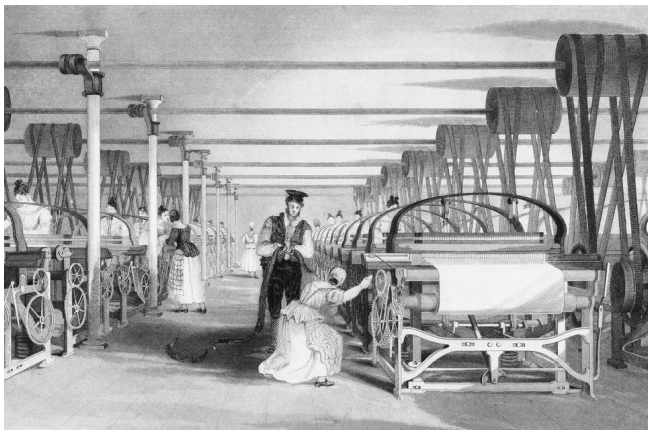
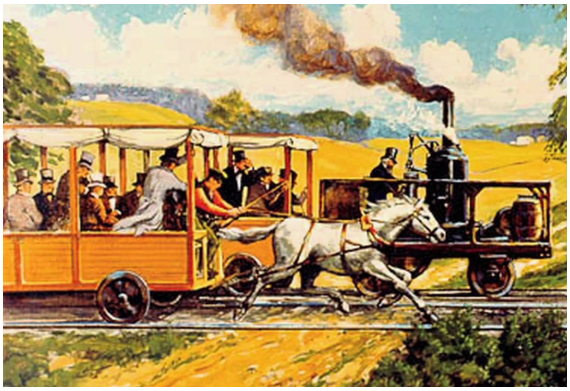
E. The "Age of Steam" or "Proto-Industrial" Phase of History (1769-1869)

1. The Watt Steam Engine is the invention that triggered the "Age of Steam."
2. Simply put, this means that a variety of inventions that transformed human life all proceeded from this one fount.
3. One great transformation that occurred was the pairing of the steam engine with various forms of machinery for the production of clothing. Everything from "spinning" (the production of thread from raw materials like cotton and wool), and weaving (turning thread into cloth) was mechanized with this new form of power. Machines like the *Spinning Jenny (c.1764)* and the power loom (c.1787) created a "Textile Revolution" whereby it became normal for there to be an abundance of clothing for the first time in history.



A factory with steam powered looms could produce thousands of times more clothing that traditional "cottage" industry with the same amount of human labor.

4. Apart from engines for elevators and other industrial machinery in mines, the pairing of steam engines to ships and wagons also began soon after **1769.**
5. A steam engine could be paired with a paddle wheel to make it turn and propel a vessel through water even if there was no wind. Never again would sailors have to rely on nature to sail down (or especially *up*) rivers or across oceans. The first hybrid steam ship to cross the Atlantic ocean, the SS Savannah did so in less than a month in **1819**, whereas the Mayflower had taken 63 days. The SS Sirius was the first ship to do it completely under steam power (no wind), and it made the voyage in only 19 days in **1837.**
6. Somewhat later, steam engines were paired with very basic carriages, of the same kind that were pulled by horses, and with the invention of rail, this type of transportation innovation generated railroads—first in England, and soon in America.

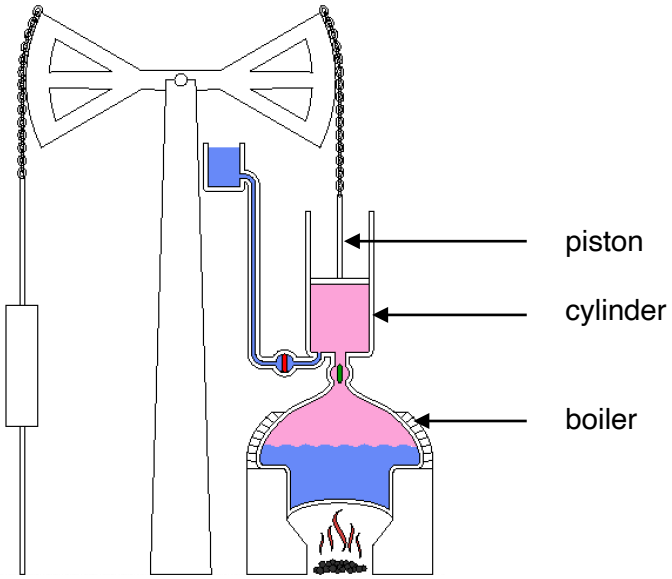


Early steam "locomotives" did lose the first races against horse-drawn carriages, but advancements in steam power soon proved the worth of the new technology.

