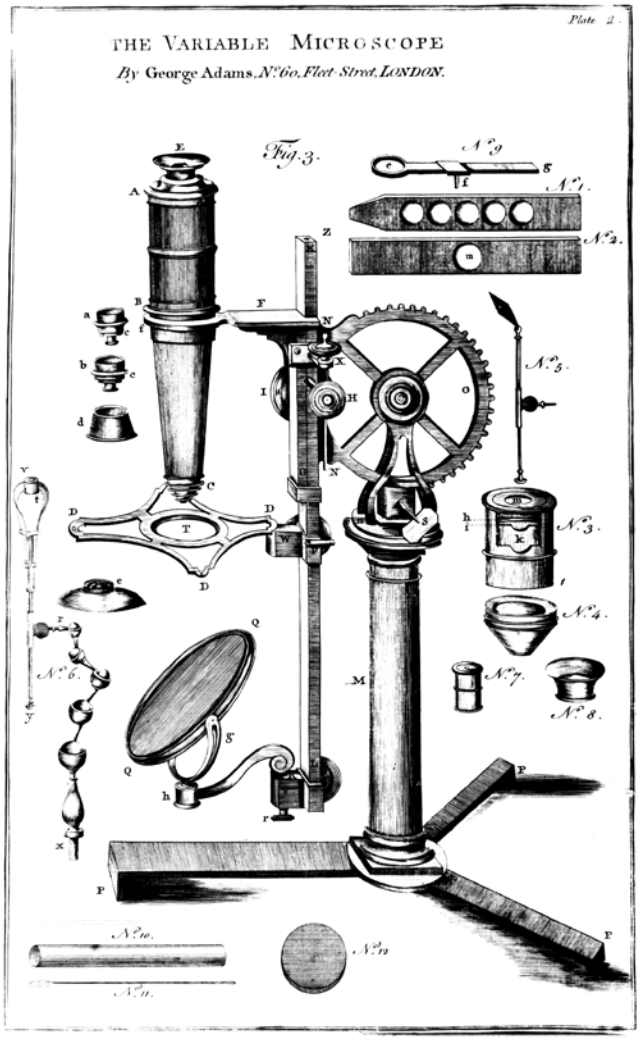
# Seeing the infinitely small

## Instruments at the Musée d'histoire des sciences of Geneva trace the history of microscopy

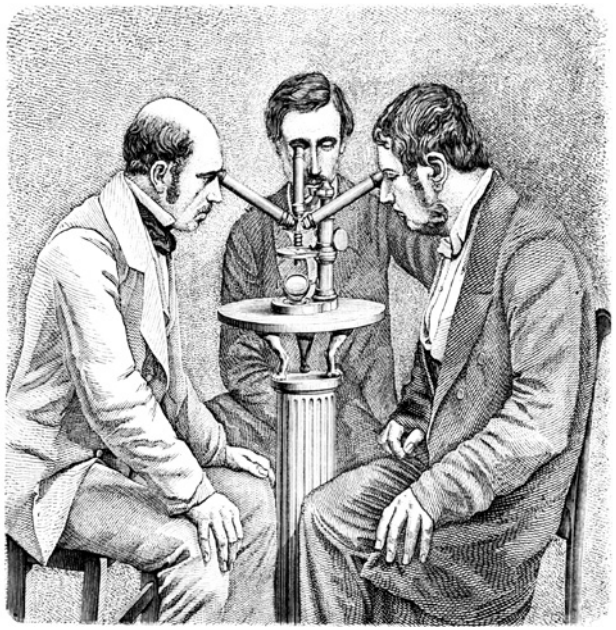



*The variable microscope*
*Micrographia Illustrata, Adams, London, 1771,*
*Library of the Musée d'histoire des sciences*

*Cover : Using a compound microscope*
*Les applications de la physique, Guillemin, Paris, 1874, Cantonal and University Library, Dorigny*

# The instrument which was never invented

The origin of the microscope is linked to that of the telescope. Legend has it that the telescope has its origins in Holland where children had apparently discovered that they could see into the distance while looking through two lenses placed one in front of the other. At the beginning of the 17th century Lippershey, a Dutch craftsman, sold an instrument "for seeing things far away as if they were nearby" to the government. It consisted of two lenses mounted in a tube which could be adjusted to change the distance between the lenses. The telescope quickly spread around Europe. From 1609, Galileo Galilei pointed his telescope to the sky over Venice and made his extraordinary astronomical observations. The Italian scientist was also the first to use a modified form of the telescope to observe "flies which appeared as large as lambs". It was not until around 1625 that this instrument was called a microscope.

