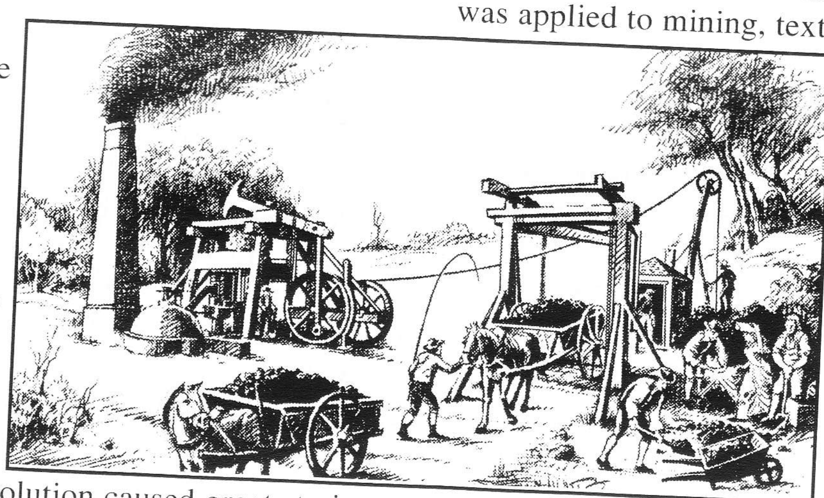
The Industrial Revolution Begins

In the final decades of the 18th century, Europe (and the thirteen English colonies of North America) was the scene of important revolutions. In America, the colonies fought to separate themselves from the control of the English king, George III, and Parliament. In Europe, the great political upheaval called the French Revolution sent shock waves across the Continent as revolutionaries executed Louis XVI and his queen, and founded a republican form of government.

While these great political changes were altering the lives of millions of people in America and Europe, another "revolution" was taking place that changed the economies of Europe and the United States from agricultural to industrial.



This Industrial Revolution caused great strains and even violence as economic systems shifted from hand field labor to artificial labor, the work done by machines. The changes brought about by this revolution began to take on speed around the mid-18th century.

When describing the changes brought about by steam power, the use of the word "revolution" may be misleading. Generally, a revolution takes place in a short period of time—within a generation at most. However, the Industrial Revolution spans several generations, and the changes it brought were gradual. What really occurred might better be called an evolution. However, when one looks at the dramatic impact of industrial trends on life in England, America, and the Continent, it is nothing if not revolutionary.

The center of the industrial revolution was England. Later, the United States—a country full of inventors, machinists, and tinkerers—caught the fever, only to be followed slowly by the other nations of Europe. In time, this industrialization expanded throughout the world. The revolution hit its stride around 1815 and continued for the remainder of the 19th century. The great new power of this increasingly mechanical age was the steam engine, the cornerstone invention of this early industrial period. Originally built to pump water out of English coal and iron mines, this artificial power became the driving force for over a century.

Within decades of its invention, steam power was applied to mining, textile production, iron smelting, and dozens of other industrial pursuits. By the early decades of the 19th century, the invention of the steam engine led to the invention of the railroad. Steam engines allowed for the invention of steamboats and later steamships, which plied across the ocean, drastically reducing the time required to travel overseas.

While many factors played a role in the development of the industrial age, the Industrial Revolution was rooted in three factors: coal, iron, and steam. Steam engines were fired by coal that was produced in England in great quantities. Such machines and other mechanical devices of the age were crafted and forged out of iron. And the entire age was powered by the man-made and controlled energy of great steam engines.

The changes which began in the Industrial Revolution have really never come to an end. In some respects, the revolution had its roots thousands of years ago. Historians speak of an Iron Age in human history. This age began around 1000 B.C. when ancient peoples began making tools and weapons out of iron. Today, the Iron Age endures as we continue to rely on this important metal (a constituent of steel), and the effects of the Industrial Revolution continue to alter modern economies, making further ripples in the industrialized world.

