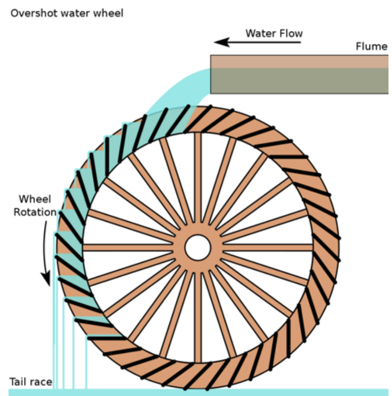
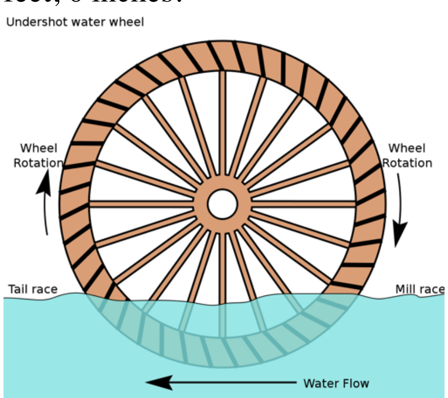
Gears to the Water Wheel! Round and Round and Up and Down

The distinguishing feature of Colvin Run Mill is the wonderful water wheel. Imposing at twenty feet in diameter, with 10-foot spokes, and 60 buckets to catch water, the water wheel is stately and majestic when motionless and quietly awesome when in motion. We explain to visitors that the water wheel harnesses water's energy which is transferred to the axel to drive the gears that propel the running stone to grind the grain. Seldom do we have an opportunity to explain that the Colvin Run water wheel is but one type of wheel and grinding grain is but one function of a water-powered mill. What are other types of wheels and mills?



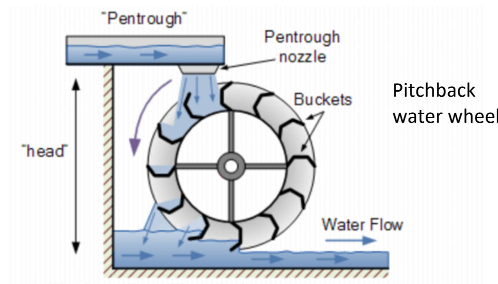
Colvin Run has an "overshot" vertical water wheel. Water from the flume hits the wheel slightly forward of vertical center. The potential energy of the water is a product of the weight of the water times the acceleration of gravity times the height the water falls when in the buckets. The water's energy propels the wheel around the axle, like a rotating lever with the axle being the fulcrum. The wheel moves a greater distance than the axle, but the axle has greater force transmitting the water's energy to drive the gears and running stone. A well-designed "overshot" wheel transfers 80 percent of the water's potential energy to the axle. The twenty-foot water wheel clearly generates more force that a smaller one. The largest water wheel in the world is the Laxey Wheel in the Isle of Man with a diameter of 72 feet, 6 inches!



The first and simplest vertical water wheel was an "undershot" or "stream" wheel. Flowing water from a stream or river pushed paddles on the water wheel in the same direction as the flowing water. Rather inefficient as it captures only about 20 percent of the water's energy because it does not use gravity to amplify the water's weight.

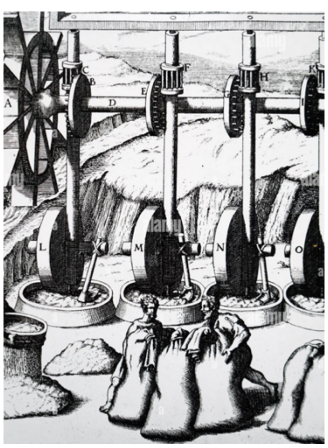
Variations on the themes of "overshot" and "undershot" water wheels are the "breastshot" and "pitchback" water wheels. In the former, the water enters the wheel's buckets about halfway up, around axle height, and pushes the wheel backwards. Accordingly, only about half of the gravitational force is generated compared to an overshot wheel. The flow of the water released from the buckets provides additional push to the water wheel as the water exits the tail race.

The difference between a “breastshot” and “pitchback” water wheel is that the latter releases the water at the top of the water wheel making full use of gravity and is about 80 percent efficient.



