

The Industrial Revolution in Europe

Origins.

Mines and manufactories have for many centuries been a part of European society, as have the means of trading and transporting their products. From the mid-18th century the economies of Great Britain and of some other countries became increasingly concerned with 'industry', a term that had previously indicated a virtue and came to mean the production of goods on a large scale. Some cities came to be dominated by factories, and by the canals and railways that delivered their raw materials and took away their products. An increasing proportion of the people of Europe came to be city-dwellers. This 'industrial revolution' was a self-sustaining process. Its consequences have shaped society in every European nation through the 19th and 20th centuries, and its global implications are determining our future. Nevertheless in some respects the term is misleading. The shoots of growth in the mid-18th century sprang from deep roots, and to regard the growth of industry as a purely British or a purely 18th century phenomenon can lead to neglect of industrial activities that flourished in other countries, some of them established long before the 18th century.

Industry depended on trade, on the interchange of commodities, whether natural resource, like salt or minerals, or manufactured goods that could readily be produced in certain localities. Some of the best evidence of the antiquity of European trade is provided by the warehouses that remain in several cities of the Hanseatic League, the association of merchant guilds from cities in the Rhineland and the Baltic ports that was most prosperous between the 13th and 15th centuries. The governing body met for the last time in 1699, but the office in Bergen continued to operate until 1763, and the German Quay (Tysksebryggen), the painted wooded warehouses rebuilt after a fire of 1702 remained a point of interchange between northern and southern Europe working in much the same way into the 20th century. Smoked and dried fish (re-barrelled in Bergen to remove sea water) were taken to Bergen in the summer months, and stored before being exported by merchants, some of whom had brought to Bergen salt, made by evaporation on the shores of the Mediterranean or the Bay of Biscay. Bergen, like most great trading cities drew on the natural resources of its hinterland, one to which it was linked by the little ships that sailed to and from the fjords and islands of Norway's west coast. Newcastle traded in coal, Memel in timber, Lisbon in salt. The

currency of some cities was the appropriately processed agricultural produce of its region, the wines traded at Bordeaux and Oporto, the grain sent abroad from the wooden warehouses of Gdansk, the olive oil handled at Naples, the cheeses exported from Amsterdam and Bristol. The products of what would now be called industry were also carried to the great trading cities of 17th century Europe from their hinterlands, copper ingots and bars of wrought-iron from Dalarna to Stockholm, Flemish linens to Antwerp, textiles of various kinds to Venice. Evidence of Europe's flourishing trade before the industrial revolution can be found in many places. When the Norwich haberdasher John Hovell died in 1681, the contents of his shop included wooden rattles, drums and dolls-house furniture and plaything animals, hens, chickens and peacocks, that probably originated in Holland, where they had been made by wood-carvers who had learned their skills from craftsmen in Nurnberg or the Black Forest. On the banks of the Rhine at Andernach, the Main at Wurzburg and the Mosel at Trier are cranes for lifting barrels of wine that might have been consigned to customers in many parts of Europe. Goods travelled slowly along the great rivers, the Rhine, the Seine, the Danube, the Severn, on some of which boats were hauled upstream by gangs of men. Some were taken by road on the backs of packhorses or in ponderous stage wagons.

The principal sources of non-ferrous metals in Europe had been accustomed to the disciplines of mining and the polluting effects of smelting long before 1700. At Falun there is archaeological evidence that copper ores were being extracted from the 8th century ad, and visitors to the museum at the great copper mine can see the company's charter which dates from 1288. Mining ceased at Falun only in 1992. The origins of mining for silver, lead and iron ore at Banska Stiavnica go back to the 13th century, and the geological and mineralogical collections from the mines are displayed in a 16th century merchant's house. One of the principal mines in the Harz Mountains, the Rathstiefsten Drift was opened in the mid-12th century, and the region around Goslar and Zellerfeld is rich in monuments of mining activity of every subsequent century until the 20th. Miners from the Harz are credited with the discovery of veins of silver near Freiberg in 1168, and the surrounding region, the Erzgebirge was an important source of metallic ores for many centuries.

The products of Europe's forests were traded on a large scale before 1700. Rafts of timber for building houses or ships floated downstream on many rivers,



A crane for loading barrels of wine on to barges alongside the River Mosel at Trier.

the Garonne, the Dordogne, the Severn, the Volga, the Niemen, but above all on the Rhine, where well into the age of the railway as many as 400 people lived on rafts up to 200 m long that travelled from the Black Forest and the Eifel to the wharfs and shipyards of Dordrecht. Wood was the principal means of heating homes in many European cities. Paris drew its fuel from many parts of France, from which it was conveyed to the capital by road and river. Most European forests in the 18th century were managed, and to a greater or lesser extent were self-sustaining. They produced mature timber for houses, ships and mills, staves that were used by coopers, cordwood of about 20 years' growth that could be used to make charcoal or poles for hopyards or vineyards. Underwood and cuttings were used to make baskets, or faggots, the bundles of twigs used in bakers' ovens. Wood ash was a source of potash, used in making soap and glass, while in northern Europe wood tar was made in kilns, and traded as a preservative. Manufactured products of forest regions were widely traded, toys from the Erzgebirge and the Black Forest, and chairs from the Chiltern Hills and the Wyre Forest for example. Nevertheless in the broad context of European history the most important produce of the forest regions was the mature timber floated or carried in barges to estuary ports where it was used to make the ocean-going ships that enabled the development of trade with other continents.

A market place was the primary reason for the existence of a town, and around that market place in the 18th century would be premises where people made things, most of them for trading within the

town's hinterland. Some prepared food, baking bread, brewing beer and cutting meat, tailors provided clothing and shoemakers footwear, while smiths, coopers and cabinet makers made those items that were essential to make houses habitable. Some trades needed premises larger than workshops. The grinding of grain required a water- or wind-powered mill. Malting barley needed a building with a cistern that could be filled with water, extensive floor space, and a kiln fired with a smokeless fuel. Hides and skins were prepared in tanyards with pits for lime water and tanning liquid made from oak bark, and multi-storey buildings used for trimming and drying. No trader of this kind was necessarily producing for customers beyond a day or so's journey from the town in which he worked, but some urban craftsmen did produce goods for wider markets. In England in the early 18th century these were often called 'manufactures'. Many developed from the traditional local trades, but there was no reason for their success beyond the enterprise of individuals. Gingerbread, for example, a stable form or carbohydrate, was traded from Aachen, Deventer and Ashbourne, among other places, but it could equally have been made in almost any city in Europe. Decorative steelwork was made by a dozen or so craftsmen in 18th century Woodstock. Watch springs made in Pershore, curriers' knives made in Cirencester and whips made in Daventry met large parts of the national demand for such products. Many local specialisms of this kind disappeared as the scale of industry grew, but some became the starting points for enterprises with international markets.

