

# Seeing the infinitely small



**Une institution  
Ville de Genève**

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VILLE DE  
GENÈVE

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*Cover: Using a compound microscope*

*Les applications de la physique, Guillemin, Paris, 1874*

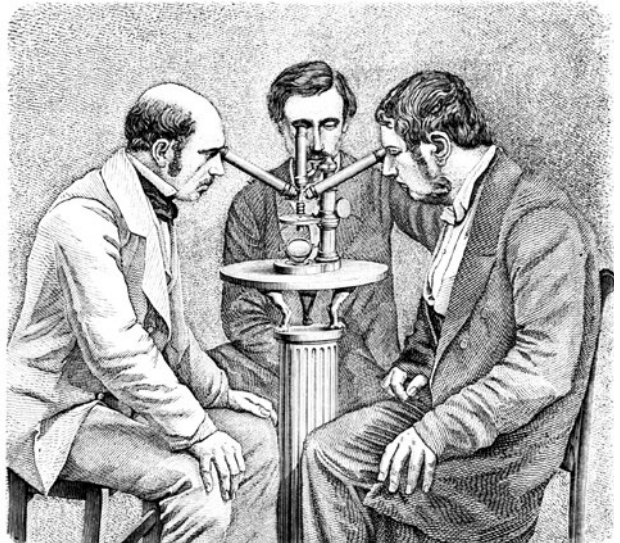
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## The instrument which was never invented

Like the telescope, the microscope is an instrument that developed with use. No one knows exactly when it was invented. The term “microscope” to designate the instrument was first mentioned by the Roman physician Giovanni Faber in 1625, some ten years after the appearance of the telescope.

Galileo, who in 1609 turned his telescope to the sky to make his extraordinary discoveries, would also have been one of the first to use a modified form of his telescope to observe “flies that look as big as lambs”.

It seems reasonable to think that these two optical instruments, based on combination of several glass lenses, were invented in the same workshop by a master glassmaker. Netherlands, Italy, England? The question remains open.



***A microscope for simultaneous observations***

*Les applications de la physique, Guillemin, Paris, 1874*

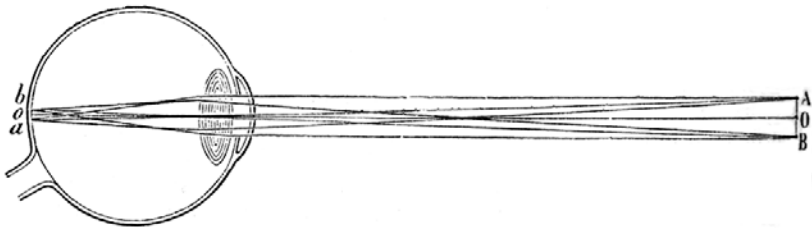
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## Sight

# The eye sees truth, lenses deform

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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.

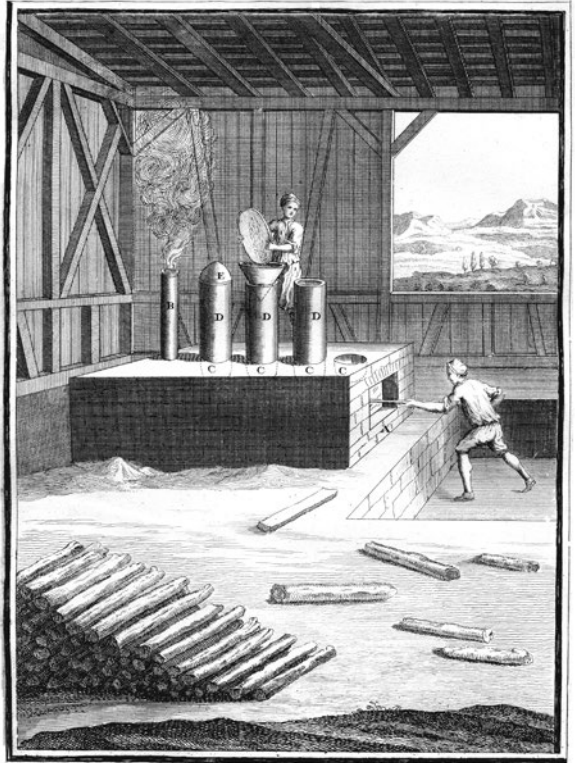


**The function of rays in the eye**  
*Traité de physique, Ganot, 1884, Paris*  
*Library of the Musée d'histoire des sciences*

## 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. The first use of 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 with a diamond and subsequently shaped by hand by rubbing it against metal forms or by wheel abrasion.



