CNS & PNS
Outline

• CNS
  – Basic CNS Pattern
  – Spinal Cord
    • Anatomy
    • Reflexes
    • Trauma
  – Meninges & CSF
  – Blood Brain Barrier
  – Brain

• PNS
  – ANS
    • Sympathetic
    • Parasympathetic
    • Neurotransmitters
  – Somatic
    • Cranial Nerves
    • Spinal Nerves
Basic Pattern of the Central Nervous System

Figure 12.5
Central Nervous System – Spinal Cord
Spinal Cord

• Functional Areas
  – Dorsal Root
  – Ventral Root

– Spinal Tracts
  • Ascending Tracts
    – Dorsal column tract
    – Anterolateral System
  • Descending Tracts
    – Corticospinal Tract
Reflexes

• A reflex is a rapid, predictable motor response to a stimulus
• Reflexes may:
  – Be inborn or learned (acquired)
  – Involve only peripheral nerves and the spinal cord
  – Involve higher brain centers as well
Reflex Arc

There are five components of a reflex arc

- Receptor
- Sensory neuron
- Integration center
- Motor neuron
- Effector
Reflex Arc

Figure 13.12
Reflex Classification

• Classified Functionally

• Somatic Reflexes

• Autonomic reflexes
Reflexes in Adult Humans

- Accommodation reflex
- Achilles reflex
- Biceps stretch reflex
- Brachioradialis reflex
- Corneal reflex (also known as the blink reflex)
- Crossed extensor reflex
- Gag reflex
- Mammalian diving reflex
- Patellar reflex (knee-jerk reflex)
- Photic sneeze reflex
- Plantar reflex (Babinski reflex)
- Pupillary reflex
- Quadriceps reflex
- Salivation
- Scratch reflex
- Sneeze
- Tendon reflex
- Triceps stretch reflex
- Vestibulo-ocular reflex
- Withdrawal reflex
- Yawn
Flexor and Crossed Extensor Reflexes

• The flexor reflex is initiated by a painful stimulus (actual or perceived) that causes automatic withdrawal of the threatened body part.

• The crossed extensor reflex has two parts
  – The stimulated side is withdrawn
  – The contralateral side is extended
Crossed Extensor Reflex

Figure 13.17
Mammalian Diving Reflex

• Submerging the face into water causes the mammalian diving reflex

• Includes three factors:
  – Bradycardia
  – Peripheral vasoconstriction
  – Blood shift

• When the face is submerged, receptors that are sensitive to water within the nasal cavity and other areas of the face supplied by cranial nerve V (trigeminal) relays the information to the brain and then innervates cranial nerve X (vagus).
Photic Sneeze Reflex

- A medical condition by which people exposed to bright light sneeze.
  - Occurs in 17% to 25% of humans

- The probable cause is a congenital malfunction in nerve signals in the trigeminal nerve nucleus.
  - Overstimulation of the optic nerve triggers the trigeminal nerve, and this causes the photic sneeze reflex.
Yawn

- A reflex of deep inhalation and exhalation associated with being tired, with a need to sleep, or from lack of stimulation. Pandiculation

- It is claimed to help increase the state of alertness of a person. It could possibly be from lack of oxygen.

- The exact causes of yawning are still unknown.
Spinal Cord Trauma: Paralysis

• Paralysis – loss of motor function

• Flaccid paralysis – severe damage to the ventral root or anterior horn cells

• Spastic paralysis – only upper motor neurons of the primary motor cortex are damaged
Spinal Cord Trauma: Transection

• Cross sectioning of the spinal cord at any level results in total motor and sensory loss in regions inferior to the cut

• Paraplegia – transection between $T_1$ and $L_1$

• Quadriplegia – transection in the cervical region
Poliomyelitis

• Destruction of the anterior horn motor neurons by the poliovirus

• Early symptoms – fever, headache, muscle pain and weakness, and loss of somatic reflexes
Amyotrophic Lateral Sclerosis (ALS)

- Lou Gehrig’s disease

- Symptoms – loss of the ability to speak, swallow, and breathe
The Brain

- Composed of wrinkled, pinkish gray tissue
- Surface anatomy includes cerebral hemispheres, cerebellum, and brain stem
Adult Neural Canal Regions