Great Britain Leads the Way

There are reasons why the Industrial Revolution began in England during the last quarter of the 1700s. In earlier centuries, England had become the leading commercial power in the world. By the early 18th century, British trade overseas made England wealthy. During the wars of the century, especially the Seven Years War, England gained control of many overseas colonies. By mid-century, one of England's primary trade rivals, France, had lost control of India and Canada to the British. English sea captains commanded great trading ships, which could be found all over the world.

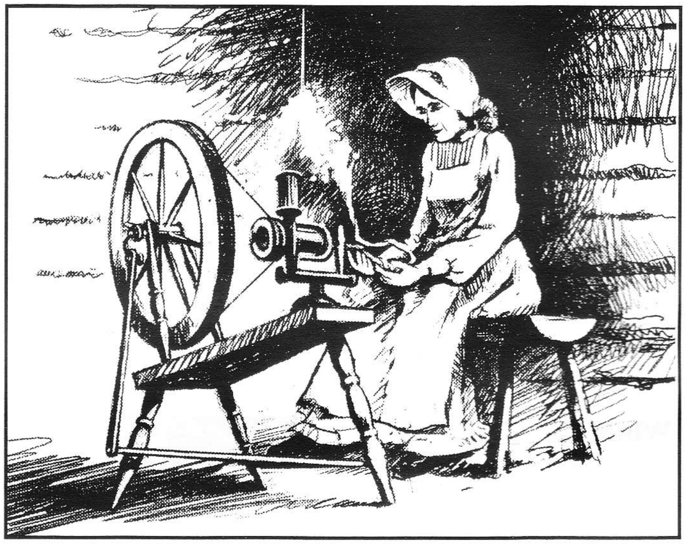
But by the second half of the 18th century, England was beginning to experience serious problems at home on several fronts: the population of the British Isles was growing rapidly; England was starting to face serious shortages of wood; and the growing population was straining the domestic producers of cloth and clothing.

The shortage of wood led to an increased reliance on coal as a fuel for heating stoves and fireplaces, and for blacksmithing and the smelting of iron ore. With this increased need for coal came an increase in mining.

By the 18th century, coal was difficult to mine close to the surface and miners were driven deeper underground. In these deeper mines, water seepage was a constant challenge. Something had to be done to solve the problem of the flooding of coal mines. The answer proved to be the invention of steam-powered pumps, which forced the water out of the mines.

As England relied increasingly on coal as a fuel, it began replacing wood in the smelting of iron ore. In early years, burnt wood, known as charcoal, was used to heat iron ore and remove the carbon impurities. By the 18th century, iron smelting plants began using coke—a hard, grayish material produced by heating soft coal in an airtight oven, removing the coal tar and coke gas—as the fuel for smelting iron. This trend only increased the expansion of England's coal-producing mines.

As for the problem of clothing the ever-growing population in 18th-century England, new machines were being invented to replace the old



system of cloth production. For centuries since the Middle Ages, England had been home to a great wool trade. English farms raised sheep, and their wool was regularly spun into thread and then woven into woolen garments and other items.

With the expansion of English trade to India, Egypt, and later the United States, a new material was introduced to England: cotton. Thousands of older women (known as spinsters) worked in their homes, spinning wool and now cotton into thread. But their production was starting to lag behind eighteenth-century population growth. Faster and more efficient methods of production were needed.

The old system (known as the *putting out system*) relied on businessmen providing the raw materials to women who worked out of their homes on their own spinning wheels. The drive to improve and increase cloth production was, therefore, pursued on two fronts—to build faster, more efficient machinery and to rehouse production—not in private homes, but in larger facilities. This, in time, led to the development of the factory system, another result of the Industrial Revolution.

Review and Write

Explain how England's problems with population, wood, and cloth production helped lead to the Industrial Revolution.