Some cities developed manufactures that used raw materials imported from tropical countries with which links had been established, with indigenous governments or with colonial settlers, as a result of the voyages of discovery made in the 15th and 16th centuries to Africa, India, the Far East, and the Americas. Ports that traded with America, London, Bristol, Glasgow and Amsterdam for example, processed sugar, tobacco and cocoa. Ports with links to Asia transformed spices, coffee, dyestuffs and rice into products that traders and householders could use. From the small port of Lancaster one 18th-century manufacturer supplied customers all over Britain with furniture made from the mahogany brought in by ships trading with the Caribbean. The most impressive monument to this aspect of European industry is at Zaandam where 400 windmills along the banks of the River Z processed the products European countries to make flour, wooden boards, paper, tobacco, cooking oil, colours for paints, mustard and abrasives.

Textiles formed one of the most important trades within Europe. The manufacture of fabrics was transformed during the 18th century by the introduction of powered machines located in multi-



The spinning process illustrated on the staircase of the Red House in Monschau.

storey factories, but the industry had ancient roots, and much of the commercial pattern of the textile trade was established when fabrics were made in the homes of the producers and carried to markets in cloth halls or to merchants' warehouses. The centre of Ypres is dominated by the skeleton of the great 15th-century cloth hall, destroyed by fighting during the First World War, while the Piece Hall of 1777 in Halifax, the only example that remains in the textile region of Yorkshire, is now a tourist attraction. The landscape of the parish of Saddleworth, in the Pennine Hills on the borders of Yorkshire and Lancashire, is an evocative monument of the domestic textile system. Its townships include many houses of the durable local stone, with long-light windows that illuminated the looms of weavers, who took the woollens they produced to the market at Huddersfield. Several small water-powered mills at Saddleworth were used from the late 18th century for mechanised wool-carding. The carders and their families lived with their machines, illustrating the subtlety of the change between domestic and factory systems. A more paternalist system of domestic production can be observed at Monschau, a spectacular town of timber-framed houses along the banks of the Laufenbach in the Eifel. The Red House of 1752, a seven-storey building in the Baroque style was the focus of a system of domestic production, and account books displayed within record the passing of raw materials to spinners and weavers and the receipt of yarn or fabrics. The central staircase is ornamented with 21 wooden plaques showing stages in the production of cloth, although the workers are Rococo cherubs rather

than natives of the Eifel. There are groups of houses designed to accommodate textile workers, monuments to the domestic system of production, in most European countries and they continued to be built well into the 19th century. One of the most imposing monuments of hand manufacture is the 15-bay, 3-storey building of the Dijonval woollen cloth manufactory at Sedan, which dates from 1755, although the complex was established in 1646. It shows that the large-scale state enterprises commonplace in many European countries during the *ancien regime*, were not necessarily restricted to the manufacture of armaments.



Brownhill Mill, Saddleworth, a late-18th century carding mill, in which the carders and their families lived alongside the machines they worked.

The British Industrial Revolution.

Society in Britain began to change radically in the second half of the 18th century. An astonishing number of innovations occurred in a short space of time, while entrepreneurs whose skills were in management rather than technology, Richard Arkwright in textiles, Abraham Darby II in ironmaking and Josiah Wedgwood in ceramics, transformed the ways in which production was organised. Labour and capital became concentrated in large-scale manufacturing plants, many of them in cities. Social structure came to be determined by the relationship between capital and labour in manufacturing plants rather than by patterns of agrarian landholding. The speed of change in Britain was observed by many commentators, including Adam Smith, Claude de Saint-Simon and Friedrich Engels, who, from different viewpoints, concluded that the development of manufacturing industry in Britain brought with it profound changes in the organisation of society. This 'revolution' also changed economic relationships between Britain and

Europe, and for a time continental countries looked to Britain as a model for growth.

The textile industry has been called one of the 'leading sectors' of the industrial revolution in Britain. It was the first sector, other than mining, to organise and discipline workers in large groups, with the process of manufacture broken down into many simple tasks. It applied water-power to the manufacturing process, and from the 1780s made use of steam engines. It was closely involved with international trade, with the import of raw materials, particularly cotton, and with the export of finished fabrics. The factory system first appeared in the silk sector, when in 1721 John Lombe built a five-storey mill in Derby, accommodating on the ground and first floors circular silk-throwing machines, based on Italian precedents, and with ranks of winding machines on the three upper floors, all powered by horizontal and vertical shafting from a water wheel. The Italian machines that Lombe copied have been replicated at the Aldini-Valeriani Museum in Bologna. The mill stood alongside a building of 1704 in which Thomas Cotchett had unsuccessfully tried to use Dutch silk-throwing technology, and remains, in a much-altered form following a fire, and now houses Derby's industrial museum. Several silk mills using the same principles were built in England in the decades that followed. Seven of them were in Cheshire, one of which, the Old Mill at Congleton, was 73 m long, 7.3 m wide and 14.6 m high, and housed 11 circular throwing machines. The Derby mill by the 1720s was a tourist attraction, and statistics about its operations were circulated in books intended for travellers.

The cotton sector of the textile industry was organised on a factory basis by Richard Arkwright, who was one of many people in the Bolton area of Lancashire in the mid-18th century to take an interest in the improvement of spinning machinery. He moved to Nottingham in 1768, and the following year patented the spinning machine with rollers rotating at different speeds that could be operated with water-power and gained the name of the water frame. He also developed machines for carding, and devised a complete system by which raw cotton could be transformed by machines into yarns that could be used by weavers and hosiers. With the aid of partners he established a horse-powered factory at Nottingham, and a water-powered mill at Cromford, the land for which was purchased in 1771. Cromford Mill it may not have operated until 1774, but it was soon enlarged. A second factory, Masson Mill with the appearance of a mansion, was built in the early 1780s, together with cottages for workers, a corn mill and an inn. For a time Cromford

was one of the most visited industrial sites in England. It set the pattern for many other cotton mills, in small towns or rural locations, like those at Milford and Belper in the Derwent Valley, or at New Lanark, or in cities like Manchester, some of which from the 1780s were steam-powered. Edmund Cartwright in 1785-7 patented a loom that could be worked with water- or steam-power, which made it possible to organise the weaving side of cotton production on a factory basis, although extensive production on hand looms in weavers' homes continued for many decades.



North Street, Cromford, some of the first houses built for his workers by Richard Arkwright. The rooms on the top floor with long-light windows would have been used for weaving or framework knitting.