Gears transform the vertical rotation of the axle to the horizontal rotation of the grinding stone. At Colvin Run we show how the axle drives the greater face wheel, which is a spur gear with inserted teeth or “cogs,” in a vertical direction like the water wheel. The cogs mesh with cylindrical rods of a birdcage gear, which again rotates vertically, but being smaller than the greater face wheel, moves faster. The birdcage gear drives an axle attached to a lesser face wheel with cogs, still turning vertically. But here comes the switch! The lesser face wheel cogs mesh with a birdcage gear that turns horizontally! Again, being smaller, this gear turns the fastest of all, driving the shaft attached to the running stone. The running stone rotates horizontally about ten times for every time the water wheel rotates once. Thus, gears change the speed, the direction, and torque (that is the rotational equivalent of linear force – a twist to an object around a specific axis) of the water’s energy.

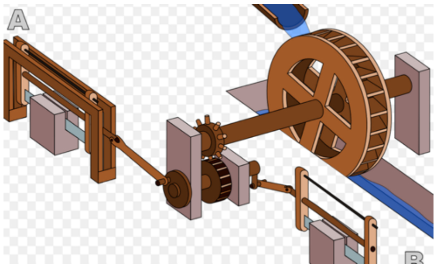
While a bit complicated to describe, it is fascinating in operation. Essentially what we have here are mechanisms going around and around.



What about other types of mills? Oil mills with vertically rotating stones crushed or bruised oil-bearing seeds, like linseed, hempseed, peanuts, and olives. A chalk mill would grind chalk into powder to be mixed with linseed oil to create a filler, like spackling. Bark mills ground tree bark into powder for tanning.

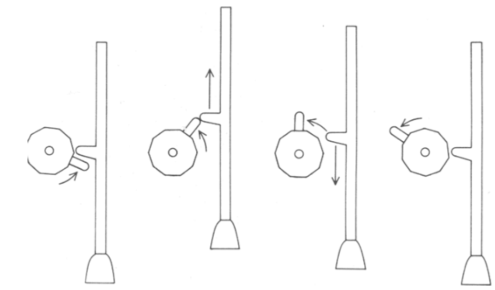
Gunpowder mills ground cool charcoal and sulfur to a fine powder. That powder was mixed with moist saltpeter (calcium nitrate excavated from guano-rich bat caves mixed with potassium), then crushed in a press mill to form a cake. The cake would be cut in a corning mill, dried, then tumbled in a glazing mill with graphite so the grains would not stick together.

Wait a minute! A cutting action like that of a saw blade requires a back and forth or up and down action, what mechanics call reciprocating motion. How can rotary motion be converted to reciprocating motion? There are several ways. But for purposes of water mills we confine ourselves to two: the “crank-and-rod” and the “cam-and-follower” methods.



A crank and rod coverts rotatory movement to a linear one using a hinged wheel attached to a rod. The rod moves backwards and forwards as the wheel rotates. This technique was used in early stone and saw mills.

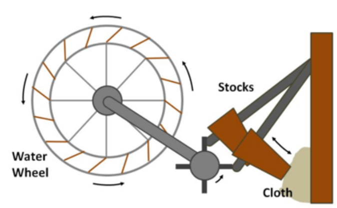
In the “cam-and-follower” method a cam, which is rounded with an irregular profile, is placed on a follower, a straight rod. When the cam rotates up its irregular shape lifts a protruding piece on the follower (see illustration) causing the follower to rise. Once it passes that piece, gravity drops the follower down. Bang!



The reciprocating, up and down action could be used to crush rocks, pound pig iron into wrought iron, hammer copper into plates for making coins, open and close forge bellows, and cut wood. “Knock and drop" sawmills employed a frame (follower) carrying the saw blade that is knocked upwards by a cam as the shaft turns. When the frame/saw drops it cuts the tree trunk. Sawing up and down.

One more rather curious example of a water driven mechanism is a “fulling mill.” Yarn spun and woven needed the resulting loose web of cloth be “fulled,” that is cleansed of its natural grease and matted together to produce a smooth, thick, compact fabric. Once “fulled,” the fabric could be stretched and dyed. Initially, the chief scouring agent was stale urine because its nitrogen content possessed, among other things, detergent qualities. A tub or two or urine was kept in every house for the task. A miller might pay the poor for their product. Fortunately, after 1800 *fuller’s earth*, which resembles clay, replaced urine, and was used in combination with soda and soap to clean grease and grime from the wool.

In a fulling mill the water wheel rotated an axle with spokes that would lift wooden rods fitted with heavy wooden mallets. Once the spoke passed the rod, the mallet would fall on the cloth. The mallets’ constant rising and falling pounded the cloth in a water-filled trough.



There you have it. Examples of different water wheels and the mechanisms they operated: round and round and up and down (and back and forth). Gears to the water wheel!