Medical Neuroscience | Tutorial Notes

Cranial and Spinal Nerves

MAP TO NEUROSCIENCE CORE CONCEPTS[1]

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

LEARNING OBJECTIVES

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

1. Discuss the functions of the cranial nerves in terms of the sensory and motor signals conveyed by each nerve.
2. Discuss the organization and composition of a typical spinal nerve.

NARRATIVE

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Introduction

After working through this tutorial, you should be able to discuss the composition and function of the cranial nerves, and you should be able to discuss the general organization of spinal nerves. In the next tutorial, you will learn how the cranial nerves relate to gray matter structures in the brainstem that grew out the axons in the cranial nerves (motor axons) or receive synaptic input from ganglionic neurons associated with the nerves (sensory axons). But before proceeding, you should make sure that you understand the basic layout of sensory and motor neurons in the brainstem and spinal cord.

The central nervous system interacts with the outside world through primary sensory neurons, which convey information from the body or its environment into the brain and spinal cord, and motor neurons, which activate striated muscles and modulate the activity of cardiac and smooth muscles and glands (see **Fig. 1** below and/or **Figure A1A**[2]). The cell bodies of primary sensory neurons lie in the **dorsal root ganglia** or the **cranial nerve ganglia**. Each neuron gives rise to a peripheral process, which receives information either directly or through association with receptors, and a central process, which enters the central nervous system and forms synapses with second order neurons. The cell bodies of somatic motor neurons lie in clusters or **nuclei** within the central nervous system and give rise to axons that innervate striated muscles in the body or head. You will also be introduced to other motor neurons that are part of the visceral motor system (a.k.a., autonomic nervous system) and are indirectly responsible

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

for governing cardiac muscle, smooth muscle or glands. By the conclusion of this and the next tutorial, you will learn how to locate:

1. nuclei that are the destination of all primary somatic sensory, visceral sensory, and special sensory *input* into the CNS (i.e., the location of all of the second-order neuronal cell bodies that receive the primary sensory input), except for olfaction and vision. The olfactory nerve and the optic nerve are not included in this discussion; for several reasons they are atypical.
2. nuclei that are the origin of all of the somatic and visceral motor *output* of the CNS (i.e., the location of all of the alpha motor neurons and preganglionic visceral motor neurons).

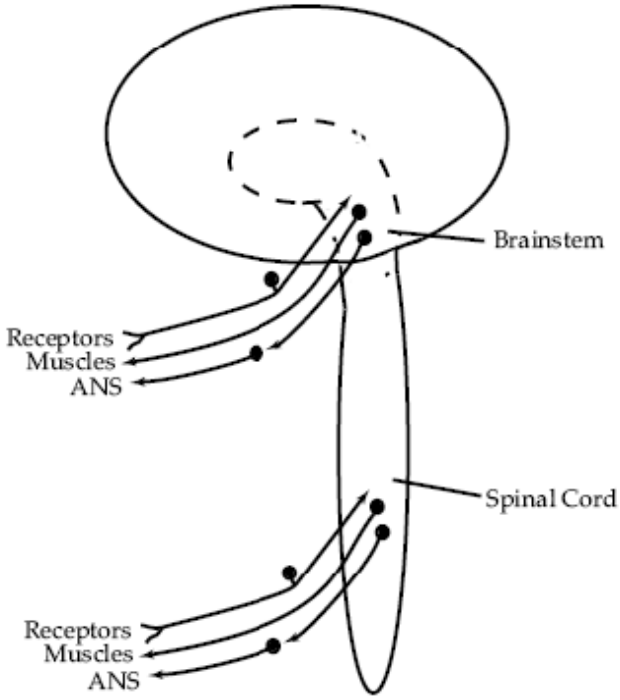

Fig. 1. Both the spinal cord and brainstem receive input from primary sensory neurons; the cell bodies of these neurons lie in sensory ganglia. In addition, both the spinal cord and brainstem give rise to motor output to striated muscles and to the autonomic ganglia (*ANS*, autonomic nervous system; synonymous with visceral motor system). (Illustration by N.B. Cant)

From the viewpoint of clinical practice, the most important general principle of organization in the central nervous system is that each ***CNS function*** (e.g., perception of sensory stimuli, control of motor behavior) ***involves groups of neurons—interconnected through synapses—that are spatially distributed throughout several CNS subdivisions***. Groups of neurons that together subserve a particular function are called a 'system'; for example, there are the visual, motor, and somatic sensory systems. The structures containing the neurons and axons of a particular system are collectively referred to as a 'pathway'. (The term 'system' has a functional connotation, whereas the term 'pathway' refers to the structures involved.) We will study several important sensory and motor pathways in detail in future tutorials.