Figure 12.3a, b
Adult Neural Canal Regions

Figure 12.3c
<table>
<thead>
<tr>
<th>Secondary brain vesicles</th>
<th>Adult brain structures</th>
</tr>
</thead>
<tbody>
<tr>
<td>Telencephalon</td>
<td>Cerebrum: Cerebral hemispheres (cortex, white matter, basal nuclei)</td>
</tr>
<tr>
<td>Diencephalon</td>
<td>Diencephalon (thalamus, hypothalamus, epithalamus)</td>
</tr>
<tr>
<td>Mesencephalon</td>
<td>Brain stem: midbrain</td>
</tr>
<tr>
<td>Metencephalon</td>
<td>Brain stem: pons</td>
</tr>
<tr>
<td>Myelencephalon</td>
<td>Cerebellum</td>
</tr>
<tr>
<td></td>
<td>Brain stem: medulla oblongata</td>
</tr>
<tr>
<td></td>
<td>Spinal cord</td>
</tr>
</tbody>
</table>
# Adult Neural Canal Regions

<table>
<thead>
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<th>Adult neural canal regions</th>
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<tbody>
<tr>
<td>Telencephalon</td>
<td>Lateral ventricles</td>
</tr>
<tr>
<td>Diencephalon</td>
<td>Third ventricle</td>
</tr>
<tr>
<td>Mesencephalon</td>
<td>Cerebral aqueduct</td>
</tr>
<tr>
<td>Metencephalon</td>
<td>Fourth ventricle</td>
</tr>
<tr>
<td>Myelencephalon</td>
<td>Central canal</td>
</tr>
</tbody>
</table>

Figure 12.3c, e
Ventricles of the Brain

![Diagram of ventricles of the brain](image)

(a) Anterior view  
(b) Left lateral view
Protection of the Brain

• The brain is protected by bone, meninges, and cerebrospinal fluid
• Harmful substances are shielded from the brain by the blood-brain barrier
Meninges

• Three connective tissue membranes that lie external to the CNS – dura mater, arachnoid mater, and pia mater

• Functions of the meninges include:
  – Cover
  – Protect
  – Contain
  – Form
Meninges

Figure 12.20a
Dura Mater

• Leathery, strong meninx composed of two fibrous connective tissue layers

• The two layers separate in certain areas and form dural sinuses

• Three dural septa extend inward and limit excessive movement of the brain
  – Falx cerebri
  – Falx cerebelli
  – Tentorium cerebelli
Dura Mater

Figure 12.21
Arachnoid Mater

• The middle meninx, which forms a loose brain covering

• It is separated from the dura mater by the subdural space
Arachnoid Mater

Figure 12.20a
Pia Mater

- Deep meninx composed of delicate connective tissue that clings tightly to the brain
Cerebrospinal Fluid (CSF)

• Watery solution similar in composition to blood plasma

• Contains less protein and different ion concentrations than plasma

• Forms a liquid cushion that gives buoyancy to the CNS organs
Cerebrospinal Fluid (CSF)

- Circulates through the ventricle system of the brain to the brainstem

- Aided by circulatory, respiratory and postural changes

- Barrier between the blood in the capillaries of the choroids plexus and the
Choroid Plexuses

• Clusters of capillaries that form tissue fluid filters, which hang from the roof of each ventricle

• Have ion pumps that allow them to alter ion concentrations of the CSF

• Help cleanse CSF by removing wastes
Choroid Plexuses

(a)

Figure 12.22a

- Ependymal cells
- Capillary
- Connective tissue of pia mater
- Cavity of ventricle
- Filtrate containing glucose, oxygen, vitamins, and ions (Na⁺, Cl⁻, Mg²⁺, etc.)
- Section of choroid plexus
Blood-BRAIN Barrier

• Protective mechanism that helps maintain a stable environment for the brain

• Bloodborne substances are separated from neurons by:
  – Continuous endothelium of capillary walls
  – Relatively thick basal lamina
  – Bulbous feet of astrocytes
Blood-Brain Barrier: Functions

• Selective barrier

• Absent in some areas

• Responds to stress
Blood-Brain Barrier: Functions

– Reduce the immune systems access to the brain

– Comprised of the cells that make up the smallest blood vessels of the brain
  • Anatomical structures
  
  • Physiological transport systems
    - Accounts for some drug actions
      » Morphine vs. heroin
    – Many substances are not lipid soluble
      » Glucose and other important brain substrates
Brain

• Brainstem
  – Midbrain
  – Pons
  – Medulla Oblongata
• Cerebellum
• Forebrain
  – Diencephalon
  – Cerebrum
• Limbic System
Brain Stem

![Diagram of the brain stem with labeled structures](image)

- Third ventricle
- Thalamus
- Lateral geniculate nucleus
- Medial geniculate nucleus
- Trochlear (IV) nerve
- Superior cerebellar peduncle
- Middle cerebellar peduncle
- Inferior cerebellar peduncle
- Facial (VII) nerve
- Vestibulocochlear (VIII) nerve
- Glossopharyngeal (IX) nerve
- Vagus (X) nerve
- Accessory (XI) nerve
- Posterior (dorsal) root of first cervical nerve

