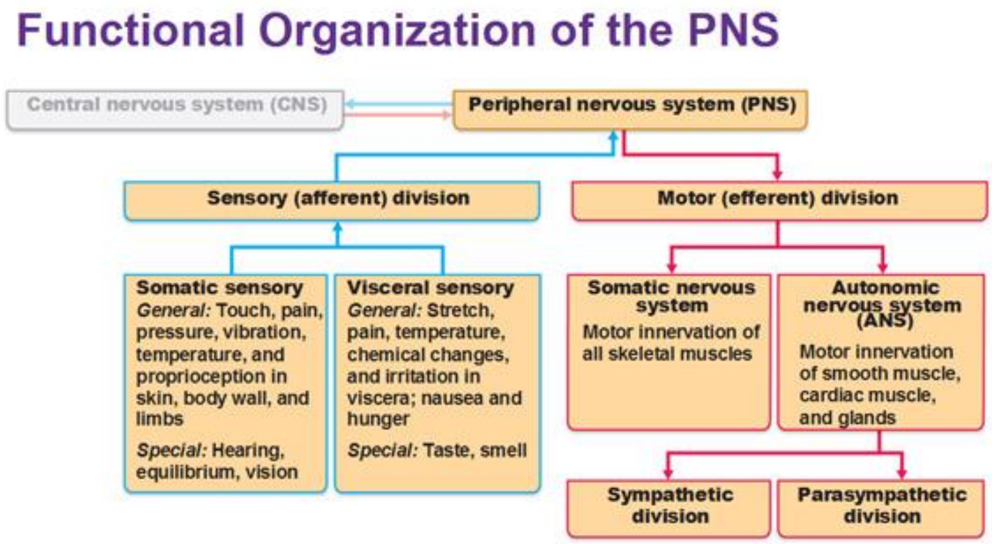
CHAPTER 13



Includes:

- Sensory receptors
- Peripheral nerves
- Ganglia
- Motor nerve endings

REGENERATION OF NERVE FIBRES

Endoneurium: delicate layer of loose connective tissue that surrounds the axon and encloses fibres associated with Schwann cells

Perineurium: courser connective tissue which binds groups of fibres together into bundles called fascicles

Epineurium: encloses all fascicles to form the nerve

Mixed nerves: contain both sensory and motor fibres and transmit impulses both to and from the CNS

Sensory (afferent) nerves: carry impulses to the CNS

Motor (efferent) nerves: carry impulses away from the CNS

Most nerves are mixed

PNS fibres can regenerate successfully. Schwann cells help axons in the PNS but in the CNS the oligodendrocytes actively suppress axon regernaton in the CNS

- Secrete growth inhibiting proteins (stop growth of axon after injury)
- End of damaged axon collapses
- Astrocytes at site of injury form scar tissue which blocks regrowth of the axon

In the PNS

1. The axon fragments → Wallerian degeneration
    - Separated ends seal themselves off and swell as the substances being transported accumulated at the end
    - Axon and myelinated sheath disintegrate as they cannot receive nutrients from the body
    - This spreads distally from injury

2. Macrophages clean out the dead axon
    - Macrophages degrade axon within a week and release chemicals that stimulate Schwann cells to divide
    - Myelin sheath remains intact within the endoneurium
3. Axon filaments grow through a regeneration tube
    - Schwann cells proliferate in response to mitosis-stimulating chemicals and migrate to injury site
    - Release growth factors that express cell adhesion molecules (CAMs) that encourage axon growth
    - Form a regeneration tube → regulates sprouts across the gap to their original contacts
4. Axon regenerates and a new myelin sheath forms

Axons regenerate of 1.5 mm a day

SENSORY RECEPTORS

Respond to changes in their environment (stimuli)

- Stimulus trigger impulses PNS to CNS. Sensation and perception occur in the brain

There are 3 types of ways of classify sensory receptors

1. Stimulus type
2. Body location
3. Structural complexity

Stimulus type

- **Mechanoreceptors:** respond to mechanical force (touch, pressure, vibration and stretch)
- **Thermoreceptors:** respond to temperature changes
- **Chemoreceptors:** respond to chemical in solution
- **Nociceptors:** respond to damaging stimuli that result in pain

Classification by Location

- **Exteroceptors:** sensitive to stimuli arising outside the body so they are near the body surface
    - Touch, pressure, pain, temperature and special senses
- **Interoceptors:** respond to stimuli inside the body → Internal viscera, blood vessels
    - Chemical changes, tissue stretch and temperature
    - Causes pain, discomfort and hugner
- **Proprioceptors:** also respond to internal stimuli but occur in tendons, skeletal muscles, joints and ligaments
    - Advise brain of our body movements by monitoring how much organs are stretched

