Medical Neuroscience | Tutorial Notes

Visceral Motor System—Functional/Anatomical Divisions

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

NCC1. The brain is the body's most complex organ.

NCC3. Genetically determined circuits are the foundation of the nervous system.

LEARNING OBJECTIVES

After study of the assigned learning materials, the student will:

A. Describe the anatomical organization of the sympathetic and parasympathetic divisions of the visceral motor system, including the sources of preganglionic innervation and the location of postganglionic visceral motor neurons.

B. Characterize the major functions of the sympathetic and parasympathetic divisions of the visceral motor system.

C. Identify and discuss the neural centers in the CNS that regulate the outflow of activity in the preganglionic fibers of the visceral motor system.

TUTORIAL OUTLINE

I. Introduction
    A. maintains the internal state of the body (homeostasis) and promotes changes (allostasis) by regulating the activity of visceral organs, glands and blood vessels
    B. divisions
        1. three peripheral structural/functional divisions
            a. **sympathetic** & **parasympathetic** divisions
                i. two-neuron chains that connect CNS to peripheral effectors
                ii. sympathetic division organizes involuntary responses that prepare the body for exertion (e.g., “fight or flight”)
                iii. parasympathetic division organizes involuntary activities of the viscera in a state of relaxation, when there is a need to replenish bodily reserves (e.g., “rest and digest” conditions)
            b. **enteric** nervous system

[1] Visit **BrainFacts.org** for *Neuroscience Core Concepts* (©2012 Society for Neuroscience) that offer fundamental principles about the brain and nervous system, the most complex living structure known in the universe.

a. largely autonomous nervous system located in the walls of the gastrointestinal tract that functions to regulate motility along the tract, secretion, and absorption across the gut epithelium

b. involves a large number of neurons that coordinate the activity of two neural networks in the wall of the gut

i. myenteric plexus: regulates the musculature of the gut

ii. submucus plexus: monitors chemical composition of the lumen and regulates glandular secretions

c. capable of independent patterns of neuromuscular activity, but is influenced by activities of sympathetic and parasympathetic divisions, as well as circulating hormones

II. Visceral Motor Efferents & Afferents

A. efferent limb (review relevant notes from PT602)

1. sympathetic division (see **Figure 21.1**[2])

a. **preganglionic neurons** are arranged in the **intermediolateral cell column** of the thoracic/upper lumbar spinal cord (**Figure 21.2**)

(i) most preganglionic neurons (which may be considered as 'premotor' interneurons) project only a very short distance to the **paravertebral ganglia** (or sympathetic chain ganglia)

(ii) some preganglionic neurons project a longer distance to reach **prevertebral sympathetic ganglia** (e.g., superior and inferior mesenteric ganglia, pelvic plexus)

(iii) in addition, some preganglionic axons innervate the adrenal medulla, which is considered a special sympathetic ganglion modified for endocrine function (release of catecholamines)

(iv) use **acetylcholine**, which binds to nicotinic (ionotropic) and muscarinic (metabotropic) receptors on ganglionic neurons

b. **postganglionic neurons** in the paravertebral and prevertebral ganglia directly innervate the smooth muscle of blood vessels and glands in the viscera, reproductive organs and skin, and the cardiac muscle and pacemaker nodes of the heart

(i) postganglionic axons travel with virtually every peripheral nerve of the body to reach their widely distributed targets

(ii) most use **norepinephrine**, which binds to alpha and beta adrenergic (metabotropic) receptors

c. functional considerations

(i) generally allow body to make maximum use of its resources in stressful or otherwise threatening circumstances

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[2] Figure references to Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc., 2012. [click here]

(ii) there is always some tonic activity in postganglionic sympathetic fibers

(iii) sympathetic control of effector systems can be graded

(iv) many sympathetic reflexes operate independently

2. parasympathetic division (see **Figure 21.1**)

a. **preganglionic neurons** are restricted to certain cranial nerve nuclei and the intermediate gray matter of the sacral cord (**Figure 21.3**)