A Revolution in English Textiles

England led the way for several generations in the creation and expansion of the Industrial Revolution. There are important reasons why Great Britain was a leader in this drive from dependence on agriculture to an increased reliance on industrialization.

For example, in the late 1700s, England was led by ministers and parliamentarians who were sympathetic to trade, commerce, and industrial expansion. England had ample amounts of raw materials at home, such as iron ore and coal. Labor was cheap. There were financial institutions, such as lending houses and banks that raised the needed capital to build factories, construct mills, purchase steam engines, and employ hundreds of workers.

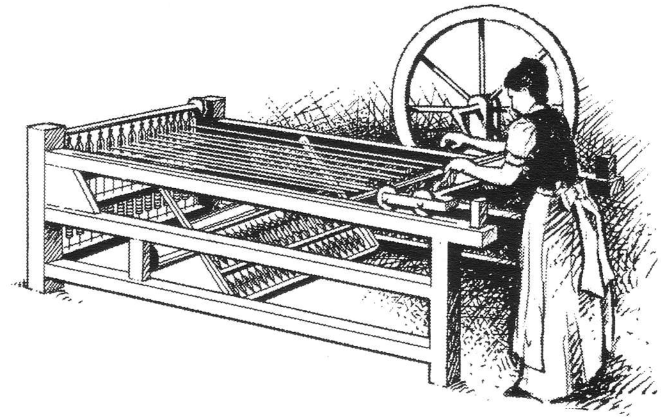
In addition, England had established extensive overseas markets by 1750. Such connections were necessary to serve as potential buyers for English textiles, iron, coal, and other items.

As has been emphasized on earlier pages, one source of the Industrial Revolution was found in the textile industry. The production of cotton thread, cloth, and clothing introduced into England in the 1600s led the way in transforming the means of production of cotton materials. These changes were brought on by a series of inventions and innovations.

In 1733, an English weaver from Lancashire, John Kay, invented the fly-shuttle, which allowed one workman rather than two to operate a hand loom. Short-sighted individuals decried Kay's innovation, claiming it would put weavers out of work. In time, angry mobs attacked and destroyed his home. (Kay later died in France in poverty.)

Kay's innovation did not catch on quickly, however. While his fly-shuttle improved the production of a single weaver, the real problem was in the production of thread. Typically, a one-man loom required the work of four to ten spinners to produce enough thread to keep one or two loom workers busy.

Within a generation, James Hargreaves, a carpenter, also from Lancashire, invented a spinning machine in 1765, which he patented in 1770. Rather than a single worker spinning thread on a single spinning wheel, Hargreave's new invention (called a *jenny* after his wife's name) allowed a single spinner



to spin eight threads simultaneously. Later models increased the number of simultaneously produced threads to 100! Acceptance of such a device by cloth workers was slow. (In fact, Hargreaves, too, had his house sacked and his first spinning jenny burned by angry spinners fearing for their jobs.)

Such devices revolutionized cotton thread production. By 1778, English spinners were busy working 20,000 spinning jennies. The jenny cut down on the number of hours required to produce cotton thread or yarn. For example, prior to the jenny, a hand spinner using a spinning wheel worked 1000 hours to produce 22 pounds of cotton yarn. With the early spinning jenny, the same amount of yarn required only 400 hours of labor. By 1830, using improved models, the time was reduced to 20 hours!

Later devices followed. In 1769, Richard Arkwright, a barber from Lancashire, patented the water-frame, which used water-powered rollers and spindles to make strong, but coarse, cotton thread. A decade later, another Lancashire tinkerer, Samuel Crompton, combined the spinning jenny and Arkwright's water-frame to produce strong and fine cotton thread.

Such machines revolutionized textile production in England. In the 1770s, England worked eight million pounds of raw cotton into thread and cloth. By the 1790s, the amount of cotton had increased to 37 million pounds. In 1815, England reached the 100 million pound mark, and, by 1830, English spinners and weavers were busy working 250 million pounds of raw cotton.

