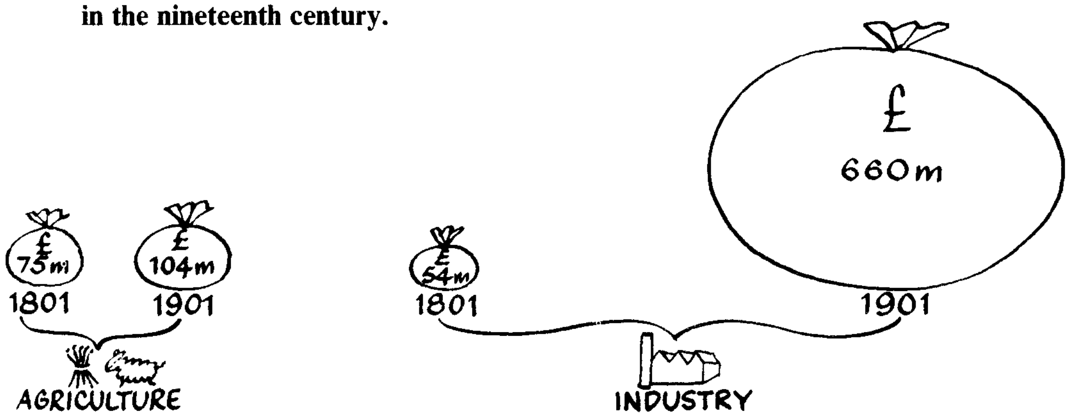
THE INDUSTRIAL REVOLUTION

The story of Britain in the years 1789-1900 is largely the story of the Industrial Revolution—that is, how Britain changed from being an agricultural country to an industrial one. This diagram shows the changes in agricultural and industrial output between 1801 and 1901.

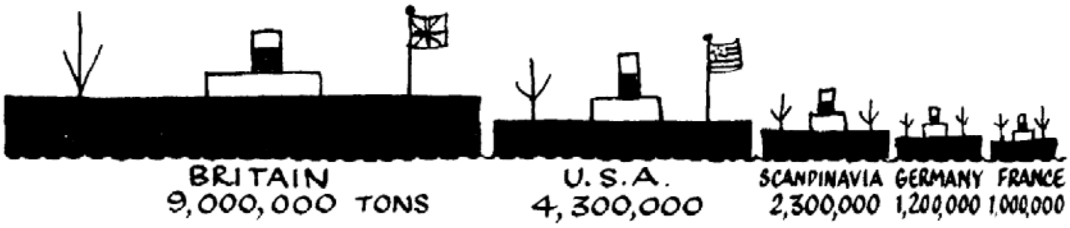
Changes in the amount of money received by agriculture and industry in the nineteenth century.



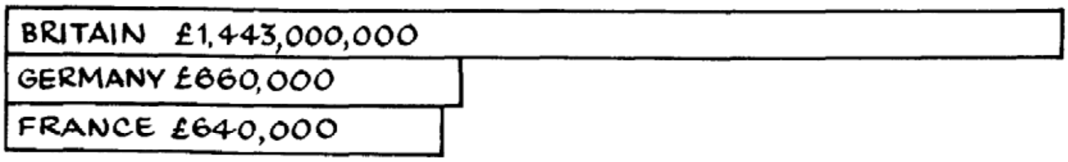
This is the century when wood gave way to iron and steel, and when muscle power was replaced by steam power. These were the years when the manufacture of all kinds of goods moved from simple hand machines in people's homes to huge, powered machines in gigantic factories. These were the years when great industrial cities sprang up in the midlands and north of England and Scotland; in which horse-drawn waggons lumbering along muddy roads at 3 miles an hour gave way to express trains rushing along a network of railways at 60 miles an hour, and in which the population rose from a mere 10 millions to 30 millions.

These were the years of science, discovery and invention; of slums, disease and plague. This was the age of the struggle of the working people for education, freedom and a decent standard of living. These were the years that made Britain the richest, most powerful and most advanced country in the world, importing food and raw materials from every corner of the globe and more than paying for them by exporting vast quantities of every type of manufactured product from drawing pins to sea-going liners. These charts give some idea of Britain's position in the world at the end of the nineteenth century.

The world's merchant shipping in 1890.

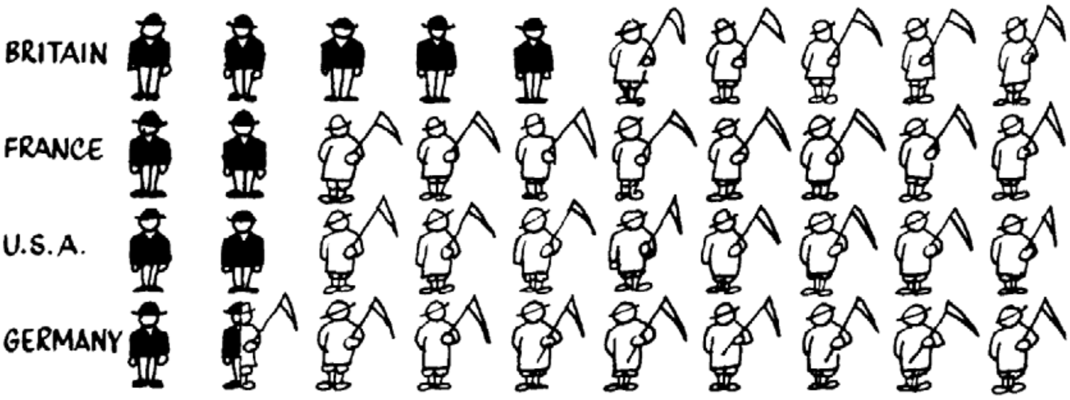


Trade (exports and imports) for 1880 and 1890.



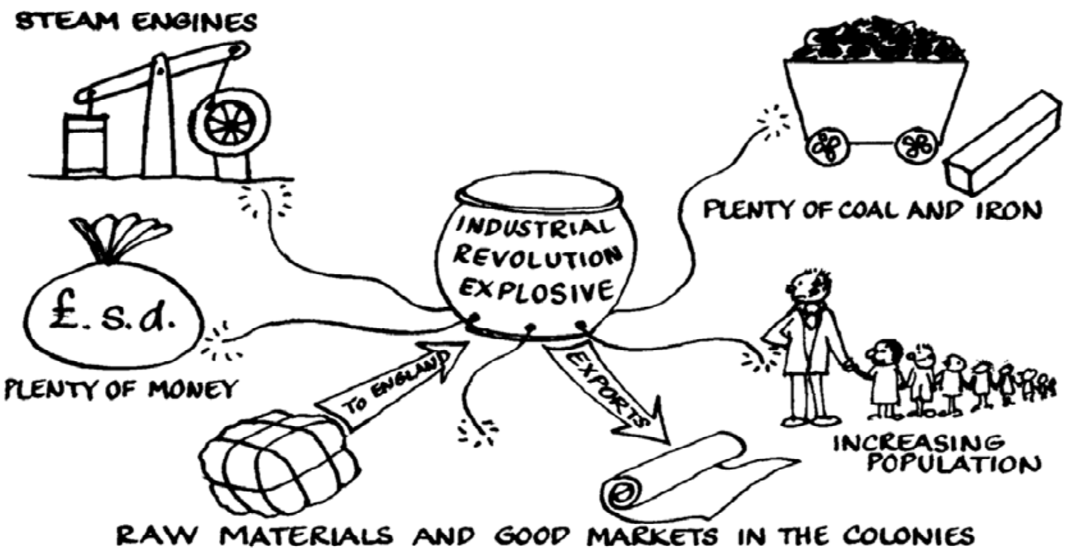
Town and country dwellers.

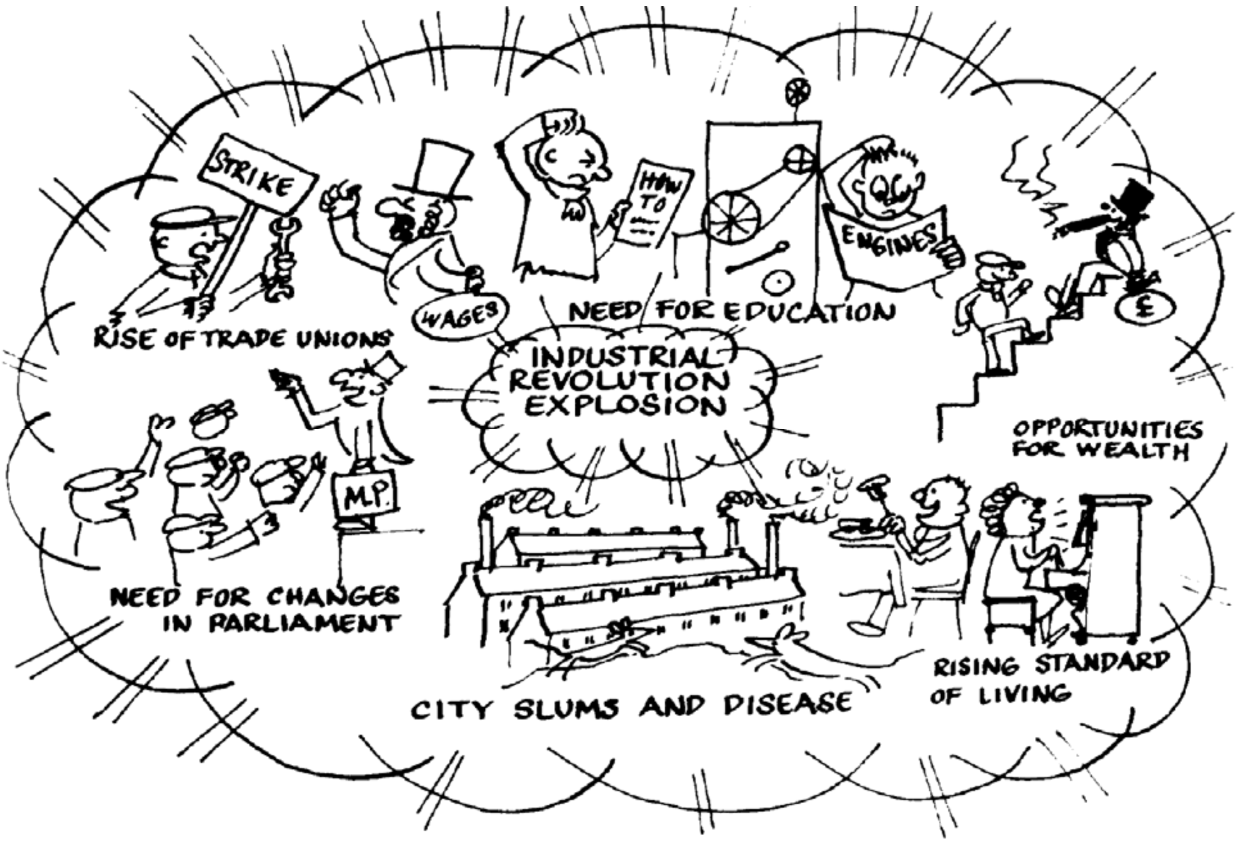
Of every ten people the following lived in towns.



