BIO 004 · HUMAN ANATOMY · SOLANO COMMUNITY COLLEGE

Week 8 Course Notes.

Nervous System · Spinal Cord, PNS, Integration

BIO 004 · WEEK 8

Contents

Functional Organization and Nervous Tissue

Functional Organization and Nervous Tissue

A reference for the nervous tissue video and lab. This page covers the organization of the nervous system and its divisions, the three functions, the structure of a neuron, the synapse, the classification of neurons, the neuroglia, myelination, and the collections of nervous tissue. The focus is on the structures and the job each one does.

BY THE END

1. Outline the organization of the nervous system and its divisions.
2. Identify the parts of a neuron and classify neurons by shape and by function.
3. Name the neuroglia and describe myelination and the collections of nervous tissue.

The Nervous System, an Overview

The nervous system gives the body the ability to feel, think, and act. It has two main divisions: the central nervous system and the peripheral nervous system.

Nervous system	the body's fast control system; it lets us feel, think, and act
Central nervous system (CNS)	the brain and the spinal cord; it processes information and issues commands
Brain	the CNS organ in the cranial cavity, with about 85 billion neurons
Spinal cord	the CNS cord in the vertebral canal that links the brain to the body
Peripheral nervous system (PNS)	every neural structure outside the brain and spinal cord
Nerves	bundles of axons in the PNS; 12 pairs of cranial nerves and 31 pairs of spinal nerves
Ganglia	small masses of neuron cell bodies located outside the CNS
Sensory receptors	structures that monitor changes inside and outside the body

Divisions of the Peripheral Nervous System

The motor side of the peripheral nervous system is split by the kind of effector it controls. The somatic system runs skeletal muscle; the autonomic system runs the viscera; the enteric system runs the gut.

Somatic nervous system (SNS)	the voluntary division; its motor neurons carry commands from the CNS to skeletal muscle
Autonomic nervous system (ANS)	the involuntary division; its motor neurons carry commands to smooth muscle, cardiac muscle, and glands
Sympathetic division	the ANS division for fight or flight, supporting exercise and emergencies
Parasympathetic division	the ANS division for rest and digest, supporting routine activities
Enteric nervous system (ENS)	the brain of the gut, about one million neurons in the wall of the GI tract that can operate on their own

The Three Functions of the Nervous System

Whatever the task, the nervous system handles it in the same three steps. A stimulus comes in, the information is processed, and a response goes out.

1. **Sensory function** sensory receptors detect a change inside or outside the body and send the input toward the CNS
2. **Integrative function** the CNS analyzes the sensory input, stores it, and decides on a response
3. **Motor function** the CNS sends commands out to the effectors, the muscles and glands, which carry out the response

The Structure of a Neuron

A neuron is the signaling cell of the nervous system. It is excitable, it can carry an impulse, and it cannot divide. Every neuron has three basic parts.

Neuron	the excitable cell that receives, conducts, and transmits nerve impulses; neurons cannot divide
Cell body	the soma or perikaryon; it holds the nucleus and cytoplasm and is the metabolic center of the neuron
Dendrites	the branched, tree-like processes that receive incoming signals
Axon	the single long process that carries the nerve impulse away toward other cells
Nissl bodies	clusters of rough ER and ribosomes in the cell body; the site of protein synthesis
Neurofibrils	cytoskeletal fibers that give the neuron its shape and support
Microtubules	cytoskeletal tubes that transport materials along the neuron
Axon hillock	the cone-shaped region where the cell body joins the axon
Axoplasm and axolemma	the cytoplasm of the axon and the plasma membrane of the axon
Axon terminals	the fine branches at the far end of the axon that contact the target cell
Lipofuscin	a harmless pigment that builds up in neurons with age

The Synapse

A synapse is the junction where a neuron passes its signal to another neuron, a muscle, or a gland. At a chemical synapse the signal crosses as a chemical message.

Synapse	the site where a neuron communicates with another neuron, a muscle cell, or a gland
Axodendritic synapse	an axon ending on a dendrite
Axosomatic synapse	an axon ending on a cell body
Axoaxonic synapse	an axon ending on another axon
Chemical synapse	a synapse with no direct contact; the signal crosses as neurotransmitter molecules
Synaptic cleft	the narrow gap between the two cells that the neurotransmitter diffuses across
Synaptic end bulbs	the swellings at the axon terminal that hold the signal-sending machinery
Synaptic vesicles	the tiny sacs inside the end bulbs that store neurotransmitter
Neurotransmitters	the chemical messengers that carry the signal across the cleft to the next cell

Classification of Neurons

Neurons are classified two ways: by their shape, which is the structural classification, and by the direction they carry signals, which is the functional classification.

Structural classification, by shape

Multipolar neuron	many dendrites and one axon; the most common type, found in the brain and cord and as motor neurons
Bipolar neuron	one dendrite and one axon; found in the retina, the inner ear, and the olfactory area
Unipolar neuron	a single fused process; the typical shape of a sensory neuron
Purkinje cells	a distinctive multipolar neuron found in the cerebellum
Pyramidal cells	a distinctive multipolar neuron found in the cerebral cortex

Functional classification, by direction

Sensory (afferent) neurons	carry sensory input toward the CNS; most are unipolar
Motor (efferent) neurons	carry motor commands away from the CNS; these are multipolar
Interneurons	also called association neurons; they connect sensory and motor neurons within the CNS and are multipolar

Neuroglia

Neuroglia, or glial cells, are the support cells of nervous tissue. They are smaller and far more numerous than neurons, and unlike neurons they can still divide.

