PEARSON NEW INTERNATIONAL EDITION

Neuropsychology
Clinical and Experimental Foundations

Lorin Elias   Deborah Saucier

First Edition

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the **Real** world

Chicken Pox, Shingles, and Dermatomes

Unless you had a vaccination, there is a good chance that you had chicken pox when you were a child. Although the sores produced by the virus *Herpes varicella zoster* eventually went away, the virus did not. Instead, it is living in your cranial and spinal nerves (Kleinschmidt-DeMasters & Gilden, 2001). In most people, the virus is dormant, although in adulthood, stress, fatigue, or other events that compromise the immune system (e.g., HIV) may trigger the virus to become active again, resulting in a condition known as shingles. Typically, the virus becomes active in only one dorsal root ganglion, leading to hyperexcitability of that dorsal root ganglion. The increased sensitivity of the affected dorsal root ganglion leads to excessive firing, which is often perceived as a burning sensation or sharp stabbing pain. Shingles is an interesting condition to study because the virus maps the dermatome of the affected dorsal root by producing blisters on the skin along the nerve endings. Although shingles usually affects only the dorsal root of a spinal nerve, typically in the torso or face, there are cases in which the virus becomes active in other nerve tissue and can result in stroke or blindness. Regardless of the site of infection, immediate medical attention is required for shingles, as treatment may help to prevent chronic **neuralgia** (pain that does not result from any obvious lesion). Treatments for shingles might include drugs that stop the virus from reproducing (e.g., Acyclovir) and steroids to reduce inflammation.

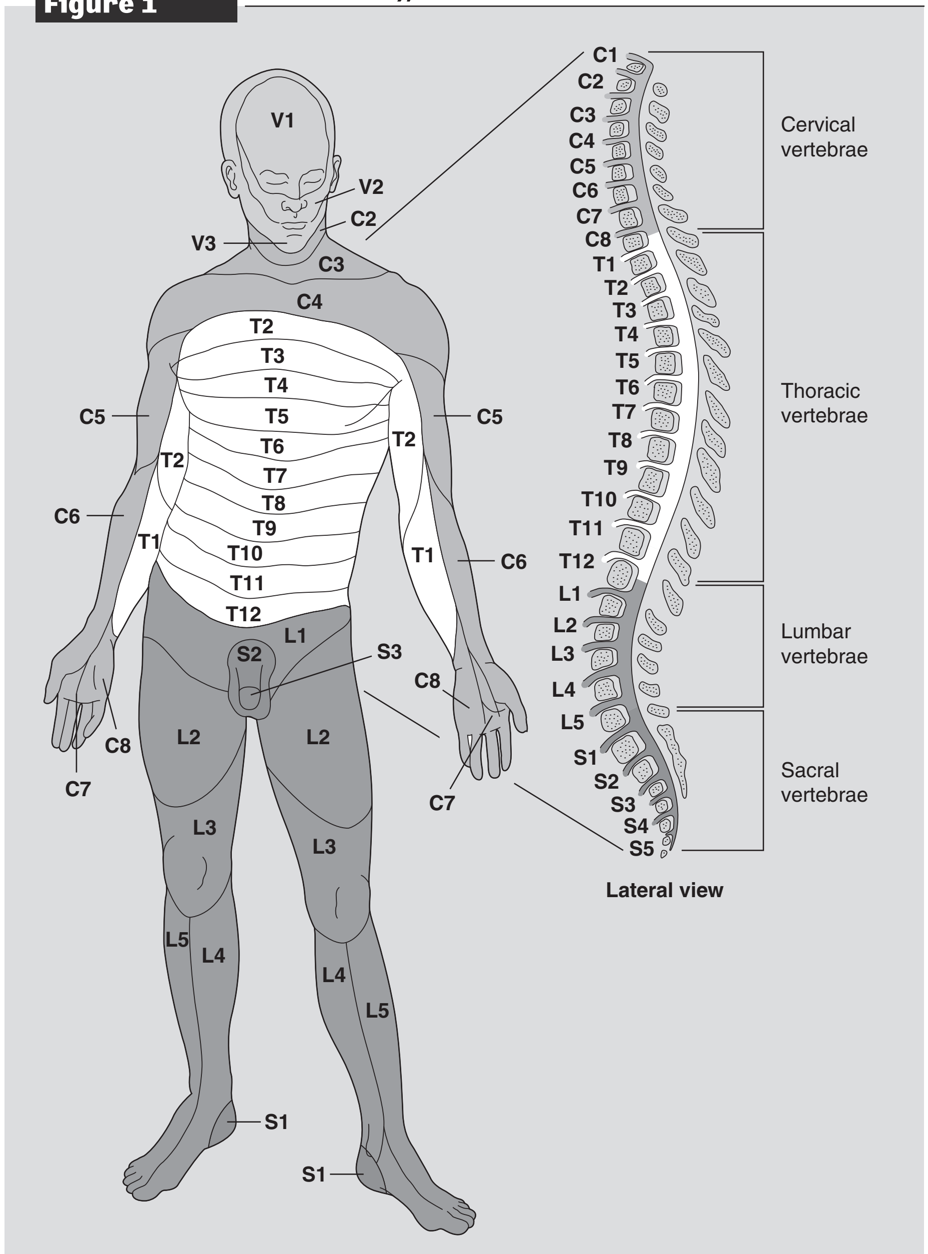
which then activates the mechanoreceptors. There are many different types of mechanoreceptors throughout the body, although most are axons that have mechanosensitive ion channels on them. Although not much is known about how these mechanosensitive ion channels work, the axons that contain these ion channels are primary afferent axons that enter the spinal cord through the dorsal roots. The cell bodies of the primary afferent axons reside in the dorsal root ganglia of the spinal cord.

