*18–9 Superconductivity

At very low temperatures, well below 0°C, the resistivity (Section 18–4) of certain metals and certain compounds or alloys becomes zero as measured by the highest-precision techniques. Materials in such a state are said to be **superconducting**. This phenomenon was first observed by H. K. Onnes (1853–1926) in 1911 when he cooled mercury below 4.2 K (−269°C) and found that the resistance of mercury suddenly dropped to zero. In general, superconductors become superconducting only below a certain *transition temperature* or *critical temperature*, T_C, which is usually within a few degrees of absolute zero. Current in a ring-shaped superconducting material has been observed to flow for years in the absence of a potential difference, with no measurable decrease. Measurements show that the resistivity ρ of superconductors is less than $4 \times 10^{-25}\,\Omega\cdot\mathrm{m}$, which is over 10^{16} times smaller than that for copper, and is considered to be zero in practice. See Fig. 18–26.

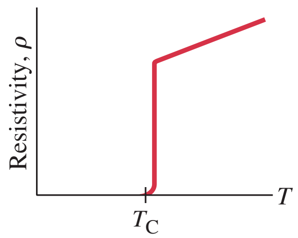

FIGURE 18–26 A superconducting material has zero resistivity when its temperature is below T_C, its "critical temperature." At temperatures above T_C, the resistivity jumps to a "normal" nonzero value and increases with temperature as most materials do (Eq. 18–4).

Before 1986 the highest temperature at which a material was found to superconduct was 23 K, which required liquid helium to keep the material cold. In 1987, a compound of yttrium, barium, copper, and oxygen (YBCO) was developed that can be superconducting at 90 K. Since this is above the boiling temperature of liquid nitrogen, 77 K, liquid nitrogen is sufficiently cold to keep the material superconducting. This was an important breakthrough because liquid nitrogen is much more easily and cheaply obtained than is the liquid helium needed for earlier superconductors. Superconductivity at temperatures as high as 160 K has been reported, though in fragile compounds.

To develop high-T_C superconductors for use as wires (such as for wires in "superconducting electromagnets"—Section 20–7), many applications today utilize a bismuth-strontium-calcium-copper oxide (BSCCO). A major challenge is how to make a useable, bendable wire out of the BSCCO, which is very brittle. (One solution is to embed tiny filaments of the high-T_C superconductor in a metal alloy, which is not resistanceless but has resistance much less than a conventional copper cable.)

*18–10 Electrical Conduction in the Human Nervous System

An interesting example of the flow of electric charge is in the human nervous system, which provides us with the means for being aware of the world, for communication within the body, and for controlling the body's muscles. Although the detailed functioning of the hugely complex nervous system still is not well understood, we do have a reasonable understanding of how messages are transmitted within the nervous system: they are electrical signals passing along the basic element of the nervous system, the **neuron**.

Neurons are living cells of unusual shape (Fig. 18–27). Attached to the main cell body are several small appendages known as *dendrites* and a long tail called the *axon*. Signals are received by the dendrites and are propagated along the axon. When a signal reaches the nerve endings, it is transmitted to the next neuron or to a muscle at a connection called a *synapse*.

FIGURE 18–27 A simplified sketch of a typical neuron.