Figure 12.15
Midbrain

• Located between the diencephalon and the pons

• Midbrain structures include:
  – Cerebral peduncles
  – Cerebral aqueduct
  – Various nuclei
Midbrain Nuclei

Superior colliculus
Periaqueductal gray matter
Oculomotor nucleus
Medial lemniscus
Red nucleus
Substantia nigra
Corticospinal fibers
Cerebral aqueduct
Reticular formation
Cerebral peduncle

(a) Midbrain

Figure 12.16a
Midbrain Nuclei

• Nuclei that control cranial nerves III (oculomotor) and IV (trochlear)

• Corpora quadrigemina
  – Superior colliculi
  – Inferior colliculi

• Substantia nigra

• Red nucleus – largest nucleus of the reticular formation
Pons

- Superior cerebellar peduncle
- Trigeminal-main sensory nucleus
- Trigeminal motor nucleus
- Middle cerebellar peduncle
- Trigeminal nerve
- Middle lemniscus
- Fourth ventricle
- Reticular formation
- Pontine nuclei
- Fibers of pyramidal tract

Figure 12.6b
Pons

• Bulging brainstem region between the midbrain and the medulla oblongata

• Forms part of the anterior wall of the fourth ventricle

• Fibers of the pons:
  – Connect higher brain centers and the spinal cord
  – Relay impulses between the motor cortex and the cerebellum

• Origin of cranial nerves V (trigeminal), VI (abducens), and VII (facial)

• Contains nuclei of the reticular formation
Reticular Formation

- Radiations to cerebral cortex
- Auditory impulses
- Descending motor projections to spinal cord
- Visual impulses
- Reticular formation
- Ascending general sensory tracts (touch, pain, temperature)
Reticular Formation: RAS and Motor Function

• RAS – reticular activating system
  – Sends impulses to the cerebral cortex to keep it conscious and alert
  – Filters out repetitive and weak stimuli

• Motor function
  – Helps control coarse motor movements
  – Autonomic centers regulate visceral motor functions
Medulla Oblongata

• Most inferior part of the brain stem

• Contains a choroid plexus on the ventral wall of the fourth ventricle

• Pyramids – two longitudinal ridges formed by corticospinal tracts
Medulla Oblongata

Figure 12.16c
Medulla Nuclei

• Inferior olivary nuclei – gray matter that relays sensory information

• Cranial nerves X, XI, and XII are associated with the medulla

• Vestibular nuclear complex

• Cardiovascular control center – adjusts force and rate of heart contraction

• Respiratory centers – control rate and depth of breathing
Cerebellum

• Proprioceptors and visual signals “inform” the cerebellum of the body’s condition

• Cerebellar cortex calculates the best way to perform a movement

• Plays a role in language and problem solving

• Recognizes and predicts sequences of events
Forebrain

- Two Regions
  - Cerebrum
  - Diencephalon
Forebrain

• Cerebrum
  – Right and left cerebral hemispheres
    • Cerebral cortex an outer shell of gray matter
    • White matter
    • Cell clusters called subcortical nuclei

  – Fiber tract carry information out & in and form connections within a hemisphere

  – Hemispheres connected via the corpus callosum
    • Left hemisphere
    • Right hemisphere
Forebrain

– Cortex
  • Divided into four lobes
    – Frontal
    – Temporal
    – Parietal
    – Occipital

– Subcortical Nuclei
  • Heterogenous groups of gray matter than lie within the cerebral hemispheres
  • Basal ganglia
Cerebral Cortex – Functional Areas

– Sensorimotor cortex = all of the parts of the cerebral cortex that act together in the control of muscle movement
  • Primary motor cortex
  • Premotor area
  • Supplementary motor cortex
  • Parietal-lobe association cortex
  • Somatosensory cortex
Functional Areas: Left Cerebral Cortex
Primary Motor Cortex
Sensorimotor Cortex

• Premotor cortex – the part of the brain responsible for planning, selection and execution of actions

• Supplementary motor cortex – responsible for planning and coordination of complex movements

• Parietal-lobe association cortex – responsible for transforming visual information to motor commands
Somatosensory Cortex
Somatosensory Cortex
Diencephalon

Figure AB-20: Diencephalon

Cortex
Cingulate Gyrus
Thalamus
Medial Forebrain Bundle
Hypothalamus
Pituitary Gland
Amygdala
Basal Ganglia
Hippocampus
Parahippocampal Gyrus

