Control of Movement Lecture Review

The skeletal muscles, or **somatic muscles**, are responsible for carrying out the behavioral responses to sensory inputs. The somatic muscles can be divide**d into axial muscles, which are associated with the body axis, and the appendicular** muscles, which are associated with the limbs. The control of these muscles can be divided into to parts: **Direct control**, which is carried out by **somatic motor neurons** that innervate the muscle fibers, and the reflex circuits of the brainstem and spinal cord. **Indirect control**, which is carried out by descending commands from the brain. With the exception of those that innervate muscles of the face and eyes, the somatic motor neurons have their cell bodies in the **ventral horn of the spinal cord**, and send their axons out through the **ventral roots**. The motor neurons that innervate the facial muscles and eye muscles lie in the brainstem. In this lecture I focused on the motor neurons of the spinal cord. Because these motor neurons directly innervate the muscles they are sometimes called **primary motor neurons**. Because there are more primary motor neurons in the spinal cord segments that innervate your arm (C3-T1) and leg (L1-S3) these parts of the cord appear enlarged. The motor neurons in the spinal cord are organized into groups or pools on the basis of the muscles that they innervate. The motor neuron pools of the axial muscles are generally located in the medial part of the ventral horn; where as those of the appendicular muscles are located in the more lateral portion of the ventral horn. The motor neuron pools are organized in finer detail than what I described in lecture, but I will not expect you to memorize these details. Also, the book details the steps involved in muscle contraction, but I will not hold you responsible for this material. There are two types of primary motor neurons: **Alpha motor neurons** innervate the extrafusal (force generating) muscle fibers. **Gamma motor neurons** innervate the intrafusal (muscle spindle) muscle fibers.

Each muscle fiber receives innervation from only one alpha motor neuron. An alpha motor neurons and all the muscle fibers that it innervates is called a **motor unit**. A motor unit is the smallest voluntary contractile component of a muscle. When a motor unit is activated, all the muscle fibers contract in an all or none fashion. Each skeletal muscle in your body consists of many motor units of varying size. Some motor units have many muscle fibers, while others have relatively few. Because larger motor units have more muscle fibers, they generate greater force than smaller motor units. So, by varying the size and number of motor units that are active, the nervous system can control the force of contraction of a muscle. During a normal contraction not all of the motor units in a muscle are activated simultaneously. Rather, there is a gradual activation of the motor units of a muscle. This gradual activation of motor units is called **motor unit recruitment**. In general, when a muscle contracts, the smallest motor units are recruited first, and then there is a gradual increase in the size of active motor units. Motor unit recruitment serves to provide finer control of muscle contraction, and results in smooth movement.

The primary motor neurons receive inputs from three main sources: **Proprioceptors** (**muscle spindles** and **Golgi tendon organs**). **Interneurons** in the spinal cord. **Descending inputs for the brain**. Muscle spindles are stretch receptors, which consist of modified muscle fibers, called intrafusal fibers, which are innervated by **Ia sensory afferents**. All skeletal muscles have muscle spindles in them. The muscle spindles monitor the length and rate at which muscle length is changing during a muscle contraction. The CNS uses this information to sense limb position and coordinate movements. I reviewed the four connections that the Ia afferents make in the spinal cord and you should know these connections and be able to explain the significance of each connection (i.e. **muscle tone**, **reciprocal inhibition**). You should also know the roll of the gamma motor neuron innervation of the intrafusal fibers in setting muscle spindle sensitivity. The Golgi tendon organs are located in the tendons that attach the muscle to the bone. These receptors are innervated by **Ib sensory afferents** and mediate a protective reflex, called the clasp-knife reflex, that prevents the muscle from generating too much force and possibly damaging itself. The Golgi tendon organ and muscle spindle also act together as a modulation system that allows you to determine and exert the appropriate amount of force for the task being performed. The motor neurons also get inputs from sensory afferents that innervate other receptors, such as **C-fibers** that innervate pain receptors. These C-fibers make complex connections in the spinal cord that mediate a withdrawal reflex called the **crossed extensor reflex**. This reflex acts to activate the extensor muscles on the contralateral side of the body, and the flexor muscles on the ipsilateral side of the body, when you step on a sharp object. There are two descending pathways that carry motor commands from the brain: the **lateral pathway** and the **ventromedial pathway**. You should know the tracts that compose each of these pathways, where they originate and the function of each.

The motor plans for voluntary movement originate in the **motor cortex (Brodman areas 4 and 6)**, which lies in the frontal lobe of the cerebrum. The **primary motor cortex** (**area 4**) lies on the precentral gyrus. **Premotor** and **supplementary motor cortex** (**area 6**) lie just in front of area 4. Area 6 receives inputs for frontal cortex and parietal cortex, and is responsible for planning and initiating skilled motor acts. This part of motor cortex sends the plan of muscle activation to the primary motor cortex, which is responsible for carrying out the muscle activation pattern.

Motor cortex has reciprocal connections with two subcortical sites, the **basal ganglia** and the **cerebellum**. The basal ganglia consists of nuclei in the basal telencephalon, thalamus and midbrain (**don't worry about memorizing the names of these nuclei!**). The exact function of the basal ganglia is not clear, but it seems to be involved in controlling the release of motor commands from area 6. Either difficulty initiating movement (akinesia) or inability to control movement (hyperkinesia) characterizes diseases of the basal ganglia (Parkinson's disease and Huntington's Chorea). The cerebellum is responsible for the timing and coordination of muscle activation. It is also where new motor tasks (like learning to riding a bike) are learned.