Studying cells: Microscopy

Sheet 7

A cell is the smallest unit of a living thing. A living thing, whether made of one cell (like bacteria) or many cells (like a human), is called an organism. Thus, cells are the basic building blocks of all organisms.

Several cells of one kind that interconnect with each other and perform a shared function form tissues, several tissues combine to form an organ (your stomach, heart, or brain), and several organs make up an organ system (such as the digestive system, circulatory system, or nervous system). Several systems that function together form an organism (like a human being). Here, we will examine the structure and function of cells.

There are many types of cells, all grouped into one of two broad categories: prokaryotic and eukaryotic. For example, both animal and plant cells are classified as eukaryotic cells, whereas bacterial cells are classified as prokaryotic. Before discussing the criteria for determining whether a cell is prokaryotic or eukaryotic, let's first examine how biologists study cells.

Cells vary in size. With few exceptions, individual cells cannot be seen with the naked eye, so scientists use microscopes (micro = *small*; scope = *to look at*) to study them. A microscope is an instrument that magnifies an object. Most photographs of cells are taken with a microscope, and these images can also be called micrographs.

The optics of a microscope's lenses change the orientation of the image that the user sees. A specimen that is right-side up and facing right on the microscope slide will appear upside-down and facing left when viewed through a microscope, and vice versa. Similarly, if the slide is moved left while looking through the microscope, it will appear to move right, and if moved down, it will seem to move up. This occurs because microscopes use two sets of lenses to magnify the image. Because of the manner by which light travels through the lenses, this system of two lenses produces an inverted image (binocular, or dissecting microscopes, work in a similar manner, but include an additional magnification system that makes the final image appear to be upright).

Light microscopes

To give you a sense of cell size, a typical human red blood cell is about eight millionths of a metre, or eight micrometres (abbreviated as eight μm) in diameter; the head of a pin is about two thousandths of a metre (two mm) in diameter. That means about 250 red blood cells could fit on the head of a pin.

Most student microscopes are classified as light microscopes. Visible light passes and is bent through the lens system to enable the user to see the specimen. Light microscopes are advantageous for viewing living organisms, but since individual cells are generally transparent, their components are not distinguishable unless they are colored with special stains. Staining, however, usually kills the cells.

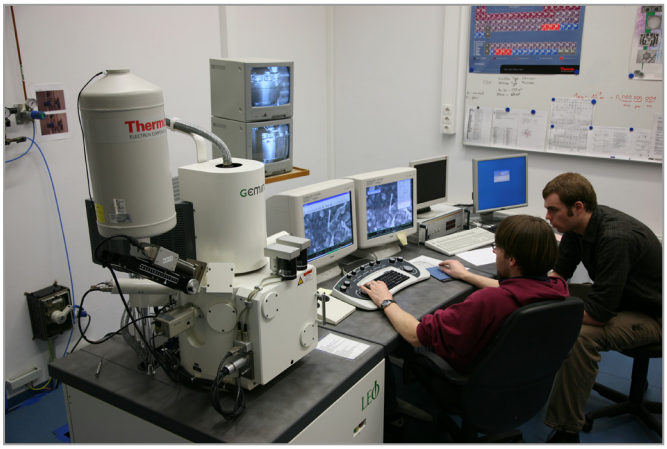
Light microscopes commonly used magnify up to approximately 400 times. Two parameters that are important in microscopy are magnification and resolving power. Magnification is the process of enlarging an object in appearance. Resolving power is the ability of a microscope to distinguish two adjacent structures as separate: the higher the resolution, the better the clarity and detail of the image. When oil immersion lenses are used for the study of small objects, magnification is usually increased to 1,000 times. In order to gain a better understanding of cellular structure and function, scientists typically use electron microscopes.

Sheet 7



Light microscope

Lehmann, W, *Leitz Metallux 2*, https://commons.wikimedia.org/wiki/File:Metallux_II.jpg, CC BY-SA 3.0 creativecommons.org/licenses/by-sa/3.0/deed.en



Scanning electron microscope

Schwen, D, *Students working on a Scanning Electron Microscope (SEM) Leo Supra 35*, https://commons.wikimedia.org/wiki/File:Goe_SEM_students_working1.jpg, CC BY-SA 2.5 https://creativecommons.org/licenses/by-sa/2.5/deed.en

Electron microscopes

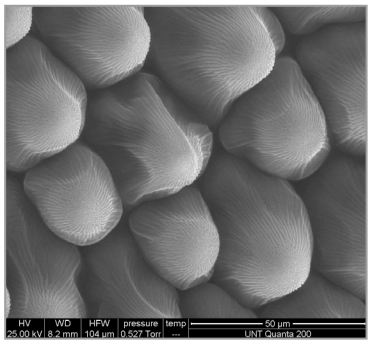
In contrast to light microscopes, electron microscopes use a beam of electrons instead of a beam of light. Not only does this allow for higher magnification and, thus, more detail, it also provides higher resolving power. The method used to prepare the specimen for viewing with an electron microscope kills the specimen. Electrons have short wavelengths (shorter than photons) that move best in a vacuum, so living cells cannot be viewed with an electron microscope.