Simple tests of cranial nerve function provide clues for localization of neurological injury and disease

One means for reinforcing your understanding of the functional significance of the cranial nerves is to actually test their functions in yourself and a willing friend or family member. Review **Table A2** below (from Purves et al., *Neuroscience, 5th Ed.*, Sinauer Assoc., Inc.), which lists the cranial nerve nuclei from which the sensory and motor components of each nerve arise. Then, consider the means by which you would assess the functional integrity of the cranial nerves. Actually, there are a number of tests of cranial nerve function that can be done with very simple materials. These tests provide considerable information about the presence or absence of normal function in the brainstem and the nerves

themselves. Some of these are described on these next few pages to give you an idea of the types of tests that can be used and why a foundational understanding of functional neuroanatomy is critical for clinical practice[3].

TABLE A2 The Cranial Nerves and Their Primary Functions *(continued)*

CRANIAL NERVE	LOCATION OF CELLS WHOSE AXONS FORM THE NERVE	CLINICAL TEST OF FUNCTION
I	Nasal epithelium	Test sense of smell with standard odor
II	Retina	Assess acuity, pupillary light reflex, and integrity of visual field
III	Oculomotor nucleus in midbrain; Edinger-Westphal nucleus in midbrain	Test eye movements (patient can't look up, down, or medially if nerve involved); look for ptosis and pupillary dilation; assess pupillary light reflex
IV	Trochlear nucleus in midbrain	Can't look downward when eye adducted
V	Trigeminal motor nucleus in pons; trigeminal sensory ganglion (the gasserian ganglion)	Test sensation on face; test ability to clamp jaw tightly; palpate masseter muscles and temporal muscle
VI	Abducens nucleus in pons	Can't look laterally
VII	Facial motor nucleus; superior salivatory nuclei in pons; geniculate ganglion	Test facial expression plus taste on anterior tongue
VIII	Spiral ganglion; vestibular (Scarpa's) ganglion	Test audition with tuning fork; test vestibular function by assessing gaze fixation during head rotation and balance during purturbation; perform caloric test
IX	Nucleus ambiguus; inferior salivatory otic ganglion; glossopharyngeal ganglia	Test swallowing; pharyngeal gag reflex
X	Dorsal motor nucleus of vagus; vagal nerve ganglion nucleus ambiguus	Test above plus hoarseness; observe uvula and posterior pharynx at rest and during phonation
XI	Spinal accessory nucleus	Test sternocleidomastoid and trapezius muscles
XII	Hypoglossal nucleus of medulla	Test deviation of tongue during protrusion (points to side of lesion) and symmetry of force when pushing tongue against cheek

***NEUROSCIENCE 5e*, Table A2 (Part 2)**

Cranial nerves III, IV, and VI

These nerves are tested as a unit, since all supply muscles for eye movement. The oculomotor nerve also supplies the levator muscle that elevates the lids and the smooth muscles that constrict the pupils. Range of ocular movement is checked by asking the patient to follow the movements of the examiner's fingers as they are moved in all directions of gaze. With involvement of the oculomotor nerve, the patient will not be able to look up, down or medially with the affected eye. There will also be dilatation of the pupil and droopiness (ptosis) or closure of the lid on the affected side. If the trochlear nerve is affected, the patient will be unable to look downward when the eye is adducted. If the abducens nerve is affected, the patient will not be able to look laterally with the involved eye. In any of these cases, the patient may complain of double vision. (It is important to remember that either the nerves themselves or their nuclei in the midbrain and pons may be involved.) Examination of the pupillary reflexes involving nerves II and III will be explored in a later course session.

Cranial nerve V

The examiner first checks for the presence of the several types of sensation and then determines whether both sides of the face are equally sensitive. Failure to feel wisps of cotton touching the forehead, cheeks and jaw indicates anesthesia to light touch. Differences in response on the two sides of the face indicate increased or decreased sensitivity to light touch. The same procedure is followed in

[3] For more on cranial nerve exams, visit **neuroexam.com** [click here] and explore videos that show tests of cranial nerve function, with accompanying explanation by Dr. Hal Blumfeld, MD, PhD (author of *Neuroanatomy through Clinical Cases*; Sinauer Assoc., Inc.).

testing for degree of sensitivity to pinpricks and to warm and cold objects.

The masseter and temporalis muscles (muscles of mastication innervated by the motor component of the fifth nerve) are examined by palpating them when the jaws are clamped tightly together. The examiner should note whether there is deviation of the jaw when the mouth is opened.

