

LECTURE 14

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NEUROPHYSIOLOGY REVIEW

Before beginning this lecture material, read Chapter 48 to page 964 as a general review of basic neurophysiology. Don't forget to review the chemical and physical events of the action potential if you've forgotten them.

Neurons vs. Neuroglia

The entire nervous system is comprised of two basic types of specialized cells, neurons and neuroglial (glial) cells. Neurons are the conductile elements of the nervous system that transmit information encoded as patterns of **action potentials (impulses)**. Neuroglial cells are the supportive (“glue”) elements of the nervous system that give organs of the nervous system their distinctive shapes. Glial cells serve a variety of functions depending upon their specialization. Schwann cells and oligodendroglial cells are glial cells of particular interest because they provide the **myelin** sheaths that characterize myelinated **white matter** and distinguish it from nonmyelinated **gray matter**.

Neurons, the longest cells of the body, consist of **cell bodies** containing the nuclei and numerous cytoplasmic processes (**neurites**). Neurites are of two types distinguished by the direction of conduction across them. **Axons** are neurites that conduct action potentials away from the cell body, while **dendrites** are neurites conducting toward the cell body. Organizationally, neuron cell bodies occur primarily in the central nervous system (CNS, brain and spinal cord) while peripheral nerves (peripheral nervous system, **PNS**) are bundles of neurites originating with the CNS cell bodies and extending outward to supply peripheral **receptors** and **effectors** (muscles and glands). Nerves that comprise the PNS may be classified as **sensory, motor or mixed** depending upon the direction of conduction across them. Sensory nerves (**afferents**) carry information from the periphery to the CNS and motor nerves (**efferents**) transmit from the CNS toward the periphery. Although a few purely sensory and purely motor nerves exist, the majority of peripheral nerves are mixed.

Myelinated neurons of white matter show a marked increase in transmission velocity and energy efficiency over their nonmyelinated, gray matter counterparts. In the process of myelination, glial cells (Schwann or oligodendroglia) wrap around the neurites of neurons forming a sheath analogous to the insulation of electrical wires. These glial cells line up like beads on a string along the neurite length. However, gaps (**nodes of Ranvier**) exist between adjacent glial cells at which the neuron membrane is exposed.

Action potentials move across this sheath by jumping from node to node (**saltatory conduction**). This saltatory conduction is much faster and involves less of the membrane surface than in unmyelinated neurons. Since less membrane surface is depolarized, less ATP is needed to restore the ion distribution of the resting potential. Thus, white matter conduction is faster and more efficient than that of gray matter.

REVIEW QUESTIONS:

1. Explain the effect of hyper- and hypocalcemia on neuron excitability.
2. Why would recovery from brain trauma be less likely than that from peripheral nerve injury?

Synapses and Neural Pathways

Organizing the billions of neurons of the human nervous system into functional units, such as pathways, circuits and reflex arcs, requires numerous connections among component neurons. These connections are accomplished without actual contact between participating neurons. Instead, neurons communicate across gaps (**synaptic clefts**) by means of the secretion and diffusion of chemical “**neurotransmitters**” characteristic of **chemical synapses**. Chemical synapses connect the axon of one neuron either to a neurite of another neuron or to a specialized area of the surface membrane of a muscle or gland cell. Since only the axon ends of neurons possess neurotransmitter vesicles, and postsynaptic cells possess transmitter chemical receptors, conduction across a synapse can occur in only “one-way,” from axon to postsynaptic cell and never in reverse. Consequently, pathways containing synapses transmit only in one direction making it impossible for a single pathway to serve both sensory and motor functions. Thus, a “mixed” nerve must have numerous pathways going in both directions.

A variety of neurotransmitter chemicals exist allowing for different effects across synapses. **Acetylcholine (ACh)** is the most common transmitter chemical, and it can have different effects on postsynaptic cells. If a cell possesses “**nicotinic**” receptors, it will be excited by acetylcholine. But, if the receptor is “**muscarinic**” the effect is inhibition. Once synaptic activation is completed, the neurotransmitter must be removed from the synapse allowing recovery of the postsynaptic cell. This is accomplished in a variety of ways. Sometimes neurons or neuroglial cells in the vicinity of the synapse take in the neurotransmitter chemical and destroy or recycle it. Acetylcholine is destroyed by the enzyme **cholinesterase**, which occurs naturally in these synaptic clefts. **Norepinephrine**, which also occurs in adrenalin, is another neurotransmitter chemical that is generally excitatory in nature and commonly occurs with the sympathetic division of the autonomic nervous system. Finally, **gamma amino butyric acid (GABA)** is an unusual neurotransmitter that is generally inhibitory at synapses where it occurs. Although there are over 50 different neurotransmitter chemicals, these three will suffice to demonstrate the general activities that occur across synapses.

REVIEW QUESTION:

1. Of the three neurotransmitters discussed, which combinations of neurotransmitter and receptor would produce EPSP's and which would yield IPSP's? Why?

Reflex Arcs

The reflex arc is a more complex example of a neuronal pathway that represents the basic functional unit of the human nervous system.

Examine the reflex arc diagram on page 941 as you work through this discussion.