The spinal cord is organized into dorsal and ventral root ganglia; the **dorsal root ganglia** are somatosensory, and the **ventral root ganglia** are motor. There are thirty pairs of spinal nerves, each of which is made up of dorsal and ventral roots that exit the spinal cord through a notch in the vertebrae of the spine. These spinal segments can be divided into four groups on the basis of where the nerves originate (Figure 1): cervical (C) 1–8, thoracic (T) 1–12, lumbar (L) 1–5, and sacral (S) 1–5. Each of the thirty dorsal roots of the spinal cord innervates different areas of the skin referred to as **dermatomes.** Maps of dermatomes (see Figure 1) really reflect the areas of skin that are served by the dorsal roots of a specific spinal nerve. When a dorsal root is cut, the spinal cord can no longer obtain information from that nerve. However, not all sensation from that dermatome is lost, as there is extensive overlap between dermatomes. In fact, to lose complete sensation in one dermatome, you must cut three dorsal roots: the one serving the dermatome and the dorsal roots above and below it.

Somatosensory Pathways in the Brain

There are a number of sensory pathways in the brain, and they are often divided into two main pathways, which are named for their position in the spinal cord and the

Figure 1 **The Four Sections of the Spinal Cord (Cervical, Thoracic, Lumbar, and Sacral), Which Innervate Dermatomes**



