Nervous system

The human brain

The cerebrum (upper part of the brain) consists of an outer cerebral cortex of gray matter, an internal region of cerebral white matter and gray matter nuclei deep within the white matter.

Gray matter: Contains the cell bodies, dendrites and axon terminals of neurons, so it is where all synapses are.
White matter: Made of bundles of axons connecting different parts of **grey matter** to each other.

Right hemisphere: Spatial orientation
- ➔ Primary auditory cortex
- ➔ Non-verbal language (body language, emotional expression e.g. tone of language)
- ➔ Spatial skills (3D)
- ➔ Conceptual understanding
- ➔ Artistic/musical skills

- ➔ Effects of injury:
  - Loss of non-verbal language and speech lacks emotion
  - Spatial disorientation
  - Inability to recognise familiar objects
  - Loss of musical appreciation

Left hemisphere: Language
- ➔ Primary auditory cortex
- ➔ Broca's
- ➔ Wernicke's
- ➔ Supramarginal gyrus
- ➔ Angular gyrus

Cerebral cortex:
- ➔ Region of gray matter forming the outer rim of the cerebrum
- ➔ Contains billions of neurons arranged in layers, gray matter develops rapidly compared to white matter resulting in folds called gyri/gyrus or convolutions
- ➔ Deepest grooves between folds: Fissures
- ➔ Shallower grooves between folds: Sulci/sulcus

Lobes of the cerebrum
- ➔ Frontal lobe: Main anterior section
  - Central sulcus separates the frontal lobe from the parietal lobe
  - Lateral fissure separates the frontal lobe from the temporal lobe
- ➔ Parietal lobe: Superior posterior section
  - Lateral fissure is the horizontal deep groove which divides the parietal and temporal lobe and extends downwards between frontal and temporal
- ➔ Temporal lobe: Inferior posterior section
  - Lateral fissure surrounds the temporal lobe

- ➔ Occipital lobe: Furthest posterior section, smaller more tightly packed lobe
  - Parieto-occipital sulcus separates the occipital lobe from the rest of the cerebrum, starts at the preoccipital notch
  - When protrudes called occipital protuberance

Cerebral **white matter**: Consists of myelinated axons

- ➔ Corpus callosum: Wide, thick nerve tract containing commissural cell fibers. Allows for communication between hemispheres.

<u>Functional organisation of the cerebral cortex</u>

Sensory areas: Receive sensory information and are involved in perception, the conscious awareness of a sensation

- ★ Damage here would result in a lack of eyesight, hearing etc

Sensory association areas are adjacent to primary areas, they receive input and integrate experiences to generate recognition patterns

- ★ Damage here would result in misrecognition of an object or sound etc

Post central gyrus: Primary sensory cortex

- ➔ Directly posterior to the central sulcus in the parietal lobe of each hemisphere
- ➔ Receive nerve impulses for touch, pressure, temperature etc
- ➔ Mapped for the body with each point in the area receiving impulses from a specific part of the body, known as the sensory homunculus
- ➔ The size of the cortical area receiving impulses from a particular part of the body depends on the number of receptors present there (instead of the size of the body part) and thus resulting in being sensitive to touch
- ➔ Largest part is the face, mainly the lips, followed by the fingertips

- ❏ Parietal association cortex: Sensory association area
  - Posterior to the primary sensory area in the post central gyrus
  - Spatial skills and 3D recognition of shapes, faces, concepts, abstract perception etc
  - Stores memories of past somatic sensory experiences allowing pattern recognition

- ❏ Supra marginal gyrus and angular gyrus: Reading and writing regions
  - Only in the left hemisphere
  - The SMGLA is primarily (but not exclusively) responsible for understanding visual symbols as words
  - The AGLA is primarily (but not exclusively) responsible for allowing us to plan out the symbols necessary to write what we want to express.
  - Nearby to Wiernicke's area for translation of language
    - ★ Damage results in agraphia - inability to communicate through reading and writing

Primary visual area: Posterior tip of the occipital lobe

- ➔ Receives and orders visual information and passes to the visual association area
- ➔ Highest density of small sensory cells

- ❑ Visual association area: Occipital lobe, anterior to the primary visual cortex
    - Receives information from the primary visual area to interpret and form patterns for recognition

Primary auditory area: Superior part of the temporal lobe near the lateral fissure

- ➔ Breaks sounds into lateral tones known as tonotopic representation
- ➔ Located in both hemispheres (because two ears)

- ❑ Auditory association area: Region inside wernicke's area in the temporal cortex
    - Allows you to recognize a particular sound as speech, music or noise