Why the Industrial Revolution took place

The Industrial Revolution was the greatest change that had ever taken place in British history—or indeed in the history of the modern world, because Britain became industrialised almost 50 years before any other country. The explosion shook the nation to its very foundations and turned its whole way of life upside down. Even today, over a century later, the effects of this great upheaval are still being felt in our housing, our transport systems, our attitude to industry and our position in the world.





During the seventeenth and eighteenth centuries Britain had won many colonies such as India, Canada and much of America until 1783. As many of these countries were undeveloped they urgently needed manufactured goods of all kinds, especially cloth and small metal items. In return Britain could obtain raw materials such as cotton very cheaply from them.

Many merchants, especially the slave dealers, were very wealthy, and were anxious to invest their money to make even more. They were willing to pour large sums into new businesses, factories and inventions if these looked like showing a good profit.

There was, therefore, a great demand for goods, and many business men were anxious to make them, but these reasons alone might not have been enough if the population had not risen so sharply. in the eighteenth and nineteenth centuries. All of these extra people had to be fed and clothed, and work had to be found for them. The new methods of farming introduced between 1700 and 1800 needed fewer labourers so that there were large numbers of unemployed country men and women, who were desperate to find work.

The old system of hand manufacture could not absorb all of these extra people, but just at the right moment there came a number of inventions which changed the whole picture. The Darby family discovered ways of producing iron cheaply and in large quantities: Kay, Hargreaves, Arkwright and Crompton invented machines to speed up weaving and spinning, and James Watt improved the clumsy steam engine so that it could drive the new machinery efficiently.

Yet all of this might have come to little if Britain had not had vast seams of coal and iron waiting to be mined. As it was, everything was in its right place at the right time: the demand for cloth, the money, the inventors, the coal and iron, and the workers. The five pieces of the jig-saw fitted perfectly. and the Industrial Revolution was under way.

The coming of the steam engine

Without a doubt the one invention that made the Industrial Revolution possible was that of an efficient steam engine to replace machines driven by human muscles, horses or water power.

As early as 1705 Thomas Newcomen had invented a crude steam engine for pumping water from the Cornish tin mines, but this worked very slowly and used an enormous amount of coal. In addition it produced only an up and down movement which was quite suitabie for pumping but could not be used to drive other machinery.

About 1760 James Watt was asked to repair a model of Newcomen's engine and he realised at once that he could improve it. He produced the simple but revolutionary device you can see in Fig 2, and by 1780 he had a factory turning out engines which were faster and more powerful than Newcomen's, and also used less than one quarter of the coal. In addition, Watt invented a way of making his engines turn a large wheel which could be used to drive machines such as spinning jennies. This was all that was needed to set the Industrial Revolution sweeping through the land. Long before 1800 the steam engine was pumping water and lifting cages in coal mines, working bellows and great hammers in iron works and turning machinery in factories of all kinds.

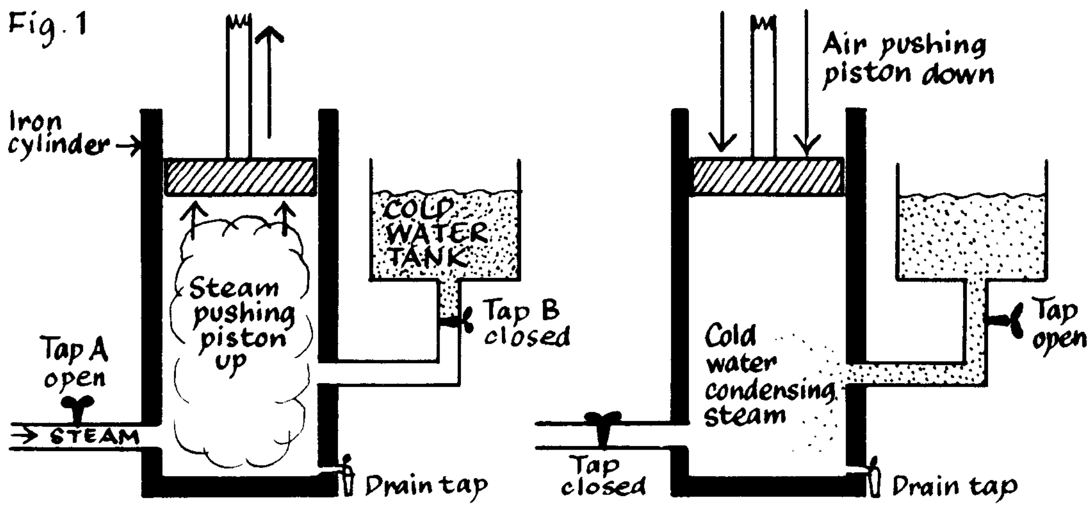
Such an engine was obviously going to be used in transport, too, and by 1812 the first serious steamship and goods railway were in operation.

All through the nineteenth century engineers improved and redesigned the steam engine to make it more powerful and more efficient until Watt would scarcely have recognised his own invention. There were steam cranes, steam ploughs, steam road trucks and even attempts to make steam flying machines. For over a hundred years steam was king, for it was the steam engine that had made Britain the richest and most powerful country in the world. British trains and British ships carried goods made in British factories all over the world—and all of these depended on the steam engine.

Then, suddenly, in fifteen years, came three developments which in the twentieth century were to unseat steam as the king of power. In 1870 scientists working in Italy, Belgium and France discovered how to make electricity in a practicable way using a dynamo. This obviously had a great future, but it was not a success until Sir William Parsons invented the turbine in 1884. This was still driven by steam but it was a completely different machine from the old Watt-type engine, and as it ran very smoothly and at high speed it was ideal for driving dynamos and ships. About the same time Dr Daimler in Germany perfected the petrol engine which now powers cars, buses, ships and aeroplanes all over the world. By the end of the nineteenth century, however, all three of these great discoveries were only just coming into serious use.

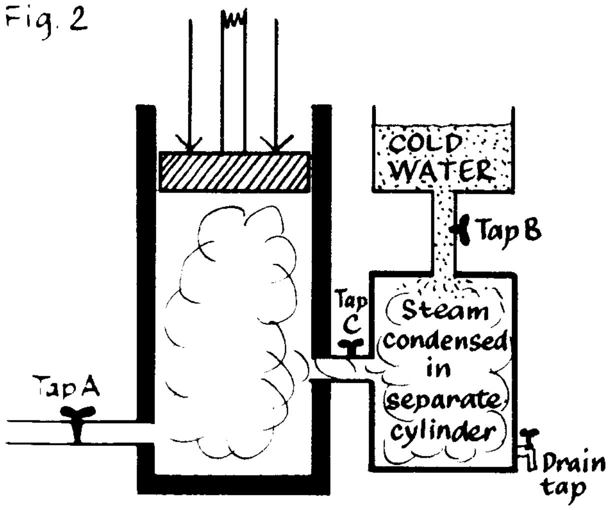
Newcomen's steam engine.

Fig. 1



To start, tap B was closed and tap A opened to let the steam push the piston upwards. When this was at the top, tap A was closed to shut off the steam and tap B opened to let cold water into the cylinder to condense the steam. The air then pushed the piston back down. Unfortunately the cold water also cooled the heavy iron cylinder which had to be heated again before the steam could start to push up the piston for the second stroke. This wasted a great deal of fuel.

The secret of James Watt's engine.



Watt's great invention was very simple. When the piston reached the top of its stroke, tap A closed to shut off the steam. Tap C then opened to let the steam escape from the main cylinder into a separate cylinder by the side. Cold water was let into this second cylinder to condense the steam. By this means the main cylinder was not cooled a in the Newcomen engine, and the piston was ready for the next stroke immediately. This saved so much fuel that for every ton of coal burned by a Newcomen engine, a Watt engine used only five hundredweights.

The effects of steam power

The coming of steam power to replace hand labour was bound to have a great effect on the lives of the people. First of all, the engines were very big and expensive and could not be bought by ordinary people to drive their spinning wheels or simple machinery at home. Wealthy merchants built huge sheds, installed machines in them and powered these by steam. Instead of working at home as they had done in the past, people were forced to go to the new factories as they could no longer make enough money on their slow hand machines.

As the steam-driven equipment worked so much harder and faster than hand machines, many more goods were produced by the same number of workers. This not only meant that prices began to fall but also that more people could enjoy them. At the end of the century ordinary working families had clothes, furniture, carpets, ornaments. books, food, amusements and many comforts which a hundred years earlier would have been beyond the dreams of anyone except a very rich man.

The steam-driven railways and ships made transport faster, more comfortable and much cheaper so that ordinary people could now travel. Before the Industrial Revolution few men went more than ten miles from their birthplace in the whole of their lives, but now they could travel far and wide seeking work, visiting relatives or even just for pleasure. The faster transport enabled perishable foods such as milk, vegetables, fruit, meat and fish to be moved quickly from the country or coast to the towns so that even poor people could now enjoy them. In the end the steam engine caused the standard of living to rise in every direction. hut to millions of working people in the first half of the nineteenth century it seemed to bring nothing but evil.