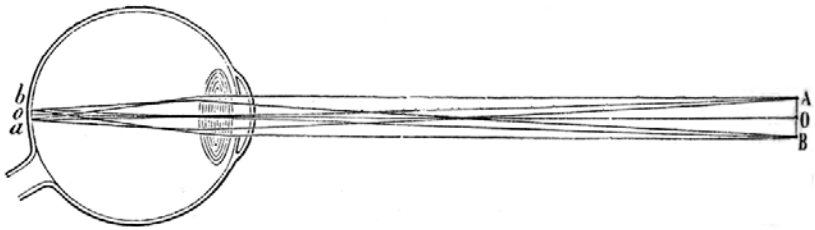


*A microscope for simultaneous observations*
*Les applications de la physique, Guillemin, Paris, 1874, Dorigny cantonal and university library*

Sight

# The eye sees true, lenses deform

At the end of the 16th century, most scholars thought that only the human eye saw reality and that any magnifying instrument was unreliable and misleading. This was apparently confirmed by viewing shapes which were considered perfect : the spheres. Looking through glass or crystal certainly enlarged objects but also severely deformed them. The essential task then was to understand "how we see" rather than "what we see". Theories handed down from antiquity were still authoritative. According to Plato and Euclid, vision is a voluntary function of the eye which projects sight lines towards an object. On the other hand Democritus and the atomists thought that atoms were projected from an object to the eye, though they were not able to explain how enough atoms could be sent to allow the object to be seen by several people at once.




*The function of rays in the eye*
*Traité de physique, Ganot, 1884, Paris, Library of the Musée d'histoire des sciences*

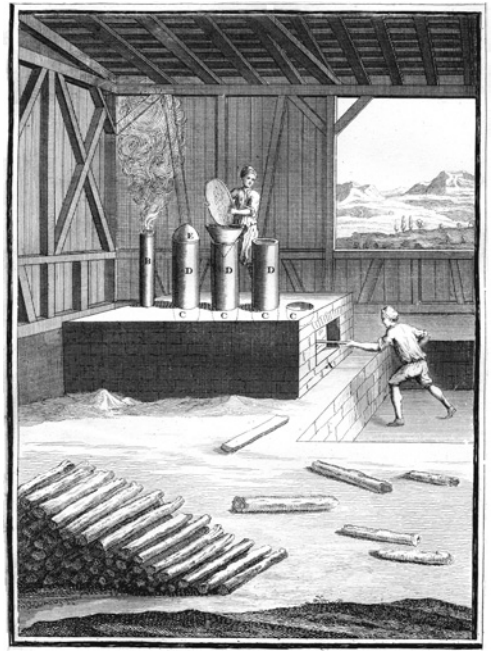


Glass lenses

# Origins in antiquity

Since the 13th century, craftsmen had been able to produce eyeglasses using pieces of glass cut in different ways called a "lens". The word lens comes from the Latin word for a "lentil" because of its similar shape. Use of the first optical lenses was in antiquity. In his work on optics the Persian scholar Alhazen (965-1039) described the magnifying power of lenses.

In Europe, the production of lenses began to develop with the introduction of microscopes and telescopes. Optical glass was obtained from a mixture of sand and caustic soda which was heated until it liquefied. A small quantity of the liquid was then drawn off and spread on a marble surface to obtain a sheet of glass. A disc of the required size was then cut by a diamond and subsequently shaped by hand by rubbing it against metal forms or by wheel abrasion.



