



**MUSÉE
D'HISTOIRE
DES SCIENCES
GENÈVE**



Mechanical moves

The principle of least effort

English texts of the exhibition

Une institution
Ville de Genève

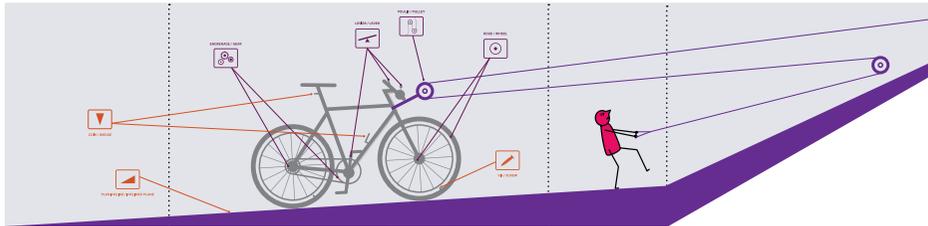
www.museum-ge.ch



Mechanical moves: the principle of least effort

How do you get a weight to move without exhausting yourself?

Since Antiquity, or even before, humans have developed a range of techniques and schemes for moving, carrying or immobilising heavy weights. We have called them “machines”. In their most rudimentary form they are called “simple machines”. They can be divided into two classes: those based on an inclined plane, and those which use a lever. Simple machines are part of our everyday lives although we don’t always notice them. They simplify our lives through many familiar individual or connected objects. We invite you or your family to try lifting some weights and finding out how simple machines work.



Mechanical moves : the principle of least effort is an original and bilingual (french/english) exhibition of the Musée d'histoire des sciences of Geneva, presented from the 17th of October 2018 until the 15th of September 2019.

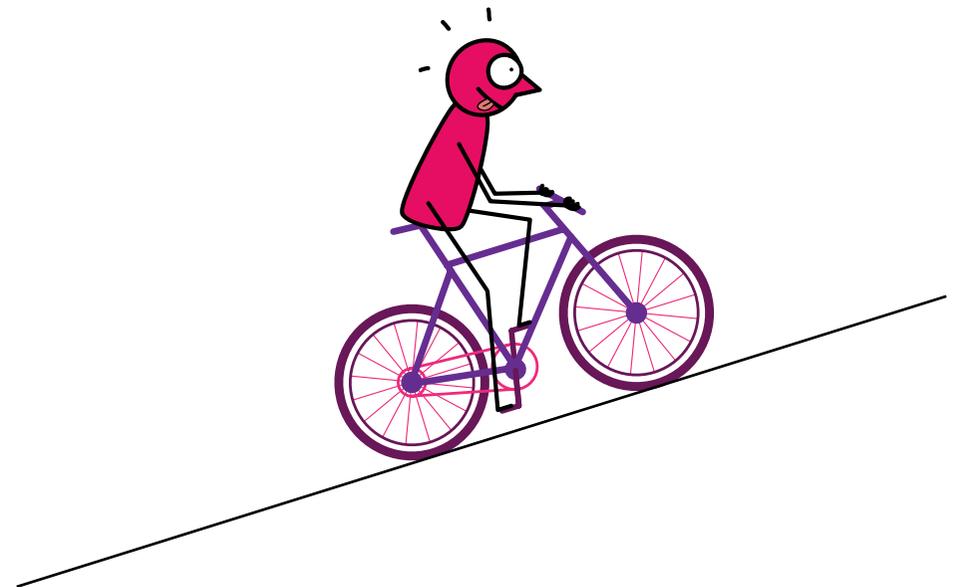
More information about the exhibition on the website

www.ville-ge.ch/museum

English translation : Liz Hopkins

Graphism and photos: Elise Gaud de Buck, Gilles Hernot, Philippe Wagneur

© Musée d'histoire des sciences, Genève 2018



What is a simple machine ?

Simple machines are the building blocks of complex machines.