- ❑ Wernicke's area: Association area in the left temporal and parietal lobes
    - Responsible for the comprehension of speech
    - Stroke in Wernicke's area the individual could still speak but cannot arrange words in a coherent fashion known as fluent aphasia producing a "word salad"
        - ★ Word deafness (inability to understand spoken word) or word blindness (inability to understand written word)

Motor areas: Control the execution of voluntary movements

Precentral gyrus: Primary motor area:

- ➔ Immediately anterior to the central sulcus in the frontal lobe
- ➔ Contains very long myelinated cells that connect and activate muscles
- ➔ Map of the body known as the motor homunculus where each region within the area controls voluntary contractions of specific muscles or groups of muscles.
- ➔ Electrical stimulation of any point in the primary motor area causes contraction in the corresponding region of the body (on the opposite side to the hemisphere stimulated)
- ➔ More cortical area devoted to muscles involved in skilled, complex or delicate movement
- ➔ Largest part is the hands/fingers and speech area

- ❑ Premotor area: Anterior to the primary motor area in the frontal cortex
    - Motor planning for neuron activation
    - Can learn motor activities of a complex and sequential nature e.g. writing your name
    - Contains:
        - ➢ Broca's area
        - ➢ Frontal eye field: Controls scanning movements of the eye
        - ➢ Exner's area: Plans hand and finger movements

Broca's speech area: Frontal lobe in the pre-motor cortex, anterior to the precentral gyrus and near the lateral fissure

- ➔ Found in the left hemisphere for 97% of the world (the language hemisphere of the brain) where planning and production of speech occur
- ➔ Receive nerve impulses from wernicke's area and then pass to the motor region for muscle contractions of larynx, pharynx and mouth
    - ★ A cerebrovascular accident or stroke results in individuals being unable to coordinate the muscle movements required to physically form or articulate words, they know what they wish to say but cannot speak, known as nonfluent aphasia/ motor aphasia
- ➔ Connected to Wiernicke's area through the arcuate fasciculus, an arch shaped bundle of white fibres which transports information from W to B to align speech recognition/comprehension with speech production to give an appropriate verbal response.
    - ★ Conduction aphasia is when there are deficits in the speech production and speech comprehension areas

Other association areas

Frontal association cortex/prefrontal cortex: Anterior portion of the frontal lobe

- ➔ Determines intelligence, personality, behaviour, mood, cognitive function
- ➔ Bilateral damage causes mood swings, being inconsiderate and a lack of emotional intelligence

Temporal association cortex: Inferior portion of the temporal lobe

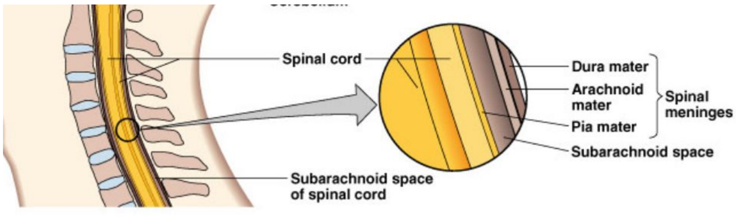
- ➔ Determines memory, mood, aggression, intelligence
    - ★ Epileptic patients have a lesion here, if removed then prevent seizures but takes away memory too.

The Spinal Cord

Protective structures

- ➔ First layer of defence: Hard bony skull and vertebral column protect against damaging blows or bumps to the CNS
- ➔ Second layer of defence: Meninges - three membranes circling the bony encasement and the nervous tissue. Cranial meninges and spinal meninges are continuous with each other.
    - Superficial: Dura mater
    - Middle: Arachnoid mater
    - Deep: Pia mater - very vascular to supply oxygen and nutrients to the spinal cord
    - ❑ Between the Dura mater and the Arachnoid mater is a thin subdural space containing interstitial fluid
    - ❑ Between the Arachnoid mater and the pia mater is the subarachnoid space containing cerebrospinal fluid

- ➔ Third layer of defence: Cerebrospinal fluid in the space between the arachnoid mater and the pia mater which acts as a shock absorbing hydraulic cushion and suspends the tissue in a weightless environment



Exterior structure

- ➔ Spinal cord extends from the medulla to ~L1-L2
- ➔ Diameter is around 2cm yet larger in the lower cervical and mid lumbar regions and smallest at the inferior tip.
  - Superior enlargement: Cervical enlargement - extends from C4-T1, nerves to and from the upper limbs arise from the cervical enlargement.
  - Inferior enlargement: Lumbar enlargement - extends T9-T12, nerves to and from the lower limbs arise from the lumbar enlargement.
- ➔ Conus medullaris: Spinal cord terminates at L1- L2, just after the lumbar enlargement

Spinal nerves: Path of communication between spinal cord and specific regions of the body, 31 pairs that arise from the 31 spinal segments where each spinal nerve is connected to their specific spinal cord segment through roots (bundles of axons)