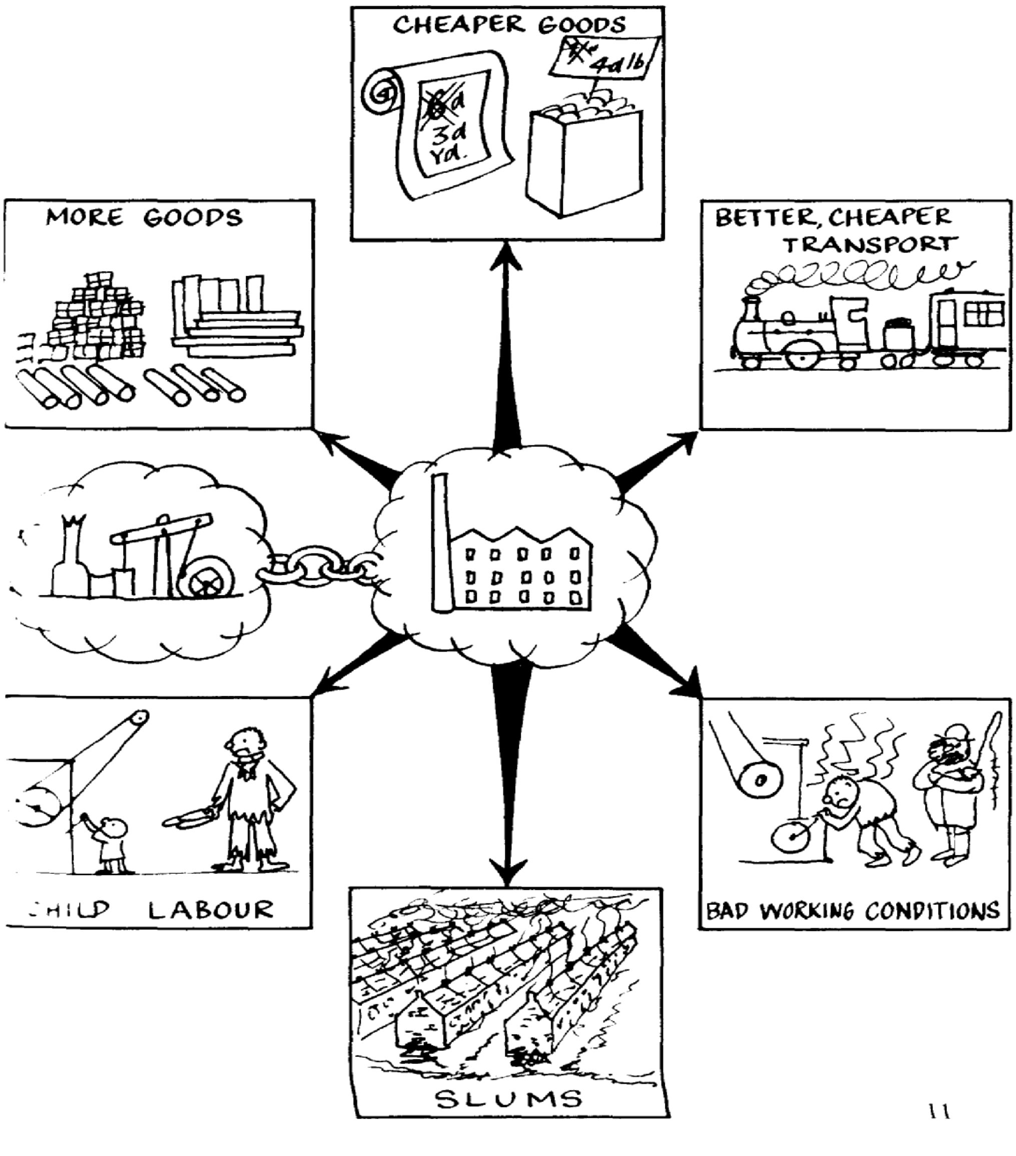
Before the Industrial Revolution much of industry had depended on muscle power. Women and children were not strong enough for working with iron, for example, nor even for the heavy hand looms, so that these had to be managed by men. Now, under the factory system, steam supplied the power and a woman or even a child could pull a lever or turn a knob to make the machine work as easily as a man could—and a child could be paid less than a quarter of a man's wage. As a result wages were very low, and often the whole family—father, mother and all the children over three or four years old—had to work in the factory or mine for twelve or more hours a day in order to earn enough to live.

Although when people worked in their own homes the hours were long and the work hard, they were their own masters and could stop when they felt like a break. In the factory they were forced to keep moving as long as the engine kept pounding, and there are many reports of children collapsing from sheer weariness into the machines, The factories were often very hot. badly ventilated and full of fumes and fluff. Many of the factory owners were so harsh and greedy that if any worker stopped for a drink or to open a window he was often fined as much as half a day's wages.

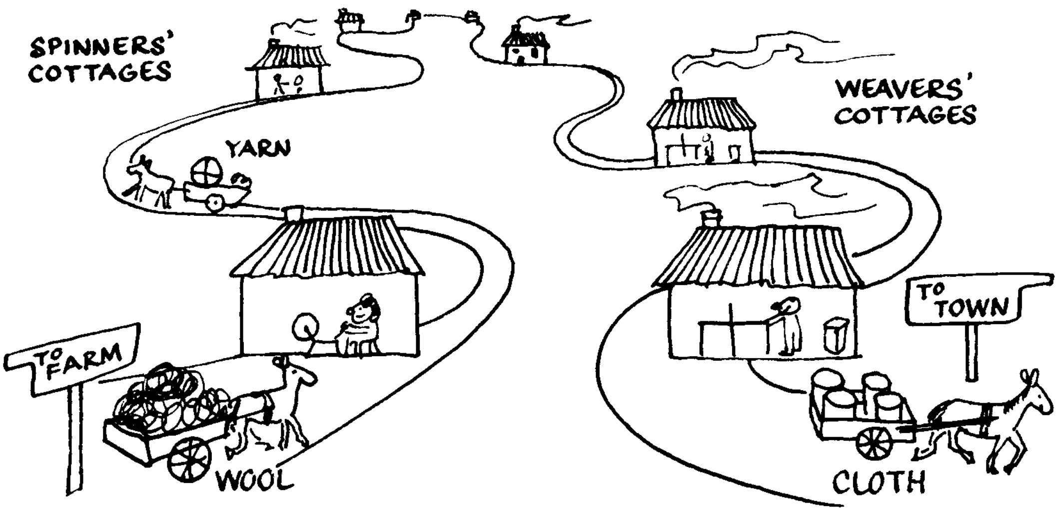
Life in the factory was bad, and life outside was, for much of the century, little better. The workers usually lived in rows of tiny, poorly built hovels which clustered round the factory itself. These over-crowded, rat-infested, filthy streets soon became the worst slums in Europe, as you can read in Chapter 4. The working people of the early Industrial Revolution paid a terrible price for the comfort' and prosperity they were to bring to later generations.

Although we tend to think of steam engines driving machines in factories, railways and steamships, they were tried in many other fields. There were steam airships, steam aeroplanes (which did not really fly), steam roundabouts, steam organs, steam cranes, steam cars, steam tractors, steam motorcycles, and even a steam submarine in 1879.

SOME OF THE EFFECTS OF THE STEAM ENGINE

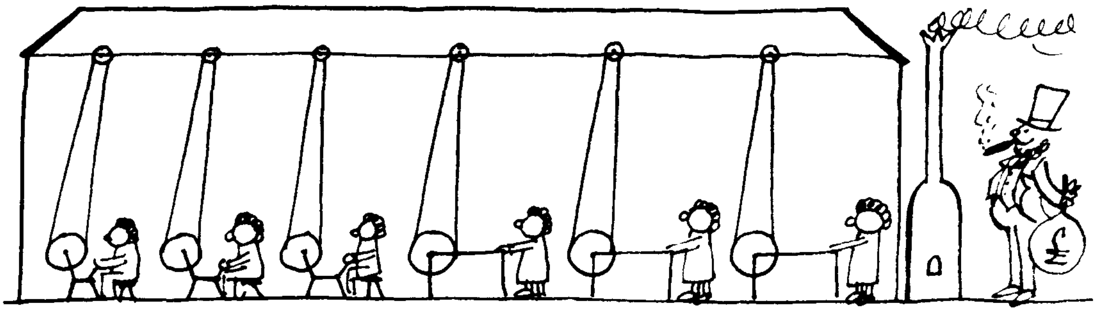


The cottage system.



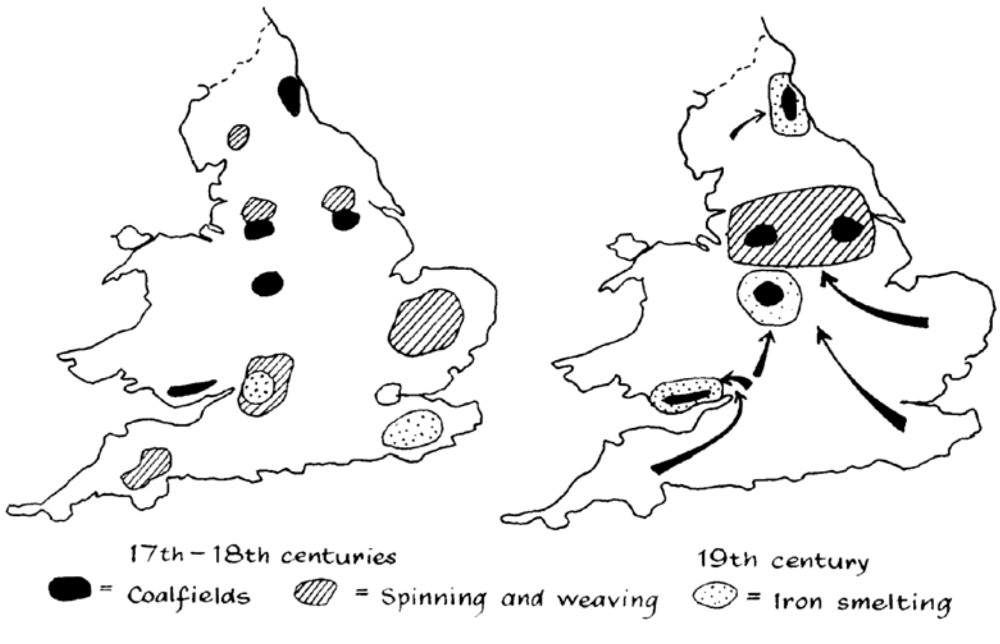
The merchant collected the wool . . . took it to the spinners and collected the yarn they had spun. He took the yarn to the weavers' cottages and took away the cloth they had woven. This method was slow and led to great variation in quality because some workers were much better than others.

The factory system.



The merchant installed all the spinning machines in a huge shed and powered them first by water wheels, and later by steam engines. He could now keep an eye on his workers, but for them it was almost slavery.

How industry moved during the Industrial Revolution following the coal which was needed for the steam engine.



Before the industrial revolution, in the days of the cottage industry. spinning and weaving took place all over the country, but East Anglia. Gloucester, Somerset and Wiltshire, parts of Devon, Cumberland, Lancashire and Yorkshire were especially well known. After the steam engine and the factory system became widespread there was little textile industry except in Lancashire (mainly cotton) and Yorkshire (mainly wool). The main iron smelting areas moved from Sussex and Gloucestershire to the coal fields of Wales, the midlands and the north east.

Coal mining

Until the eighteenth century there was little demand for coal in Britain. A small amount was used for heating the vats in making beer and soap, and some was used in houses in the towns where it was difficult to get wood. But as the majority of the population still lived in the countryside, timber was the chief fuel for all purposes.

The mines, therefore, were small and shallow, and the coal was brought to the surface in baskets either carried on men's backs or hauled up by horse-driven windlasses. On the surface the roads from the pithead to the nearest port or customer were usually too bad for carts so that the loads had to be carried by packhorses. As each animal could carry only a few hundredweights at a time, moving coal in any quantity was a slow and expensive business.