It is the basic functional unit because it is capable of the three basic nervous system functions, sensory and motor transmission with CNS integration. The arc has a “**sensory arm**” with sensory neurons centered in the dorsal root ganglion of spinal nerves. There is also a “**motor arm**” with neuron cell bodies in the anterior horns of the gray matter of the spinal cord. These sensory and motor arms are **integrated** by means of an interneuron within the gray matter of the cord. A reflex arc can operate independently so that anytime a receptor is stimulated, an effector response will occur. Additionally, the arc can be controlled by other areas of the nervous system. For example, connecting neurons from a brain region can descend the cord to the interneuron to modulate the arc's activity.

In addition to this simple spinal, or somatic, reflex arc, additional arcs exist for the sympathetic and parasympathetic divisions of the autonomic nervous system. When these various reflex arcs are integrated with CNS control, the multitude of nervous system activities are explainable at a primitive level, which is adequate for this course.

Notice that these reflex arcs are associated with spinal and cranial peripheral nerves as they connect to and are integrated within the brain stem and spinal cord. No higher brain involvement has been implicated at this point. Although these reflexes can operate without brain involvement, regulatory control over these reflexes does require brain intervention.

REVIEW QUESTION:

1. Describe the anatomy and physiology of the “integration” that occurs within a reflex arc.

Basic Brain Anatomy

Understanding how the brain interacts with peripheral nerve reflexes of the brain stem and spinal cord requires a basic knowledge of major brain regions and functions. Most importantly, the distinction must be made between voluntary, conscious, brain control and involuntary, subconscious, brain involvement. Recall that the **cerebral cortex** (the outer thin layer of gray matter of the cerebral hemispheres) is the conscious

area of the brain. Thus, brain regions below the cortex are generally subconscious and without voluntary control.

Recall that the **cerebrum** is divided into two highly convoluted hemispheres by the **longitudinal fissure** and each hemisphere is further divided into lobes named for the cranial bones that overlie them (pages 946-951 for review). Pay particular attention to one of the convolution valleys, the **central sulcus** that separates the frontal and parietal lobes. The **precentral gyrus**, in the frontal lobe just anterior to the central sulcus, is the **primary voluntary motor** integration area of the human cerebrum. Any conscious, voluntary movement must originate in this area. On the posterior side of the central sulcus is the **postcentral gyrus**, with the **somatic sensory** integration area. Each hemisphere has its own set of pre- and postcentral gyri. These somatic senses include pain, pressure, touch, and temperature that are detected by receptors distributed unevenly across the body surface. Special senses, such as vision and hearing, are not integrated here. In fact, the special senses have their own individually dedicated brain regions for integration.

More importantly, cerebral interaction with body regions is both reversed and inverted with regard to the pre- and postcentral gyri. It is reversed in that the left hemisphere controls the right side of the body and vice versa. The inverted aspect describes how lower body regions are integrated in the uppermost aspects of the gyri and vice versa. Thus, damage to the lower left precentral gyrus would cause loss of motor ability on the right side of the face or head. **You might want to check in your textbook (page 949) for an illustration of both sensory and motor homunculi as well as the basic functions of each of the cerebral lobes.**

REVIEW QUESTIONS:

1. Discuss the importance of the pre- and postcentral gyri in normal neurophysiology.
2. Which cerebral lobe would be involved in post-traumatic impaired vision? Why is vision one of the “special senses”?

Below the cerebral hemispheres are areas of the brain often collectively referred to as the “**brainstem**.” Activities integrated in the brainstem are involuntary and below the realm of consciousness. The first brainstem region is the **diencephalon** containing a number of important areas. The **thalami**, which direct information to and from the various cord tracts and brain regions, occur there. The floor of this brain region, the **hypothalamus**, contains the centers for thirst, sleep, temperature regulation, and osmoregulation via secretion of ADH from the related posterior pituitary. Sympathetic nerve tracts supplying the iris of the eye originate in the hypothalamus. When active, radial muscles of the iris are stimulated to contract causing the pupil to dilate. The midbrain portion (**mesencephalon**) of the brainstem shows the cerebral aqueduct for CSF passage between the third and fourth ventricles. The midbrain is also important because of its involvement in eye pupil control. Cranial nerve III (**oculomotor**) originates from

paired nuclei in the midbrain and provides parasympathetic innervation of the iris. When active, circular muscles of the iris contract causing pupils to constrict. Further back lies the **cerebellum** and **pons** that comprise the **metencephalon** along with the 4th ventricle. The cerebellum is responsible for the coordination of voluntary motor activity while the pons is a major transmission area consisting of numerous tracts carrying information up and down through the brainstem. The last brainstem region is the **myelencephalon**, or the **medulla oblongata**, containing the integration centers for vital reflexes such as breathing and vasomotor activity controlling blood vessel diameter and heart rate.

REVIEW QUESTIONS:

1. Knowing that alcohol blocks ADH release, what would be the anticipated effects of excess alcohol consumption?
2. Why would lower brainstem injuries be considered life threatening?

DISCUSSION QUESTIONS: (Post answers to the “Patho Discussion Group)

1. Given that the polio virus destroys anterior horn gray matter, what signs and symptoms might a polio victim exhibit?
2. Where in the brain might a stroke have occurred if the patient shows right side weakness with alterations in personality traits?