STRUCTURAL COMPLEXITY

Simple

Modified dendritic ends → touch, pressure, temperature, muscles stretch and pain

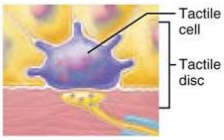
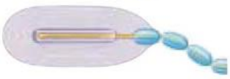
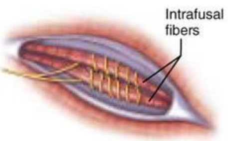
Nonencapsulated: free nerve endings

- Abundant in epithelia and connective tissue
- Non-myelinated with knoblike distal endings
- Respond to temperature and painful stimuli and pressure
- Ones that respond to cold are superficial whilst heat is depper
- Nociceptors respond to anything outside normal range and cause pain
- Itch receptor in the dermis
- **Merkel discs:** deepest layer and respond to touch
- **Hair follicle receptors:** wrap around hair follicles & detect bending of hair

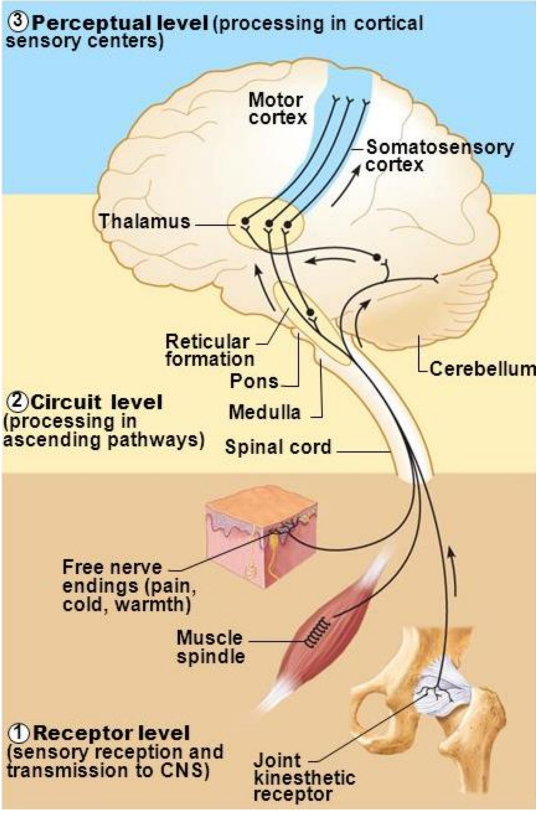
Encapsulated: dendritic endings (not free) enclosed in connective tissue capsule

- Mechanoreceptors →Meissner’s corpuscles, Pacinian corpuscles, Ruffini endings

Table 13.1 General Sensory Receptors Classified by Structure and Function

STRUCTURAL CLASS	ILLUSTRATION	FUNCTIONAL CLASSES ACCORDING TO LOCATION (L) AND STIMULUS TYPE (S)	BODY LOCATION
Nonencapsulated			
Free nerve endings of sensory neurons		L: Exteroceptors, interoceptors, and proprioceptors S: Thermoreceptors (warm and cool), chemoreceptors (itch, pH, etc.), mechanoreceptors (pressure), nociceptors (pain, hot, cold, pinch, and chemicals)	Most body tissues; most dense in connective tissues (ligaments, tendons, dermis, joint capsules, periostea) and epithelia (epidermis, cornea, mucosae, and glands)
Modified free nerve endings: Tactile (Merkel) discs		L: Exteroceptors S: Mechanoreceptors (light pressure); slowly adapting	Basal layer of epidermis
Hair follicle receptors		L: Exteroceptors S: Mechanoreceptors (hair deflection); rapidly adapting	In and surrounding hair follicles
Encapsulated			
Tactile (Meissner's) corpuscles		L: Exteroceptors S: Mechanoreceptors (light pressure, discriminative touch, vibration of low frequency); rapidly adapting	Dermal papillae of hairless skin, particularly nipples, external genitalia, fingertips, soles of feet, eyelids
Lamellar (Pacinian) corpuscles		L: Exteroceptors, interoceptors, and some proprioceptors S: Mechanoreceptors (deep pressure, stretch, vibration of high frequency); rapidly adapting	Dermis and hypodermis; periostea, mesentery, tendons, ligaments, joint capsules; most abundant on fingers, soles of feet, external genitalia, nipples
Bulbous corpuscles (Ruffini endings)		L: Exteroceptors and proprioceptors S: Mechanoreceptors (deep pressure and stretch); slowly or nonadapting	Deep in dermis, hypodermis, and joint capsules
Muscle spindles		L: Proprioceptors S: Mechanoreceptors (muscle stretch, length)	Skeletal muscles, particularly in the extremities
Tendon organs		L: Proprioceptors S: Mechanoreceptors (tendon stretch, tension)	Tendons
Joint kinesthetic receptors		L: Proprioceptors S: Mechanoreceptors and nociceptors	Joint capsules of synovial joints