Neuroglia — the support cells of nervous tissue; they nourish, support, and protect neurons and make up about half the volume of the CNS

Glia of the central nervous system

GLIAL CELL	ROLE
Astrocytes	star-shaped cells that give structural support, help form the blood-brain barrier, guide neuron growth, and maintain the chemical environment
Oligodendrocytes	cells that form the myelin sheaths of the CNS
Microglia	small phagocytic cells that remove debris and microbes
Ependymal cells	cells that line the ventricles and central canal and help produce and circulate cerebrospinal fluid

Glia of the peripheral nervous system

GLIAL CELL	ROLE
Schwann cells	cells that form the myelin sheath around PNS axons and aid axon regeneration
Satellite cells	cells that surround and support the cell bodies of PNS neurons in ganglia

Myelination

Myelin is a fatty wrapping around an axon. It insulates the axon and makes the nerve impulse travel much faster.

Myelin sheath — a multilayered covering of lipid and protein wrapped around an axon

Function of myelin — it insulates the axon and speeds up the nerve impulse

Nodes of Ranvier — the gaps in the myelin sheath, spaced along the axon

Saltatory conduction — the fast conduction in which the impulse jumps from node to node

The cell that builds the myelin differs between the PNS and the CNS, and that difference decides whether a damaged axon can regrow. Compare them.

FEATURE	PNS MYELINATION	CNS MYELINATION
Cell that makes the myelin	a Schwann cell, one per axon segment	an oligodendrocyte, one cell for up to 15 axons
Neurolemma	present; it is the outer layer of the Schwann cell	absent
Axon regeneration	possible; the neurolemma guides the axon as it regrows	very limited, because there is no neurolemma

Myelination increases from birth to maturity, so an infant's nerve conduction is slower than an adult's.

Collections of Nervous Tissue

The same kind of structure has a different name depending on whether it sits in the CNS or the PNS. Learn these as pairs.

STRUCTURE	IN THE CNS	IN THE PNS
A cluster of cell bodies	nucleus	ganglion
A bundle of axons	tract	nerve

White matter — nervous tissue made of myelinated axons

Gray matter — nervous tissue made of cell bodies, dendrites, unmyelinated axons, and neuroglia

In the spinal cord	white matter is on the outside, gray matter is on the inside	**In the brain**	gray matter is on the outside, white matter is on the inside

When the support cells fail

Neurons cannot divide, so a tumor of nervous tissue almost never comes from neurons. It comes from the **glia**, which can still divide. A **glioma** is a tumor of glial cells, and it is the most common type of brain tumor.

Myelin is as important as the axon it wraps. In **multiple sclerosis**, the immune system strips myelin from CNS axons and signals slow or fail. The presence of the **neurolemma** on Schwann cells, and its absence on oligodendrocytes, is why a cut nerve in the arm can regrow but a cut tract in the cord usually cannot.

The **cell body** is the neuron's life-support. Because the axon depends on the cell body for proteins, an injury that separates the two kills the axon beyond the cut. The location of a nerve injury, near or far from the cell body, helps predict whether the neuron survives.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the parts of a neuron and the direction a signal travels through them.
2. Compare neurons and neuroglia by what each one does.
3. Classify neurons by structure and by function, and give an example of each.
4. Explain what myelin is, which glia produce it, and what it does for a signal.

Gross Anatomy & Neuronal Integration

Gross Anatomy and Neuronal Integration

A reference for the neuronal integration video and lab. This page covers gray and white matter, the names for bundles of fibers and clusters of cell bodies, the reflex arc, types of reflexes, and neuronal pools.

BY THE END

1. Distinguish gray matter from white matter.
2. Define the terms tract, nerve, nucleus, and ganglion.
3. Name the five components of a reflex arc in order.
4. Compare the types of reflexes and describe a neuronal pool.

An Overview

This page covers two things: how nervous tissue is organized into the larger structures of the system, and how neurons work together in groups to process information.

Gross organization	how nervous tissue is arranged into the brain, cord, and nerves
Neuronal integration	how neurons work together in groups to receive, combine, and respond to information
Gray matter	regions made mostly of neuron cell bodies, dendrites, and synapses
White matter	regions made mostly of myelinated axons
Reflex	a fast, automatic, predictable response to a stimulus

Gray Matter and White Matter

Nervous tissue sorts into two looks. Where cell bodies gather, the tissue looks gray; where myelinated axons run, it looks white. Compare them.

TYPE	WHAT IT IS MADE OF	WHERE IT IS
Gray matter	neuron cell bodies, dendrites, and unmyelinated fibers	the cortex of the brain and cerebellum, and the inner core of the spinal cord
White matter	myelinated axons running in bundles	beneath the cortex of the brain, and the outer part of the spinal cord

Bundles of Fibers and Clusters of Cell Bodies

The same structure has a different name in the CNS and the PNS. Learn the four terms as two pairs: bundles of axons, and clusters of cell bodies.

TERM	WHERE	WHAT IT IS
Tract	CNS	a bundle of axons within the central nervous system
Nerve	PNS	a bundle of axons within the peripheral nervous system
Nucleus	CNS	a cluster of neuron cell bodies within the central nervous system
Ganglion	PNS	a cluster of neuron cell bodies within the peripheral nervous system

The Reflex Arc

A reflex is fast because it runs a short, fixed pathway. Every reflex arc has the same five components, in order.

1. **Receptor** detects the stimulus
2. **Sensory neuron** carries the signal from the receptor to the CNS
3. **Integration center** one or more synapses in the CNS where the signal is processed
4. **Motor neuron** carries the command from the CNS to the effector
5. **Effector** the muscle or gland that carries out the response

Types of Reflexes

Reflexes are sorted several ways: by the effector, by the number of synapses, and by whether they are inborn. Compare them.

