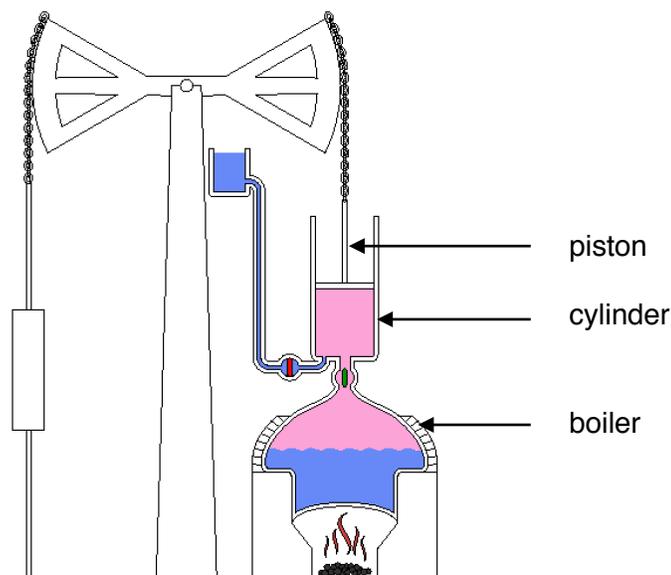


### F. The Second Power Revolution, Part 1: Oil

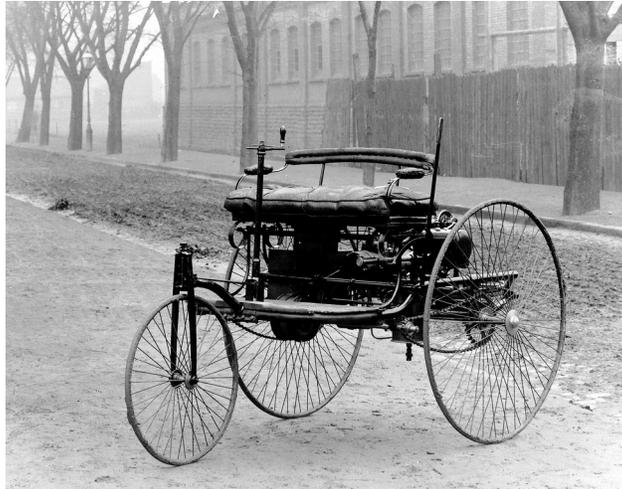
1. Marking the formation of the Standard Oil company of John D. Rockefeller in **1870** is one way to capture the transition from proto-industrial to truly industrial technology. Oil (refined into gasoline) is the fuel that makes possible kinds of engines which propelled the most transformative inventions 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 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:

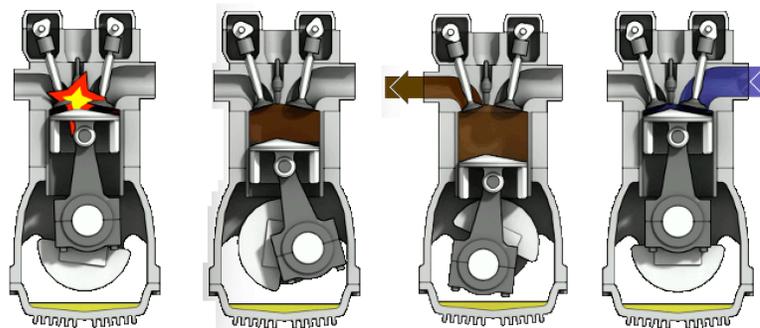


4. By contrast, “internal combustion engines” are so much more compact, that early models more resembled bicycles (technically tricycles) than cars.



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**.