Linen manufacturing was transformed in a similar pattern by John Marshall, son of an obscure Leeds linen merchant, who, with partners, from 1787 employed flax-spinning frames patented by John Kendrew and Thomas Porterhouse of Darlington, in a water-powered mill north of Leeds. He replaced them with machines designed by his mechanic, the subsequently eminent mechanical engineer Matthew Murray. From 1791 they constructed a steam-powered mill complex south of the centre of Leeds that was later distinguished by the building of Ignatius Bonomi's Temple Mill in the Egyptian style in 1838-41. From 1793 Marshall was in partnership with Thomas and Benjamin Benyon of Shrewsbury, who had been active in the ancient Shrewsbury-based trade of dealing in Welsh woollen cloth. They admitted to the partnership one Charles Bage, a surveyor and wine merchant with a profound knowledge of the properties of iron, who built the first wholly iron-framed textile mill at Ditherington, Shrewsbury, in 1796-7. Soon the partners split and the Benyons and Bage created a parallel business with an iron-framed mill in Shrewsbury, now demolished, and factories in Leeds. A high

proportion of the iron-framed mills built before 1830 were intended for flax-spinning, but they were used in other sectors. The mill at Saltaire of 1851 marked the zenith of this form of construction, but the majority of mills up to that date had wooden frames, and from the 1860s most mills had steel frames. The woollen industry was transformed more slowly. Most of the processes for spinning and weaving cotton could be adapted for use with wool, but the range of fabrics was more varied, and some were still made by hand well past the middle of the 19th century. Small carding mills, like those in Saddleworth, were some of the first to use water power. Several significant woollen mills were built in England in the 1790s and the early years of the 19th century, among them Benjamin Gott's Bean Ing mill in Leeds of 1792, now demolished, a very large integrated manufacturing complex, the iron-framed Armley Mill in Leeds of 1805, now the city's industrial museum, and Stanley Mill in Gloucestershire, an extraordinary iron-framed structure of 1813 that has the appearance of a landowner's mansion.

By the late 18th century textile manufacturing technologies were being applied in Britain that were attractive to manufacturers all over Europe. Arkwright's system of manufacturing cotton was carried to Germany by Johann Brugelman, who set up a factory colony at Ratingen that was named Cromford after the Derbyshire original. Arkwright-style mills were also working in France and Bohemia before 1790, and within the next half-century such mills set the pattern for large-scale industrial developments in many parts of the continent.



The mill at Cromford near Ratingen, built by Johann Brugelman in 1782, where he employed the cotton-spinning techniques developed by Richard Arkwright at Cromford, Derbyshire.

Coal was the essence of the Industrial Revolution in Britain. It is difficult to estimate coal production but by 1800 it had probably reached 15 million tons per year in England and Wales, an average of about 1350 kg per year per person. The growth of coal production had repercussions throughout the country. It stimulated economic activity in regions where fuel of whatever kind had previously been expensive. Coal became the principal fuel of the iron industry. Its use transformed the manufacture of alkali (sodium carbonate) by the Leblanc process, enabling increases in the production of glass and soap. The growth of ceramics manufactures in North Staffordshire took place on a coalfield. Coal was used to smelt the increasing amounts of copper ore that were mined in Britain, from which were made the copper sheets used to clad the hulls of ships, which were thereby enabled to trade for longer periods in distant waters. The majority of the textile mills built before 1800 used water-power, but the machinery in most of those constructed subsequently was powered by steam. The steam engine made possible the use of energy from coal in ever-widening locations, and many of those locations were coal mines. Its proliferation established a self-sustaining circle of growth.

The expansive properties of steam were well-known to scientists by the late 17th century. Thomas Newcomen put those properties to practical use in 1712 when he built a beam engine to pump water from mines at Coneygre near Dudley in the West Midlands. His engine was deemed to be covered by patents previously granted to Thomas Savery, which, until they expired in 1733, were controlled by a consortium. The Newcomen engine quickly proved of great utility, especially to mine owners. About 100 were installed in Britain between 1712 and 1733, and before 1750 engines were also built in Sweden, Germany, France and Bohemia. Many engineers made improvements to the Newcomen engine in the second half of the 18th century, most notably James Watt who was responsible for the separate condenser, the enclosure of cylinders in steam jackets, the application of parallel motion to link beams to connecting rods, the introduction of rotative motion, initially by means of sun-and-planet motion, and the double-acting engine. Watt's key patent for the separated condenser was granted in 1769. He moved in 1774 from Scotland to Birmingham where he worked in partnership with Matthew Boulton, providing designs for engines used in mines, ironworks and textile mills in Britain and overseas. By 1800 when the patents expired the Boulton and Watt partnership had supplied 24 engines that had been set to work in continental Europe. Watt's aim, from his earliest experiments,

had been to increase the thermal efficiency of the steam engine, a significant consideration in textile mills or non-ferrous metal mines, at a distance from coalfields. The cost of fuel was of less consequence in coal mines, where boilers could be fired with small coal that otherwise could not be sold. There was a surge in the number of steam engines built in Britain in the closing years of the 18th century – perhaps between 2500 and 3000 were working by 1800 – but only about 400, a relatively small proportion, were supplied by Boulton & Watt. Most of the remainder were Newcomen or ‘common’ engines, or



The forehearth of the Wendener Hütte blast furnace in Wenden, Northrhine-Westphalia, Germany.

other, more recent designs, many of them adapted to rotative motion, and set to work winding coal from pits. Iron was being smelted and forged in most European countries in 1700. In some areas, the Siegerland and the Sheffield region for example, there were long traditions of making tools and other objects from iron and steel, which were distributed to international markets. The indirect process of producing iron had been adopted in most of the principal iron-working regions. Iron ore was smelted with charcoal and limestone in a blast furnace, into which air was propelled by bellows operated by a water wheel. The molten cast-iron was tapped, usually twice a day, and taken to a forge, similarly charcoal-fuelled and water-powered, to be refined into wrought-iron. The blast furnace had its origins in Sweden and Germany in the middle ages. By the 15th century there were blast furnaces in Italy, in the Liege area and the Pays de Caux, and in due course the technology spread to Great Britain, and to southern and eastern Europe. The old direct process, the bloomery, in which wrought-iron was made directly from ore, but on a small scale, persisted in some regions, in Styria and Carinthia

until the late 18th century and in the Basque provinces and the department of Ariège into the 19th. Some bloomeries, the *stückerofen* used in Austria for example, could produce blooms of iron of up to 150 kg, were water-powered, and of dimensions which matched those of contemporary blast furnaces. Methods of working iron were shaped by regional traditions. In northern Europe the stacks of most furnaces were constructed above four arches forming a square. Air was blown into the furnace through one arch by means of pipes called tuyeres, while molten iron flowed out through another, the tapping arch. In the Mediterranean countries most furnaces were of the Bergamasque type, with flat fronts, retained by wrought-iron bars that extended between two towers. In Britain the molten iron from a blast furnace flowed along a trough shaped in sand, from which it was diverted into side channels from which extended smaller channels at right angles, said to resemble pigs feeding from a sow. The resultant iron was thus called sow iron and, more commonly, pig iron. In France iron was usually cast into a long shallow fin, usually called a *saumon* (salmon), while in Styria it formed a flat sheet of metal, which was subsequently broken up with heavy hammers. In northern Europe furnace and forge bellows were usually blown with leather bellows worked by cams on shafts rotated by waterwheels. In Italy, Provence and Spain blast for both furnaces and forges was often obtained from water trumpets (*trompes*), of the kind that are well-preserved at Capalbio and other sites in Tuscany. There was a lively international trade in iron in the early 18th century. Regions that could not produce iron needed to obtain it from elsewhere for such necessities as horseshoes, nails, fire irons and hand tools. The Swedish ironmaster Reinhold Rücker Angerstein travelled through Europe in 1753-5 on behalf of the Swedish ironmasters' association (the *Jernkontoret*) that controlled the trade in that country. He observed many complexities in the iron trade in England, where particular needs were met by imports of iron from Sweden, Russia, Spain, the Netherlands and the American colonies.