REFLEX TYPE	BASIS OF THE NAME	EXAMPLE
Somatic reflex	the effector is skeletal muscle	the patellar, or knee-jerk, reflex
Autonomic reflex	the effector is smooth muscle, cardiac muscle, or a gland	the pupillary light reflex
Monosynaptic reflex	just one synapse in the integration center	the stretch reflex
Polysynaptic reflex	two or more synapses, with interneurons	the withdrawal reflex
Innate reflex	present from birth, not learned	the blink reflex
Learned reflex	built through practice and repetition	catching a suddenly dropped object

Neuronal Pools and Circuits

Neurons rarely act alone. They are wired into groups, the neuronal pools, and the wiring pattern shapes how a signal is handled.

Neuronal pool — a functional group of interconnected neurons in the CNS that processes information together

Convergence — a circuit in which many neurons feed their signals onto one neuron

Divergence — a circuit in which one neuron spreads its signal to many neurons

Serial processing — a signal passing along a single straight chain of neurons, as in a reflex arc

Parallel processing — a signal sent along several pathways at the same time

Integration — the combining of all the incoming signals so that a neuron produces a single response

Sensory and Motor Pathways

Information travels the CNS on long tracts: sensory signals climb upward, motor commands descend, and most pathways cross to the opposite side.

Sensory receptor — a structure that detects a stimulus and triggers a signal in a sensory neuron

Types of receptors — named for what they detect: mechanoreceptors, thermoreceptors, photoreceptors, chemoreceptors, and nociceptors for pain

Ascending pathways — the tracts that carry sensory information up the spinal cord to the brain

Descending pathways — the tracts that carry motor commands down from the brain to the body

Decussation — the crossing of a pathway to the opposite side, so each half of the brain serves the opposite half of the body

Reading the wiring in the clinic

A tap below the kneecap triggers the **patellar reflex**, and a clinician watches the leg kick. That single test checks the whole **reflex arc**: the receptor, the sensory and motor neurons, and the spinal cord in between. A missing reflex points to a break somewhere along that pathway.

Because most pathways **decussate**, crossing to the opposite side, the right half of the brain controls and senses the left half of the body. This is why a stroke on one side of the brain causes weakness on the opposite side.

The split into **gray and white matter** shows up on a brain or spinal cord scan, and a change in that pattern, gray where white belongs or the reverse, is one of the things a radiologist looks for.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Compare gray matter and white matter by what each one is made of.
2. Define a nucleus, a ganglion, a tract, and a nerve, and state whether each is in the CNS or the PNS.
3. Trace the structures of a reflex arc in order, from stimulus to response.

4. Explain why a reflex can happen without involving the brain.

The Spinal Cord

The Central Nervous System, the Spinal Cord

A reference for the spinal cord video and lab. This page covers the external anatomy of the cord, its enlargements and terminations, the roots and rootlets that connect it to the spinal nerves, and the internal anatomy of its gray and white matter. The focus is on the structures and the job each one does.

BY THE END

1. Describe the external anatomy of the spinal cord, including its enlargements and terminations.
2. Identify the roots, rootlets, and dorsal root ganglion.
3. Describe the internal anatomy of the gray horns and the white columns and tracts.

The Spinal Cord, an Overview

The spinal cord runs from the medulla oblongata down the vertebral canal. It carries signals between the brain and the body and is the center for spinal reflexes.

Spinal cord	the cord of nervous tissue within the vertebral canal, continuous with the medulla above
Length	about 16 to 18 inches in the adult, running from the medulla to the L1 to L2 level
Diameter	not uniform; widest in the cervical region and narrowest in the thoracic region
Cord growth	the cord stops lengthening at about 4 to 5 years of age, while the vertebral column keeps growing
Functions	conducting sensory and motor signals between the brain and the body, and acting as the integration center for spinal reflexes

External Anatomy of the Spinal Cord

Two regions of the cord are visibly wider, and the cord ends well above the end of the vertebral column. Two grooves run its full length.

Cervical enlargement	a widening from C4 to T1 where the nerves of the upper limbs arise
Lumbar enlargement	a widening from T11 to S2 where the nerves of the lower limbs arise
Conus medullaris	the tapered, cone-shaped end of the spinal cord, at the disc between L1 and L2
Filum terminale	a thread of pia mater extending from the conus medullaris that anchors the cord to the coccyx
Cauda equina	the hair-like bundle of nerve roots that descends past the conus medullaris within the vertebral canal
Anterior median fissure	the deep groove down the front of the cord
Posterior median sulcus	the shallow groove down the back of the cord; with the fissure it divides the cord into right and left halves

The Roots and Rootlets

Each side of the cord connects to a spinal nerve through two roots. Tiny rootlets gather into a root, and the two roots join to form the mixed spinal nerve.

Rootlets	the small bundles of axons that attach in a row along the cord and merge to form a root
Root	a bundle of axons that connects a spinal nerve to the cord; each spinal nerve has two
Posterior (dorsal) root	the sensory root; it carries sensory axons from receptors in the periphery into the cord
Posterior (dorsal) root ganglion	the swelling on the posterior root that holds the cell bodies of the sensory neurons
Anterior (ventral) root	the motor root; it carries motor axons from the cord out to muscles and glands
Spinal nerve	the mixed nerve formed where the posterior and anterior roots join; it carries both sensory and motor axons
Intervertebral foramen	the gap between adjacent vertebrae where the spinal nerve exits the vertebral canal

Internal Anatomy: The Gray Matter

A cross-section of the cord shows a butterfly of gray matter at the core, wrapped in white matter. This is the reverse of the brain, where gray matter is on the outside.

