The Industrial Revolution: Crash Course History of Science #21

Crash Course: History of Science
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You probably know some of the signs of industrialization in the nineteenth century: Trains connected cities, symbolizing progress.

But they also brought about the destruction of rural lands, divisions between social classes, and rapid urbanization. Clocks, meanwhile, became technologies of standardization: They created a universal time, as opposed to a local “sun time.” But clocks were also technologies of control, ushering in new relationships between owners and workers, and governors and the governed.

Not that life was great before clocks... feudalism was also really unpleasant. And factories appeared, creating new goods, new classes of owners and laborers, and new environmental problems. And communications technologies, starting with the telegraph, made the world smaller.

Like the Scientific Revolution, the Industrial Revolution is a trope—one about changes to technical systems that began in England in the late 1700s. Some historians call this the First Industrial Revolution, and the changes that happened in the United States a century later, the Second Industrial Revolution. No matter what you call it, a revolution started with coal, iron, and textiles in the 1700s.

By 1800, industrialization was still pretty limited, even in England. But by 1900, industrialization had transformed the world. [Intro Music Plays] So, what allowed the Industrial Revolution to take off in England? One reason was social stability.

A period of peace followed the unification of England and Scotland. And both enjoyed a strong rule of law and a free market. Another reason was a population boom.

Industrialization required a large pool of labor to staff the new factories. The population grew thanks in part to what some historians call the British Agricultural Revolution or the Second Agricultural Revolution—the first being the invention of farming itself. From the mid-1700s to the mid-1800s, farms changed rapidly, growing larger as common land became enclosed.

And farmers started using an improved crop rotation plan to get more of out of their land—big ups to my dudes, turnips and clover! Yields went up, resulting in fewer farmers being needed—and, eventually, more people looking for work in towns. But technologically speaking, the Industrial Revolution happened thanks to coal.

Burning coal produced the high temperature necessary to smelt iron. Coal burned more efficiently than charcoal. And unlike charcoal, the coal supply wasn’t limited by the size of a region’s forests.

So coal became the source of heat for the steam engine. The steam engine is a reminder that a revolutionary technology often isn’t one new invention, but a process of improving existing ones. Two earlier scientists came up with ideas for steam engines powered by … gunpowder.

One was Dutch natural philosopher Christiaan Huygens, who’s famous for many things, including the pendulum clock. The other was Dutch–Swiss mathematician Daniel Bernoulli, famous for his work in fluid dynamics. But neither of these gunpowder engines really took off.

Though they may have *explosion sound* in that way. Thought Bubble, show us how the steam engine became a reality: In 1698, English engineer Thomas Savery patented the first workable steam pump, which he called the “Miner’s Friend, or an Engine th Raise Water by Fire.” It was made to pull water up out of coal mines, so you can see that industrialization was linked to the quest for fossil fuels from the very beginning. This “miner’s friend” worked by boiling steam and then cooling it to create a partial vacuum, which then drew the water out of the mine.

It had no moving parts, but it also broke down a lot and was super dangerous. So historians usually give the props for the first steam engine to English preacher and engineer Thomas Newcomen, whose “atmospheric engine” was economically practical. Note, this was in 1712, well before the Industrial Revolution!

Newcomen’s engine was not very efficient—but it didn’t have to be. It ran on coal, but it was used at coal mines, so they had plenty of coal. His engine worked by using a boiler to heat the air inside a cylinder.

A valve then sprayed cold water into the cylinder, creating steam and a partial vacuum, which pulled a piston down through the cylinder. Then the process repeated, heat the cylinder, condense steam, this moved the piston up and down, which also moved an attached beam, which pumped water up from the mine. Savery’s engines didn’t go away when Newcomen’s design hit the market, by the way, because Newcomen’s engines had to be pretty big.

Smaller operations were happy with Savery’s version. This overlap of older, less efficient and newer, more efficient models would continue… and still does today. But in 1781, Scottish chemist and engineer James Watt improved the work of Newcomen.

Watt added a new chamber called a separate condenser where the steam could be collected without affecting the heat of the cylinder. This made Newcomen’s design more cost-effective and doubled its efficiency by reducing wasted energy. Later, Watt tweaked his design again so that it could generate rotary motion, which made it way more useful than a mere water pump.

Watt then teamed up with a Birmingham manufacturer, Matthew Boulton, to produce his engine on a large scale. Thanks Thought Bubble. The steam engine became the workhorse of the Industrial Revolution.

In a matter of decades, steam-powered machines such as trains reshaped much of England. But steam wasn’t the only new technÄ“ around. If the seventeenth century was the century of science, and the eighteenth was the century of philosophy, then the nineteenth century was the century of engineering.

One critical development in engineering was precision manufacturing. For the first time, tool systems like lathes and milling machines worked with high precision. Precision manufacturing enabled the production of interchangeable parts at scale.