Suddenly in the eighteenth century the demand for coal soared. In 1730 a method of smelting iron with coke instead of wood charcoal was discovered, and as timber was already becoming scarce in iron districts, large quantities of coal began to be used. After 1780 Watt's steam engine began to be used more and more in industry and this once more pushed up the demand for coal. During the nineteenth century railways, steamships, factories and gas works all needed fuel in ever-increasing amounts.

The tiny pits and the slow, lumbering packhorses could no longer supply enough to meet the new needs, and mines had to be made deeper and deeper to reach the bigger, richer seams that lay below. But with every yard downwards fresh problems arose. Water began to flood the workings; dangerous gases leaked into the tunnels; it was so far to the surface that the coal could no longer be carried by men or by horse windlass. Finally, at the great depths the danger of passages collapsing increased alarmingly.

Transport on the surface was the first of the problems to be solved. By the middle of the eighteenth century canals were being built to carry coal cheaply and quickly from the mines to the ports and to some inland towns. The railways came into use early in the nineteenth century, carrying coal more quickly than the barges and to places where the canals could not reach.

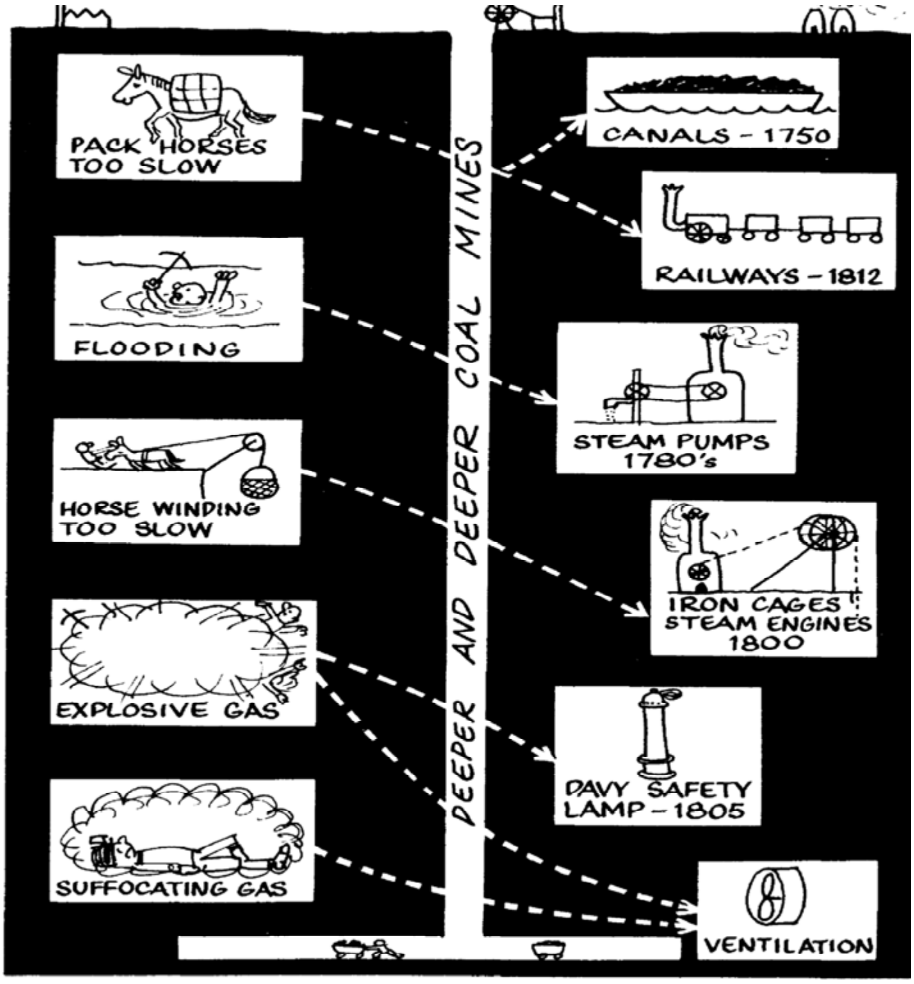
Almost as soon as it was invented the Watt steam engine was seized on by the colliery owners for pumping water from the pits and for hauling coal up the shafts. A little later iron cages and wire ropes were introduced to make transport to the surface quicker and safer. Better pumps and lifting gear tempted mine owners to make their pits deeper still so that the problem of ventilation rapidly grew worse. One gas suffocated the miners and another, much more dangerous, was so highly explosive that a single spark could destroy a whole pit. In 1805 Sir Humphrey Davy invented a safety lamp which allowed the miners to have a glimmer of light at the coal face without the danger of explosion, but mine owners made this an excuse to make their pits deeper still. As a result the number of deaths rose: there were fewer from explosions but the increase in those from rock falls more than made up for this.

The only real answer to the gas problem was good ventilation. I he powerful fans which are used today had not been invented so that the best that could be done was to dig two shafts to each pit. At the bottom of one a huge fire was lit and the hot air rising from this drew fresh air down the other and through the tunnels. To make sure the clean air passed through all of the passages doors were fixed across any side galleries.

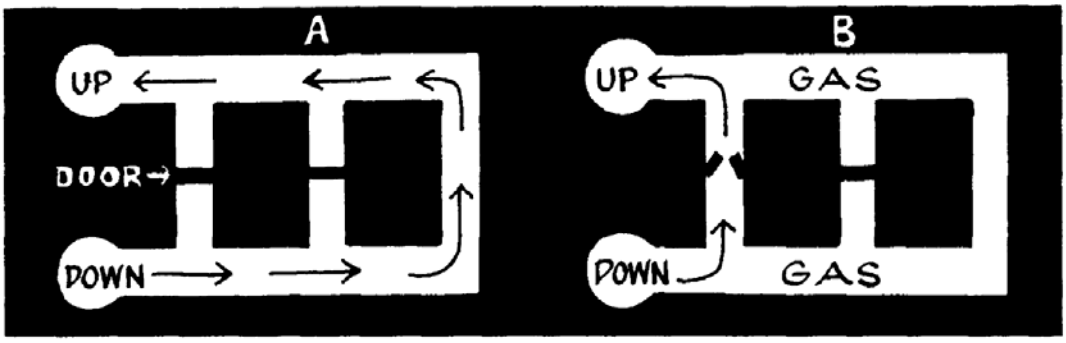
Opening and closing these doors when a tub of coal was being pushed along the tunnel was the job of children often only four years old. As you see in the drawing above, failure to close even one door could lead to an explosion which would kill hundreds of people. And this responsible job was left to mere babies working in pitch darkness hundreds of feet below the ground. This is what two of these children said to the government inspectors in 1842:

“I’m a trapper in the Gamber Pit. I have to trap without a light and I’m scared. I go at four and sometimes half-past three in the morning and come out at five and half-past. I never go to sleep. Sometimes I sing when I’ve a light, but not in the dark

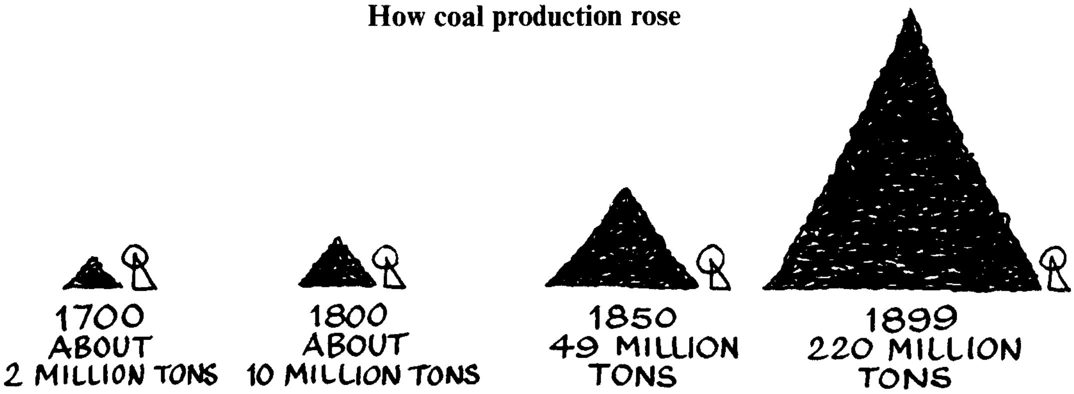
“1 been down almost three years [that is, when he was 4½]. When I first went down I couldn’t keep my eyes open: I don’t fall asleep now; I smokes my pipe .



How fresh air was sent round the mine workings. In sketch **B** a door has been left open to show how the clean air could take a short cut and allow gas to accumulate.



How coal production rose



As you can see in the drawing here above five times as much coal was produced in 1850 as in 1800, and by 1899 over twenty times as much was being mined. To give some idea of what 220,000,000 tons of coal means, imagine it all loaded on 5-ton lorries. If these trucks were placed nose to tail they would stretch in an unbroken line for 200,000 miles—eight times round the earth. This tremendous amount could not have been produced without the great improvements in the workings underground which came in the second half of the century.

