## The transformation of the world

At one time, humans provided most of their own energy. They ate plants and animals for fuel, burned wood, and were helped by domestic animals. Windmills and waterwheels captured some extra energy, but little could be saved. All life depended on the energy the Sun sent to the Earth.

Everything changed during the Industrial Revolution, which began around 1750. People found an extra source of energy that could work for them. That source was fossil fuels — coal, oil, and natural gas. These formed underground from the remains of plants and animals from much earlier geologic times. When they were burned, they released energy, originally from the Sun, that had been stored for hundreds of millions of years.

Workers shovel coal in England, 1912

Coal was formed when huge trees from the Carboniferous period (345 million to 280 million years ago) fell and were covered with water, so that oxygen and bacteria could not decay them. Materials pushing down compressed them into dark, carbonic, burnable rock.

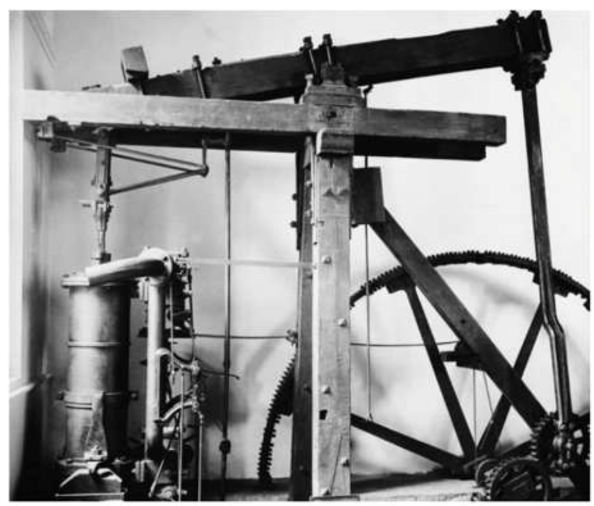
Most of the Earth's oil and gas formed over a hundred million years ago from tiny animal skeletons and plant matter that fell to the bottom of seas or were buried in sediment. This organic matter was compressed by the weight of water and soil.

Coal, oil, and gas are relatively common on Earth. But they are not evenly distributed. Some places have much more than others due to the diverse ecosystems that existed long ago.

## Early steam engines

The story of the Industrial Revolution begins on the small island of Great Britain. By the early eighteenth century, people there had cut down most of their trees to build houses or ships and for cooking and heating. They needed something else to burn. They turned to the hunks of black stone (coal) that they found near the surface of the Earth. Soon they were digging deeper to mine it. These coal mines, deep in the Earth, began to fill with water. Using horses to pull up bucketfuls of water was too slow.

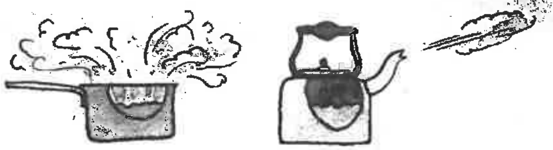
To the rescue came James Watt (1736–1819), a Scottish instrument-maker. In 1776, he designed an engine that used burning coal to produce steam. The steam drove a piston. This steam engine was first used to efficiently pump water out of coal mines. But his engine worked well, and it was put to other uses. He became a wealthy man. After his patent ran out in 1800, others improved on his engine. By 1900, engines burned 10 times more efficiently than they had a hundred years before.



A James Watt steam engine

# STEAM POWER

When water is boiled it turns to steam. As it changes states, it expands dramatically; as a gas it fills 1,600 times the volume that it did as a liquid.



Boil water in an open pot, and the steam will vanish into the air. But boil water in an enclosed space, and the swelling steam will push hard against what holds it. That pushing, that pressure, can be directed and used. It can make a tea kettle whistle—or a locomotive move.

In the locomotive, the enclosed space that holds the water is called the boiler. At the back of the boiler is the firebox, which holds a coal or wood fire. At the front is the smokebox. Dozens of small tubes run from the firebox through the water to the smokebox; these tubes carry the heat of the fire to the water and bring the water to a boil. The steam that results pushes up into the steam dome at the top of the boiler.