Thomas Newcomen Invents an Engine

The Industrial Revolution represents more than an increased reliance on things mechanical. What gave this industrializing age its drive was the harnessing of an age-old source of natural power—steam.

Even in the ancient world, innovative minds understood the tremendous force of steam power. Around A.D. 60, a Hellenistic tinkerer named Hero of Alexandria built a small device consisting of a metal sphere with jets sprouting out of it mounted on a center shaft. When the water inside the sphere was heated over a fire, the ball rotated as steam sprayed out of the jets. This crude device (called an *aeolipile*) was nothing but a toy, serving no practical purpose.

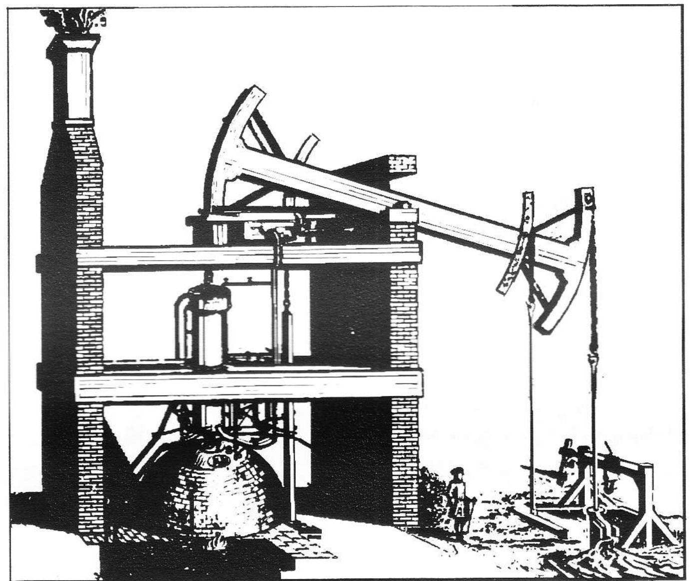
Hundreds of years passed before the next steam engines came into existence. They were built to solve a specific problem that was plaguing English coal miners. By the 1700s, the surface coal in many mines in Great Britain was depleted. Miners were forced to dig their shafts deeper and deeper underground. As mines were sunk deeper, the problem of water seepage became more acute.

Closer to the surface, the problem of water in the mines had been addressed by the use of horse gins (*gin* was short for "engine"). This primitive system was little more than a horse-drawn bucket system, involving a horse walking in a circle turning a large drum attached to a pulley and bucket. With the small amount of water found in mines closer to ground level, this system worked adequately. But as miners worked further and further down to retrieve their coal, the water problem increased until the horse gins were no longer doing the job. A new technology was needed.

In 1702, another inventor, an Englishman named Thomas Savery, built a low-power steam engine that worked as a pump. He called his device an *atmosphere engine*. Although intended to pump water out of coal mines, it was not very efficient.

Within a decade, however, an English iron and metals salesman, Thomas Newcomen, was at work on his own steam engine. Like others, he was trying to solve the problem of building an engine that could adequately and efficiently pump water out of English coal mines. He built his first engine in 1712 for a mine near Dudley Castle near Coalbrookdale in the Midlands.

Newcomen's engine was more efficient than earlier steam engine models. His machine consisted of a



piston inside a cylinder. Water sprayed into the bottom of the cylinder was heated from below, creating steam. The steam created a vacuum, which forced the piston to rise. The piston was attached to one end of a great wooden beam that resembled a giant seesaw. As the piston rose, it forced the beam up on one end and down on the other.

The opposite end of the beam was attached to pump rods. When the steam in the cylinder condensed, atmospheric pressure pulled the piston down, bringing with it that end of the beam. The other end raised up, pumping water out of the mine.

The Newcomen engine was capable of about twelve strokes of the piston a minute with the pump rods removing between eight and nine gallons with each stroke. Newcomen built other such engines and, by 1760, approximately one hundred of them were in use in England.

