The Industrial Revolution

As told by Dr. Frank Elwell

Rate of Innovation

Throughout much of the agrarian era, the rate of technological innovation was less than one would expect in view of the size of agrarian societies, the amount of information available to them, and the extent of contact among them.

Rate of Innovation

The cause of this lay in their highly exploitive social systems, serfdom and slavery in particular, and in the ideologies that shaped their member's economic attitudes and activities.

Rate of Innovation

- Not surprisingly, these had negative feedback effects on both technological and economic development.
- Late in the agrarian era the rate of innovation in western Europe increased substantially, and by the latter part of the 18th century the industrial revolution was well under way.

Industrial Revolution

The industrial revolution involved the transformation of a technology resting heavily on human and animal labor into a technology characterized by machines.

Industrial Revolution

Along with this came the transition from a heavy reliance on agricultural production to a reliance on the manufacture of goods for sale in the context of a factory system.

Industrial Revolution

The industrial revolution was, at bottom, a revolution in technology; nevertheless, it created new and profound changes in the structure and superstructures of the new society.

Industrial Revolution

It brought new methods of production and exchange of goods, profound changes in the organization of labor, and leading to changes in community, family life, ideologies, and ways of thought.

Industrial Revolution

What was responsible for this important development? What happened to break the agrarian mold and produce this burst of technological innovation in societies that had been so resistant to change? What happened to turn the system of negative feedback into a system of positive feedback?

Industrial Revolution

- Advances in Agriculture
- Environmental Depletion
- Capitalism
- Advances in Transportation
- Accumulation of Information
- Unique historical circumstance

Advances in Agriculture

- Declining Efficiency
- Moldboard plow
- Horse Collar
- Three-field rotation

Declining Efficiencies

BETWEEN THE 13TH AND 16TH CENTURIES, WESTERN EUROPE BEGAN TO EXPERIENCE DECLINING EFFICIENCIES IN AGRARIAN PRODUCTION.

Declining Efficiencies

Wood, the energy base of the medieval way of life, became increasingly scarce. The subsequent search for alternatives finally led to the replacement of wood with coal. The move to an economy based on coal changed the entire way of organizing life in western Europe.

Moldboard Plow

The land in western Europe was very different from the land in the semiarid Middle East. There the soil was extremely light; in the wetter climate of western Europe the soil was often moist and heavy, making it much harder to plow.

Moldboard Plow

THE CROSS PLOW WAS EQUIPPED WITH A "VERTICAL BLADE TO CUT THE LINE OF THE FURROW, A HORIZONTAL PLOWSHARE, AND A MOLDBOARD TO TURN OVER THE SOD."

Moldboard Plow

AS A RESULT, PRODUCTIVITY BEGAN TO RISE DRAMATICALLY. BY THE 9TH CENTURY THE CROSSPLOW HAD BEEN INTRODUCED THROUGHOUT THE CONTINENT.

Moldboard Plow

Its effectiveness in plowing west European soils led to the deforestation of mile after mile of low-lying timberlands, as the expanding population brought more and more acreage into cultivation.

Moldboard Plow

THE NEW PLOW CHANGED THE ORGANIZATION OF AGRICULTURAL LIFE. BECAUSE IT WAS SO HEAVY, THE CROSS PLOW REUIRED A TEAM OF 8 OXEN TO PULL IT. ENCOURAGED COOPERATIVE FARMING AND LARGE FIELDS.

Three Field Rotation

The traditional two-field rotation system, where half the land was always left fallow in order to renew fertility, gave way to the three-field system, where only one-third of the land remained fallow every year.

Three Field Rotation

Increased population pressure began exerting demands for increased crop yields. Under the three field rotation system production was increased by one-third.

Three Field Rotation

BY INCREASING THE USE OF THE LAND, THE 3 FIELD SYSTEM DISSIPATED THE SOILS ENERGY. MORE HAD TO BE BROUGHT UNDER CULTIVATION. MILE AFTER MILE OF LOW-LYING TIMBERLAND WAS DEFORESTED.