Diencephalon = Thalamus + Hypothalamus + MFB
Forebrain

• Diencephalon
  – Three major parts
    • Thalamus
    • Hypothalamus
    • Epithalamus
Limbic System

Figure 12.18
Limbic System

- Structures located on the medial aspects of cerebral hemispheres and diencephalon

- Includes the rhinencephalon, amygdala, hypothalamus, hippocampus, cingulate gyrus, and anterior nucleus of the thalamus

- Hypocampal structures

- Parts especially important in emotions:
  - Amygdala
  - Cingulate gyrus
Cerebrovascular Accidents (Strokes)

• Caused when blood circulation to the brain is blocked and brain tissue dies

• Transient ischemic attacks (TIAs) – temporary episodes of reversible cerebral ischemia
Alzheimers Disease

• Neurogenerative disease

• Progressive loss of higher function

• Caused by neuronal loss and atrophy
Huntingtons Disease

• Genetic disorder
  – HD gene located on chromosome 4
  – Extra CAG repeat on the end of the gene
• Caused by degeneration of neuronal cells
  – Frontal lobes
  – Basal ganglia
  – Caudate nucleus
• Symptoms
  – Jerky uncoordinated movements which become progressively worse
  – Executive function, abstract thinking, speech and perceptual and spatial function are all affected
Blood Supply

• Glucose is the only energy source that the brain uses for energy production (under normal circumstances)

• Brains glycogen stores are minimal so dependent of a continuous blood supply for oxygen and sugar

• Adult brain makes up only 2% of the body weight, it receive 12 – 15% of the total blood supply

• Deprivation of either oxygen or glucose can lead to brain death
Peripheral Nervous System (PNS)

- PNS – all neural structures outside the brain and spinal cord

- Includes: sensory receptors, peripheral nerves, associated ganglia, and motor endings

- Can be divided into:
  - Autonomic Nervous System
  - Somatic Nervous System

- Provides links to and from the external environment
Autonomic Nervous System

- Efferent innervation of all tissues other than skeletal muscle

- Parallel chains of two neurons connect the CNS and effector cells
  - Preganglionic Neuron
  - Preganglionic Fibers
  - Autonomic ganglia
  - Postganglionic Neuron
  - Postganglionic Fibers
Autonomic Nervous System

• Two Divisions
  – Many glands and muscle are innervated by both the parasympathetic and sympathetic nervous system called dual innervation
  – Two divisions usually activated reciprocally
  – Autonomic responses usually occur without conscious control
  – Distinguished by
    • Their unique origin sites
    • Relative fiber lengths
    • Location of their ganglia
    • Degree of fiber branching
    • Functional role
    • Neurotransmitters
Anatomy of ANS

<table>
<thead>
<tr>
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<th>Length of Fibers</th>
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Sympathetic Nervous System

- Extensive branching of the preganglionic fibers

- Innervates visceral organs in the internal body cavities and in the superficial part of the body
  - Sweat glands and arrector pili muscles
  - All arteries and veins (smooth muscle)

- Anatomy ties the entire system together so that it can act as a single unit
  - Small segments of the system can be regulated independently

- Usually increases its response under conditions of physiological stress
Role of the Sympathetic Division

• The sympathetic division is the “fight-or-flight” system

• Involves E activities – exercise, excitement, emergency, and embarrassment

• Promotes adjustments during exercise – blood flow to organs is reduced, flow to muscles is increased

• Its activity is illustrated by a person who is threatened
  – Heart rate increases, and breathing is rapid and deep
  – The skin is cold and sweaty, and the pupils dilate
Sympathetic Nervous System

• Fibers leave from the thoracic and lumbar regions of the spinal cord (T1-L2)

• Preganglionic fibers form the lateral horn of the gray matter in the spinal column

• Ganglia lie close to the spinal cord and form two chains of ganglia one on each side of the cord called sympathetic trunks
Unique Roles of the Sympathetic Division

• Regulates many functions not subject to parasympathetic influence

• These include the activity of the adrenal medulla, sweat glands, arrector pili muscles, kidneys, and most blood vessels

• The sympathetic division controls:
  – Thermoregulatory responses to heat
  – Release of renin from the kidneys
  – Metabolic effects
Thermoregulatory Responses to Heat

- Applying heat to the skin causes reflex dilation of blood vessels

- Systemic body temperature elevation results in widespread dilation of blood vessels

- This dilation brings warm blood to the surface and activates sweat glands to cool the body

- When temperature falls, blood vessels constrict and blood is retained in deeper vital organs
Metabolic Effects