There are two main classes of simple machines: those based on an inclined plane and those based on a lever. Each class can be further sub-divided producing different types of simple machine, the numbers depending on their inventors: 5 for the Greek Heron of Alexandria, 6 or even 7 or 8 for other inventors

We have chosen to present 7: the inclined plane, wedge, screw, lever, wheel, pulley, gears.



When simple machines are combined, they become complex machines. We find them among most everyday objects.

The role of simple machines is to make our daily lives easier by helping us to move, lift or immobilise weights, or simply to save time. We use them to change the direction, distance or intensity of a force but not to change the amount of energy required for a task.

They all depend on the same fundamental law:

$$\text{work} = \text{force} \times \text{distance}$$

Work is the energy provided by a force when an object is moved. Machines make the work easier by adjusting the **force** or the **distance** to our advantage, but not both at the same time! If we want to reduce the force, we must increase distance; if it's the distance we want to shorten, it's the force which must be increased according to the law of conservation of energy.

Inclined planes

An inclined plane is a flat surface tilted at an angle. This type of structure facilitates the vertical movement of a weight.

Inclined planes are the basis of several simple machines such as wedges and screws whose principles are applied in many familiar objects.

Inclined plane

Formed of a flat, sloping surface, the inclined plane facilitates the upward movement of a weight. By changing the degree of slope, the effort required can be reduced but the distance travelled is increased.



Wedge

A wedge is a simple machine with two functions which may appear contradictory: they are the separation of joined materials (splitting wood, for example) or blocking and holding an object (such as a peg or a nail). Its form is of two inclined planes which meet at the point.



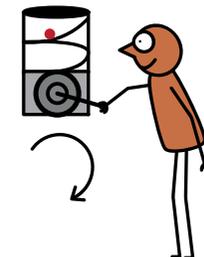
Screw

Screws are used to fix things in place. In addition to its head, the stalk of a screw is twisted, that is, it's a spiral inclined plane.



Archimedes' screw

The screw attributed to Archimedes is a specific type. It does not fix objects but lifts liquids or solids along its coils.



Lever

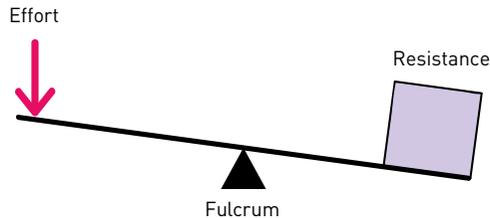
A lever is usually composed of a rod or beam (called an arm) which rests on a fulcrum. With the addition of a force the lever helps to move a load.



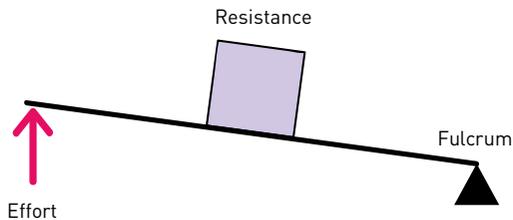
The length of the arm allows the effort required to move the load to be changed.

There are **three classes** of lever depending on the relative position of the arm, the fulcrum, the effort and the load (or resistance):

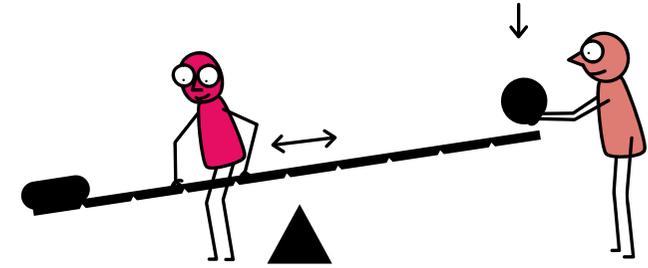
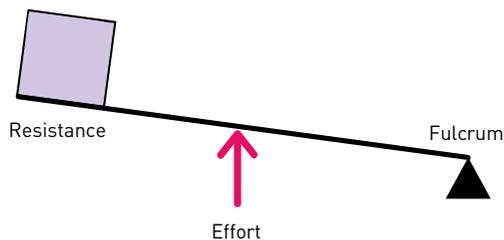
- **Fulcrum in the middle:** the fulcrum is located between the effort and the resistance, for example, a seesaw, scissors or a crowbar.