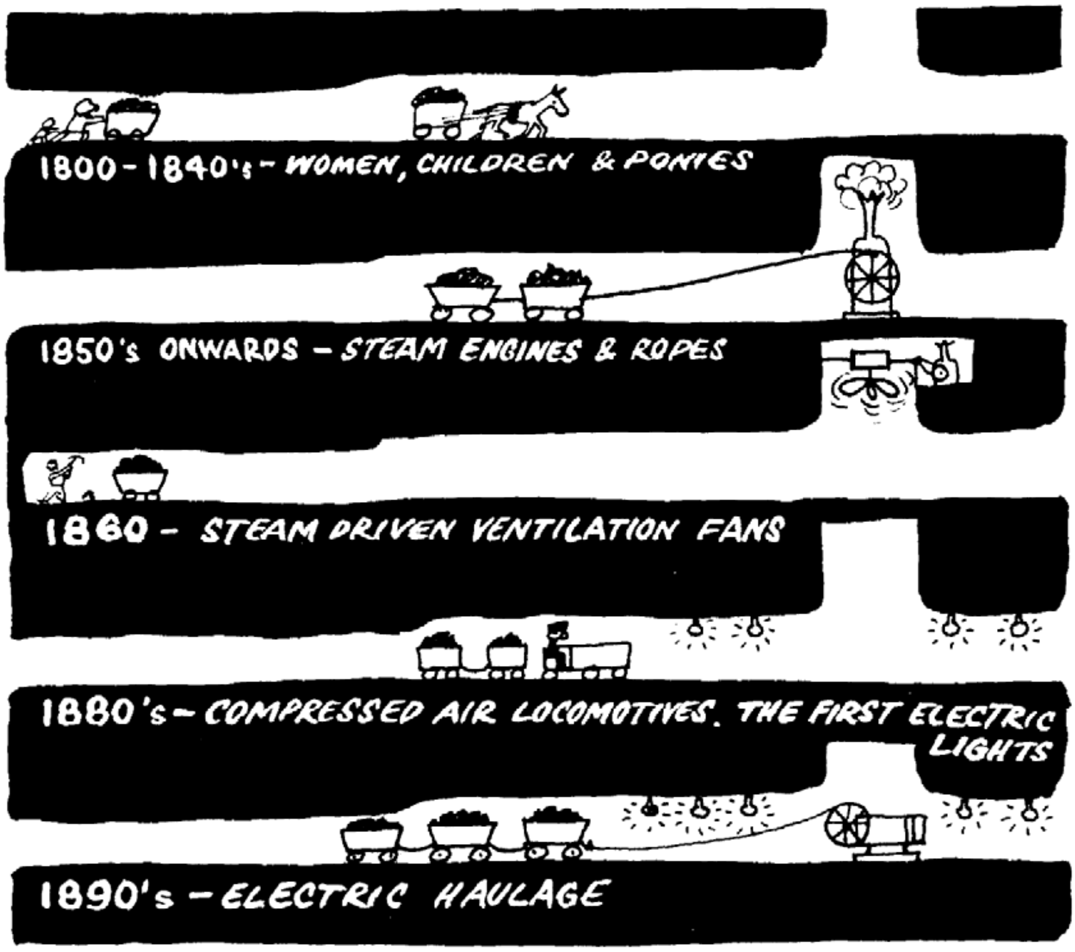
The steam engine which was so useful for hauling coal to the surface and for pumping out water was at a disadvantage underground. Its smoke would add to the ventilation problem and, more serious, there was the danger of setting fire to the gases. Nevertheless, some pits did install engines at the bottom of the shafts to pull trucks along the tunnels by means of long ropes. Until the 1840s however, most mines still employed women and children to drag the tubs of coal from the face to the shaft. When this was forbidden by law in 1842 ponies were used wherever the size of the tunnel allowed it.

Soon after the middle of the century steam-driven fans on the surface were used to suck out stale air and drive fresh down. This enabled pits to be made deeper and further afield, but it increased the problems of haulage underground.

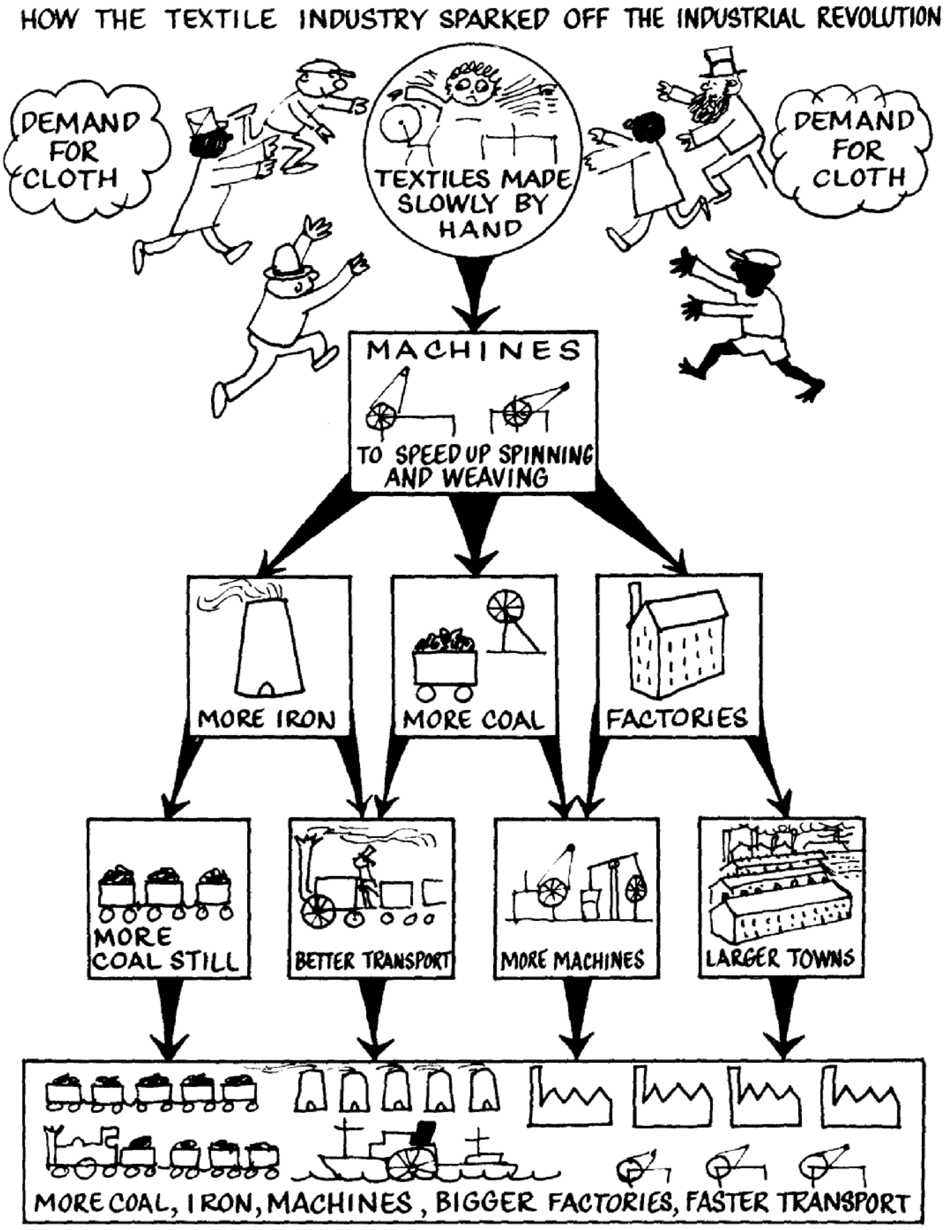
The first big advance in this direction came in 1880 when locomotives driven by compressed air were used to pull trains of tubs along the tunnels.

These were safe and fast but they were liable to run out of air at inconvenient places. At about the same time the first experiments were made with electric lights underground and a few lucky miners even had portable lamps. These, however, were extremely rare and the Davy safety lamps were general for the next thirty or forty years. With the coming of electricity it was obvious that here was the perfect answer for underground haulage. In the 1890s huge electric motors were installed in a few pits to pull the tubs by means of wire opes, some of them several miles long. Electricity too, seemed the perfect way of replacing the miner's pick and shovel, and a rush of inventions for mechanical cutting and digging machinery appeared. By the end of the century these were still in their infancy and almost all of that incredible weight of over two hundred million tons was hacked out by human muscle power.

Later developments in the mines.



Note-—even in the 1950s thousands of ponies were still used in the coal mines.



Textile manufacture

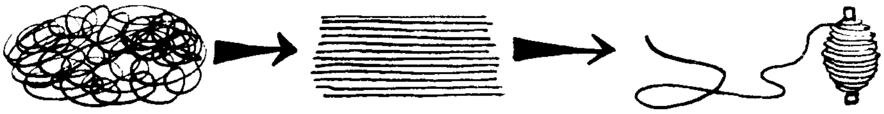
At the beginning of the eighteenth century the making of cloth was very little quicker than it had been in Roman times. It is true that the spinning wheel had speeded up the making of yarn a little, but the looms on which this thread was woven into cloth had scarcely changed in eighteen hundred years.

By 1700 the colonists in North America, the slave merchants trading to Africa and the people of the East were demanding so much cloth that the hand spinners and weavers could no longer keep pace with their simple equipment. In the last three-quarters of the eighteenth century many new machines were invented to speed up the manufacture of textiles which solved the problem of demand but created a great many difficulties the inventors had never dreamed of. More machines needed more iron: more iron needed more coal; the machines had to be placed in factories. More iron and more coal meant better transport and more machines to mine coal and smelt the iron. Factories meant more people in one place so that houses had to be built, which meant yet more transport, which meant more iron, more coal and more machines. The whole thing went in a steep spiral which we call the Industrial Revolution.

In the manufacture of textiles, either by hand or by machine, there are two main processes by which wool or cotton is turned into cloth.

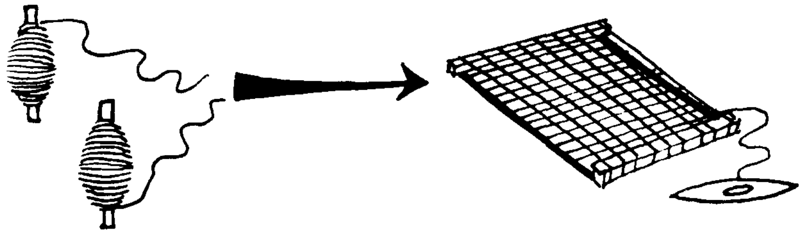
These are spinning and weaving.

Spinning



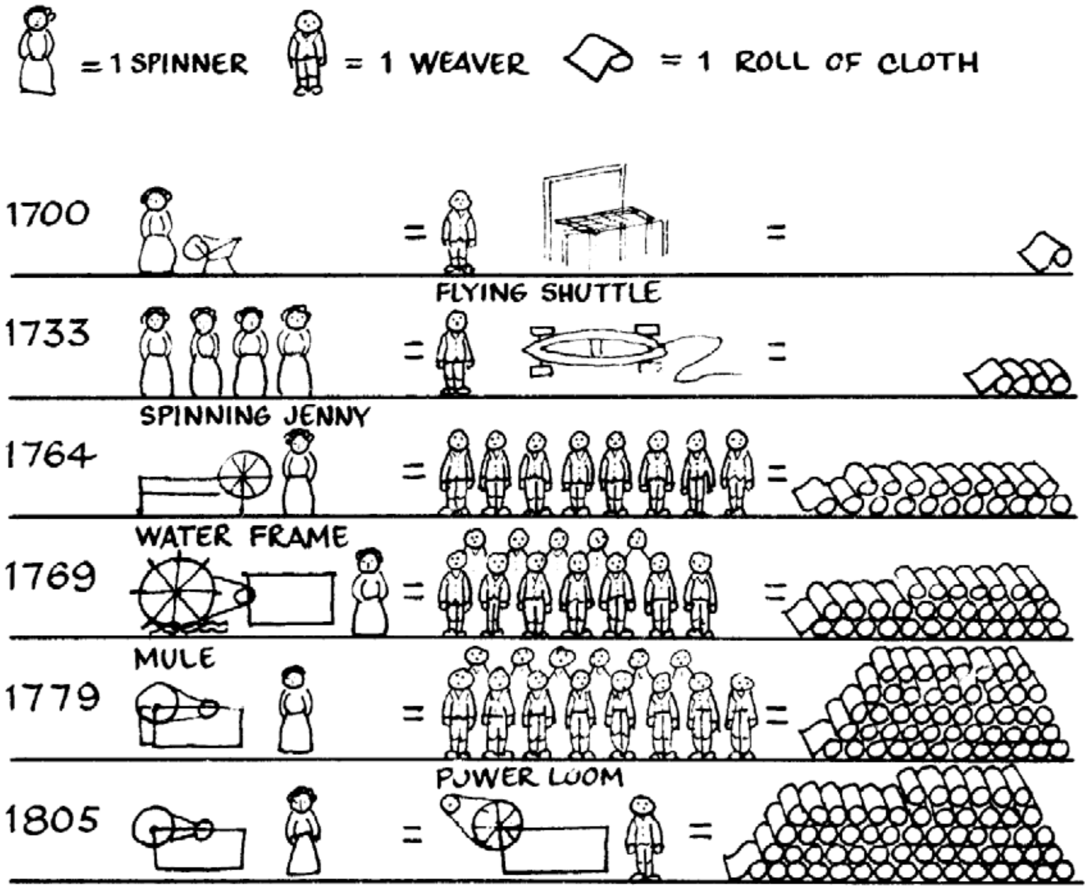
The tangled wool or cotton . . . is combed out straight . . . and is then twisted together to make a thread, or yarn.

