Electron Microscope: المجهر الالكتروني

An electron microscope is a microscope that uses a beam of accelerated electrons as a source of illumination. It is a special type of microscope having a high resolution of images, able to magnify objects in nanometers, which are formed by controlled use of electrons in a vacuum captured on a phosphorescent screen.
Ernst Ruska (1906-1988), a German engineer and academic professor, built the first Electron Microscope in 1931, and the same principles behind his prototype still govern modern EMs.

Two types of electron microscopes أنواع المجهر الالكتروني

A- transmission electron microscope (TEM) المجهر الالكتروني النافذ

B- Scanning electron microscope (SEM) المجهر الالكتروني الماسح

Principle OF Electron Microscope Working: مبدا عمل المجهر الالكتروني

Electron microscopes use signals arising from the interaction of an electron beam with the sample to obtain information about structure, morphology, and composition.

1. The electron gun generates electrons.
2. Two sets of condenser lenses focus the electron beam on the specimen and then into a thin tight beam.
3. To move electrons down the column, an accelerating voltage (mostly between **100 kV-1000 kV**) is applied between the tungsten filament and anode.
4. The specimen to be examined is made extremely thin, at least 200 times thinner than those used in the optical microscope. Ultra-thin sections of **20-100 nm** are cut which is already placed on the specimen holder.
5. The electronic beam passes through the specimen and electrons are scattered

depending upon the thickness or refractive index of different parts of the specimen.

6. The denser regions in the specimen scatter more electrons and therefore appear darker in the image since fewer electrons strike that area of the screen. In contrast, transparent regions are brighter.
7. The electron beam coming out of the specimen passes to the objective lens, which has high power and forms the intermediate magnified image.
8. The ocular lenses then produce the final further magnified image.

Electron Microscope parts أجزاء المجهر الالكتروني

Electron Microscope is in the form of a tall vacuum column that is vertically mounted. It has the following components:

1. **Electron gun**

- The electron gun is a heated tungsten filament, which generates electrons.

2. **Electromagnetic lenses**

- **The condenser lens** focuses the electron beam on the specimen. A second condenser lens forms the electrons into a thin tight beam.
- The electron beam coming out of the specimen passes down the second of magnetic coils called the **objective lens**, which has high power and forms the intermediate magnified image.
- The third set of magnetic lenses called **projector (ocular) lenses** produce the final further magnified image.
- Each of these lenses acts as an image magnifier all the while maintaining an incredible level of detail and resolution.

3. **Specimen Holder**

- The specimen holder is an extremely thin film of carbon or collodion held by a metal grid.

4. **Image viewing and Recording System**

- The final image is projected on a fluorescent screen.
- Below the fluorescent screen is a camera for recording the image.

Application of Electron Microscope: تطبيقات المجهر الالكتروني

- Electron microscopes are used to investigate the ultrastructure of a wide range of **biological and inorganic specimens including microorganisms, cells, large molecules, biopsy samples, metals, and crystals.**
- Industrially, electron microscopes are often used for quality control and failure analysis.
- Modern electron microscopes produce electron micrographs using specialized digital cameras and frame grabbers to capture the images.
- **The science of microbiology owes its development to the electron microscope. The study of microorganisms like bacteria, virus, and other pathogens have made the treatment of diseases very effective.**

Advantage of Electron Microscope: مزايا المجهر الالكتروني

1.Very high magnification of the specimen

2. Incredibly high resolution

3. To study microscopic organisms smaller than 0.2 micrometers.

4. To analyze the cellular structure in the cell.

5. To study pathogens and viruses inside cells.

6. Cell metabolism.

7. To study the fine structures in nature.

Disadvantage of Electron Microscope مساوئ المجهر الالكتروني

1. The live specimen cannot be observed.

2. As the penetration power of the electron beam is very low, the object should be ultra-thin. For this, the specimen is dried and cut into ultra-thin sections before observation.

3. As the EM works in a vacuum, the specimen should be completely dry.

4. Expensive to build and maintain

5. Requiring researcher training

6. Image artifacts resulting from specimen preparation.

7. This type of microscope is large, cumbersome extremely sensitive to vibration and external magnetic fields.

There are two main types of electron microscopes:

1. Scanning electron microscope (SEM): المجهر الالكتروني الماسح

The Scanning Electron Microscope (SEM): produces images by detecting secondary electrons which are emitted from the surface of the specimen due to excitation by the primary electron beam. There for SEM is used to examine the surfaces of the microorganisms in great detail. like study the atomic composition of specimens, example, the surface distribution of immune-labels.

Advantages:

1- Almost all kinds of samples, conducting and non-conducting (stain coating needed)

2- Based on surface interaction , no requirement of electron-transparent sample.

3- Imaging at all directions through x-y-z (3D) rotation of sample.

Disadvantages:

1- Low resolution, usually above a few tens of nanometers.

2- Usually required surface stain-coating with metals for electron conducting.

2- Transmission Electron Microscope: المجهر الالكتروني النافذ

The transmission electron microscope (TEM): TEM forms image when radiations pass and are transmitted through the specimen, is used to view thin specimens or for viewing internal features that are inside or beyond the surface (e.g. organelles, macromolecules, atoms).

Advantages:

1- High resolution, as small as 0.2 nm.

2- Direct imaging of crystalline lattice.

3- Delineate the defects inside the sample.

4- No metallic stain-coating needed, thus convenient for structural imaging of organic materials.

5- Electrons can only travel through a vacuum, so the specimen must be completely dehydrated.