- **Resistance in the middle:** the resistance or load is located between the fulcrum and the effort, as in a wheelbarrow, a door or a nutcracker.



- **Effort in the middle:** the effort is located between the fulcrum and the resistance, for example tweezers, a broom or a stapler.



Wheel

The wheel is none other than a round lever!

A wheel is composed of a disc (solid or openwork) which turns around a shaft which functions as the axis as well as the fulcrum in this specific type of lever. The difference in size between the wheel and the shaft means that the force to be applied and the distance to be travelled, can be adjusted. In addition, wheels reduce friction.

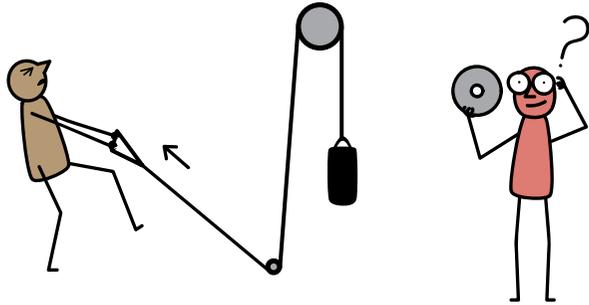


Pulleys

A pulley is a wheel which serves to transmit movement, often with a groove to guide a cord, a chain or a belt.

Pulleys are used to change the direction of movement in relation to that of its task. There are fixed and mobile pulleys, working together on the load. By grouping several pulleys the weight can be reduced as long as the distance covered by the cords is increased.

We invite you to test various mixtures of stationary and mobile pulleys. Note the effort required each time and the length of the cord.



Gears

Gears are formed of toothed wheels which, by temporarily meshing with each other, transmit movement.

The number of toothed wheels, their diameter, the number of teeth and their form determine the direction and speed of movement.

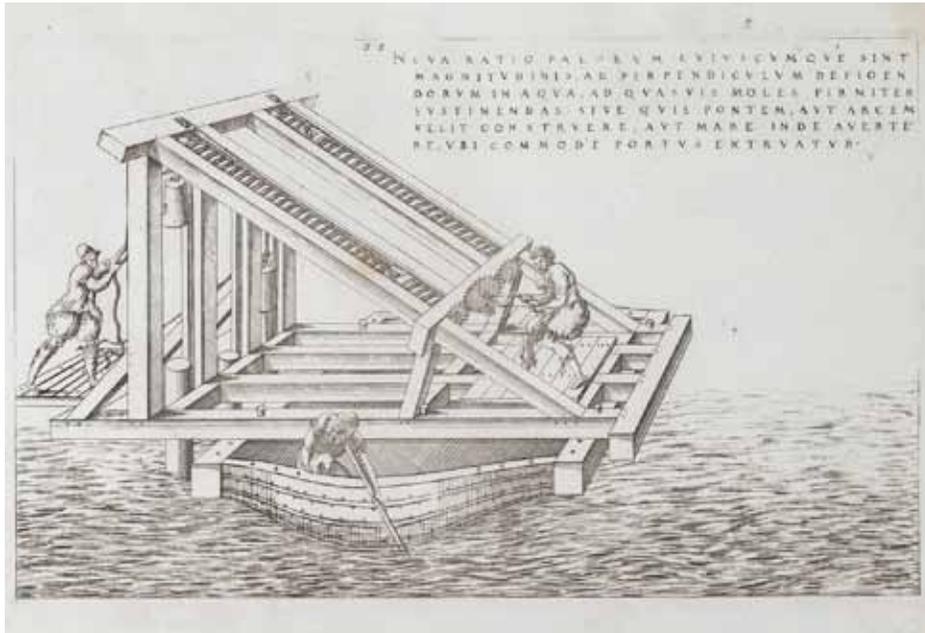


A quiz

See how many simple machines you can identify amongst everyday objects.

A game to begin or end your visit to the exhibition.





A catalogue of 16th century machines

The theatre of mathematical and mechanical instruments by Jacques Besson (published in Geneva in 1578).