Weaving



Two or more sets of yarn . . . are criss-crossed on a loom to make cloth.

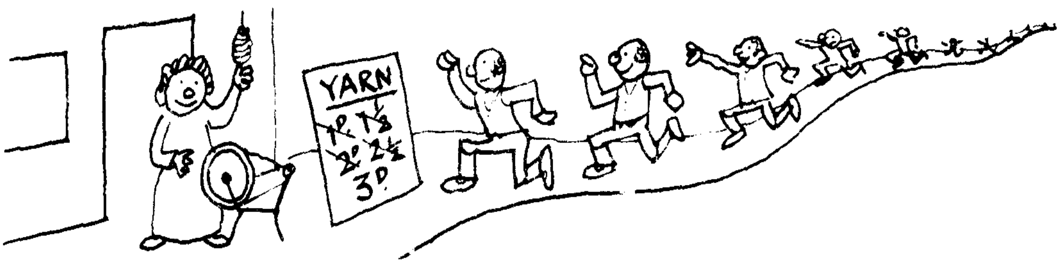
How the balance changed.



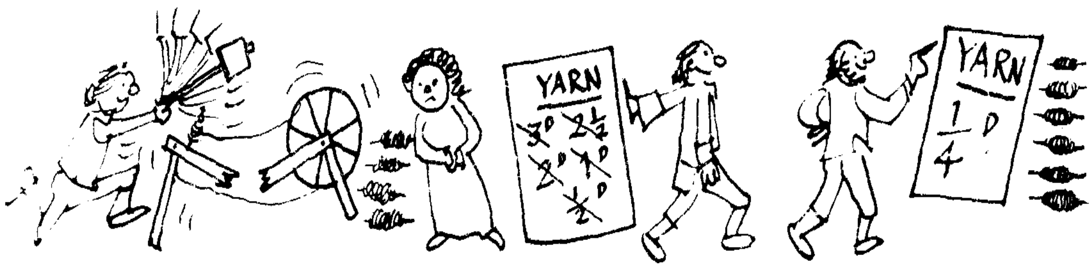
In the early eighteenth century the spinning was normally done by women and girls on a spinning wheel, and the weaving by men on a hand loom. One spinner could usually make just enough yarn to keep one weaver busy, and the upsetting of this one-spinner-one-weaver balance was one of the main causes of the Industrial Revolution. Here are the main inventions in the textile industry.

1733 ***John Kay's Flying Shuttle.*** This simple device enabled a weaver to make four times as much cloth on his loom. The cloth was not only woven more quickly. hut could also he made wider.
1767 ***Hargreaves' Spinning Jenny***. This was a new kind of spinning wheel which spun up to 80 threads at a time instead of one.
1769 ***Arkwright's Water Frame***. This was another spinning invention which was driven by a water wheel. It spun faster than the Jenny and made a stronger, thinner thread
1779 ***Crompton's Mule*.** This was another spinning invention which was a cross between the Jenny and the Water Frame but which was better than either. This was often powered by a steam engine.
1805 ***Cartwright's power loom*.** This was the first important weaving invention since the Flying Shuttle. It was driven by a steam engine and could use all of the yarn spun by one mule.

Notice that in 1700 one spinner could spin enough yarn on a hand wheel to keep one weaver busy on a hand loom. In 1805 one spinner working steam-driven jennies could still make enough yarn to keep one weave; on a power loom busy, but they would produce about fifty times as much cloth as the hand workers.
When the Flying Shuttle was invented the SPINNERS were delighted because all of the weavers wanted more and more yarn. This meant the spinners were always busy and could put up their prices.



When the Jenny and other spinning machines were invented it was the WEAVERS who were pleased. There was so much yarn being spun that they could bargain and force prices down. This meant that the weavers became richer and richer, while the spinners became desperately poor Many of them, working as fast a they could for twelve or more hours a day, seven days a week, would earn less than 10 -. The spinners blamed the machines for their poverty and many of them went from house to house and sometimes factory to factory, smashing the jennies and water frames.



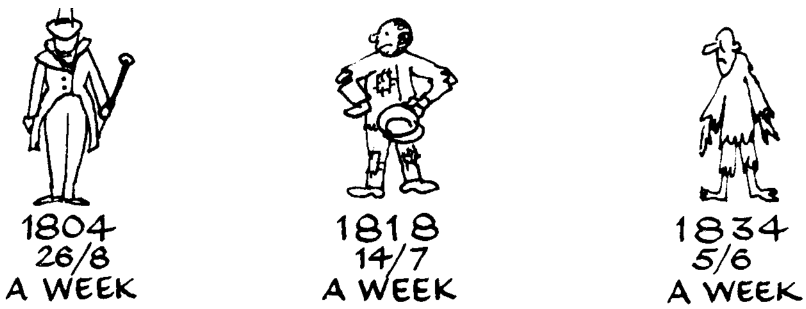
The government passed very strict laws against the machine smashers as this extract from The Liverpool Mercury of April 25th, 1817, shows.

"Leicester, April 17th. The most melancholy spectacle ever witnessed at Leicester took place this day, in the execution of seven men under sentence of death, viz, the six Luddites [a gang of men who broke up machines] for destroying lace machines . . . in the factory of Messrs Heathcote and Boden, at Loughborough last June. . . As early as six o'clock in the morning they were removed, under military escort, from the jail to the new Bridewell, to be executed on the new drop. Many thousands of spectators kept assembling until noon, to witness this truly tragic scene, and conducted themselves in the most peaceable manner."

When the power loom was invented in 1805 the tables were turned and now the hand-loom workers could not keep pace with the steam- driven machines in the factories. Those who refused to enter the mills and continued to work in their own homes on the hand loom found themselves slaving for longer and longer hours for less and less money. By 1835, the weavers who thirty years earlier had been among the highest paid workmen and able, as one said, to have meat every day AND butter AND tea, were toiling for up to eighteen hours a day for five or six shillings a week. Hundreds died of sheer starvation and those who managed to survive usually worked and lived in conditions like these, described in 1840:

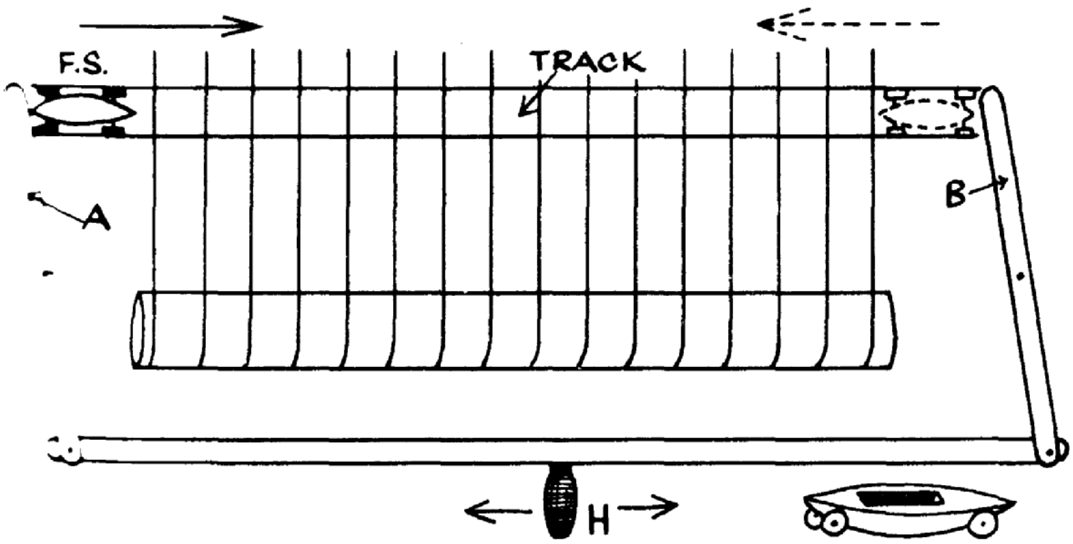
"I have seen them [the hand-loom workers]working in cellars dug out of an undrained swamp; the streets formed by their houses without sewers, and flooded with rain; the water therefore running down the bare walls of the cellars and rendering them unfit for the abode of dogs or rats. The floor to these cellars is but seldom boarded or paved:
a proper place for coals or ashes, but less fitted for a workshop than even an Irish hovel, because underground."

Weavers' Wages



The two most important textile inventions.

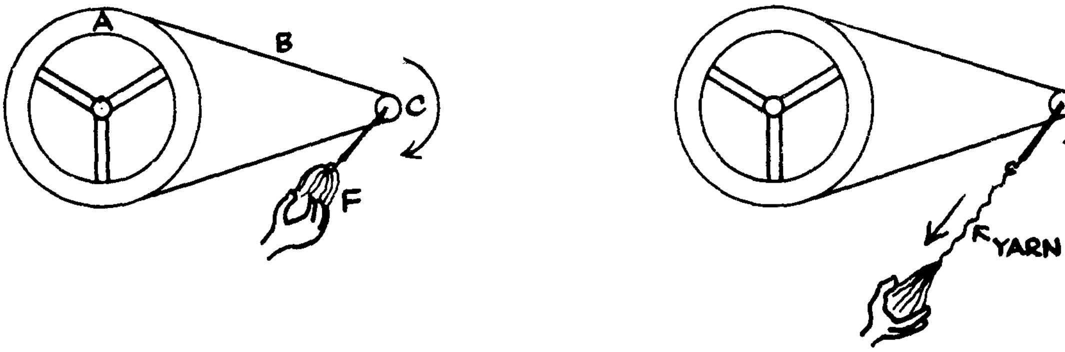
In an ordinary hand-loom, the weaver had to pass the shuttle S from hand to hand. This meant he could not weave very wide cloth.