Gray matter the inner, butterfly-shaped region of neuron cell bodies

Central canal the small cerebrospinal fluid channel at the center of the cord, continuous with the fourth ventricle

Gray commissure the bridge of gray matter that connects the two sides, surrounding the central canal

Anterior white commissure the bridge of white matter that connects the two sides of the cord

The gray matter is shaped into projections called horns. Compare what each horn holds.

HORN	CONTENTS
Posterior (dorsal) horn	interneurons and the incoming axons of sensory neurons
Lateral horn	autonomic motor nuclei; present only in the thoracic and lumbar segments
Anterior (ventral) horn	somatic motor nuclei that drive skeletal muscle contraction

Internal Anatomy: The White Matter

The white matter of the cord is sorted into columns, and each column holds tracts. A tract is a bundle of axons that share a common origin and destination.

White matter the outer region of the cord, made of myelinated axons

Columns the anterior, posterior, and lateral white columns, the major divisions of the cord's white matter

Tracts bundles of axons within the columns that share a common origin and destination

Ascending tracts sensory tracts that conduct impulses up toward the brain; also called afferent tracts

Descending tracts motor tracts that conduct impulses down away from the brain; also called efferent tracts

A cluster of cell bodies and a bundle of axons each have a different name in the CNS and the PNS. Compare the four terms.

LOCATION	CLUSTER OF CELL BODIES	BUNDLE OF AXONS
Central nervous system	nucleus	tract
Peripheral nervous system	ganglion	nerve

Distinguishing the Cord Segments

A cross-section taken at different levels of the cord does not look the same. The proportions of gray and white matter, the shape, and the size all shift from top to bottom. Compare them.

SEGMENT	DISTINGUISHING FEATURES
Cervical	large diameter with a large amount of white matter; oval in shape
Thoracic	small diameter with a small amount of gray matter; has a small lateral gray horn
Lumbar	almost circular; less white matter than the cervical segments
Sacral	relatively small, with more gray matter and little white matter
Coccygeal	the smallest; resembles the lower sacral segments

Where the cord ends, and what that allows

The spinal cord ends at the **conus medullaris** near the L1 to L2 disc, but the vertebral column runs much lower. Below the conus, only the loose **cauda equina** hangs in the canal. That gap is the safe target for a lumbar puncture: a needle can draw cerebrospinal fluid there without risking the cord itself.

The **posterior root ganglion** is the home address of every sensory neuron cell body for that segment. The varicella virus hides in these ganglia for decades; when it reactivates as shingles, the rash follows the exact strip of skin served by that one ganglion.

A **spinal cord injury** interrupts the ascending and descending tracts. Because the tracts carry every signal between the brain and the body below, function is lost below the level of the injury, while everything above it is spared.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Describe the external landmarks of the spinal cord: the enlargements, the conus medullaris, and the cauda equina.
2. Compare the dorsal and ventral roots by the kind of information each one carries.
3. Explain the cross-sectional organization of the cord using its gray horns and white columns.
4. Contrast an ascending and a descending tract by the direction each carries information.

The Peripheral Nervous System

The Peripheral Nervous System

A reference for the peripheral nervous system video and lab. This page covers the structure of a nerve, the spinal nerves and their roots, the rami, the nerve plexuses, and the classification of sensory receptors. The cranial nerves are covered on their own sheet. The focus is on the structures and the job each one does.

BY THE END

1. Describe the structure of a nerve and name its connective tissue wrappings.
2. Identify the spinal nerves, their roots, and their rami.
3. Classify the sensory receptors by stimulus, location, and structure.

The Peripheral Nervous System, an Overview

The peripheral nervous system is everything outside the brain and spinal cord. It carries input from the body's receptors in to the CNS, and carries the response back out to the effectors.

Peripheral nervous system	all neural structures outside the brain and spinal cord
Function	to carry sensory input from receptors to the CNS, and to carry motor output from the CNS to the effectors
Sensory (afferent) receptors	structures that detect changes in the internal and external environment
Peripheral nerves	bundles of axons that connect the CNS to the body
Ganglia	clusters of neuron cell bodies located outside the CNS
Motor (efferent) endings	the terminals where motor neurons meet the muscles and glands
Cranial nerves	the 12 pairs of nerves that arise from the brain, covered on their own sheet
Spinal nerves	the 31 pairs of nerves that arise from the spinal cord

The Structure of a Nerve

A nerve is a cordlike organ: many axons bundled together and wrapped in three layers of connective tissue.

Nerve	a cordlike organ of the PNS; a bundle of peripheral axons, some myelinated and some not, enclosed by connective tissue
Axon	a single nerve fiber; many axons make up a nerve
Endoneurium	the innermost wrapping, around each individual axon
Fascicle	a bundle of axons grouped together
Perineurium	the middle wrapping, the thicker layer around each fascicle
Epineurium	the outermost wrapping, around the entire nerve

The Spinal Nerves

Thirty-one pairs of spinal nerves connect the cord to the body. Every one is a mixed nerve, carrying both sensory and motor axons.

Spinal nerves	the 31 pairs of nerves that arise from the spinal cord
Mixed nerves	every spinal nerve carries both sensory and motor axons
Posterior (dorsal) root	the sensory root that brings axons into the cord
Anterior (ventral) root	the motor root that carries axons out of the cord
Intervertebral foramen	the opening between adjacent vertebrae where a spinal nerve exits the vertebral canal

The 31 pairs are grouped by the region of the cord they arise from. Compare the count in each region.