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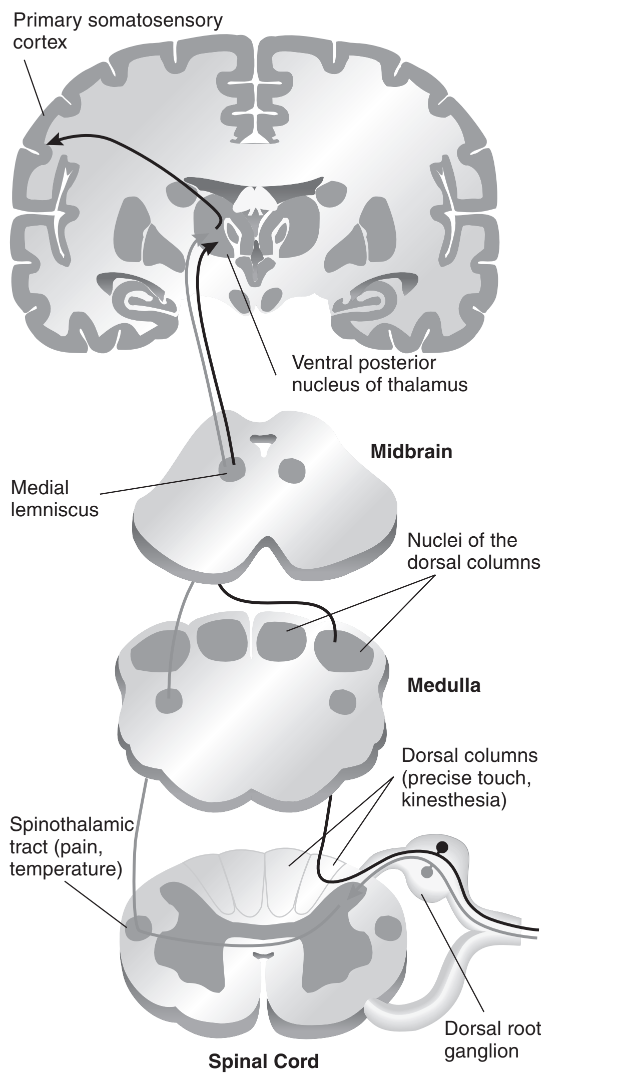
Somatosensory Pathways (Dorsal Spinothalamic Tract and Ventral Spinothalamic Tract) from the Spinal Cord to the Somatosensory Cortex

Figure 2



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connections made: the dorsal spinothalamic tract and the ventral spinothalamic tract. The **dorsal spinothalamic tract** (Figure 2), which is responsible for transmitting information about proprioception and hapsis, enters the spinal cord through the dorsal root ganglion and synapses ipsilaterally in the dorsal column nuclei of the spinal cord. The axons of the dorsal column nuclei ascend through the spinal cord until the brainstem, where they decussate or cross, and continue to ascend through the brainstem in a pathway called the medial lemniscus. The axons of the medial lemniscus synapse in the ventrolateral thalamus, which sends projections to both the motor and somatosensory cortex. Nociceptive information travels separately in the **ventral spinothalamic tract** (see Figure 2), which enters the spinal cord through the dorsal root ganglion and ascends the spinal cord contralaterally. In the brainstem, these axons join the medial lemniscus and ascend to the ventrolateral thalamus. As was the case for the dorsal spinothalamic tract, some of these neurons send projections to the somatosensory cortex.

Although somatosensory information for hapsis and nociception is transmitted separately, because they send information through the same pathways to the same destinations, damage to the brainstem or thalamus results in equal loss of both hapsis and nociception. However, damage to the spinal cord can result in different patterns of deficits. As you most likely know, damage to the spinal cord results in a loss of sensorimotor function below the site of injury. However, if the spinal cord is not completely **transected** (cut through), nociception is lost for the side of the body contralateral to the injury, and hapsis is lost for the side of the body ipsilateral to the injury.

WHERE WE HAVE BEEN

Somatosensory information plays an essential role in the production of movements, primarily by providing critical feedback to the brain about the position of the body. Somatosensory information can be divided into three separate functions: proprioception, nociception, and hapsis. Hapsis and proprioception are mediated by the dorsal spinothalamic tract, and nociception is mediated by the ventral spinothalamic tract.