Deforestation

"Many parts of Western Europe had achieved a kind of saturation with humankind by the 14th century. The great frontier boom that began about 900 led to a replication of manors and fields across the face of the land until, at least in the most densely inhabited regions, scant forests remained. . .

Deforestation

"...Since woodlands were vital for fuel and as a source of building materials, mounting shortages created severe problems for human occupancy." -- William McNeill

Deforestation

THE PROBLEM WAS GREATLY MAGNIFIED BY THE EXPANDING POPULATION IN CITIES THAT NEEDED TO BE FED. NOW, WITH POPULATION INCREASING FASTER THAN AGRICULTURAL OUTPUT, THERE WERE NO MORE SURPLUSES TO BE TRADED AND THE CITIES BEGAN TO COLLAPSE.

Environmental Depletion

The whole fabric of medieval economic, social, and political life began to disintegrate. It was at this point that a new energy base took hold, the replacement of wood (solar) with coal (fossil fuels).

Environmental Depletion

In order to comprehend the magnitude of the medieval energy crisis, it is important to understand how crucial wood was used for just about everything. Carpenter's tools, rakes, the cart, wagon, washtub, bucket and broom, the loom and spinning wheel, ships, the principal machines of industry were often made of wood.

Environmental Depletion

While the clearing of forests for cultivation greatly reduced the available wood supply, it was the quickened pace of commercial activity that led to a timber famine.

Environmental Depletion

For example, the new glass works and soap industry required large amounts of wood ash. but it was the production of iron and building of ships that made the greatest demands.

Environmental Depletion

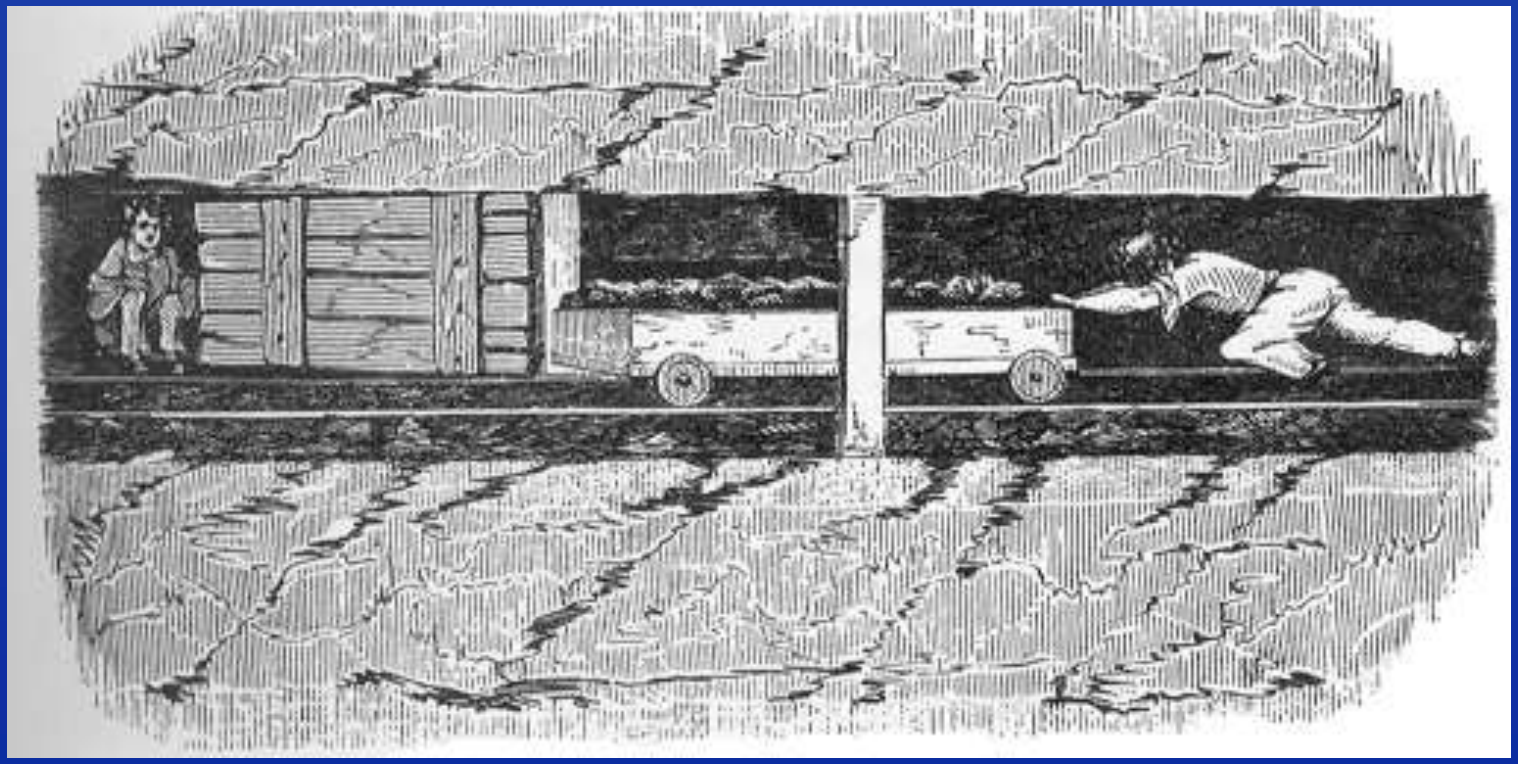
- BY THE 16TH CENTURY THE TIMBER CRISIS WAS SO ACUTE IN ENGLAND THAT A ROYAL COMMISSIONS ATTEMPTED TO REGULATE THE CUTTING OF FORESTS.
- BY 1630, WOOD HAD BECOME 2 AND A HALF TIMES MORE EXPENSIVE THAN IT HAD BEEN IN THE LATE 15TH.