SENSORY INTEGRATION



Survival depends on sensation (awareness of changes in the internal and external environments) and perception (conscious interpretation of the stimulus)

Somatosensory System

Receives inputs from exteroreceptors, proprioceptors and interoceptors. There are three main levels of neural integration

1. Receptor level
2. Circuit level: processing ascending pathways
3. Perceptual level: processing in cortical sensory areas

Perception of Pain

Pain receptors are activated by extremes of pressure and temperature. Histamine, K and ATP are the most potent pain-producing chemicals

- Sharp pain carried out by myelinated A delta sensory fibres
- Burning pain carried out by non-myelinated C fibres
- Both release glutamate and substance P which activate second-order sensory neuron which ascend to the prain via the spinothalamic tract
- Brain has pain-supressing analgesic systems where endogenous opioids (endorphins and enkephalins)

Brain stem nuclei (periacqueductal grey area in midbrain) → relay descending pain-inhibiting signals to interneurons in SC → release endogenous opioids

MOTOR INTEGRATION

Cerebral cortex is the highest level of conscious motor pathways but receives help from cerebellum and basal nuclei. There are 3 levels of control

1. **Segmental level**
   - Lowet level consists of reflexes and spinal cord circuits that control automatic movements
   - Activates network of ventral horn neurons in group of cord segments causing stimulation of specific muscles
   - Central pattern generators (CPGs) are circuits that control locomotion and other specific and repeated motor activities → network of oscillating inhibitory and excitory neurons s
2. **Projection level**
   - Spinal cord
   - Upper motor neruons initiate direct pathways which produce discete voluntary movements
   - Convey information to lower motor neurons and send a copy of that information as internal feedback to higher command levels
3. **Precommand level**
   - Unconscious planner
   - Control outputs of the cortex and brain stem motor centers and are highest level of motor hierarchy
   - Basal nuclei stops
   - Cerebellum starts

REFLEX ARC

1. **Receptor**: site of stimulus action
2. **Sensory neuron**: transmits afferent impulses to CNS
3. **Integration centre**: may be single synapse between sensory and motor neuron (monosynaptic reflex) or multiple synapses which chains of interneurons polysynaptic reflex)
4. **Motor neuron**: conducts efferent impulses from the integration entre to an effector organ
5. **Effector**: muscle fibre or gland cell that responds to efferent impulses

Inborn: unlearned, no involvement from brain

Acquired: learned, practice, past experience, required higher processing

Somatic reflexes → skeletal muscle

Autonomic reflexes → smooth or cardiac muscle, glands

Stretch Reflex

Fastest possible response

- Ensures muscle stays the same length

Eg: patellar reflex

- Prevents knee from buckling when standing
- When quadriceps are stretched → activates muscle spindle → femoral nerve afferent → L2-4 spinal cord → femoral nerve efferent → quadricep contraction = stay upright
- Uses monosynaptic pathways

Muscle Spindles

3-10 intrafusal fibres in fibrous capsule and are non-contractile

Sensory nerve endings (afferent)

- Primary sensory endings (type 1a) → stimulated by the rate and degree of stretch
- Secondary sensory endings (type 2a) → stimulated by degree of stretch only

Motor nerve endings (efferent)