REGION	NUMBER OF PAIRS
Cervical	8 pairs
Thoracic	12 pairs
Lumbar	5 pairs
Sacral	5 pairs

REGION	NUMBER OF PAIRS
Coccygeal	1 pair

The Rami of a Spinal Nerve

Just past the intervertebral foramen, each spinal nerve splits into branches called rami. Each ramus serves a different territory. Compare them.

RAMUS OR BRANCH	WHAT IT SUPPLIES
Posterior (dorsal) ramus	the deep muscles and the skin of the posterior surface of the trunk
Anterior (ventral) ramus	the muscles and skin of the limbs and the lateral and anterior trunk; these rami form the plexuses
Meningeal branch	re-enters the vertebral canal to supply the vertebrae, the ligaments, the blood vessels of the cord, and the meninges
Rami communicantes	small branches off the anterior ramus that carry autonomic fibers to and from the sympathetic trunk

The Nerve Plexuses

The anterior rami of most spinal nerves do not run straight to their targets. They first join into networks called plexuses. The thoracic rami are the exception.

Nerve plexus — a network formed by the anterior rami of several spinal nerves

Cervical plexus — formed from C1 to C4; serves the neck and shoulders, and gives off the phrenic nerve to the diaphragm

Brachial plexus — formed from C5 to T1; serves the shoulder and the upper limb

Lumbar plexus — formed from L1 to L4; serves the lower abdominal wall and part of the lower limb

Sacral plexus — formed from L4 to S4; serves the buttock, the perineum, and most of the lower limb

Intercostal nerves — the anterior rami of T2 to T12, which do not form a plexus but run straight to the thoracic wall

The plexuses are covered in more detail, including the region affected by damage, on the Nerve Plexuses sheet.

Classifying Sensory Receptors

Sensory receptors are classified in three ways: by the type of stimulus they detect, by where they are located, and by their structure.

By stimulus type

Mechanoreceptors — respond to mechanical force such as touch, pressure, vibration, and stretch

Thermoreceptors — respond to changes in temperature

Photoreceptors — respond to light; found in the retina of the eye

Chemoreceptors — respond to chemicals in solution, such as smell and taste molecules

Nociceptors — respond to potentially damaging stimuli and produce the sensation of pain

By location

Exteroceptors — detect stimuli at or near the body surface, such as touch, temperature, and the special senses

Interoceptors — also called visceroceptors; detect stimuli inside the body, in the organs and blood vessels

Proprioceptors — detect the position and movement of the body, in muscles, tendons, and joints

By structure

Free nerve endings	nonencapsulated receptors; bare dendrite tips found in most tissues	**Encapsulated receptors**	nerve endings wrapped in a connective tissue capsule

The Sensory Receptors

The named sensory receptors, with where each one is found and what it detects. Compare them.

RECEPTOR	LOCATION	WHAT IT DETECTS
Free nerve endings	most body tissues, dense in connective tissue and epithelium	pain, temperature, and crude touch
Tactile (Merkel) discs	the deepest layer of the epidermis	light, discriminative touch
Hair follicle receptors	wrapped around hair follicles	movement of the hair
Tactile (Meissner) corpuscles	the dermal papillae of hairless skin	fine, discriminative touch
Lamellar (Pacinian) corpuscles	the deep dermis and the hypodermis	deep pressure and vibration
Bulbous (Ruffini) corpuscles	the deep dermis and joint capsules	continuous, steady pressure
Muscle spindles	within skeletal muscles	the stretch of a muscle
Tendon organs	within tendons	the tension a muscle places on its tendon
Joint kinesthetic receptors	the capsules of synovial joints	joint position and movement

Following the nerve to the deficit

Because a nerve is wrapped in connective tissue, it has some protection and some ability to heal. The **epineurium** and **perineurium** hold a cut nerve's shape, which is what lets a surgeon line up the fascicles and repair it.

The rami explain referred patterns. The **anterior rami** carry most limb signals, so a problem in the anterior rami or the plexus they form affects the limbs, while a **posterior ramus** problem stays in the muscles and skin of the back.

Receptors are not spread evenly. The fingertips and lips are crowded with **tactile corpuscles** and **Merkel discs**, which is why those areas feel fine detail so well, while the skin of the back, with far fewer, senses touch only crudely.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the components of the peripheral nervous system and what each one connects.
2. Compare a spinal nerve's dorsal and ventral rami by the region each one supplies.
3. Explain the structure of a peripheral nerve using its connective tissue wrappings.
4. Classify sensory receptors by the kind of stimulus each one detects.

The Cranial Nerves

The Peripheral Nervous System, the Cranial Nerves

A reference for the cranial nerve video and lab. This page covers the twelve pairs of cranial nerves: the number and name of each, its classification as sensory, motor, or mixed, its function, the skull foramen it passes through, and its nuclei. The focus is on the structures and the job each one does.

BY THE END

1. Name the twelve cranial nerves in order and give the number of each.
2. Classify each cranial nerve as sensory, motor, or mixed.
3. Identify the function, skull foramen, and nuclei of each cranial nerve.

The Cranial Nerves, an Overview

Twelve pairs of cranial nerves arise from the brain. They are numbered I to XII from front to back by where they attach. The first two attach to the cerebrum and diencephalon; the rest attach to the brainstem.

Cranial nerves — twelve pairs of nerves that arise from the brain and brainstem, part of the peripheral nervous system

Numbering — the nerves are numbered with Roman numerals I to XII, from anterior to posterior

Olfactory (I) and optic (II) — the only cranial nerves that attach above the brainstem, to the cerebrum and the diencephalon

Brainstem nerves — cranial nerves III through XII all attach to the brainstem, where their nuclei sit

Nucleus — the cluster of cell bodies in the brain that a cranial nerve arises from or projects to

Foramen — the opening in the skull that a cranial nerve passes through to reach its target

Classifying the Cranial Nerves

Every cranial nerve is classed by the kind of signal it carries: sensory only, motor only, or both. A nerve carrying both is called mixed.