Environmental Depletion

The answer to the wood crisis was coal. But the changeover necessitated the radical uprooting of an entire way of life.

Environmental Depletion

The cultures of Europe had been thoroughly integrated into a wood-based existence. The changeover necessitated changes in the way people made a living, the way they dressed, the whole way of life.



Boys working in a British mine in the nineteenth century: after the Mine Act of 1842, boys under the age of 10 could no longer be employed in mines.

Intensification

In 13th century England the people of Newcastle were without firewood and literally freezing to death. King Henry II consented to the mining of coal as an alternative energy source.

Intensification

In the 15th century, Pope Pius II wrote that while in Scotland on a visit he was surprised at the sight of people in rags lining up at church doors to "receive for alms pieces of black stone with which they went away contented. This species of stone they burn in place of wood of which their country is destitute."

Intensification

By 1700 coal had begun to replace wood as the energy base for England. Within 150 years the same held true for much of western Europe.

Intensification

Today we think of the substitution of coal for wood as a great leap forward. It would have been difficult to convince the folks back then. Coal was treated with contempt as an inferior energy source. It was dirty and created a great deal of pollution.

Intensification

Coal was also more difficult to extract and process than wood. It required the expenditure of a great deal more energy to transform it into a usable state.

Intensification

The reason is that available energy is constantly being dissipated. The more available sources of energy are always the first to be used. Each succeeding environment relies on a less available form of energy than the one preceding it.

Intensification

It is more difficult to mine coal and process it than it is to cut down trees. It's still more difficult to drill and process oil, and even harder to split atoms or fuse them together.

Intensification

Over the course of social evolution man has been forced over and over again to change the resources he depended on and the methods he used to exploit them. Slowly she has had to involve herself in more and more complicated processing and production techniques to exploit a depleting environment.

Intensification

We are used to thinking of great leaps forward in history occurring because someone came up with a better way of doing things. Actually, these so-called better ways are in reality only different ways of doing things occasioned by the need to readjust to harsher, less easily exploitable energy resources.