Review and Write

What were some of the obvious advantages brought about by the invention of Thomas Newcomen's steam engine? What problems might the new engine have solved?

James Watt's Fire Engine

While the Newcomen engine was an important step in the right direction, it was, unfortunately, not yet the answer coal producers needed.

The steam engine was underpowered and used huge quantities of coal as fuel. The primary problem with Newcomen's design was that the water in the cylinder was alternately heated (to create steam) and then cooled to draw the piston down by atmospheric pressure. Then the cycle had to be repeated to cause another stroke of the engine. The process of heating and cooling was slow and inefficient.

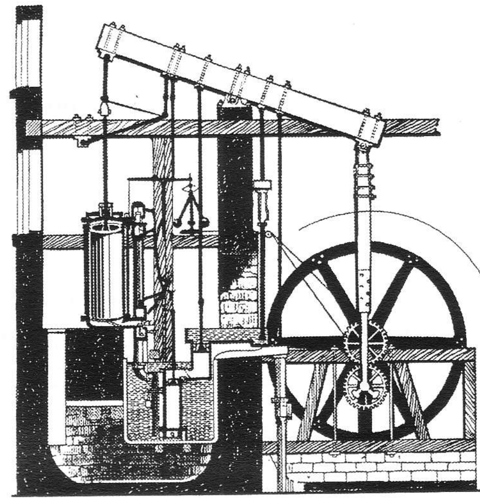
It fell to another creative mind to solve this problem. In 1764, James Watt, who made mathematical instruments for a living, was summoned by a professor at Glasgow University to work on a Newcomen engine in need of repair. Untrained, yet blessed with a creative mind, Watt soon figured out the problem.

While making his repairs, he discovered the root of the inefficiency of the Newcomen engine. The solution lay in keeping the cylinder hot, rather than shifting back and forth from hot to cold. Watt redesigned Newcomen's model, deciding that a second cylinder, which he called a *condenser*, was needed.

With Watt's design, when steam was created in the first cylinder, it was allowed to escape into the second cylinder. Once there, the steam condensed into water again. This allowed the first cylinder to remain hot constantly, increasing the speed of the entire machine. It also decreased the steam engine's fuel consumption. Later Watt models were designed to make the piston work by steam power, creating a machine that ran exclusively on steam. These later designs ran so efficiently, they cut fuel consumption by 75 percent.

By 1768–1769, Watt was busy taking out patents on his new creation—one he called his *fire engine*. He also struck up a friendship with a manufacturer named Matthew Boulton. Watt was looking for someone to produce his steam engines for commercial purposes.

Throughout the early 1770s, Watt refined and perfected his steam engine designs. In 1775, he installed an engine in Birmingham, England, where it pumped water out of a mine at a rate three times faster than a Newcomen model without using any



additional fuel. Before the end of 1775, Watt and Boulton went into business together.

The last problem left to Watt in perfecting his steam engine was solved in 1775, as well. Watt knew that his engine needed a closer fit between the piston and the cylinder. Boulton proposed putting the problem to an ironworker named John Wilkinson, owner of Bradley Ironworks. Wilkinson had recently built a machine for boring cannon barrels smoothly. He applied his techniques to boring steam engine cylinders, and the result was another improvement in Watt's steam engine design. (In later years, Wilkinson used a Watt engine to power his cannon-boring machines.)

Driven to perfection, Watt made other adaptations in his engine designs. In 1781 and 1782, he patented a steam and water gauge, as well as a flywheel device that allowed the engine to run at a constant, uniform speed. Watt also created an index to measure the power of a steam engine. He called it horsepower (with one horsepower being equivalent to 33,000 foot-pounds per minute).

By 1800, the Boulton and Watt Company had constructed nearly three hundred steam engines. Approximately half of them were used to pump water from mines. Others were adapted to additional industries, such as the production of textiles.

