# Journey of the Microscope

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The journey of microscope has been a remarkable one, from the simple hand lenses of the early Egyptians to the 16th century Dutch designs through the magnificent microscopes of 18thand 19th century Europe to the latest microprocessor- powered models available today.

From ancient times, man has wanted to see things far smaller than could be perceived with the naked eye. It has been known for over 2000 years that glass bends light. In the 2nd century BC, Claudius Ptolemy described a stick appearing to bend in a pool of water & accurately calculated the refraction constant of water.

The beginning of the use of hand lens dates back to about 2600 BC when Egyptians practiced the art of cutting polished stones that included rock crystals in the form of convex lenses.

The Greek and Romans continued with these types of lenses up to the end of the Roman empire(31 BC). Earliest writing describing the action of the lens appears in the writings of the Arabian Alhazen (962-1038) described in his “Optics Thesaurus AlhazeniArabius Basil”

Magnifiers & 'magnifying lens” are mentioned in the writing of Seneca & Pliny of Elder, Roman philosophers during the 1st century A.D, but apparently were not used much until the invention of spectacles, towards the end of the 13th century [1,2].

**Birth of the Light Microscope**

The early simple "microscopes" which were only magnifying glasses had one power, usually about 6x - 10x. One thing that was very common and interesting to look at, were fleas and other tiny insects, hence these early magnifiers called "flea glasses".

The first documented 'inventors of the microscope' (based on the letters of William Boreel, Dutch envoy to the court of France), are the Dutch spectacle makers, Zacharias Jansen and his son Hans who used several lenses in a tube with a plate for the object at one end (Figure 1), which was the forerunner of both the compound microscope and of the telescope (Galileo, 1609)

**Figure 1. Zacharias Jansen microscope**

Giovanni Faber coined the name **microscope** (from the Greek: mikrós, "small" and skopeîn, "to look" or "see")for Galileo Galilee's compound microscope in 1625. Galileo had called it the "occhiolino" or "little eye" (Figure 2).

**Figure 2. Galileo Galilee develops a compound microscope with a convex and a concave lens**

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In 1665, Robert Hook (secretary of the Royal Society) publishes “Micrographia”, describing and coining the phrase 'cell' when observing a slice of cork using a microscope power of 30xmagnification (Figure 3) [3].

**Figure 3. Robert Hooke microscope**

**Anton Van Leeuwenhoek (1632-1723): 'Father of Microbiology'**

A tradesman of Delft, Holland, he started as an apprentice in a dry goods store where magnifying glasses were used to count the threads in cloth.

He ground and polished tiny lenses of great curvature which gave magnifications of up to $270_x$, the finest known at that time and further went on to make some of the most important discoveries in biology. Anton van Leeuwenhoek was the first person to observe and describe single celled organisms, which he originally referred to as animalcules (which we now refer to as microorganisms). He was also the first to record and observe yeast, bacteria, spermatozoa and blood flow in capillaries, reporting his findings in over a hundred letters to the Royal Society of England and the French Academy [4, 5].

Leeuwenhoek's microscope used a single convex glass lens attached to a metal holder and was focused using screws (Figure 4).

**Figure 4. Leeuwenhoek's microscope**

**Microscopes of the 18th century**

At the dawn of the 18th century British instrument designers were introducing improved versions of the tripod microscope, based on a model by Edmund Culpeper.(Figure 5).

Later, John cuff introduced the first microscope designed to be user-friendly with an advanced focus mechanisms. However, blurred images and optical aberration prevailed throughout most of the century [5].

**Figure 5. 18th century microscopes from the Musée des Arts et Métiers, Paris**

**Microscopes of the 19th century**

First part of the 19th century witnessed dramatic improvements in optics with the introduction of achromatic objectives by Van Deijl, Armici and Lister (1823) (Figure 6).

**Figure 6. Joseph Jackson Listermicroscope**

In 1873, Ernst Abbe published his work on the theory of the microscope, clearly defining the terms of 'magnification' and 'resolution'. The maximum resolution that Abbe was able to achieve (0.2 microns or 200 nanometers) isabout 10 times better than the resolution Leeuwenhoek had achieved about 100 years earlier (Figure 7).

Professor August Kohler in 1880, introduced a method of illumination, (Kohler illumination) using the light source and optimal condenser position, leading to the microscope lamp with filters.