- Gamma (y) motorneuron fibres that adjust resting tone

Alpha motorneuron fibres are extrafusal (skeletal muscle) fibres

Superficial Reflexes

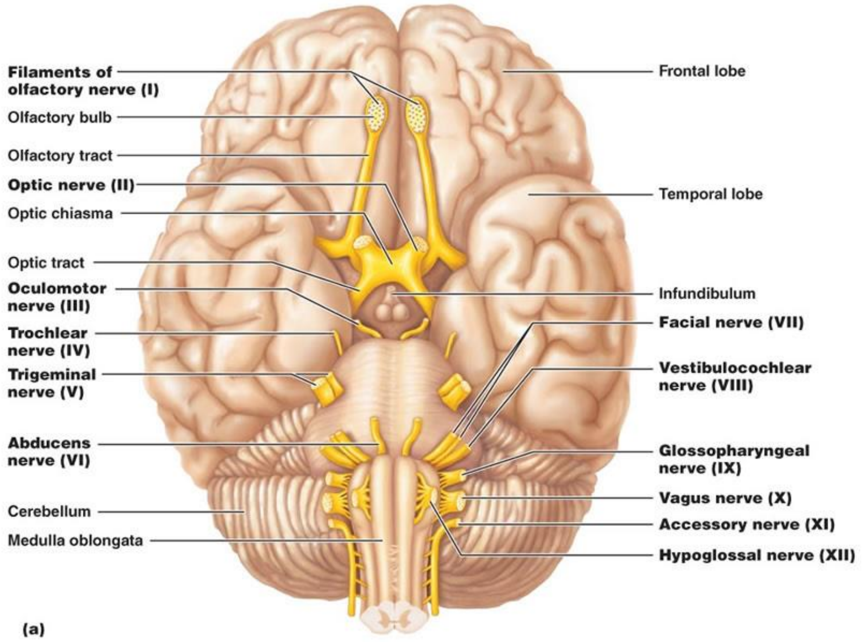
Respond to gentle cutaneous stimulation → stroking skin with firm object

Depends on the functional UMN and spinal cord reflex arc (plantar reflex or abdominal reflex)

Plantar reflex

- Integrity of spinal cord levels L4 – S2
- Integrity of corticospinal tract indirectly
- Normal response – curling toes (-ve)
- Abnormal response – extension of the great toe and fanning of other 4 toes (+ve)
- Infant response is +ve as their nervous system are incompletely myelinated

CRANIAL NERVES



(a)

Cranial nerves I – VI	Sensory function	Motor function	PS* fibers
I Olfactory	Yes (smell)	No	No
II Optic	Yes (vision)	No	No
III Oculomotor	No	Yes	Yes
IV Trochlear	No	Yes	No
V Trigeminal	Yes (general sensation)	Yes	No
VI Abducens	No	Yes	No

Cranial nerves VII – XII	Sensory function	Motor function	PS* fibers
VII Facial	Yes (taste)	Yes	Yes
VIII Vestibulocochlear	Yes (hearing and balance)	Some	No
IX Glossopharyngeal	Yes (taste)	Yes	Yes
X Vagus	Yes (taste)	Yes	Yes
XI Accessory	No	Yes	No
XII Hypoglossal	No	Yes	No

(b)

*PS = parasympathetic

I. Olfactory: sense of smell
- Purely sensory, carries afferent impulses for sense of smell
- Arises from olfactory epithelium in nasal cavity beneath frontal lobe into olfactory cortex

II. Optic: sense of sight
- Purely sensory
- Arises from retina, converges with other optic nerve to form optic chiasma → thalamus → optic radiation → visual cortex

III. Oculomotor: movement of eyes
- **Motor**: somaic motor fibres to 4 extrinsic eye muscles help direct eyeball and raise upper eyelid
- **Sensory**: proprioceptive afferents from extrinsic eye muscles to midbrains
- Parasympathetic → autonomic muscle fibres to intrinsic muscles
  - Sphincter pupilae – pupil constriction
  - Ciliary muscle – lens accommodation
- Extends from ventral midbrain (near pons) through supraorbital fissure to eye

IV. Trochlear: movement of eyes
- Supply motor fibres to (and carry proprioceptor fibres from) superior oblque muscle (extrinsic eye muscle) which passes through pulley-shaped trochlea
- Fibres emerge from dorsal midbrain and go ventrally to midbrain to enter orbit through superior orbital fissure

V. Trigeminal: sense of touch (face) and movements of jaw (chewing)
- **Sensory**: pain, touch, temperature from face to teeth
- **Motor**: muscles of mastication
- 3 branches
  1. Ophthalmic (V1): conveys sensory impulses from skin of scalp, upper eyelid, nose, nasal cavity, cornea and lacrimal gland
  2. Maxillary (V2): conveys sensory impulses from nasal cavity, palate, upper teeth, skin of cheek, upper lip and lower eyelid

3. Mandibular (V2, V3): conveys from tongue, lower teeth, skin of chin and supplies motor fibres to muscles of mastication → site for dental anaesthesia

VI. **Abducens:** movement of eyes
- Supplies motor fibres to Lateral Rectus extrinsic muscle of the eye → abducens the eye
- Proprioception afferent fibres from Lateral Rectus muscle
- Emerges from pons through superior orbital fissure to eye