Intensification

The modern steam engine was designed and first used to facilitate the mining of coal.

Intensification

As mines had to be sunk deeper into the ground to extract available supplies, it became more difficult to ventilate the mines and to lift the coal up the shafts.

Intensification

During the 17th century, mines faced still another problem. At a certain depth the water table was reached and drainage became a priority. All these problems required a technological solution. The steam engine was the answer.

Intensification

The steam pump used in mining was only the first in a long series of mechanical innovations to come directly out of the new coal environment.

Intensification

For example, no sooner had the problem of mining the coal been resolved with the introduction of the steam pump than a second problem arose--how to transport the coal to markets throughout the country.

Intensification

Because of the heavy bulk, coal was not easily transported over land by horse-drawn wagons. The steam locomotive was a direct technological response to the needs created by the new coal environment.

Intensification

Throughout social evolution, qualitative changes in technology have always been toward more complexity and greater energy expenditure, because each major change in the environment has been toward less available, harder-to-reach sources of energy.

Intensification

Not only has more work been required with each new environment, but the new way of doing things is usually perceived as an inferior substitute for the old way. coal, canned and packaged food

Capitalism

By the middle of the 18th century, England had clearly emerged as the dominant power within the expanding European world-economy.

Capitalism

England had expanded her import and export markets through capitalism and had concentrated within herself enormous quantities of wealth. This wealth became essential as capital to be used in financing factories and machinery, and thus England was in a uniquely favorable financial position to engage in industrial development.

Capitalism

Capitalism has a bias towards increased profitability and will innovate when it is profitable to do so.

Capitalism

INDUSTRIALIZATION PERMITTED INCREADING PRODUCTIVITY AND LOWERED COSTS, WHICH IN TURN, ALLOWED FOR THE EXPANSION OF ENGLAND'S EXISTING DOMESTIC AND FOREIGN MARKETS AND FOR THE CREATION OF NEW ONES.

Capitalism

THE RESULT WAS THE INCREASING ACCUMULATION OF CAPITAL ON A GRAND SCALE. (MACHINERY WAS NOT A PREREQUISITE TO FACTORY PRODUCTION--PRE- AND POST-SEWING MACHINE DRESS FACTORIES.)

Advances in Transportation

Prior to compass navigation beyond the sight of land was extremely hazardous. Stern rudder replaced steering oars attached to the sides of ship, construction of larger ships with multiple masts, several sails, and a reduction in width of ships relative to their length.

Recent reconstruction of the Santa Maria illustrates the advances in shipbuilding in the late medieval period. Note the multiple masts and sails, the stern rudder, and the relatively narrow beam.

Advances in Transportation

All of these innovations made ships more responsive and more manageable. With such ships western European sailors increasingly venture out into open seas for extended periods.

Accumulation of Information

Another factor causing the industrial revolution was the gradual accumulation of technological information throughout the agrarian era. As a result of many advances, the store of technological information available in the 18th century was far greater than in the 13th.

Accumulation of Information

Advances in construction and engineering, for example, can still be traced if one compares the churches and cathedrals built in western Europe in successive centuries.

Accumulation of Information

Printing press resulted in a tremendous increase in the quantity of printed materials in western Europe, including materials on science, technology and agricultural practice.