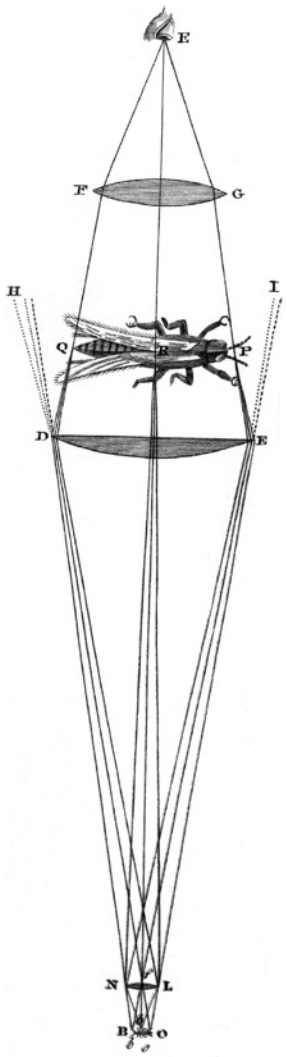
*Glass-making workshop*
*L'art de la verrerie, Neri, Paris, 1752*
*Library of the Musée d'histoire des sciences*

# How does a microscope work ?

The earliest "simple" microscopes were single-lensed and functioned like a magnifying glass. They offered an enlarged virtual image of the object.

Compound microscopes were equipped with several lenses. One lens (placed close to the object) gave an enlarged image which was not visible to the naked eye. An objective (close to the eye) further enlarged the image and delivered it to the observer.

Today, lenses and eye lenses are made of different types of glass in order to correct various optical distortions related to the passage of light through glass. A condenser (originally a mirror reflecting the light) is attached to the base of the instrument to illuminate the sample being examined.



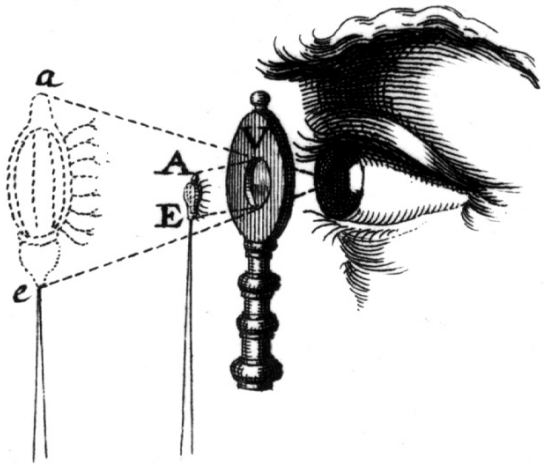

*Functioning of a compound microscope*
*Micrographia Illustrata, Adams,*
*London 1771,*
*Library of the Musée d'histoire des sciences*





# The draper's thread-counter

In 1670 a Dutch fabric merchant, Antonie van Leeuwenhoek, discovered spermatozoa and bacteria using a rudimentary microscope consisting of a tiny glass pearl set between two metal sheets which he usually used to examine fabrics. The instrument was held close to the eye while the specimen was fixed to a sharp point on the other side of the glass plate. Leeuwenhoek, who had no scientific qualifications, sent a report to the Academy of Sciences in London which encouraged him to continue his observations. In spite of scepticism from some commentators who thought that what he was seeing was in his imagination rather than an image through his lenses, he opened a hitherto unexplored area of investigation.




*The way a single-lens microscope works*
*Physics Elementa Mathematica, Gravesande, Leyde, 1721, Geneva Library*

*Micrographia*

# Discovery of the infinitely small

Although Galileo did not invent the telescope and the Englishman Robert Hooke (1635-1703) did not invent the microscope, the two men nevertheless created a frenzy of interest in their respective disciplines – astronomy and microscopy – by publishing works that became best-sellers. In the "Starry Messenger" of 1610, Galileo describes observations of the earth's moon, Jupiter's moons and the phases of Venus. Published in 1665, Hooke's "Micrographia" deals with microscopy but also astronomy and physics and is illustrated with beautiful pen and ink drawings of the eye of a fly, the sting of a bee and of other insects. The book created a sensation amongst contemporary scholars.