In a scanning electron microscope, a beam of electrons moves back and forth across a cell's surface, creating details of cell surface characteristics. In a transmission electron microscope, the electron beam penetrates the cell and provides details of a cell's internal structures. As you might imagine, electron microscopes are significantly more bulky and expensive than light microscopes.

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Sheet 7

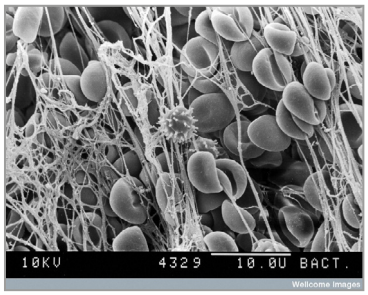
Some example electron micrographs (images captured using an electron microscope) are given below. For some eye-catching colour images refer to the **Website — Under the electron microscope** (Kuriositas) http://www.kuriositas.com/2013/07/under-electron-microscope.html



i. Sunflower petals — these conical cells are reflecting light in all directions, making the flower more visible for pollinators



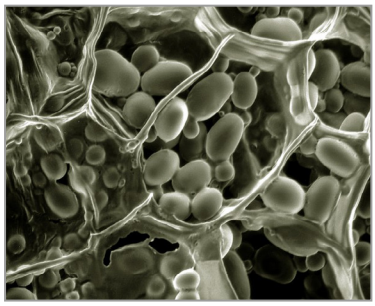
ii. Guinea pig inner ear showing the cochlea — sensory cells that respond to different sound frequencies can be seen along the outside of the spiral structure. The whole organ is only a few millimetres long



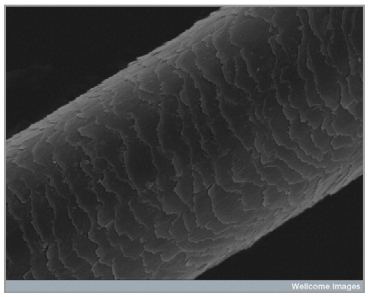
iii. Blood clot showing a white blood cell in centre



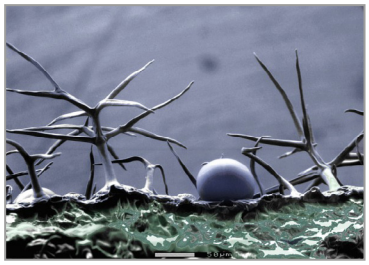
iv. Moth fly showing compound eyes, mouth parts, antennae and front legs; wings can be seen in the background



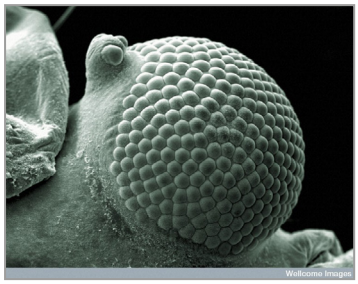
v. Potato starch granules



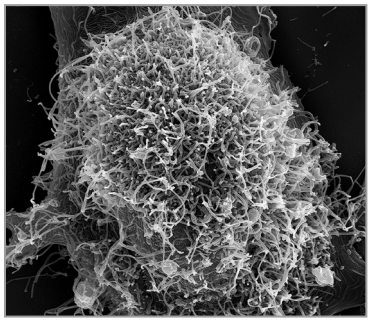
vi. A strand of human hair (0.95 mm wide) showing the randomly arranged overlapping scales of the cuticle. (750x magnification)



vii. Lavender leaf (245x magnification)



viii. Aphid (greenfly) compound eye — the curved bulging eye is made up of thousands of repeating units each with a tiny lens on the front surface (eye is 0.28mm wide)



ix. Ebola virus particles (15,000x magnification)

i. CamellaTWU, *Scanning electron micrograph of the sunflower ray floret corolla/petals*, https://www.flickr.com/photos/cameliatwu/8368759184/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
ii. Wellcome Images, *Cochlea of the inner ear*, https://www.flickr.com/photos/wellcomeimages/5987498511/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
iii. Wellcome Images, *Electron micrograph of blood clot*, https://www.flickr.com/photos/wellcomeimages/5988077684/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
iv. Wellcome Images, *Moth fly*, https://www.flickr.com/photos/wellcomeimages/7413120108/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
v. Uwins, P., *Potato starch*, https://commons.wikimedia.org/wiki/File:Potato_starch.jpg, CC BY-SA 3.0 creativecommons.org/licenses/by-sa/3.0/deed.en
vi. Wellcome Images, *Human hair*, https://www.flickr.com/photos/wellcomeimages/16040451851/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
vii. Uwins, P., *Lavender leaf*, https://commons.wikimedia.org/wiki/File:Lavender_leaf.jpg, CC BY-SA 3.0 creativecommons.org/licenses/by-sa/3.0/deed.en
viii. Wellcome Images, *Greenfly compound eye*, https://www.flickr.com/photos/wellcomeimages/16665492568/, CC BY-NC-ND 2.0 creativecommons.org/licenses/by-nc-nd/2.0/
ix. NIAID, *Ebola virus particles*, https://www.flickr.com/photos/niaid/14861104405/, CC BY 2.0 creativecommons.org/licenses/by/2.0/