Sensory nerves — carry only sensory signals into the brain; CN I, CN II, and CN VIII

Motor nerves — carry mainly motor signals out to muscles; CN III, CN IV, CN VI, CN XI, and CN XII

Mixed nerves — carry both sensory and motor signals; CN V, CN VII, CN IX, and CN X

Special sensory — the senses of smell, vision, taste, hearing, and balance

Somatic motor — voluntary control of skeletal muscle

Visceral motor — parasympathetic control of smooth muscle and glands; carried by CN III, VII, IX, and X

A memory aid for the order of the names is the sentence "On Old Olympus' Towering Tops A Finn And German Viewed Some Hops." For the sensory, motor, or both pattern, "Some Say Marry Money But My Brother Says Big Brains Matter Most."

The Twelve Cranial Nerves

The twelve nerves in order, with the classification, the main function, and the skull foramen each one passes through. Compare them.

CRANIAL NERVE	CLASS	PRIMARY FUNCTION	SKULL FORAMEN
CN I · Olfactory	Sensory	smell	cribriform plate of the ethmoid
CN II · Optic	Sensory	vision	optic canal of the sphenoid
CN III · Oculomotor	Motor	most eye movements, raising the eyelid, and constricting the pupil	superior orbital fissure
CN IV · Trochlear	Motor	eye movement by the superior oblique muscle; the smallest cranial nerve	superior orbital fissure
CN V · Trigeminal	Mixed	sensation from the face and the muscles of chewing; the largest cranial nerve, with three branches	superior orbital fissure (V1), foramen rotundum (V2), and foramen ovale (V3)
CN VI · Abducens	Motor	eye movement by the lateral rectus muscle	superior orbital fissure
CN VII · Facial	Mixed	facial expression, taste from the front of the tongue, and tear and saliva production	internal acoustic meatus, then the stylomastoid foramen

CRANIAL NERVE	CLASS	PRIMARY FUNCTION	SKULL FORAMEN
CN VIII · Vestibulocochlear	Sensory	hearing and balance	internal acoustic meatus
CN IX · Glossopharyngeal	Mixed	taste from the back of the tongue, swallowing, and saliva from the parotid gland	jugular foramen
CN X · Vagus	Mixed	autonomic control of the thoracic and abdominal organs, plus voice and swallowing	jugular foramen
CN XI · Accessory	Motor	movement of the sternocleidomastoid and trapezius muscles	jugular foramen
CN XII · Hypoglossal	Motor	movement of the tongue	hypoglossal canal

Cranial Nerve Nuclei

Each cranial nerve connects to one or more nuclei, the clusters of cell bodies in the brain that the nerve arises from or carries signals to. Most sit in the brainstem.

CRANIAL NERVE	NUCLEI OR ORIGIN
CN I · Olfactory	the olfactory epithelium projects to the olfactory bulb, then along the olfactory tract to the cortex
CN II · Optic	the retina projects through the optic nerve and the optic chiasm to the lateral geniculate nucleus
CN III · Oculomotor	the oculomotor nucleus and the Edinger-Westphal nucleus of the midbrain
CN IV · Trochlear	the trochlear nucleus of the midbrain
CN V · Trigeminal	the trigeminal ganglion and the trigeminal nuclei of the pons
CN VI · Abducens	the abducens nucleus of the pons
CN VII · Facial	the facial motor nucleus and the solitary nucleus of the pons
CN VIII · Vestibulocochlear	the cochlear and vestibular nuclei at the pons and medulla
CN IX · Glossopharyngeal	the solitary nucleus, the nucleus ambiguus, and the inferior salivatory nucleus of the medulla
CN X · Vagus	the dorsal motor nucleus, the nucleus ambiguus, and the solitary nucleus of the medulla
CN XI · Accessory	the spinal accessory nucleus of the medulla and the upper spinal cord, C1 to C5
CN XII · Hypoglossal	the hypoglossal nucleus of the medulla

Twelve nerves, twelve exams

Because each cranial nerve has one job and one path, testing the nerves one by one is a fast way to localize a problem in the brainstem. A clinician who finds **CN VI** weak knows to look at the pons, where its nucleus sits.

The foramina group nerves together. The **jugular foramen** carries CN IX, X, and XI side by side, so a tumor or fracture there can knock out all three at once, producing a recognizable cluster of swallowing, voice, and shoulder signs.

Two of the most common nerve problems are cranial. **Bell's palsy** is a sudden weakness of CN VII that drops one side of the face. **Trigeminal neuralgia** is a stabbing facial pain along the branches of CN V. The anatomy of the nerve predicts exactly where each one shows up.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Classify the twelve cranial nerves as sensory, motor, or mixed.
2. For three cranial nerves, name the foramen each one passes through.
3. Describe how you would test one cranial nerve, and what a failure of that test would tell you.
4. Compare the cranial nerves that move the eye and what each one contributes.

The Nerve Plexuses

The Peripheral Nervous System, the Nerve Plexuses

A brief reference for the nerve plexuses. A plexus is a network where the anterior rami of spinal nerves regroup before traveling to the body. This page covers the principal plexuses at a general level: where each one forms and what region it serves, so you can predict the area of the body affected if a plexus is damaged.

BY THE END

1. Define a nerve plexus and explain why the anterior rami regroup.
2. Name the principal nerve plexuses and the spinal nerves that form each.
3. Predict the region of the body affected if a given plexus is damaged.