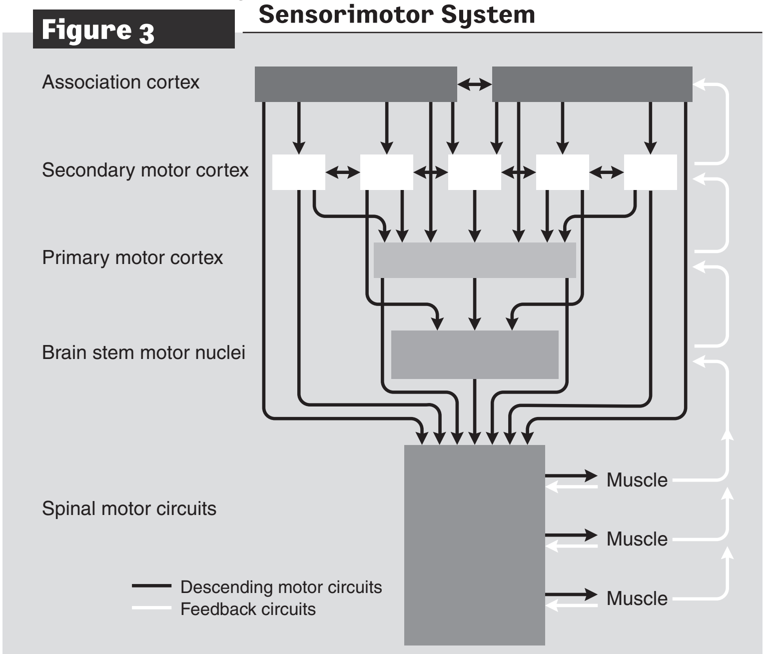
WHERE WE ARE GOING

The next section of this module will explore how the brain produces movements and how sensation is integrated in the production of accurate movements. The second section will discuss disorders of movement that result from brain damage.

Association Cortex

Control of voluntary behavior is organized like a business. There is a boss at the top, who gives out commands (often without doing much of the work directly), and there are various levels of workers with different functions, who are goal directed and fairly autonomous. In the case of the sensorimotor control, the two different areas of association cortex are at the top of the hierarchy (Figure 3). As we will see, the secondary and primary motor areas actually carry out the commands fairly independently, sending their commands to the muscles through the descending motor pathways. Rather than playing a direct role in voluntary movements, the basal ganglia and cerebellum modulate motor responses, the independent contractors in the organization. Critical feedback, both somatosensory and motor, is achieved through the ascending sensorimotor pathways.

Figure 3 Hierarchical Organization of the Sensorimotor System



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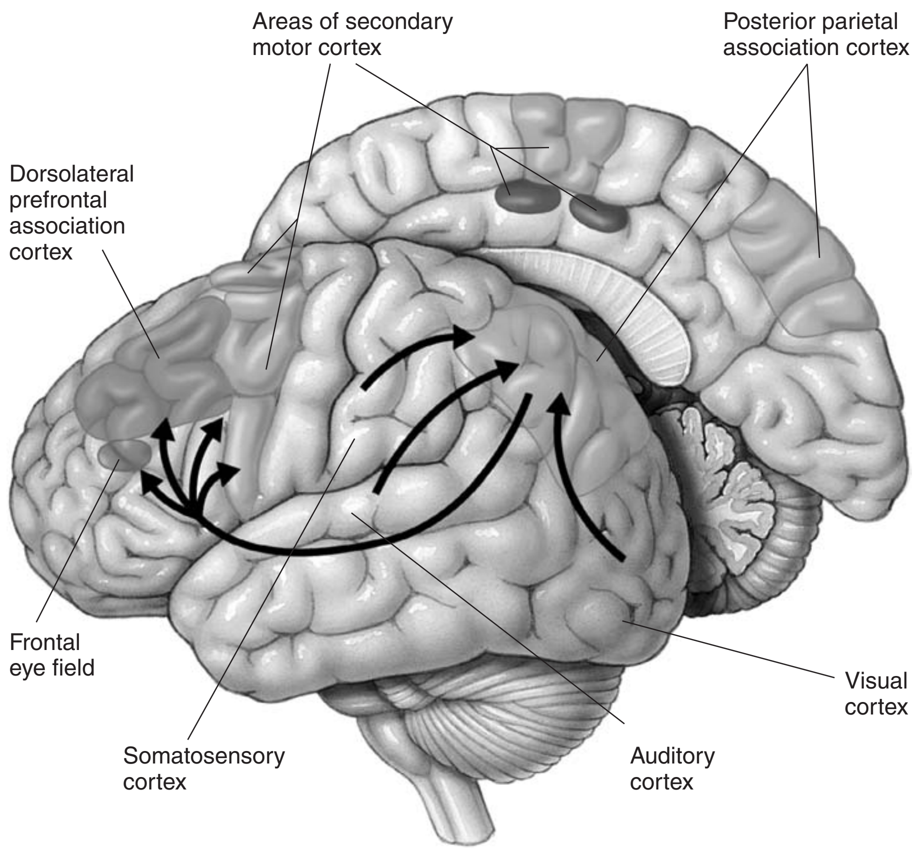
POSTERIOR PARIETAL ASSOCIATION CORTEX. The parietal lobes tend to be active whenever the brain is interacting with space or with spatial information. As such, the posterior parietal association cortex plays (Figure 4) an important role in determining both the original position of the body and objects around the body in space. If you think about it, any movement through space requires extensive knowledge about the spatial relations of the objects in the space, including your own body. If you want to do anything that actually contacts other objects, such as picking up a cup of coffee, you need to correctly estimate the distance between your hand and the cup. In addition you need to compute the angle and size of the handle in order to pick the cup up efficiently. Thus, knowledge of the spatial arrangement and position of the body is required to effectively move through the world. (In the example at the beginning of the chapter, the failure of the anaesthetized tongue to provide information about its position can result in unintentional injury to the tongue.) However, knowl-

