Normal CNS, Special Senses, Head and Neck

TOPIC: INTRODUCTION

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LECTURE: Monday, 09 March 2009, 8:30a.m. - 10:00a.m.

READING: Neuroanatomy, Text and Atlas (J. H. Martin), 3rd Edition
Chapter 1, 'Introduction to the Central Nervous System.'

OBJECTIVES AND GOALS:
From the reading and lecture the students should know:

1) key terms that represent the fundamental nomenclature for describing the anatomical and functional organization of the central nervous system
2) the cellular components of the central nervous system - neurons and glia
3) neurons are polarized cells that communicate with each other at specialized cellular junctions known as synapses
4) the central nervous system can be grossly divided into six component parts and the cerebral cortex is divided into lobes
5) the three main anatomical planes used in viewing the internal anatomy of the central nervous system
6) the nervous system is highly vascularized and anatomy of the vascular supply will be touched upon in each lecture

Sample Exam Question:
A nucleus in the central nervous system is defined as:

A) a bundle of axons
B) an anatomically discrete collection of neuronal cell bodies
C) neuronal structure specialized for receiving synapses
D) the DNA-containing subcellular structure found within every neuron

Answer: B

I. Introduction:

This lecture will provide a broad overview of the organization of the CNS Head & Neck sequence – lectures, laboratories, quizzes and exams.

With respect to nervous system, the specific goal of this lecture is to introduce and discuss key terms and concepts regarding the functional anatomy of the central nervous system. This will orient you to the approach we will take in describing the functional anatomy of the central nervous system and provide you with sufficient background to allow you to understand the terminology and concepts that will be used in this week's lectures and beyond.

In this sequence, you will simultaneously learn six aspects of the central nervous system.

1. regional anatomy (spinal cord, brainstem, etc.)
2. surface (gross) anatomy
3. internal anatomy
4. names and locations of nuclei and tracts and the pathways they form
5. functions of the sensory, motor and autonomic systems in the CNS
6. blood supply to the CNS

In addition, you will receive lectures on the cell biology of neurons, nerve development and regeneration and neurotransmitters. Add to this gross anatomy, histology and two lectures on pharmacokinetics. You will be kept busy during the next three weeks!

II. Anatomical planes and major axes of the central nervous system

A) There are three principal planes that are used for slicing and viewing the brain: **horizontal, frontal (or coronal) and sagittal.**

B) There are three principal axes along which the internal anatomy of the nervous system is organized and structures are named. They are:

1) **rostral-caudal** axis
2) **dorsal-ventral** axis
3) **medial-lateral** axis

For the human central nervous system, the rostral-caudal axis contains a significant bend (or **flexure**), which appears during development. As a result, the dorsal-ventral axis changes as one moves from the cerebral hemispheres through the brainstem and spinal cord. This creates a sometimes-confusing terminology.

C) We will use several terms to indicate the relative positions of structures. Relative position also serves as the basis for many named structures, e.g., <u>lateral</u> corticospinal tract, <u>medial</u> geniculate nucleus.

Dorsal - above or superior
Ventral -below or inferior
Rostral -toward the front
Caudal - toward the back
Medial - toward the midline
Lateral - away from the midline

Ipsilateral - on the same side
Contralateral - on the opposite side

III. The central nervous system contains two principal cell types: neurons and glia

1) neurons communicate with other neurons at a specialized junctions known as a **synapse**.

2) **neurotransmitter** is released at a synapse by a **pre-synaptic** process. These molecules bind to receptors on **post-synaptic** processes and alter the electrical activity of the post-synaptic neuron. This change in electrical activity is signaled at a synapse to the next neuron, etc. Neurotransmitters can be **inhibit** or **excite** electrical activity in a post-synaptic neuron.

3) **neurons** are polarized cells that have **dendrites**, which receive synaptic contacts and **axons**, which relay electrical signals and synapse on target cells and structures within or outside the central nervous system. Neurons have wildly varying sizes and shapes and, corresponding, a variety of descriptive names.

4) **glia** provide structural and metabolic support to neurons and are essential for communication between neurons. Glia are 10-50 times more numerous than neurons. There are various types of glia, depending upon their structure and function.

A) A discrete collection of neuronal cell bodies outside the central nervous system is known as a **ganglion**.

B) A discrete collection of neuronal cell bodies within the central nervous system is known as a **nucleus**.

C) A discrete bundle of axons outside the central nervous system is known as a **nerve**.