• The sympathetic division promotes metabolic effects that are not reversed by the parasympathetic division
  – Increases the metabolic rate of body cells
  – Raises blood glucose levels
  – Mobilizes fat as a food source
  – Stimulates the reticular activating system (RAS) of the brain, increasing mental alertness
Effects of Sympathetic Activation

• Sympathetic activation is long-lasting because NE:

  – Is inactivated more slowly than ACh

  – Is an indirectly acting neurotransmitter, using a second-messenger system

  – NE and epinephrine are released into the blood and remain there until destroyed by the liver
Parasympathetic Nervous System

• Fibers leave from the brain and the sacral portion of the spinal cord

• Preganglionic axons extend from the CNS nearly all the way to the structures to be innervated

• Terminal ganglia lie within the organs innervated by the postganglionic neurons or very close to the organs

• Short postganglionic axons issue from the terminal ganglia and synapse with the effector organ
Parasympathetic Division Outflow

• Cranial Output
  – Run in the oculomotor, facial, glossopharyngeal and vagus nerves

  – Oculomotor Nerve III (preganglionic fibers)
    • Innervate smooth muscles in the eyes that cause the pupils to constrict and lens to bulge (so that you can focus on objects close up)

  – Facial Nerve VII (preganglionic fibers)
    • Stimulate many large glands in the head
    • Nasal glands and lacrimal glands
    • Submandibular and sublingual salivary glands
Parasympathetic Division Outflow

• Cranial Output
  – Glossopharyngeal Nerve IX (preganglionic fibers)
    • Activate the parotid salivary glands anterior to the ear
  – Distal ends of the preganglionic fibers from nerve III, VII and IX jump over to branches of the trigeminal nerve to synapse with postganglionic fibers in the trigeminal nerve (V), they travel down the trigeminal nerve tract to reach the face
Parasympathetic Division Outflow

- Cranial Output
  - Vagus Nerve (X)
    - Account for about 90% of all preganglionic parasympathetic fibers
    - Serve virtually every organ in the thoracic and abdominal cavities
    - Have branches that go to the cardiac plexus that slow heart rate
    - Have branches that go to the pulmonary plexus and esophageal plexus
    - Have branches from the aortic plexus that go to the abdominal viscera
Parasympathetic Division Outflow

• Sacral Output
  – Branch of the spinal cord to form the pelvic nerves that pass through the inferior hypogastric plexus
  – Have synapses in the distal half of the large intestine, urinary bladder, ureters and reproduction organs

• Made up of relatively independent components
  – Responses can be quite variable and are tailored to the demands of the situation
Interactions of the Autonomic Divisions

- Most visceral organs are innervated by both sympathetic and parasympathetic fibers.

- This results in dynamic antagonisms that precisely control visceral activity.

- Sympathetic fibers increase heart and respiratory rates, and inhibit digestion and elimination.

- Parasympathetic fibers decrease heart and respiratory rates, and allow for digestion and the discarding of wastes.
Neurotransmitters and Receptors

- Acetylcholine (ACh) and norepinephrine (NE) are the two major neurotransmitters of the ANS

- Cholinergic fibers – ACh-releasing fibers

- Adrenergic fibers – sympathetic postganglionic axons that release NE
Nicotinic Receptors

• Nicotinic receptors are found on:
  – Motor end plates (somatic targets)
  – All ganglionic neurons of both sympathetic and parasympathetic divisions
  – The hormone-producing cells of the adrenal medulla

• The effect of ACh binding to nicotinic receptors is always stimulatory
Muscarinic Receptors

• Muscarinic receptors occur on all effector cells stimulated by postganglionic cholinergic fibers

• The effect of ACh binding:
  – Can be either inhibitory or excitatory
  – Depends on the receptor type of the target organ
Adrenergic Receptors

- $\beta_1$
  - Location
    - Heart and Coronary Blood Vessels, kidney, liver and adipose tissue

- Effect
  - Increases heart rate and strength
  - Dilates coronary arterioles
  - Stimulates renin release
Adrenergic Receptors

- $\beta_2$
  - Location
    - Lungs and most other sympathetic target organs
    - Abundant on blood vessels serving the heart
  
  - Effect
    - Stimulates secretion of insulin
    - Causes dilation of blood vessels and bronchioles
    - Relaxes smooth muscle walls of digestive and urinary visceral organs
    - Relaxes pregnant uterus
Adrenergic Receptors

- $\beta_3$
  - Location
    - Adipose Tissue
  - Effect
    - Stimulates lipolysis by fat cells

- $\alpha_1$
  - Location
    - Blood vessels serving the skin
    - Mucosae, abdominal viscera, kidneys and salivary glands
    - All sympathetic target organs except the heart
  - Effect
    - Constricts blood vessels and visceral organ sphincters
    - Dilates pupils of the eye
Adrenergic Receptors