- ➔ 8 pairs of cervical nerves: Head and upper limbs
- ➔ 12 pairs of thoracic nerves: Ribs abdominal area
- ➔ 5 pairs of lumbar nerves: Anterior side of lower limbs
- ➔ 5 pairs of sacral nerves: Posterior side of lower limbs and genitals
- ➔ 1 pair of coccygeal nerves: No sensory root only motor

Cavernous testicals like sex continously

Nerves arising from the lumbar, sacral and coccygeal regions area are below the spinal cord, the roots of these nerves therefore angle inferiorly alongside the filum terminale and are referred to as the cauda equina (horses tail)

Posterior dorsal roots contain only afferent sensory axons conducting nerve impulses from sensory receptors in the skin muscles and internal organs

- ➔ Each posterior root contains a posterior (dorsal) root ganglion a swelling containing the cell bodies of sensory neurons

Anterior (ventral) roots contain only efferent motor neuron axons conducting nerve impulses from the CNS to the effectors (muscles and glands)

Dermatome - Areas of skin that are mainly innervated by afferent sensory nerve fibres
Myotome - Motor region innervated by a spinal nerve

Internal anatomy of the spinal cord

- ➔ Regions of white matter lateral to an inner core of gray matter
- ➔ Two grooves penetrate the white matter of the spinal cord dividing it into right and left sides
    - Anterior median fissure: Groove on anterior (ventral) side
    - Posterior median sulcus: Narrow furrow on posterior (dorsal) side

White matter:

- ➔ Anterior (ventral) white commissure: Anterior to the gray commissure connecting the anterior white column on the right and left sides of the spinal cord
- ➔ Anterior (ventral) white columns: Located on either side of the anterior median fissure with the white commissure connecting them
- ➔ Posterior (dorsal) white columns: Located on either side of the posterior median sulcus
- ➔ Lateral white columns: Located on either side of the gray horns (butterfly wings)

Gray matter:
Gray matter shaped like a butterfly, consisting of dendrites, cell bodies of neurons, unmyelinated axons and neuroglia

- ➔ Gray commissure: Cross bar of the butterfly
- ➔ Central canal: Small space in the center of the gray commissure which extends the entire length of the spinal cord and filled with cerebrospinal fluid.
- ➔ The gray matter on each side of the spinal cord is subdivided into horns (the wings of the butterfly)
    - Posterior (dorsal) gray horn: Contains axons of sensory neurons receiving input
    - Anterior (ventral) gray horns: Contain cell bodies of motor neurons providing output for contraction of skeletal muscles
    - Lateral gray horns: Between posterior and anterior, present only in thoracic and upper lumbar segments of the spinal cord contain motor neurons

Sensory systems of the brain

- ➔ Afferent system: Towards

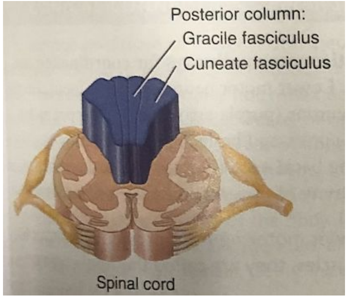
Two major pathways of the somatosensory system going from the skin and through the spinal cord and ascending to the brain

- ➔ Posterior column - Medial lemniscus pathway: Discriminative pathway for rapid and precise touch and pressure sensations
- ➔ Anterolateral spinothalamic tract: Non-discriminative pathway for slow and imprecise pain and temperature sensations

Posterior column - medial lemniscus pathway
Discriminative pathway enabling **sensory modality** of touch and pressure
Runs through the posterior column of the spinal cord and the medial lemniscus of the brain stem and enters the medulla

First order neuron:

- Encapsulated nerve endings: Connective tissue encapsulates receptor to enhance its sensitivity making it discriminative and specific.
  - Myelinated axons conducting at 50m/s
  - Touch: **Meisner's** corpuscles
  - Pressure: **Pacinian** corpuscle
- Pseudounipolar neuron passes through the posterior/dorsal root ganglion where the cell body lies and through the fasciculus ascending the spinal cord
  - Funiculi are bundles of white matter which combine to make fasciculus (gracile and cuneate)
- Enters into the posterior white matter columns (dorsal fasciculus) of the medulla consisting of:
  - Gracile fasciculus: Medial column where discriminative axons of the feet and legs pass through
  - Cuneate fasciculus: Lateral column where discriminative axons of the trunk, arms and head passes through
- Some axons also synapse in the posterior gray horn and then **converge** with the impulses in the posterior column
- Synapse with the second order neuron at the gracile or cuneate nucleus (depending on where ascended from)



Second order neuron:

- Synapse with the first order neuron in the gracile or cuneate nucleus in the medulla
- Axons decussate in the internal arcuate fibres in the medulla (arch shaped fibers crossing over to the other side of the rain stem cord)
- Ascend through the medial lemniscus to enter the ventral posterior nucleus of the thalamus
- Synapse with the third order neuron in the ventral posterior nucleus

Third order neuron:

- Synapse with the second order neuron in the ventral posterior nucleus
- Project through the internal capsule to the primary somatosensory area

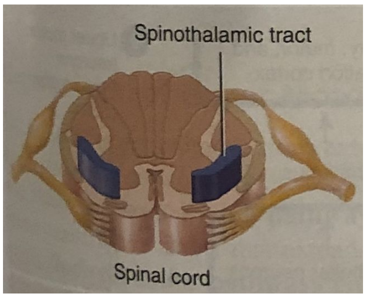
Anterolateral/spinothalamic tract

Non-discriminative pathway enabling sensations of pain and temperature to be passed from the skin, through the spinal cord and ascending to the brain.

First order neurons:

- Free nerve endings: Bare dendrites and unmyelinated axon conducting non-discriminative sensations at 1m/s
  - Pain
  - Temperature
- Pseudounipolar neuron cell body lies in the posterior root ganglion
- Enters into the spinal cord through the dorsolateral tract of lissauer
- Synapse with the second order neurons in the posterior gray horn of the spinal cord

Second order neurons:
- Synapse with the first order neuron in the posterior gray horn
- Decussate at the anterior white commissure in the spinal segmental level as the axons cross to the opposite side of the spinal cord
- Ascends through the anterolateral/ lateral spinothalamic tract in the medulla
- Joins with the discriminative medial lemniscus pathway and passes through the medial lemniscus in the pons
- Ascends and enters the posterior ventral nucleus of the thalamus where it synapses with the third order neuron



Third order neuron:
- Synapse with the second order neuron in the ventral posterior nucleus of the thalamus
- Project through the internal capsule to the primary somatosensory on the same side as the thalamus

Damage to the spinothalamic tract or the posterior column - medial lemniscus tract

Lesion - Region in an organ or tissue that has suffered damage through injury or diseases resulting in cell death/tumor etc

Lesion in the **brain stem**
- **Associative** sensory loss
  - Loss of discriminatory touch and pressure sensations from the opposite side
  - Loss of non-discriminatory pain and temperature sensations from the opposite side

Lesion in the **spinal cord** below the internal arcuate fibres
- **Dissociative** sensory loss
  - Loss of discriminatory touch and pressure from the same side
  - Loss of non-discriminatory pain and temperature sensations from the opposite side
- Where two pathways are operating from different sides of the body e.g. Brown-sequard syndrome: disruption of one half of the spinal cord

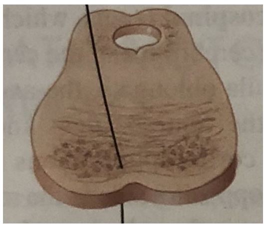
Motor systems of the brain
- Efferent system (away)

Motor cortex and the pyramidal tract
- Primary motor cortex: Initiates and controls precise muscle movements
- Consists of pyramidal neurons: Very large pyramidal cell body shaped neurons (150 micron diameter) which extend to the spinal cord (carrying impulses for over a meter)

Corticospinal-pyramidal tract (primary cortex motor pathway):

- ➔ Arises in the cortex and goes to spine, pyramidal because contains pyramidal shaped motor neurons as well as forming a pyramid shape upon decussation

1. Upper motor (pyramidal) neurons arise in the primary motor cortex (on specific homunculus area)
2. Descend through the internal capsule (bundle of white matter running between the caudate nucelus + thalamus and putamen + globus pallidus)
3. Pass through the crus cerebri (bridge to the cerebellum) anteriorly from the forebrain to the midbrain
4. Pass through the pyramidal tract
5. Enter the pons in the brain stem - enlargement for cranial nerves to innervate the face and deviate from the spinal nerves (similarly for sensory information it comes into the pons before ascending to the post central gyrus).
    - ➔ Pons also contains cranial nuclei and many bundles of fibres thus the axons separate into small fibres as it passes through here to bend around nuceli



6. Fibres rejoin at the medulla where they separate, 15% control the core axial muscles while 85% is for fine movement control of limbs. Potentially if there is a lesion on one side then the other side can take control of movements too.