7. Progress in this area was slow. This is part of what characterizes the "proto-industrial" phase from the most modern industrial periods. In the *pre-industrial* era, there was almost *no* progress. In the *proto-industrial* period, there was measurable progress—which was itself quite radical compared to pre-industrial times, but almost laughable compared to what we experience today in terms of the pace of change. That's one element that distinguishes this period.
8. During this still relatively slow period of progress, pre-industrial technologies still prevailed in some cases. For instance, the Erie Canal—basically a long ditch connecting Lake Erie to the Hudson River and thus New York City in **1825** still represented a huge boon to New York, which became the main commercial city in America because of all the goods flowing from the mid-West to the city instead of Boston or Philadelphia.
9. Another reason to refer to this phase of industrial history as "proto-industrial," is that all the inventions of this period are now obsolete, and have been replaced by more advanced implementations of similar technologies. With regard to steam power, for instance, we now use *oil* (refined as gasoline) to fuel *internal combustion engines* in our ships and trains—*and* in modes of transportation that would never be practical with wood or coal-fired steam engines, but which are with with internal combustion engines, namely planes and automobiles.
10. The Age of Steam or Proto-Industrial phase of history is almost exactly **one century.** That's handy, especially when trying to remember the dates. **C. 1769,** the Watt Steam Engine was invented, and in **1869** the greatest accomplishment of the era, the construction of the first *transcontinental* railroad—the Union Pacific Railroad—was completed, linking California to the East Coast.
11. As is often the case in the story of modern industry, just as one form of technology is peaking, it's already becoming obsolete. In **1870**, an industrial colossus was formed: the Standard Oil company of John D. Rockefeller. This company would propel a whole new industry forward, and make Rockefeller possibly the richest man in all of history. (It's hard to compare wealth across periods. Rockefeller was certainly the richest man that had ever lived until his time. How his wealth compares to that of Bill Gates or Jeff Bezos is hard to reckon.) Regardless, the full-fledged Industrial Age, or as it is commonly known "*The Industrial Revolution"* was truly beginning.

F. The Second Power Revolution, Part 1: Oil

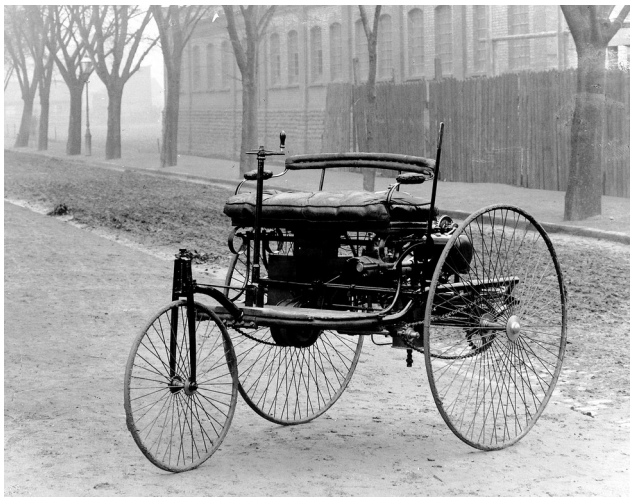
1. Marking the formation of the Standard Oil company of John D. Rockefeller in **1870** is one way to capture the transition from proto-industrial to truly industrial technology. Oil (refined into gasoline) is the fuel that makes possible kinds of engines which propelled the most transformative inventions of the modern age: automobiles and airplanes.
2. Steam engines could never have been used in cars and planes for the simple reason that they are too large and heavy. A steam engine derives its power from a vessel called a "boiler" in which water is boiled to create steam, usually by burning coal. The pressure created by that steam then enters the mechanical contraption called an "engine"—specifically a cylinder in which pressure changes move a piston, as in the schematic of a simple steam engine below.