- \( \alpha_2 \)
  - Location
    - Membrane of adrenergic axon terminals
    - Blood platelets
  - Effect
    - Mediates inhibition of NE release from adrenergic terminal
    - Promotes blood clotting
Effects of Drugs

• Atropine – blocks parasympathetic effects

• Neostigmine – inhibits acetylcholinesterase and is used to treat myasthenia gravis

• Tricyclic antidepressants – prolong the activity of NE on postsynaptic membranes

• Over-the-counter drugs for colds, allergies, and nasal congestion – stimulate $\alpha$-adrenergic receptors

• Beta-blockers – attach mainly to $\beta_1$ receptors and reduce heart rate and prevent arrhythmias
Homeostatic Imbalances

• Hypertension
  – Can be caused by an overactive sympathetic vasoconstrictor response promoted by continuous high levels of stress
  
  – Increases the work load on the heart, which may precipitate heart disease, and increases wear and tear on the arteries
Homeostatic Imbalances

• Raynaud’s Disease
  – Characterized by intermittent attacks that cause the skin of the fingers and toes to become pale then cyanotic and painful
  – Caused by exposure to cold or emotional stress
  – Exaggerated vasoconstriction response
  – Can lead to ischemia and gangrene
  – Treated by severing the preganglionic sympathetic fibers in the affected regions
Homeostatic Imbalances

• Hirschsprung's Disease
  – The parasympathetic innervations of the distal portion of the large intestine fails to develop
  – The colon is immobile and feces accumulate prior to the inactive bowel segment
  – Condition is corrected surgically by removing the inactive portion of the large intestine
Homeostatic Imbalances

• **Orthostatic Hypotension**
  – A form of low blood pressure that occurs in older individuals since the aging sympathetic vasoconstrictor centers do not respond as quickly to postural changes

• **Age Related**
  – Reduced gastrointestinal tract motility
  – Dry eyes and frequent eye infections
  – Caused by structural changes of some preganglionic axonal terminals
Somatic Nervous System
Cranial Nerves

- Twelve pairs of cranial nerves arise from the brain
  - Two arise from the forebrain and the rest originate from the brainstem
  - With the exception of the vagus nerve all serve regions in the head or neck
  - Oh Once One Takes The Anatomy Final A Good Vacation Seems Heavenly

- They have sensory, motor, or both sensory and motor functions.
# Summary of Function of Cranial Nerves

<table>
<thead>
<tr>
<th>Cranial nerves I – XII</th>
<th>Sensory function</th>
<th>Motor function</th>
<th>PS* fibers</th>
</tr>
</thead>
<tbody>
<tr>
<td>I Olfactory</td>
<td>Yes (smell)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>II Optic</td>
<td>Yes (vision)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>III Oculomotor</td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>IV Trochlear</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>V Trigeminal</td>
<td>Yes (general sensation)</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>VI Abducens</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>VII Facial</td>
<td>Yes (taste)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>VIII Vestibulocochlear</td>
<td>Yes (hearing and balance)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>IX Glossopharyngeal</td>
<td>Yes (taste)</td>
<td>Yes</td>
<td>Yes</td>
</tr>
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</tr>
<tr>
<td>XII Hypoglossal</td>
<td>No</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>

(b) *PS = parasympathetic

Figure 13.4b
Cranial Nerve I: Olfactory

- Arises from the olfactory epithelium
- Fibers run through the olfactory bulb and terminate in the primary olfactory cortex
- Functions solely by carrying afferent impulses for the sense of smell
- Anosmia – fracture of the ethmoid bone or lesions of the olfactory fibers may lead to a loss either total or partial of smell
Cranial Nerve I: Olfactory

Table 13.2(I)
Cranial Nerve II: Optic

• Arises from the retina of the eye

• Optic nerves pass through the optic canals and converge at the optic chiasm

• They continue to the thalamus where they synapse

• From there, the optic radiation fibers run to the visual cortex
Cranial Nerve II: Optic

• Functions solely by carrying afferent impulses for vision

• Anopsias – damage to the optic nerve or to the vision pathway beyond the optic chiasm can lead to total or complete loss of sight in that eye
Cranial Nerve II: Optic

- Eyeball
- Retina
- Optic nerve (II)
- Optic chiasma
- Optic tract
- Lateral geniculate nucleus of thalamus
- Optic radiation
- Visual cortex

Table 13.2(II)
Cranial Nerve III: Oculomotor

- Supplies four of the extrinsic eye muscles that move the eyeball in its orbit

- Has
  - Somatic motor fibers
  - Parasympathetic fibers
  - Sensory afferents

- Testing
  - Pupils examined for size, shape and equality (concussion pupils of uneven size)
  - Pupillary reflex is tested
  - Convergence for near vision

- External Strabismus – oculomotor nerve is paralyzed,
Cranial Nerve III: Oculomotor

Table 13.2(III)
Cranial Nerve IV: Trochlear

- Fibers emerge from the dorsal midbrain and travel ventrally around the midbrain to enter orbits via the superior orbital fissure.