Unique Historical Circumstance

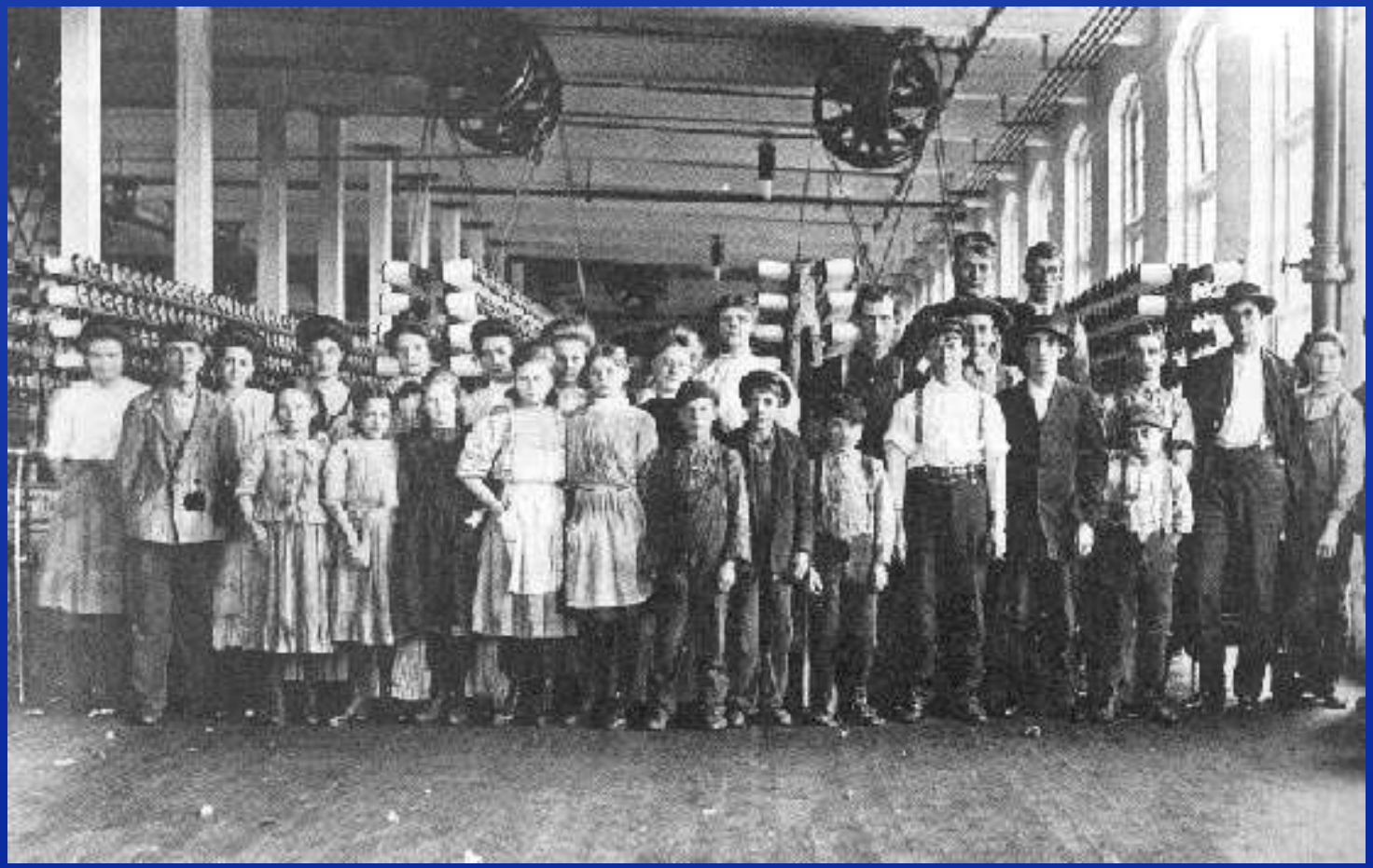
Discovery of the New World. In addition to gold and silver, western Europe quickly gained control over vast territories with tremendous resources and farmlands