VII. **Facial:** movement of muscles (face)
- Mixed nerve
- **Motor**: skeletal muscle of facial expression
- **Sensory**: taste buds (anterior $2/3^{rd}$ of tongue)
- Parasympathetic: tear glands (lacrimal) and salivary glands (submandibular and sublingual)
- 5 branches:
  1. Temporal
  2. Zygnomatic
  3. Buccal
  4. Mandibular
  5. Cervical
- Travels from pons → temporal bone → inner ear → lateral aspect of face

Damage:

- **Bells Palsy:** viral inflammation often in facial canal leads to acute loss of facial nerve function
  - Facial paralysis to both upper and lower parts of one side of the face
  - Treatment involves corticosteroid, antivirals, spontaneous resolution
- **Hemifacial Spasm:** arterial loop contacts facial nerve which causes transient activation and twitching
  - Treatment involves microvascular decompression surgery or botox which blocks ACh release and muscle contraction

VIII. **Vestibulocochlear:** sense of hearing and balance
- **Sensory**: transmits afferent impulses for sense of equilibrium which are in the vestibular ganglia
- Cochlear branch transmits hearing
- Small motor component adjusts sensitivity of sensory receptors
- Projects from inner ear to pons/medullar border

IX. **Glossopharyngeal:** movement of tongue and pharynx, sense of taste
- Mixed nerve
- **Motor**: provides fibres to and from pharangeal muscle which allows swallowing
- **Parasympathetic**: salivary glands (parotid)
- **Sensory:** involved in taste and general sensation of posterior $1/3^{rd}$ of tongue and pharnx from chemoreceptors in carotid body which monitor O and CO_2 levels in the blood. Also use baroreceptors
- Arises medulla → jugular formation → throat

X. **Vagus:** swallowing, innervates heart, lungs and digestive system
   - Mixed nerve
   - **Motor:** swallow muscles of the pharynx and larynx
   - **Parasympathetic:** heart, lungs, digestive tract
   - **Sensory:** from abdomen, viscera, baroceptors (aortic arch) and taste buds in the epiglottis
   - Wandering nerve extending beyond head and neck from medulla into abdomen
   - Test in common with Glossopharyngeal

XI. **Accessory:** movement of neck and shoulder
   - Mixed nerve → form rootlets that emerge from the spinal cord not the brain stem
   - **Motor:** to muscles in the neck
     - Sternoclastoid → rotates away and flexes
     - Trapezius → shrug
   - **Sensory:** proprioceptive information from same muscles
   - Formed from ventral roots of spinal cord (C1-C5)

XII. **Hypoglossal:** movement of tongue
   - Mixed nerve
   - **Motor:** to muscle of tongue → protrude, retract and deviate tongue side to side
   - Proprioceptive fibres from same muscle to brain stem
   - Arises from medulla → hypoglossal canal → muscles of tonue

SPINAL NERVES

There are 31 pairs from the spinal cord that innervate all areas of the body except the head and some areas of the spinal cord. They are named according to the point of issue from spinal cord

- 8 pairs from cervical (C1-C8)
- 12 pairs from thoracic (T1-T12)
- 5 pairs from lumbar (L1-L5)
- 5 pairs from sacral (S1-S5)
- 1 pair from coccygeal (Co1)

All are mixed nerves. There are 8 cervical nerves and 7 cervical vertebrae because C1-C7 emerge superior to the vertebrae of the same name while C8 exits inferior to C7.

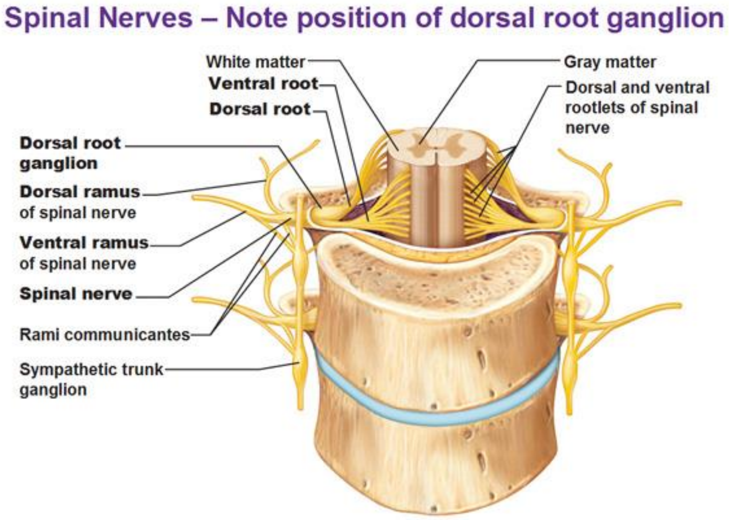
Spinal nerves below the cervical spine (T1-CO1) emerge inferior to vertebrae of the same name