85% of fibres	15% of fibres
6. Decussate at the pyramidal decussation 7. Descend through the lateral corticospinal tract (lateral white columns) to the anterior grey horn (to their specific spinal segmental level)	6. Descend through the ventral/anterior corticospinal tract (anterior white columns) into the anterior grey horn 7. Decussate at the specific spinal segmental level across the anterior white commissure

8. Upper motor neuron synapses with a lower motor neuron in the anterior grey horn
    - ➔ Homuncular representation of flexors (upper) and extensors (lower) at the same spinal segmental level e.g. when walking requires flexing and extending your leg so the nerves are interacting back and forth
9. Lower motor neuron extends out of the ventral root to innervate a muscle at the motor end plate

Lesion in the upper motor neurons - spastic paralysis

- ➔ Disconnection between upper and lower neurons
- ➔ Lower motor neurons have no central control, generally they maintain muscle tone (e.g. activate muscles to stay on your feet) so revert to their intrinsic activity overactivates **on the opposite side of the body**
- ➔ Reflexes are exaggerated as there is no inhibitory influences from the upper motor neurons
- ➔ E.g. when someone pulls your arm and releases you are usually able to control the spring back and stop it yet when the lesion in the brain stem occurs you cannot stop the spring because there is too much tone

Lesion in the lower motor neurons - flaccid paralysis

- ➔ Removes all motor input from the lower motor neurons providing muscle tone on the **same side of the body**
- ➔ Permanent relaxing (dead weight)

Paraplegia and quadriplegia

- ➔ Quadriplegia: paralysis resulting in the partial or total loss of use of all their limbs and torso, caused by a lesion in the lower motor neurons of their cervical, thoracic, lumbar, sacral and coccygeal nerves
- ➔ Paraplegia: Paralysis resulting in the partial or total loss of use of their torso and lower limbs, caused by a lesion in the lower motor neurons of their thoracic, lumbar and sacral nerves
- ➔ The loss is usually sensory and motor, which means that both sensation and control are lost

Basal ganglia

- ➔ Subcortical grey matter structures of neurons bundles deep within each cerebral hemisphere near the base of the forebrain
- ➔ Basal ganglia refine motor movement by determining exactly which neurons to activate, giving fine movement control and communicating to the premotor region
- ➔ Regulate initiation of movements

5 basal ganglia:

- Caudate nucleus: Superior to the thalamus
- Putamen: Lateral to the thalamus on the lateral side
    - ➔ In most species putamen and caudate nucleus are linked together and referred to the striatum
- Globus pallidus: Lateral to the thalamus, on the medial side
    - ➔ Divided into two different regions: Externus (lateral) and internus (medial)
- Subthalamic nucleus: Inferior to the thalamus
- Substantia nigra: Located in the **midbrain**

Thalamus is the key important part to make this a circuit with the premotor area, despite not being a basal ganglia

Basal ganglia circuit: System improves our ability to engage in movement and show our mood, initiates movement

- ➔ Information circuits goes from premotor cortex -> basal ganglia -> thalamus -> premotor cortex -> primary motor cortex which thus activate the muscles

1. Premotor cortex communicates to the striatum (caudate and putamen) through a glutamatergic neuron conveying the **excitatory** neurotransmitter glutamate
2. Neurons project from the striatum (caudate and putamen) to the substantia nigra, external globus pallidus, internus pallidus through a gabaergic fibre conveying the **inhibitory** neurotransmitter GABA (gamma amino butyric acid)
3. Gabaergic fiber from the internus globus pallidus extends to the ventral anterior nucleus conveying GABA

4. Glutamatergic fibre from the ventral anterior nucleus of the thalamus to activate the premotor area and thus the primary motor region
5. Dopaminergic fibres from the substantial nigra extend to the striatum (caudate and putamen) conveying the neurotransmitter dopamine which can be **excitatory/inhibitory depending on the receptor**
   - ➔ Keep the gabaergic fibres from the striatum primed and ready to fire so that a small amount of input (e.g. action potential or neurotransmitter) from the cortex immediately results in the rest of the circuitry engaging

95% of gabaergic fibres are located in the striatum (caudate nucleus and putamen)

Cerebellar system

- ➔ Neural circuits interconnect the cerebellum with the premotor and primary motor cortex through the thalamus to terminate the activity of the upper motor neurons
- ➔ Coordinates movements making them smooth as well as controlling posture and balance
- ➔ Is able to bring back the movement planned if disrupted
- ➔ If a patient is unable to know when to start and stop e.g. touch your ear, touch your nose and instead jabs their eye then must have a lesion in the glutaminergic fibre between the cerebellar and the ventral anterior nucleus of the thalamus

1. Glutamatergic fiber extends from the cerebellar cortex to the ventral anterior nucleus of the thalamus conveying glutamate and acts to terminate movement

Parkinson's disease

- ➔ Cell bodies in the substantia nigra die, thus affecting the dopaminergic fibre extending to the striatum (putamen and caudate nucelus)
- ➔ As domaine keeps the system primed and ready to fire, it takes away the tone of the gabaergic neurons
- ➔ The system therefore take a lot of time to start because it requires a lot of glutamate input to fire up the gabaergic neurons
- ➔ Results in muscle movements and emotion taking a long time to start because the initiation circuit is dysfunctional, however, once the automatic movement has started they are normal