Unique Historical Circumstance

- Protestantism
- Division of authority
- Black Plague

I.R.: First Phase

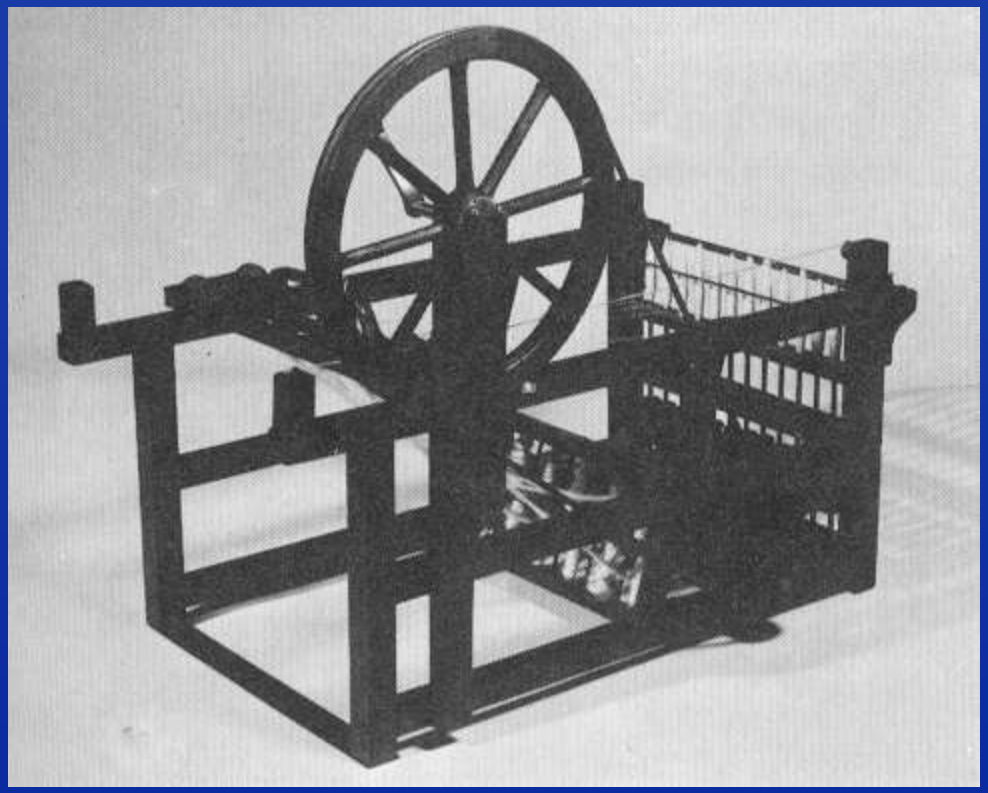
The industrial revolution began in England during the second half of the 18th century, its first phase typically dated from about 1760 to 1830. This phase was first marked by major developments in the textile industry.



During the early stages of the Industrial Revolution, large numbers of children were employed in factories in both the United States and Britain.

I.R.: First Phase

Inventions include: spinning jenny, water frame, the power loom, cotton gin, steam engine. The growth of textile manufacture spurred the development of the factory system. Textiles formed a vital part of the English economy and were a major export in the international system



James Hargreave's spinning jenny.

I.R.: First Phase

The invention of the steam engine was also an important part of this process, as it was used to power the heavy machinery housed in the textile factories.

I.R.: First Phase

The iron industry also underwent significant expansion in the first phase of industrial development. Iron was increasingly in demand for the manufacture of steam engines and machine tools; machine tool production itself became a significant feature of the English economy.