The microscope Hooke used has apparently not survived. From the description in the preface of his book, the body of the instrument was made of cardboard and was composed of four tubes which fitted into each other in a similar manner to a telescope.

*The surface of a nettle leaf with its stinging hairs*
*Micrographia, Hooke, London, 1667*
*Geneva Library*

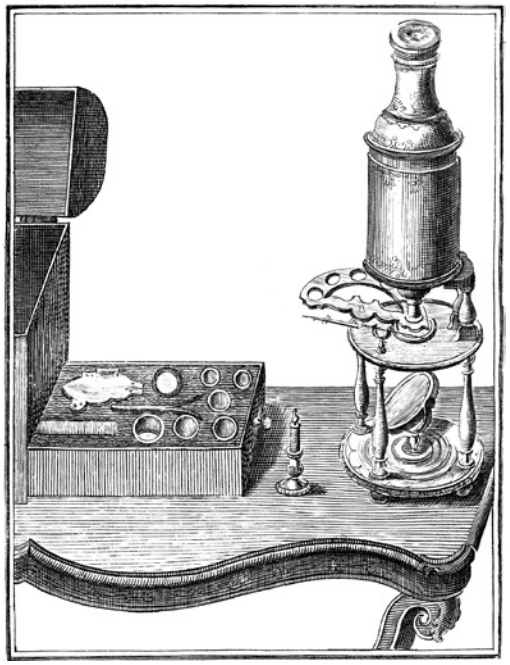


Charles Bonnet's microscope

# Science linked to prestige

This compound microscope probably belonged to the Geneva naturalist Charles Bonnet (1720-1794). Amongst other work, Bonnet demonstrated experimentally that aphids could reproduce through parthenogenesis (alone and without fertilisation). Bonnet would have used the microscope for his work on freshwater worms before passing it on to his nephew Horace-Benedict de Saussure after his sight had deteriorated.

Although unsigned, it is almost certain that the microscope was made in the workshops of Abbé Nollet (1700-1770) a French maker and physics scholar as well known for his teaching as for the elegant instruments he made. Richly decorated, made of brass and lacquered wood this is both a scientific instrument and a prestigious object which no wealthy naturalist of the time would be without.

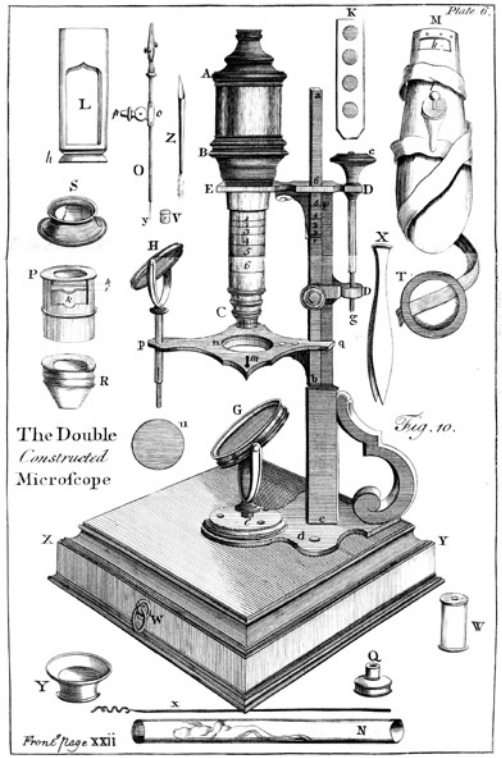


*Culpeper's microscope*
*Leçons de physique expérimentale, Nollet,*
*Paris, 1749, Library of the Musée d'histoire des sciences*

Compound microscope of John Cuff

# The first modern microscope

In the 18th century, the tripod compound microscope invented by the Englishman Edmund Culpeper (1660-1738) in 1725 was used and made all over Europe. Composed of an optical tube (with a lens and an objective) mounted onto three wooden or brass columns it was fixed to a wooden base.