Symptoms:
Tremour: Involuntary skeletal muscle contractions interfere with voluntary movement
Catatonia: Muscle tone rigidity
Bradykinesia: Slowness of movements
Hypokinesia: Decreasing range of motion e.g. written words gradually become smaller and smaller

Treatment
Drugs:

- ➔ Taking dopamine in the form of Levodopa: precursor for dopamine that is able to cross the blood brain barrier and be taken up by the remaining cells in the substantia nigra to turn into dopamine
- ➔ As levodopa is taken 6 types a day there can be too high and too low concentrations.
- ➔ Low point where parkinson's diseases symptoms exist
- ➔ When too high: Hallucinations, depression, psychosis - schizophrenia symptoms
- ➔ Similarly for schizophrenia patients will take anti dopamine to combat but then they will get parkinson's symptoms

Pallindotomy

- ➔ Original treatment was to disrupt the upper motor neurons
- ➔ Terminating the artery in the internus globus pallidus removed the communication to the ventral anterior nucleus in the gabaergic fibre
    - Successful when done on one side but not when bilaterally
- ➔ Removed inhibition in the thalamus so that the thalamus can project normal levels of glutamate into the motor cortex - restored normal activity of the thalamic pathway

Thalamotomy

- ➔ Ventral anterior thalamus
- ➔ Interrupt pathways of nervous transmission through the ventral anterior thalamus disrupting the gabaergic neurons.

Deep brain stimulation

- ➔ Electrodes or pacemakers are implanted into either the subthalamic nucleus or the globus pallidus internus to improve cell communication
- ➔ Treatment in the Subthalamic Nucleus can result in a reduction in levodopa medication
- ➔ Treatment in the Globus Pallidus can result in greater recovery in verbal fluency and voluntary movement

Novel new treatments:

- ➔ Cell transplantation (fetal/stem cells)
- ➔ Gene therapy

<u>Summary</u>

	Medial lemniscus pathway	Lateral spinothalamic pathway	Corticospinal-pyramidal pathway
Direction	Afferent	Afferent	Efferent
Convey	Discriminatory - touch and pressure	Non-discriminatory - pain and temperature	Motor
Synapse	Cuneate/gracile	Posterior grey horn,	Anterior grey horn

	nuclei, ventral posterior thalamus	ventral posterior thalamus	
Decussate	Internal arcuate fiber	Anterior white commissure	85% pyramidal decussation, 15% anterior white commissure
Tracts pass through	Medial lemniscus tract	Lateral spinothalamic tract and medial lemniscus	Pyramidal tract, 15% ventral corticospinal tract, 85% lateral corticospinal tract
Speed	50m/s	1m/s	-
Myelinated?	Yes	No	Lower
Periphery	Encapsulated receptor	Free nerve ending	Motor end plate
Enters spinal cord via	Dorsal funiculus	Dorsolateral tract of lissauer	-

Autonomic-endocrine system

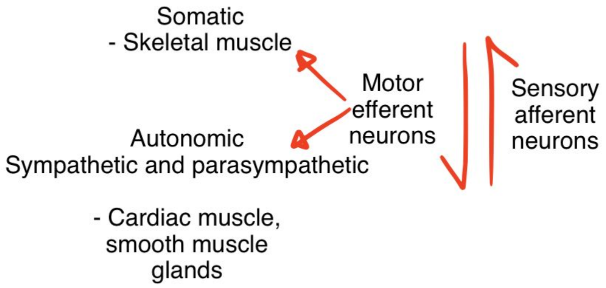
Autonomic and endocrine systems

➔ Function together to achieve and maintain homeostasis
➔ Autonomic: Neurons communicate to <u>nearby target tissues</u> with neurotransmitters
➔ Endocrine: Secretory cells communicate to <u>tissues throughout the body</u> by secreting hormones into the bloodstream

Autonomic nervous system

<u>Organisation of the nervous system</u>

CNS: Brain and spinal cord



PNS: Cranial nerves, spinal nerves, ganglia, peripheral nerves

<u>Autonomic system</u>

➔ Involuntary and self governing, controls the body's internal responses
➔ Inducible system being turned on and off when required

Main organ: Hypothalamus

➔ Controls internal organs via: Autonomic system and pituitary gland
➔ Regulates: Behaviour patterns, circadian rhythm, body temperature, eating and drinking

Two components:

➔ Sympathetic division
  - Alarm response
  - Exercise, emotion, excitement
➔ Parasympathetic division
  - Relaxation response
  - Repletion, rest, relaxation