The Flying Shuttle

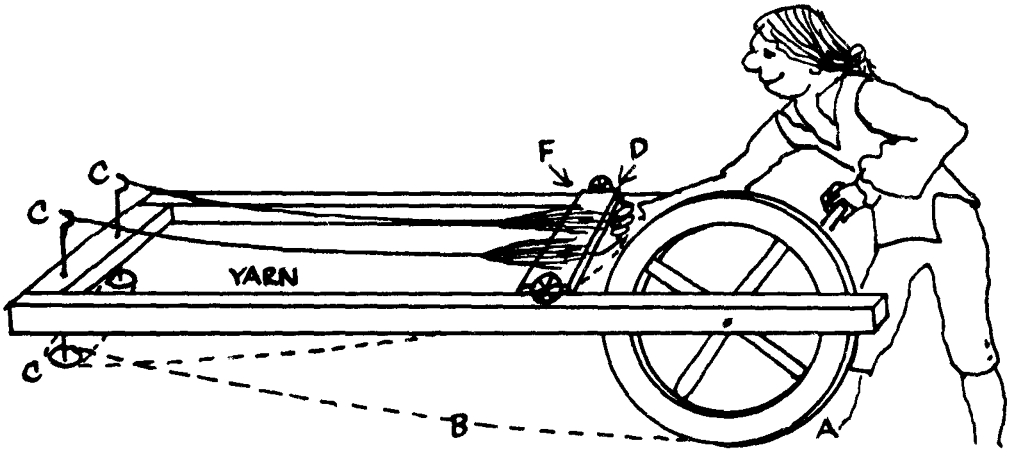
The flying shuttle had four small wheels and ran on a track across the threads. The weaver jerked the handle H to the left which made the arm A hit the shuttle. This shot across the threads (warp) dragging the cross thread (weft) with it until it was stopped by the arm B. The handle was then jerked to the right and the shuttle was knocked back to its original position. This obviously enabled the weaving to be done much more quickly and allowed a wider cloth to be made.

The great secret of the Industrial Revolution—the Spinning Jenny.



A spinning wheel

A handful of combed fibre F was hooked into the notch on the end of the spindle C. When the large wheel A was turned, the belt B caused the spindle to revolve at high speed. At the same time the bundle of fibre was drawn backwards so that a thin twisted yarn was formed. When the fibre was moved towards the machine again, the yarn wrapped itself round the spindle.

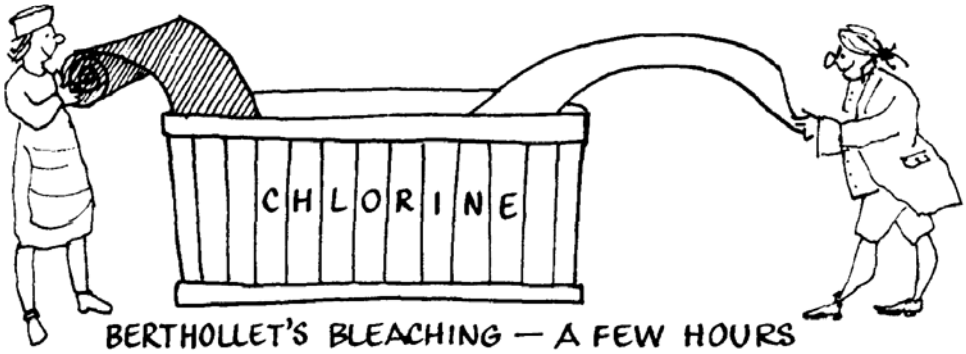


The Spinning Jenny

The Jenny was really a spinning wheel with more than one spindle, and lying on its side. The combed fibres F were fixed to a little carriage which moved backwards and forwards on wheels. The spinner moved this carriage right forward and hooked the fibres into the notches on the spindles C only two are shown but some jennies had 120. When the large wheel A was turned the belt B revolved the spindles. At the same time the spinner pulled the carriage D back, so pulling out a thread. When he pushed the carriage forward again the yarn wrapped itself round the spindles and the fibres were ready for pulling out once more.

Some other textile inventions

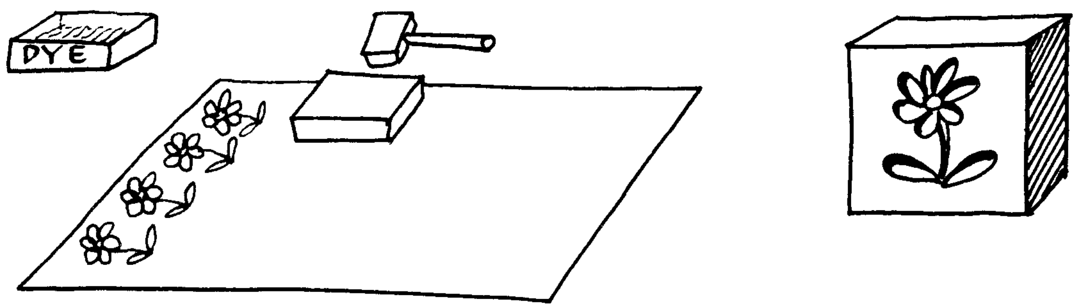
Although the most important inventions were in spinning and weaving, these alone would not have been enough. For example, when cotton has been woven it is a plain grey or brown in colour. Before it can be used it has to be bleached- that is, made white. Until the middle of the eighteenth century this process of bleaching took from three to six months. First of all the cloth was soaked in strong soda for a week. Then it was spread on the grass in the sunlight for several months, all the time being kept damp. Finally, it was soaked for another week in sour milk.



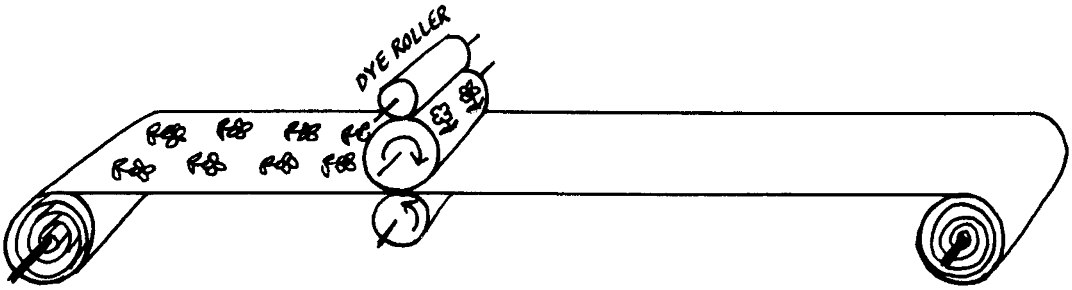
In 1786 a Frenchman, Berthollet, discovered that the gas chlorine would bleach cloth in a few hours. The cotton was soaked in water in which chlorine had been dissolved or else treated with chloride of lime, a powder containing the gas.

Printing

When cotton has been bleached it is, of course, pure white. While this is suitable for such articles as sheets, for most purposes it needs to be printed with a coloured pattern. Until the middle of the eighteenth century this was done by hand, with large wooden blocks like lino-prints.

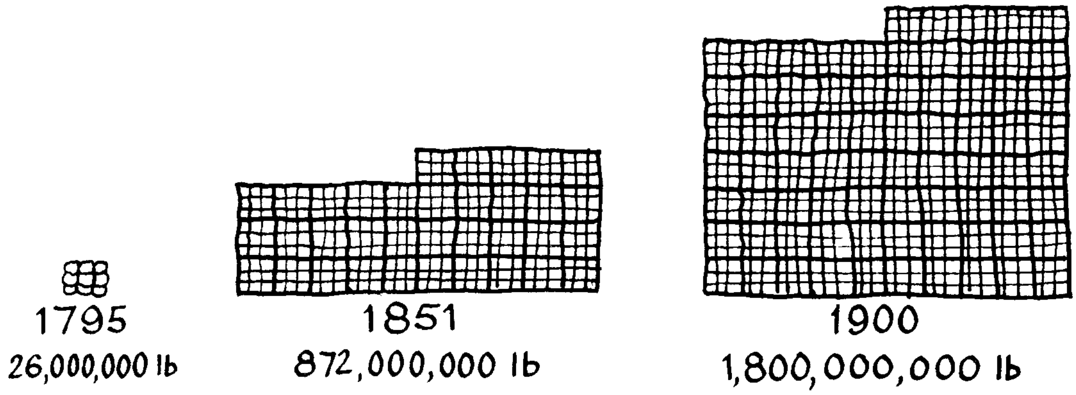


Naturally this method was very slow indeed, especially if several colours were needed, as each had to be pressed on separately. For every square yard of cloth the block had to be hammered on sixteen times for each colour.

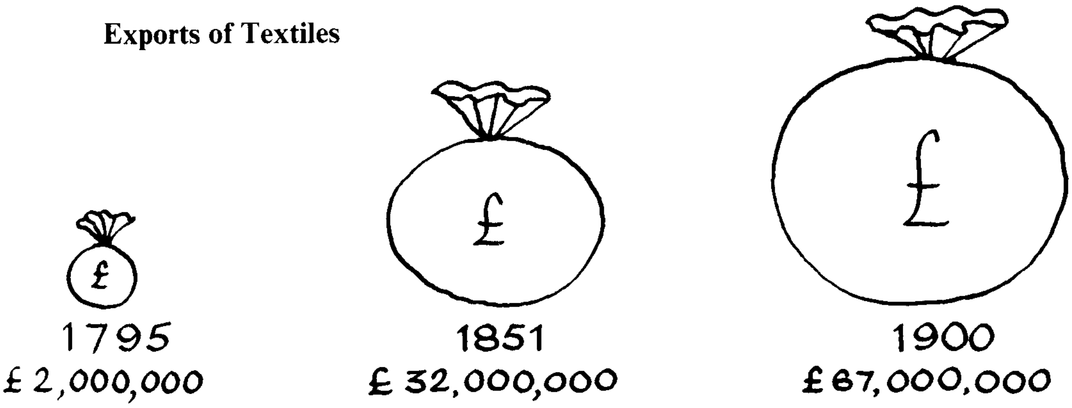


In 1785 an Englishman named Bell invented a machine for roller printing. The pattern was engraved on a copper cylinder which rubbed against a roller soaked with dye. As the cloth ran through the cylinder, rather like clothes through a wringer, the pattern was printed. If more than one colour was needed, there was a separate roller for each and the cloth ran through them one after another. One roller might have flowers engraved on it and would press against a red dye and the next one would have the stem and leaves and would press against a green dye. Roller printing could colour hundreds of yards of material an hour.