**Figure 7. Ernst Abbe microscope**

In 1873, Ernst Leitz microscope was introduced with a revolving mount (turret) for 5 objectives. With the use of the oil immersion lens (cedar oil) in 1878 for a homogeneous optical path and the designing of apochromatic objective(brings red, yellow & blue in to one focus) by Ernst Abbe, the final advancement of the theoretic limit of resolution for visible light microscope had been reached(2000 angstroms).

**1800-1900 :** Louis Pasteur and Robert Koch both became engaged in microscopy and the study of bacteria [6, 7].

**Twentieth century: 'Renaissance in microscope technology'**

The first commercial microscope by Zeiss was introduced in 1904. The resolution based on Abbe's formula is twice that of a visible light microscope.

In 1930, Fritz Zernike discovered he could view unstained cells using the phase angles of rays. It took until 1941 to bring a commercial microscope to market. Zernike was awarded the Nobel prize in 1953 for his work on the phase contrast microscope.

**The Electron microscope**

Maxknoll and Ernst Ruska construct the first electron microscope in 1931 and in 1933, Ruska built the firsttransmissionelectron microscope that exceeds the resolution of the light microscope with an accelerating voltage of 75KV (Figure 8).

**Figure 8. Ruska Electron microscope**

The first scanning electron microscope was developed by Professor Sir Charles Oatley and his postgraduate student Gary Stewart in 1937, and in 1939, the first commercially available electron microscope was supplied by Siemens (Figure 9).


**Figure 9. Scanning electron microscope**

Ultimately the power of the electron microscope was not realized until the 1950s when ultra-microtomes were built: 1951-the first ultra-microtome built by Porter and Blum and the first diamond knife in 1954. These instruments could slice (section) pieces of biological materials as thin as 500 angstroms (angstrom= $10^{-10}$meters)[8].

**Later Developments – Modern day microscopes**

The rise of fluorescence microscopy and immunofluorescence drove the development of a major modern microscope design, the confocal microscope. Confocal microscopy yields noninvasive serial optical sectioning deep within intact, or even living, three dimensional specimens [9].

The end of the 20th century saw the advent of scanning laser confocal microscope (1983)when Thomas and Christoph Cremer developed the first practical confocal laser scanning microscope and the technique rapidly gained popularity through the 1980s.

In 1981 – Gerd Binnig and Heinrich Rohrer invented the scanning tunneling microscope that gives three-dimensional images of objects down to the atomic level. Binnig and Rohrer won the Nobel Prize in Physics in 1986. The powerful scanning tunneling microscope is the strongest microscope to date.

Scanning probe microscopes (1982) are developed that work by measuring current and in 1986, the Atomic Force Microscope was built,which measures force instead of current(Figure10).

When the first silicon based processing for computers was developed around 1968, with the beginning of the computer era and simultaneous development of film and camera technology to a high level of sophistication, the progress in microscopy has been largely eclipsed by rapid advances in digital imaging technology and the traditional optical microscope has more recently evolved into the digital microscope, in which a type of sensor similar to those used in a digital camera is used to obtain an image, which is then displayed on a computer monitor(Figure 11) [10].

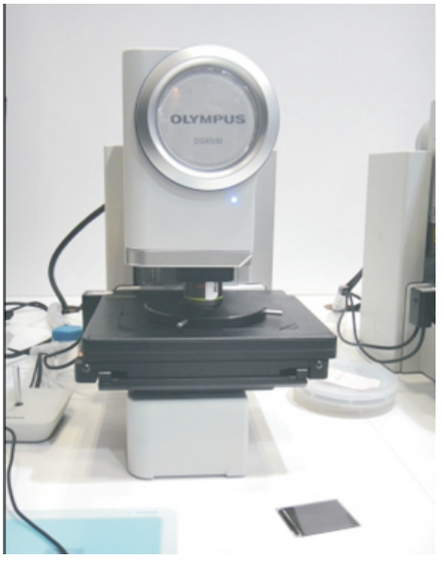


**Figure 10. Atomic Force microscope**

**Figure 11.Opto - digital microscope**

In his most celebrated work, 'Micrographia', Robert Hooke writes, “In the collection of most of which I made use of microscopes and some other glasses and instruments that improve the senses... only to promote the use of mechanical helps for the Senses, both in the surveying the already visible World, and for the discovery of many others hitherto unknown"- Micrographia, by Robert Hooke (1665) [3]; which demonstrates Hooke's perspective on how the microscope is utilised to enhance the senses...

This remarkable invention by man has undergone some incredible evolution through the ages, fulfilling his ever increasing thirst for knowledge to see beyond the visible world that the naked eye could perceive,into the unknown… the world of the microbes.

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