Cranial nerve VII

The patient is asked to imitate the examiner as he or she looks at the ceiling, wrinkles the forehead, frowns, smiles, shows teeth, and raises the eyebrows. Any asymmetry of the face is noted. To test the strength of the eyelid muscles, the patient is asked to keep his or her eyes closed while the examiner attempts to open them. The sensory portion of the facial nerve can be tested by having the patient identify the taste of sugar or salt placed on the anterior part of the tongue on each side.

Cranial nerve VIII

The eighth nerve is divided into two parts, the cochlear or auditory nerve and the vestibular nerve. Special equipment is required to examine the vestibular nerve and it is not tested routinely. (If the patient gives a history of vertigo or disturbed balance, the possibility of vestibular dysfunction should be considered and the patient can be given a caloric test, which is described in Purves et al., *Neuroscience 5th Ed.*, Chapter 14, Box 14C.) Preliminary tests of hearing can be done with a tuning fork, but detailed auditory testing is done by an audiologist.

Cranial nerves IX and X

The pharyngeal gag reflex is tested by touching each side of the pharynx with a tongue depressor or applicator stick. The palatal reflex is tested by stroking each side of the mucous membrane of the uvula. The side touched should rise. Normal function of the vagus nerve is revealed by the patient's ability to swallow and to speak clearly without hoarseness, by symmetrical movements of the vocal cords, and by symmetrical movements of the soft palate when he or she says "Ahhh."

Cranial nerve XI

The examiner 1) palpates and notes the strength of the trapezius muscle while the shoulders are shrugged against resistance, and 2) palpates and tests the sternocleidomastoid muscle for strength.

Cranial nerve XII

Any lateral deviation of the tongue when it is protruded is noted. The examiner also looks for atrophy or tremor of the tongue. The strength of the tongue is tested by asking the patient to protrude it and to move it from side to side against a tongue depressor.

The spinal cord

The spinal cord extends caudally from the brainstem, running from the medullary-spinal junction at about the level of the first cervical vertebra to about the level of the twelfth thoracic vertebra. The vertebral column (and the spinal cord within it) is divided into **cervical**, **thoracic**, **lumbar**, **sacral**, and **coccygeal** regions. The peripheral nerves (called the spinal or segmental nerves) that innervate much of the body arise from the spinal cord's 31 pairs of spinal nerves. On each side of the midline, the cervical region of the cord gives rise to eight cervical nerves (C1–C8), the thoracic region to twelve thoracic nerves (T1–T12), the lumbar region to five lumbar nerves (L1–L5), the sacral region to five sacral nerves

(S1–S5), and the coccygeal region to one coccygeal nerve. The segmental spinal nerves leave the vertebral column through the intervertebral foramina that lie adjacent to the respectively numbered vertebral body. Sensory information carried by the afferent axons of the spinal nerves enters the cord via the dorsal roots, and motor commands carried by the efferent axons leave the cord via the ventral roots. Once the dorsal and ventral roots join, sensory and motor axons (with some exceptions) travel together in the segmental spinal nerves.

Two regions of the spinal cord are enlarged to accommodate the greater number of nerve cells and connections needed to process information related to the upper and lower limbs. The spinal cord expansion that corresponds to the arms is called the cervical enlargement and includes spinal segments C3–T1; the expansion that corresponds to the legs is called the lumbar enlargement and includes spinal segments L1–S2. Because the spinal cord is considerably shorter than the vertebral column, lumbar and sacral nerves run for some distance in the vertebral canal before emerging, thus forming a collection of nerve roots known as the *cauda equina*. This region is the target for an important clinical procedure called a "lumbar puncture" that allows for the collection of cerebrospinal fluid by placing a needle into the space surrounding these nerves to withdraw fluid for analysis. In addition, local anesthetics can be safely introduced to produce spinal anesthesia; at this level, the risk of damage to the spinal cord from a poorly placed needle is minimized.

STUDY QUESTION

Q1. Identify the CORRECT pairing of **cranial nerve** to function.

A. hypoglossal nerve / movement of facial muscles for expression
B. trigeminal nerve / somatic sensation from face
C. optic nerve / eye movements
D. abducens nerve / medial eye movement (eye adduction)
E. spinal accessory nerve / vocal articulation

Q2. Which of the following structures associated with the spinal cord contains the cell bodies of **primary somatic sensory neurons**?

A. dorsal column
B. ventral horn
C. dorsal horn
D. dorsal root ganglia
E. sympathetic chain ganglia