3. Steam engines are sometimes called "external combustion engines," because the burning of of the fuel is done outside the engine itself, in the compartment called the boiler. If a car had such an engine, it would look something like this:

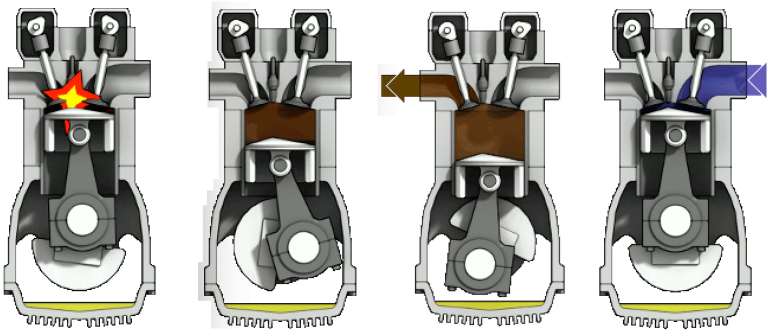
boiler

4. By contrast, "internal combustion engines" are so much more compact, that early models more resembled bicycles (technically tricycles) than cars.



The first Mercedes Benz - 1885!

5. The ability to burn gasoline inside the engine is what leads motors of this kind to be referred to as "internal combustion engines." As per the diagram below, in such an engine a mixture of fuel and air are pumped into the cylinder, and then exploded! The explosion creates the pressure to move the piston and generate mechanical force. This is many times more efficient and powerful than what steam engines can do.

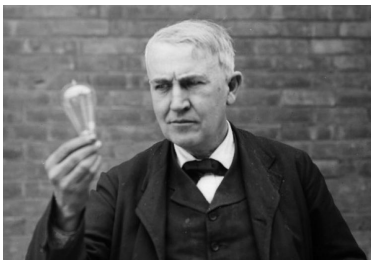


A fuel-air mixture explodes thanks to a spark plug, driving the piston down, cranking the axle that turns the wheels of the vehicle, and pumping the exhaust out, permitting the entry of new fuel. This process occurs perhaps 30-50 times per *second* in your family car as it travels down the road!

6. The incorporation of small and light internal combustion engines into the first airplane, flown by the Wright Brothers in **1903**, and then in mass-produced automobiles like the Ford Model-T, which began production in **1908** are what propelled the industrial phase of the transportation revolution.
7. Meanwhile, a parallel power revolution was transforming other aspects of industrial life such as the livability of our shelters, our ability to communicate at great distances, and our ability to produce and distribute food…

G. The Second Power Revolution, Part 2: Electricity

1. The Industrial phase of the history of technology, also called the *"Industrial Revolution,"* is based on the use of oil as a fuel source in modern means of transportation, and the use of electricity to power a host of previously unimaginable devices from lightbulbs to refrigerators and televisions.
2. The linked phenomena of magnetism and electricity had fascinated human beings for thousands of years, but they had found little practical use apart from the magnetic compass used by mariners such as Christopher Columbus.
3. The modern scientific study of these phenomena resulted not only in great scientific progress, but also spawned many and wondrous technological inventions, starting with the telegraph, invented **c.1837** by Samuel Morse (after whom "Morse code" is named). Telegraphs were powered by batteries that sent an electric signal down a wire, which could be interrupted and re-established with a Morse key to create a message.
4. As batteries improved, other uses for electricity were imagined by amazing inventors, such as Alexander Graham Bell, who invented the telephone **c.1876** and Thomas Edison, who invented the incandescent light bulb **c.1879.**
5. When the ability to generate electricity by spinning motors called "turbines" with water falling from a great height (as at Niagara falls) became possible **c.1882**, "hydro-electric" power generation, paired with long-distance electrical transmission eventually made it possible to light the cities and homes of the world.
6. Who can even begin to calculate what new wonders were created because inventors could work through the night in well-lit laboratories and offices from that point onward?!

Alexander Graham Bell makes his first famous public telephone call in **1876** (left) and Thomas Edison shows off his lightbulb in **1879.**