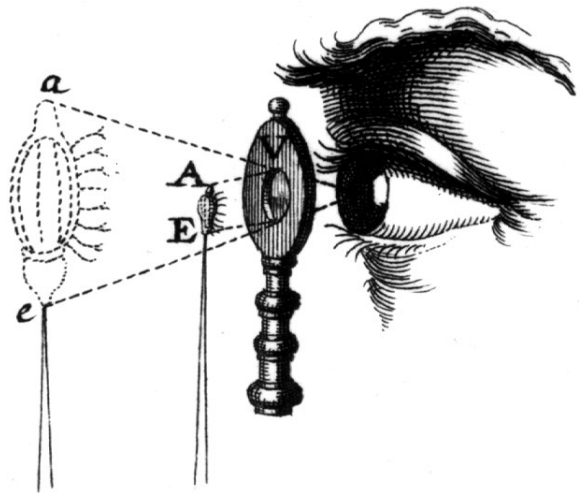
**Glass-making workshop**  
*L'art de la verrerie, Neri, Paris, 1752*  
*Library of the Musée d'histoire des sciences*



## Leeuwenhoek microscope The draper's thread-counter

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In 1670 a Dutch fabric merchant, Antonie van Leeuwenhoek (1632-1723), 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**  
*Physica Elementa Mathematica, Gravesande, Leyde, 1721*  
*Bibliothèque de Genève*

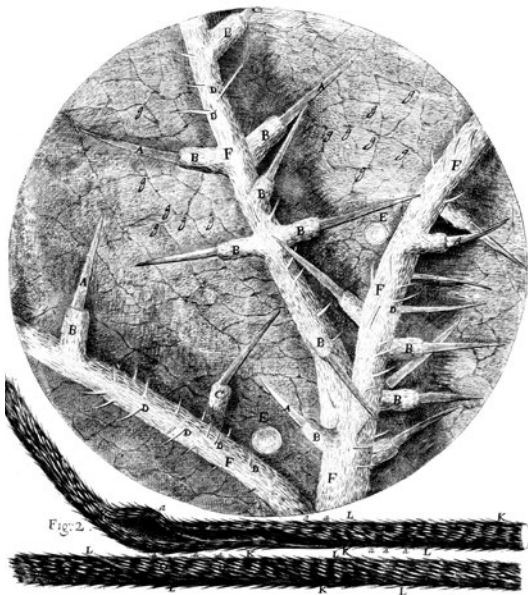
## Micrographia

# Discovery of the infinitely small

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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 stars. 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

Bibliothèque de Genève

## Charles Bonnet's microscope Science linked to prestige

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This compound microscope probably belonged to the Genevan 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.



**Compound microscope**

MHS 149

Wood, ivory, brass, bone, Nollet(?), France, 18th century

## Compound microscope of John Cuff

# The first modern microscope

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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 completely clear stage which could accommodate various accessories such as a spring-loaded cylinder, specimen holder, magnifying glass, etc. A mobile mirror for lighting the specimen was fixed to the base of the apparatus.

### **Compound microscope**

*MHS 1900*

*Wood, brass, glass, Cuff, London,  
18th century*

## Abraham Trembley's aquatic microscope An instrument developed for field studies

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In 1745, the Genevan 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 double articulation 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.



**Aquatic microscope**  
MHS 10  
Brass, wood, glass, Cuff, London, 18th century

Projection microscope

## Microscopes provide entertainment

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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**

MHS 399

Wood, brass, glass, 18th century

## Giovanni Amici's catadioptric microscope Mirrors take the place of lenses

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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 instrument maker and physicist Giovanni Amici (1786-1863) 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. The light rays coming from the object are reflected by a prism and sent back towards a concave mirror placed at the end of the optical tube.

The reflected beam crosses the entire length of the tube and forms an enlarged image of the object close to the eyepiece.



**Catadioptric microscope**

MHS 377

Wood, brass, glass, Amici, Modena, 1822

## Selligie's microscope

# An objective with several lenses

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No doubt inspired by the theoretical work of Euler (1707-1783), the English manufacturer John Dollond (1706-1761) 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.



In 1824, the Frenchman Alexandre Selligie (1784-1845) presented an achromatic microscope composed of several lenses to the Academy of Sciences of Paris. Its performance was received with great enthusiasm by Augustin Fresnel (1788-1827) 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.

***Achromatic microscope type Selligie***  
*MHS 655*  
*Brass, glass, Chevalier, Paris, 19th century*

## Electron microscope

# Electrons replace light

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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 light microscope: a beam passes through a condenser, then through the sample and is finally magnified by a system of lenses.

