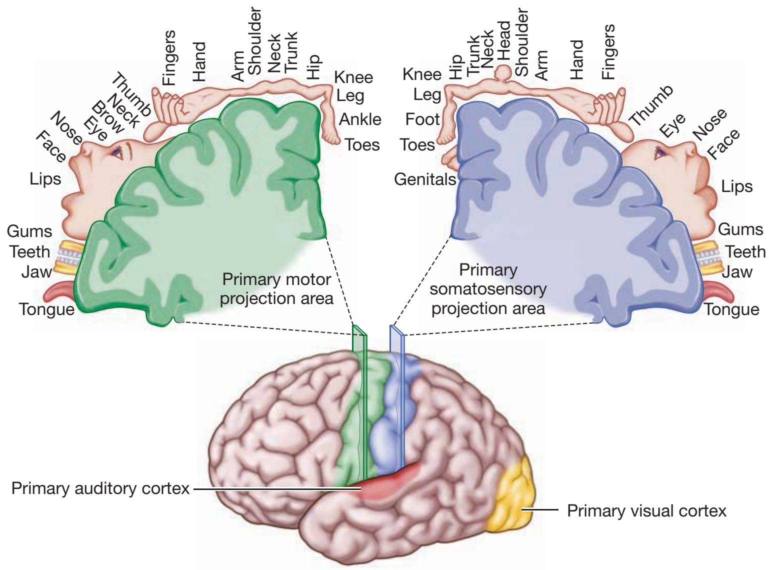

3.33 The primary motor and somatosensory projection areas The primary motor projection area is located at the rearmost edge of the frontal lobe, and each region within this projection area controls the motion of a specific body part, as illustrated on the top left. The primary somatosensory projection area, receiving information from the skin, is at the forward edge of the parietal lobe; each region within this area receives input from a specific body part. The primary projection areas for vision and hearing are located in the occipital and temporal lobes, respectively. These two areas are also organized systematically. For example, in the visual projection area, adjacent areas of the brain receive visual inputs that come from adjacent areas in visual space.

areas, adjacent sites in the brain represent adjacent locations in the external world. For the auditory projection areas, adjacent sites in the brain represent similar pitches.

As it turns out, the brain has multiple projection areas—multiple maps—for each sense modality. The term *primary projection area* is therefore used to designate the initial receiving station for information arriving from the sense organs—and so there's a primary projection area for vision, one for hearing, and one for information arriving from the skin.

We also find projection areas in the motor areas of the cortex. In that case, adjacent sites in the brain usually represent adjacent parts of the body. And there, too, we find a primary projection area—the departure point for signals that exit the cortex and ultimately result in muscle movement.

PRIMARY MOTOR AREAS

The discovery of the primary motor projection area dates back to the 1860s, when investigators began to apply mild electric currents to various portions of the cortex of anesthetized animals. The effects were often quite specific. Within the frontal lobe, stimulating one point led to a movement of the forelimb; stimulating another point made the ears prick up. These early studies also provided evidence for the pattern of **contralateral control,** in which stimulating the left hemisphere led to movements on the right side of the body and stimulating the right hemisphere caused movements on the left.

Similar results have been obtained with humans. Canadian neurosurgeon Wilder Penfield, for example, collected data from his patients who were undergoing surgery for epilepsy. The surgery was intended to remove diseased tissue; and, as is common in neurosurgery, the patients were awake during the procedure. (Because the brain itself has no pain receptors, neurosurgery is often performed with only local anesthesia that is required just to allow the surgeon to penetrate the scalp and skull.) In the surgeries, Penfield confirmed that stimulating the motor area in the frontal lobe led to movement

contralateral control The typical pattern in vertebrates in which movements of the right side of the body are controlled by the left hemisphere, while movements of the left side are controlled by the right hemisphere.

of specific body parts—much to the surprise of the patients, who had no sense of willing the action or performing it themselves.

Systematic exploration persuaded Penfield that for each portion of the motor cortex, there was a corresponding part of the body that moved when its cortical counterpart was stimulated. These findings are often summarized with a "motor homunculus," a schematic picture showing each body part next to the bit of the motor projection area that controls its movement (Figure 3.33, top left).

As Figure 3.33 makes plain, equal-sized areas of the body are not controlled by equal amounts of cortical space. Instead, the parts that we can move with the greatest precision (e.g., the fingers, the tongue) receive more cortical area than those over which we have less control (e.g., the shoulder, the abdomen). Evidently, what matters is function—the extent and complexity of that body part's use (Penfield & Rasmussen, 1950).

PRIMARY SENSORY AREAS

3.34 The sensory homunculus An artist's rendition of what a man would look like if his appearance were proportional to the area allotted by the somatosensory cortex to his various body parts.

Methods similar to Penfield's revealed the existence of sensory projection areas. The *primary somatosensory projection area* is directly behind the primary motor projection area, in the parietal lobe (see Figure 3.33, top right). This area is the initial receiving area for sensory information arriving from the skin senses. Patients stimulated at a particular point in this area usually report tingling somewhere on the opposite side of their bodies. (Less frequently, they report experiences of cold or warmth.) The somatosensory projection area resembles its motor counterpart in several ways. First, it shows an orderly projection pattern in which each part of the body's surface sends its information to a particular part of the cortical somatosensory area. Second, the assignment of cortical space is not in proportion to the size of each body part. Instead, the space corresponds to the sensitivity of each region; the parts of the body that are most sensitive to touch (such as the index finger, lips, and tongue) receive more cortical space (Figure 3.34). Finally, sensation—like motor control—is contralateral. That is, sensory information from each part of the body proceeds to the brain hemisphere on the side opposite to it—so that (for example) sensations from the right thumb arrive in the left hemisphere, sensations from the left shoulder are sent to the right hemisphere, and so on. (Information from the trunk of the body close to the body's midline is represented in both hemispheres.)

The brain has similar primary projection areas for vision and for hearing, and they're located in the occipital and temporal lobes, respectively (see Figure 3.33). Patients stimulated in the visual projection area report optical experiences, vivid enough but with little form or meaning—flickering lights, streaks of color. When stimulated in the auditory area, patients hear things—clicks, buzzes, booms, and hums.

As we noted earlier, the visual and auditory areas are—like the somatosensory area—well organized spatially. In the occipital lobe, especially the area known as the visual cortex, adjacent brain areas represent adjacent locations in visual space. In the temporal lobes, adjacent areas represent similar ranges of pitch. The visual area also respects the principle of contralateral input: Objects seen (by either eye) to the left of a person's overall line of sight are processed by the right visual area, and objects seen on the right are processed by the left visual area. The auditory projection area, in contrast, provides a rare exception to the brain's contralateral wiring, because both cerebral hemispheres receive input from both ears.