In 1744, another Englishman, the optician John Cuff (1708-1772) launched a new highly innovative brass model which brings to mind modern microscopes. The tube (equipped with an eye piece and interchangeable objectives) moved the length of a vertical lateral pillar above a detached drawer which could accommodate various accessories such as a spring-loaded cylinder, forceps, magnifying glass, etc. A mobile mirror for lighting the specimen was fixed to the base of the apparatus.

*Cuff's compound microscope*
*Cuff, London, 1744, Bibliothèque de Genève*

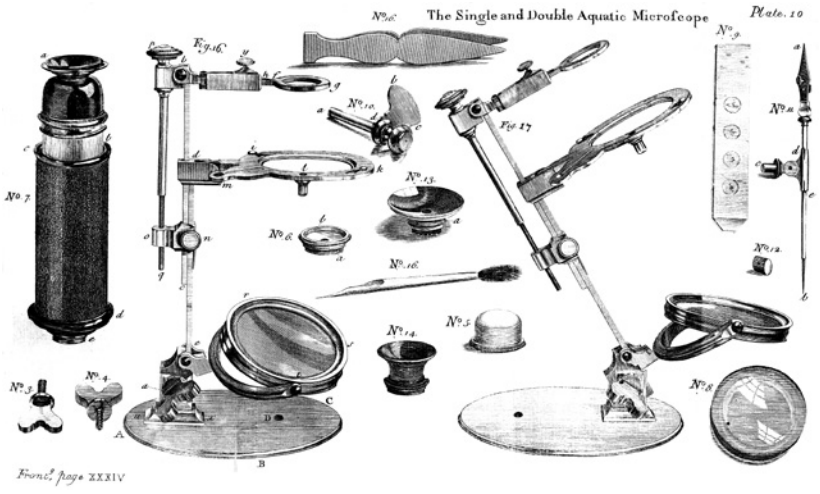


Abraham Trembley's aquatic microscope

# An instrument developed for field studies

In 1745, the Geneva naturalist Abraham Trembley (1710-1784), who had just discovered the reproductive mechanisms of freshwater hydra, visited London where he met John Cuff. He asked him to design a microscope for the study of aquatic organisms. Cuff designed and built an instrument with several innovations: the stage is mobile and placed to one side to facilitate study in water. The stand, equipped with a two-way hinge, can take a simple magnifying glass or a compound microscope.

The aquatic microscope was an immediate success with scientists who became enthralled by aquatic organisms following Trembley's discoveries.

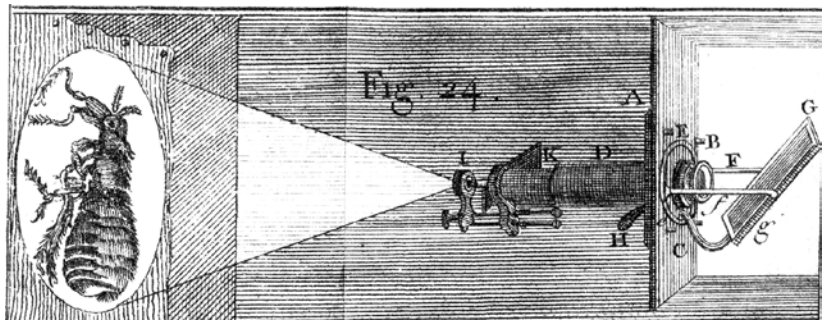



*The aquatic microscope*
*Micrographia Illustrata, Adams, London, 1771,*
*Library of the Musée d'histoire des sciences*

Projection microscope

# Microscopes provide entertainment

Appearing during the 18th century, the first projection microscopes, also known as solar microscopes because they used the sun for illumination, rapidly became common in scientists' laboratories. Inspired by magic lanterns they project a magnified image of the specimen which therefore becomes accessible to a large audience. They were usually installed near a window so that sunlight fell onto a large adjustable mirror which was directed through the optical tube to the sample. The image was then projected onto the wall opposite. Towards the end of the century, the solar microscope was replaced by the lucernal microscope which was illuminated by a powerful oil lamp, the image being projected onto a ground-glass screen.