<u>Autonomic (involuntary) vs somatic (voluntary) system</u>

Sensory input	Interoceptors: Receptor which receives stimuli from within the body e.g. gut	Special senses (senses that have specialized organs) and somatic senses
Control of output	Involuntary from limbic, hypothalamus, brain stem, spinal cord	Voluntary from cerebral cortex
Motor neuron	1 myelinated preganglionic axon (cell	One myelinated neuron

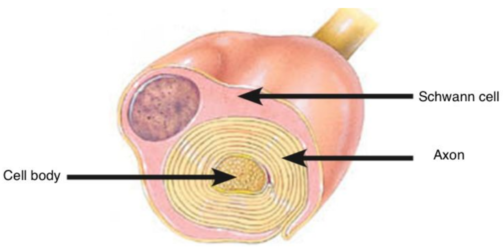
pathway	body lies in lateral grey horn) and 1 unmyelinated post ganglionic axon	(cell body lies in anterior grey horn)
Neurotransmitters	Acetylcholine or norepinephrine	Acetylcholine
Effectors	Smooth muscle contraction or relaxation, cardiac muscle increased or decreased rate and force of contraction, glands increased or decreased secretions	Skeletal muscle contraction

Autonomic nerves

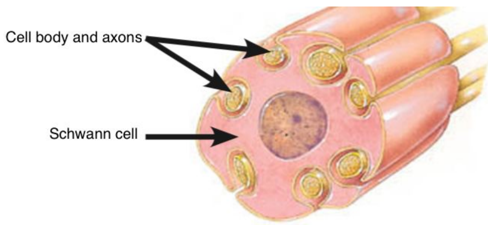
- ➔ Parasympathetic
  - Preganglionic axon <u>myelinated</u> and communicates to post ganglionic with ACh
  - Post ganglionic axon <u>unmyelinated</u> and communicates to effector with ACh
- ➔ Sympathetic
  - Preganglionic axon <u>myelinated</u> and communicates to post ganglionic with ACh
  - Post ganglionic axon <u>unmyelinated</u> and communicates to **sweat glands** with ACh
  - Post ganglionic axon <u>unmyelinated</u> and communicates to fibres **other than sweat glands** with Norepinephrine

<u>Structure of neurons</u>

- ➔ Cell body located in the center of dendrites, long axon extending away with axon terminals at the end to connect to dendrites or tissue
- ➔ Schwann cells have a myelin membrane that can wrap around the axon to insulate and keep the current from dissipating



Myelinated nerve
- One schwann cell surrounds axon to increase conduction speed of impulses



Unmyelinated nerve
- One schwann cell in the center of multiple axons to maintain environment

Multiple sclerosis: Disease causing the progressive destruction of myelin sheaths of nerves in the CNS and PNS

- ➔ Slow propagation of nerve impulses
- ➔ Severe MS patients may lose the ability to walk independently or at all
- ➔ Other symptoms: Numbness or weakness in one or more limbs (typically on one side of the body at a time), Lhermitte sign: electric shock sensations occurring with certain

neck movements, tremor, effects on vision, slurred speech, dizziness, tingling or pain in other parts of the body

Nerve synapses

1. Nerve impulse action potential travels down the axon and reaches the presynaptic axon terminals
2. Voltage gated Ca2+ channel opens and Ca2+ enters the axon terminals
3. Ca2+ encourages the movement of synaptic vesicles containing ACh towards the membrane and they fuse
4. ACh is released into the synaptic cleft via exocytosis and diffuses to the post synaptic membrane
5. ACh binds to ligand-gated receptors and they open allowing Na+ to enter the postsynaptic neuron
6. Cell depolarizes to suprathreshold and next action potential is generated
7. Nerve impulses propagate

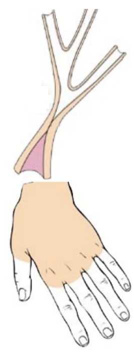
Body responses

➔ Nerves coordinate our actions and bodily functions to allow us to react quickly to our external environment
➔ Alarm response: Adaptive response to prevent danger
➔ Relaxation response: Response for after meals or sleeping

The alarm response/fight or flight: Sympathetic system

➔ Heart: Increased rate and force of contraction to increase flow of oxygen to tissues
➔ Pupils: Dilate to take in more information
➔ Gut and salivation: Decreases to save energy by slowing digestion processes
➔ Bronchi: Dilate to breath faster to increase oxygen intake
➔ Skin: Contraction of arrector pili muscles (muscles attached to hair follicles) causing the hairs to stand up and increased secretion from sweat glands. This increases the surface area on the skin assisting heat loss during the alarm response.
➔ Blood vessels: Constrict, especially in the periphery to increase blood pressure for pumping around the body and ensure central organ good supply
➔ Water retention: Increases blood pressure and prepares for any damage
➔ Blood sugar: Increases to produce ATP