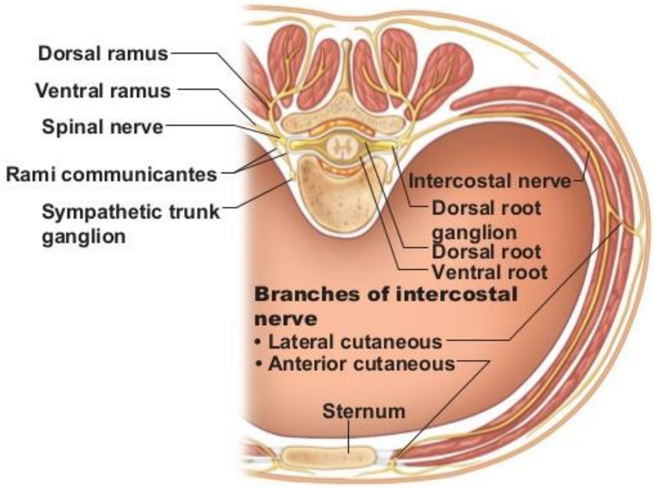
Rootlets from the spinal cord merge into

- Ventral roots (motor)
- Dorsal roots (sensory)
- Ventral and dorsal rots merge distal to dorsal root ganglion to form a spinal nerve before emerging from the vertebral column via their intervertebral foramina
- Spinal roots elongate as they extend from cervical (short) to lumbar regions (long flowing cauda equina) before exiting spinal column
- In the cervical region, the roots are short and run horizontally. In the lumbar and sacral regions, the nerves extend inferiorly for some distance through the lower vertebral canal (cauda equina) before exiting the vertebral column

Spinal nerve is only 1-2 cm long

- After emerging from foramen, it divides into a small dorsal ramus, a larger ventral ramus and a tiny meningeal branch which reenters vertebral canal to innervate the meninges
- Rami communicantes attach to base of ventral rami and contain autonomic nerve fibres





(b) Cross section of thorax showing the main roots and branches of a spinal nerve.

Figure 13.7 (b)

Spinal nerve rami innervate the entire somatic region of the body from the neck dow

- Dorsal rami supply posterior body trunk
- Thicker ventral rami supply rest of the trunk and limbs
  - Except for T2-T12 all branch and join one another lateral to vertebral columm forming nerve networks called **nerve plexuses** → C, B, L and S. serve limbs
  - Ventral rami cris cross one another inside and become redistributed so that each plexus contain fibres from several spinal nerves and fibres from each ramus travel to body periphery
  - Therefore, damage to one spinal segment doesn't completely paralyze any limb muscle

Roots → lie medial to and form the spinal nerves. Either sensory or motor

Rami → lie distal to and are lateral brances of the spinal nerves → can carry both sensory or motor

Cervical Plexus and the Neck

Under the sternocleidomastoid muscle → first four cervical nerves

- Ventral rami that are cutaneous nerves that only supply the skin
- Transmit sensory impulses from skin of neck, ear, back of head and shoulder
- **Phrenic nerve:** C3-C5 runs inferiorly to thorax and supplies both motor and sensory fibers to the diaphragm → breathing movments

Brachial Plexus and the Upper Limb

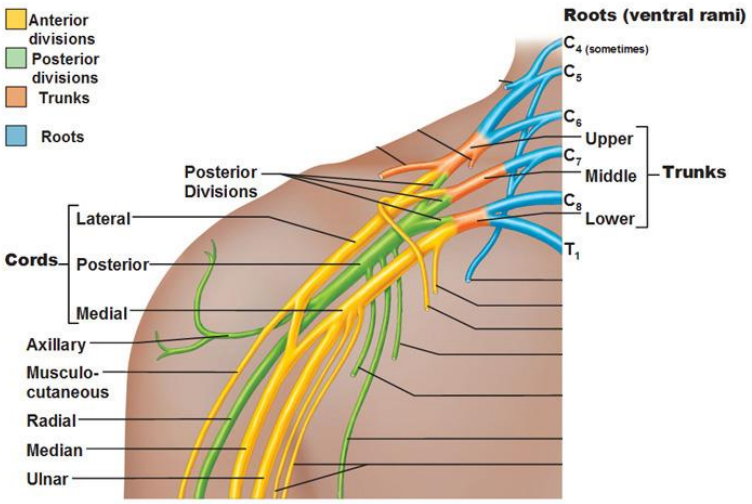
Partly in the neck and partly in the axilla → gives rise to all nerves that innervate the upper limb