*Solar microscope*
*Leçons de physique expérimentale, Nollet, Paris, 1749,*
*Library of the Musée d'histoire des sciences*

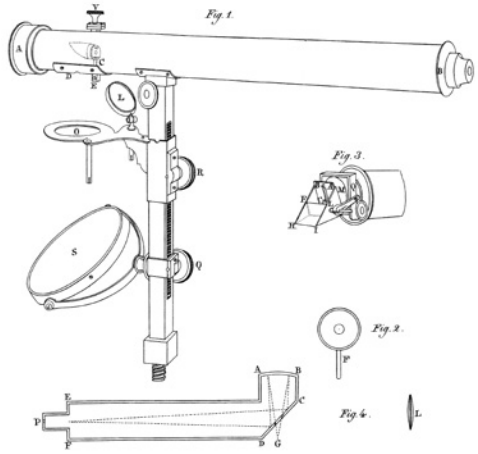


Giovanni Amici's catadioptric microscope

# Mirrors take the place of lenses

Until the 18th century, microscopes suffered from the serious optical problem of colour distortion, a result of the dispersion through glass of the colours composing white light. A halo of colours surrounded the magnified images of specimens diminishing the quality of the observations. Newton, who thought that there was no solution to this problem, turned instead to the construction of a telescope which used mirrors (rather than a lens) to observe the sky.

The catadioptric microscope invented in 1814 by the Italian maker and physicist Giovanni Amici to overcome the colour distortion problem, does in fact resemble a small inverted Newton telescope. The object to be examined is placed on the stage under the horizontal tube. A convex mirror turned towards a second concave mirror placed at the base of the tube reflects the image which is channelled towards the eye piece at the other end of the tube.

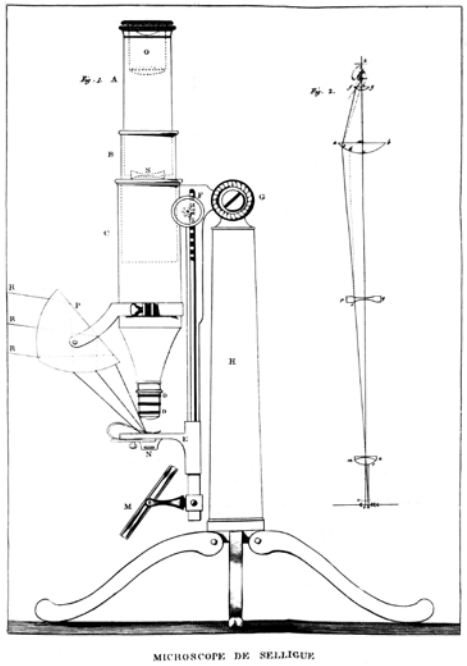



*Catadioptric microscope*
*Bibliothèque universelle, Amici, Genève, 1821*

Selligue's microscope

# An objective with several lenses

No doubt inspired by the theoretical work of Euler, the English manufacturer John Dollond produced the first achromatic objective in 1766 by using two different types of glass. This discovery led to great improvements in the optical quality of both telescopes and single-lens microscopes. For microscopes composed of several lenses, progress was slower.




*Sellig's achromatic microscope*
*Observations des rédacteurs sur l'emploi des microscopes dans Annales des sciences naturelles, Genève, 1824*

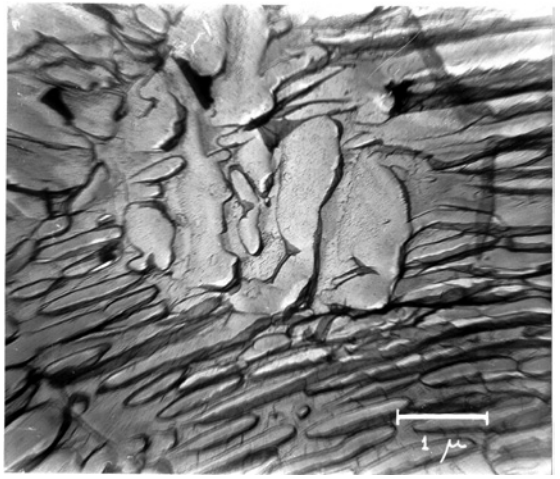
In 1824, the Frenchman Selligue presented an achromatic microscope composed of several lenses to the Academy of Sciences of Paris. Its performance was received with great enthusiasm by Augustin Fresnil which encouraged Amici, the Italian inventor of the Catadioptric microscope, to return to his research on achromatics. In 1827, he designed an instrument with an objective composed of several different types of glass. This is the forerunner of the achromatic system used in modern microscopes.