Raynaud disease:



- After emotional stress or exposure to the cold, the sympathetic system overactivates and takes a long time to turn down
- Chronic vasoconstriction: Blood vessels constrict resulting in lack of blood supply to fingers and toes (ischemic) and appear white

The relaxation response/rest and digest: Parasympathetic system

➔ Heart: Decreased rate and force of contraction
➔ Pupils: Contract, don't need to take in information
➔ Salivation and digestion: Increases
➔ Bronchi: Constrict, increases ability to clear secretions and keep the body healthy

➔ Blood vessels: Dilate to provide more warmth and decrease blood pressure

<u>Endocrine system</u>

<u>Main organs</u>

➔ HPA axis: Hypothalamus, pituitary, adrenal glands
➔ Other organs: Skin, pineal, thyroid, thymus, stomach, liver, pancreas, kidney, small intestine, ovary and testes
➔ Circulatory organs: Heart and lungs

<u>Types of hormones</u>

Circulating hormones

➔ Endocrine cell secretes hormones into the bloodstream which act on hormone receptors at **distant** target cells

Local hormones

➔ Paracrine cells secrete paracrine which act on paracrine receptors at **nearby** target cells
➔ Autocrine cells secrete autocrine which act on autocrine receptors on the **same** cell

<u>Control of hormone release</u>

Endocrine system is a molecular driven system which is inducible and allows us to control our body in a slower way than the nerves in the autocrine system

1. Endocrine organ synthesizes hormones and either stores or releases it to the blood
2. Hormone reaches receptors on target tissue and changes behaviour to achieve desired response
3. Hormones are broken down/excretion or has a positive or (usually) negative feedback signal relayed back to the hormone producing cell

Lipid soluble hormones e.g. steroid and thyroid hormones

1. Hormone is transported through the bloodstream in a transport protein
2. Reaches cell and diffuses through the plasma membrane into the nucelus
3. Activates a receptor in the nucleus
4. Receptor hormone complex binds to an exon on a gene to alter gene expression
5. Upregulates or downregulates the transcription of a gene
6. Newly formed mRNA is translated to protein required
7. New protein alters cells activity

Water soluble hormones e.g. catecholamines, peptides and proteins

1. Hormone circulates through the bloodstream to reach target cell
2. Binds to a G protein coupled receptor, activates it therefore activating the G protein on the cell side
3. G protein activates adenylyl cyclase
4. Adenyl cyclase converts ATP to cAMP
5. cAMP acts as a secondary messenger phosphorylating protein kinase enzymes

6. Protein kinase phosphorylation cascade occurs with other enzymes
7. Phosphorylated enzymes catalyse reactions that provide physiological responses
8. Phosphodiesterase is the negative feedback mechanism to inactivate cAMP

Cholera:
- ➔ Grows in villi crypts
- ➔ Produces the cholera toxin which irreversibly binds to the G protein on the epithelial cells on the intestines
- ➔ High concentration of cAMP
- ➔ Causes continuous secretion of chloride ions from the bloodstream to the intestines
- ➔ Water accompanies chloride secretion so water goes to intestines
- ➔ Results in chronic diarrhoea and dehydration

<u>Inducibility of the system</u>
- ➔ Target cell must have receptor for reaction to occur
- ➔ Hormone production is changed

<u>Autonomic and endocrine systems and the stress response</u>
- ➔ Hypothalamus links the nervous system with the endocrine system by controlling the pituitary gland, which secretes hormones to control other endocrine glands
- ➔ The stress response is a coordinated activity linking the nervous system with the endocrine and autonomic systems - this further extends to the immune system

<u>Hypothalamus-pituitary axis</u>
- ➔ Hypothalamic nuclei are connected to the posterior and anterior pituitary gland by the infundibulum
- ➔ Network of capillaries lay at the base of the hypothalamus and then neural hypophyseal portal veins connect them to the capillary network surrounding both pituitary glands
- ➔ Neural hypophyseal portal veins is where the hypothalamus endocrine hormones travel through to effect the anterior pituitary gland
- ➔ Together regulate growth, development, metabolism, homeostasis

Hypothalamus
- Produces 9 types of hormones acting on pituitary gland cells
- Releasing: Stimulate the release of pituitary hormones to the bloodstream
- Inhibiting: Diminish the release of pituitary hormones to the bloodstream

Anterior pituitary connected through the hypophyseal portal system and produces 7 types of hormones which have an effect on other endocrine organs in the body

Posterior pituitary is connected through the hypothalamic hypophyseal tract and instead responds directly to hypothalamic neurons to release hormones.