In the half-century after Angerstein's tour the iron trade was transformed by developments in Britain. In the 17th century there had been attempts to use coal rather than charcoal in blast furnaces, but it was not until 1709 that this was done successfully, by Abraham Darby I, an iron founder and brass maker in Bristol, who had moved to Coalbrookdale on the River Severn in Shropshire, and used coke, of the kind used in malt kilns. For several decades, as Angerstein observed, coke-blast iron was used only for castings, but in the early 1750s the second

Abraham Darby and his partners began to produce iron that could satisfactorily be forged into wrought-iron. They also used steam engines to re-circulate water than had passed over furnace bellows, making it possible to operate furnaces throughout the year. The Seven Years War between 1756 and 1763 provided an incentive to increase iron production. In the space of four years nine new furnaces were built in Shropshire, and coke-blast furnaces were erected in South Wales, the Black Country and Scotland. In 1776 a steam engine was employed by John Wilkinson to blow air through a water-balance into a blast furnace, dispensing with the need for a waterwheel. The use of steam-power and coke removed the previous constraints on the size of ironworks, and in the following decades complexes developed, with six or even more blast furnaces, large-scale forges, coke ovens, foundries, and mechanical engineering shops. The forging process was transformed gradually. Henry Cort in 1784 devised a system of producing iron by the process called puddling, in a coal-fired reverberatory furnace, from which the ball of metal could be shingled into a bloom under a hammer that could be steam-powered (although the *steam hammer* was not invented until the late 1830s), before being passed through grooved rolls in a steam-driven rolling mill. In the same way that Arkwright transformed cotton spinning, Cort integrated a series of processes, some of them well-established, into a coherent system.

British ironworking technology was taken to France in 1777 by William Wilkinson, whose advice was sought by the French authorities anxious to produce cannon of equal quality to those cast in Britain. He set up an ironworks at Indret at the mouth of the Loire, and in the mid-1780s was involved Charles de Wendel with the establishment of the Fonderie Royale at Le Creusot in Burgundy. The ironworks, unlike those in Britain which grew from small beginnings, was planned from the start as a large-scale venture, with a symmetrical layout, similar to that of a palace in its parkland. The ironworks has gone, but the Crystallerie de la Reine, a glassworks established at the same time, follows a similar pattern, its architecture reflecting the role of the state in industry in a way that, outside the royal dockyards, would have been unthinkable in Britain. Men skilled in ironmaking took their expertise to other European countries, and the coming of main line railways in the 1830s gave great opportunities for such ironmasters as John Cockerill and Friedrich Krupp to establish large vertically-integrated concerns to provide track, locomotives and constructional ironwork.

The growth of the British economy in the late 18th century was sustained by overseas trade. The fashion for cotton fabrics had been introduced from India, where a flourishing industry was ultimately destroyed by exports from England. Much of the raw cotton that was used in British mills came from the American colonies, after 1784 the southern states of the United States, where it was grown using the labour of slaves, taken across the Atlantic from Africa, where they had been traded for iron, metal products and textiles made in England. Sugar and tobacco from the Caribbean, and forest products from Maine, Nova Scotia and New Brunswick were traded in increasing quantities. Eastern trade provided markets for goods, and gave access to tea, coffee, dyestuffs and numberless other commodities. New means were established for handling international trade in estuary ports like London, Glasgow and Liverpool, that were not natural harbours endowed with deep water. Wet docks had been used early in the 18th century for the repair of ships, but the West India Docks in London, completed by Sir John Rennie in 1800-1, were to first to be designed on a large scale for commercial trading. Ships moored in the docks could be loaded and unloaded at any state of the tide, although they needed to await the tide before being released on to the river. London, Liverpool, Bristol, Glasgow and Hull became ports that were focussed on wet docks, which came to be built in many other European ports. With wet docks went multi-storey warehouses, which passed out of fashion when railways gained access to waterfronts. They were replaced by transit sheds, such as the ornamented examples that remain at Antwerp. Liverpool's Albert Dock is an outstanding surviving example of a group of port buildings of the first half of the 19th century, constructed before the railway became a factor in the design of cargo-handling installations.

Roads across Europe varied greatly but where they were of reasonable quality they were a significant influence on the development of industry. In Britain during the 18th century most main roads were brought under the control of groups of trustees from the areas through which they ran, whose income depended on tolls. The improvements that they carried out were gradual, but overall they enabled the fastest coaches to reach the principal provincial cities at about 16 km ph by the 1820s. Roads in most countries were similarly financed by tolls collected at gates placed at strategic intervals. In some countries the state played a prominent role in the construction of roads. In France the road system was transformed by re-surfacing and by the building of many bridges under the direction of Jean Rodolphe Perronet (1708-94), founder in 1747 of

the Ecole des Ponts et Chaussées. In Britain government was concerned directly only with roads in Scotland, which originally had a military purpose, and with the road linking Holyhead, the port for Dublin, with London, improved from 1815 by a commission whose engineer was Thomas Telford, which incorporated many substantial engineering works, including the suspension bridge across the Menai Straits, opened in 1826, and set significant precedents in the organisation of large-scale projects.

Regular passenger coaches linked the cities of the wealthier European countries, the fastest of them carrying mail on behalf of governments. In France 'diligences' provided regular services by the 1740s, that were generally regarded as rather smaller vehicles, carrying less than 10 people, than the stage coaches that developed gradually from 17th century origins in England. In most German states the generally similar 'Eilwagen' were worked by government. The greater difficulties of road travel in eastern Europe are indicated by the size of the diligence in the Habsburg Empire, which carried no more than three passengers. Alternative forms of road travel were offered by coaches that were available for hire, post coaches in England, 'voituriers' in France and 'vetturinos' in Italy, driven by *postillions* between inns or farmhouses at appropriate intervals whose owners guaranteed to have replacement horses available. In most countries there were also regular services of stage wagons, 'postwagen' in Germany, carrying small consignment of agricultural produce and manufactured goods over long distances. Road transport was changed by the building of canals, and transformed completely by the opening of main line railways, but it continued throughout the 19th century to be a vital part of the industrial system, conveying goods and passengers beyond the limits of the newer systems.