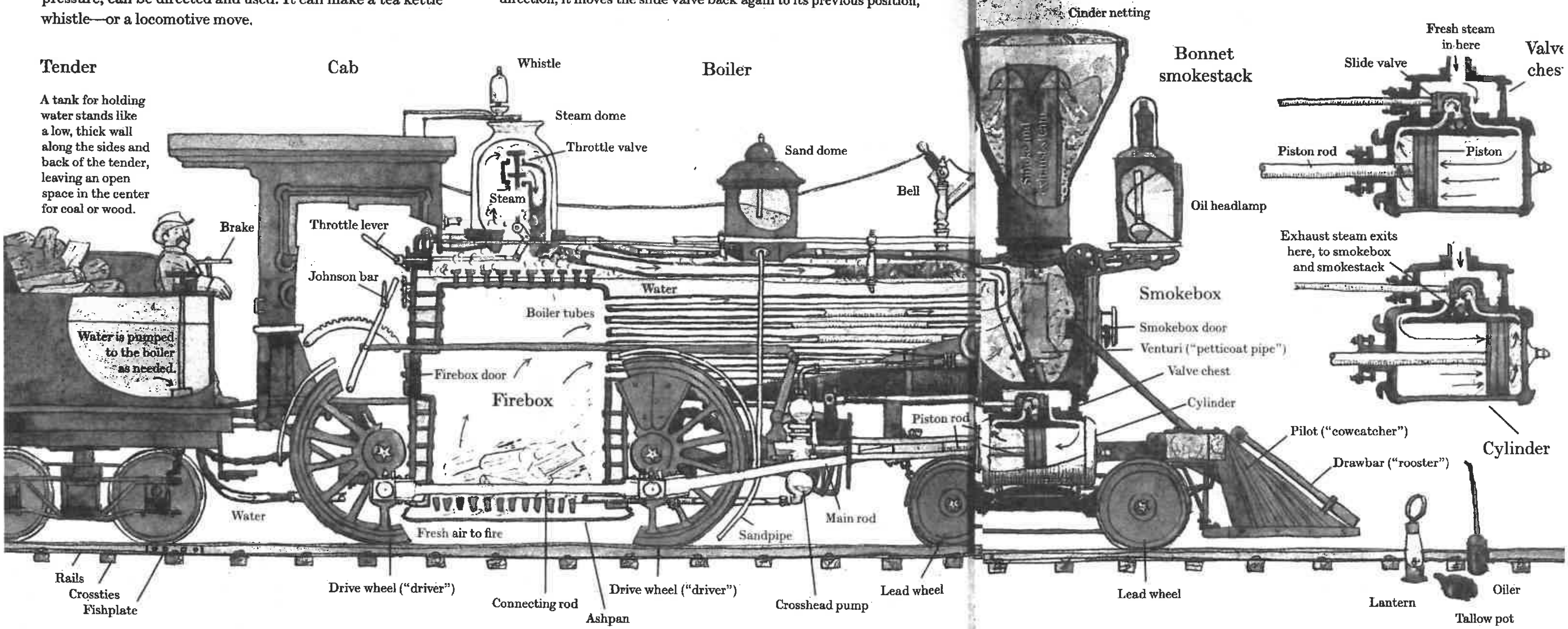
By pulling on the throttle lever in the cab, the engineer can open a valve in the steam dome—the throttle valve—and allow the steam to rush forward to cylinders at the front of the engine. Inside the cylinders, the steam pushes on pistons. The pistons push and pull on rods connected to the engine's drive wheels. The rods convert the piston strokes into circular movement and turn the wheels, putting the engine into motion.

Each piston stroke also moves a small slide valve that sits in a chest atop the cylinder. The position of the slide valve controls whether steam enters the front or the back of the cylinder, so when the slide valve moves, the piston reverses direction. As the piston reverses direction, it moves the slide valve back again to its previous position, which reverses the next piston stroke, which moves the slide valve, and so on, and so on. This cycle keeps the pistons moving back and forth and keeps the drive wheels turning.

The piston strokes also push exhaust steam out from the cylinders, through the smokebox, and out the smokestack. The rush of ejected steam through the smokebox creates a drop in pressure that reaches back through the boiler tubes to the firebox; the vacuum pulls heat forward through the tubes and pulls fresh air into the firebox through grates in the firebox floor. The air feeds the fire, the fire boils the water, the boiling makes the steam, the steam moves the pistons, and on the sequence goes.