D) A discrete bundle of axons within the central nervous system is known as a **tract**. (!!axons are also commonly referred to as fibers!!)

1) Tracts within the central nervous system are also sometimes called a **lemniscus** or **fasciculus**. You will be introduced to additional names, as well.

2) Axons that form a tract typically:

- have cell bodies in a common nucleus
- synapse onto a common target (or set of targets)
- perform a common function, e.g., somatic sensation, voluntary movement

3) Tracts are often named based on the site of origin and termination of their axons, e.g.,:

• spinothalamic tract – from the spinal cord to the thalamus
• corticospinal tract – from the cerebral cortex to the spinal cord

4) The names of tracts often identify their relative location within the CNS white matter, e.g.,:

- lateral spinothalamic tract – lateral in the spinal cord
- medial lemniscus – near the midline

5) Tracts can carry information either up or down the **neuraxis**

- ascending tract (spinothalamic tract) - sensory function
- descending tract (corticospinal tract) - motor function

6) Sensory and motor pathways are generally organized in parallel, e.g., pain and temperature vs. fine discrimination

The size, shape and location of nuclei and tracts define the internal anatomy of the CNS. The functions subserved by these structures determine the functional anatomy of the CNS.

IV. Various staining methods can reveal individual neurons, nuclei or tracts.

A) Golgi stains completely label individual neurons, but only a tiny fraction of the total

B) Stains that bind to nucleic acids only label all neurons, but only components within cell bodies

C) Stains that bind to myelin (a lipid in oligodendrocytes that wrap axons) label white matter (but myelin stains turn white matter black!!)

V. Schematic representation of the functional organization of the CNS:

A) The nervous system of all animals performs 3 fundamental biological functions:

1) Monitor and regulate the internal environment
2) Monitor the external environment
3) Initiate behaviors based on information from both the internal and external environments

B) You are generally not conscious of the vast majority of the functions performed by the central nervous system

C) The central nervous system can broadly be divided into **sensory** and **motor** systems.

1) sensory systems: transduction, transmission, perception

2) motor systems: mentation, transmission, behavior

VI. Regional anatomy of the central nervous system:

A) The central nervous system can be divided into 6 component parts.

From inferior to superior, they are:

1) **spinal cord**
2) **medulla** (myelencephalon)
3) **pons** (metencephalon)
4) **midbrain** (mesencephalon)
5) **thalamus** (diencephalon)
6) **cerebral hemispheres** (telencephalon)

The medulla, pons and midbrain are known as the **brainstem**.

You may on occasion encounter the terms **hindbrain** and **forebrain**.

1) hindbrain - brainstem and spinal cord
2) forebrain - thalamus and cerebral hemispheres

VII. Examples pathways and relevant concepts

Nuclei and tracts that are synaptically linked are known as a **pathway**.

1) Pathways functionally link distant structures with one another

- the skin with the cerebral cortex
- the cerebral cortex with skeletal muscle

2) Most pathways consist of 2, 3 or more neurons

- 3 neuron sensory pathway consists of a:
  primary (first order) neuron, secondary (second order)
  neuron, tertiary (third order) neuron

3) Pathways can relay signals either up or down the neuraxis.

- ascending pathways – somaticsensory pathway
- descending pathways – voluntary motor pathway

4) Tracts form specific components of pathways

- lateral spinothalamic tract is a component of the ascending pain and temperature pathway

5) Names generally identify the function they subserve

- pain and temperature pathway, which subserves conscious awareness and localization of pain and thermal signals
- voluntary motor pathway, which subserves the ability to make volitional movements

Some additional terms relating to pathways and tracts

afferent axons – carry information into the CNS
efferent axons – carry information out of a structure
decussation – site where a tract crosses the midline

VIII. Sensory and Motor Pathways are topographically organized

1) Virtually every pathway in the central nervous system is organized in a point-to-point manner. For example, adjacent points on the skin are represented as adjacent points throughout the somaticsensory pathway. As a result, there is a coherent 'map' of the body surface within the pathway and in the corresponding sensory regions of the cerebral cortex. The same principle is true for other sensory and almost all motor pathways.

XI. The central nervous system is highly vascularized

X. The central nervous system is filled with and surrounded by cerebrospinal fluid

A) The internal, fluid-filled space is known as the ventricular system.

1) lateral ventricles
2) 3rd ventricle

3) 4th ventricle

B) The **subarachnoid space** on the surface of the brain is filled with cerebrospinal fluid.