Figure 4 **Input and Output Pathways of the Posterior Parietal Association Areas**



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edge of the body is not enough for accurate purposeful movements, such as catching a ball. To accomplish these types of movements requires precise knowledge of the spatial relationships between external objects and the body.

The posterior parietal association cortex is an association cortex because it receives input from a variety of sensory systems, including proprioception, hapsis, and vision. Using this information, the posterior parietal association cortex is responsible for creating a mental picture of the body in space. Within the posterior parietal cortex, Brodmann's area 5 (BA5) receives inputs from primary somatosensory cortical areas, whereas BA3, BA1, BA2, and BA7 receive higher-order visual information. Individuals with damage to these areas of the parietal lobes tend to have difficulties with spatial relations, but they also tend to have disturbances of body image. It is as if individuals with parietal damage fail to recognize parts of their body as belonging to themselves. The posterior parietal lobes are involved in the processing of spatial relations of both the body and objects surrounding the body, which plays a critical role in the production of accurate movements. However, it is the extensive interconnections between the posterior parietal association cortex and the dorsolateral prefrontal association cortex that allow this information to guide movements. In addition, the posterior parietal association cortex has extensive reciprocal connections with areas that are lower in the motor hierarchy, such as secondary and primary motor cortex.

DORSOLATERAL PREFRONTAL CORTEX. The dorsolateral prefrontal association cortex (Figure 5) is thought to be involved with the decision to execute voluntary movements. In a series of experiments performed by using monkeys, Patricia Goldman-Rakic and colleagues demonstrated that the dorsolateral prefrontal association cortex actively directs lower areas in the motor hierarchy, such as the secondary and primary motor cortex (Goldman-Rakic, 1987). Furthermore, activation in the dorsolateral prefrontal association cortex occurred before the monkey began to pick up an object, suggesting that the decision to make the movement to pick up the object is initiated by the dorsolateral prefrontal association cortex (Goldman-Rakic, Bates, & Chafee, 1992). Neuroimaging studies in humans have observed that when neurologically intact participants were asked to make a series of movements with their fingers or toes, activation was observed in the dorsolateral prefrontal cortex (BA8) and the secondary (BA6) and primary motor cortex (BA4) (Rolani & Zilles, 1996). Interestingly, when participants were asked to only imagine moving their fingers similar levels of activity were observed in these areas, except for the primary motor cortex.

Given the large interconnections between the dorsolateral prefrontal association cortex and the posterior parietal association cortex, it seems likely that the sensory information that is provided to the dorsolateral prefrontal association cortex by the posterior parietal association cortex plays a large role in the decision to make the movement. However, given the large role that the frontal lobes play in memory and attention, it is likely that the dorsolateral prefrontal lobe also is assessing the likely outcome of planned movements. The dorsolateral prefrontal association cortex sends extensive projections to the secondary and primary motor cortex. As we will see in the next sections, the dorsolateral prefrontal association cortex is specifying *what* movement to make, and the lower levels are specifying *how* the movements will be made.