These two charts give some idea of how the cotton industry grew in the nineteenth century.

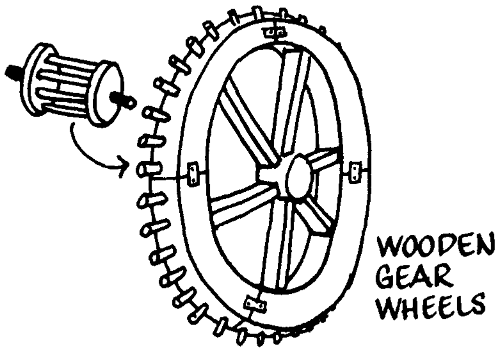


Exports of Textiles



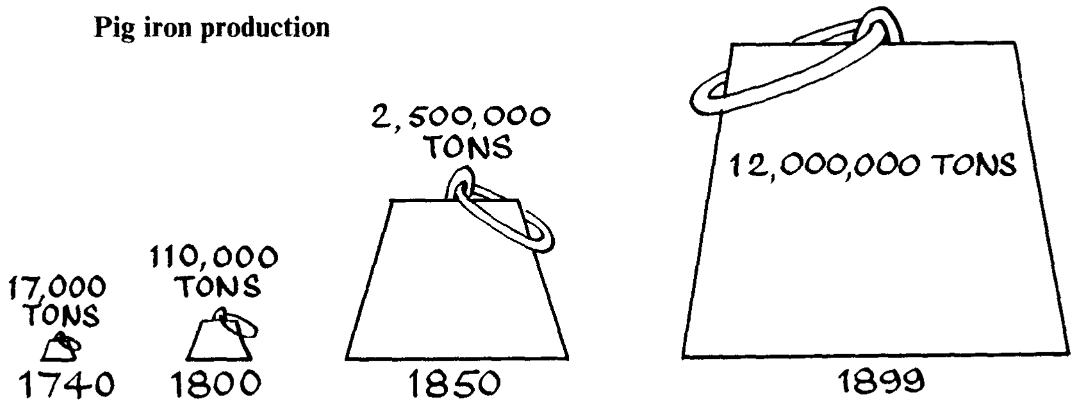
Iron and steel

Although Britain had plenty of ore waiting to be quarried, very little iron was actually produced until the eighteenth century. In 1740, for example, all the furnaces in the country together made only 17,000 tons of pig iron—that is, a heap forty feet long, forty wide and forty high. Wood was still the chief material for building and industry and even gear wheels for many machines were made of timber with wooden pegs for teeth. But wooden machinery was so clumsy and slow that if industry was to develop there had to be more iron, cheaper iron and better iron. Many of the great inventions of the eighteenth and nineteenth centuries were aimed at producing this, and their success can be judged by the next chart which shows the production of pig iron in Britain between 1740 and 1899.



At the beginning of the eighteenth century pig iron was made by setting fire to a mixture of ore and charcoal (which gave a hotter flame than coal) in a furnace and then blowing in air from a water-driven bellows. When the furnace was hot enough the ore melted to give CAST iron. This could be run off into moulds of any shape, but unfortunately it was very brittle and would not bend. It had, therefore, to be used mainly for large, solid and rather heavy objects such as rollers, pillars. weights and rather clumsy machinery.
If the cast iron was re-melted and treated in a special furnace it could be turned into WROUGHT iron. This process was fairly expensive but it was considered worthwhile because wrought iron could be hammered and twisted into shape and it did not break as easily as cast. Much more accurate machines could now be made but unfortunately wrought iron was not very hard and would not take an edge for tools or weapons. However, for nearly a century it was the best material that the engineers of the industrial revolution had in any quantity.

Pig iron production



By melting wrought iron yet once again and putting it through a long, tedious and expensive process, steel could be made, but only in small amounts. Steel is much harder than wrought iron, but at the same time it is much more flexible and can be sharpened and toughened so that it is ideal for tools and fine machines. Because of its high cost (five times the price of wrought iron) for most of the nineteenth century it was kept for making knives, tools, weapons and other engineering equipment in which strength and hardness were essential.

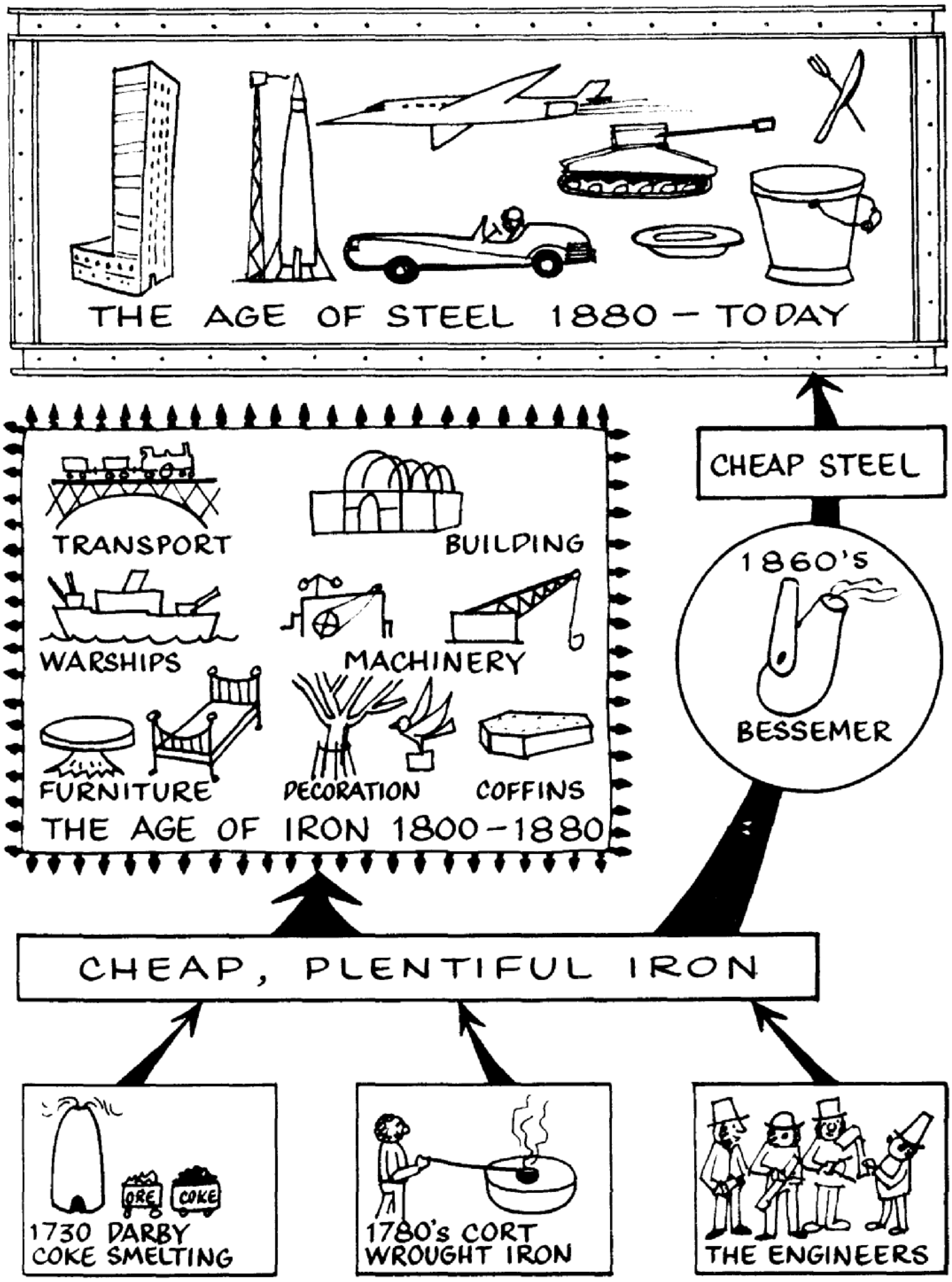
By the beginning of the eighteenth century wood for charcoal was becoming scarce in the iron-smelting districts. There was plenty of coal available in Britain but although many people had tried to use it in the manufacture of iron, no-one had succeeded. About 1730 however, Abraham Darby discovered that if he used coke instead of coal, the ore could be smelted quite satisfactorily. At once the foundries and furnaces moved from the forest areas of Sussex and Gloucestershire to the coal fields of the midlands and north. Coal was reasonably cheap there and by a fortunate coincidence the iron ore was often found near the mines, so that the price of iron fell sharply.

Unfortunately Darby's process gave only cast iron. It was wrought iron and steel that the industrial revolution really needed, and these were still expensive. The next big advance came in 1784 when Henry Cort invented a method of making large quantities of wrought iron at a reasonable price. To do this molten cast iron was poured into a special 'puddling' furnace and stirred with something which looked like a huge long-handled spoon. The increased supply gave a great boost to engineering, but the steel which would have made things even better, was still scarce and expensive.

All through the nineteenth century scientists, inventors and engineers turned their efforts to improving the quality of iron and to increasing its output. Neilson discovered that by blowing hot air into the furnaces he could use powdered coal instead of having to make coke first. Nasmith invented a gigantic steam hammer for beating out the iron ingots. Maudsley, Wilkinson and many others produced lathes. borers and machine tools of all kinds for shaping the finished metal.

Railways, locomotives, bridges, buildings, machinery, cranes, warships (most merchant ships were made of wood until the last quarter of the century) and a thousand other industrial items were understandably made of iron. But the craze did not stop there. Pillars, ceilings, decorations, ornaments, furniture and even coffins were made of it. It is little wonder that the Victorian period is sometimes called the Age of Iron. Yet all the time the engineers knew that even wrought iron was not the material they wanted, and they longed for a way of making cheap steel. Then suddenly in 1856 Henry Bessemer found an answer with his 'converter'. He took a huge container full of white-hot liquid iron and blew through the bottom a blast of hot air. With an ear-splitting roar a jet of flame shot a hundred feet into the air. When it had burnt itself out Bessemer added a few chemicals to the swirling molten mass and the container was full of steel.

There were still many problems to be overcome but on the whole steel could now be produced almost as cheaply as iron, and engineering took a great leap forward into the twentieth century.


THE AGE OF STEEL 1880 – TODAY
CHEAP STEEL
1860'S
BESSEMER
TRANSPORT
BUILDING
WARSHIPS
MACHINERY
FURNITURE
DECORATION
COFFINS
THE AGE OF IRON 1800–1880
CHEAP, PLENTIFUL IRON
ORE
COKE
1730 DARBY
COKE SMELTING
1780's CORT
WROUGHT IRON
THE ENGINEERS