This technical work with some 60 beautiful plates, presents a series of instruments and mechanical machines, mostly invented by the author himself.

Browse through it and be inspired.

(Library of the History of Science Museum)

The exhibition continues at the ground floor...

Astronomical regulators

Astronomical regulators are clocks which mark seconds and are designed especially for astronomers.

Chronoscopes

Designed in the 1850s for physics and ballistic experiments, chronoscopes are electromechanical clocks which measure time intervals to the precision of one millisecond. They were widely used in experimental psychology to study reaction times. The clock's movement is controlled by an electromagnet.



Mathematical machines

The calculating machine was invented in the 17th century. In order to help his father, who was a tax inspector, Blaise Pascal made the Pascaline, a machine which could add and subtract and which had an automatic carry-over mechanism. Later in the century Gottfried Wilhelm Leibniz developed a machine which could multiply (and divide) equipped with a driving mechanism of stepped cylinders and a mobile carriage.

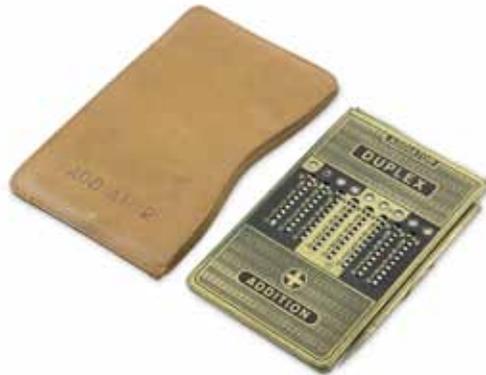
These two technologies, which lay dormant for nearly two centuries, were taken up again by many calculator manufacturers in the 19th century, the period of the industrial revolution and the growth of world trade. Insurers, traders and bankers needed to make very rapid, accurate calculations repeatedly. Instead of employing several people to



do this as in the past, they turned to mechanical instruments which could be operated by one person. A German maker called one of his machines TIM, an acronym for Time is Money. Hundreds of thousands of these machines were produced until the 1950s when mechanical calculating machines were replaced by electronic calculators and then computers.

Cross calculators, help for calculations

Cross calculators appeared in the second half of the 19th century and remained popular until the 1960s because of their reasonable price and light weight. They could carry out additions and subtractions. Unlike mechanical calculators, they needed the intervention of an operator for carry-over operations. They were equipped with metal strips, operated with a stylus, within an aluminium casing. The working parts include windows onto the notched metal strips where the numbers 9 to 0 appear from top to bottom. The grooves are placed in the form of a cross to make the carry-over operation easier.



Instruments for professional calculations

From the second half of the 19th century, new mechanical instruments appeared alongside calculating machines. They were for mathematical operations much more complex than addition, subtraction, multiplication and division. Designed for engineering and surveying they were precision instruments capable of reducing or enlarging drawings, transferring coordinates onto plans, measuring surface areas delineated by curves or diagrams without involving any calculations at all. In the midst of the industrial revolution, engineers, technicians and surveyors had an ever greater need of mathematical analyses for planning road and bridge construction, calculating the efficiency of a steam engine as a function of its thermodynamic diagram or assessing the performance of agricultural machines.

Amongst these calculation instruments, some of the more recent models of which were still being used in the 1950s, we find pantographs, area meters, integrators, coordinatographs, etc.

In the 19th century, the mathematical instrument market was dominated by the English, Germans and Americans. In spite of this, two Swiss companies managed to acquire a worldwide reputation for the quality of their products. The first, Amsler, was founded in Schaffhausen by the physicist and mathematician Jacob Amsler-Laffon (1823-1912) who had invented the polar planimeter in the middle of the 19th century. In addition to producing over 50,000 area machines, the firm made other precision mathematical instruments and measuring equipment.

The second Swiss company, Coradi, founded in 1830 by Gottlieb Coradi, a precision technician from Zurich, was established in Zurich. Beginning with geodesic instruments and pantographs, Coradi gradually specialised in making high-quality mathematical precision instruments.