(i) cranial nerve nuclei: **Edinger-Westfall nucleus** (midbrain), **superior** & **inferior salivatory nuclei** (pons & medulla), and **nucleus ambiguus** & **dorsal motor nucleus of vagus** (medulla)

(ii) sacral preganglionic innervation arises from neurons in the lateral portion of the intermediate gray matter

(iii) preganglionic axons travel a long distance to innervate **parasympathetic ganglia** in or very close to end organs

(iv) use **acetylcholine** (nicotinic & muscarinic effects)

b. **postganglionic neurons** in the parasympathetic ganglia directly innervate the smooth muscle of the eyes, viscera and reproductive organs, cardiac muscle and the glands of the head

(i) since neurons are already in or near end targets, their axons travel a very short distance to innervate peripheral tissues

(ii) use **acetylcholine**

c. functional considerations

(i) generally opposed to sympathetic activity: increases reserves when conditions allow for "rest and digest" (see **Figure 21.1**)

(ii) parasympathetic control of effector systems can be graded (not all-or-none) and many reflexes operate independently

B. afferent limb (see **Figure 21.5**)

1. sensory receptors

a. mechanoreceptors: pressure receptors in ventricles, atria and carotid arteries (baroreceptors), and lungs; and stretch receptors that respond to distension of the veins, bladder or gastrointestinal tract

b. chemoreceptors: sensitive to chemical concentrations in the blood; specialized cells in the aortic and carotid bodies (oxygen), medulla (pH, carbon dioxide), and hypothalamus (blood glucose, certain ions)

c. nociceptors: sensitive to noxious stretch, ischemia, irritating chemicals in the visceral walls and walls of arteries

d. thermoreceptors: sensitive to changes in internal (hypothalamus) or external temperature (skin)

2. afferent pathways

    a. afferent axons enter the CNS via two routes (roots)

        (i) dorsal roots of the spinal cord

        - axons terminate in intermediate gray matter
        - target efferent neurons involved in segmental reflexes
        - other targets are second order neurons that project to brainstem and thalamus as part of the anterolateral system; one important brainstem target is the **nucleus of the solitary tract** (see **Figure 21.5 & 21.6**)
        - some second order neurons also receive input from superficial (e.g., cutaneous) nociceptors; thus, referred pain is common with activation of visceral sensory nociceptors (see **Box 10B**)
        - other nociceptive second order neurons project through the dorsal columns to the dorsal column nuclei (see **Box 10C**); therefore, dorsal column nuclei may also be a site for the genesis of referred pain

        (ii) cranial nerve roots

        - sensory axons enter brainstem via cranial nerves **IX** (glossopharyngeal) and **X** (vagus)
        - project to caudal half of the nucleus of the solitary tract, which integrates visceral sensorimotor function
        - nucleus of the solitary tract sends axons to visceral motor control centers in the reticular formation, periaqueductal gray, and higher integrative centers in the hypothalamus and limbic forebrain (via the parabrachial nucleus and thalamus)

3. thus, visceral sensory inputs drive local reflexes that govern ongoing visceral function and provide signals to a higher "central autonomic network" (see **Figure 21.5 & 21.7**)

4. several structures in the forebrain and have an important role in the regulation of homeostasis/allostasis; these include the **amygdala**, orbital and medial parts of the **prefrontal cortex**, **insular cortex**, and the **hypothalamus** (see **Figure 21.5 & 21.7**); together they constitute a *central autonomic network*

STUDY QUESTION

Suppose you are like me and you have great difficulty controlling your “nerves” when about to perform music (or dance, theatre, etc., whatever performance art form appeals to you). At such moments, what do you think is happening in your “central autonomic network”?

A. Activity is dramatically increasing in the neural networks that promote parasympathetic visceral motor outflow.
B. Activity is dramatically increasing in the neural networks that promote sympathetic visceral motor outflow.
C. Activity is dramatically increasing in neural networks that promote enteric secretions and motility.