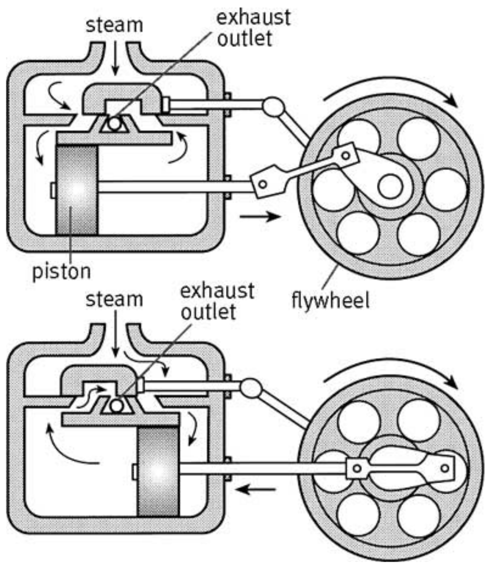
Finally, the blast of steam leaving the smokestack makes a noise—a *huff* or *chug*, the unmistakable sound of a steam locomotive at work.

These ingeniously interlocked events, managed by a skilled crew, send a locomotive *chug chug chugging* on its way.




"What the infant electricity has in store for us it would be rash to predict, but for locomotives its steps have been thus far weak and uncertain, and when we want a giant of steel or a race-horse of iron our only sure reliance is steam."—*The American Railway*, 1888

# Parts, Purposes, and Puzzles




| What are the parts of the steam engine? | What is their purpose? |
|---|---|
| Steam inlet/outlet | |
| valve | |
| Cylinder | |
| Piston | |
| Piston rod | |
| Flywheel | |

What puzzles remain?

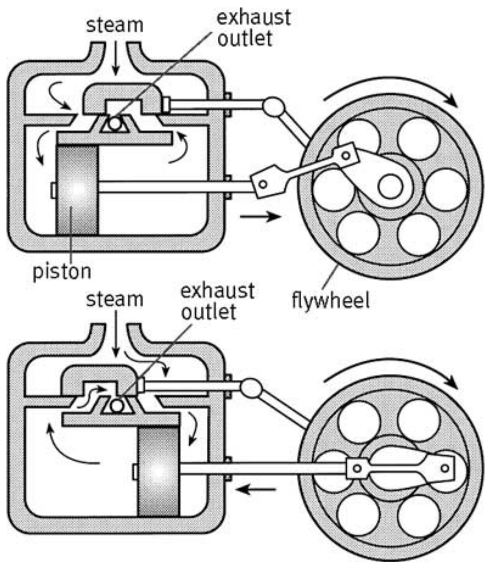
What material should it be made from?

What source of energy will boil water for steam?

What was the benefit of the steam engine?

What uses can the steam engine be put toward?

# Parts, Purposes, and Puzzles




| What are the parts of the steam engine? | What is their purpose? |
|---|---|
| Steam inlet/outlet | The inlet/outlet allows the pressure of the  steam to enter and exit the cylinder. |
| valve | The valve controls which side of the cylinder the steam will enter, as well as, controlling the steam input and output |
| Cylinder | The cylinder captures the pressure of the steam to direct the piston. |
| Piston | The piston is the moving part of the engine that receives the pressure of the steam |
| Piston rod | The piston rod directs the movement from inside the cylinder outside upon the wheel |
| Flywheel | The flywheel captures the inertia of the movement to support the back and forth flow of the piston smooth and continuous. p |

What puzzles remain?

What material should it be made from?

In order to capture the pressure of the steam, the engine must be made of a strong material, like metal.

What source of energy will boil water for steam?

Any combustible matter will work, but at the time people were transitioning from wood to fossil fuels, like coal and oil.

What was the benefit of the steam engine?

Previously wind and water were used to power machines, but those machines depended on the proper location. The steam engine could be used anywhere and was not dependent environmental factors.

What uses can the steam engine be put toward?

The movement can be put toward transportation by turning the wheels that move trains, steamboats and cars.  They also can be used to power various types of machinery like pumps, looms, spinners.