Electron microscope

# Electrons replace light

In the 20th century the invention of the electron microscope allowed even closer scrutiny of the heart of matter, almost at the scale of the atom. Magnification reached the order of a million times compared to a thousand times with optical microscopes. The working principles remain similar to those of the classical illuminated microscope: a light source passes through a condenser, then through the sample and is finally magnified by a system of lenses.
The difference lies in the light source: white light is replaced by a high voltage electron beam. The electrons circulate in a vacuum where they are deviated and focussed by magnetic lenses. Having passed through the sample being examined, the light beam is enlarged by other lenses before being projected onto a fluorescent screen where it forms a transparent image of the sample. Second-generation electron microscopes, called scanning microscopes, deliver a 3-D image.



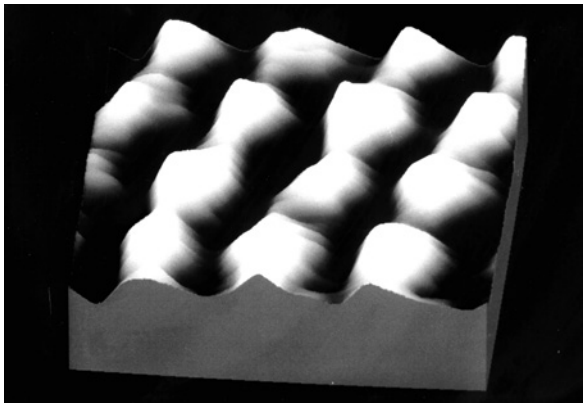

*The surface of tool steel seen through an electron microscope*
*University of Geneva, around 1970*

Tunnel microscope

# An optics-free instrument

Current developments in nanotechnology (the study and manipulation of matter at the atomic scale) are largely based on a key invention in 1981: the tunnel or transmission electron microscope (TEM). Offering magnification of up to a billion times this new type of microscope can examine matter atom by atom without recourse to optics!

The microscope functions in a manner analogous to a microgroove disc reader. A very fine point attached to a piezoelectric crystal (deformation of the crystal generates a current and vice versa) moves very close to the object being studied. It produces a low voltage (the tunnel effect) between the surface of the object and the point which varies according to the distance between them. As the point is moved, while keeping the voltage constant, the height variations of the point are recorded and are then transformed into electrical signals by the piezoelectric crystals which are, in turn, converted into a three-dimensional image by a computer programme.



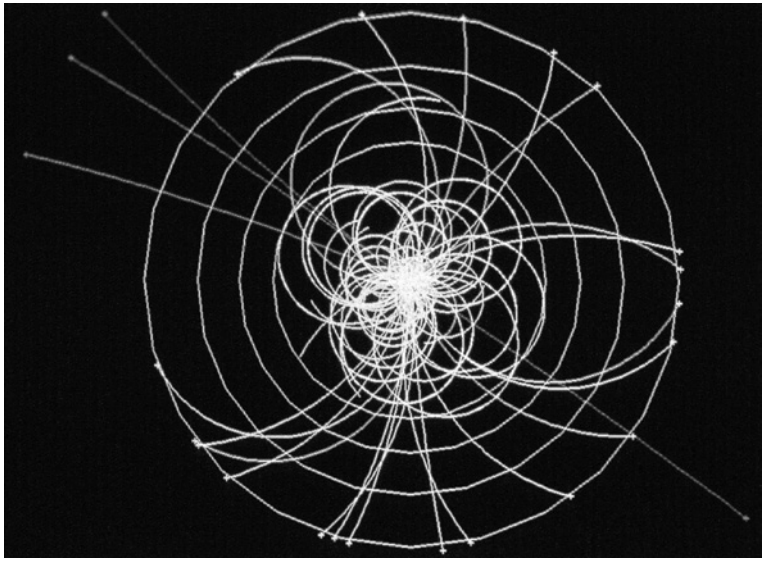
*Graphite atoms seen through a tunnel microscope*
*A scanning tunnel microscope, Emch, University of Geneva, 1990, Geneva*



