Advances in Microscopy

Most of our understanding of cells and cellular processes has come from observing cells with microscopes. The light microscope is a compound microscope, consisting of one or more glass lenses. It works by passing beams of light through a specimen to produce an enlarged image of the specimen. Cells viewed under a light microscope can be stained with fluorescent dyes that give off visible light. When ultraviolet rays are passed through the dyed specimens, a coloured image of the cell is produced (Figure 1). This improves the visibility of cellular structures, which is very useful for cell biologists.

Since the invention of the light microscope, scientists have tried to improve its magnifying power. To make images larger, lenses became thicker. However, thicker lenses decreased the clarity of the image produced. Most light microscopes can magnify objects by up to 1500× before the clarity of the image is affected.

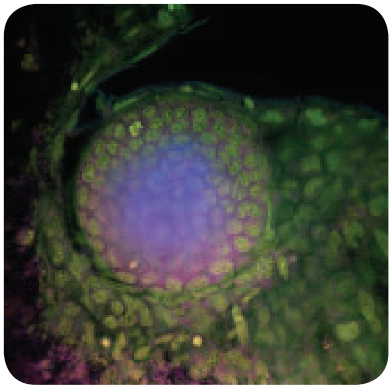

Figure 1 The nuclei of all the cells in this zebrafish embryo are stained with a fluorescent dye, which produces a blue colour when illuminated by ultraviolet light.

The Electron Microscope

In 1931, two German scientists, Ernst Ruska and Max Knoll, produced a new type of microscope. It used magnetic lenses and a beam of electrons to produce a highly magnified image. They called this microscope the **electron microscope**. It had a total magnification of 400×. Six years later at the University of Toronto, James Hillier and Albert Prebus developed an improved electron microscope with a magnification of 7000×. Today's electron microscopes can magnify objects by up to 2 000 000×! Since electron microscopes do not use visible light, images cannot be seen by looking through the ocular lens. Instead, computers produce images called electron micrographs on a computer screen (Figure 2).

electron microscope: a microscope that uses beams of electrons instead of beams of light; has more magnifying power than a compound light microscope

Electron microscopes allow biologists to explore cells in more detail. Organelles that can only be seen in detail with an electron microscope include the following:

- Mitochondria: circular or rod-shaped organelles that produce energy for cells by combining sugar and oxygen to form carbon dioxide and water
- Ribosomes: tiny organelles that produce proteins needed for cell growth, repair, and reproduction
- Endoplasmic reticulum (ER): a series of folded membranes that transports materials through the cytoplasm
- Golgi apparatus: an organelle that stores and packages proteins produced by the ribosomes
- Lysosomes: organelles that clean the cytoplasm by releasing digestive proteins that break down harmful substances and large particles, which the cell can then use for growth and repair

Figure 2 A scientist using an electron microscope

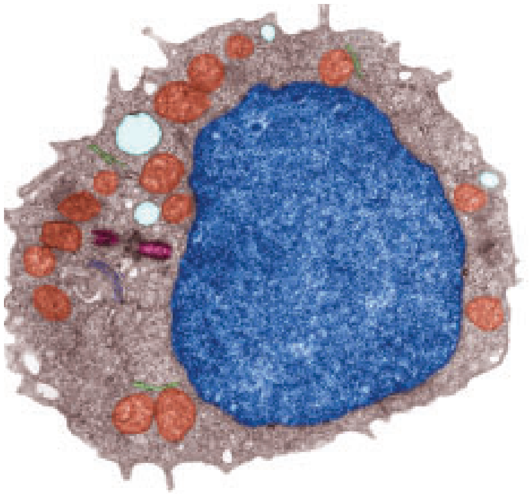

Figure 3 A cell (magnification 25 710×) showing the nucleus (blue), mitochondria (orange), endoplasmic reticulum (green), and Golgi apparatus (purple).

The electron microscope provided the first look at the structure of these important organelles (Figure 3).

Two commonly used electron microscopes are the transmission electron microscope (TEM) and the scanning electron microscope (SEM). In the TEM, the lenses used are magnetic. As the electron beam passes through the specimen, some of the electrons are reflected or change direction. The electrons that pass through the specimen produce an electron micrograph (Figure 4(a)).

The scanning electron microscope differs from this design. The SEM uses the electrons that are reflected or scattered to produce the image of the specimen. The result is three-dimensional imaging (Figure 4(b)).

Electron microscopes are used in science laboratories and in many industries, such as forensics, nanotechnology, and mining. Electron microscopes do have disadvantages. They are large machines, require training, and are very expensive. Also, specimens require a lot of preparation. For example, because electrons have to pass through a specimen to create a TEM image, very thin slices of cells must be used. If the slice is too thick, the specimen absorbs all of the electrons and no image is produced. The specimens are mounted in plastic, which means that only dead cells can be viewed. A limitation of the SEM is that only the exterior of a specimen can be viewed. This is because electrons must be reflected to produce an image.

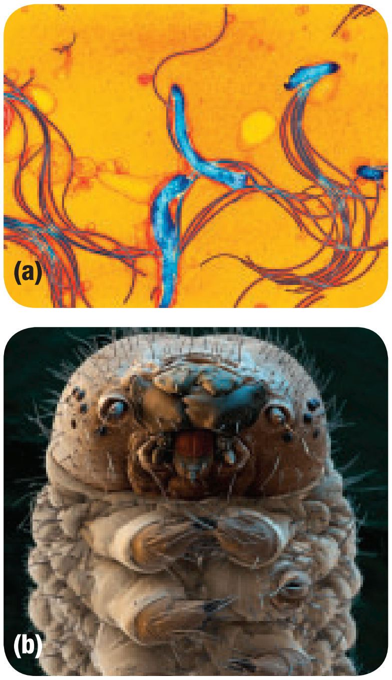

Figure 4 A coloured TEM (a) of bacteria and their flagella. A coloured SEM (b) of the head of a caterpillar.

Electron microscopy has also allowed us to make advances in detecting disease. Heavy metals (such as lead) are used to stain cells before they are viewed with a TEM. The stain is more visible in organelles than in the surrounding cytoplasm. Defects in a cell's organelles are easily seen. Viruses and bacteria that cause disease can be identified in blood samples using electron microscopes. Also, changes and abnormalities in cellular structures that are only visible with an electron microscope (such as the mitochondria) can now be identified and treated.

CHECK YOUR LEARNING

1. Compare the images you saw when using the microscope in Activity 4.6 to the TEM and SEM images shown in this section.
   - **(a)** Explain the differences in the two types of images.
   - **(b)** Which do you prefer? Why?
2. What organelles can only be seen in detail using an electron microscope?
3. What are two commonly used types of electron microscopes?
4. In what industries are electron microscopes used today?
5. What are some of the disadvantages of electron microscopy?
6. Explain the differences between the transmission electron microscope and the scanning electron microscope.