Canals were not a novelty in 18th century Europe. In France the Briare Canal, Europe's first summit-level waterway, was completed by 1642, and the Canal du Midi (or Canal de Languedoc) linked the Atlantic and Mediterranean coasts by 1681. Of the technological features of navigational canals, the pound lock had been employed in Italy by the 15th century, and lofty and lengthy masonry aqueducts carried drinking water to Avignon, Seville and other cities of the Roman Empire. The Netherlands had a dense network of canals serving drainage purposes, on which 'trekvaarten' operated regular services carrying goods and passengers. Ambitious schemes for navigational canals were realised in late 17th and early 18th centuries in Russia, Prussia, Sweden and

Ireland. Nevertheless the 8 km canal linking Worsley with Manchester completed in 1761 by Francis Egerton, Francis, third Duke of Bridgewater, was a significant innovation. It affirmed by passing over the River Mersey on an aqueduct at Barton that became an attraction to visitors, that canals could cross the grain of the countryside and need not follow natural waterways, and it also showed that a canal could profitably provide a great city with coal. Similar canals took coal in the following decades into Coventry, Liverpool and Birmingham, and in a pattern of direct growth from the Bridgewater Canal, a network of canals developed in England by 1805 that carried coal to most towns of consequence, distributed agricultural produce and consignments of manufactured goods for shops with previously unparalleled efficiency, and carried the raw materials for mechanical engineering works. The canals that were built in subsequent decades in Germany, France and Belgium all tended to fulfil the Duke of Bridgewater's requirement that 'a navigation should have coals at the head of it', and all contributed significantly to the economic development of the areas they served.

The success of the new technologies developed in Britain in the late 18th century attracted much attention in other European countries for both commercial and strategic reasons. Ironworking technology was of particular interest because other countries, in an age when metallurgical knowledge was unsophisticated, were anxious to reproduce cannon of the quality made in Britain. Knowledge of ship-building technology, and of the manufacture of sailcloth also had clear strategic implications. Governments were also concerned that their countries should be able to apply new technology to produce their own textiles and hardware, and to export them competitively to other countries. For several decades John Holker, born near Manchester in 1719, a Roman Catholic and a Jacobite, was involved on behalf of the French government, working through Daniel-Charles Trudaine, director of the Bureau de Commerce, and, after his death in 1769, his son and successor, Troudaine de Montigny, in discovering details of the technology used in industries in England, with obtaining samples of products, tools and minerals, and with enticing experienced English workmen to take their skills to France. The British government responded with a series of Acts of Parliament forbidding the export of essential tools and machines, and restricting the travel overseas of skilled workers. Holker was involved with the transfer of textile technology, particular that of finishing fabrics, calendaring, dyeing and bleaching, and with the manufacture of sulphuric acid, but he was also

concerned that the French should gain expertise in making steel, and steel files, leather processing, furnace-building, and the manufacture of effective firebricks. Many Englishmen were attracted to France, some with their families. Most were anonymous skilled workers of whom little is known, but they included John Kay, inventor of the flying shuttle, who emigrated in 1746 and apart from a few return visits remained in France until his death in the winter of 1780-1, and William Wilkinson, brother of John Wilkinson the ironmaster. The transfer of technology posed many difficulties. Even when industrial spies were welcomed in other countries, difficulties of language and lack of knowledge inhibited their understanding of what they observed, and when skilled workers were persuaded to travel to other countries, differences in raw materials and the availability of appropriate tools and constructional techniques often made difficult the replication of processes to which they were accustomed.

Technology was transferred in the 18th century in many directions, not just from Britain to continental countries. The growth of alkali manufacture depended on the process invented by the Frenchman Nicolas Leblanc (1742-1806), and the technology used to cast glass at the celebrated works at Ravenhead, Lancashire was also imported from France. Porcelain was made at Meissen near Dresden in Saxony from 1710, before knowledge of its manufacture passed to France in the 1730s and then to England.

Industrial development in Britain depended on private enterprise, on the ability of entrepreneurs like Richard Arkwright, John Wilkinson, Josiah Wedgwood and Matthew Boulton to borrow money for investment, and to operate their factories, furnaces or mines profitably. Some industrial concerns, the Bridgwater Canal and its mines, and the coal mines of the Marquesses of Londonderry in Co Durham, for example, operated as parts of aristocratic estates, and some, like the textile manufactures of Saddleworth, developed from the need for people to have additional sources of succour in areas where agriculture was difficult. In Sweden contrasts could be observed between ironworking villages (*bruks*) that belonged to aristocrats, and those where furnaces or forges were operated by peasant co-operatives. In France and in Prussia, whose boundaries were extended to the Rhineland by the Treaty of Vienna of 1815, government played an active role in the encouragement of industrial concerns. In almost every European country governments were directly concerned with the production of armaments,

particularly of fighting ships, and the arsenals at Vienna, Naples and Venice, and the dockyard at Karlskrona are evidence of the role of governments in 18th and early 19th century industry.

The social balance.

Industrial growth increased well-being in some respects. Cheap textiles, that enabled clothes and bed linen to be changed regularly, with soap, made possible by the growth of the chemical industry, and the greater availability of coal fuel, increased public health. Some industrial communities of the late 18th and early 19th century, particularly those where textiles were manufactured in water-powered mills, whose owners had philanthropic inclinations, might have seemed idyllic. In manufacturing towns the situation was very different. Houses were built with neither a supply of safe drinking water nor adequate drainage, while steam-powered factories and the use of coal as domestic fuel created stifling levels of pollution. The situation was made worse by the onset of contagious diseases, of which Asiatic Cholera, which reached western Europe in the late 1820s and early 1830s was the worst.

One of the most significant social changes of the Industrial Revolution was the imposition of time discipline, of the notion that a worker's time had a monetary value, and that an employer could purchase that time. The symbols of that change were the clocks, the cupolas protecting bells and the steam whistles that were features of many workplaces of the period. Young children, some of only four or five years of age, were employed in many enterprises of the late 18th and early 19th centuries, a practice that in most countries was gradually controlled by legislation. The first significant Acts of Parliament in Great Britain relating to child labour were passed in the 1840s. Women were employed in large numbers in some industries, even in mining, although whether or not they worked underground depended largely on regional customs. In Great Britain their employment below ground was prohibited by legislation of 1842.

One reaction to the squalor of the first generation of industrial cities was to seek to create utopian settlements, that depended on manufactures, but which were isolated from the temptations of urban life. The most celebrated was New Lanark, where in the first years of the 19th century the millowner Robert Owen provided schools both for children and for his adult workers, as well as communal dining facilities. Owen inspired several other idealistic communities, at Orbiston in Scotland and at Manea Fen and Tytherley in England, but they were short-

lived. A more individualistic tradition is represented by the five land colonies established in the 1840s by the Chartist Land Company, that reflected a deep-seated longing amongst industrial workers for a self-sufficient pattern of life. While they were not built as a reaction to industrialisation, the three Moravian colonies in England, with their distinctive buildings in West Yorkshire, Derbyshire and Manchester, are evidence of how religious movements can be reflected in the landscape. In France the writings of the utopian socialist Charles Fourier were influential, and in 1859 the iron founder Jean-Baptiste Godin established a community at Guise the design of which was directly inspired by Fourier's writings

From the mid-19th century large-scale public works were undertaken in every major European city to create healthier living conditions. Drinking water was pumped by steam engines from rivers or brought by canals or pipelines from mountainous regions. Sewage was led through deep sewers before being pumped by steam engines to treatment works. All over Europe the optimistic feeling that cities could be made safe places in which to live was reflected in the architecture of water- and sewage-pumping stations, many of which were set in parkland, and ornamented with tiles, terracotta and stained glass. The structures designed by Otto Wagner in Vienna in the first decade of the 20th century are the most notable.