- Ventral rami of C5-C8 and most of T1. Also C4 and T2

There are four main branches from medial to lateral

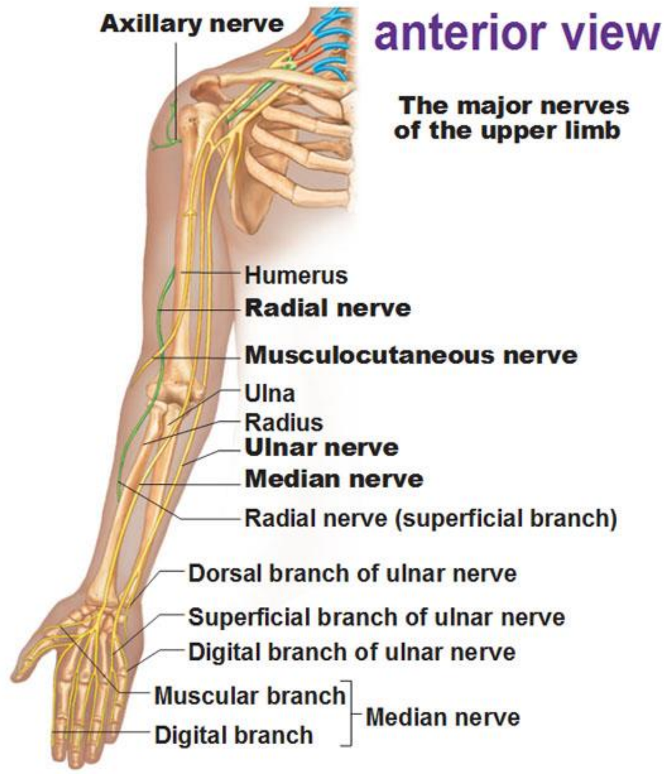
1. Roots (ventral rami C5-T1) → in the sternocleidomastoid
2. Trunks
3. Divisions
4. Cords

Organization of the Brachial Plexus



Roots (rami C_5–T_1), trunks, divisions, and cords

Nerves of the Upper Limb



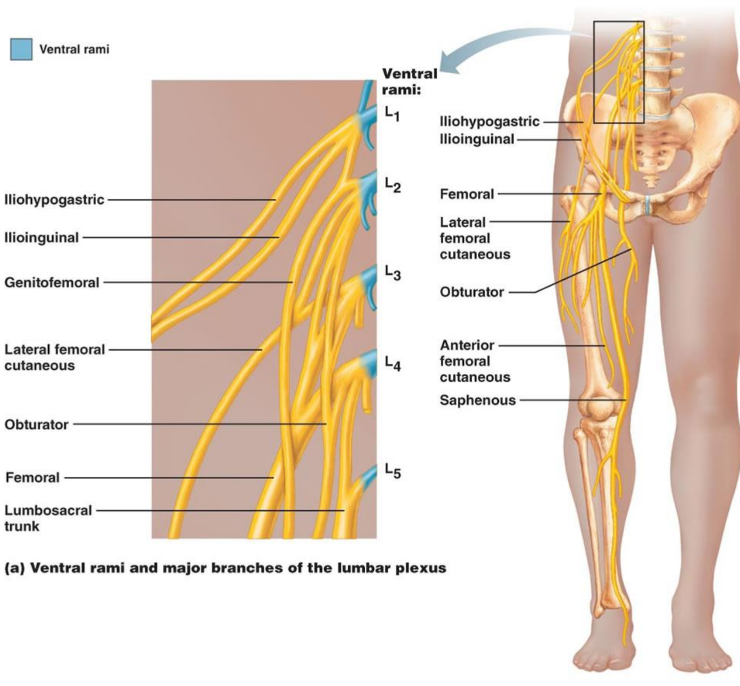
Ends in the axilla where its 3 cords wind along the axillary artery and give rise to the main nerves of the upper limb

