Despite the very small size of most cells, knowledge of cell structure and function has accumulated through the use of various techniques. One technique is **microscopy**—the use of several types of microscopes to peer into the innermost parts of a cell.

The **light microscope (LM)** relies on the bending (refraction) of light rays. Light rays pass through the center of a curved lens. The farther they are from the center, the more they bend (figure 1*a*). The compound microscope used in most zoology laboratories contains at least two of these lenses (figure 1*b*). All the rays eventually converge through the lens system onto one focal point—the eye(s). Specific stains are often used to highlight certain structures. Unfortunately, these staining procedures kill the cell. However, living cells can be observed through the phase contrast microscope. In this type of light microscopy, small differences in the way different parts of the cell refract light are converted to larger variations in brightness. In the dark-field microscope, living cells can be observed by making the field surrounding the specimen appear black while the specimen itself is brightly illuminated. The best light microscopes magnify images approximately two thousand times.

In the **transmission electron microscope (TEM),** an electron beam focuses on a thin section or slice of the cell by means of electromagnets (figure 1*c*). After passing through the cell, the electron beam travels through more magnetic lenses, which magnify the image and project it onto either a fluorescent screen or photographic film. Magnifications of several hundred thousand times are possible with the TEM.

The **scanning electron microscope (SEM)** is used to study surfaces rather than thin sections of cells (figure 1*d*). SEM photomicrographs, with their three-dimensional quality, reveal remarkable details of the surface of cells or other objects. Surfaces to be studied are first covered with a very thin layer of metal, such as gold. In the SEM, electron beams scan the surface of the specimen, driving off electrons from the atoms of the metal surface—called secondary electrons. The pattern of these scattered secondary electrons is then detected on a cathode-ray tube like that in a television set. Maximum magnifications of the SEM are usually around twenty thousand times.

The **scanning tunneling microscope (STM)** was invented in the 1980s and can achieve magnifications of over 100 million. This magnification allows viewing of atoms on the surface of a solid. The electrons surrounding the surface atoms tunnel or project a very short distance from the surface. The STM has a needle probe with a point so sharp that often only one atom is at its tip. The probe is lowered toward the surface of the specimen until its electron cloud just touches the surface atoms. When a small voltage is applied between the tip and specimen, electrons flow through a narrow channel in the electron clouds. The arrangement of atoms on the surface of the specimen is determined by moving the probe tip back and forth over the surface. As the tip follows the surface contours, a computer records and analyzes the motion to create an accurate, three-dimensional image of the surface atoms. The surface map can be either displayed on a computer screen or plotted on paper. The microscope's inventors, Gerd Binnig and Heinrich Rohrer, shared the 1986 Nobel Prize in Physics for their work. Interestingly, another recipient of the prize was Ernst Ruska, the inventor of the first transmission electron microscope.

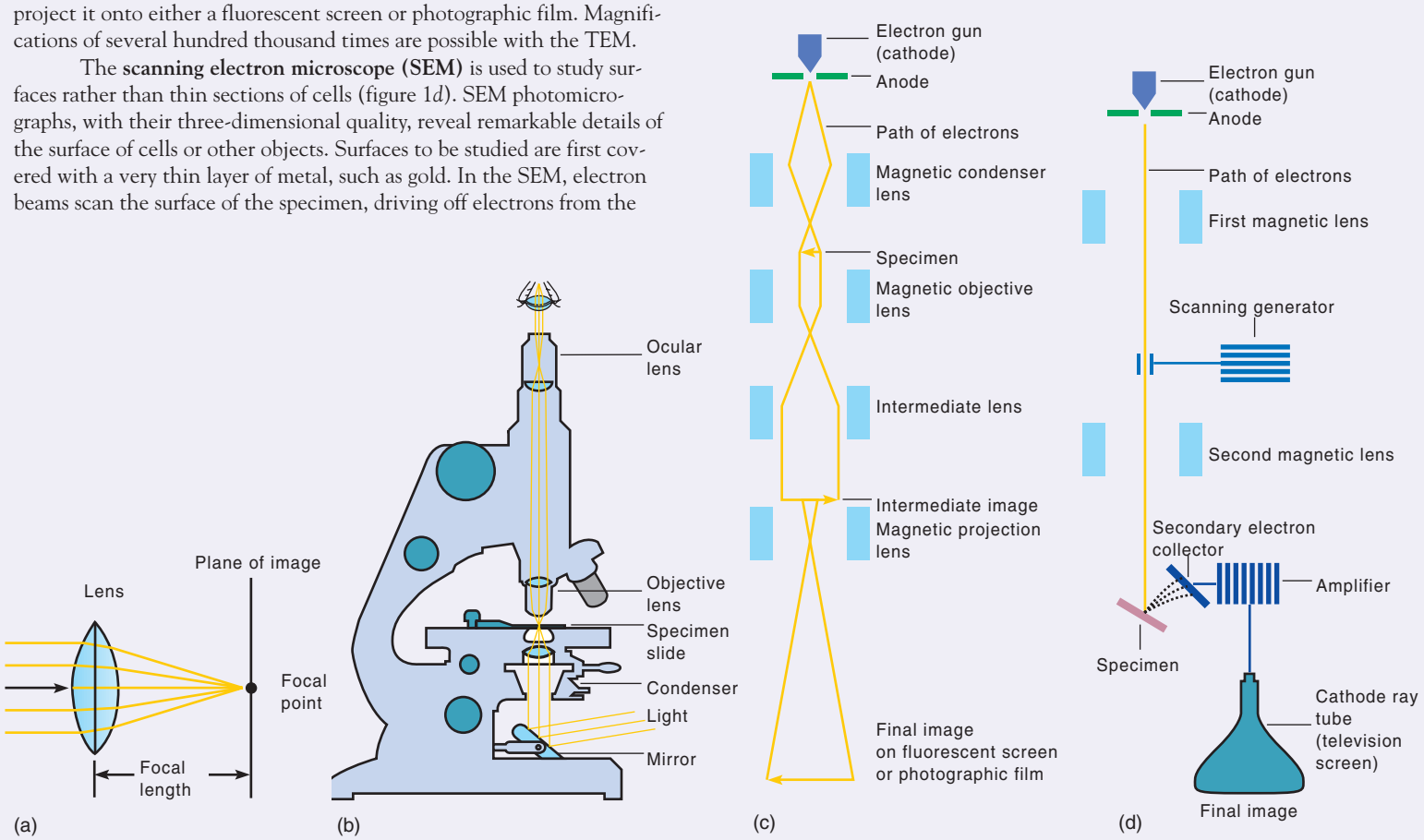

FIGURE 1

Types of Microscopes and Their Images (Sperm Cells). *(a)* Focusing of light rays. *(b)* Compound light microscope. *(c)* Transmission electron microscope. *(d)* Scanning electron microscope. Box 3.2, c, d: *Thomas D. Brock,* Biology of Microorganisms, *3e., © 1979, p. 774, 775. Adapted by permission of Prentice Hall, Englewood Cliffs, New Jersey.*