I.R.: First Phase

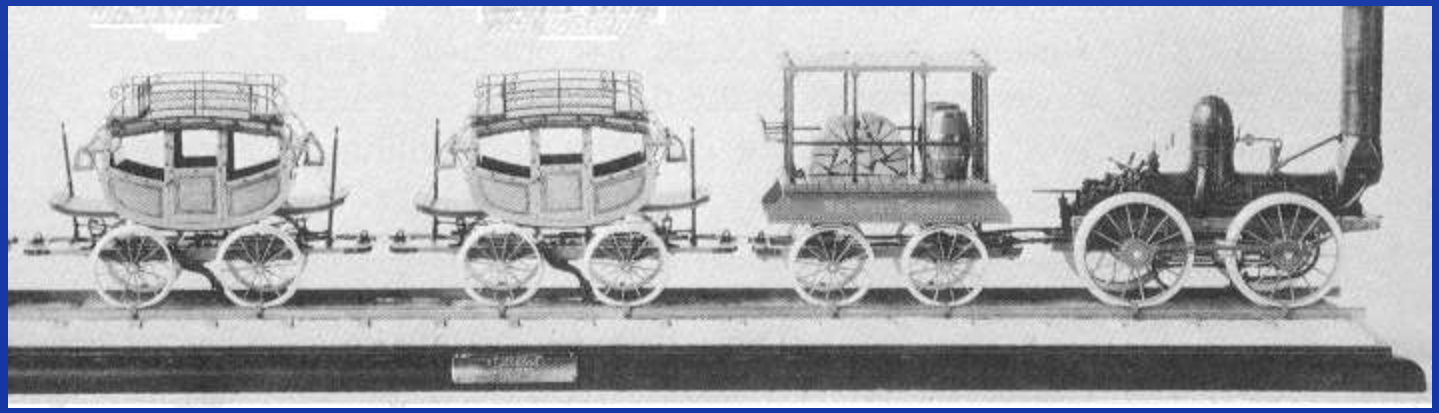
- The increasing manufacture of these products, in turn, caused an increase in the demand for coal and the expansion of the coal-mining industry.
- Industrial technology soon spread to several other parts of Europe during the 19th century, especially to France, Belgium, Germany, and the U.S.

I.R.: Second Phase

In the middle of the 19th century, further technological innovations emerged and existing technologies were elaborated and applied to production on a wider scale.

I.R.: Second Phase

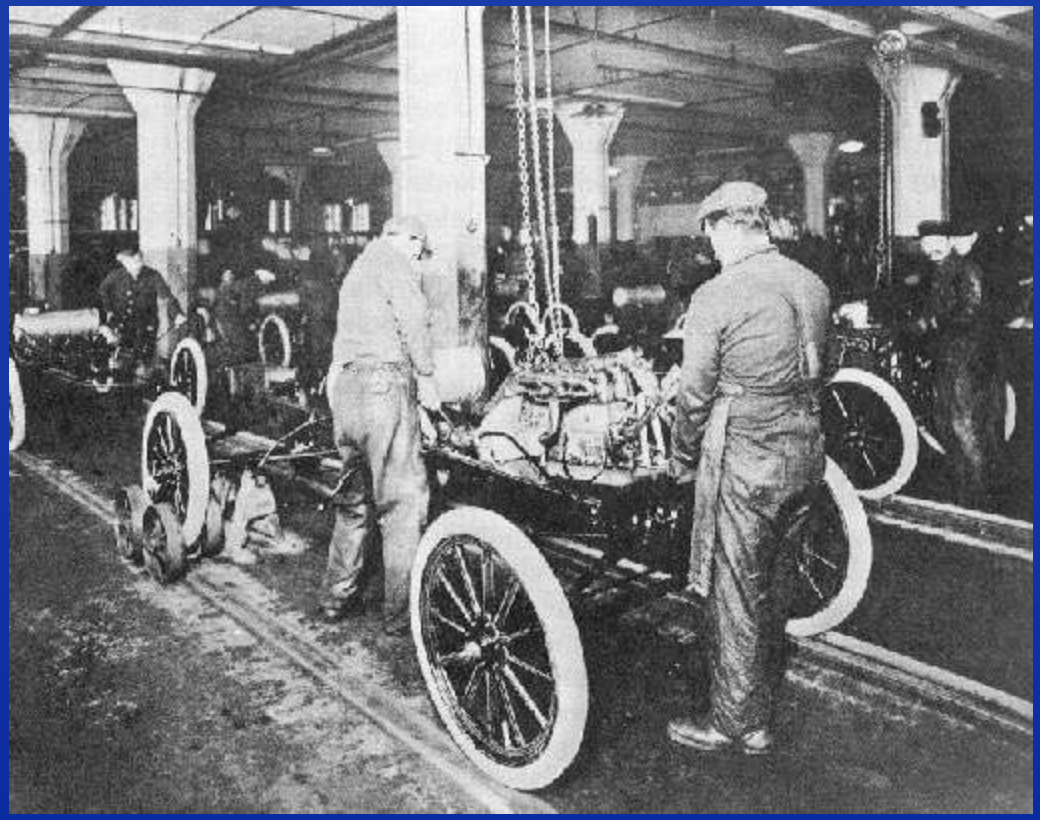
For instance, the steam engine came to be applied to transportation. It was used to create the first steam railway and was applied as well to navigation with the invention of the steamboat.