The difference lies in the nature of the beam: white light is replaced by a high voltage electron beam. The electrons travel in a vacuum where they are deviated and focussed by magnetic lenses. Having passed through the sample being examined, the 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.



### **Electronic microscope**

*MHS 906*

*Epoxy resin, metal, glass, Trub, Täuber&Cie,  
Zürich, circa 1960*

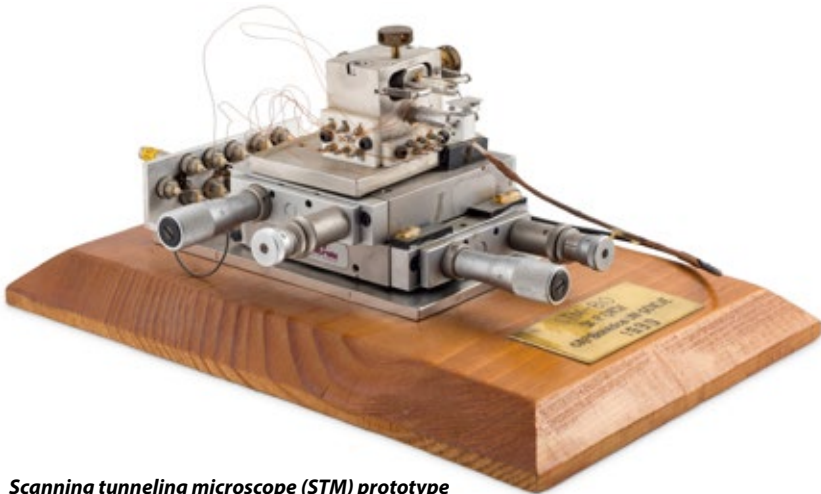
## Scanning tunneling microscope (STN)

### An optics-free instrument

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Current developments in nanotechnology (the study and manipulation of matter at the atomic scale) are largely based on a key invention in 1981: the scanning tunneling microscope (STN). 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.



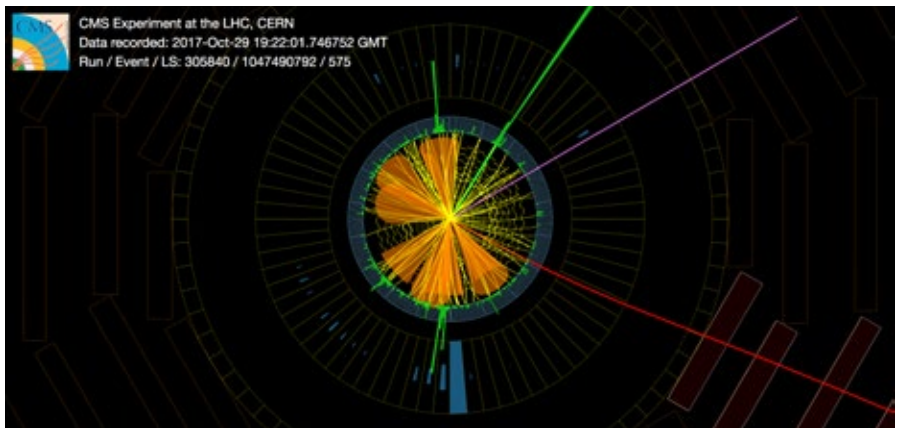
**Scanning tunneling microscope (STM) prototype**  
MHS 2237  
Cooper, metal, brass, Emch, Geneva, circa 1990

## Particle accelerator

# Collisions to penetrate to the core of matter

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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) came 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.



### **Particle collision**

*An event recorded by Cern's CMS detector showing a candidate Higgs boson produced in association with two top quarks. The Higgs boson and the top quarks desintegrate, leaving in the final state seven jets of particles (orange cones), an electron (green line), a muon (red line) and some missing transverse energy (pink line). (Image: CMS/CERN)*

# 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 tunneling microscope
- 2008 Inauguration of the LHC particle accelerator at CERN

## Further reading

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## Booklets of the Musée d'histoire des sciences

The museum collections described in short thematic booklets

1. Under the skies of Mont Blanc
2. Once upon a time, there was electricity
3. Sun time
4. Seeing the infinitely small
5. Models of the universe
6. Observing the sky
7. The Pictet Cabinet
8. Jean-Daniel Colladon, Genevan scholar and industrialist
9. From foot to metre, from marc to kilo
10. The birth of modern meteorology
11. Vacuum tubes and light bulbs at the Musée d'histoire des sciences
12. The Villa Bartholoni

Downloads available at: <http://institutions.ville-geneve.ch/fr/mhn/votre-visite/site-du-musee-dhistoire-des-sciences/parcours-permanent/>

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