In 1802 the works of Boulton & Watt, steam engine manufacturers in Birmingham, was lit by coal gas, whose properties had been demonstrated by their onetime engine erector William Murdock. The company came to supply gas-making equipment, at first to the owners of large factories wishing to illuminate their premises, and then to public utility companies, at first supply gas for street lighting, and then for lighting, cooking and heating in homes. In every country the industry grew as the railway system became capable of delivering coal to gasworks in the smallest of towns. In large cities gasworks were installations of enormous size. In the course of the 20th century small works closed as their networks were linked to those of larger suppliers, and in the second half of the century natural gas supplanted coal gas, although the former is distributed to households through the networks established for the latter.

The supply of electricity developed from the 1880s along similar lines. Thomas Alva Edison's Pearl Street station in New York of 1882 was the first generating plant to which the word 'central' meaning 'for public use' was applied. The French word for power station, 'centrale', is derived from it. The

generators in early power stations were powered by small steam or oil engines, but from c 1910 steam turbines were employed in most new installations. Steam is generated by coal-, oil- or gas-fired boilers, or, from the 1950s, by nuclear reactors.



The municipal power station of 1906 that houses the Museum of Workers, Craftsmen and Industry at Horsens.

The tendency to build ever-larger plants was reversed in the closing years of the 20th century. In mountainous countries power has been generated by hydro-electric power stations, one of the first of which was installed at Cragside by Sir William Armstrong in 1880. Large-scale plants of the early 20th century in France, Italy, Switzerland, Bavaria, Sweden and Norway enabled the electrification of railways, and the development of industries dependent on the use of electric power such as aluminium smelting and the manufacture of some chemicals.

Progress comes on iron rails.



A hund in the transport museum at Lucerne.

The railway has a long ancestry in Europe. The earliest form, used in non-ferrous mines in the German-speaking lands, appears to have been the 'hund', a box-like wagon with broad wooden wheels, running on parallel baulks of timber, and guided by a pin projecting below the front into the gap between the planks. Such vehicles were described by Georgius Agricola in the 16th century, and examples are preserved at Lucerne and Eisenerz. From the early 17th century two systems

developed in coalfields in England. In the north-east wooden tracks of around 1 m in gauge carried wagons with a capacity of about 2½ tonnes from mines to wooden platforms called staithes on navigable water, where coal was discharged through the bottom doors of the wagons to the holds of ships. By the early 18th century there were railways up to 20 km long, with substantial bridges, of which the Causey Arch of 1727 is the outstanding survivor. A different system developed in Shropshire, with lines of gauges less than 1 m, some of which penetrated underground into coal workings. Wagons had low sides, and minerals were held on by wrought-iron hoops. Iron wheels were introduced from 1729, inclined planes by the 1740s, and iron castings were used as the upper sections of two-level rails from 1767. Angled track, plateways were introduced from c 1790. The Shropshire system spread to other areas, most notably to South Wales.

From c1800 the scale of railways increased with the building of what have been termed 'hybrid' lines, which employed mixed systems of traction, horses, locomotives and inclined planes, and some of which were operated under Acts of Parliament, that enabled them to establish their routes by compulsory purchase, and put obligations upon them as public carriers. In the North East the steam locomotive was developed as a viable means of hauling wagons, and in 1820 James Birkinshaw of the Bedlington Ironworks introduced the T-section wrought-iron rail that took his name. There are many relics of hybrid railways in Britain, and the outstanding monument to this phase of transport history in continental Europe is the line between Linz and Ceske Budejovic (Budweis), a horse-operated



The Causey Arch in Co Durham, an arched bridge of 1727 on a railway that carried coal to navigable water.

railway that worked between 1831 and 1870, where 19 stations and some bridges are preserved.

The Liverpool and Manchester Railway opened in 1830, had specialised track and mechanical traction, was subject to public control, and accommodated public traffic and passengers. No previous line had fulfilled all these criteria that were the essentials of the main-line network that spread across Europe in the following decades. There were 9700 km of railway in Britain by 1850 and over 32000 km by 1911. main line railways were opened in France in 1832, in Germany and Belgium in 1835, in Austria in 1837, in Italy and the Netherlands in 1839, and in Spain in 1848. By 1914 there were 61000 km in the German Empire, 47000 in the Hapsburg Empire, and 64000 in Russia. 'Progress comes on iron rails' was a popular slogan in mid-19th century Italy, and in many respects this was true, for the railway carried the Industrial Revolution to almost every town in Europe. Railways delivered cheaper sources of energy, usually in the form of coal. They brought factory-made consumer products for sale in local shops, and facilitated the despatch of the produce of farms and forests to distant markets. They delivered the iron and coke that made possible the establishment of mechanical engineering works in towns all over Europe. They linked communities with their national and regional capitals and provided the means of travel to the ports from which Europeans migrated to other continents.

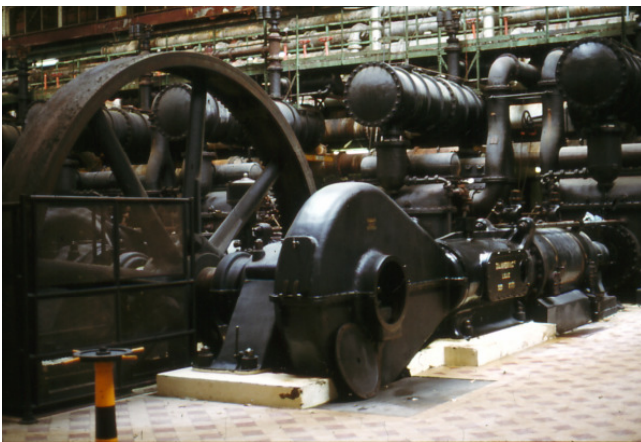


A rail rolled at the Dowlais Ironworks in South Wales that is displayed in the Norwegian Railway Museum at Hamar.

Industries of the 19th century.