- Innervates an intrinsic eye muscle.

- Supply somatic fibers to and carry proprioceptor fibers.

- Trauma to this nerve results in double vision and reduced ability to rotate the eye inferolaterally.
Cranial Nerve IV: Trochlear
Cranial Nerve V: Trigeminal

- Supplies sensory fibers to the face and motor fibers to the chewing muscles
- Largest of the cranial nerves
Cranial Nerve V: Trigeminal

- Fibers extend from the pons to the face to form three divisions
  - Ophthalmic division
  - Maxillary division
  - Mandibular division
Cranial Nerve V: Trigeminal

- Trigeminal neuralgia – caused by inflammation of the trigeminal nerve
  - Extreme pain
  - Treated via analgesics, carbamazepine and in severe cases nerve is cut proximally to the trigeminal ganglia
Cranial Nerve V: Trigeminal

Superior orbital fissure
Ophthalmic division (V₁)
Trigeminal (semilunar or gasserian) ganglion
Trigeminal nerve (V)
Pons
Maxillary division (V₂)
Mandibular division (V₃)
Foramen ovale
Foramen rotundum
Anterior trunk to chewing muscles

Distribution of sensory fibers of each division

Temporalis muscle
Medial pterygoid muscle
Masseter muscle
Anterior belly of digastric muscle
Inset shows motor branches of the mandibular division (V₃)
Cranial Nerve VI: Abducens

- Controls the extrinsic eye muscle
- Supplies somatic motor fibers to the lateral rectus muscle and brings back proprioceptive impulses to the brain
Cranial Nerve VII: Facial

• Innervates muscles of facial expression
• Fibers issue from the pons and enter the temporal bone via the internal acoustic meatus
• Mixed nerve with fiber major branches
  – Temporal
  – Zygomatic
  – Buccal
  – Mandibular
  – Cervical
Cranial Nerve VII: Facial

- Convey motor impulses skeletal muscles of the face and proprioioceptor impulses to the brain

- Transmit parasympathetic motor impulses to the lacrimal, nasal, palatine, submandibular and sublingual glands

- Convey sensory impulses from the taste buds on the anterior 2/3’s of the tongue

- Bell’s Palsy
  - Characterized by paralysis of facial muscles on the affected side of the face.
  - Caused by herpes simplex I viral infection which causes swelling and inflammation of the facial nerve
Cranial Nerve VII: Facial

(a) Parasympathetic efferents and sensory afferents

(b) Motor branches to muscles of facial expression and scalp muscles
Cranial Nerve VIII: Vestibulocochlear

- Sensory nerve for hearing and balance

- Fibers arise from hearing and equilibrium apparatus of the inner ear and pass through the internal acoustic meatus to enter the brain at the pons-medulla border
Cranial Nerve VIII: Vestibulocochlear

- Two branches
  - Cochlear
  - Vestibular

- Lesions of cochlear nerve

- Damage to the vestibular division
Cranial Nerve VIII: Vestibulocochlear
Cranial Nerve IX: Glossopharyngeal

- Innervates the tongue and pharynx

- Provide motor fibers to and carry proprioceptors from the stylopharyngeus, which elevates the pharynx during swallowing.

- Provides parasympathetic motor fibers to the parotid salivary gland
Cranial Nerve IX: Glossopharyngeal

- Sensory fibers conduct taste and general sensory impulses from the pharynx and posterior tongue, from chemoreceptors in the carotid body, and from pressure receptors of the carotid sinus

- Damage impairs swallowing and taste, particularly for sour and bitter substances
Cranial Nerve IX: Glossopharyngeal
Cranial Nerve X: Vagus

- Extends into the thorax and abdomen
- Almost all are parasympathetic efferents
  - Supply the heart, lungs and abdominal viscera
  - Are involved in regulation of heart rate, breathing and digestive system activity
Cranial Nerve X: Vagus

- Transmit sensory impulses from the thoracic and abdominal viscera, from the carotid sinus, the carotid and aortic bodies, and taste buds of the posterior tongue and pharynx.