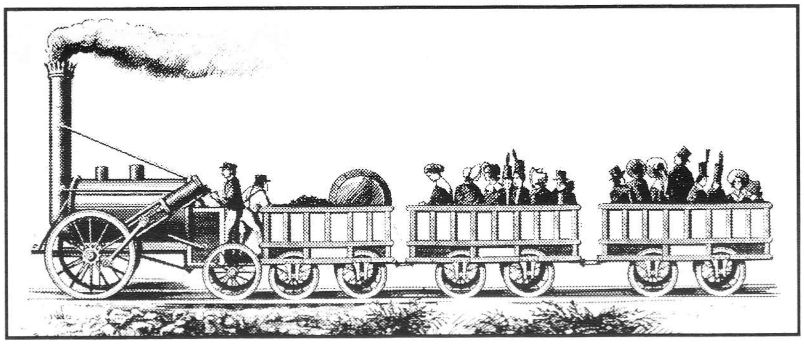
Review and Write

Describe the primary differences between a Newcomen engine and a Watt model.

The Revolution on Wheels

Steam power was the driving force behind the Industrial Revolution. While steam engines were being used to pump water from mines and for other practical, industrial purposes, perhaps one of the most important applications was the building of the world's first railroad.

Wheeled cars running along wooden tracks were in use as early as the 1500s as a more convenient method of removing and transporting coal from mines. But such mine cars were powered by horses and miners. By the 1700s, iron was being used to replace the wooden rails and the wheels of the coal cars. Such wheels were flanged, meaning they had an inside lip which kept the wheels on the tracks, making their use safer.



The next great innovation in early railways was the use of steam power to pull the carts. But a practical steam locomotive was not invented overnight. Early tinkerers included William Burdock, who worked for James Watt. He built a small model steam locomotive in 1786.

One of the significant inventors who designed steam locomotives was a Cornish machinist named Richard Trevithick. In 1801, Trevithick designed and tested a locomotive which unfortunately was destroyed by fire when its boiler malfunctioned. In 1802, he constructed a high-pressure locomotive featuring a funnel smokestack that channeled the steam away from the locomotive and its engineer. But the engine did not draw much attention.

Trevithick's work led him to build one of the first steam-powered coal trains. This little train was capable of pulling ten tons of iron and seventy men in five wagons, their wheels set on iron tracks. This experimental railroad was nine and a half miles in length. The locomotive pulling the small train of iron, men, and cars traveled at the slow speed of five miles an hour!

In 1808, to gain more attention for his work, Trevithick went to London where he built a model train outdoors that ran on a circular track. Its cars were identical to the road coaches of the day. Trevithick sold rides on his circular train for a shilling each. While many curious Londoners visited and rode on his model train, his project failed to receive financial backing and he decided to abandon his work with locomotives altogether.

Only later did Trevithick discover that he had left his work too soon. In 1812, a former employee of Trevithick, Matthew Murray, built a steam locomotive to use in pulling coal cars. (He used some of Trevithick's old designs, paying him for the privilege.) Over the next few years, other inventors and mechanics built their own locomotive models for use as mine trains.

One inventor named George Stephenson decided that a steam locomotive could be employed to pull not just coal cars, but passenger cars. His short railroad, the Stockton and Darlington Railway opened in 1825. (Darlington was a coal field and Stockton was a nearby port.) His first locomotive engine used on the Stockton-Darlington Line was named the *Rocket*, and it hurtled along at the breakneck speed of 16 miles an hour! The Rocket was later used on another early railroad, the Liverpool-Manchester line. By 1830, Stephenson was a well-known railroad inventor and developer.

Improvements came to these early railroads and their locomotives. More powerful steam engines were built, allowing for faster trains. By 1840, England's railroads stretched over 1300 hundred miles of track. More powerful locomotives, fueled by coal, carried freight and passengers at 40 miles an hour. The age of the Iron Horse was here to stay.