870. He made horizontal   
  
integration of oil industry. In 1880, Standard Oil Company controlled 90% of the rail industry. He is widely considered   
as the wealthiest American of all time and the richest person   
in the modern history

\*The petroleum industry, both production and refining, began   
in 1848 with the first oil-works in Scotland [23]. In 1850,   
James Young (1811–1883), a Scottish chemist, built the first   
truly commercial oil-works and oil refinery in the world at   
Bathgate. He is often referred to as Paraffin Young. Using oil   
he extracted from locally mined turbinate, shale, and   
bituminous coal to manufacture naphtha and lubricating oils

\*The famous English scientist and experimentalist Michael   
Faraday (1791–1867) established the basis for the concept of   
the electromagnetic field in physics. Sir Humphrey Davy   
(1778–1829), a Cornish chemist and inventor, using   
  
electricity isolated a series of elements for the first time:   
potassium and sodium in 1807 and calcium, strontium,   
barium, magnesium and boron the following year, as well as   
discovered the elemental nature of chlorine and iodine

\*In 1870, there was no supply of electricity in the houses and   
offices. The insides of dwelling units were not only dark but   
also smoky from the burning of candles and oil lamps, and   
cooking by iron stove and hearth [43]. In the 1870s, the use   
of electricity expanded quickly. In 1886, Frank J. Sprague   
(1857–1934), an American naval officer and inventor,   
developed the electric motor, electric railways, and electric   
elevator. He was known as the “Father of Electric Traction”

\*By the 1880s, streetcars and subways of major European   
cities are lighted by electricity. Electricity could be easily   
converted into other forms of energy, such as heat, light, and   
motion, and moved easily through space by means of wires.   
By the use of electric lights, factories could remain open 24   
hours every day. Telephone, radio, conveyor belts, cranes,   
and machines could all be powered by electricity. By 1910,   
hydroelectric power stations and coal-fired steam generating   
plants established

\* Firms distributed their products to regional or   
national markets due to the improvement of transportation.   
Prices for manufactured goods were lower because of   
reduced transportation costs. Development of new financial   
institutions, such as the stock market, commercial banks, and   
investment in houses increased the opportunities for   
collecting capital. Corporation organizers raised money by   
selling shares of stock in the company. The US entrepreneurs took advantage of changes in business organization.

\*During the IR2, business leaders of the USA turned to   
corporations which raised money by selling shares of stocks   
in the company and Stockholders received dividends.

\*In 1877, the average income of an US urban family was $738.   
Two-thirds of that earning was spent on food and heating. A   
family can save only $44 after managing other family   
expenditures. But there was a rapid economic growth at the   
late 19th century. Old economy with a relatively slow speed   
of technical changed to a new one with a relatively fast speed.   
Real gross domestic product (GDP) became more than seven   
times (about 1.7% per year) between 1865 and 1920 [19].   
The US economy also experienced sustained and gradually   
accelerating real per capita growth rates of 1–2% per year for the next two centuries Industrial production, appears to have   
increased at a sustained rate of about 5% per year from   
1790–2014. Between 1869 and 1910, the value of the US   
manufacturing rose from $3 billion to $13 billion. Germany   
and the USA captured the markets and occupied superior   
ranks in the world economy

\*After the Civil War a new economy emerged in the USA on   
the basis of steam-powered manufacturing, the railroad, the   
electric motor, the internal combustion engine, and the   
practical application of chemistry [56]. At the beginning of   
the Civil War, there were only 400 millionaires in the USA   
and by 1892; the number had risen to 4,047 due to the rise of   
big business. By 1929, nine out of ten Americans had   
electricity and indoor plumbing, four-fifths had automobiles,   
two-thirds had radios, and nearly half had refrigerators and   
phonographs

\*State banking systems expanded rapidly and the rapid growth   
of the economy increased demands for credit. Many banks   
were established by entrepreneurs who used them as funding   
agencies [64]. In the early 1790s, Philadelphia and New York   
opened stock exchanges. Public stock markets grew rapidly from the 1880s to the   
1930s to make liquid the securities of increasing numbers of   
large, capital-intensive enterprises

\*European countries developed railways, mines, electrical   
power plants, and banks. Europe dominated the world   
economy by the beginning of the 20th century

\*Development of steel and oil refining industry has changed   
the construction of sophisticated machinery, bridges, tall   
buildings, etc. In 1897, Rudolf Diesel (1858–1913), a German inventor and mechanical engineer, invented the   
Diesel engine which was used both in road cars and   
  
locomotives. Maximum efficiency was obtained from it by   
isothermal expansion so that very few energy was wasted,   
and a cheap, crude fuel could be used to boot.