What a Nerve Plexus Is

Most spinal nerves do not run straight to their targets. The anterior rami of neighboring spinal nerves first weave together into a network called a plexus, then sort their axons into the nerves that leave it. The thoracic region is the exception.

Nerve plexus	a network where the anterior rami of several spinal nerves join and regroup before their axons travel on to the body
Anterior rami	the branches of the spinal nerves that form the plexuses and supply the limbs and the front of the body
Why a plexus forms	regrouping lets each body region receive axons from several spinal nerves, so damage to one spinal nerve does not erase all function in that area
Intercostal nerves	the exception; the anterior rami of T2 to T12 do not form a plexus but run directly to the muscles and skin of the thoracic wall
Principal plexuses	the cervical, brachial, lumbar, sacral, and coccygeal plexuses, each named for the region it serves

The Principal Nerve Plexuses

Each plexus is formed by a known set of spinal nerves and serves a known region of the body. Compare them.

PLEXUS	FORMED BY	REGION SERVED	MAJOR NERVES
Cervical plexus	the anterior rami of C1 to C4, with a contribution from C5	the skin and muscles of the neck and the upper shoulders; it also gives rise to the phrenic nerve, the motor supply to the diaphragm	phrenic nerve
Brachial plexus	the anterior rami of C5 to C8 and T1	the shoulder and the entire upper limb	musculocutaneous, axillary, radial, median, and ulnar nerves
Lumbar plexus	the anterior rami of L1 to L4	the anterolateral abdominal wall, the external genitals, and part of the lower limb	femoral and obturator nerves
Sacral plexus	the anterior rami of L4 to L5 and S1 to S4	the buttocks, the perineum, and most of the lower limb	sciatic nerve (dividing into the tibial and common fibular nerves), superior and inferior gluteal nerves, and the pudendal nerve
Coccygeal plexus	the anterior rami of S4 to S5 and the coccygeal nerves	a small area of skin over the coccyx	coccygeal nerve

Predicting the Effect of Plexus Damage

Because each plexus serves one region, the location of a plexus injury predicts the region of the body that loses movement and sensation. This is the level of detail to know for this course.

PLEXUS DAMAGED	REGION AFFECTED
Cervical plexus	weakness or numbness of the neck and shoulder; if the phrenic nerve is involved, the diaphragm on that side is weakened and breathing is affected
Brachial plexus	weakness and sensory loss across the shoulder and the whole upper limb on that side

PLEXUS DAMAGED	REGION AFFECTED
Lumbar plexus	weakness and sensory loss of the lower abdominal wall and the front and inner surfaces of the thigh
Sacral plexus	weakness and sensory loss of the buttock, the back of the thigh, and the leg and foot
Coccygeal plexus	numbness of the small patch of skin over the coccyx

Why the network matters

The plexus design is a safety feature. Because each limb region draws axons from several spinal nerves, a single damaged spinal nerve root weakens an area but rarely paralyzes it completely. The overlap covers the gap.

Damage to the plexus itself is different. A plexus injury sits downstream of that regrouping, so it can take out a whole region at once. The level of the injury predicts the deficit: a **brachial plexus** injury affects the upper limb, a **lumbar** or **sacral** injury the lower limb.

The **phrenic nerve** is the one to remember. It leaves the cervical plexus and is the sole motor supply to the diaphragm. The teaching phrase "C3, 4, 5 keep the diaphragm alive" is a reminder that a high cervical injury can stop breathing.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Name the four major nerve plexuses and the region of the body each one supplies.
2. Explain what a plexus is, and why nerves regroup into one rather than running straight from the cord.
3. Predict which region would be affected if the brachial plexus were injured, and which if the lumbar plexus were.
4. Compare the cervical and sacral plexuses by the body region each one serves.

The Autonomic Nervous System

The Autonomic Nervous System

A reference for the autonomic nervous system video and lab. This page covers the difference between the somatic and autonomic systems, the two-neuron motor pathway, the named autonomic ganglia, the sympathetic and parasympathetic divisions, and the autonomic and enteric plexuses. The focus is on the structures and the job each one does.

BY THE END

1. Contrast the somatic and autonomic motor systems.
2. Describe the two-neuron motor pathway and name the autonomic ganglia.
3. Compare the sympathetic and parasympathetic divisions and the plexuses.

The Autonomic Nervous System, an Overview

The autonomic nervous system is the involuntary motor division. It quietly regulates the organs, adjusting them without conscious effort or awareness.

Autonomic nervous system — the involuntary division of the motor system; it controls cardiac muscle, smooth muscle, and glands

Autonomic effectors — the targets of the ANS: cardiac muscle, smooth muscle, and glands

Autonomic sensory neurons — neurons that carry input from receptors in the viscera and blood vessels to the CNS

Autonomic motor neurons — neurons that carry commands out to the visceral effectors, either exciting or inhibiting them

Two divisions — the sympathetic and the parasympathetic divisions, which usually act in opposite directions on the same organ

Involuntary control — most autonomic activity cannot be consciously altered, although emotion and pain can influence it

Somatic Versus Autonomic

The somatic and autonomic systems are both motor, but they differ in what they control, how many neurons they use, and what effect they have. Compare them.

FEATURE	SOMATIC NERVOUS SYSTEM	AUTONOMIC NERVOUS SYSTEM
Effector	skeletal muscle	cardiac muscle, smooth muscle, and glands
Control	voluntary	involuntary
Motor neurons in the pathway	one, from the CNS straight to the muscle	two, with a synapse in a ganglion
Effect on the effector	always excitation; it causes contraction	either excitation or inhibition
Awareness	normally conscious	normally not conscious

The Two-Neuron Motor Pathway

Where the somatic system reaches its muscle with a single neuron, the autonomic system always uses two neurons in a row, with a synapse in a ganglion between them.