The large-scale manufacture of chemicals during the Industrial Revolution provided bleaching materials for the chemical industry, and enabled the production of glass and soap on a much-increased scale. Sodium carbonate, or alkali, was obtained from natural sources, from barilla or kelp, in the 18th century, until the process devised in 1787 by Nicolas Leblanc (1742-1806) was adopted, at first in France,

at Newcastle upon Tyne from 1796, and in South Lancashire, where it was used on a large scale from the 1820s. It caused severe atmospheric pollution, and created large quantities of solid waste. The economy of the process was improved by the recovery of hydrochloric acid and sulphur, but it was superseded from the 1860s by the ammonia-process devised by the Belgian Ernest Solvay, which uses brine as its raw material. Large plants were established at Dombasle and Tavaux in France, near Charleroi in Belgium, at Ludwigshafen in Germany and at Northwich in England, which provided materials that were used in a vast range of 20th century products. Late 19th century plants making phosphorus, originally for matches, explosives or aniline dyestuffs similarly became involved over time with many wholly different products. In the 20th century increasing use was made of electrolysis, and the industry became increasingly concerned with petrochemicals. Processes are continually changing, but very large plants often continue in use because they are conveniently located for raw materials, whether locally-obtained salt, the by-products of a nearby oil refinery or commodities delivered by sea, and because the infrastructure of pipe systems, electric power and transport facilities is expensive to replicate.



Steam engines worked by waste steam at the chemical works at Tavaux, France.

The petroleum industry in Europe grew up in parallel to that in the United States, where traditionally it began with the drilling of an oil well at Titusville, Pennsylvania, in 1859 by Edward Drake. Demand for lighting oils had been stimulated early in the 19th century by the Argand lamp, which originated in France. The use of petroleum from seepages was long-established in Alsace, Sicily, Galicia and Baku, but in 1840 a refinery was established at Lucacesti in Romani. J J I Lukasiewicz opened a refinery in

Poland in 1859, and one was built in Vienna in 1862. The refinery at Angelsberg in Sweden of 1875-6, is the outstanding monument of this phase of the industry's development. In the early 20th century the oil industry came to depend largely on imports of crude oil from the Middle East or the Americas. After the Second World War many chemical products were made from feedstocks from oil refineries. From the 1960s the Netherlands, Norway, Great Britain and Ireland had access to gas and oil reserves under the sea, which dictated that most refineries were situated on coastal sites. A museum at Stavanger displays the history of the off-shore oil industry.

Steel is an alloy of iron and carbon, sometimes incorporating other elements. In the 18th century it was used for tools and in the intricate parts of clocks and other machines, and was made, generally on a small scale, by the cementation or crucible processes, both of which are illustrated by surviving monuments in Sheffield. Mild steel, first made by Henry Bessemer in 1856, is a different product, that had some of the properties both of cast-iron and wrought-iron, and could be made on a large scale. It became one of the characteristic features of 20th century civilisation. William Siemens and Pierre-Emile Martin provided an alternative means of making mild steel, the open hearth furnace, from 1863. Bessemer's process, using a tilting converter, could initially only be used successfully with non-phosphoric ores, but in 1879 Sidney Gilchrist Thomas demonstrated that linings could be used in converters that would absorb phosphorus, thus making it possible to produce steel from pig iron smelted from the phosphoric ores that were used in many ironworks in Britain, Germany and France. The basic slag that was the waste product of the process was used as an agricultural fertiliser. Huge steel plants became a feature of several parts of Europe from the late 19th century, in South Wales, Scotland, North Yorkshire, Clydeside, Luxembourg, Lorraine, the Ruhrgebiet, Piombino, Ymuiden and Borlange. Iron ore, coal and limestone were received as raw materials. The coal was coked, and the resulting by-products sent to chemical plants, while ore was prepared in a sintering plant, before being smelted in a blast furnace, that in a new works in the 20th century would have been a tall structure constructed of metal plates lined with refractories, into which air would be blown through hot blast (usually Cowper) stoves. The resultant pig iron was converted in Bessemer or open hearth plants into steel, that was rolled in mills into coils or sections. The technology of this phase of the industry is illustrated, on a relatively small scale, in the Bessemer plant at Hagfors and the open hearth steelworks at Munkfors, both in Sweden, while the preserved blast

furnaces at Volklingen in the Saarland are evidence of the scale of the industry in the late 19th century. A new means of making steel, the basic oxygen or LD (Linzer Dusenverfahren) process, was demonstrated at Linz in 1949, and has since become the only means of producing mild steel used in western Europe, employed at a decreasing number of plants, most of which are located on the coast.



A distant view in 1989 of the blast furnaces at Volklingen in the Saarland, before the commencement of large-scale restoration work. The train in the foreground had delivered liquid steel in torpedo wagons to a nearby steelworks.

The Industrial Revolution of the 18th and early 19th centuries had only a limited effect on the production of consumer goods. The food that people ate, the clothes and shoes that they wore, the furniture in their homes, were usually made locally. There were shoemakers, tailors, dressmakers and cabinet makers in every town, as well as traders who supplied food. In the second half of the 19th century the numbers of such craftsmen diminished as the production of consumer goods came to be organised on a factory basis. The manufacture of footwear and clothing was transformed by the introduction from the late 1850s of the sewing machine, developed in the United States by Elias Howe and Isaac Merit Singer, whose corporation built a huge works at Clydebank in 1884, that was designed to supply the whole of Europe. The manufacture of footwear became the speciality of certain regions, of Northamptonshire in England, where workshops for domestic manufacture were built alongside factories between the 1860s and 1890s, and Offenbach in Rhineland-Palatinate. Clothing was manufactured on a large scale in the poorest areas of large cities, often by immigrant workers. In England in the late 19th century the trade was dominated by Jewish manufacturers in the east end of London and in Leeds, where the imposing factory built by

Montague Burton in the early 20th century is a monument both to the significance of the clothing industry in the city, and of the role of chain stores in making clothing of reasonable quality available to mass markets. The manufacture of furniture was similarly concentrated in large cities, but with furniture, as with other consumer goods, the availability of railways made it possible for entrepreneurs to establish successful factories in towns in every region.

The manufacture of some types of food was also transformed. Condensed milk was developed in the United States during the Civil War of the 1860s by Gail Borden, and the technology was used in Switzerland by the brothers Charles and George Page, who in the early 1870s opened condenseries in England. In 1905 the Pages' company was taken over by that established by Henri Nestle, which already had factories in Britain. By 1914 it also had factories in Norway, Germany and Spain, and came to produce chocolate, instant coffee and many other food products. In north Germany, the Netherlands, Ireland and the Scandinavian countries in the late 19th century dairy farmers established co-operatives working creameries that could produce cheese and butter to reliable standards that could be marketed internationally. Their success depended largely on the cream separator, developed by the Swede, Carl G P de Laval and the Dane, L C Nielson, and patented in 1878. The creamery preserved *in situ* at Hjedding in Jutland is valuable evidence of this stage of the industry's development. Margarine was developed in 1870 as a substitute for butter by the Frenchman Hippolyte Mège-Mouriés,. While the dairy industry was transforming itself by the establishment of co-operative creameries, the manufacture of the new product grew on a large scale, with manufacturers like the Dutch concern Van der Bergh & Jurgens establishing plants in several countries.

Chocolate came to be manufactured on a large scale in the late 19th century, and chocolate companies built model villages for their workers at Noisiel, Bournville and New Earswick (York). Fish was landed and distributed by rail from industrial-scale fishing ports, of which Grimsby, Boulogne, Esbjerg and Zeebrugge are examples, where there were factories that preserved fish for which there was no immediate sale, and processed non-edible parts into fish meal and glue.