The concept of interchangeable parts actually originated in the United States, and was called the American system of manufacturing. We did something This system arose shortly after Watt’s engine, at sites such as the Springfield Armory in Massachusetts, because the US government wanted to be able to quickly repair muskets on the field during war. Eventually, the American system allowed unskilled workers to make large quantities of guns quickly.

Together, precision manufacturing and interchangeable parts allowed for people to replace only part of a machine, not make a whole new one. This lead to a machine revolution that changed every stage of manufacturing in the textile, iron, printing, paper-making, and other industries. So the combination of all of these developments—bigger farms, plentiful coal, miners to dig it up, steam engines, trains to move materials, and precision machines—led to many new technologies.

For example, the first iron-hulled gunboat, the Nemesis, was built in 1839 for the British East India Company. Some iron warships called “dreadnoughts,” and paddle-powered “steamers” were built in the mid-1800s. But steamships didn’t become common until the 1870s.

Communication was also transformed for many people by the development of telegraphy, or sending messages over long distances using electrical signals. Synthetic chemicals also appeared in the mid-1800s. William Henry Perkin developed the first synthetic dye, a shade of purple known as mauveine, in 1856.

And the mid-1800s also saw the rise of machines in agriculture, both for plowing fields and harvesting crops. Then, of course, in the 1880s, inventors introduced electrical light to a murky, gas-lighted world—but we’ll have a separate episode on all that. Cool new gizmos aside, the enormous wealth concentrated in cities, and their dense populations, led to a whole new scale of construction of old technologies, like bridges.

Around 1800, the Port of London decided it needed another bridge across the River Thames. Lots of folks submitted proposals, including the famous engineer Thomas Telford, who designed a single cast-iron arch with a span of six hundred feet.v Cast-iron bridges were a brand new thing, so there were no technÄ“, or experience-based standards for determining if any given design would actually work. Likewise, there was no epistÄ“mÄ“, or theoretical science, relevant to this scale.

Universities didn’t even have engineering professors yet! So Parliament created two committees to solve the bridge problem, one consisting of mathematicians and natural scientists, and the other of practicing builders. The upshot: neither group could figure out how to scientifically determine if a given bridge design would work, just by looking at the plan!

Instead, some really good silliness ensued. The Astronomer Royal suggested that the bridge be needed to be painted white, so its strength wouldn’t be affected by the sun. Meanwhile, the Pavilion Professor of Geometry was able to calculate the length of the proposed bridge down to one ten-millionth of an inch, and its weight to one thousandth of an ounce.

But he couldn’t determine if it would actually be stable. So what I’m getting at is, the Industrial Revolution was sometimes not very revolutionary-looking. Now, what were the social effects of the Industrial Revolution?

Before the early nineteenth century, most finished goods were made in small batches in the so-called cottage system, where craftspeople, including women, worked at home. But, by 1800, the capital generated by cottage industries became the foundation for factories. And factories offered lots of advantages over a rural cottage—namely, production could be mechanized and centralized, to make things more quickly for less money.

And the introduction of interchangeable parts meant that, instead of one skilled craftsman making one musket, several people could work on different parts of it. So, crafts went from being unique to being mass-produced. And if production changed, you know that labor was bound to change, too.

As industrialization took off, labor went from being seasonally based to being based on clock time. Factory work started early in the morning and stopped late at night. Laborers worked in shifts and were fined if they didn’t keep pace.

And as a result of all these changes in the labor force, the whole idea of class also changed. Before the Industrial Revolution, your lot in life was determined by birth. But industrialization led to a new view of society where classes were tied not to nobility but to money.

Which raised the possibility of class mobility. In fact, the Industrial Revolution produced a whole new middle class of non-noble property owners. The middle class became both the chief producer and consumer of factory products.

And most of the early factory owners were middle-class entrepreneurs. The working classes on the other hand often worked in crowded, unsanitary facilities. Poor draining of sewage gave rise to a host of new hygienic problems, especially outbreaks of typhus and cholera.

In the 1800s, epidemics of cholera killed at least 140,000 people in Britain, mostly the poor. And the urban poor weren’t the only people affected by the industrial revolution. The burning of so much coal, so quickly left behind a literal mark in the earth’s geohistory.

Today, many earth scientists agree that we are actually living in a new geological epoch due to human alterations of the earth. Earth scientists have proposed a name for the new epoch—the Anthropocene, the “age of man.” We’ll come back to this, too. So the Industrial Revolution is indeed a trope—a useful, if reductive, shorthand for this period in history.

But it’s hard to argue with the fact that, in many ways, for at least some people, it was truly revolutionary. Industrialization increased the standard of living for many and led to sustained economic growth. But it also led to environmental degradation, harsh working conditions, and the Anthropocene itself.

But before we move on from the early 1800s, there’s one more scientific revolution we’ll want to to explore. Next time—we’ll travel around the world twice with the first modern biologists: Chuck Darwin and Al Wallace. Only the fittest will survive!

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