1. **Axillary Nerve:** innervates the deltoid and teres minor muscles, the skin and joint capsule of the shoulder → from posterior cord and runs posteiror to the surgical neck of the humerus
2. **Musculocutaneous Nerve:** Supplies motor fibres to the bicep brachii, brachialis and coracobrachialis muscles
   - Major end branch of the lateral cord and courses inferiorly in the anterior arm.
   - Provides cutaneous sensation in the lateral forearm
3. **Median Nerve:** innervates 5 intrinsic muscles of the lateral palm on reaching hand. Median nerve activates muscles that pronate forearm, flex wrist and fingers and oppose thumb
   - Descends through arm to anterior forearm where it gives off brances to the skin and most flexor muscles
4. **Ulnar Nerve:** innervates most intrinsic hand muscles and skin of medial aspect of the hand
   - Descends along medial aspect of arm toward elbow and swings behind medial epicondyle then to medial forearm
   - Causes wrist to flex and adduct and abducts medial fingers
5. **Radial Nerve:** elbow extension, forearm supination, wrist extension, finger extension
   - Wraps around humerus (in radial groove) and runs anteriorly around the lateral epicondyle at the elbow
   - Divides into superifical branch that follows lateral edge of radius to hand
   - Deep branch runs posteriorly

Lumbar Plexus and Lower Limb

L1-L4, lies within the psoas major muscle

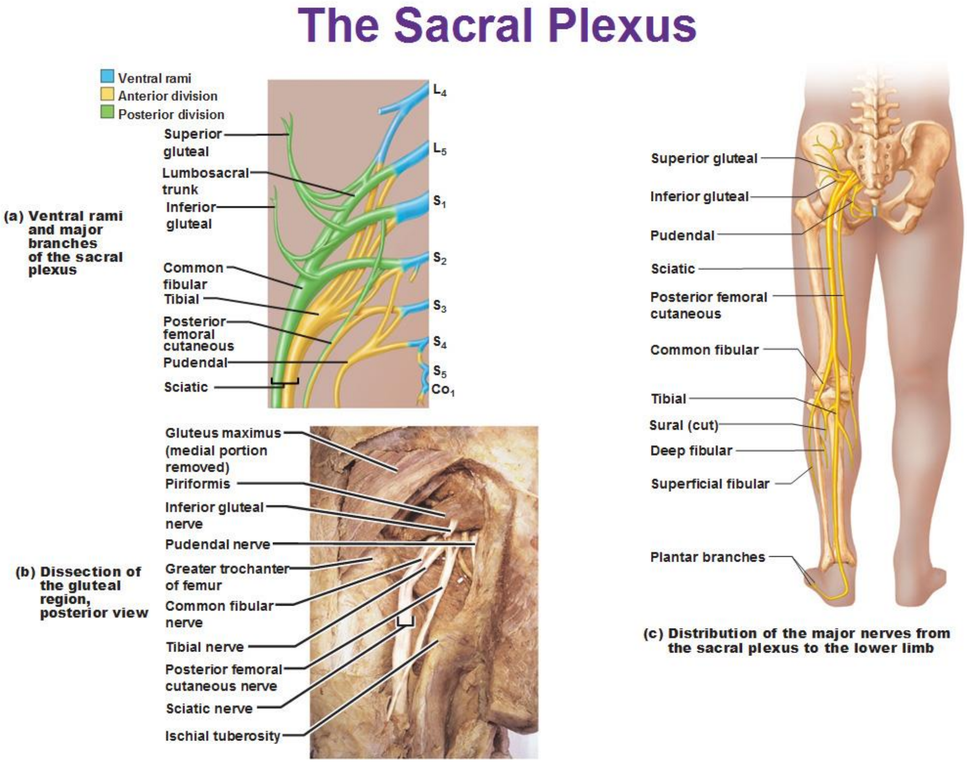
- Innervates parts of the abdominal wall muscles and the psoas muscle
- Major branches descend to innervate the anterior and medial thigh
- **Femoral nerve:** largest terminal nerve → innervates quadriceps (thigh flexors and knee extensors)
- **Obturator nerve:** innervates adductor muscles



(a) Ventral rami and major branches of the lumbar plexus

(b) Distribution of the major nerves from the lumbar plexus to the lower limb

Sacral Plexus and the Lower Limb



L4-S4, lies caudal to lumbar plexus → serves buttock, lower limb, pelvis and perineum

Sciatic nerve: supplies entire lower limb and is the longest nerve in the body

- Tibial and common fibular wrapped in a common sheath
- Leaves pelvis via greater sciatic notch and goes to gluteus maxmus to posterior thigh
- Hamstring, adductor magnus
- Tibial: posterior muscle thigh, leg and foot
- Common fibular: anteriolateral leg muscles

INNERVATION OF SKIN

Dermatone: area of skin innervated by cutanous branches of a single spinal nerve

- Every spinal nerve except C1
- Can pinpoint damaged nerves and injured region by determining which dermatons are effecgted
- Neighbouring dermatonal regions can overlap considerably therefore destruction of one spinal nerve will not cause complete numbness anywhere