Preganglionic neuron — the first neuron; its cell body sits in the brain or spinal cord, and its myelinated axon runs out to an autonomic ganglion

Autonomic ganglion — the cluster of cell bodies where the two neurons synapse

Postganglionic neuron — the second neuron; its cell body sits in the ganglion, and its unmyelinated axon runs from the ganglion to the visceral effector

The pathway — the preganglionic neuron synapses in the ganglion with the postganglionic neuron, which then reaches the effector

The Autonomic Ganglia

The autonomic ganglia fall into two groups by division. The sympathetic ganglia sit close to the spinal cord; the parasympathetic ganglia sit close to or within the organ.

Sympathetic ganglia

Sympathetic trunk ganglia — also called paravertebral ganglia; a vertical chain on each side of the vertebral column, from the base of the skull to the coccyx

Prevertebral ganglia — also called collateral ganglia; ganglia anterior to the vertebral column, near the large abdominal arteries

The five prevertebral ganglia — the celiac, superior mesenteric, inferior mesenteric, aorticorenal, and renal ganglia

White ramus communicans — the branch carrying myelinated preganglionic axons from the spinal nerve into the sympathetic trunk; present only at T1 to L2

Gray ramus communicans — the branch carrying unmyelinated postganglionic axons from the trunk back to the spinal nerve; present at every level

Parasympathetic ganglia

Terminal ganglia — the parasympathetic ganglia, located near or within the wall of the target organ

The four named terminal ganglia of the head — the ciliary, pterygopalatine, submandibular, and otic ganglia

The Two Divisions

The two divisions are told apart first by where they leave the CNS, and then by the work they do.

The sympathetic division

Sympathetic division — the fight or flight division; also called the thoracolumbar division

Origin — preganglionic cell bodies in the lateral gray horns of the T1 to L2 spinal segments

Role — it takes over during exercise, excitement, emergency, and embarrassment

Sample effects — dilates the pupils, speeds the heart, opens the airways, and slows digestion

The parasympathetic division

Parasympathetic division — the rest and digest division; also called the craniosacral division

Origin — preganglionic cell bodies in the nuclei of four cranial nerves (III, VII, IX, and X) and in the S2 to S4 spinal segments

Role — it conserves energy and runs routine housekeeping: digestion, defecation, and urination

Sample effects — constricts the pupils, slows the heart, constricts the airways, and stimulates digestion

Comparing the Two Divisions

Side by side, the two divisions differ in their origin in the CNS, the location of their ganglia, and their overall job. Compare them.

FEATURE	SYMPATHETIC	PARASYMPATHETIC
Other name	thoracolumbar division	craniosacral division
Origin in the CNS	the T1 to L2 spinal segments	the brainstem and the S2 to S4 spinal segments
Location of ganglia	close to the spinal cord	close to or within the effector organ
Overall role	fight or flight; prepares the body for action	rest and digest; conserves energy

The Autonomic and Enteric Plexuses

Autonomic axons and ganglia travel together in networks called plexuses. A separate set of networks, the enteric plexuses, runs the wall of the gut.

Autonomic plexuses

Autonomic plexus	a network of autonomic axons and ganglia in the thorax, abdomen, and pelvis
Cardiac plexus	supplies the heart
Pulmonary plexus	supplies the bronchial tree
Celiac (solar) plexus	the largest; it surrounds the celiac trunk and supplies most of the abdominal organs
Superior and inferior mesenteric plexuses	supply the small and large intestine
Hypogastric plexus	supplies the pelvic organs
Renal plexus	supplies the kidneys and ureters

Enteric plexuses

Enteric plexuses	the neural networks within the wall of the GI tract, the structural core of the enteric nervous system
Myenteric plexus	lies between the longitudinal and circular muscle layers; it controls the movement of the gut
Submucosal plexus	lies between the circular muscle layer and the muscularis mucosae; it controls the secretions of the gut

Tracing an Autonomic Pathway

Every autonomic motor command travels the same four-step route from the central nervous system to the organ.

1. **Preganglionic neuron** the cell body in the brain or cord sends its axon out toward a ganglion
2. **Autonomic ganglion** the preganglionic axon synapses here with the postganglionic neuron
3. **Postganglionic neuron** its axon carries the signal the rest of the way out
4. **Effector tissue** the cardiac muscle, smooth muscle, or gland receives the command

Two divisions, opposite effects

Because the two divisions usually pull an organ in opposite directions, the body can fine-tune an organ by easing off one division rather than only by pushing the other. Heart rate, for example, rises when **parasympathetic** input is withdrawn, even before the **sympathetic** division speeds things up.

The **vagus nerve**, CN X, carries most of the parasympathetic supply to the chest and abdomen. Its long reach is why a single nerve can slow the heart, ease breathing, and drive digestion all at once.

The **enteric nervous system** is independent enough to be called the brain of the gut. Smooth muscle in the GI tract keeps contracting in a rhythm and glands keep secreting even when the link to the CNS is cut, which is why a denervated bowel can still move food along.

Study questions

Work on answering these in writing, in your own words. They are the questions to bring to class, and good practice for the reasoning the exams ask for.

1. Compare the sympathetic and parasympathetic divisions by where their fibers leave the central nervous system.
2. For one organ, describe what the sympathetic and parasympathetic inputs each do, and why rest-and-digest versus fight-or-flight captures the difference.
3. Trace a two-neuron autonomic pathway from the CNS to an effector, naming the ganglion where the synapse occurs.
4. Why is the adrenal medulla described as a modified sympathetic ganglion?