\*By 1876, Nikolaus August Otto (1832–1891), a German   
engineer, after 14 years of effort, invented compressed charge   
internal combustion engine four-stroke powered by gasoline.   
It was the first successful horseless carriage. Within the 20   
years of his invention, Charles Duryea (1861–1938) and J.   
Frank Duryea (1869–1967) built the first practical motorcar   
in the USA. Only wealthy class passengers could use those   
cars

\*In 1885, Gottlieb Daimler (1834–1900), a German engineer,   
industrial designer and industrialist, invented a light, portable   
internal combustion engine.

\*Cars made at the late of the 19th century were handmade,   
expensive, slow speed (14 miles per hour), and unable to   
climb steep hills. In 1908, Henry Ford (1863–1947), an   
American industrialist, business magnate, and the founder of   
the Ford Motor Company, made mass-produced Model T on   
October 1, 1908 that reduced production costs. As a result,   
Ford lowered the price of the automobile that was affordable   
to middle class people and became popular among Americans.   
A Model T cost $850 in 1908 but only $360 by 1916 and   
produced 735,000 cars in a year

\*The USA followed and copied British rail technology. From   
the 1720s the USA had wooden railroads (wagon ways). In   
1827, the first passenger and freight line started between the   
Baltimore and Ohio railroad using horses to pull train cars.   
The South Carolina Canal and Rail Road Company used   
steam locomotives in 1830

\*During the IR2, railroads became faster, safer, and more   
comfortable that played a significance role in the   
  
development of the USA. The availability of cheap steel had   
an impact on the railroad industry. Steel had greater strength,   
durable, and can make longer lengths to use in railroads.   
George Westinghouse (1846–1914) had developed an air   
compressed brake, which made the locomotives safer.

\*In the late 19th century, American shipyards built modern   
metal ships that are better than the British. By 1870, steel   
ships built by the USA were much larger, more powerful, and   
faster than wooden ships. Gustav de Laval (184–1913), a   
Swedish engineer and inventor, and Charles Parson (1854–  
1931), an Anglo-Irish engineer, invented steam turbine in   
1884 that moves at 63 km/h

\*In 1903, Orville (1871–948) and Wilbur (1867–1912) Wright   
(Wright brothers) of Ohio were two American aviation   
pioneers generally credited with inventing, building, and   
flying the world’s first successful airplane for the first time at   
Kitty Hawk, North Carolina. Internal combustion engine   
used to run the flights

\*The invention of telegraph and telephone has allowed   
businesses to place long-distance orders very quickly; sent   
information for businesses to the government, newspapers,   
and private citizens [90]. The invention of typewriter has   
created the opportunities of quick production of legible   
documents and several copies at once with carbon paper that   
helped the economic development [50].   
  
In 1901, Italian inventor and electrical engineer Guglielmo   
Marconi (1874–1937) successfully commercialized radio at   
the turn of the century [53]. He built high-powered stations   
on both sides of the Atlantic and began a commercial service   
to transmit nightly news summaries to subscribing ships in   
1904

\*Working conditions during the IR2 was low wage, dangerous   
working conditions, long working hours, etc. The average US   
worker was jobless for three or four months a year due to   
illness, rough weather, or seasonal unemployment. The   
average income of an urban worker was only about $400 to   
$500 in a year that was unable to support a family. The rest   
was made up by the income of their wives and children.   
About 20% of the family income came from the children of   
aged less than 16

\*The period between 1820 and 1920 is defined America as a   
nation of immigrants or “a melting pot”. Many immigrants   
came for seeking greater economic opportunity. During this   
time more than 33 million people entered the ports of the   
USA. Between 1860 and 1900, about 14 million immigrants   
came to the USA to provide workers in industries [61].

\*Dangerous working conditions, long hours, and concern over   
wages and child labor contributed to the growth of labor   
unions. In the 1870s, in Great Britain, unions won the right to   
strike. Workers organized strikes and work stoppages that   
helped to publicize their problems

\*Many rail lines became bankrupt and were unable to pay the   
interest on their bonds major due to global economic   
depression. As a result, many workers became jobless and   
those were in job cut larger part of wages. For example, in   
1877, the Pennsylvania Railroad, the nation’s largest railroad   
company cut wages of labors by 10% in May, and another 10%   
in June. Other railroads followed it [94]. The railroads had   
their own separate unions. The great railroad strike happened   
in 1877 that was the first general strike in the US history.   
Labors agitated for higher wages, equal pay for equal work,   
shorter hours, end to child labor, and better working   
conditions, or for more fundamental transformations in the   
nation’s economy

\*There were both advantages and disadvantages during the   
IR2. The IR2 began in the USA in the mid 19th century and   
later spread throughout many other parts of the world. It   
developed global political, ecological, and cultural spheres. It   
helped to create global import and export markets. In the IR2   
the existing manufacturing and production methods of IR1   
were improved. For example, instead of iron, steel had used for the construction of ships, skyscrapers, and larger bridges.

\*