The organisation of manufacturing in the late 19th century in ever-larger units was matched by the growth of mass-movements of workers, in trade unions that in the 20th century gained sufficient

status to negotiate with governments, and in co-operative societies, that operated shops for their members, and produced consumer goods in their parties, which, directly or indirectly led to the own factories. Trade unions encouraged and often participated in the growth of socialist political introduction of accident and health insurance and pensions benefits, that in various forms were established in most European countries in the first half of the 20th century.



A commemorative stone alongside the preserved creamery of 1882 at Hjeddning.

Mass production in the twentieth century.

Factory-made domestic appliances transformed European homes in the 20th century. Cooking stoves and kitchen ranges using gas, solid fuel and later electric power were produced by several of the largest iron-making concerns in the 19th century. The manufacture of vacuum cleaners, refrigerators

and washing machines, was developed by several large corporations. The American Hoover company manufactured vacuum cleaners in Europe from 1919, and in due course established plants in several countries. The Swedish Electrolux company had its origins in 1908 when a Swede, Axel Wenner-Gren, saw an American-made vacuum cleaner in a shop in Vienna, and determined to apply his skills as a salesman to develop a company to produce and market it. He returned to Sweden in 1912 where he began to work for AB Lux, originally a manufacturer of lamps, who had a factory at Lilla Essingen, Stockholm, opened in 1907-8. He formed his own company, Elektron, which merged with AB Lux in 1918, and after the First World War began to market its products in Denmark, the Netherlands, Switzerland and the United Kingdom. Factories were built at Templehof, Berlin, in 1926, and subsequently at Luton in England and Courbevoie in France. Products of factories of this kind have transformed living conditions, and have brought changes in the role of women in society, particularly in the decades since the Second World War.



The fish market in a large concrete building at Grimsby, built by the London & North Eastern Railway in 1934. Grimsby was a characteristic 'industrial' fishing port of the late 19th century.

Factories making consumer products were established in many towns, some of them in textile mills and other buildings once used for other purposes. Many were architecturally undistinguished, but those built in Berlin by Peter Behrens (1868-1940) for the electrical company Allgemeine-Electricitäts-Gesellschaft (AEG) were of exceptional merit. The Turbinenfabrik (turbine factory) of 1908-10 and the small engines factory in Voltastrasse of 1910-3 demonstrated that factory buildings could be useful as well as beautiful.

Making motorcars was perhaps the most characteristic 20th century industry. The carriage powered by an internal combustion engine was developed in south-west Germany where Karl Benz produced his first four-wheel vehicle in 1893, a model that was the first to be available commercially, of which 572 were completed in 1899. Gottlieb Daimler completed a motorcar in 1889, and an engine called the Phoenix in 1894. Disagreements with his bankers led him to sell to Frederick Simmons the right to make the Phoenix in Great Britain, and to use the Daimler name there, which led to the establishment of the first large-scale car factory in England, the Motor Mill at Coventry. The industry developed from diverse origins, from companies who had made bicycles or sewing machines on a large scale, from coachbuilders, and from entrepreneurs fascinated by the concept of the horseless carriage with abilities in



The Turbinenfabrik built in Berlin for AEG by Peter Behrens in 1908-10.



The factory for manufacturing small electric motors in Voltastrasse, Berlin, built for AEG by Peter Behrens in 1910-3.

marketing or the organisation of production. A study of Coventry shows that some early 20th century companies operated from what were in effect domestic workshops, and others from older premises adapted to new uses. The first purpose-built car factories date from around 1900. Mass-production of cars on an assembly line was introduced in Great Britain at Henry Ford's factory at Trafford Park, Manchester, in 1911, slightly before that method of production was adopted in the parent factory at Detroit. Between the two world wars the size of motorcar factories increased, and many European companies were amalgamated or were taken over by American companies. Opel at Russelheim and Vauxhall at Luton became part of General Motors, while Ford built a plant at Dagenham in 1929-31 that was vertically integrated to such an extent that it produced iron for cylinder blocks from its own blast furnaces. The motor car changed people's lives to a greater extent even than the railways of the previous century, and an advertisement of 1953 was able to claim that Henry Ford's Model T of 1908 'established the principle of the universal ownership of automobiles... forced the building of paved highways ... No other single product has had so profound an influence on every aspect of the way we live today'.

That influence extended to the roads upon which cars travelled. In most European countries congested areas were by-passed in the 1920s and 30s, and the construction of new strategic route for long distance traffic went furthest in Germany and Italy. The construction of similar roads resumed in most countries from the late 1950s, and in the second half of the 20th century there was a large-scale movement of many types of freight traffic from waterways and railways to diesel-powered trucks on the new road systems.

Europeans began to make aircraft in the first decade of the 20th century, but the First World War stimulated their production on a large scale. Huge factories were built in France, Germany and England, but the demand for their products evaporated after 1918. Nevertheless the air transport industry grew through the 1920s and 1930s from very small beginnings in the immediate post-war periods. The Netherlands, France and Great Britain, used air services, sometimes employing flying boats, to convey mail to their overseas empires. Zeppelin airships made in Friedrichshafen made well-publicised circumnavigations of the globe, conveying passengers in spacious comfort. Airship travel never recovered from the crash of the British R101 in 1931 and the destruction by fire of the German



Hindenburg in 1937, but by the late 1930s transatlantic flights by 4-engined airliners were on the verge of inauguration, and cities all over Europe were building municipal airports. Air transport was changed utterly by the Second World War. Production facilities were greatly expanded. Hundreds of airfields with concrete or tarmac runways were constructed. Developments in technology led to the building of aircraft that could fly at greater speeds with greater payloads over greater distances, and to the establishment of systems of air traffic control. Many thousands of men and women learned to fly and maintain aircraft. Nevertheless air travel in the post-war period remained an expensive luxury, and it was not until the removal of regulations in the 1990s that the growth of traffic to and from provincial cities anticipated in the late 1930s became a reality.

The European Coal and Steel Community established in 1952, the first stage in the development of the European Community, reflected a continent that was dominated by heavy industries of the kind that characterised the Industrial Revolution. The second half of the 20th century was a period of rapid change when many features of European industry that seemed immutable disappeared. It would have seemed inconceivable in 1952 that coal mining would have ceased in the Mons region or in North East England by 2006 or that the great copper mine at Falun would close. Most kinds of product have been affected by the proliferation of computer technology, whether that technology is incorporated within them, as it is in motorcars or domestic appliances, or whether it simply controls the means of production and distribution. Many production sites are owned by companies from the Japan or Taiwan, and since the fall of the Iron Curtain some west European companies have moved their factories to sites in the former Communist states where wage rates are lower. Modern industry has deep roots. Some prominent manufacturing companies have their origins in the Industrial Revolution period or even earlier, and there are deep-seated historical reasons why some factories are located in particular places. If we wish to understand contemporary Europe we must be aware of its industrial heritage.

The Industrial Revolution in Europe

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