Particle accelerator

# Collisions penetrate to the core of matter

Housed in great caverns the size of cathedrals, with a diameter of 27 km, 9300 magnets and numerous detectors, the new particle accelerator (LHC: Large Hadron Collider) entered into operation in the autumn of 2008. It is the world's largest accelerator and the most powerful ever built. Its purpose is to observe and detect new fundamental particles of matter (the size of which are below one-billionth of a metre) by provoking collisions of two proton beams (the elements of the core of an atom) at velocities nearing the speed of light. The enormous numbers of particles liberated are identified by electronic detectors linked to a network of powerful computers.



*A simulated image of the disintegration of a Higgs boson particle in 4 muons such as can be observed at the new LHC accelerator, CERN, Geneva*

## Chronology

Key dates in the development of the microscope

1608 Invention of the astronomical telescope
1612 Galileo sends a microscope he invented to the king of Poland
1665 Publication of *Micrographia* by Robert Hooke
1677 Antoine Leeuwenhoek discovers the existence of spermatozoa with the help of his single-lens microscope
1725 The English instrument-maker, Edward Culpeper, perfects the tripod compound microscope
1743 John Cuff develops a compound microscope equipped with an arm and a free-standing stage which is similar in shape to those of modern instruments
1767 The Swiss mathematician, Leonard Euler, proposes an achromatic microscope composed of an eye piece with six lenses
1827 Giovanni Amici designs the first modern achromatic compound microscope
1931 Invention of the electron microscope and the first particle accelerator
1981 Invention of the tunnel microscope
2008 Inauguration of the LHC particle accelerator at CERN

## Further reading


- Les Découvreurs, Daniel Boorstin, Laffont, Paris, 2000
- Histoire mondiale des sciences, Colin Ronan, Points science, 2000
- Microscopes, Margarida Archinard, Musée d'histoire des sciences, 1976
- Le microscope achromatique de Selligue, Margarida Archinard, Société de physique et d'histoire naturelle, 1993




Other guides to the permanent collection available :

- Révolution(s) – A brief history of celestial measurement told through some of the astronomical instruments in the Musée d'histoire des sciences of Geneva. September 2011
- The skies of Mont Blanc - Following the traces of Horace-Bénédict de Saussure (1740-1799) pioneer of Alpine meteorology.September 2011
- Through the looking glass : once upon a time, there was electricity - The story of electricity told through the collection of instruments of the Musée d'histoire des sciences of Geneva. September 2011
- Sun time : Description and use of the main types of sundial exhibited at the Musée d'histoire des sciences of Geneva. September 2011
- Observing the sky : A brief introduction to astronomy and presentation of instruments from the first Geneva Observatory. September 2011
- The Pictet Cabinet : The art of teaching science through experiment. September 2011
- From foot to metre, from marc to kilo : The history o weights and measures illustrated by objects in the collections of the Musée d'histoire des sciences of Geneva. September 2011

This booklet can be downloaded at www.ville-ge.ch/mhs

Text : Stéphane Fischer, Anne Fauche, Musée d'histoire des sciences, Ville de Genève
Translation : Liz Hopkins
Graphic design : Corinne Charvet, Muséum d'histoire naturelle
Printing and production : Bernard Cerroti, Muséum d'histoire naturelle


Musée d'histoire des sciences, Villa Bartholoni,
Parc de la Perle du lac, rue de Lausanne 128, 1202 Genève
Tél : + 41 22 418 50 60
Open each day from 10h-17h except Thuesday
Email : mhs@ville-ge.ch
Web : www.ville-ge.ch

musée d'histoire des sciences

DÉPARTEMENT DE LA CULTURE

VILLE DE GENÈVE