Model of the DeWitt Clinton, built in New York in 1831. On its first run between Albany and Schenectady, it traveled twelve miles in less than an hour. Note the similarity of the coaches to stagecoaches and the engine to an ordinary steam engine already in use in factories and in the mines.

I.R.: Third Phase

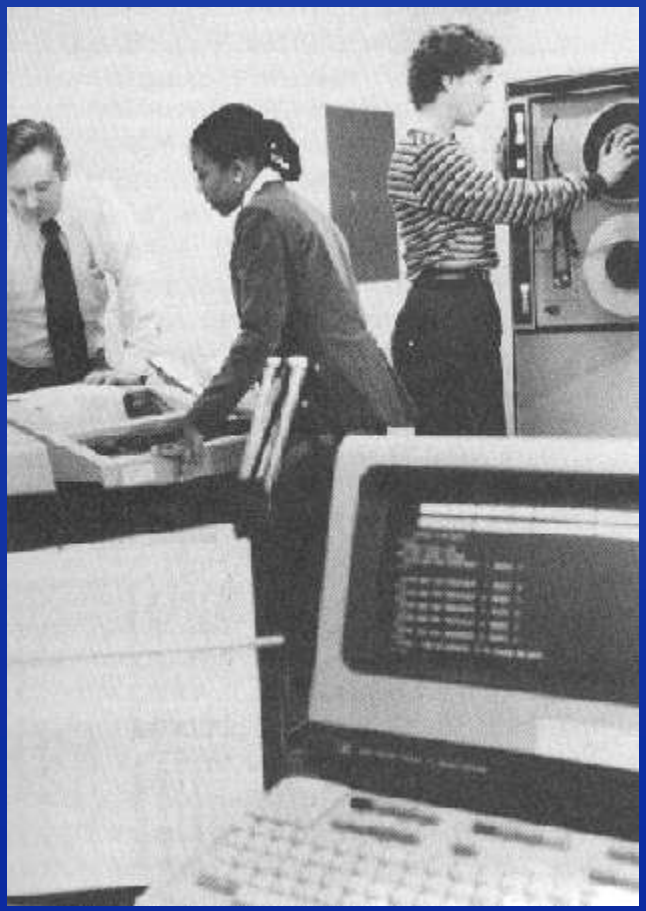
By the turn of the 20th century, the automobile, electrical, and petroleum industries were becoming important features of life in industrial societies.



Early automobile assembly line: dropping the engine into the Model T chassis, Highland Park, Michigan.

I.R.: Fourth Phase

By World War II, the aviation, aluminum, and electronics industries were achieving major economic significance.



The most revolutionary innovation of the fourth phase of the Industrial Revolution has been the computer.

Fifth Phase

I call “hyper-industrialism” in which the computer, communications, and bio-technology are all applied to intensify the industrial mode of production.

Fifth Phase

The result is a society that is rapidly bureaucratizing its structure (bureaucracies are expanding in power and scope, primary groups declining in importance) and rationalizing its superstructure (principles such as rationality, efficiency, and calculability increasingly dominate the norms and values of society.

On Phases

Rather than as an event or a series of events, industrialization is best thought of as a continuous process that has existed down to the present time.

Industrial societies as of 1995 are shown in dark blue.