- Paralysis can lead to hoarseness and loss of voice, difficulty swallowing and impaired digestive motility.
Cranial Nerve X: Vagus

Table 13.2(X)
Cranial Nerve XI: Accessory

- Considered and accessory part of the vagus nerve

- Cranial root emerges from the lateral aspect of the medulla
  - primarily motor in function
  - joins with the vagus nerve to innervate the larynx, pharynx and soft palate
Cranial Nerve XI: Accessory

Table 13.2(XI)
Cranial Nerve XII: Hypoglossal

- Runs inferior to the tongue and innervates some of the tongue moving muscles

- Fibers arise from a series of roots from the medulla and exit the skull via the hypoglossal canal to travel to the tongue

- Primarily motor in function
Cranial Nerve XII: Hypoglossal

• Carry impulses to intrinsic and extrinsic muscles of the tongue, and proprioceptors fibers from these muscles to the brain

• Allows food mixing and manipulation of the tongue

• Damage to the hypoglossal nerve causes difficulties in speech and swallowing
Cranial Nerve XII: Hypoglossal

- Medulla oblongata
- Intrinsic muscles of the tongue
- Hypoglossal canal
- Hypoglossal nerve (XII)
- Extrinsic muscles of the tongue

Table 13.2(XII)
Spinal Nerves

• Thirty-one pairs of mixed nerves

• They are named according to their point of issue
  – 8 cervical (C₁-C₈)
  – 12 thoracic (T₁-T₁₂)
  – 5 Lumbar (L₁-L₅)
  – 5 Sacral (S₁-S₅)
  – 1 Coccygeal (C₀)
Spinal Nerves

• Each spinal nerve connects to the spinal cord by a dorsal root and ventral root

• Spinal nerves are short because after emerging it divides in three parts
  – Dorsal ramus
  – Ventral ramus
  – Meningeal branch – reenters the spinal cord to innervate the meninges and the blood vessels in the CNS
Innervation of Specific Body Regions

• The spinal nerve rami and their main branches supply the entire somatic region of the body from the neck down

• Dorsal Rami
  – Supply the posterior body trunk

• Ventral Rami
  – Supply the rest of the trunk and limbs
Innervation of the Back

• Innervation follows a neat segmented plan

• Each dorsal ramus innervates a narrow strip of muscle and skin in line with its emergence point from the spinal column
Innervation of the Anterolateral Thorax and Abdominal Wall

• Ventral rami are arranged in a simple segmental pattern

• Form the intercostals nerves and have cutaneous branches to the skin
Spinal Nerve Innervation: Back, Anterolateral Thorax, and Abdominal Wall
Cervical Plexus

• Formed by the ventral rami of the first four cervical nerves

• Most branches are cutaneous nerves
Cervical Plexus

- Branches also innervate the muscles of the anterior neck
- Phrenic nerve – diaphragm - hiccups
Brachial Plexus

• Gives rise to almost all the nerves that innervate the upper limb

• Plexus formed from intermixing of ventral rami from C5-C8 and most of the T1 ramus

• Injuries are common when the upper limb is pulled hard or receives a blow to the top of the shoulder
Brachial Plexus

• Five important nerves
  – Axillary nerve – runs posterior to the surgical neck of the humerus
  – Musculotaneous nerve – travels inferiorly in the anterior arm
  – Median nerve
  – Ulnar nerve
  – Radial nerve
Brachial Plexus: Distribution of Nerves

Figure 13.8c
Brachial Plexus: Distribution of Nerves

Figure 13.8c
Lumbar Plexus

• Arises from L₁-L₄ and innervates the thigh, abdominal wall, and psoas muscle

• The major nerves are the femoral and the obturator

• Femoral nerve

• Obturator Nerve
Lumbar Plexus

Figure 13.9
Sacral Plexus

• Arises from spinal nerves L4-S4

• Has nerves that serve the buttock and lower limb

• Sciatic nerve
  – Sciatica
Sacral Plexus

Figure 13.10

(a)

Key:

= Ventral rami

(b)
Skin Innervation - Dermatomes

• Dermatomes

• Every spinal nerve except C1 innervates dermatomes

• Some overlap between innervation regions
Dermatomes

Figure 13.11
Innervation of Joints

• Hilton’s law: any nerve serving a muscle that produces movement at a joint also innervates the joint itself and the skin over the joint
Outline

• CNS
  – Basic CNS Pattern
  – Spinal Cord
    • Anatomy
    • Reflexes
    • Trauma
  – Meninges & CSF
  – Blood Brain Barrier
  – Brain

• PNS
  – ANS
    • Sympathetic
    • Parasympathetic
    • Neurotransmitters
  – Somatic
    • Cranial Nerves
    • Spinal Nerves