Sheet 7

Additional notes regarding microscopes

Given that modern light microscopes can be used to magnify objects up to 1000x, most cells will be clearly visible at this magnification, along with larger organelles such as nuclei, mitochondria and chloroplasts. Fine detail of cell structure, however, requires resolution more than magnification. By the end of the 19th century light microscopes had been developed that could show separate structures more than around 0.2 microns apart from each other.

Some of the light microscopy techniques used by modern scientists include:

- Bright-field — light is passed directly through the specimen and different structures are seen in contrast depending on how visible light is absorbed by the structures. This type of microscopy is often accompanied by staining with dyes. This kills the cells, so it isn't suitable for experiments that require observation of living cells.
- Phase-contrast microscopy — doesn't use stains so it can be used with live cell samples. As light travels through the cytoplasm into transparent structures in the cell, it is slowed down. These changes in light speed are converted into images that show structures in contrast to the surrounding cytoplasm.
- Electronic image processing systems in video cameras and computers enable image contrast to be enhanced so that small structures can be seen more clearly.
- Labelling or tagging specific molecules so that they are coloured or fluoresce is a way of tracking the movement of these molecules within living cells viewed under the microscope.

Electron microscopy, developed in the 1930s, provides much higher resolving powers than light microscopy, but the specimen is destroyed in the process.

Techniques used include:

- Transmission electron microscopy and staining — heavy metal salt solutions are used to stain structures which appear dark in the image; or specimen is placed on a surface that is stained so the whole specimen appears light against the dark background.
- Metal shadowing — metal (for example, platinum) is sprayed onto the surface of the specimen at an angle, so some structures are coated more heavily than others, resulting in a shadow effect in the image.
- Scanning electron microscopy — surface of specimen is coated with a heavy metal and the electron beam scatters from the surface, providing a three dimensional image. Because of its lower resolution, this technique is usually restricted to whole cells rather than organelles.
- Differential centrifugation — plasma membrane is broken without destroying internal cell structures. The broken cells are spun at varying speeds depending on what organelle is to be isolated. The spinning action of the centrifuge causes the mixture to separate into layers with the largest and heaviest structures on the bottom. Each layer then contains one type of structure which can be tested biochemically to determine its function.
- Artificially culturing or growing cells in the laboratory in appropriate nutrient solutions — scientists can use live cell cultures to study cell growth and developmental stages from stem cell to specialised cell. Cultures are also used for genetic studies to understand the structure and function of genes.

Some of the questions that cell biologists have been able to partly or completely answer over the last 200+ years include:

- What is the mechanism for cell division?
- Is there some kind of barrier surrounding the contents of the cell?
- How does the cell membrane regulate the movement of materials into and out of the cell?
- How does the cell produce energy-storing molecules?
- What are mitochondria?
- How do the processes of respiration and photosynthesis occur?
- How can living cells be studied in the laboratory?
- How do we keep cells alive in the laboratory?
- How are characteristics passed on (inherited) from one generation to the next?
- How is the genetic code in DNA translated into different protein molecules?
- How can the DNA of an organism be manipulated so that it has desirable features, such as disease-resistance?
- How can parents who can't get pregnant naturally be given the opportunity to have a biological child?
- Is it possible to eradicate a disease like smallpox through a worldwide vaccination program?
- What are the characteristics of the human immunodeficiency virus (HIV) that causes acquired immune deficiency syndrome (AIDS)?
- How can HIV be treated to prevent death from AIDS?
- How do genes in DNA regulate development in organisms from different species?
- What general technique can be used to analyse the DNA molecule in order that we can study the genetics of different organisms?
- Is it possible to clone an animal from an adult cell of another animal?
- Can stem cells be isolated and used to grow tissues for repairing and replacing tissues in the human body?
- Can we decode the entire genome of a human so that we have a resource for the study of genetic diseases?
- How can we stop the spread of certain cancer cells?

References:

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http://www.ncbi.nlm.nih.gov/books/NBK9941/

50 science sagas for 50 years (Council for the Advancement of Science Writing)
http://casw.org/casw/article/50-science-sagas-50-years