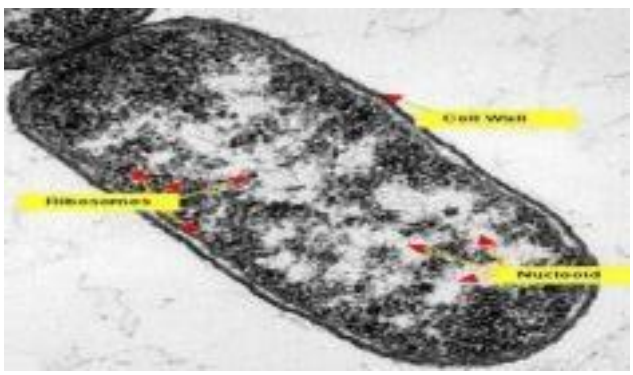
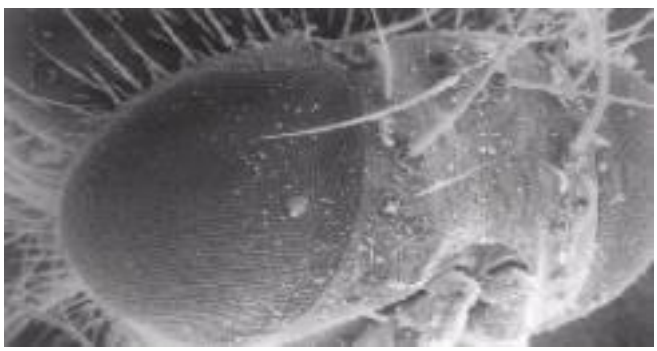
6- Electrons have poor penetrating ability. The specimen is usually imbedded in a plastic block and cut into thin sections (no more than 50 nm thick) for viewing.

7- The image contrast results when electrons are scattered by the specimen. Most biological materials scatter electrons poorly. Therefore specimens are usually "stained" with a coat of heavy metal (uranium, osmium, and tungsten) to increase scattering ability.

Disadvantages:

To prepare an electron-transparent sample from the bulk is difficult (due to the conductivity or electron density, and sample thickness).

The comparative between transmission and scanning electron microscope

Transmission Electron Microscope (TEM)	Scanning Electron Microscope (SEM)
1-Pass a beam of electrons through the specimen. 2- The electrons that pass through the specimen are detected on a fluorescent screen on which the image is displayed. 3- Thin sections of specimen are needed for transmission electron microscopy as the electrons have to pass through the specimen for the image to be produced. 4-the TEM has best resolution the even less than 50 pm. 5- the magnification that TEMs is much higher compared to SEMs users can magnify their samples by more than 50 million times. 6- the TEMs uses it in the range of 60-300 KV.	1- Pass a beam of electrons over the surface of the specimen in the form of a 'scanning' beam. 2- Electrons are reflected off the surface of the specimen as it has been previously coated in heavy metals. It is these reflected electron beams that are focused of the fluorescent screen in order to make up the image. 3- Larger, thicker structures can thus be seen under the SEM as the electrons do not have to pass through the sample in order to form the image. This gives excellent 3-dimensional images of surfaces 4- However the resolution of the SEM is lower than that of the TEM the limited to 0.5 nm. 5- the magnification for the SEM is limited up to 1-2 million times. 6- the SEMs usually use acceleration voltages up to 30 KV.
 Bacterium (TEM)	 A head and the right eye of a fly (SEM)

The comparative between light microscope and electron microscope

Light Microscope	Electron Microscope
Cheap to purchase رخيص الثمن	Expensive to buy غالي الثمن
Illumination source is the light مصدر الإضاءة الضوء	Illumination source is the beam of electrons مصدر الإضاءة الاشعاع الالكتروني
The condenser, objective and eye piece lenses are made up of glasses العدسات تكون زجاجية	All lenses are electromagnetic جميع العدسات كهرومغناطيسية
The object is 5µm or thick سمك العينة 5 مكيروميتر او اكثر	The object is 0.1 µm or thin سمك العينة 0.1 مكيروميتر او اقل
It has magnification of 500X to 1500X قوة التكبير بالمجهر الضوئي	It has magnification of 100,000X to 300,000X قوة التكبير بالمجهر الالكتروني
Small and portable. المجهر الضوئي صغير ومحمول	Large and requires special rooms. المجهر الالكتروني كبير ويحتاج غرفة خاصة
Simple and easy sample preparation. العينة سهولة تحضيرها	Lengthy and complex sample preparation. العينة معقدة التحضير
Live and dead specimens may be seen نستطيع فحص العينات الحية والميتة	Only dead or dried specimen are the seen نستطيع تفحص العينات الميتة و الجافة فقط
Material rarely distorted by preparation. العينة نادرا ما تتعرض للتشوية بسبب التحضير	Preparation distorts material. التحضير يشوة العينة
Vacuum is not required. فارغ غير موجود بالمجهر الضوئي	Vacuum is required. فارغ موجود بالمجهر الالكتروني للسماح للإلكترونات بالحركة داخل المجهر دون عائق
Natural color of sample maintained. الحفاظ على للون الطبيعي للعينة	All images in black and white. كل صور العينات تظهر باللون اسود وابيض
It is used for the study of detailed gross internal structure يتم استخدامة للدراسة التركيب الداخلي للعينة	It is used in the study of external surface, ultra structure of cells and very small organisms يتم استخدامه للدراسة السطح الخارجي والبنية الداخلية والكائنات الحية الصغيرة جدا

Discussion:

1. What is an electron microscope?
2. How does an electron microscope differ from a light microscope?
3. How do electron microscopes work?
4. What comparative between TEM and SEM ?